

THE SEED ATLAS OF PAKISTAN-VII. GERANIACEAE

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Abstract

Seed morphology of 19 taxa belonging to the family Geraniaceae, was examined using light and scanning electron microscopy (SEM). Seed macro and micro morphological characters were found useful for the taxonomic delimitation as all the taxa clearly distinguished at the generic, specific as well as at the infra specific level.

Introduction

The family Geraniaceae comprises 5 genera and c.650 species (Mabberley, 2008). The family is represented in Pakistan by 4 genera and 35 species (Nasir, 1983). Previously, the seed morphology of some taxa of the family Geraniaceae was examined by various workers (Corner, 1976; Kirkbride *et al.*, 2006; Langran & Aedo, 2008). El Naggar (1992) investigated the seed morphology of 14 Egyptian species of the genus *Erodium* and seed size, shape and surface pattern were found significant for specific delimitation. While, phylogenetic relationship in the family Geraniaceae was also reported and it was concluded that on the basis of *rbcl* data the two genera *Erodium* and *Geranium* were formed a sister group. Whereas, *Monsonia* and *Sarcocaulon* were closely related and found to be congeneric (Price & Palmer, 1993). There are no detail reports available on seed morphology of the family Geraniaceae. The present report will provide the seed morphological data of the family Geraniaceae which will be used as an additional information for taxonomic delimitation at various levels.

Material and Methods

Mature and healthy seeds of 19 taxa of the family Geraniaceae were collected from herbarium specimens.

Mostly 10 plants/species and 10 seeds/plant were studied (Appendix I) and examined under stereomicroscope (Nikon XN Model), compound microscope (Nikon type 102) and scanning electron microscope (JSM-6380A). For scanning electron microscopy dry seeds 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 terminology used is in accordance to Lawrence (1970), Radford (1974) and Stearn (1983) with slight modifications. The characters of seed viz., size, shape, colour, surface, and hilum were studied.

General seed characters of the family Geraniaceae:

Seeds 0.8-3.8 x 0.6-2.2mm, oblanceolate, oblong, sub globose, apex truncate, retuse or rounded, ridge present, brown, light brown, orange brown, reddish brown or blackish brown, undulate, foveate, rugosely foveate, foveately striate, rugosely striate, scalariform, areolate, areolate along with undulate, reticulate, reticulate foveate, reticulate with in reticulation foveate or appressedly reticulate, glabrous or sparsely pubescent. Hilum basal, sub basal or lateral.

Represented by three genera *Erodium* L, Herit ex Aiton, *Geranium* L. and *Monsonia* L.

Key to the genera

- 1 + Seeds glabrous..... 2
- Seeds sparsely pubescent..... *Monsonia*
- 2 + Seeds oblanceolate..... *Erodium*
- Seed oblong or sub globose..... *Geranium*

Erodium L, Herit ex Aiton

Seeds 1.5-3.5 x 0.6-1mm, oblanceolate, apex truncate or rounded, brown, light brown or blackish brown, undulate, foveate, foveately striate, scalariform or reticulate foveate, glabrous. Hilum basal or sub basal. (Table 1; Fig. 1A-L).

Represented by 6 taxa viz., *Erodium ciconium* (L.) L' Herit ex Aiton, *E. cicutarium* (L.)L'Herit ex Aiton, *E. laciniatum* (Cav.) Willd., *E. malacoides* (L.) L'Herit ex Aiton, *E. oxyrrhynchum* M. Bieb subsp. *bryoniifolium* (Boiss.) Sch. Tem. and *E. oxyrrhynchum* M. Bieb. subsp. *oxyrrhynchum*.

Key to the species

- 1 + Seeds blackish brown 2
- Seeds brown 3
- 2 + Seed surface foveate *E. laciniatum*
- Seed surface scalariform *E. malacoides*
- 3 + Seeds with rounded apex 4
- Seeds with truncate apex *E. ciconium*
- 4 + Seed surface foveate *E. cicutarium*
- Seed surface undulate or reticulate foveate *E. oxyrrhynchum*

Appendix I. List of voucher specimens.

