

Pollen Grains Characters and Their Evolutionary Significance in the family Papaveraceae in Iraq and some Iranian species

Ula M. Noor Almousawil and Abdulrida A. Alwan²

¹Department of Pharmacognosy and medicinal plants, college of Pharmacy, University of Basra

²Department of Ecology, College of Science, University of Basra

E-mail: ulanoor@yahoo.com , abdulalwan@yahoo.com

Abstract:

Pollen morphology of twenty seven species of Papaveraceae *sensu lato s.l.* werestudied under light and scanning electron microscopes. Seven pollen types are described of which *Eschscholzia californica*, *Roemeria hybrida* and *Corydalis rupestic* (Iranian sample) types are newly described here. Among the genera studies, pollen morphology has a very important taxonomic application. Almost all genera have its own distinct pollen type mainly distinguished by the shape and number of apertures, except *Glaucium* and *Corydalis* which have pollen grains nearly similar to those in *Papaver*.

On the Basis of Phenotypic characters of plants such as root, stem and leaf morphology, most of the taxonomists identify Plant species, but now palynological studies can provide accurate basis for the classification of plant species which may be considered as one of the most significant tools used by modern taxonomists to identify and differentiate closely related taxa (Mazari *et al.*, 2012). Pollen characters are valuable in solving confused problems of interrelationships between various taxa and estimate of their status in the classification, especially to the families,

subfamilies, tribes, genera, species, and subspecies (Fazal *et al.*, 2013).

The oldest study of the family Papaveraceae was in (1832) by Fritzsich and followed by Mohl (1834). Erdtman (1971) gave an excellent review of the systematic applications of palynology in the plant kingdom; he studied pollen belonging to 60 species from 32 genera in Papaveraceae , and divided the Papaveraceae into 3 groups, these groups are:

1. Hypecoideae

ii. Papaveroideae

iii. Fumarioideae

He also indicated the general characteristics of the family and certain species. Many other authors who have dealt with this family using pollen as a character with systematic interest are: Ownbay (1958, 1961), Ernst (1962), Rutter (1968), Huynh (1970), as mentioned by Candau & Fernandez-paniagua (1985). Rachele (1974) studied eleven Papaveraceae genera endemic to the northeastern of the United State and Canada which belong to three subfamilies Papaveroideae, Fumarioideae, and Hypecoideae. Layka (1976) dealt with the morphology of 22 species of *Argemone* and on pollen structure in the Papaveraceae. Moore and Webb (1978) mentioned several species from Papaveraceae in their survey like, *Papver argemone*, *Papver rhoeas*, *Glaucium flavum* and *Fumaria officinalis*. Abou El-Naga (1982) studied Egyptian Papaveraceae and proved how far the detailed investigation of palynological studies combined with leaf anatomy, cytology, stomatal structure and morphology can be helpful in that context by using L.M. and S.E.M. She described a key to the genera based on pollen morphology: 1-Pollen colpate.

A. Dicolpate: *Hypecoum*.

B. Tricolpate:

I- Colpus neither operculate not covered by verrucae: *Papaver*.

II- Colpus operculate: *Argemone*.

III- Colpus covered by verrucae: *Glaucium*.

2-Pollen porate

A. Pore annulate: *Fumaria*.

B. Pore non-annulate: *Roemeria*.

Candau & Fernandez – paniagua (1985) in their study divided the family into four pollen types depending on the numbers and shape of aperture:

1- *Hypecoum Imberbe* type: 2-colpate.

2- *Glaucium flavum* type: 3-zonocolpate, apocolpaia acuminate.

3- *Papaver rhoeas* type: 3-zonocolpate, apocolpaia not acuminate.

4- *Paver argemone* type: pantoporate.

El-Ghazaly (1992) in pollen flora of Qatar, studied one species of the family which was *Papver syriacum*. While in Chaturvedi *et al.*, (1999) work on pollen morphology of *Argemone mexicana* and *Argemone ochroleuca*, the pollen grains of the two species are distinct on the basis of pollen size only. Romero *et al.*, (2003) studied the ontogeny of the pollen wall of *Hypecoum imberbe* by using transmission electron microscopy (T.E.M.), and mentioned the number of aperture in this species. While

Perveen and Qaiser (2004) examined Pollen morphology of 9 species of the family Fumariaceae from Pakistan by light and scanning electron microscopes. They recognized two distinct pollen types on the basis of aperture type; these types are:

- *Corydalis diphylla* type: 3-colpate, 4-6 colpate.
- *Fumaria indica* type: 3-porate.

Gran and Sharifnia (2008) examined the micro-macro morphological features of pollens and seeds for the genus *Glaucium* in Iran by using electron microscopy. Al-Qura'n (2010) studied the pollen morphology (by light and electron microscopy) of three *Papaver* species; *Papaver hybridum*, *Papaver polytrichum* and *Papaver rhoeas* in Jordan, he compares between them depending on type of apertures. Keshavarzi *et al.*, (2011) studied the pollen morphology of seven *Fumaria* species in Iran by using light and scanning electron microscopy, and determined the number and types of apertures.

Fazal *et al.*, (2013) identified taxonomical markers for some medicinal plants by investigation and characterization of palynological types for these plants; one of these plants was *Fumaria indica*. Hanif *et al.*, (2013) studied the pollen grains of *Papaver*

somniferum in their palynological study on some ornamental plants by using (L.M.). Tavakkoli and Assadi (2013) studied morphological and micromorphological of some species of the genus *Papaver* that belong to the Sect. *Oxytona* in Iran. These studies were at the level of the world and they were limited, but in Iraq there are no studies that examined the pollen grains of Papaveraceae, only Kalaf (2012) give a brief illustration for one unidentified *Fumaria* sp. mentioning only one example without specifying the species in his study for pollen morphology of the wild plants in Basra. Therefore the aims of this study are:

- 1- To describe the pollen grains morphology of the genera of Papaveraceae and Fumariaceae.
- 2- To determine the taxonomical importance of pollen morphology in the classification of the genera under studied.
- 3- To describe the pollen types in the genera of Papaveraceae and Fumariaceae in Iraq and to assess their evolutionary importance.

Materials and Methods

Samples collections

The study was based on fresh samples collected during field trips between the years (2013-2014). We also depended on the herbarium specimens from National Herbarium of Iraq (BAG), Herbarium of Bagdad University

(BUH), Herbarium of Basra University/ Collage of Science (BSRA), National Herbarium of Iran (TARI), Herbarium of Azad University/Tehran and Herbarium of the Collage of Agriculture / University of Basra. The characters of fresh and herbarium specimens are studied by using dissection microscopy to identification of the plants. For species identification Cullen in Townsend and Guest (1980), Davis (1965), Zohary (1966) and Rechinger (1964) were consulted.

Result

Quantitative and qualitative characters are shown in tables 1 (terminology according to Erdtman (1952). figures (20-26) and plates (1-13)

In this current study we noted that the ornamentation on the external surface of pollen was:

1- Echinata – Perforate

This includes most species of family Papaveraceae (in this study).

