

Seed morphology of the genus *Delphinium* L. (Ranunculaceae) in Turkey

HILAL ILARSLAN, RESIT ILARSLAN & CESAR BLANCHÉ

Abstract

ILARSLAN, H., R. ILARSLAN & C. BLANCHÉ (1997). Seed morphology of the genus *Delphinium* L. (Ranunculaceae) in Turkey. *Collect. Bot. (Barcelona)* 23: 79-95.

The seed morphology of 28 species of *Delphinium* collected from Turkey is surveyed by Scanning Electron Microscopy (SEM). Four major seed types are reported: subglobose with continuous rings of lamellae, subpyramidal with narrow or wide scales, elongate subpyramidal with scales and sector-spheroidal reticulate, corresponding with the sections recognized in the current taxonomic systems of the genus, thus indicating its good taxonomic resolution. Biogeographical and systematic implications are discussed.

Keywords: *Delphinium*, Ranunculaceae, seed morphology, Turkey.

Resum

ILARSLAN, H., R. ILARSLAN & C. BLANCHÉ (1997). Morfologia de les granes del gènere *Delphinium* L. (Ranunculaceae) a Turquia. *Collect. Bot. (Barcelona)* 23: 79-95.

La morfologia de les granes de 28 espècies de *Delphinium* recollides a Turquia ha estat estudiada per mitjà de la Microscòpia Electrònica de Rastreig (MER). Quatre tipus principals de granes són reportats: subglobooses amb anells continus de lamelles, subpiramidals amb esquames amples o primes, subpiramidals allargades amb esquames i sector-esferoïdals reticulades, que es corresponen amb les seccions reconegudes en els sistemes taxonòmics habituals del gènere, cosa que indica llur bona resolució taxonòmica. Es discuteixen les implicacions biogeogràfiques i sistemàtiques.

Mots clau: *Delphinium*, Ranunculaceae, morfologia de les granes, Turquia.

INTRODUCTION

The genus *Delphinium* L. (Ranunculaceae) belongs to the tribe *Delphineae* Warming and comprises 385 species (BLANCHÉ & *al.* in press) mainly from temperate parts of the Northern hemisphere and montane regions of tropical Africa (MUNZ 1967 a,b and 1968).

Since the 60's decade, when MUNZ (l.c.) and DAVIS (1965) established in 22-23 the

Hilal Ilarslan and Resit Ilarslan. Ankara Universitesi. Fen Fakultesi. Biyoloji Bölümü. 06100-Tandogan Ankara (Turkey), and César Blanché. Laboratori de Botànica. Facultat de Farmàcia. Universitat de Barcelona. Avgda. Joan XXIII s/n, E-08028 Barcelona, Catalonia (Spain).

number of *Delphinium* species growing in Turkey, a number of new species has been described (HUBER-MORATH, 1978; DAVIS, MILL & KIT TAN, 1988; KIT TAN & ILARSLAN, 1990). Finally, ILARSLAN (1990) recorded 31 species from Turkey, 19 of them endemic. These data confirms the major role played by Turkey as a diversity centre in the genus *Delphinium* and the still accelerate rythm of new discoveries when botanically poorly known irano-turanian localities are studied, as suggested in BLANCHÉ (1990a).

MALYUTIN (1973, 1987) pointed out the importance of seed characters in the taxonomy of the genus. The complete classification system of this author is based

Taxon	Locality, voucher
<i>D. peregrinum</i> L.	C8 MARDIN: Bikirkiri, <i>Ilarslan 1637</i>
<i>D. virgatum</i> Poir.	C3 ANTALYA: Termessos Nat. Park, <i>Ilarslan 1645</i>
<i>D. cinereum</i> Boiss.	B5 YOZGAT: Yerköy, <i>Ilarslan 1615</i>
<i>D. venulosum</i> Boiss.	C5 NIGDE: Çaykavak pass, <i>Ilarslan 1613</i>
<i>D. davisii</i> Munz	A4 ZONGULDAK: Egriova, <i>Ilarslan 1618</i>
<i>D. staphisagria</i> L.	CI AYDIN: Davutlar, <i>Dudley 34930</i>
<i>D. albiflorum</i> DC.	A9 KARS: Sarikamis, <i>Ilarslan 1657</i>
<i>D. dasystachyum</i> Boiss. & Bal.	B7 ERZINCAN: Basgözeler, <i>Ilarslan 1606</i>
<i>D. longibracteatum</i> (Boiss.) Munz	A8 RIZE: Cimil, <i>Guner 6928 & Vural</i>
<i>D. dolichostachyum</i> Chowdhuri & P. H. Davis	B9 BITLIS: Küçüksu Kariz Mt., <i>Ilarslan 1665</i>
<i>D. schmalhauseni</i> Alboff	A9 KARS: Yalnizcam Mt., <i>Ilarslan 1607</i>
<i>D. ilgazense</i> P.H. Davis	A4 KASTAMONU: Ilgaz Mt., <i>Ilarslan 1611</i>
<i>D. fissum</i> Waldst. & Kit subsp. <i>anatolicum</i> Chowdhuri & Davis	C3 ISPARTA: Kapiz valley, <i>Ilarslan 1641</i>
<i>D. kitianum</i> R. Ilarslan	C4 KONYA: Kazanci, <i>Ilarslan 1639</i>
<i>D. munzianum</i> P. H. Davis & Kit Tan	A8 ERZURUM: Tortum to Oltu, <i>Ilarslan 1663</i>
<i>D. nydeggeri</i> Hub.-Mor.	C5 NIGDE: Demirkazik, <i>Ilarslan 1616</i>
<i>D. iris</i> R. Ilarslan & Kit Tan	A9 KARS: E. of Ardahan, <i>Vydegger 14648</i>
<i>D. cilicicum</i> P. H. Davis & Kit Tan	C3 ANTALYA: Akseki, <i>Duman 1827</i>
<i>D. güeneri</i> P. H. Davis	C3 ISPARTA: Kapiz valley, <i>Ilarslan 1643</i>
<i>D. laxiusculum</i> (Boiss.) Rouy	A9 KARS: Kagizman bridge, <i>Ilarslan 1623</i>
<i>D. pallidiflorum</i> Freyn	B9 VAN: Ereğ Mt., <i>Ilarslan 1647</i>
<i>D. vanense</i> Rech. fil.	B9 BITLIS: Kuzgunkiran pass, <i>Ilarslan 1635</i>
<i>D. kurdicum</i> Boiss. & Hohen.	B7 TUNCELI: Ovacik, <i>Ilarslan 1649</i>
<i>D. macrostachyum</i> Boiss. ex Huth	C8 MARDIN: Bikirkiri, <i>Ilarslan 1631</i>
<i>D. crispulum</i> Rupr.	B10 KARS: Büyük Agri Mt., <i>Ilarslan 1608</i>
<i>D. buschianum</i> Grossh.	A9 KARS: Sarimollaçesme valley, <i>Ilarslan 1604</i>
<i>D. formosum</i> Boiss. & Huet	A8 RIZE: Çat to Elevit, <i>A. Guner 2843</i>
<i>D. flexuosum</i> M. Bieb	A9 ARTVIN: Müezzinler, <i>Ilarslan 1603</i>

Table 1.- List of studied material and geographic origin.

mainly on data provided by seed characters, and the ecological approach in the closely related genus *Aconitum* L. by CAPELLETTI & POLDINI (1984) rely on ornamentation seed characters as adaptive features in diaspore dissemination. In the light of such previous authors, further studies were conducted to evaluate the taxonomic position of the Turkish species as well as the main diversity patterns based in seed morphology of the genus *Delphinium* using Scanning Electron Microscopy (S.E.M.) techniques, as SIMON (1986), MOLERO & PUIG (1990) and BLANCHÉ (1991) did on Western Mediterranean species of the genera *Consolida*, *Aconitum* and *Delphinium* respectively.