S.No.	Taxa	Collector, number and herbarium
1.	<i>Erodium ciconium</i>	R.R. Stewart 27425 (RAW); Shaukat Ali 25988 (RAW); M.A. Siddiqi & Z. Ali 3833 (RAW).
2.	<i>E. cicutarium</i>	M. Qaiser & A. Ghafoor 1466, 1872 (KUH); R.R. Stewart 26306 (RAW); Y. Nasir & Zaffar Ali 5491 (RAW); M.A. Siddiqui 2131 (RAW); S. Qureshi 238 (KUH); Y. Nasir 4545 (RAW); Sultanul Abedin 3297, 4601 (KUH).
3.	<i>E. laciniatum</i>	M. Qaiser et al., 1084 (KUH).
4.	<i>E. malacoides</i>	R.R. Stewart 13804 (RAW); Y. Nasir 3342, 4546 (RAW); E. Nasir s.n. (RAW); A. Majid 102 (RAW); Sultanul Abeidn 972 (KUH).
5.	<i>E. oxvrrhynchum</i> subsp. <i>bryoniifolium</i>	A. Rahman 35910 (RAW); Zaffar Ali 5662 (RAW); M. Sharif 35 (RAW); Sultanul Abedin 4859, 6800 (KUH); Sultanul Abedin & A. Hussain 7220 (KUH); R.R. Stewart 28345 (RAW).
6.	<i>E. oxvrrhynchum</i> subsp. <i>oxvrrhynchum</i>	R.R. Stewart 20386, 20938, 26305 (RAW); E. Nasir & G.L. Webster 5747, 5876 (RAW).
7.	<i>Geranium lucidum</i>	Y. Nasir & Z. Ali 5493 (RAW); E. Nasir & M.A. Siddiqi 4411 (RAW); R.R. Stewart 1538 (RAW); Sultanul Abedin 2795 (KUH); R.R. & I.D. Stewart 6154 (RAW).
8.	<i>G. mascatense</i>	Sultanul Abedin & A. Hussain 6221, 6223 (KUH); M.Qaiser et al., 1056 (KUH).
9.	<i>G. nepalense</i>	M.A. Siddiqi & A. Rahman s.n. (RAW); M. Qaiser & A. Ghafoor 1786, 1891, 4761 (KUH); Y. Nasir & Nazir 5402, 5490 (RAW); R.R. Stewart 24311 (RAW); E. & Y. Nasir 7737 (RAW); M.A. Kazmi 1421 (KUH).
10.	<i>G. ocellatum</i>	Hassanuddin 7550 (RAW); M.A. Siddiqi 2107 (RAW); A. Rahman s.n. (RAW); R.R. Stewart 6974, 11072 (RAW); Shaukat Ali 88 (RAW); S. Ali 25993 (RAW); R.R. & I.D. Stewart 5207 (RAW).
11.	<i>G. pratense</i>	Coll. ignot s.n. (KUH), Pannell collection gp Burtain 60877 (RAW).
12.	<i>G. pusillum</i>	S.I. Ali & S.A. Farooqi 1634 (KUH); Y. Nasir 6822 (RAW); R. R. Stewart s.n. (RAW); R. R. Stewart & E. Nasir 23258a (RAW).
13.	<i>G. rotundifolium</i>	Y. Nasir 5147 (RAW); S.I. Ali 25959 (KUH); R.R. Stewart 27483 (RAW); R.R. & I.D. Stewart 17449 (RAW); R.R. Stewart & E. Nasir s.n. (RAW).
14.	<i>G. sibiricum</i>	R.R. Stewart 18958, 20415, 20904, 20947 (RAW).
15.	<i>G. swatense</i>	R.R. Stewart 24608, 24655, 24726 (RAW); R.R. Stewart & A. Rahman 25104, 25367 (RAW); E. Nasir & M.A. Siddiqi 1103 (RAW); R. R. Stewart et al., 22897 (RAW).
16.	<i>G. wallichianum</i>	Hassandin 161 (RAW); M.A. Siddiqi & Y. Nasir 4322 (RAW); M. Qaiser & A. Ghafoor 4730 (KUH); Sultanul Abedin & M. Qaiser 8760 (KUH); Y. & E. Nasir 7496 (RAW).
17.	<i>Monsonia heliotropiodes</i>	Y. Nasir 4958 (RAW); A. Rahman 25909 (RAW, BM); R. R. Stewart & E. Nasir 27854 (RAW); M. Qaiser et al., 652, 732 (KUH); Sultanul Abedin & A. Hussain 6320 (KUH).
18.	<i>M. nivea</i>	Coll. ignot s.n. (KUH).
19.	<i>M. senegalensis</i>	S.A. Qadir s.n. (KUH).

