

## POLLEN MORPHOLOGY OF THE FAMILY BORAGINACEAE IN QATAR

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### الشكل الخارجي لحبوب لقاح العائلة البوراجينية في قطر

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أظهرت الدراسة التي تمت بواسطة المجهر الضوئي والمجهر الإلكتروني الماسح لحبوب لقاح ستة أنواع تعود لستة أجناس تمثل العائلة البوراجينية في الفلورا القطرية ، اختلافاً واضحاً في هذه الأنواع من حيث الشكل الخارجي ونوع الفتحات وزخارف السطح الخارجي . ويمثل الاختلاف في نوع وعدد فتحات اللقاح صفة هامة للتمييز بسهولة بين الأنواع المختلفة ، وتراوح فتحات اللقاح في عددها من ثلاثة إلى ثمانية فتحات ، وتميز إلى أربعة أنواع واضحة . وبينت الدراسة أن العائلة البوراجينية تعتبر تصنيفياً غير متجانسة ، وهذا يتفق مع الدراسات السابقة .

*Key words:* Pollen morphology, Boraginaceae, Qatar, Taxonomy

### ABSTRACT

The pollen morphology of six species belonging to six genera of Boraginaceae in Qatar have been investigated by LM and SEM. The examined species proved to be eurypalynous, having different morphological types and can be recognized individually from their pollen grains. The only exception is *Lappula spinocarpus* and *Echiochilon kotschyi*, where their pollen grains are morphologically similar.

In general, the pollen grains are small and isopolar. There are five different types of apertures encountered in the examined species. These types range from tricolporate, 8-colporate and 6 to 8 colpate, pollen grains. Clear variations were also observed in sexine ornamentations, particularly around apertures.

### INTRODUCTION

The Boraginaceae is a family of annual to perennial herbs, shrubs and trees. It is a large family of 100 genera and ca 2000 species, found throughout temperate and subtropical regions, but centered in the Mediterranean region [1]. In Central Europe and Asia the family is represented by only a few members. In Qatar, there are mainly six species belonging to six genera. The pollen grains are more or less similar to those in Verbenaceae [2].

The first description of Boraginaceae (*Borago officinalis*) pollen grains was made by [3-5]. Later on several authors studied the pollen morphology of other species of Boraginaceae with light microscopy, for example, [6-10].

[11-14] did scanning electron microscopy studies on pollen morphology of several species. The previous studies showed that the pollen morphology of the examined species is quite elaborated and highly eurypalynous. Recently, the ultrastructure of the exine and its ontogeny in some Boraginaceae were examined by [15, 16].

The pollen morphology of the members of Boraginaceae in the Gulf area has not been investigated in detail. So far, the only available study of the Boraginaceae in the Gulf, is by [23]. The aim of the present study is to provide a detailed account and complete descriptions of pollen morphology of the Boraginaceae species from Qatar. The characteristics of pollen morphology will be discussed to

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illustrate the relationships between the investigated species.

## MATERIALS AND METHODS

This study is based on polliniferous material of six species collected from the herbarium of the University of Qatar (QU). From each specimen, a few anthers were picked and acetolysed, using [17] standard acetolysis method.

The Light Microscopy (LM) studies were made using a Leitz Wetzlar Dialux microscope with apochromatic oil immersion objective (x100, N.A. 1.32) and periplan eyepieces (G.F. x10). Measurements were made with oil immersion, and are based on 15 or more pollen grains per species. For Scanning Electron Microscopy (SEM), acetolysed pollen grains were suspended in a drop of absolute alcohol and transferred to brass stubs. The pollens were then coated with gold-palladium for seven minutes using a Fine Coat Ion Sputter, JFC 1100. Scanning micrographics were taken with a Jeol JSM 25S-II microscope using Ilford FP4 film.

The terminology of pollen grains mainly follows that of [18].

### SPECIMENS INVESTIGATED

*Arnebia hispidissima* (Spreng.) DC. Qatar: Abu Samra. Batanouny. 171. (UQ), and El Ghazaly 245a (UQ).

*Echiochilon kotschy* (Boiss & Hohen.) I.M. Johnst. Qatar: Al-Zubarah. Batanouny. 181. (UQ), and El-Ghazaly 246a & 247a (UQ).

*Gastrocotyle hispida* (Forssk.) Bunge. Qatar: Simsima. El-Ghazaly. 234, 235 and 236 (UQ).

*Heliotropium bacciferum* (Forssk.) Qatar: Doha. El-Ghazaly. 360. (UQ). Al-Wubrah. El-Ghazaly. 356. (UQ). Ras Ushairij. Batanouny. 15. (UQ). Wadi Dhiab. Batanouny. 235. (UQ).

*Lappula spinocarpos*. (Forssk.) Aschers. ex O. Kuntze. Qatar: Abu Samra. El-Ghazaly, 269 and 270 (UQ).

*Moltkiopsis ciliata* (Forssk.) Johnst. Qatar: Umm Bab. El-Ghazaly. 341 and 242 (UQ).

## RESULTS

### *Arnebia hispidissima*

LM (Figs. 1-4)

**Polarity:** Pollen grains isopolar.

**Symmetry:** Radially symmetrical.

**Shape:** Prolate, oblong to rhomboidal in equatorial view; rounded, trilobate in polar view.

**Dimensions:** P = (20 33 (36)  $\mu$ m

E = (18) 20 (21)  $\mu$ m

P/E = 165

**Apertures:** Pollen grains 6-colpate. Colpi long (25  $\mu$ m), indistinct, narrow, although often wide at equator, with tapering ends; colpus membrane granular.