MATERIAL AND METHODS

Mature seeds of 28 of the 31 Turkish *Delphinium* species were obtained by R. Ilarslan mainly from wild localities and collected within the years 1984-1988, except for some cases in which well preserved seeds from herbarium collections were sampled. Origin of seeds and herbarium vouchers kept in ANK are listed in table 1, where the code of the DAVIS (1965)'s Flora of Turkey grid system and the corresponding vilayet (province) are given. The infrageneric classification of *Delphinium* follows the system of MALYUTIN (1987) waiting for the formal acceptance of the new typification of the genus proposed by WARNOCK (1993).

Five seeds of each sample were mounted directly on stubs and coated with a 30 nm gold-layer in a Polaron E5100 sputter coater. Observations were made in a Jeol JSM 840A scanning electron microscope at acceleration voltages of 20 kV. All five seeds were examined at low and high magnifications (x12 and x5500) to ensure the characters constancy. Additional morphological characters were obtained by direct measuring of D (length) and d (width) under a Zeiss DRC stereomicroscope on 30 seeds/population (except for a few cases of narrow endemic plants where less seeds were available or even some species have been collected once; In this case only the SEM measurements were carried out. This is indicated in the text and Table 2 as "SEM measurements").

RESULTS

The general seed structure observed in the Turkish species of *Delphinium* corresponds to the described for the genus *Aconitum* in MOLERO & PUIG (1990), i.e. more or less subpyramidal seeds derived from an anatropous ovule, having a crateriform cavity on the hilum zone (fig. 1c), opposite to the apex of the virtual pyramid.

A short description of seed morphology of each species includes both qualitative and quantitative characters. Dimensions are presented as mean \pm standard error. Numerical features are summarized in table 2.

Subgen. *Delphinium* Sect. *Delphinium*

1. *D. peregrinum* L.

Dark brown, subglobose seeds of $1,46 \pm 0,02 \times 1,54 \pm 0,03$ mm with 7-9 helicoidal rings of continuous overlapping lamellae (fig. 1a). Lamellae faces smooth, with convex shaped rectangular cells, digitate at the apex (fig. 1b) because of the ends of such rectangular cells. At higher magnification, high density stick-line, erect papillae are observed. Deep funnel-shaped hilum with regularly overlapping lamellae.

2. *D. virgatum* Poir.

Black to brown subglobose seeds of $1,57 \pm 0,02 \times 1,99 \pm 0,04$ mm with 7-9 helicoidal rings of discontinuous, merlon-shaped, overlapping lamellae (fig. 1c). Each lamella fragment or scale consists of 10-13 rows of convex rectangular cells (fig. 1d) with medium-density papillae which are rough, spherical to stick-shaped. Deep funnel-shaped hilum with light verrucate projections (fig. 1c).

3. *D. cinereum* Boiss.

Black to brown subglobose seeds of $1,09 \pm 0,01 \times 1,22 \pm 0,01$ mm with 7-9 helicoidal rings of continuous overlapping lamellae, not scaly, formed by rectangular-shaped cells

with medium-density stick-shaped papillae (fig. 1e). Deep funnel-shaped, crateriform hilum with rough cells.

4. *D. venulosum* Boiss.

Brown subglobose seeds of $1,34 \pm 0,03 \times 1,40 \pm 0,04$ mm with 7-9 helicoidal rings of

Taxon	shape	min-max D ¹	mean D \pm SE ¹	min-max d ¹	mean d \pm SE ¹	Seed faces	Scales number/side
<i>D. peregrinum</i>	sbg	1,3-1,6	1,46 \pm 0,02	1,3-1,9	1,54 \pm 0,03	c rings	7-9 rings
<i>D. virgatum</i>	sbg	1,5-1,8	1,57 \pm 0,02	1,5-2,4	1,89 \pm 0,04	d rings	7-9 rings
<i>D. cinereum</i>	sbg	1,0-1,2	1,09 \pm 0,01	1,1-1,3	1,22 \pm 0,01	c rings	7-9 rings
<i>D. venulosum</i>	sbg	1,1-1,7	1,34 \pm 0,03	1,1-1,7	1,40 \pm 0,04	c rings	7-9 rings
<i>D. davisii</i>	sbg	1,5-2,0	1,74 \pm 0,02	1,5-2,0	1,73 \pm 0,02	c rings	7-9 rings
<i>D. staphisagria</i>	scsph	6,3-8,4	7,36 \pm 0,09	4,4-7,3	6,04 \pm 0,14	reticulate	absent
<i>D. albiflorum</i>	sbgpy	SEM	measurements	(see text)	-	n sc	40-50
<i>D. dasystachyum</i>	sbgpy	1,5-2,3	1,78 \pm 0,04	1,0-2,1	1,50 \pm 0,04	w sc	15-20
<i>D. longebraeatum</i>	sbgpy	2,2-2,8	2,48 \pm 0,03	1,2-1,7	1,50 \pm 0,03	w sc	15-20
<i>D. dolichostachyum</i>	sbgpy	SEM	measurements	(see text)	-	n sc	40-50
<i>D. schmalhauseni</i>	sbgpy	1,5-2,4	2,07 \pm 0,04	1,0-1,8	1,25 \pm 0,04	w sc	22-25
<i>D. ilgazense</i>	sbgpy	SEM	measurements	(see text)	-	n sc	40-50
<i>D. fissum</i>							
subsp. <i>anatolicum</i>	sbgpy	2,0-3,1	2,40 \pm 0,05	1,1-2,0	1,52 \pm 0,05	w sc	15-20
<i>D. kitianum</i>	sbgpy	1,8-2,7	2,26 \pm 0,05	1,3-2,0	1,68 \pm 0,04	w sc	20-22
<i>D. munzianum</i>	sbgpy	1,8-2,3	2,08 \pm 0,03	1,0-1,6	1,28 \pm 0,03	w sc	28-32
<i>D. nydeggeri</i>	sbgpy	1,9-2,0	1,95 \pm 0,03	1,3-1,6	1,43 \pm 0,08	w sc	15-20
<i>D. iris</i>	sbgpy	SEM	measurements	(see text)	-	w sc	c. 15-18
<i>D. cilicicum</i>	sbgpy	SEM	measurements	(see text)	-	s sc	
<i>D. gueneri</i>	sbgpy	1,9-2,7	2,27 \pm 0,03	1,3-2,0	1,70 \pm 0,03	w sc	24-28
<i>D. laxiusculum</i>	sbgpy	1,1-1,6	1,32 \pm 0,05	0,9-1,3	1,05 \pm 0,04	w sc	15-20
<i>D. pallidiflorum</i>	sbgpy	1,6-2,3	1,93 \pm 0,03	1,2-1,8	1,51 \pm 0,03	w sc	14-20
<i>D. vanense</i>	sbgpy	1,7-2,3	2,00 \pm 0,05	1,3-1,8	1,57 \pm 0,03	w sc	17-20
<i>D. kurdicum</i>	sbgpy	1,8-2,7	2,32 \pm 0,03	1,5-2,0	1,68 \pm 0,03	w sc	15-20
<i>D. macrostochyum</i>	sbgpy	2,5-3,3	2,69 \pm 0,03	1,6-2,7	2,11 \pm 0,05	w sc	15-20
<i>D. crispulum</i>	e-sbgpy	2,4-3,2	2,83 \pm 0,04	1,4-2,2	1,71 \pm 0,04	n sc	45-60
<i>D. buschianum</i>	e-sbgpy	2,3-3,3	2,82 \pm 0,05	1,3-2,0	1,59 \pm 0,03	n sc	20-25
<i>D. formosum</i>	e-sbgpy	1,7-2,3	2,13 \pm 0,08	0,9-1,5	1,21 \pm 0,09	n sc	18-25
<i>D. flexuosum</i>	e-sbgpy	2,5-3,6	3,05 \pm 0,06	1,3-2,0	1,52 \pm 0,04	c rings	6-9 rings