Geranium L.

Seeds 0.8-3.8 x 0.9-2.2 mm, sub globose or oblong, apex truncate, retuse or rounded, brown, reddish brown or blackish brown, areolate, areolate along with undulate, rugosely striate, reticulate with in reticulation foveate or appressedly reticulate, glabrous. Hilum basal, sub basal or lateral (Table 1; Fig. 1M-T; Fig. 2A-L).

Represented by 10 species viz., *Geranium lucidum* L., *G. mascatense* Boiss., *G. nepalense* Sweet, *G. ocellatum* Camb., *G. pratense* L., *G. pusillum* L., *G. rotundifolium* L., *G. sibiricum* L., *G. swatense* Schönbeck-Temesy and *G. wallichianum* D. Don ex Sweet.

Table 1. Seeds morphological characters of the family Geraniaceae.

Name of taxa	Size mm	Shape	Apex	Colour	Surface	Indumentem	Hilum	Rigid
<i>Erodium ciconium</i>	2.3-2.5 x 0.7-0.8	Oblanceolate	Truncate	Brown	Foveately striate	Glabrous	Basal	Present
<i>E. cicutarium</i>	2.6-3 x 0.6-1	Oblanceolate	Rounded	Brown	Foveate	Glabrous	Basal	Present
<i>E. laciniatum</i>	2.8-3 x 0.7-0.8	Oblanceolate	Rounded	Blackish brown	Foveate	Glabrous	Sub basal	Present
<i>E. malacoides</i>	2.5-2.7 x 0.7-0.8	Oblanceolate	Rounded	Blackish brown	Scalariform	Glabrous	Basal	Present
<i>E. oxvrrhynchum</i> subsp. <i>bryoniifolium</i>	3.2-3.5 x 0.8-1	Oblanceolate	Rounded	Light brown	Reticulate foveate	Glabrous	Sub basal	Present
<i>E. oxvrrhynchum</i> subsp. <i>oxvrrhynchum</i>	1.5-2.7 x 0.6-0.7	Oblanceolate	Rounded	Brown	Undulate	Glabrous	Sub basal	Present
<i>Geranium lucidum</i>	1-1.2 x 0.9-1	Oblong	Rounded	Reddish brown	Rugosely striate	Glabrous	Basal	Present
<i>G. mascatense</i>	2-2.5 x 1-1.2	Oblong	Rounded	Brown	Reticulate along with foveate	Glabrous	Lateral	Present
<i>G. nepalense</i>	2-2.3 x 1-1.2	Oblong	Retuse	Blackish brown	Reticulate along with foveate	Glabrous	Lateral	Present
<i>G. ocellatum</i>	1.6-1.8 x 0.9-1.2	Sub globose	Truncate	Reddish brown	Reticulate along with appressedly reticulate	Glabrous	Basal	Present
<i>G. pratense</i>	3.7-3.8 x 2	Oblong	Rounded	Brown	Areolate	Glabrous	Basal	Present
<i>G. pusillum</i>	1.2-1.3 x 1-1.1	Oblong	Rounded	Brown	Reticulate along with foveate	Glabrous	Basal	Present
<i>G. rotundifolium</i>	1.2-2 x 0.9-1	Oblong	Rounded	Brown	Rugosely foveate	Glabrous	Basal	Present
<i>G. sibiricum</i>	0.8-1.2 x 1.2-1.3	Oblong	Rounded	Blackish brown	Reticulate along with foveate	Glabrous	Basal	Present
<i>G. swatense</i>	2-2.3 x 1-1.2	Oblong	Slightly truncate	Reddish brown	Areolate along with undulate	Glabrous	Basal	Present
<i>G. wallichianum</i>	2.9-3.8 x 1.6-2.2	Oblong	Slightly truncate	Blackish brown	Reticulate along with foveate	Glabrous	Lateral	Present
<i>Monsonia heliotropiodes</i>	2.3-2.5 x 0.6-0.7	Oblanceolate	Truncate	Orange brown	Foveately striate	Apically sparsely pubescent	Basal	Present
<i>M. nivea</i>	2.3-2.5 x 0.6-0.7	Oblanceolate	Truncate	Orange brown	Reticulate	Apically sparsely pubescent	Basal	Present
<i>M. senegalensis</i>	3.5-3.7 x 1	Oblanceolate	Slightly retuse	Orange brown	Reticulate along with foveate	Sparsely pubescent	Basal	Present