**Apocolpium Diameter:** 10  $\mu$ m

**Exine:** 1  $\mu$ m thick. Sexine as thick as nexine, minutely spinulose; forming a discontinuous girdle at equator, 8 x 5  $\mu$ m large plates between colpi; irregularly thickened at poles.

**SEM** (Figs. 5-7)

**Apertures:** Colpi unequally wide, with irregular margin; colpus membrane beset with densely spaced round-pointed sexinous elements.

**Exine:** Sexine sparsely perforate, uneven, beset with numerous short, pointed spinules, broad at base.

**Comments:** This species is common in Qatar. The pollen grains are characterized by six long colpi with granular membranes and by spinulose sexine.

### *Echiochilon kotschy*

LM (Figs. 8-13)

**Polarity:** Pollen grains isopolar.

**Symmetry:** Radially symmetrical.

**Shape:** Prolate spheroidal, square-shaped to rectangular in equatorial view; rounded, trilobate in polar view.

**Dimensions:** P = (16) 17 (20)  $\mu$ m

E = (14) 15 (18)  $\mu$ m

P/E = 113

**Apertures:** Pollen grains 3-colporate. Colpi short (6  $\mu$ m) and narrow (1  $\mu$ m wide), situated in an elliptic granular area (9 x 5  $\mu$ m).

**Apocolpium diameter:** 20  $\mu$ m

**Exine:** 1  $\mu$ m thick. Sexine as thick as nexine, finely granular.

**SEM** (Figs. 14-17)

**Apertures:** Colpus area filled with rounded, spinuliferous elements.

**Exine:** Sexine smooth, tetate perforate. Perforations densely spread along colpi margins; fewer towards centre of mesocolpia and apocolpia.

**Comments:** This species is not common in Qatar, it is located mainly in AlZubarah and Fuwairat. The pollen grains are distinguished by their small size and square to rectangular outline in equatorial view.

### *Gastrocotyle hispida*

LM (Figs. 18-24)

**Polarity:** Pollen grains isopolar.

**Symmetry:** Radially symmetrical.

**Shape:** Prolate spheroidal and oblate. Rectangular to oval-shaped with protrusions at equator; rounded to star-

shaped in polar view.

**Dimensions:** P = (18) 21 (23)  $\mu\text{m}$ , (16) 20 (24)  $\mu\text{m}$   
E = (17) 19 (21)  $\mu\text{m}$ , (30) 34 (37)  $\mu\text{m}$   
P/E = 110, 59

**Apertures:** Pollen grains 8-colporate. Colpi long (14  $\mu\text{m}$ ), narrow (1  $\mu\text{m}$ ), faintly delimited into pointed ends; membrane densely granular. Ora lalongate to lolongate (3  $\mu\text{m}$  in dia.). Equatorial area and along colpi margins studded with densely spaced granules.

**Apocolpium diameter:** 3  $\mu\text{m}$

**Exine:** 1  $\mu\text{m}$  thick, smooth; stratification obscure.

**SEM** (Figs. 25-27)

**Apertures:** Colpus margins, membrane and ora covered with densely spaced granules which form an equatorial band.

**Exine:** Sexine smooth, in places slightly uneven, tectate perforate, perforations minute unevenly distributed, denser along colpi margins, fewer in the apocolpia.

**Comments:** Fairly common plant in Qatar, located mainly in the North. The pollen grains are distinguished by having larger number of colpi than in the previous species.

#### *Heliotropium bacciferum*

**LM** (Figs. 28-32)

**Polarity:** Pollen grains para-isopolar.

**Symmetry:** Radially symmetrical.

**Shape:** Prolate. Elliptic in equatorial view, rounded, lobed rarely square-shaped in polar view.

**Dimensions:** P = (26) 29 (32)  $\mu\text{m}$   
E = (14) 17 (20)  $\mu\text{m}$   
P/E = 170

**Apertures:** Pollen grains 3-colporate (rarely 4). Colpi long, narrow (22 x 0.5 - 1  $\mu\text{m}$ ), with pointed to broad ends. Equatorially constricted, margin uneven, membrane granular. Ora slightly lalongate (3 x 2  $\mu\text{m}$ ), outline faint. Each mesocolpium provided with a pseudocolpus which is narrow, as long as or longer than the colpi.

**Apocolpium diameter:** 3 - 5  $\mu\text{m}$

**Exine:** 1  $\mu\text{m}$  thick, smooth; stratification obscure.

**SEM** (Figs. 33-36)

**Apertures:** Colpi equatorially constricted due to sexinous protrusions over ora. Colpus membrane granular.

**Exine:** Sexine smooth in apocolpia, uneven in mesocolpia beset with densely spaced minute, faint, unevenly distributed perforations. Sexine protruding over ora; in some cases fused to form a bridge.

**Comments:** This species is common all over Qatar and shows distinct morphological variations in the length and texture of the leaves and flowers. It appears well-suited for a detailed taxonomic investigation. There is some pollen morphological variation in the different specimens examined.

#### *Lapulla spinocarpos*

**LM** (Figs. 37-42)

**Polarity:** Pollen grains isopolar.

**Symmetry:** Radially symmetrical.

**Shape:** Subprolate. Elliptic in equatorial view with broad to more or less straight ends and rounded corners; rounded triangular in polar view.