Table 2. - Seed characteristics of *Delphinium* species of Turkey. **e-sbgpy** = elongate-subpyramidal, **sbg** = subglobose, **sbgpy** = subpyramidal, **scsph** = sector-sphaeroidal; **c rings** = continuous rings, **d rings** = discontinuous rings, **n sc** = narrow scales, **s sc** = short scales, **w sc** = wide scales. ¹ Dimensions are given in mm. D = maximum diameter (length) and d = minimum diameter (width), following the terminology proposed by MOLERO & PUIG (1990).

continuous lamellae with minutely undulate margin, due to the digitiform ends of the rectangular-shaped cells (fig. 1f). Faces with medium-density spherical to stick-shaped, usually erect papillae. Deep crateriform hilum with wrinkled, crested cells.

5. *D. davisii* Munz

Black to brown subglobose seeds of $1,74 \pm 0,02 \times 1,73 \pm 0,02$ mm with 7-9

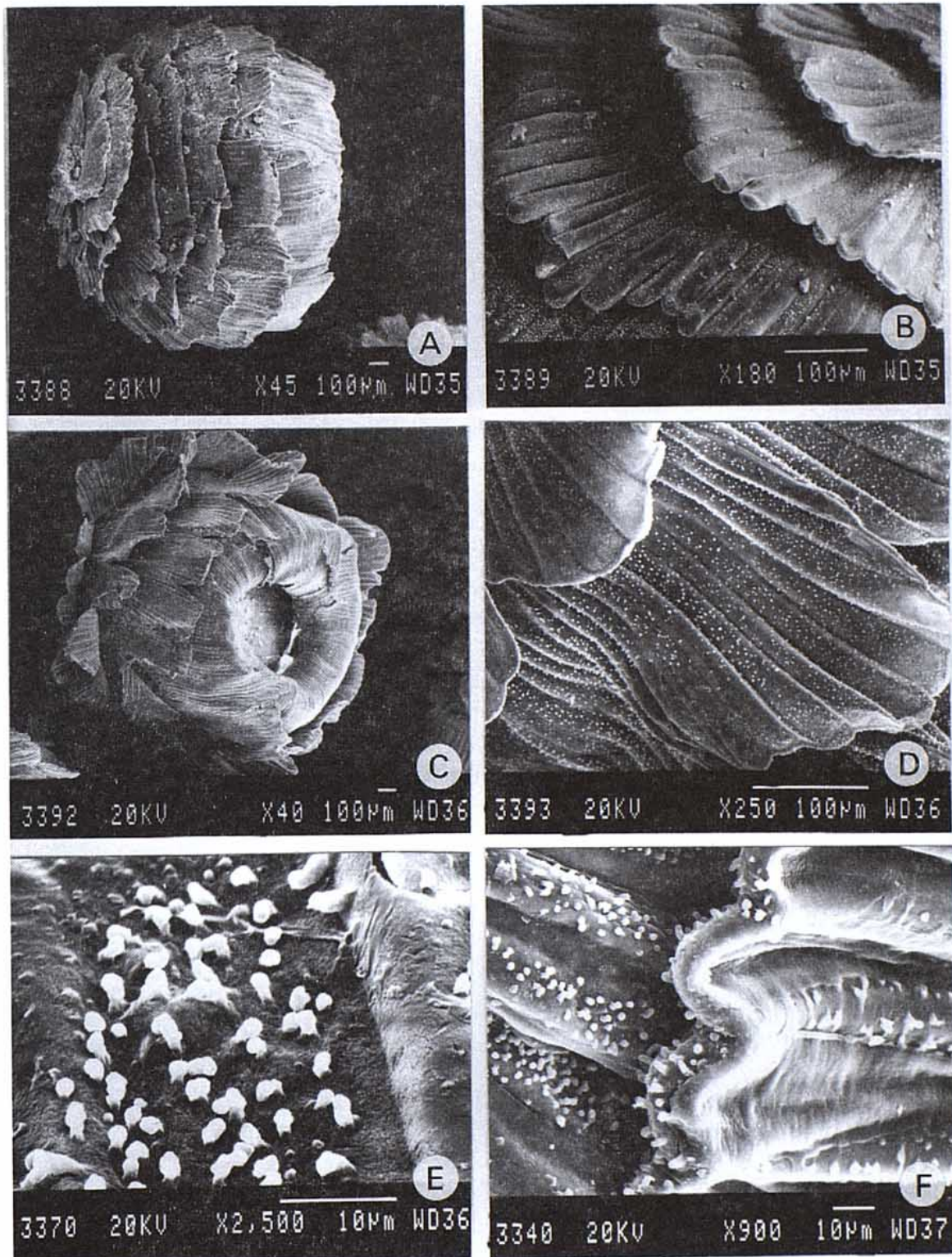


Figure 1.- SEM photographs of *Delphinium* sect. *Delphinium* seeds: *D. peregrinum* a) lateral view, subglobose shape, b) digitiform cells forming lamellae; *D. virgatum*, c) inferior view showing umbilical hilum region and the merlon-shaped margins of lamellae, d) papillate surface of lamellae on the abaxial face; *D. cinereum*: e) Detail of papillae on the cell surface; *D. venulosum*, f) Side view of the terminal thickenings of the digitiform cells of a lamella and the continuous cuticular covering being split, showing the papillae formation pattern.

helicoidal rings of continuous lamellae formed by light concave rectangular cells, digitate at the apex. Medium- and high-density rough, spherical and stick-shaped papillae. Crateriform hilum with verrucate and crested cells.

Subgen. *Staphisagria* (DC.) Peterm.
Sect. *Staphisagria* DC.

6. *D. staphisagria* L.

Black, sector-spheroidal seeds of $7,36 \pm 0,09 \times 6,04 \pm 0,14$ mm. Wings, lamellae or scales absent. Reticulate sides (fig. 2a) of digitiform cells sometimes emerging arranged in ridges producing the reticulate pattern. Cell surface covered by erect, long and stick-like papillae (fig. 2b).

