CHAPTER VI

POLLEN MORPHOLOGY OF THE FAMILY GERANIACEAE
INTRODUCTION

The Geraniaceae is a comparatively big family with 750 species in about 11 genera (Heywood, 1978) distributed both in temperate and subtropical regions. The family is represented by 10 genera and a large number of species in India, particularly of the genus Impatiens. The plant has showy flowers and hence has become important for ornamental purposes. Some of the species provide aromatic smell, although not exploited for economic purposes.

The family has engaged the attention of taxonomists and most modern taxonomists have agreed with the division of the Geraniales by Bentham & Hooker (1962-83) into Geraniaceae (sensu stricto), Oxalidaceae, Balsaminaceae and Pelargonioideae, to which Erdtman (1952) also agreed from the point of view of pollen morphology. Bortenschlager (1967) studied the pollen morphology of the family and made elaborate conclusions on taxonomy, suggesting its division into 5 families. The family
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has been also studied by several other authors (Gagnepain, 1903; Saur, 1933; Bortenschlager, 1967; Oltmann, 1969, 1971; Huyss, 1968, 1969a, b and van Jame, 1976).

Among the Indian workers, the study made by Shinj & Razi (1979) on the pollen morphology of species of Impatiens is of significance. The present investigation includes 10 genera and 29 species.

Pollen Descriptions

Averrhoa bilimbi L. (Pl. 12; Fig. 51-53)

3-zonocolpate; colpus very wide, crustate, being ornamented similar to that of the general exine surface with the result that the furrow appears faint. Exine 3 μm thick; ectoexine thicker than endoexine, with wavy margin, tectate; surface reticulate, with broad muri and small lumina (SEM); columnella stem like, sometimes thickened at the base and branched in tip region in some grains (TM).

Amb: Circular; apocolpium 13 μm.


Shape: Oblate spheroidal.
A. garambola L.

3-zono-colporate, brevicolporate. Exine 4 µm thick; ectoexine thicker than endoexine, tectate, tectum sub-apical, columnella rod-shaped, apparently dupliciate, striato-reticulate with free tips (1M).
Amb: circular; apocolpium 23 µm.
Grain size: 54 µm (42 - 72 µm).
Shape: Spheroidal.

Bibersteinia emodi Jaub. & Spach. (Pl. 12; FIGS. 54-56)

3-zono-colporate; aspidote with a paraequatorial collar; endocolpium lo-longate (15 x 9 µm); aspis slightly raised, diameter 20 µm, cavate; ectocolpium small and narrow. Exine 3.3 µm thick, tectate, columnella clear; ectoexine thicker than endoexine (thickest at the centre of the mesocolpium) and gradually narrower towards the outer limit of aspis. Exine surface striate (1M), with closely packed vermiform ridges, converging at the poles, on the one hand and at the centre of the 3 aspides on the other, as seen in SEM.
Amb: Angular; apocolpium 16 μm.
Grain size: 45 μm (35 - 55 μm).
Shape: Spheroidal.

*Biophyton reinwardtii* Walp.

3-zonocolporate; endocolpium not defined; ectocolpium faintly marked. Exine 3.0 μm; ectoexine + of same thickness as of endoexine, sometimes thicker, tectate, columella clear, clavate, reticulate with + circular to hemispherical lumina as seen in LM.
Amb: Circular; apocolpium 18 μm.
Grain size: 34 × 28 μm (25-47 × 18-35 μm).
Shape: Subprolate.

*R. sensitivum* D.C. (Pl. 13; Figs. 57-59)

3-zonocolporate; colpus long and narrow, streak-like, margin wide having a thickening around (margo).
Exine 1.7 μm thick; ectoexine thicker than endoexine, tectate, columella rod-shaped; surface reticulate with small brochi (LM and SEM).
Grain size: 35 × 23 μm (31-42 × 18-32 μm).
Shape: Prolate.
Arodiuim cicutarium L'Herit. (PL 13; FIGS. 60-62)

3-zonocolporate; endocolpium long-exlongate (14 × 12 μm); ectocolpium short with pointed ends. Exine 8.7 μm; ectoexine thicker than endoexine; colulella crenate, heads free at the top; pattern striato-reticulate, colulella free at the sub-surface level (LM), but striate as seen in SEM with the rod-like lirae of various lengths, lying in various directions in groups, at two levels producing a matted appearance.