**Dimensions:** P = (13) 15 (17)  $\mu\text{m}$   
E = (10) 12 (14)  $\mu\text{m}$   
P/E = 125

**Apertures:** Pollen grains 3-colporate. Colpi 11 x 15 - 4  $\mu\text{m}$ , with pointed ends, margin smooth faintly delimited; membrane densely granular. Ora lalongate (4 x 1  $\mu\text{m}$ ), frequently slit-like, outline faint.

**Apocolpium diameter:** 1.0 - 1.5  $\mu\text{m}$

**Exine:** Exine 1.5  $\mu\text{m}$  thick. Sexine smooth with mixed LO-OL-pattern.

**SEM** (Figs. 43-47)

**Apertures:** Colpi with pointed ends, margin uneven; membrane densely granular. Ora not easily discernible.

**Exine:** Sexine smooth, tectate perforate. Perforations minute, sparse, unevenly scattered, frequently grouped or fused to form slit-like openings.

**Comments:** The species is not found frequently in Qatar. The pollen grains are small in size.

#### *Moltkiopsis ciliata*

**LM** (Figs. 48-53)

**Polarity:** Pollen grains isopolar.

**Symmetry:** Radially symmetrical.

**Shape:** Variable in size. Prolate. Elliptic with pointed or blunt ends in equatorial view; triangular in polar view.

**Dimensions:** P = (15) 19 (24)  $\mu\text{m}$   
E = (10) 14 (19)  $\mu\text{m}$   
P/E = 135

**Apertures:** Pollen grains 3-colporate. Colpi long (14-22  $\mu\text{m}$ ), with tapering ends, wide around ora, margin thickened, much thicker towards ora; membrane faintly granular. Ora lalongate (1.5 x 3.0  $\mu\text{m}$ ).

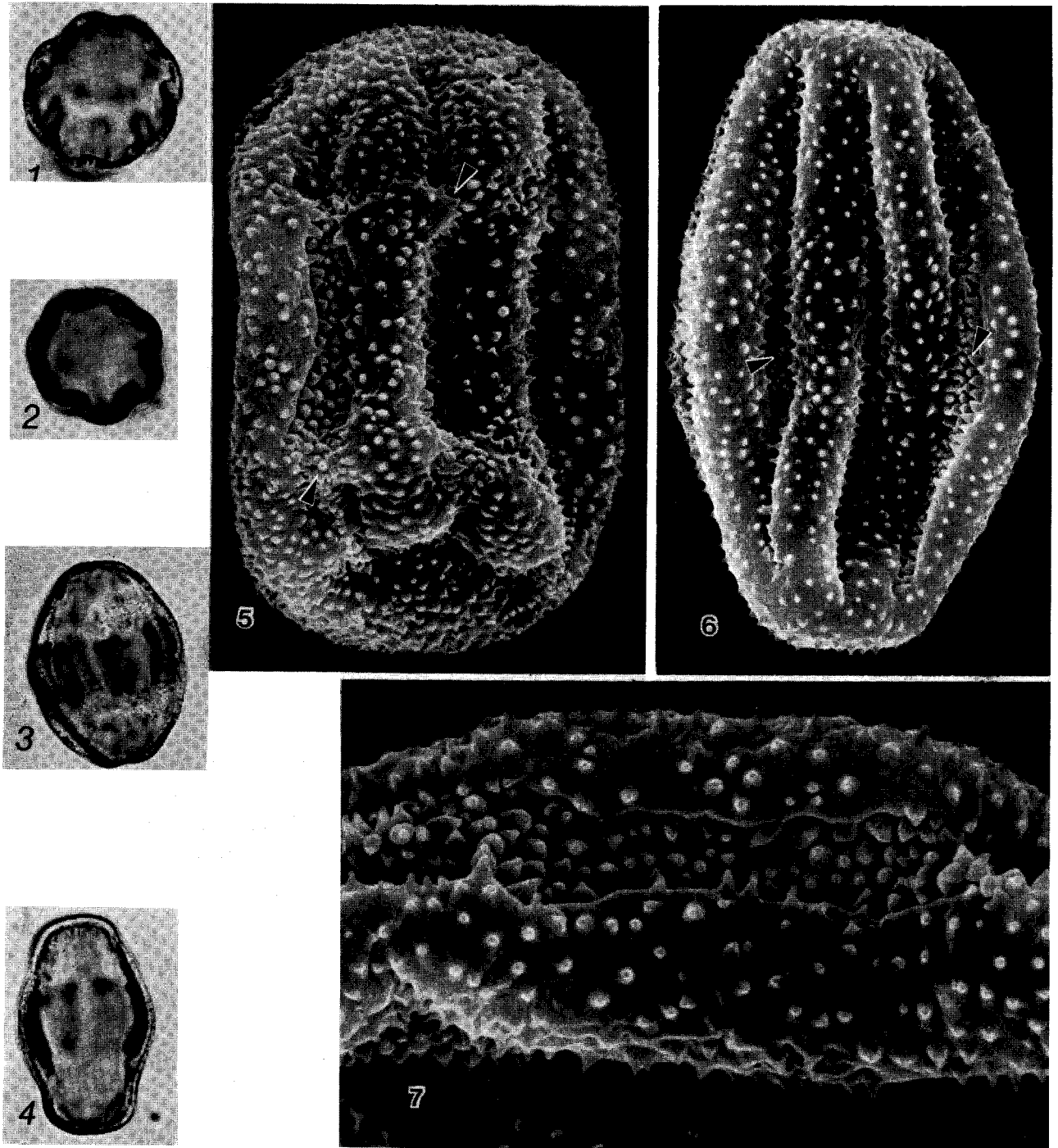
**Exine:** Exine 1  $\mu\text{m}$  thick or less, stratification obscure. Sexine smooth, densely granular in the apertural areas.