Subgen. *Oligophyllon* Dimitrova
Sect. *Oligophyllon*

7. *D. albiflorum* DC.

Dark brown, subpyramidal seeds of $2,5 \times 1,2$ mm (SEM measurements). Faces scaly bearing c. 40-50 narrow scales/side (fig. 3f), without longitudinal wings neither transversal lamellae. In each scale, smooth (without papillae) rectangular cells are observed, although in some cases, rough spherical papillae still appear. Widely crateriform hilum with irregularly overlapping lamellae (fig. 3f).

8. *D. dasystachyum* Boiss. & Bal. in Boiss.

Light brown, subpyramidal seeds of $1,78 \pm 0,04 \times 1,50 \pm 0,04$ mm. Sides covered by scales in a number of 15-20 wide scales/side (fig. 2c), without longitudinal wings. Scales partially overlapping one each other and formed by rectangular-shaped cells covered by high-density papillae irregularly arranged. The cuticle of the lateral walls of such cells presents lines of rough, spherical papillae. Deep crateriform hilum with irregularly overlapping lamellae with wrinkled-crested cells (fig. 2c).

9. *D. longebracteatum* (Boiss.) Munz

Brown, subpyramidal seeds of $2,48 \pm 0,03 \times 1,54 \pm 0,03$ mm. Absence of longitudinal wings but presence of 15-20 wide scales /side. Such scales are long, much overlapping one to each other row (fig. 3c), irregularly and sometimes obliquely arranged. The scales are formed by rectangular cells covered by medium- and low density, rough papillae. Widely crateriform hilum with irregular lamellae.

10. *D. dolichostachyum* Chowdhuri & P. H. Davis

Brown, subpyramidal seeds of $2,2 \times 2,0$ mm (SEM measurements). Absence of longitudinal wings and presence of narrow scales, c. 40-50 scales/side.

Scales, scarcely overlapping, are formed by rectangular cells, undulate or zig-zag shaped at the apex (fig. 3e) with low-density or absence of stick-like papillae. Deep, crateriform hilum with wrinkled, undulate cells.

11. *D. schmalhauseni* Alb.

Black to dark brown subpyramidal seeds of $2,07 \pm 0,04 \times 1,25 \pm 0,04$ mm. Scaly sides

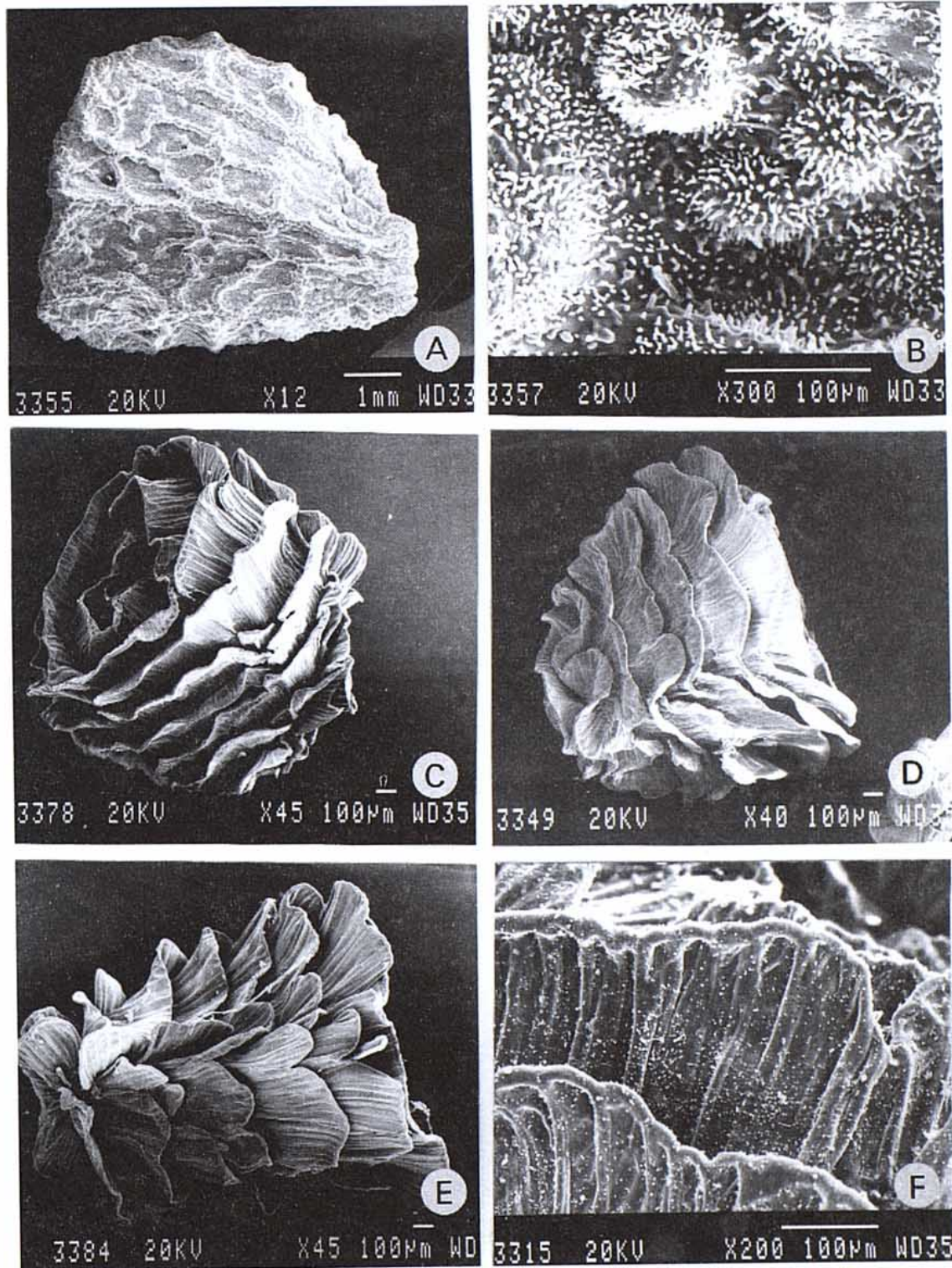


Figure 2.- SEM photographs of *Delphinium* subgen. *Staphisagria* seeds: *D. staphisagria*, a) general view with reticulate faces, b) long, stick-like papillae emerging from the rough episperm surface. *Delphinium* subgen. *Oligophyllon* sect. *Oligophyllon*: c) *D. dasystachyum*, general view, d) *D. pallidiflorum*, general view, e) *D. vanense* Rech. fil. f) *D. macrostachyum*, detail of the transverse scales overlapping, with medium-density papillae over the cell surfaces.