Amb: Circular lobate; apocolpium 41 μm.
Grain size: 66 μm (62 - 73 μm).
Shape: Spheroidal.

A. malachoides Wulld.

3-zonocolporate; brevicolpate; endocolpium long-exlongate (15 × 11 μm). Exine 8 μm thick, ectoexine 6 μm thick, surface striato-reticulate (LM).
Amb: Circular lobate; apocolpium 39 μm.
Grain size: 78 μm (70 - 86 μm).
Shape: Spheroidal.
E. stephanianum Wild.

3(4)-zonocolporate; 10-longate (15 \times 10 \mu m); brevicolporate. Exine 3 \mu m thick, ectoexine thicker than endoexine; surface striato-reticulate (LM).

Amb: Circular lobate; apocolpium 36 \mu m.
Grain size: 61 \mu m (53 - 68 \mu m).
Shape: Spheroidal.

Geranium aconitifolium L’Herit.

3-zonocolporate, brevicolporate, colpus margin thick, endocolpium 10-longate (17 \times 12 \mu m).
Exine 17 \mu m thick, ectoexine thicker than endoexine; columnella cub-shaped, columnella heads in + heteromorphic circles of brochi with narrow lumina; heads of columnella are of different shapes and sizes, adjacent columnella being fused by the side, surface retipilate-reticulate.

Amb: Circular lobate; apocolpium 67 \mu m.
Grain size: 91 \mu m (88 - 95 \mu m).
Shape: Spheroidal.

G. collinum M. Bieb.

3-zonocolporate, brevicolporate, colpus margin thin, endocolpium 10-longate (18 \times 13 \mu m). Exine 11 \mu m
thick, ectoexine thicker than endoexine, columnella clavate, toothed, heads of columnella of different shapes and sizes, forming heteromorphic circles of brochi with slightly bigger lumina, surface retipilate.

Amb: Circular lobate; apocolpium 60 μm.
Grain size: 66 μm (62 - 73 μm).
Shape: Spheroidal.

G. lucidum L. (PL. 11; FIGS. 63-65)
3-zonocolpate; endocolpium longate (15 x 12 μm); colpus 16 μm long, margin thin. Exine 7.0 μm thick, ectoexine thicker than endoexine, columnella dimorphic, broader columnella alternates with the thinner columnella (LM), tips slightly apart and united by infratectum appearing on narrow bridges between pilae. Pila heads appear lobate on surface, being the result of union of two or more columnella, as clear from SEM; surface retipilate (LM and SEM).
Amb: Circular lobate; apocolpium 37 μm.
Grain size: 68 μm (61 - 76 μm).
Shape: Spheroidal.
G. molle

3-zonocolporate; brevicolpate, colpi margin thin, endocolpium lo-ongate (15 × 10 µm). Exine 7.7 µm thick; ectoexine thicker than endoexine, columnella clavate in isomorphic circles of brochi, adjacent columnella being connate by the side of contact, surface striato- reticulate (LM).

Amb: Circular lobate; apocolpium 42 µm.

Grain size: 73 µm (70 - 78 µm).

Shape: Spheroidal.

G. nepalense Sweet Geran. (Pl. 14; Figs. 66-68)

3-zonocolporate; endocolpium circular (15 µm); colpus 20 × 4 µm; margin thin. Exine 7.7 µm thick; ectoexine thicker than endoexine, columnella clavate with toothed apices connected along the length, producing variously sized brochi and narrow lumina, surface retipilate-reticulate (LM).

Amb: Circular; apocolpium 33 µm.

Grain size: 66 µm (60 - 69 µm).

Shape: Spheroidal.
G. ocellatum Facquem.

3-zonocolpate (colporate?); ectocolpium long with thin margin. Exine 8 µm; ectoexine thicker than endoexine, columella clavate ± isomorphic, fused, producing comparatively narrow muri and broad lumina; surface striato-reticulate (LM).