2- Granulate – Tuberculate

This includes *F. bracteosa* and *F. parviflora*.

3- Punctate

This includes *C. rupestris*, as shown in plates (1-13).

Pollen morphology of the genera studied

Pollen morphology of *Papaver*

Pollen grains size varied between small to medium between (17.5- 41) μm and Shape varied between oblate spheroidal, suboblate, prolate spheroidal and spherical. Pollen grains have two types of apertures; 3-colpate in most of species and 6-pores which was found in *P. argemone*. Ornamentation was echinate-perforate. Exine thicker than entine, thickness for entine was ranged between (0.375 - 1.125) μm while the thickness in exine was (0.875 - 1.75) μm . Width of apertures was (5 -10) μm whereas the length of aperture was (12.6 - 26.25) μm . Ratio of P/E was ranged between (0.75 -1.14).

Pollen morphology of *Glaucium*

Pollen grains with medium size were between (0.97- 1.16) μm , shape oblate spheroidal, prolate spheroidal and subprolate; 3-zonocolpate and ornamentation were echinate-perforate. Exine is thicker than entine, thickness for entine was ranged between (0.875-1.875) μm , while in exine the thickness was ranged between (1.375-2.75) μm . Width of apertures was (6-15.5) μm , whereas length of aperture was (20-25.95) μm . Ratio of P/E was changed from (0.97-1.16).

Pollen morphology of *Roemeria*

Pollen grains with medium size were (29) μm , spherical. 8-pores and entire thickness was (0.875) μm and exine thickness was (1.375) μm , with echinate-perforate ornamentation. Aperture dimensions between (8.5-9) μm .

Pollen morphology of *Hypecoum*

Pollen grains with variation in size between small to medium, ranged between (18.5- 30.5) μm . Suboblate to oblate, ornamentation was echinate-perforate. 2-colpate thickness for entire was (0.625- 0.875) μm , while thickness in exine was (1.25-1.75) μm . Length of aperture was (13-26.2) μm . Ratio of P/E was ranged between (0.622- 0.86).

Pollen morphology of *Eschscholzia*

Pollen grains with medium size were (31) μm , prolate spheroidal, 5-6 Colpate, entire thickness was (1.25) μm to and exine was (1.875) μm . Ornamentation was echinate-perforate and the length of aperture was (16.75) μm . Ratio of P/E was (1.01).

Pollen morphology of *Fumaria*

Pollen grains medium size, ranged between (32-33) μm , spherical shape, 6-pores entire thickness was (0.875) μm and exine thickness was (1.375) μm . Ornamentation was granulate – tuberculate. Aperture dimensions between (11-11.5) μm .

Pollen morphology of *Corydalis*

Pollen with medium size from (20-25) μm , was subprolate grains, 3-zonocolpate, entire thickness was (0.875) μm and exine thickness was (1.375) μm . Ornamentation was Punctate and the length of aperture was between (17-20) μm . Ratio of P/E was (1.24).

Pollen Types

The results showed that pollen grains of species under studied of Papaveraceae and Fumariaceae have 7 types, four of these types were mentioned before, and the other types are: *Eschscholzia californica*, *Roemeria hybrida* type and *Corydalis rupestris* type, are described for the first time in this present study, and these types are:

1- *Hypecoum imberbe* type (plate 12)

Pollen grain is characterized by 2-colpate with echinate - perforate ornamentation and this type includes *H.imberbe*, *H.geslinii* and *H. pendulum*.

2- *Papaver rhoeas* type (plates 1-8)

Pollen grain is characterized by 3-colpate with echinate - perforate ornamentation and this type includes *P.acrochaetum*, *P. armeniacum*, *P. bornmuelleri*, *P. curviscapum*, *P.cylindricum*, *P.decaisnei*, *P. dubium*, *P.fugax*, *P. glaucum* *P.hybridum*, *P.*

macrostomum, *P.persicum*, *P.rhoeas*, *P. somniferum*.

of the current study, we put a key to separate species under research

3- *Glaucium flavum* type (plate 9)

Pollen grain is characterized by 3-zonocolpate with echinate - perforate ornamentation and this type includes *G.cornculatum*, *G.grandiflorum*, *G. haussknechtii*.

Key to the genera and species of

Papaveraceae in Iraq based on pollen types

4- *Papaver argemone* type (plates 1 and 13)

Pollen grains are characterized by 6-pores with echinate - perforate or granulate-tuberculate ornamentation and this type include *P. argemone*, *F. bracteosa* and *F.parviflora*.

1-Pollen grains colpate 2

1-Pollen grains

porate..... 6

2- Pollen grains 2-colpate.....*Hypecum*

2- Pollen grains 3-colpate or more 3

3- Pollen grains 3-colpate..... 4

3- Pollen grains 5-6 colpate *Eschscholzia*

4- Pollen grains 3-colpate subterminal

.....*Papaver*

4-Pollen grains 3-zonocolpate..... 5

5- Ornamentation punctate *Corydalis*

5- Ornamentation echinate *Glaucium*

6- Pollen grains 6- porate..... 7

6- Pollen grains 8- porate..... *Roemeria*

7- Ornamentation tuberculate *Fumaria*

7- Ornamentation echinate *P.argemone*

5- *Eschscholzia californica* type (plate 11)

Pollen grain is characterized by 5-6colpate with echinate - perforate ornamentation and this type includes *E. californica*.

6- *Roemeria hybrida* type (plate 10)

Pollen grain is characterized by 8-pores with echinate - perforate ornamentation and this type includes *R. hybrida* and *R. refracta*.

7- *Corydalis rupestic* type (plate 13)

Pollen grain is characterized by 3-zonocolpate with Punctate ornamentation and this type includes *C. rupestic*. As for the summary results

It is obvious that the pollen morphology characters provided significant taxonomical characteristic on generic level and can easily be used to separate the genera studied.