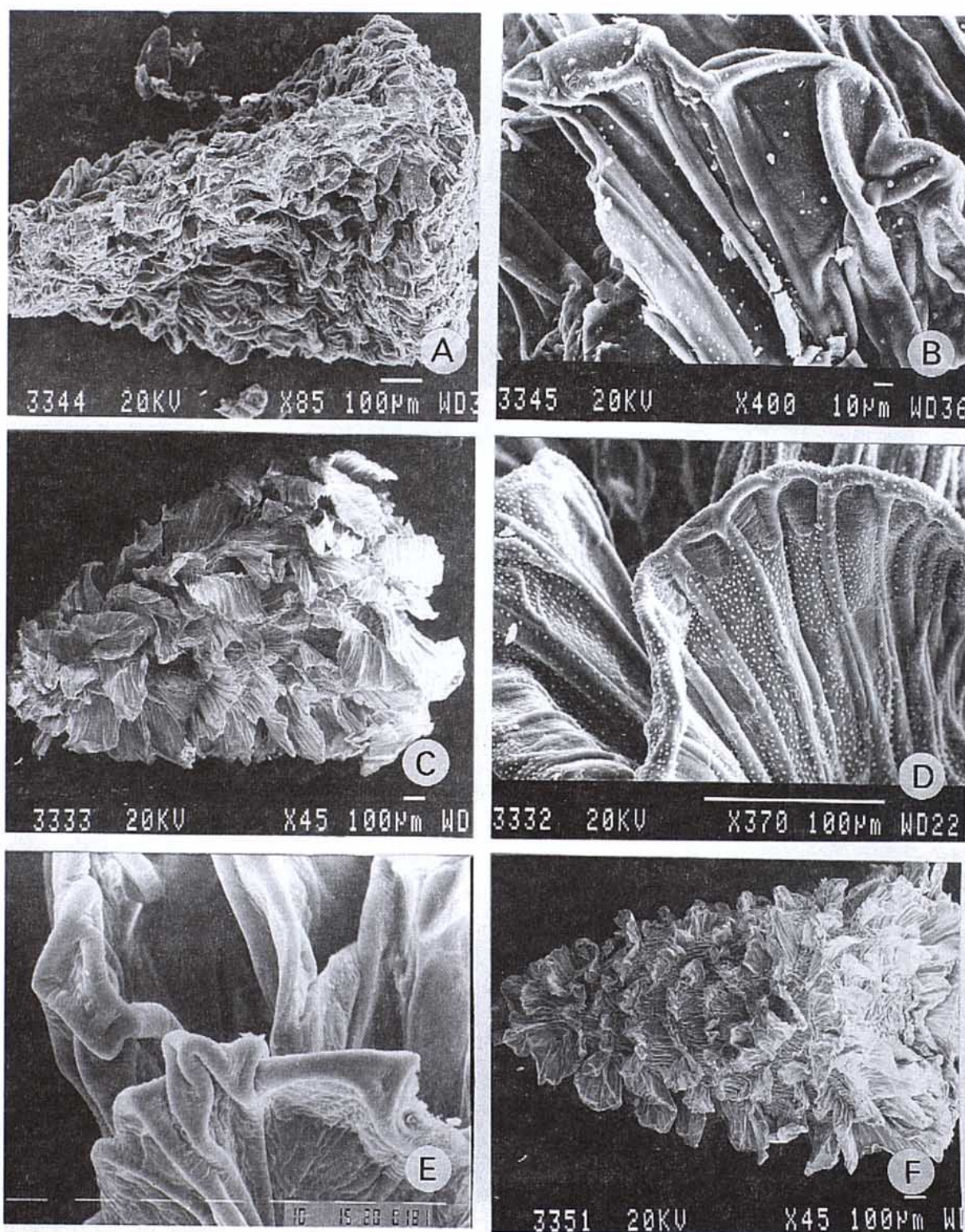


Figure 3.- SEM photographs of *Delphinium* sect. *Oligophyllon*: *D. cilicicum* a) general view, b) short scales with low density papillae; *D. longibracteatum*, c) general view with long, curlingly arranged scales; *D. munzianum*, d) densely papillate surface of rectangular cells forming the scale; e) *D. dolichostachyum*, smooth surface of the scale's cells without papillae; f) *D. albiflorum*, general view.

without longitudinal wings. Scales wide, 22-25 scales/side, short, overlapping only in the lower rows (fig. 4d). Each individual scale is formed by elongate rectangular cells provided with low-density rough, sphaerical papillae. Widely crateriform hilum with irregularly overlapping lamellae.

12. *D. ilgazense* P. H. Davis

Shiny light brown, subpyramidal seeds of 1,85 x 1,75 mm (SEM measurements). Scaly sides without longitudinal wings, presenting c. 40-50 narrow scales /side (fig. 4b). Scales partially overlapping (fig. 4a), consisting on long rectangular cells smooth or medium- and low-density papillate, with sphaerical or reclining stick-shaped papillae. Wide crateriform hilum with wrinkled-undulate cells (fig. 4b).

13. *D. fissum* Waldst. & Kit. subsp. *anatolicum* Chowdhuri & P. H. Davis

Reddish brown, subpyramidal seeds of $2,4 \pm 0,05$ x $1,53 \pm 0,05$ mm. Absence of longitudinal wings and presence of scales on the sides in number of c.15-20 wide scales/side. Very low-density stick-like papillae on the rectangular cells forming scales. Wide crateriform hilum with wrinkled, undulate cells.

14. *D. kitianum* R. Ilarslan

Shiny brown, subpyramidal seeds of $2,26 \pm 0,05$ x $1,68 \pm 0,04$ mm. Seeds scaly, with 20-22 scales/side and without longitudinal wings. Rectangular cells of reinforced thick margins having high-density rough sphaerical papillae. Widely crateriform hilum with irregularly overlapping scales.

15. *D. munzianum* P. H. Davis & Kit Tan

Brown, subpyramidal seeds of $2,08 \pm 0,03$ x $1,28 \pm 0,03$ mm. Absence of longitudinal wings and presence of medium sized scales, c.28-32 scales/side, on a figure suggesting undulate lobes in scales of the wide-type (fig. 3d). Rectangular cells with medium-density rough sphaerical papillae. Wide crateriform hilum with wrinkled, undulate cells.

16. *D. nydeggeri* Hub.-Mor.

Light brown, subpyramidal seeds of $1,95+0,03$ x $1,43+0,08$ mm. Sides with wide scales, without longitudinal wings (fig. 4f). 15-20 scales/side. Rectangular cells with medium- and high-density rough sphaerical papillae except at the external apex, where are smooth.

17. *D. iris* Ilarslan & Kit Tan

Shiny dark brown, subpyramidal seeds of 1,1 x 1,0 mm (SEM measurements, not fully mature seeds available). Longitudinal wings absent, sides scaly, with wide scales. Rectangular cells covered by high density sphaerical papillae. Widely crateriform hilum with irregularly overlapping scales.

18. *D. cilicicum* P. H. Davis & Kit Tan

Yellowish brown, subpyramidal seeds of 1,20 x 0,7 mm (SEM measurements). Three well marked longitudinal ridges giving a well defined triangular cross section, although no well developed wings were observed (fig. 3a). Rectangular cells with medium- to low-density papillae conform short irregular topographic emergences from the seed surface, giving rise sometimes to undulations, nippings and to short scales too (fig. 3b).