**Sem** (Figs. 54-55)

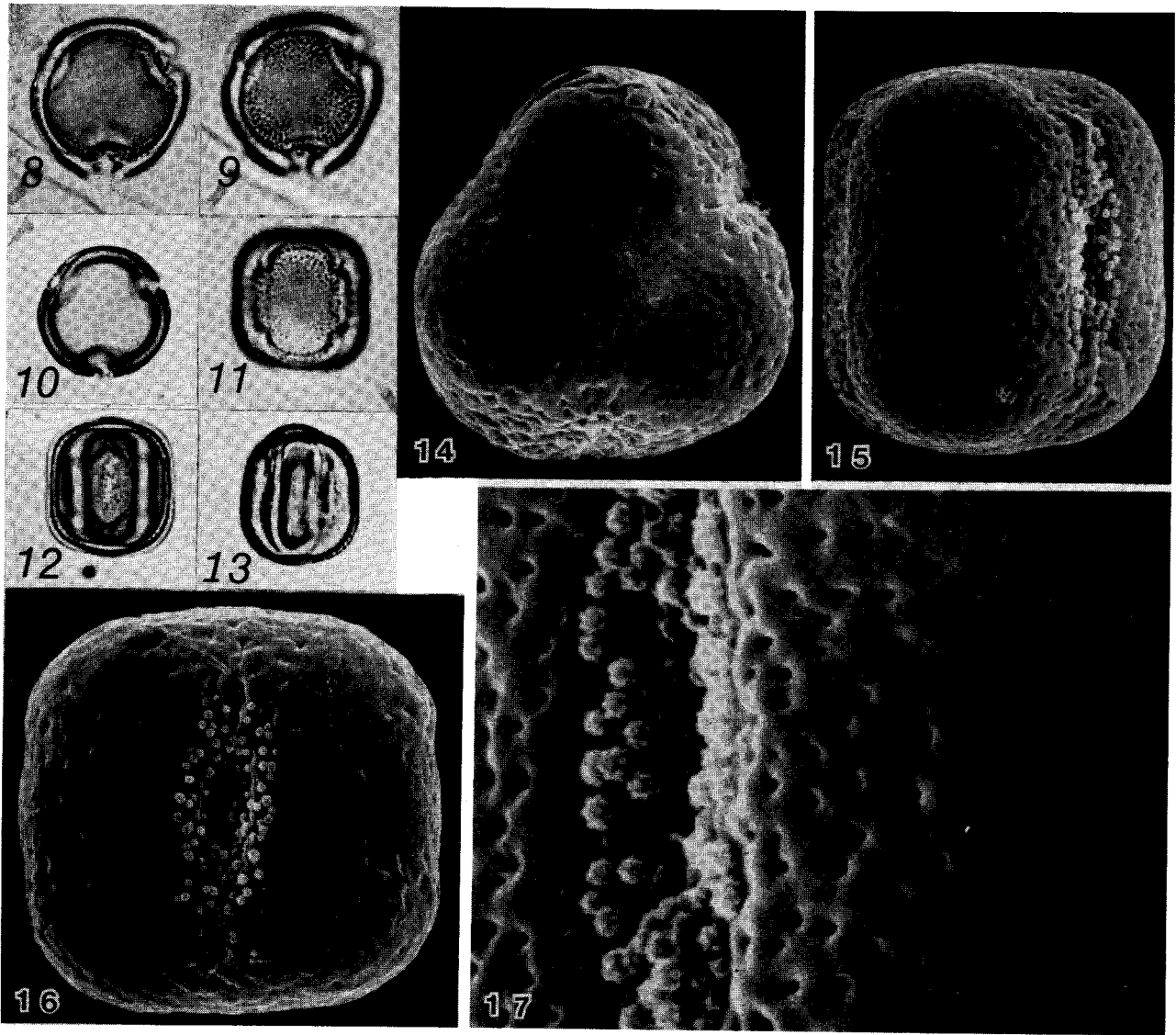
**Apertures:** Colpi ends tapering, ora oval-shaped. Area around ora studded with densely spaced, distinct, more or less rounded elements.