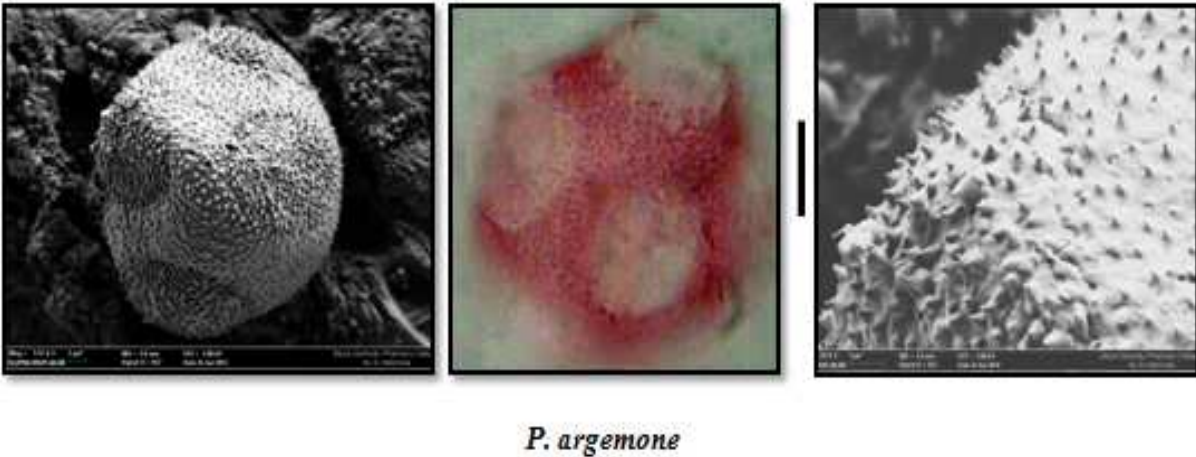
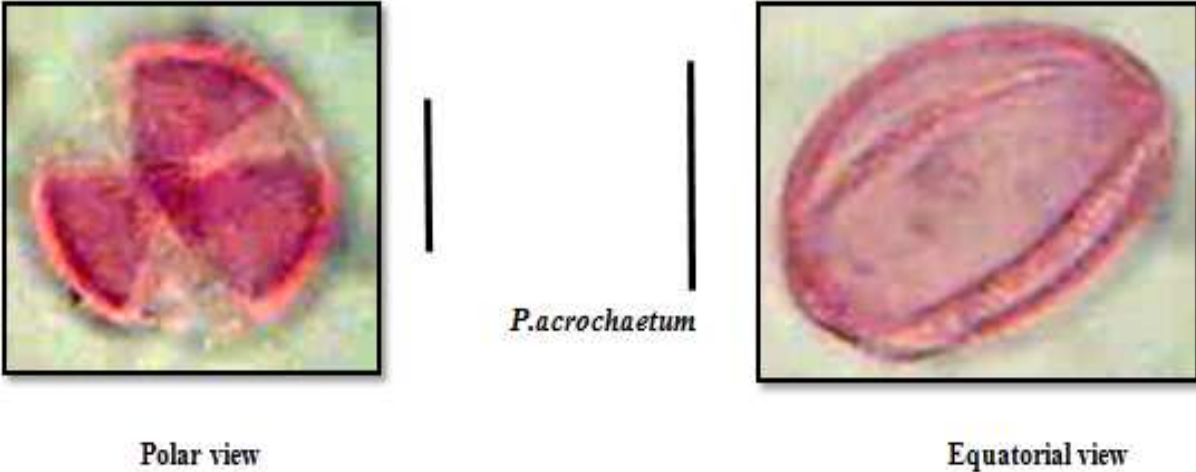
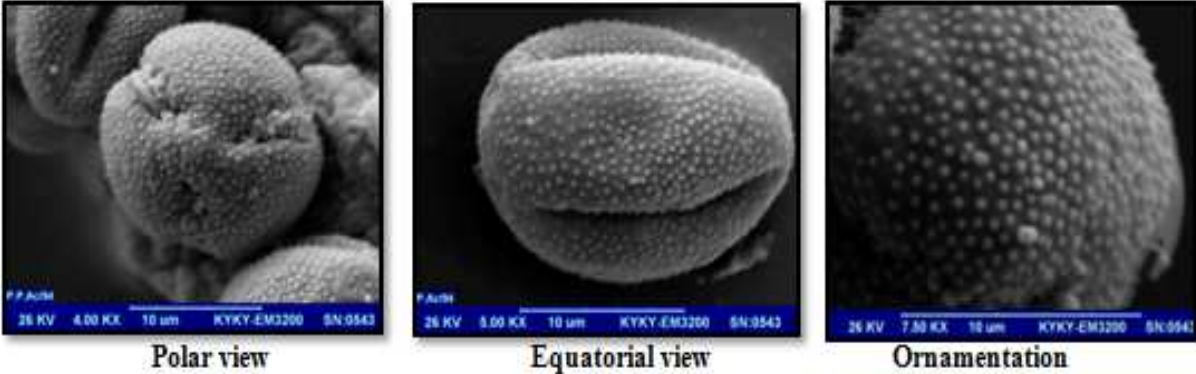
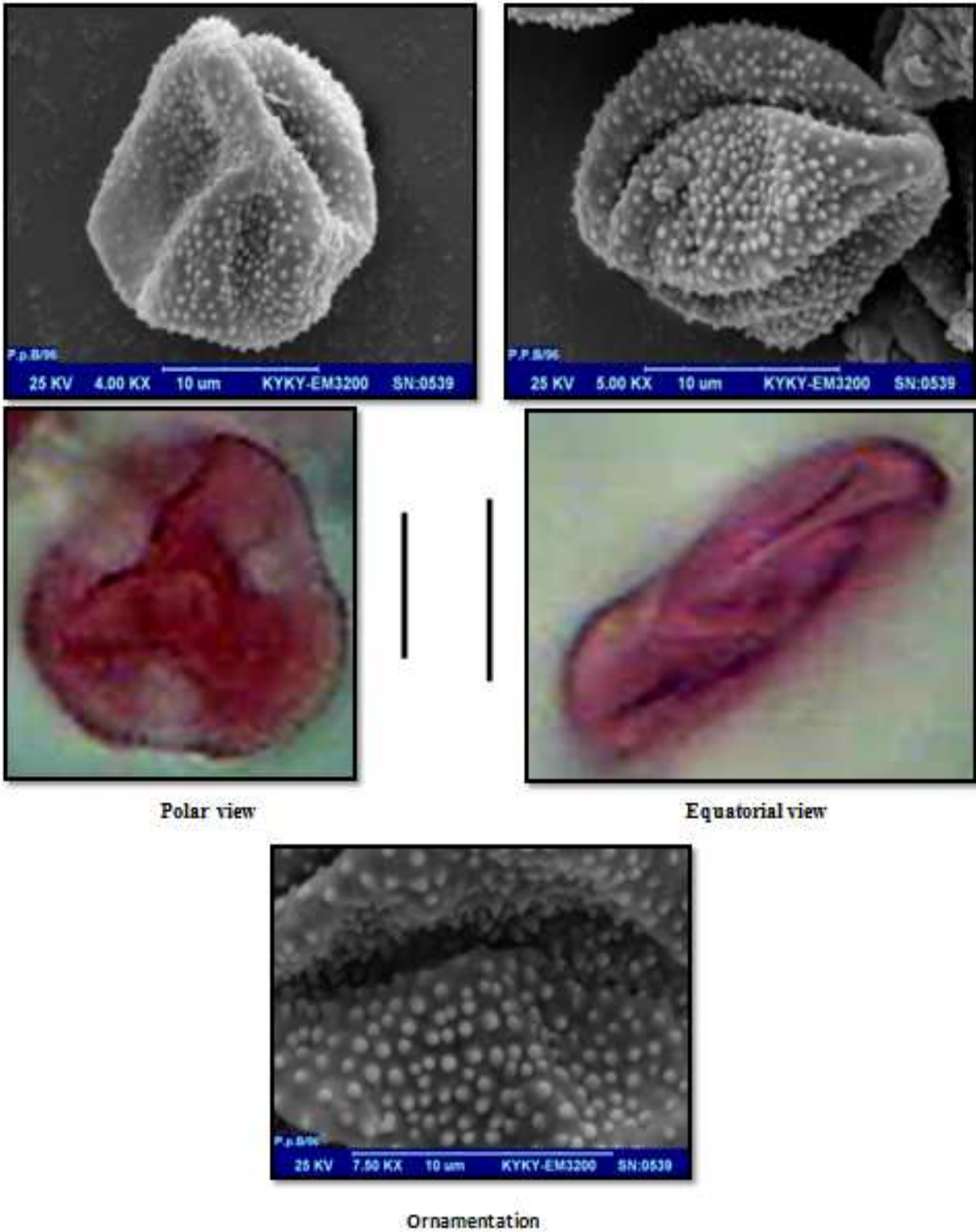