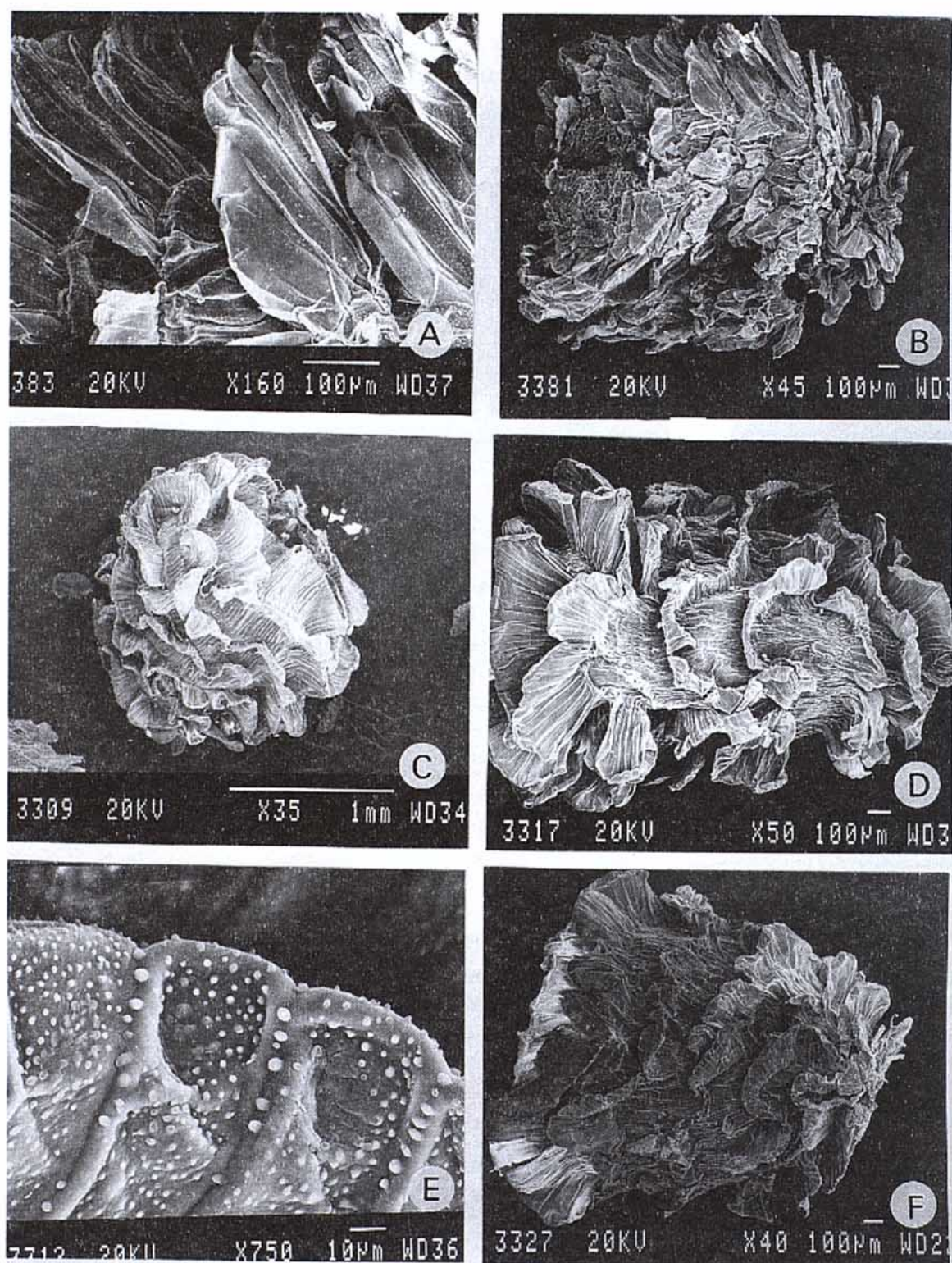


Figure 4.- SEM photographs of *Delphinium* sect. *Olygophyllon*: *D. ilgazense*, a) Detail of scales, b) general view.; *D. güeneri*: c) general view, e) detail of the high-density covering of papillae over the scale's cells, showing larger, sphaerical papillae on the thick lateral walls; d) *D. schmalhauseni*, general view; f) *D. nydeggeri*, general view.

19. *D. gueneri* P.H. Davis

Shiny dark brown, subpyramidal seeds of $2,27 \pm 0,03 \times 1,7 \pm 0,03$ mm. Absence of longitudinal wings and presence of wide scales in number of 24-28 scales/side (figure 4c). Rectangular cells forming each scale bearing rough spherical high-density papillae, of bigger dimensions on the thickened cell margins (fig. 4e). Wide crateriform hilum with wrinkled-undulate cells.

20. *D. laxiusculum* (Boiss.) Rouy

Light brown, subpyramidal seeds of $1,32 \pm 0,05 \times 1,05 \pm 0,04$ mm. Absence of longitudinal wings and presence of very wide scales nearly arranged in rows or rings hellicoidal. 15-20 scales/side. Scales formed by long rectangular cells smooth, lacking papillae, except in the abaxial face of some scales, where papillae appear. Deep, crateriform hilum with rough, wrinkled and crested cells.

21. *D. pallidiflorum* Freyn

Shiny brown, subpyramidal seeds of $1,93 \pm 0,03 \times 1,51 \pm 0,03$ mm. Absence of longitudinal wings and presence of very wide scales (fig. 2d), 14-20 scales/side. Rough papillate rectangular cells. Widely crateriform hilum, with wrinkled, undulate cells.

22. *D. vanense* Rech. fil.

Light brown, subpyramidal seeds of $2,00 \pm 0,05 \times 1,57 \pm 0,03$ mm. Absence of longitudinal wings and presence of wide scales (fig. 2e). 17-20 scales/side. Irregularly distributed sphaerical to stick-shaped cuticular papillae. Widely crateriform hilum with wrinkled, undulate cells.

23. *D. kurdicum* Boiss. & Hohen.

Shiny light brown, subpyramidal seeds of $2,32 \pm 0,03 \times 1,68 \pm 0,03$ mm. Absence of longitudinal wings and presence of scales on seed sides. 15-20 wide scales/side, formed by long rectangular cells with high-density rough and stick-like papillae on surface, except on the lateral walls which are smooth. Wide and slight, deep, crateriform hilum with wrinkled undulate cells.

24. *D. macrostachyum* Boiss. ex Huth

Light brown, subpyramidal seeds of $2,69 \pm 0,03 \times 2,11 \pm 0,05$ mm, without longitudinal wings. 15-20 wide scales/side, formed by long rectangular cells (fig. 2f) with thick, scarcely undulate margins at the edges. Rough, medium-density papillae on surface. Crateriform hilum with wrinkled, undulate polygonal cells.

Sect. *Pogonanthus* W.T. Wang25. *D. crispulum* Rupr.

Brown, elongate supyramidal seeds of $2,83 \pm 0,04 \times 1,71 \pm 0,04$ mm. Absence of longitudinal wings but sharply marked edges along the angles and subtriangular cross section of the seed. 45-60 narrow scales/side distributed in 6-15 rows. Thick and strongly undulate (fig. 5b) top of rectangular cells with medium-density stick-shaped papillae. Widely crateriform hilum with rough, crested cells.

26. *D. buschianum* Grossh.