**Exine:** Sexine smooth, much wrinkled and beset with sparsely spaced, minute pits.

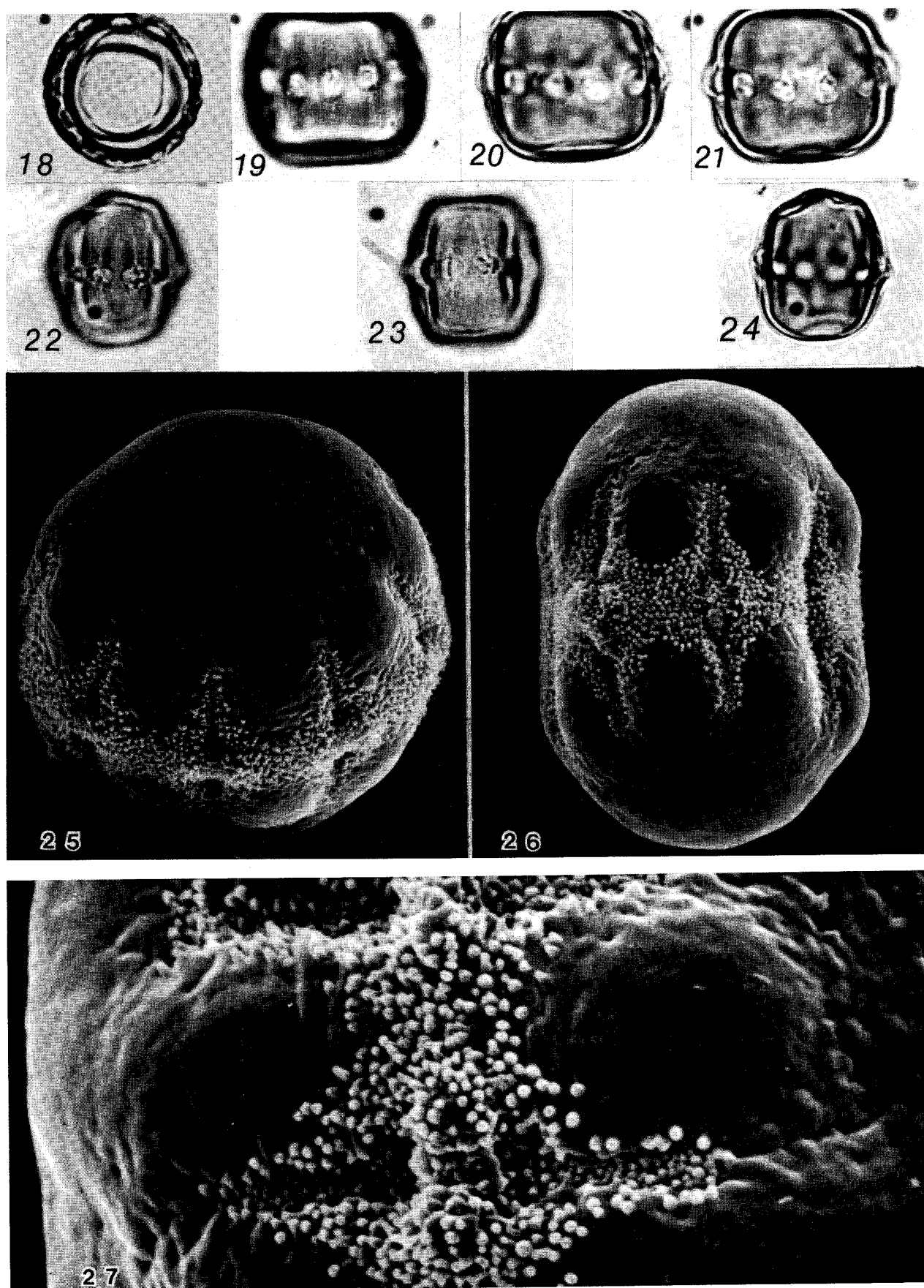
**Comments:** The species is quite common, particularly in the south. The pollen grains are distinguished by their elliptic shape, thin exine and characteristic ornamentation around the ora.



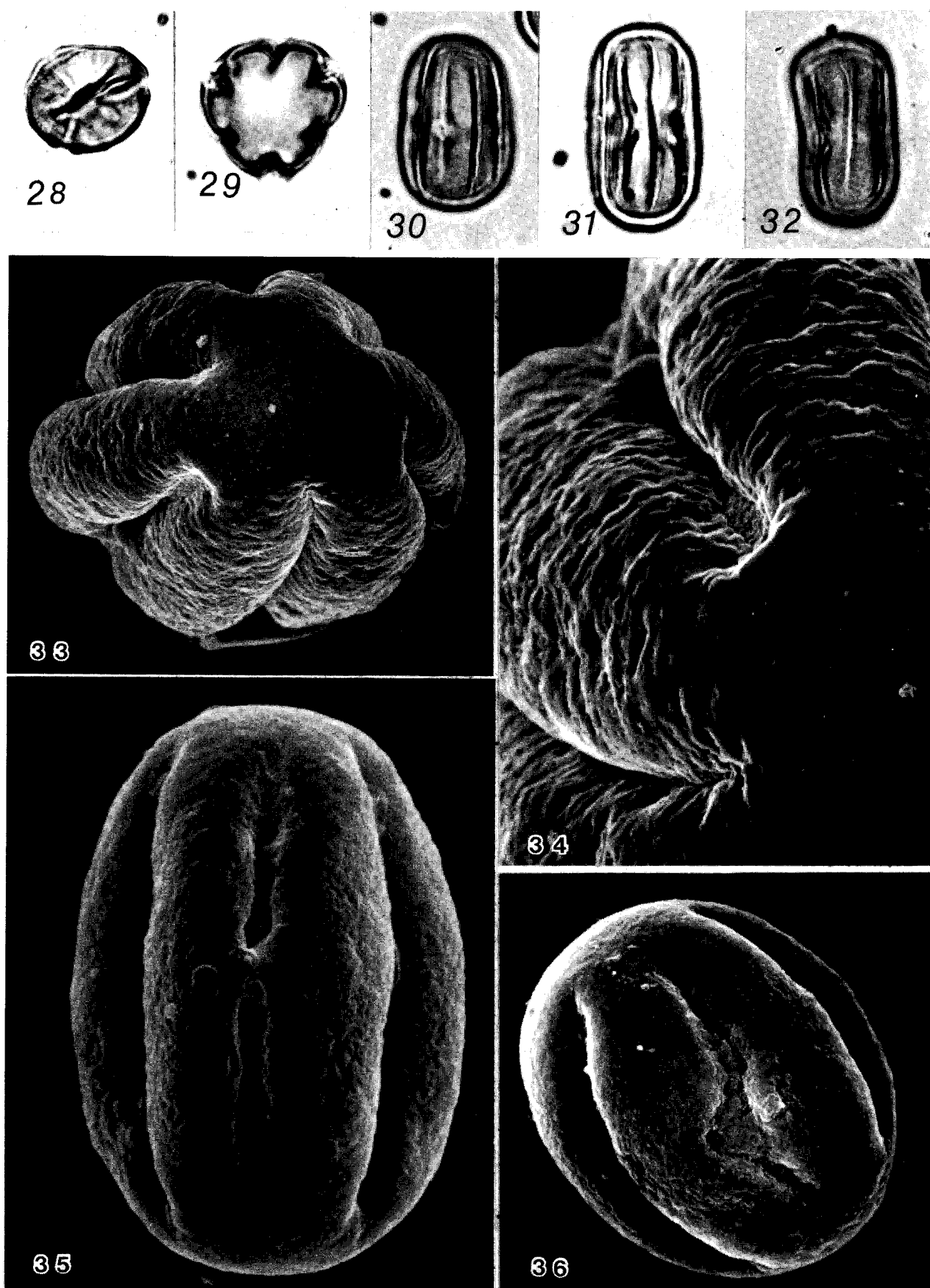
Figs. 1-7 *Arnebia hispidissima*. - 1-4 LM, x 1 200. 1 subpolar view. 2 polar view. 3,4 equatorial view of different pollen showing variation in shape. 5-7 SEM. 5,6 equatorial view showing variation in pollen shape, x 4 800. Note extensions of the sexine over both ends of colpi (arrow heads) in Fig. 5. 7 magnified part of Fig. 6 showing details of sexine and colpi membranes beset with spinules (arrow heads), x 10 000.