Plate (1): Pollen grains of some *Papaver* species (10 Micrometer)

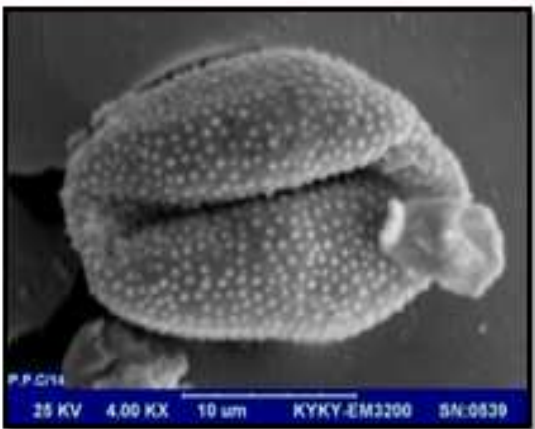
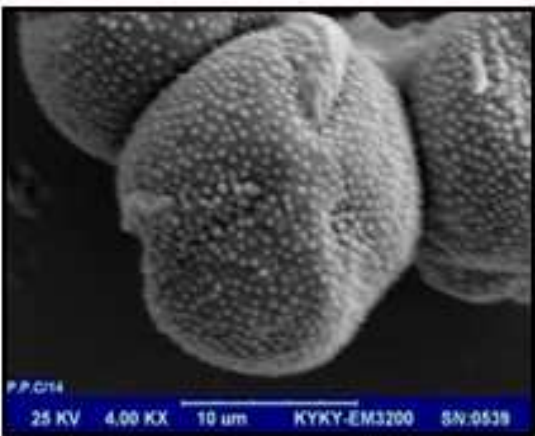


Polar view

Equatorial view

Ornamentation

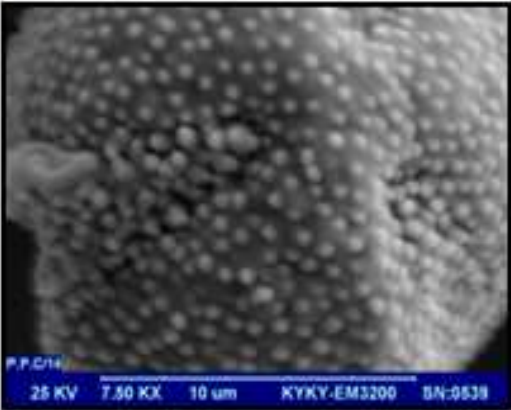
Plate (2): Pollen grains of *P. bornmuelleri* (10 Micrometer)



Polar view

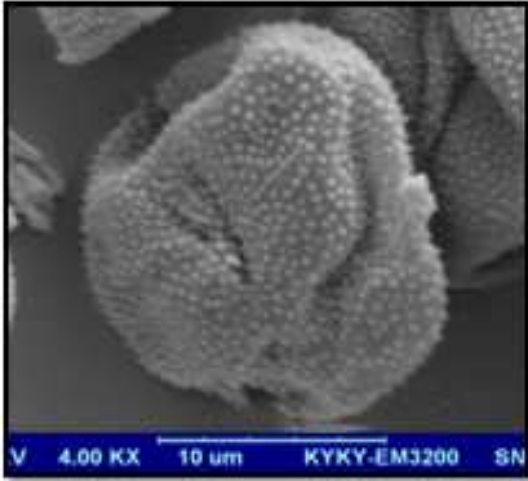


Equatorial view

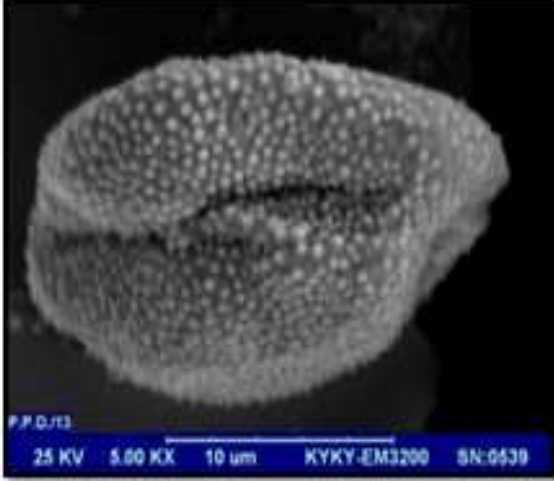


Ornamentation

Plate (3): Pollen grains of *P.cylindricum* (10 Micrometer)



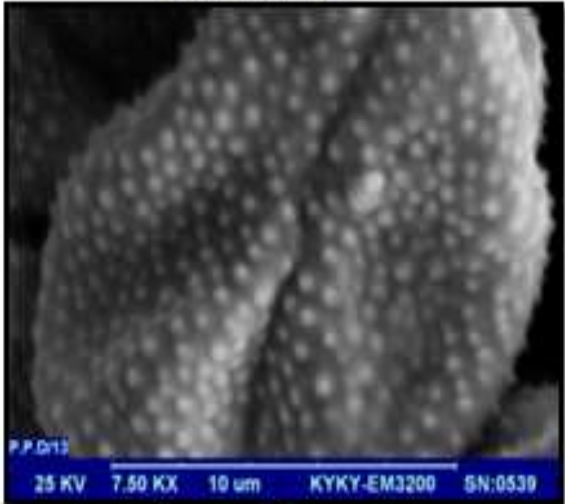
Polar view



Equatorial view

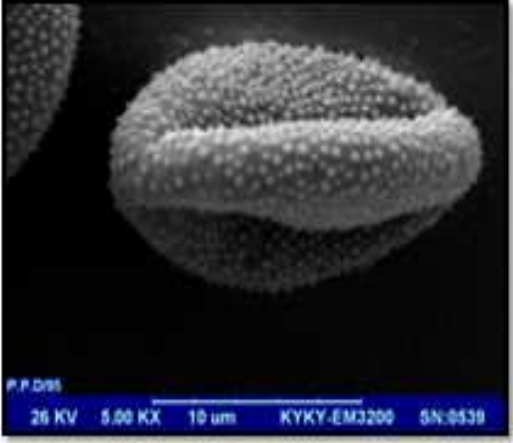


Polar view



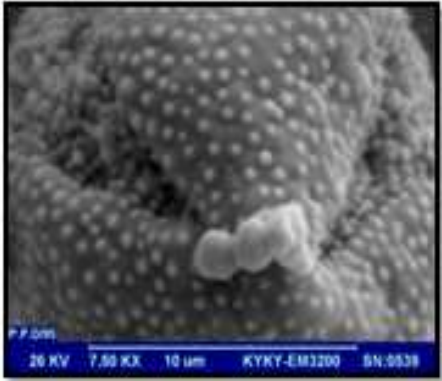
Ornamentation

Plate (4): Pollen grains of *P. decaisne* (10 Micrometer)