Key to the species

- 1 + Seeds sub globose *G. ocellatum*
 - Seeds oblong 2
 2 + Seeds apically rounded 3
 - Seeds apically truncate or retuse 8
 3 + Seeds brown 4
 - Seeds reddish brown or blackish brown 7
 4 + Seed surface areolate or reticulate along with foveate 5
 - Seed surface rugosely foveate *G. rotundifolium*
 5 + Seeds 2-3.8mm long 6
 - Seeds 1.2-1.3mm long *G. pusillum*
 6 + Seeds 2-2.5mm long with lateral hilum *G. mascatense*
 - Seeds 3.7-3.8mm long with basal hilum *G. pratense*
 7 + Seeds reddish brown, rugosely striate *G. lucidum*
 - Seeds blackish brown, reticulate along with foveate *G. sibiricum*
 8 + Seeds 2-2.3mm long 9
 - Seeds 2.9-3.8mm long *G. wallichianum*
 9 + Seeds blackish brown, seed surface reticulate along with foveate *G. nepalense*
 - Seeds reddish brown, seed surface areolate with undulate *G. swatense*

Monsonia L.

Seeds 2.3-3.7 x 0.6-1.1mm, oblanceolate, apex truncate or retuse, orange brown, foveately striate, reticulate or reticulate along with foveate, sparsely pubescent. Hilum basal. (Table 1; Fig. 2M-R).

Represented by 3 species viz., *Monsonia heliotropiodes* (Cav.) Boiss., *M. nivea* (Decne.) Decne. ex Webb. *M. senegalensis* Guill. & Perr.

Key to the species

- 1 + Seed apically truncate 2
 - Seed apically retuse *M. senegalensis*
 2 + Seeds surface reticulate *M. nivea*
 - Seeds surface foveately striate *M. heliotropiodes*