Amb: Circular; apocolpium 19 µm.
Grain size: 74 µm (71 - 79 µm).
Shape: Spheroidal.

G. palustria L.

3-zonocolpate; brevicolpate with thin margin. Exine 11 µm thick; ectoexine (7 µm) thicker than endoexine (2 µm); columella clavate, toothed, columella fused by the sides producing variously sized brochi and narrow lumina; surface retipilate (LM).

Amb: Circular; apocolpium 70 µm.
Grain size: 120 µm (98 - 128 µm).
Shape: Spheroidal.
3-zonocolpate; brevicolopate, there is a thickening around colpus. Exine 13.6 μm thick; ectoexine thicker than endoexine, columnella thick and densely placed with columnella heads in isomorphic circles of brochi with narrow lumina, the heads of columnella are of different shapes and sizes, toothed adjacent columnella being connate at the side of contact. Exine surface retipilate-reticulate (LM).

Amb: circular; apocolpium 72 μm.

Grain size: 136 μm (114 - 140 μm).

Shape: Spheroidal

G. rectum Trautv. (PL 15; FIGS. 69, 70)

3-zonocolpate, colpus 26 μm long with thick margin. Exine 10 μm thick, ectoexine (8 μm) thicker than endoexine (2 μm), columnella clavate, densely placed, columnella heads forming isomorphic circles of brochi with narrow lumina, the head of columnella re of different shapes and sizes, toothed, columnella fused at the side of contact; surface retipilate (LM).

Amb: Circular; apocolpium 70 μm.

Grain size: 105 μm (98 - 111 μm).

Shape: Spheroidal.
G. robertianum L. (Pl. 15; Figs. 71, 72)

3-zonocolporate; bravoicolpate; corpus margin thick; endocolpium lo-ongate (16 x 11 μm). Exine 8 μm thick, ectoexine thicker (6 μm) than endoexine (2 μm), columella clavate, toothed, fused at the side of contact; surface reticulate (1M).
Amb: Circular; apocolpium 45 μm.
Grain size: 62 x 70 μm (59-65 x 67-76 μm).
Shape: Suboblate.

G. sibiricum L.

3-zonocolporate; endocolpium not defined. Exine 10 μm thick; ectoexine thicker than endoexine, columella club-shaped, densely packed with toothed spines, fused at the side of contact; surface retipilate (1M).
Amb: Circular; apocolpium 40 μm.
Grain size: 92 μm (85 - 107 μm).
Shape: Spheroidal.
Hydrocera triflora v. & s. (PL. 16; FIGS. 73-75)

3-zonocolpate; colpus small and narrow (all grains in polar view). Exine 2.1 μm thick; ectoexine thicker than endoexine, tectate, columnella nodular; surface reticulate with large and toothed muri and crustate lumina (LM and SEM).

Amb: Angular; apocolpium 21 μm.

Grain size: 37 × 27 μm (30-39 × 23-30 μm).

Shape Prolate.

Impatiens balsamina v. (PL. 16; FIGS. 76-78)

3(5)-zonocolpate; all the grains lie in polar view; brevicolpate, aperture region swollen.

Exine 1.8 μm thick; ectoexine as thick as endoexine, tectate; columnella rod-shaped with pointed ends; surface reticulate, heterobrochate, brochi being larger at the poles, smaller at the mesocolpium, lumina crustate (LM and SEM).

Amb: Rectangular; apocolpium 13 μm.

Grain size (in polar view along longest and shortest axis): 39 × 26 μm (33-42 × 23-30 μm).
L. sultani Hook.f.

4-zonocolpate (rarely 1-2-colpate); all the grains lie in polar view. Exine 2.0 µm thick; ectoexine as thick as endoexine, tectate, muri high, columella spine-like; surface reticulate.

Amb: Squarish-rectangular; apocolpium 20 µm.
Grain size (in polar view along longest and shortest axis): 44 x 32 µm (37-46 x 29-36 µm).