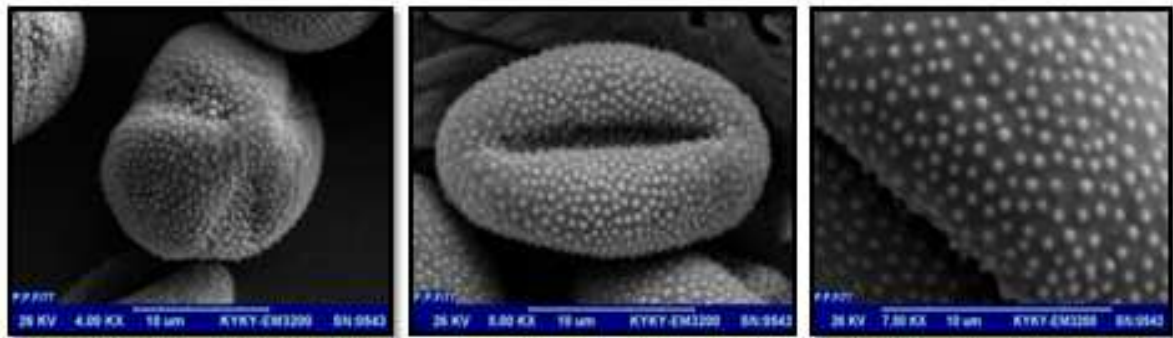
Polar view

Equatorial view

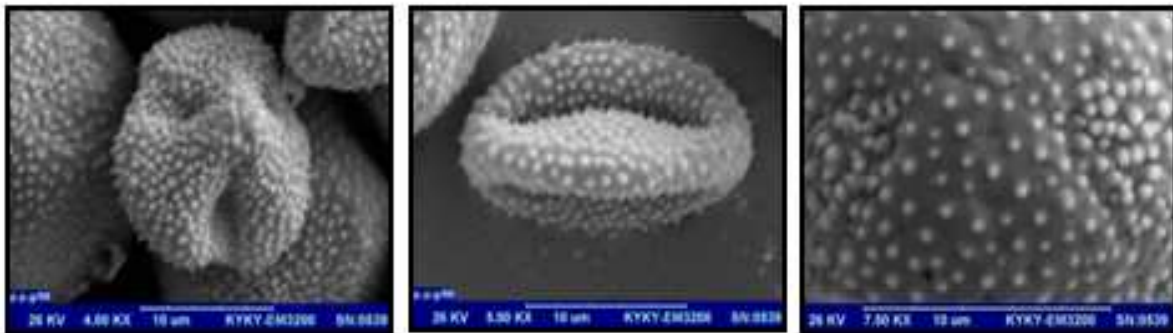


Ornamentation

Plate (5): Pollen grains of *P. dubium* (10 Micrometer)