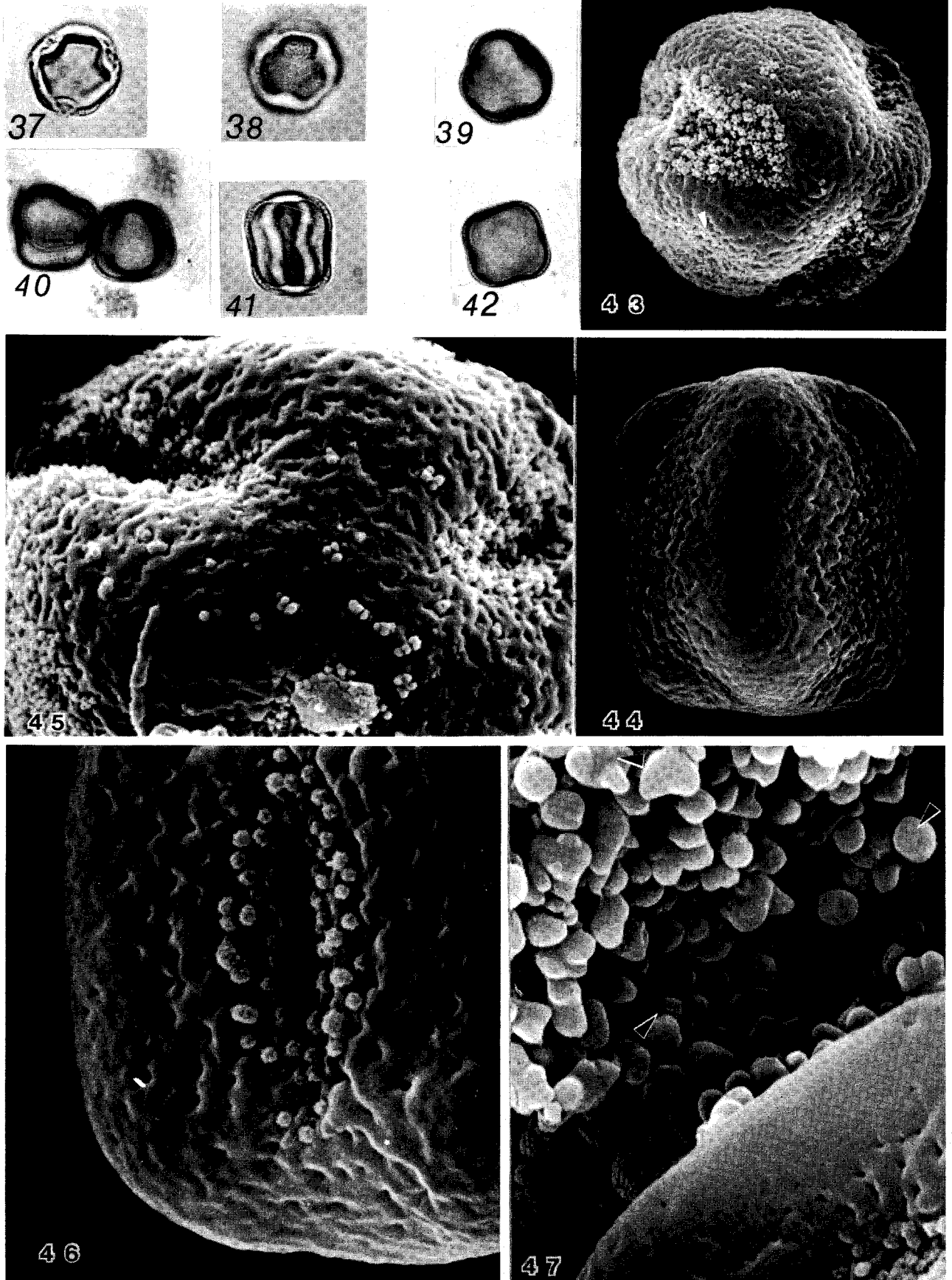
Figs. 8-17 *Echiochilon kotschy*. 8-13 - LM. x 1 600. 8-10 polar views in different foci. 11-13 equatorial views in different foci. 14-17 SEM. 14 polar view, x 4 000. 15, 16 equatorial views, x 4 000. 17 detail of the exine near one of the colpi, showing dense perforation along colpi margin, colpus area filled with spinuliferous elements, x 13 000.