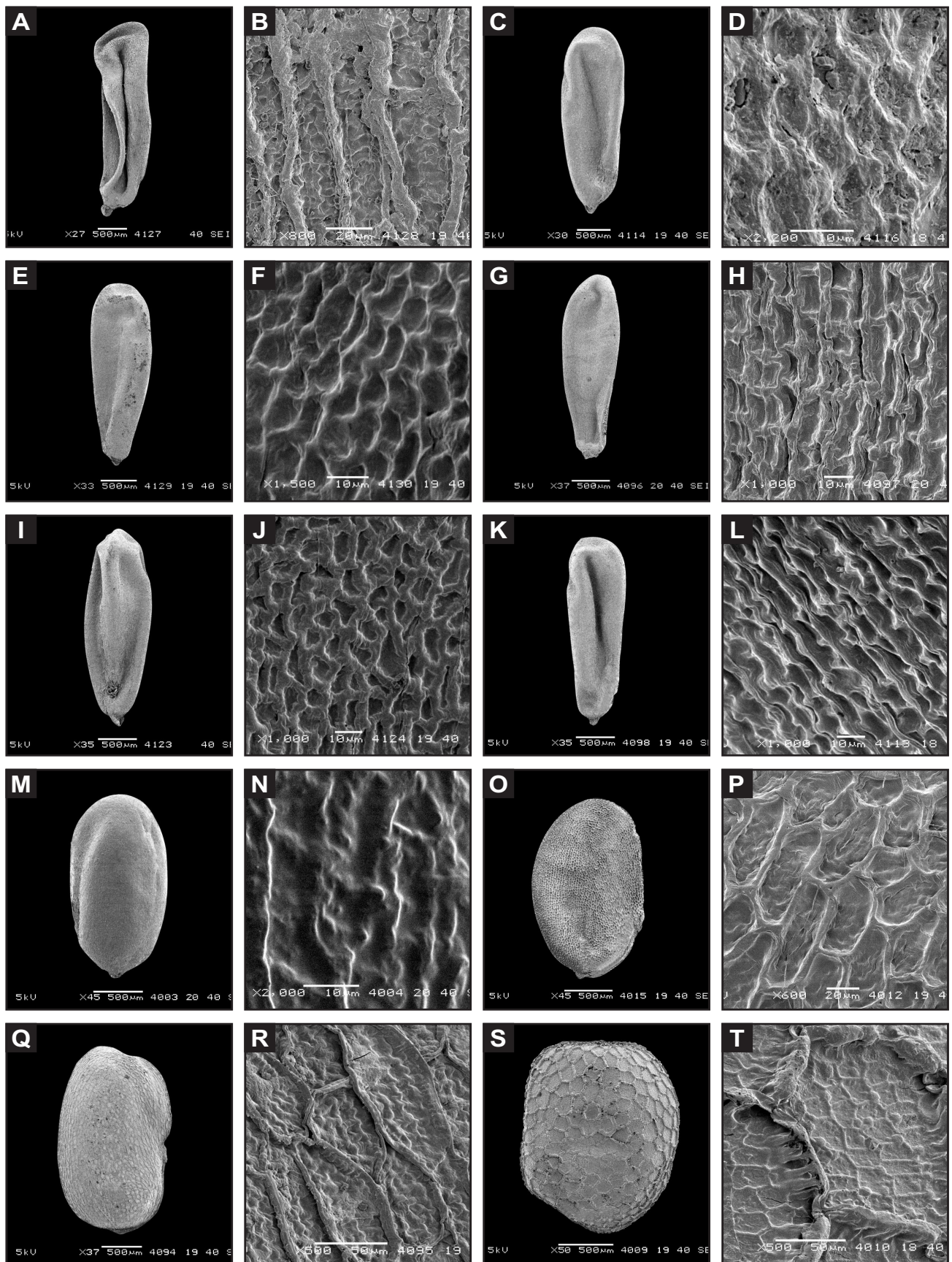


Fig. 1. Scanning electron micrographs. *Erodium ciconium*: A, seed; B, surface. *E. cicutarium*: C, seed; D, surface. *E. laciniatum*: E, seed; F, surface. *E. malacoides*: G, seed; H, surface. *E. oxvrrhynchum* subsp. *bryoniifolium*: I, seed; J, surface. *E. oxvrrhynchum* subsp. *oxvrrhynchum*: K, seed; L, surface. *Geranium lucidum*: M, seed; N, surface. *G. mascatense*: O, seed; P, surface. *G. nepalense*: Q, seed; R, surface. *G. ocellatum*: S, seed; T, surface. (scale bar: A, C, E, G, I, K, M, O, Q, S = 500 μ m; R, T = 50 μ m; B, P = 20 μ m; D, F, H, J, L, N = 10 μ m).