P. fugax

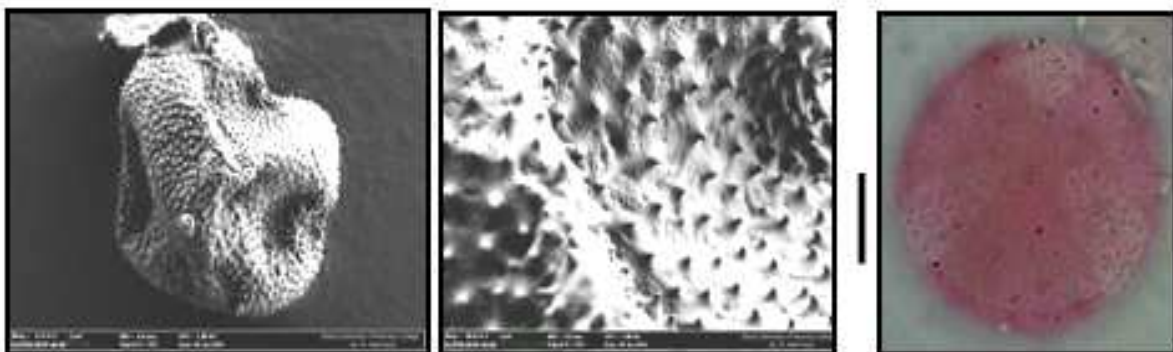


Polar view

Equatorial view

Ornamentation

P. glaucum



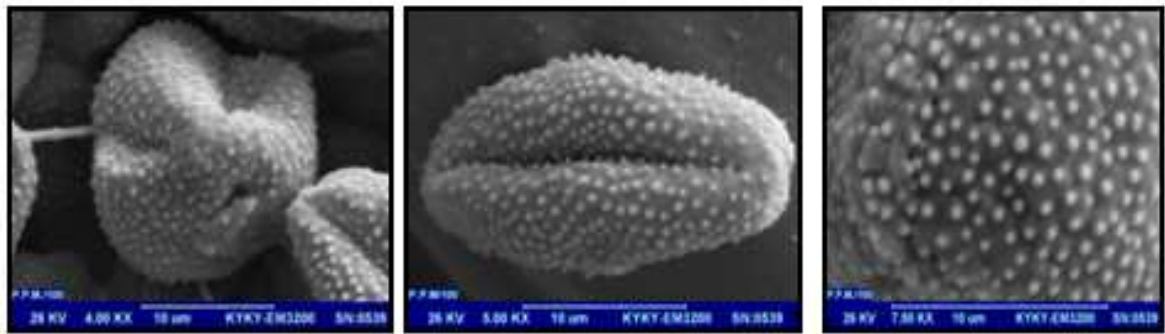
Polar view

Ornamentation

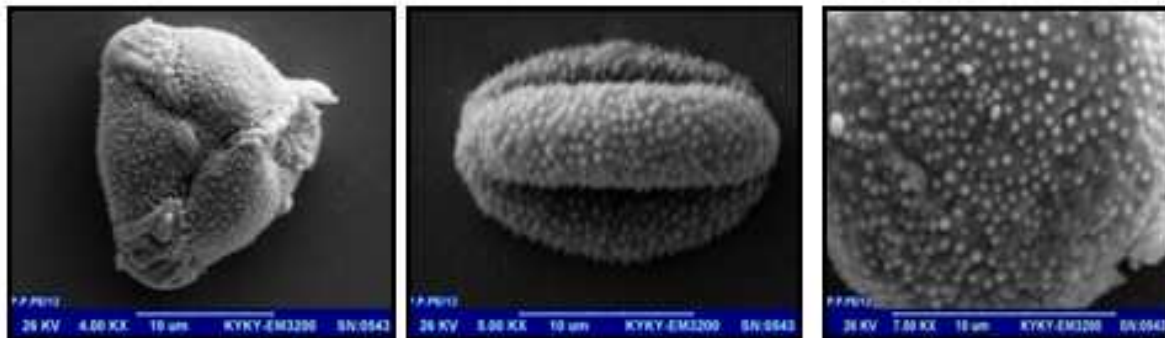
Polar view

P. hybridum

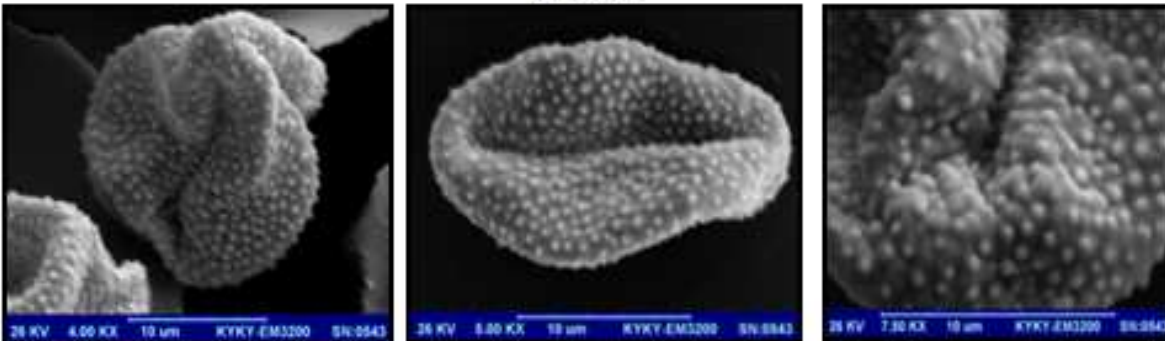
Plate (6): Pollen grains of some *Papaver* species (10 Micrometer)



P. macrostomum



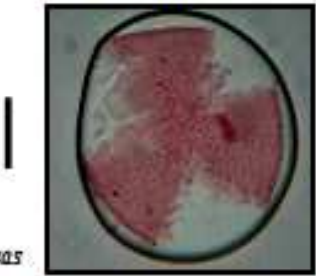
P. persicum



Polar view

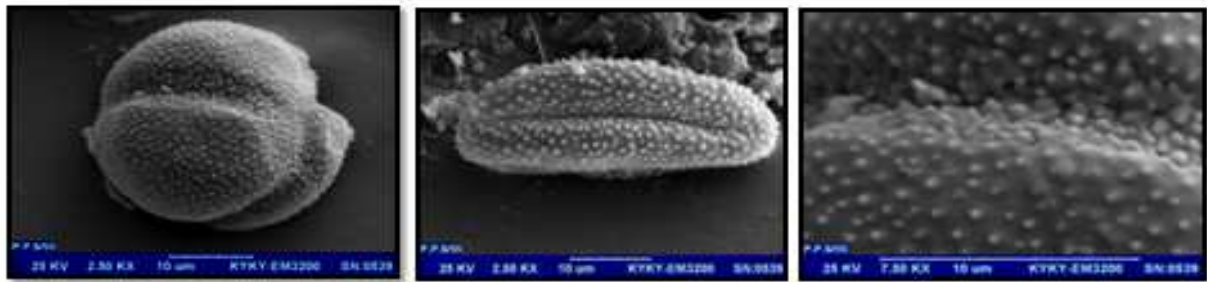
Equatorial view

Ornamentation



P. rhoeas

Plate (7): Pollen grains of some *Papaver* species (10 Micrometer)



Polar view

Equatorial view

Ornamentation

P. somniferum



G. grandiflorum



G. haussknechtii



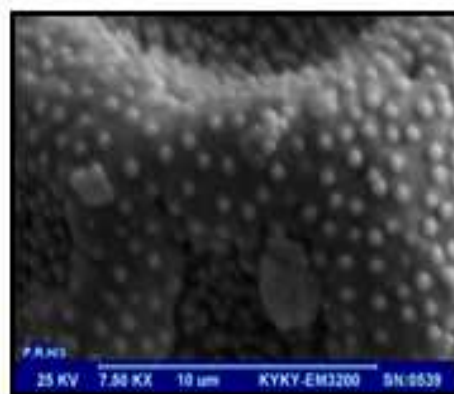
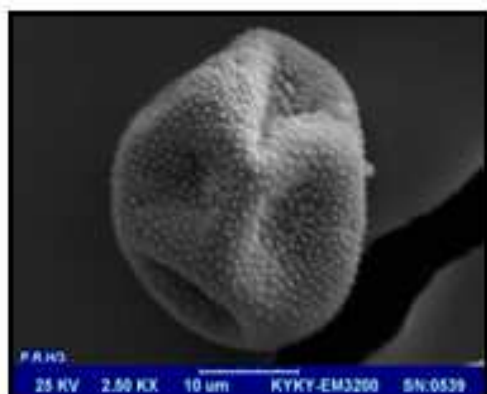
G. corniculatum

Polar view

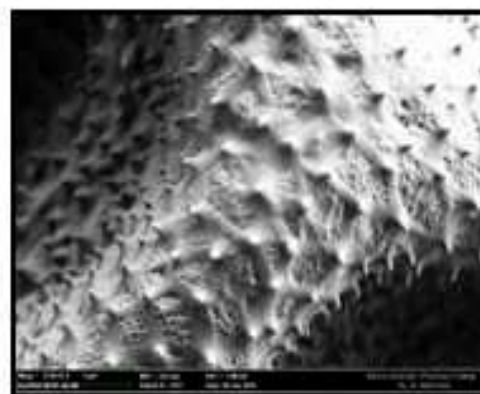
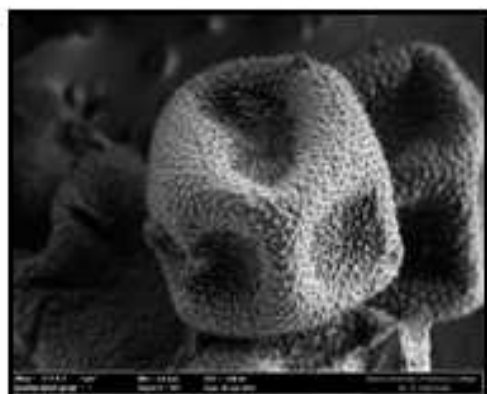
Equatorial view

Ornamentation

Plate (9): Pollen grains of some *Glaucium* species (10 Micrometer)