Shiny brown, elongate subpyramidal seeds of $2,82 \pm 0,05 \times 1,59 \pm 0,03$ mm. Absence of longitudinal wings and presence of 20-25 narrow and long scales/side, arranged in 10-

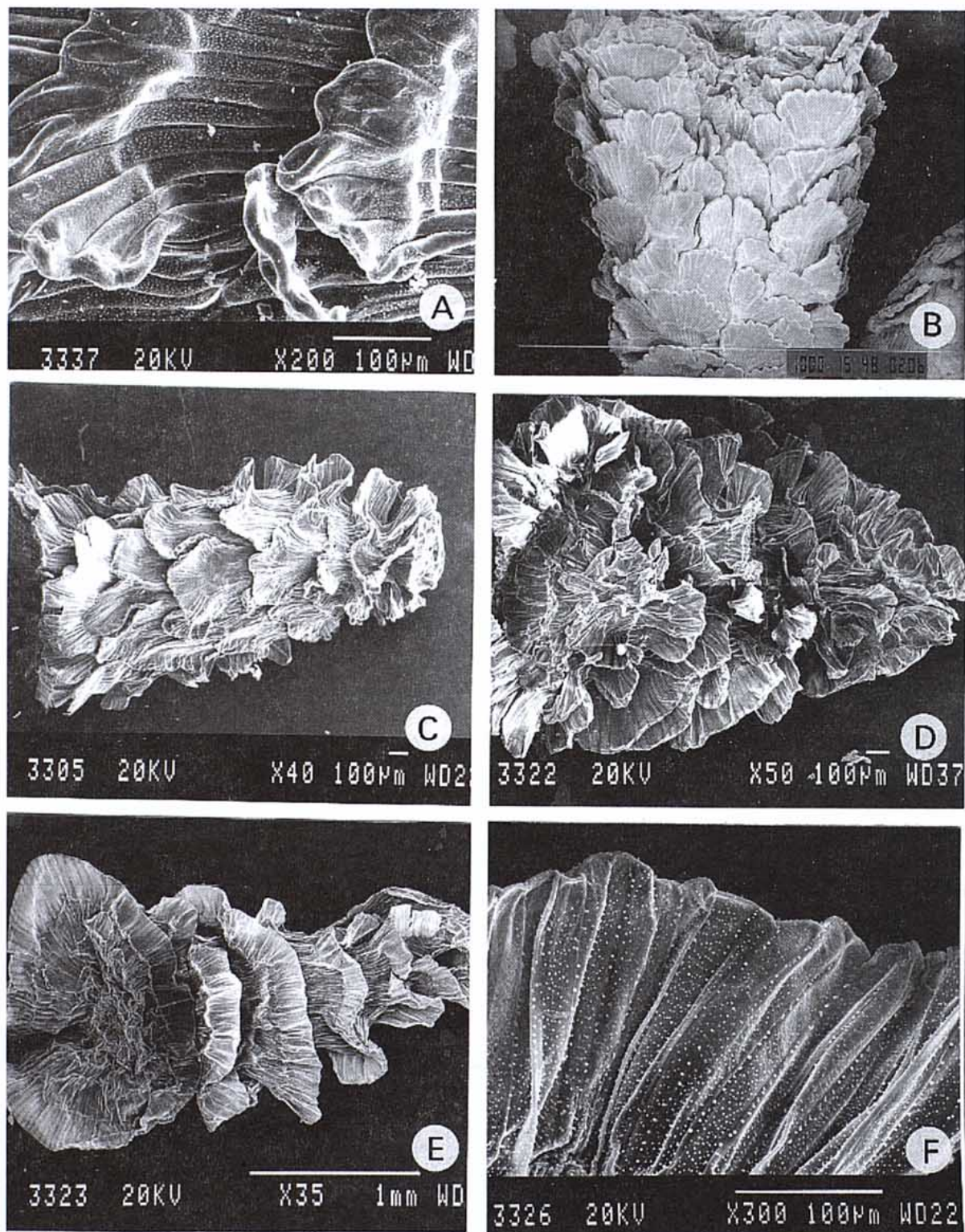


Figure 5.- SEM photographs of *Delphinium* subgen. *Oligophyllum* sect. *Pogonanthus*: *D. crispulum*: a) emerging, young scales on lateral faces, b) general view. Remark the undulate margin of each scale. *D. buschianum*, c) general view; *D. formosum* d), general view; *D. flexuosum*: e) general view. Remark the wide, continuous helicoidal rings (skirt-like) of lamellae. f) Detail of the papillate surface of scales.

15 rows (fig. 5c). Rectangular cells with medium-density stick-shaped papillae. Widely crateriform hilum with irregularly, wrinkled, undulate cells.

27. *D. formosum* Boiss. & Huet in Boiss.

Brown, elongate subpyramidal seeds of $2,13 \pm 0,08 \times 1,21 \pm 0,09$ mm. Abaxial or external seed face somewhat curved. Absence of longitudinal wings and presence of long, narrow scales in number of 18-25 scales/side (fig. 5d) overlapping one each other. Rectangular cells with medium-density rough, sphaerical papillae. Wide crateriform hilum with wrinkled, undulate cells.

28. *D. flexuosum* M. Bieb.

Shiny light brown, elongate subpyramidal seeds of $3,04 \pm 0,06 \times 1,52 \pm 0,04$ mm. Absence of longitudinal wings and of individual scales. Rectangular cells arranged in 6-9 continuous rings of transversal wings (fig. 5e) in a figure resembling skirts. Long rectangular cells of each transversal wing, arranged as in the scales of the remaining species and with medium- to high-density stick-like or sphaerical papillae (fig. 5f). Crateriform hilum with wrinkled undulate cells.

DISCUSSION

A great diversity of seed types both within and among groups of species has been found. This fact agrees with the high macro-morphological diversity found among the species of *Delphinium* growing in Turkey (ZOHARY, 1973; ILARSLAN, 1990). In addition, such diversity fits consistently with the systematic approaches followed previously in the genus.

The following groups can be recognized, using the descriptive terminology of MOLERO & PUIG (1990) and BLANCHÉ (1991):

1. Subglobose, small (c. 1 x 1 mm) seeds with continuous rings of lamellae (subgen. *Delphinium*: *D. peregrinum*, *D. virgatum*, *D. cinereum*, *D. venulosum*, *D. davisii*).
2. Subpyramidal, medium size (c. 1,5-2,5 x 1-1,5 mm) seeds with scales in the lateral seed sides (subgen. *Olygophyllon*, sect. *Olygophyllon*). Two groups can be recognized within this section:
 - a. Species with wide scales (15-20 scales/side): *D. dasystachyum*, *D. longebracteatum*, *D. schmalhauseni*, *D. fissum*, *D. kitianum*, *D. munzianum*, *D. nydeggeri*, *D. iris*, *D. gueneri*, *D. laxiusculum*, *D. pallidiflorum*, *D. vanense*, *D. kurdicum* and *D. macrostachyum*. It is the majoritary group in Turkey.
 - b. Species with narrow scales (up to 40-50 scales side): *D. albiflorum*, *D. dolychostachyum*, *D. ilgazense*. *D. cilicicum* appears as intermediate between groups a and b.
3. Subpyramidal, elongate seeds of medium size (c. 2-3 x 1,2-1,5 mm) with less scales/side, because of the narrow surface of each side. (Subgen. *Oligophyllon*, sect. *Pogonanthus*: *D. crispulum*, *D. buschianum*, *D. formosum*, *D. flexuosum*)
4. Sector-sphaeroidal large seeds (c. 6-7 mm) without scales, but with reticulate surface (subgen. *Staphisagria*: *D. staphisagria*).