Figs.18-27 *Gastrocotyle hispida*. 18-24 LM x 1 200. 18 a polar view. 19-21 oblate pollen grains in equatorial view in different foci. 22-24 prolate spheroidal pollen grains in equatorial view in different foci. 25-27 SEM. 25 oblique polar view, x 4 500. 26 equatorial view, x 3 000. 27 part of the exine showing colpi margins, membrane and ora covered with granules that form an equatorial band, x 10 000.

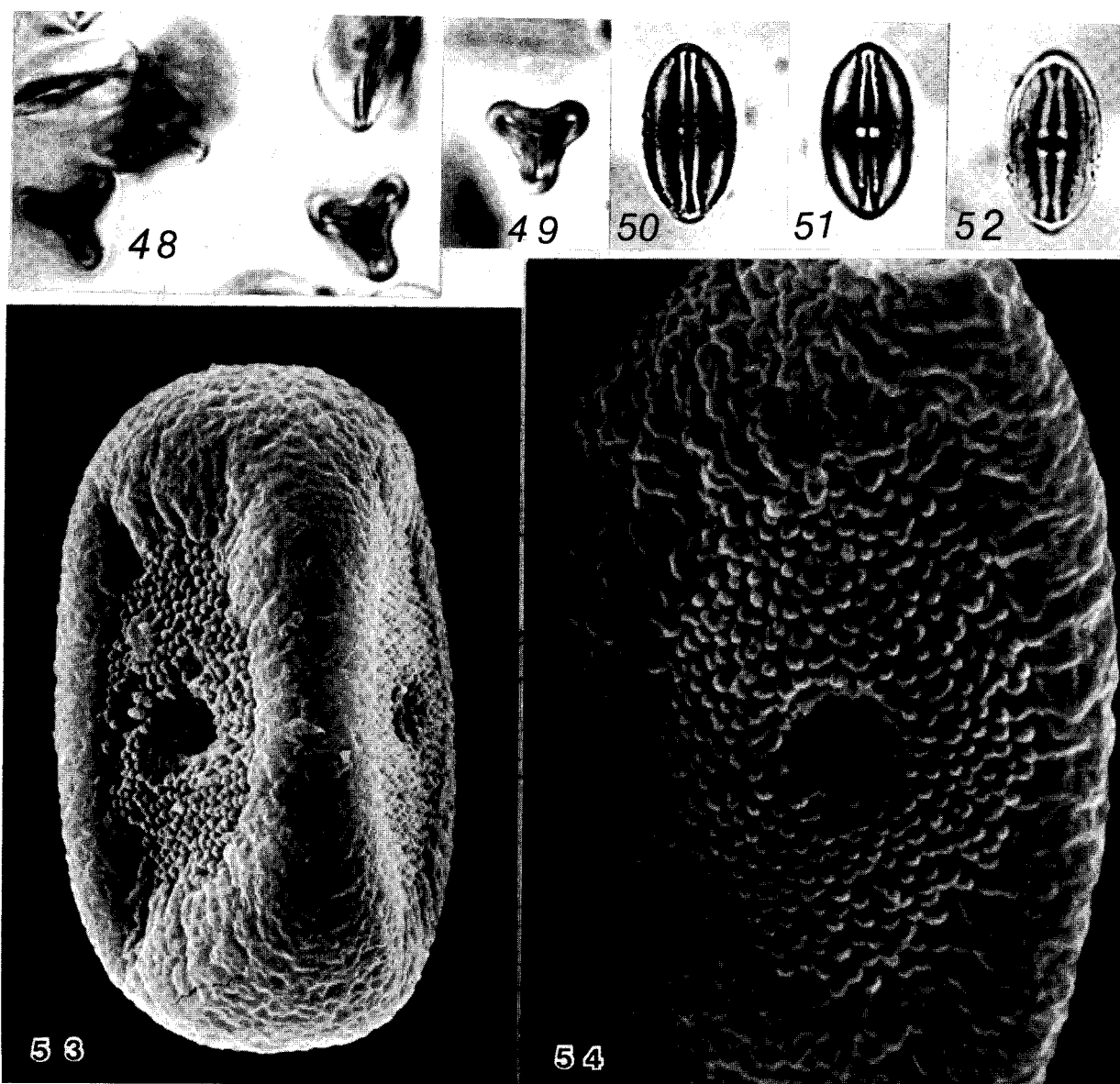


Figs.28-36 *Heliotropium bacciferum*. 28-32 LM x 1 200. 28, 29 polar view. 30-32 equatorial view in different foci. 33-36 SEM. 33 oblique polar view, x 4 500. 34 magnified part of Fig. 33, showing part of the exine with minute perforations, x 10 000. 35 equatorial view showing two of the colpi with sexine protruding over ora. Note a pseudo-colpus (arrow head) is situated in mesocolpium, x 4 500. 36 equatorial view showing irregular apertures, x 3 000.



Figs.37-47 *Lappula spinocarpos*. 37-42 LM x 1 200. 37-49 polar view. 40-42 equatorial view in different foci. 43-47 SEM. 43 oblique polar view, x 4 500. 44 equatorial view, x 4 500. 45 magnified part of polar area showing perforated exine beset with orbicules (Ubisch bodies), x 10 000. 46 equatorial view showing detail of the perforated exine and a colpus with granular membrane (arrow heads), x 10 000. 47 part of the exine and orbicules at different views, (arrow heads), x 15 000.