Monsonia heliotropioides Cav. (PL. 17; FIGS. 79-81)

e-zonocolpate, brevicolpate. Exine 13.1 µm thick; ectoexine thicker than endoexine, tectate, columella thick and clavate with swollen heads; distance between the columella not constant; exine surface reticulate (LM and SEM) with irregular and variously sized brochi having lobed muri as seen in SEM. Columella partially fused in muri showing distinct heads.

Amb: Circular lobate; apocolpium 50 µm.
Grain size: 88 µm (72 - 96 µm).
Shape: Spheroidal.
**M. senegalensis** Guill & Perr. (PL. 17; FIGS. 82-84)

3-zonocolpate, brevicolpate. Exine 12.0 μm thick, tectate; columella pin-shaped, brochi regular and hexagonal; surface reticulate (LM), reticulate with regular hexangular brochi with plane muri surface and spinules at the corners of the brochi as clear from SEM. Columella free below the surface.

Amb: Circular lobate; apocolpium 50 μm.

Grain size: 90 μm (80 - 93 μm).

Shape: "Spheroidal".

**Oxalis acetosella** . (PL. 18, FIGS. 85-87)

3-zonocolpate; colpus long and narrow with dentate and slightly thickened margin. Exine 2.8 μm thick; ectoexine thicker than endoexine, tectate; columella rod-shaped, surface reticulate with the muri showing columella heads.

Amb: Circular lobate; apocolpium 12 μm.

Grain size: 51 x 50 μm (45-57 x 44-54 μm).

Shape: Prolate spheroidal.
Q. corniculata Zucc.

3-4-zonocolpate; colpus broad and long (sometimes narrow also), crulate, margin uneven, dentate (grain looks broken at the colpus). Exine 3.1 μm thick; ectoexine thinner than endoexine, tectate, columnella pin-shaped, rooted in endoexine, surface finely reticulate; reticulum heterobrocate with brochi of various sizes and shapes with crustate lumina (LM).
Amb: Circular; apocolpium 15 μm.
Grain size: 39 × 38 μm (37-44 × 36-40 μm)
Shape: Prolate spheroidal.

Pelargonium graveolens L'Herit.

3-zonocolporate; endocolpium lo-longate (13 × 8 μm).
Exine 10 μm thick; ectoexine thicker than endoexine; columnella rod-like with pointed ends; surface striato-reticulate with frilled muri.
Amb: Circular; apocolpium 36 μm.
Grain size: 75 × 79 μm (70-82 × 75-88 μm).
Shape: Oblate spheroidal.
**P. sonale** U'Herit. (PL. 18; FIGS. 88-90)

3-zonocolporate; endocolpium lo-longate (14 x 8 μm); colpus margin thick. Exine 8.9 μm thick; surface stristo-recticulate (LM and SEM) with plate-like wavy muri at two levels and right angles to each other.

Amb: Circular lobate; apocolpium 28 μm.

Grain size: 66 x 75 μm (60-70 x 64-79 μm).

Shape: Suboblate.

### KEY TO THE SPECIES

**Grains 3-zonocolporate; Amb circular-lobate**

<table>
<thead>
<tr>
<th>Grain size less than 50 μm</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumina small with broad and plain muri</td>
<td><strong>Averrhoa</strong> spp., <strong>Biophytum sensitivum</strong>, <strong>Oxalis</strong> spp.</td>
</tr>
<tr>
<td>Lumina large with narrow and toothed muri</td>
<td><strong>Hydrocera triflora</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grain size more than 60 μm</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Exine surface retipilate</td>
<td><strong>Geranium palustre</strong>, <strong>G. pratense</strong>, <strong>G. rectum</strong></td>
</tr>
<tr>
<td>Exine surface reticulate</td>
<td></td>
</tr>
<tr>
<td>brochi irregular; muri surface lobed</td>
<td><strong>Monsonia halotropiodes</strong></td>
</tr>
<tr>
<td>brochi regular; muri surface p'ain with spinules at the corners</td>
<td><strong>M. senegalensis</strong></td>
</tr>
<tr>
<td>Exine surface striato-reticulate</td>
<td><strong>Geranium ocellatum</strong></td>
</tr>
</tbody>
</table>
Grains 3-4-sonocolpate:
Amb rectangular