Seeds of smooth sides provided with longitudinal wings are completely absent from the Turkish species. This is a characteristic feature of subgen. *Delphinastrum*, were the alpine European species (*D. elatum*, *D. dubium*, *D. oxysepalum* and *D. montanum*) have to be placed (PAWLOWSKY, 1963; MALYUTIN, 1987; BLANCHÉ, 1991).

Group 1- Subgen. *Delphinium*

The seeds of annuals are the smallest found within the Turkish species of *Delphinium* and it agrees with the results obtained in W. Mediterranean representatives (BLANCHÉ, 1991), thus indicating that it is a fixed character associated to the subglobose shape, useful for taxonomical purposes. The continuous rings of lamellae arranged helicoidally consisting on the major structural pattern, minor differences at specific level have to be pointed out as a bigger size in *D. davisii* (1,5-2,0 mm in front of 1,-1,5 mm, for the remaining annual species), and the linear, undulate or fragmented (merlon-shaped) discontinuous margin of the lamellae in *D. virgatum* (fig. 1a-d). This differentiation can suggest an hypothesis of the origin of such continuous lamellae, from the scaly seed of perennials of sect. *Olygophyllon* by size reduction and further fusion of individual scales to continuous lamellae, being the merlon-shaped seeds of *D. virgatum* an example of intermediate positions.

Group 2- Subgen. *Staphisagria*

The results obtained agree with the previous SEM surveys of *D. staphisagria* seeds from the W. Mediterranean Region (KIROLOVA, 1988 and BLANCHÉ, 1991). This extraordinary large seeds are in extreme low number (only 2-3) within each follicle (in contrast to the 10-20 seeds/follicle found in the remaining species investigated, M. Bosch, unpubl. data). Although minor differences in papillae size and shape (the Turkish specimens presenting erect, long and radially arranged papillae in each cell as illustrated in fig. 2 of KIROLOVA (1988) in contrast to the rough, spherical and irregular ones in the Iberian representatives, cf. BLANCHÉ, l.c.), the morphological pattern for this species is the same along the whole Mediterranean Region. However, any other species of similar seed morphology is still known among the species of *Delphinium* (HUTH, 1895, MALYUTIN, 1973, BLANCHE, 1991), except the two small related endemics *D. pictum* subsp. *pictum* and subsp. *requienii* (belonging to the same group). Then, an isolated position of the group of *D. staphisagria* within the genus has to be maintained and the rank of subgenus (subgen. *Staphisagria*) seems very appropriate. The SEM- pattern of digitiform cells sometimes emerging and giving a reticulate appearance is similar to the pattern found in other genera of *Ranunculaceae* (e. g. *Nigella damascena* as reported by KARCZ & TOMCZOK, 1987) and it is caused both by epidermal cells and by subepidermal layers (KIROLOVA, l.c.)

Group 3. Subgen. *Olygopyllon*, sect. *Oligophyllon*

Seed colour of this group ranges from black to brown more or less light shiny because of the translucent aspect given by the scales, usually open, patent, of a general flying-skirt disposition. Two groups, bearing wide and narrow scales respectively have been found among the Turkish species. In the general review of the European species of PAWLOWSKY (1963), all the species with scaly seeds belong to subsect. *Squamata* B. Pawl, were two groups, of wide scales (series *Fissa* B. Pawl.) and narrow scales (ser. *Pentagyna* B. Pawl.) are recognized. The concept of subsect. *Squamata* seems to fit better with the concept of

subgen. *Oligophyllon* in the entire world's schema of MALYUTIN (1987), including all the species with scaly seeds. But at a lower taxonomic level, the series rank as proposed by PAWLOWSKY (1963) seem to be a helpful systematic tool, because it describes a diversity pattern that corresponds to that found in *Delphinium* (i. e: well defined groups by both morphological and biogeographical characteristics, composed of very closely related small species, see BLANCHÉ 1990b).

In that system of series, the species with wide scales should be placed in series *Fissa* or, at least, in a taxonomic group around *D. fissum*, as BLANCHÉ & MOLERO (1983) proposed several years ago. This group, with a maximum biodiversity in Turkey (the 14 species of subgroup 2b) extends westwards through Southern Europe to the Iberian Peninsula, where only two species (*D. fissum* and *D. bolosii* arrived, cf. GREUTER & al., 1989). The survey of seed morphology of the North African representatives of *Delphinium* (Blanché & Molero, unpubl. data) shows that any of the African species belongs to this group, supporting the hypothesis of a northern mediterranean river migration route for this group with a clear eastern Mediterranean-Irano Turanian origin. The general role of diversity-foyer of Turkey for western mediterranean stirps has been suggested by ZOHARY (1973).

Concerning the species with seeds presenting 40-50 narrow scales/side, it represents a very much smaller group in Turkey (subgroup 2b, including 3-4 species) and no clear biogeographical relationships can be drawn with other Mediterranean taxa. Series *Pentagyna* created by PAWLOWSKY (1963) includes both N. African and S. European representatives, but there is not any continuous geographic area with the Anatolian species studied here, neither with the high mountain endemic species of Tropical Africa (group of *D. leroyii*) for which MUNZ (1967a) suggested a relationship with ser. *Pentagyna*. Related species should be investigated in easternmost Irano-Turanian regions.

At the specific level, the present survey of seed morphology has been useful to help in the taxonomical consideration of the Turkish species. *D. cilicicum* and *D. flexuosum* are nitidly different and placed in separate groups (3 and 4 respectively). Another controversial case is the status of the *D. cyphoplectrum*-group in Turkey, which was considered as formed by 3 taxa at varietal level (*D. cyphoplectrum* var. *stenophyllum* var. *vanense* and var. *pallidiflorum* by DAVIS (1965), whereas MUNZ (1967b, 1968a) interpreted the group as formed by 3 species named, respectively, *D. laxiusculum*, *D. vanense* and *D. pallidiflorum*. Seed characteristics shows enough differences in size, shape and number of scales (table 1) that suggests a higher taxonomic level (species) as the better choice. This systematic arrangement agrees with the results of H. ILARSLAN (1994) based on leaf anatomy and morphology.

Group 4. Subgen *Oligophyllon*, sect. *Pogonanthus*

Only 4 species belong to this group of Asian affinities. The great diversity in seed morphology found has to be indicative of the active differentiation processes that have taken place in Turkey species of *Delphinium*. Such subconical to elongate subpyramidal seeds present from c. 18 to c. 50 scales/side (*D. formosum*, *D. crispulum*, respectively), from narrow, undulate scales (*D. crispulum*) to wide, continuous scales forming lamellae (*D. flexuosum*).

As it has been shown, major parameters varying in *Delphinium* seeds are related to wings, lamellae, etc. then suggesting selection pressures by dispersal agents or in general by ecological factors (survival, floatability, etc.) Further studies in dispersal mechanisms have to be conducted for understanding the evolutive significance of such morphological variability; presently, only very scarce data are available: a report on snow

rolling smooth winged seeds in America (CRONIN & NIELSEN, 1978) and a single data on accidental myrmecochory (TURNBULL *et al.*, 1983). CAPPELLETI & POLDINI (1984) suggested ecological macrofactors as dry, mesic and moist habitats to explain differences in number and position of seed wings in the related genus *Aconitum*.

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