Figs. 48-54 *Moltikiopsis ciliata*. 48-52 LM, x 1 200. 48-49 polar view. 50-52 equatorial view. 53, 54 SEM. 53 equatorial view, x 4 500. 54 equatorial view showing detail of one colpus provided with rounded os and dense granules, x 8 000.

## DISCUSSION

The present pollen morphological investigation confirms the eurypalymous character of the family Boraginaceae, in which a large number of species can be recognized by their pollen characters. In this study five outstanding pollen types have been distinguished, mainly on the basis of external structure and type of aperture. The species *Echiochilon kotschyi* and *Lappula spinocarpos* possess similar pollen types, while each of the other four species studied has its characteristic pollen type.

### Pollen Morphological Characteristics

#### Ornamentation

A large number of surface pattern types are observed

with in the different species examined in this study which range from psilate (smooth surface) in *Heliotropium bacciferum* to roughly echinate in *Arnebia hispidissima*. Both *Echiochilon kotschyi* and *Lappula spinocarpos* are characterized by smooth sexine with densely spread perforations along colpi margins. The membranes of the colpi are beset with small spinulose orbicules (Ubisch bodies). In *Gastroctyle hispida* the sexine is smooth with minute perforations around the colpi and dense, coarse granules delimiting the colpi margins, and covering colpi membranes. *Moltikiopsis ciliata* possess obscure ornamentation, that is much wrinkled and beset with sparsely spaced, minute pits, and with coarse, dense granules in the apertural areas.

#### Shape

The pollen of the examined species exhibits a wide va-

riety of shapes and forms. Oblong, rhomboidal and rectangular shapes were observed. Variations in shape within the same species were observed in *Heliotropium bacciferum*, and *Gastrocotele hispida*. Beside, a small percentage of malformed pollen grains was noticed in these species, where the pollen appeared comparatively smaller in size and irregular in shape.

### Size

The size of the pollen grains is generally small, but reveals considerable variations, ranging from 15 µm to 33 µm in polar axis and 12 µm to 34 µm in equatorial diameter. The size of the pollen grains is rather constant within the species. The smallest pollen grains are found in *Lappula spinocarpos*, while the largest are encountered in *Heliotropium bacciferum*.

### Apertures

Pollen grains of the family Boraginaceae are characterized by having large differences in aperture morphology. [1] described 28 different apertural types in this family and proposed a trend of apertural evolution in the family.

The pollen grains of *Arnebia hispidissima* are distinguished by having 6-8 colporate apertures with dense granular membranes. [10] described the above species and another eight species of *Arnebia* from Pakistan as having two endoapertures. This type of aperture was not observed in this study. In the present study, few cases of malformed pollen of *A. hispidissima* were observed to have irregular apertures with colpi covered at both ends with extension from the sexine, (Fig. 5 arrow heads).

The aperture type in *Echiochilon kotschyi* and *Lappula spinocarpos* is tricolporate. The colpi are short and each colpus is provided with long alongate OS.

*Gastrocotele hispida* can be easily distinguished from other species described in this study by its pollen aperture. The pollen grains are 8-colporate and characterized by the presence of dense granules that are studded on the equatorial area and along colpi margins. The distribution and density of these granules provide the pollen grains of *Gastrocotele hispida* with a unique morphological feature (Fig. 26). The position of *Gastrocotele hispida* in the tribe Eritrichieae, where most of the species have tricolporate pollen, is not supported by its apertural condition. Therefore, it should be placed at Eritrichieae where the pollen characteristics and, in particular, the aperture type show clear similarities.

The morphology and number of the apertures vary to great extent within the genus *Heliotropium*. [20] observed in *H. villosum* the colporate and colporate apertures in the same grain. [21] studied the pollen morphology of eight species of *Heliotropium* and quoted 3-4 zoicolporate, col-

porate and colporoidate apertures, whereas [9] described *Heliotropium bacciferum* from Pakistan to have 8-heterocolporate pollen grains, and *H. marifolium* as unique in its 10-heterocolporate grain. In the present study, *H. bacciferum*, is characterized by having 3-colporate pollen grains, and each mesocolpium is provided with a pseudocolpus. This interpretation is well illustrated with SEM (Fig. 35) and is not in accordance with those of [21, 9] in number and morphology of apertures of this species. The presence of pseudocolpi in *Heliotropium* is a significant characteristic that distinguishes this genus from the others and supports its position in sub-family Heliotropioidae, but probably does not have enough significance to separate the sub-family Heliotropioidae from the family Boraginaceae to a new family Heliotropiaceae as suggested by (24). One of the reasons of discrepancy in morphology of the apertures of the same species from different areas could be attributed to the effect of variation in environmental conditions, which are reflected on morphology of apertures. In addition, occurrence of polyploidy is generally known to cause variation in pollen size and number of apertures within the species [22,23].

The pollen grains of *Moltikiopsis ciliata* are 3-colporate. The oral areas are delimited with dense and coarse granules. My observation is not in agreement with [19] where he described the pollen aperture of this species as 3-porate. Tricolporate pollen apertures were observed in other species of Boraginaceae, for example, *Ehretia* [14,25]; *Bourreria* [25]. [14] considered that pollen grains of the family Boraginaceae possess tricolporate apertures and other types derived from it, and are primarily divided into two groups by having and lacking pseudocolpi.

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