R. hybrid



R. refracta

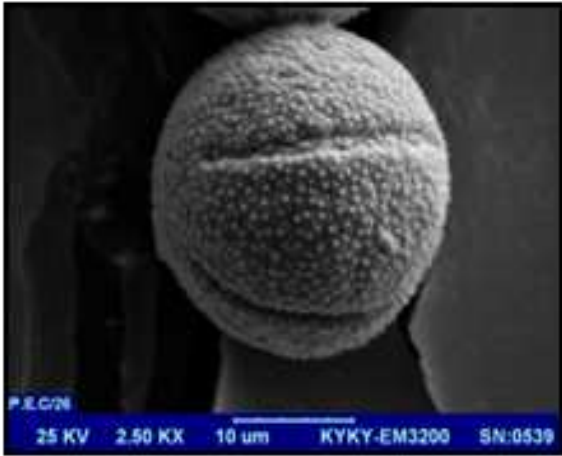
Polar view

Ornamentation

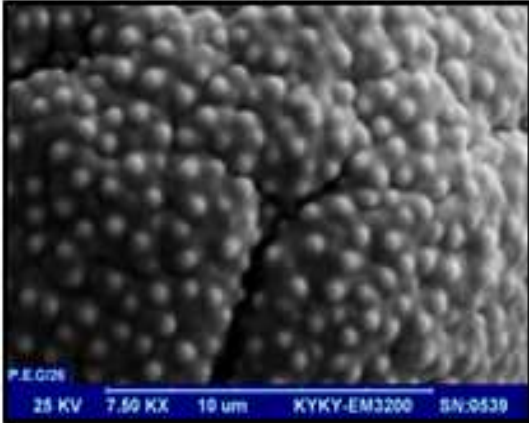
Plate (10): Pollen grains of *Roemeria* species (10 Micrometer)



Polar view



Equatorial view



Ornaamentation

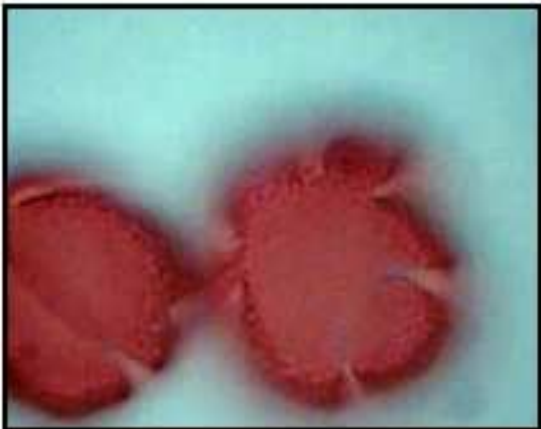
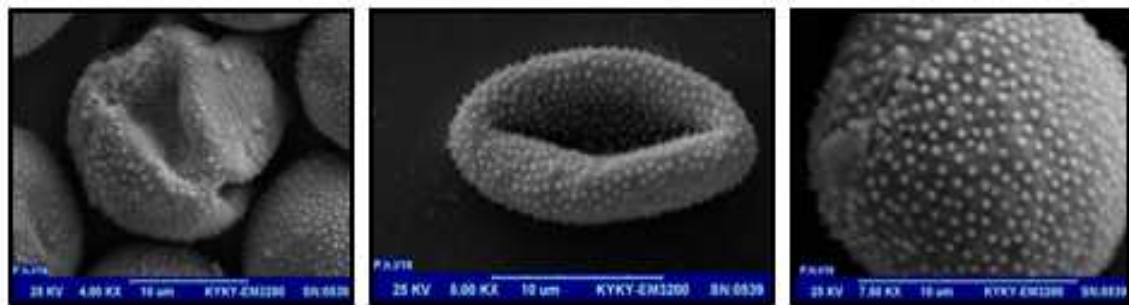
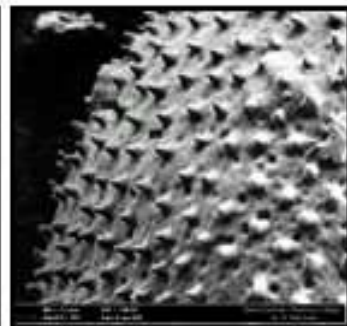
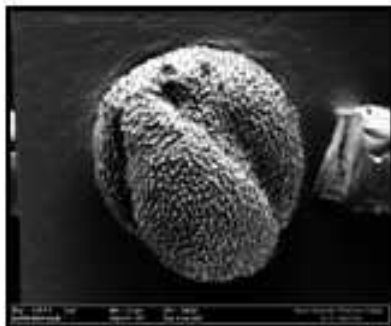


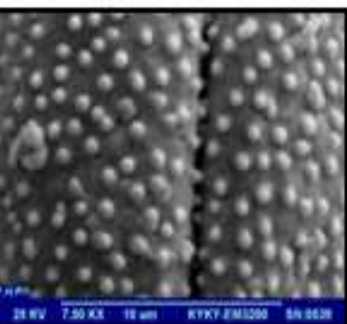
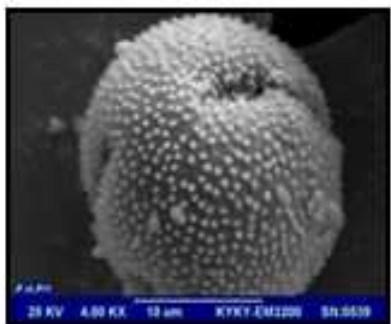
Plate (11): Pollen grains of *E. californicain* (10 Micrometer)



H. imberbe



H. geslinii



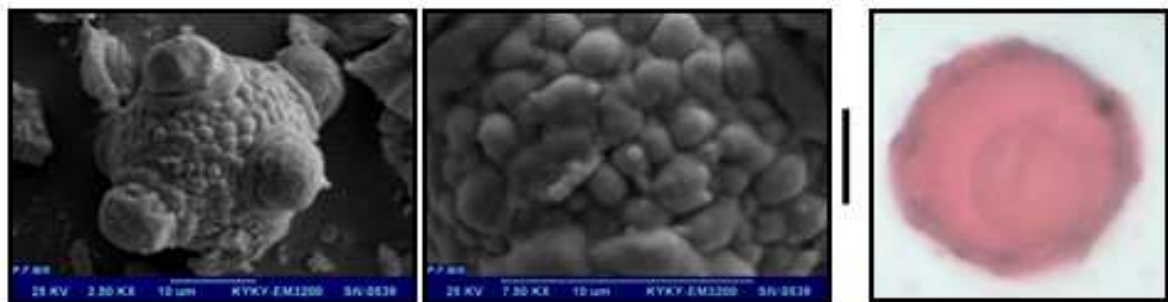
H. pendulum

Polar view

Equatorial view

Ornamentation

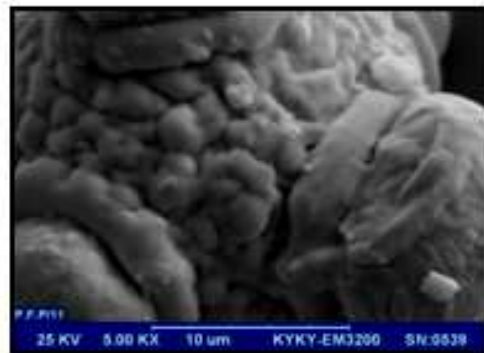
Plate (12): Pollen grains of some *Hypsicoom* species (10 Micrometer)