Grains 3-sonocolporate:
Amb circular

Grains 3-sonocolporate: Amb circular-lobate

Endocolpium lo-elongate

Surface reticulate-reticulate
exine 7-8 \( \mu \)m thick
G. lucidum, G. robertianum

exine 10-11 \( \mu \)m thick
G. collinum, G. sibiricum

exine 17 \( \mu \)m thick
G. aconitifolium

Surface striato-reticulate
Geranium spp., G. molle,
Pelargonium graveolens,
P. zonale

Surface striate
Biebersteinia emodi

Endocolpium circular
Geranium nepalense

DISCUSSION

The pollen grains of the family are apparently heterogeneous with olo-pate and olo-porate forms and also with a wide variety of ornamentation forms which are distinctly peculiar to the members of the family. Although the basic pattern is of the reticulate type, there are various stages of morphological evolution
ranging from retipilate to reticulate and among the latter, highly evolved situation with muri at two levels crossing each other and even becoming plate-like is found. In this way, this group has a highly evolved taxonomic position which is also substantiated by the floral structure which is somewhat stable, being pentamerous. As already mentioned most taxonomists and phylogenists agree with the division of Geraniaceae (sensu Bentham & Hooker, 1862-83) into the component families Geraniaceae, Tropaeolaceae, Oxalidaceae and Balsaminaceae which is supported by pollen morphology. In such a case the fundamental form of Geraniaceae is 3-colpate, with retipilate-reticulate ornamentation. In the species of Pelargonium, an advanced striato-reticulate situation with muri crossing at right angles occurs.

The family Oxalidaceae with Oxalis, Acetabularia and Biophyllum have colpate condition in pollen grains, which is a primitive character. The exine surface is reticulate with plate-like muri, which is at the same level. In all the taxa, the grains are comparatively smaller, and all these features together provide the family an entity in itself.
Similarly, in the Balsaminaceae, *Hydrocera* and *Impatiens* are also characterised by the colpate condition and the reticulate exine surface. Among the two species studied, *Impatiens sultanii* has various apertural forms. Although by the colpate and reticulate condition the family Balsaminaceae appears similar to Oxalidaceae, the two may be considered different from each other on the basis of the general floral characters. But, the separation of the families Balsaminaceae and Oxalidaceae from the Geraniaceae, is valid on the basis of pollen morphology.

It is in the Geraniaceae with genera *Biebersteinia*, *Brodium*, *Geranium*, *Pelargonium* and *Monsonia* that the exine surface shows a heavy ornamentation pattern in various stages of morphological evolution. In some species of *Geranium* the grains are 3-colporate and so also in *Monsonia* but in others the grains are 3-sonocolpate. On the basis of the fact that the basic type of surface ornamentation is retipilate-reticulate, the genera within the Geraniaceae appear to have evolved along two lines namely the reticulate and striate, respectively. All the same, by the uniqueness of the surface pattern itself the Geraniaceae
sensu stricto appears natural and such ornamentation as the one in Geraniaceae, is not repeated in Oxalidaceae, Balsaminaceae and Tropaeolaceae.

Regarding the inter-relationships of Geraniaceae (sensu lato), HESSEY (1915) considered its root in Malvales and in turn in Rosales and Ranales, while RAVIER (1912) derived it from the Cruciferales which in turn is connected to Ranales. HUTCHINSON (1969) considered the Geraniales to be directly connected with the Ranalian herbaceous taxa with the Tropaeolaceae and Balsaminaceae as a climax-taxis.

According to CRONQUIST (1968) the Geraniales as a whole consists of Oxalidaceae, Geraniaceae, Tropaeolaceae and Balsaminaceae along with Limnanthaceae, and the whole group has possibly got phylogenetic relationship with Sapindales-Linales-Polygalales complex.

From the very fact that there are colpate apertural forms in many of the genera studied, it may be assumed that the group has a clear relationship with the Ranalian plexus with perhaps the
Rosales, as the base. However, the totality of the pollen characters provides indication of an independent phylogenetic stock for the group. The relationship with the Polygalales, Sapindales and Vitales appears to be remote, at least, on the basis of pollen morphology.