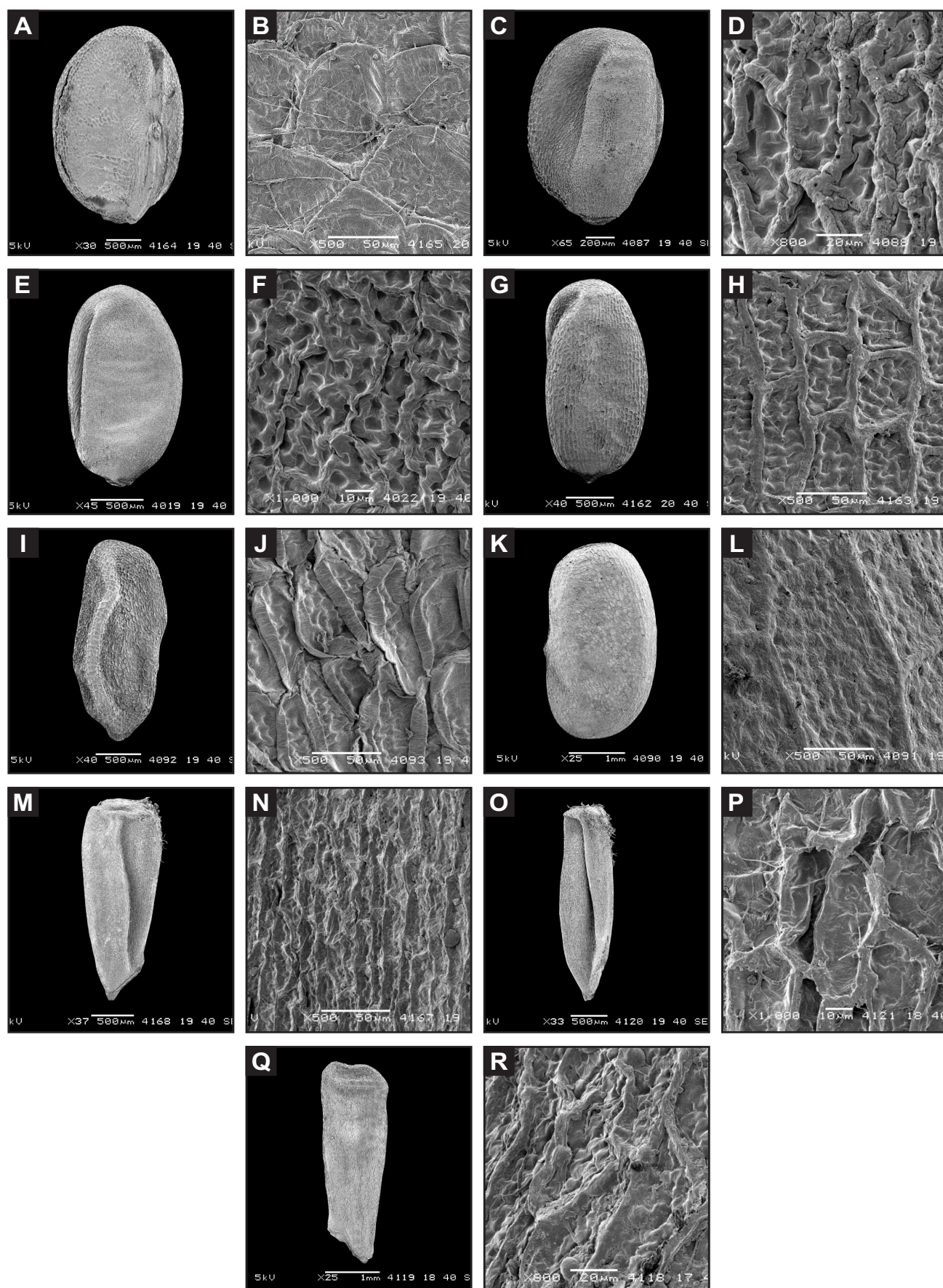


Fig. 2. Scanning electron micrographs. *Geranium pratense*: A, seed; B, surface. *G. pusillum*: C, seed; D, surface. *G. rotundifolium*: E, seed; F, surface. *G. sibiricum*: G, seed; H, surface. *G. swatense*: I, seed; J, surface. *G. wallichianum*: K, seed; L, surface. *Monsonia heliotropiodes*: M, seed; N, surface. *M. nivea*: O, seed; P, surface. *M. senegalensis*: Q, seed; R, surface. (scale bar: K, Q = 1mm; A, E, G, I, M, O = 500 µm; C = 200 µm; B, H, J, L, N = 50 µm; D, R = 20 µm; F, P = 10 µm).