In considerations of pollen morphological evolution in the Geraniaceae (sensu lato), the 3-colpate form with reticulate exine surface ornamentation may be considered basic. From the above, the 3-colpate, 4-colpate and 3-corporate forms may be considered to have evolved. On the basis of the ornamentation types, the taxa studied could be resolved on each apertural stock, the basic form being the retipilate-reticulate, and the striate (TEXT FIG. 2).
FIGS. 51-53. **Avorhhoa bilimbi:** 51. LM, optical cross-section in polar view (note exine strata) (× 2,000); 52. LM, surface in polar view showing reticulate exine (× 2,000); 53. SEM, surface view showing thick muri and small lumina (× 2,000).

FIGS. 54-56. **Biebersteinia emodii:** 54. LM, optical cross-section, aspidote grain (× 1,200); 55. LM, surface in polar view showing faint striations at the pole (× 1,200); 56. SEM, surface view, surface striate with closely vermiciform ridges converging at the poles and at the centre of the three aspides (× 1,200).
PLATE 13

FIGS. 57-59. *Biophyllum sensitivum*: 57. LM, optical cross-section in equatorial view (x 1,875); 58. LM, surface view (x 1,875); 59. SEM, surface in equatorial view showing long colpus and reticulate pattern (x 2,150).

FIGS. 60-62. *Erodium cicutarium*: 60. LM, optical cross-section showing the exine strata (x 825); 61. LM, surface view (note free columella at sub-surface level (x 750); 62. SEM, surface view striate with rod-like lireae of various length at two levels producing matted appearance (x 850).
PLATE 14

Figs. 63-65. Geranium lucidum: 63. LM, optical cross-section (×1,000); 64. LM, surface view (×1,000); 65. SEM, surface view retipilate showing lobate columella, surface being result of union of two or more columella (×1,000).

Figs. 66-68. G. nepalense: 66. LM, optical cross-section of polar view (×1,000); 67. LM, equatorial view in aperture region (×1,000); 68. SEM, surface view showing retipilate surface (×1,000).
PLATE 15

Figs. 69-70. Geranium rectum: 69. LM, optical cross-section in equatorial view showing exine strata ($\times$ 625);
70. LM, surface in equatorial view showing broad colpus ($\times$ 625).

Figs. 71-72. G. robertianum: 71. LM, optical cross-section in polar view ($\times$ 1,000); 72. LM, surface view showing reticulate pattern and aperture ($\times$ 1,000).
PICTURES 16

FIGS. 73-75. **Hydrocoris trifora**: 73. LM, optical cross-section (x 1,275); 74. LM, surface in polar view showing reticulate pattern (x 1,575); 75. SEM, surface in polar view with toothed muri (x 1,575).

FIGS. 76-78. **Impatiens balsamina**: 76. LM, optical cross-section, columnella pointed (x 1,275); 77. LM, surface in polar view (note rectangular amb) (x 1,725); 78. SEM, surface view large brochi at mesocarpium and small at poles, lumina crustate (x 1,975).
PLATE 17

FIGS. 79-81. Monsonia heliotropoides: 79. LM, optical cross-section (x 700); 80. LM, sub-surface view showing pilea heads (x 700); 81. SEM, surface in polar view showing irregular and lobed muri (x 700).

FIGS. 82-84. M. senegalensis: 82. LM, optical cross-section (x 700); 83. LM, sub-surface in polar view showing columella heads (x 700); 84. SEM, surface in polar view showing brochi with plane muri and spinules at corners (x 700).
PLATE 1B

Figs. 85-87. *Oxalis acetosella*: 85. LM, optical cross-section showing columella (× 1,300); 86. LM, surface in equatorial view (× 1,300); 87. SEM, surface in equatorial view showing reticulate pattern (× 1,400).

Figs. 88-90. *Pelargonium zonale*: 88. LM, optical cross-section (× 725); 89. LM, surface view in equatorial region showing longate endocolepium (× 725); 90. SEM, surface view showing striato-reticulate surface, muri plate-like at two levels and coIporate aperture (× 725).
TEXT FIG. 2. Showing the evolution among the sporomorphs of the family Geraniaceae on the basis of aperture and exine ornamentation.