Results and Discussion

The morphological and phylogenetic relationship of the taxa within the family Geraniaceae is well correlated with seed morphological data. The two morphologically related genera *Erodium* and *Geranium* with 5-10 stamens (Nasir, 1983) are also grouped by having glabrous seeds. While, on the basis of *rbcL* data both genera were considered as monophyletic (Price & Palmer, 1993). However, both the genera may further be separated by having different seed shapes such as, oblong or subglobose seeds are found in *Geranium* while, the genus *Erodium* is characterized due to the presence of oblanceolate seeds. The genus *Monsonia* is delimited due to presence of 15 stamens (Nasir, 1983) and sparsely pubescent seeds which is also evident phylogenetically by having specific *rbcL* data. (Price & Palmer, 1993). Palynological data also supports the taxonomical interpretation of the family as all the genera have more or less exclusive pollen types (Perveen & Qaiser, 1999). Similarly, seed morphology is also found to be significant for infrageneric, specific or infraspecific delimitation. Conventionally the genus *Erodium* was divided in two sections viz., section *Plumosa* and *Erodium*. *E. oxyrrhynchum* was placed under section *Plumosa* by having long plumose, deciduous beak with solitary groove (Schönbeck-Temesy, 1970) with exclusive seed surface pattern such as, undulate and reticulate foveate surface. While, *E. ciconium*, *E. cicutarium*, *E. laciniatum* and *E. malacoides* were placed in section *Erodium* by having short, pilose, persistent, 2-3 grooved beak (Schönbeck-Temesy, 1970) along with foveately striate, foveate or scalariform seed surface patterns. Furthermore, the seed morphological features also provide the strength to the subsectional delimitation of the section *Erodium* viz., *Absinthioidea* and *Malacoidea* (Schönbeck-Temesy, 1970). The subsection *Absinthioidea* including *E. ciconium* with apically truncate seeds while, *Malacoidea* including *E. cicutarium*, *E. laciniatum* and *E. malacoides* are characterized due to the presences of apically rounded seeds and these species could also be separated with each other by having different seed colouration and surface patterns. The two subspecies of *E. oxyrrhynchum* viz., *E. oxyrrhynchum* subsp. *bryoniifolium* and *E. oxyrrhynchum* subsp. *oxyrrhynchum* remain distinct with each other due to different surface patterns. Within the genus *Geranium* the species *G. lucidum*, *G. ocellatum* and *G. swatense* are grouped together by having reddish brown seeds. While, these species may further be distinguished by having different surface patterns. Present findings are also supported by the palynological data where all of the above three species were grouped together by having more or less similar mesocolpium length (Perveen & Qaiser, 1999). According to palynological data *G. rotundifolium* also included in the above said group but on the basis of seed characters this species could not be

placed within this group, while the remaining species *G. mascatense*, *G. nepalense*, *G. pratense*, *G. pusillum*, *G. sibiricum* and *G. wallichianum* are closely related in their gross morphology by having palmatifid and partite leaves (Nasir, 1983) along with brown or blackish brown seeds and these species could also be separated from each other by having different seed apex, size and surface patterns. The seed morphology of the three species of the genus *Monsonia* viz., *M. heliotropiodes*, *M. nivea* and *M. senegalensis* can also be significantly correlated to the gross morphology such as *M. senegalensis* is differentiated with 1-2 flowered peduncles and apically retuse seeds, while *M. heliotropiodes* and *M. nivea* are distinct by having 3-13 flowered peduncles (Nasir, 1983) with apically truncate seeds, but both can be separated due to specific seed surface patterns.

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