F. bracteausa



Polar view

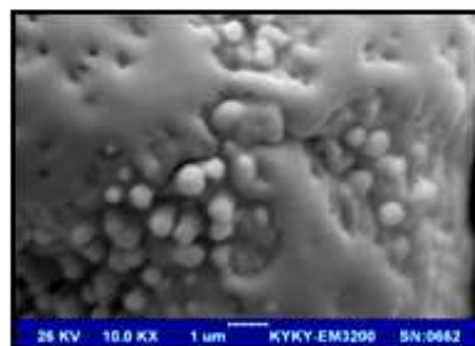


Ornamentation

F. parviflora



Equatorial view



Ornamentation

C. rupestris

Plate (13): Pollen grains of some *Fumaria* and *Corydalis* species (10 Micrometer)

Discussion

Size

In respect to the size of pollen grains, the species were varied between small and medium-sized, and that most species of

Papaver was small. The rest of the species that belongs to the related genera were mostly medium-sized except *F. parviflora* which was in large size and *H. imberbe* was in small size. Our pollen size classification was in

accordance with that in Erdetman (1971). The evolutionary trends in pollen size maybe towards the large size of pollen grains and hence the small sizes are more primitive, these trends were found in pollen grains of many other families of flowering plants as reported by Al-Mayah (1983). This indicates that the pollen grains of *Papaver* were less developed from other species, and *F.parviflora* was the most developed.

Shape

The shape of pollen grains was various between oblate spheroidal and suboblate in most species of genus *Papaver*, whereas the spherical shape is present in species *P.argemone*, *R. hybrida*, *Rrefracta*, *F. bracteosa* and *F. parviflora*. While in *Glaucium* the shape of pollen grains become variable between oblate spheroidal, subprolate and prolate spheroidal. But in *Hypocoum* the shape was oblate - suboblate. From the above it is clear to us that the evolutionary trends towards the oblate and prolate, means that the spheroidal shape is considered as the primitive shape while the oblate and prolate shapes are considered as derived. This is in agreement with ideas of Al- Mayah (1983) in his study for evolutionary trend for the shape of pollen

grains in the species of *Terminalia* and related genera.

Apertures

The results of the current study agreed with Erdtman (1971) who recorded three types of pollen grains included 2-colpate, 3-colpate, and 3-colpate or 6-rugate. The pollen grains apertures of Papaveraceae and Fumariaceae have a considerable taxonomical value, for both *Papaver* and *Glaucium*, in general, are 3-colpate, but the genus *Glaucium* and *Corydalis rupestris* can be distinguished from other species by their 3-zonocolpate grains. This disagreed with Rachele (1974) who mentioned that *P. dubium*, *P.rhoeas*, *P. somniferum*, and *G.flavum* were 3-colpate, whereas agreed with Candau & Fernandez – paniagua (1985) they consider the species; *P. dubium*, *P.rhoeas*, *P. somniferum*, *P.hybridum*, *G.corniculatum*, *G.flavum*, and *E.californica* were 3-zonocolpate.

The current study differed with the latter study regarding the type of *E.californica*, where it was a polycolpate (5-6 colpte) and this agreed with Kaderet (1993) who said that most of Papaveraceae are 3-colpate except *Roemeria* and *Papaver* Sect. *Argemonidium* with pollen grains with 4-5 rounded apertures and Eschscholzioidae polycolpate with 4-11

colpi. Al-Qura'n (2010) also mentioned that the species *P. hybridum*, *P. polytrichum* and *p. rhoeas* were 3-zonocolpate. Concerning the genus *Hypecoum*, our results have shown that all the species examined were 2-colpate and this is consistent with the results of each of Romero *et al.* (2003) and Candau & Fernandez – paniagua (1985). In *Fumaria* there were two types of apertures; porate (forate) found in *F. parviflora* and *F. bracteosa* while in genus *Corydalis* it was 3-zonocolpate in *C. rupestris*. This agreed with the suggestions of Erdtman (1971), Romero *et al.*, (2003) and Perveen & Qaiser (2004) described pollen grains of *Fumaria* species usually between 6-12 forate and in *Corydalis* was 3-colpate or 6-12 rugate.

Also Keshavarzi *et al.*, (2011) studied the pollen morphology of seven *Fumaria* species in Iran which were panto-forate ranged between 6-12 forate. While our study disagreed with Khalf (2012) who mentioned that a species of *Fumaria* (unidentified) was with 3-colpate apertures. The length of colp varies from species to species in genus *Papaver* that is ranged between (12.6) μm to (16.25) μm , while the longest length of colp was (26.25) μm which was found in *P. hybridum*.

In other species with porate apertures, the biggest diameter of porate was (13) μm in *P. argemone*, while the diameter in *Roemeria* species was close together between (8.5) μm to (9) μm and also in *Fumaria* species between (11) μm to (11.5) μm . The evolutionary trends of the number of apertures, which are often focused by other studies, become appeared that most of the pollen grains in genera *Papaver*, *Glaucium* and *C. rupestris* (18 species) were 3-colpate, and in *Hypecoum* species 2-colpate (3 species) while the species *E. californica* is distinguished in polycolpate. So the evolutionary trends may start from the 2-colpate pollen then 3-colpate or vice versus and then rise and developed to polycolpate and polyporate. This shows that the types of genus *Fumaria*, *Roemeria* and *P. argemone* gives more developed pattern of pollen grains. So depending on the apertures, the pollen grains of Papaveraceae are divided into:

1. *Hypecoum* type: included pollen grains with 2-colpate.
2. *Papaver* type: included pollen grains with 3-colpate.
3. *Eschscholzia* type: included pollen grains with polycolpate
4. *P. argemone* type: included pollen grains with polyforate or polyporate.

Ornamentation and Wall thickness

The ornamentation was echinate in genera *Papaver*, *Glaucium*, *Roemeria*, *Eschscholzia* and *Hypecoum*. But there is a variation in the ornamentation inside the colpe, which is characterized by the species *G. haussknechtii* where it was foveolate. In genus *Fumaria* the ornamentation was distinct from the other species it was granulate - tuberculate, pollen grains which are characterized by having bubbles protruding from pores with thick collars around pores. While in genus *Corydalis* differs from *Fumaria* by having different ornamentation which was punctuate. It also has unique ornamentation inside the colpe from the type pilate. As for the wall thickness of pollen grains the family is distinct in general by the exine thicker than entire or as thick as and the difference was very clear in genus *Papaver*.

Pollen morphology and taxonomy

It is clear from above that the pollen grains morphology of Papaveraceae has considerable taxonomic value. The relation between species in based on type and numbers of apertures. For example, the pollen grains of genus *Papaver* have the same type of apertures 3-colpate except *P. argemone* which has polyforate, and this is similar to genus

Roemeria, *F. bracteosa* and *F. parviflora*.

Genus *Hypecoum* has pollen grain differ from the others by having 2-colpate, while *Eschscholzia* has 5-6 colpate. Pollen morphology evidence in current study suggests the affinity of *P. argemone* with genera *Roemeria* and *Fumaria* on the one hand, and with other species of *Papaver* on macro-morphology on the other hand. Also with *C. rupestris* in this species, there is agreement with the species of *Papaver* in type of apertures, and with species of *Fumaria* on macro-morphology.

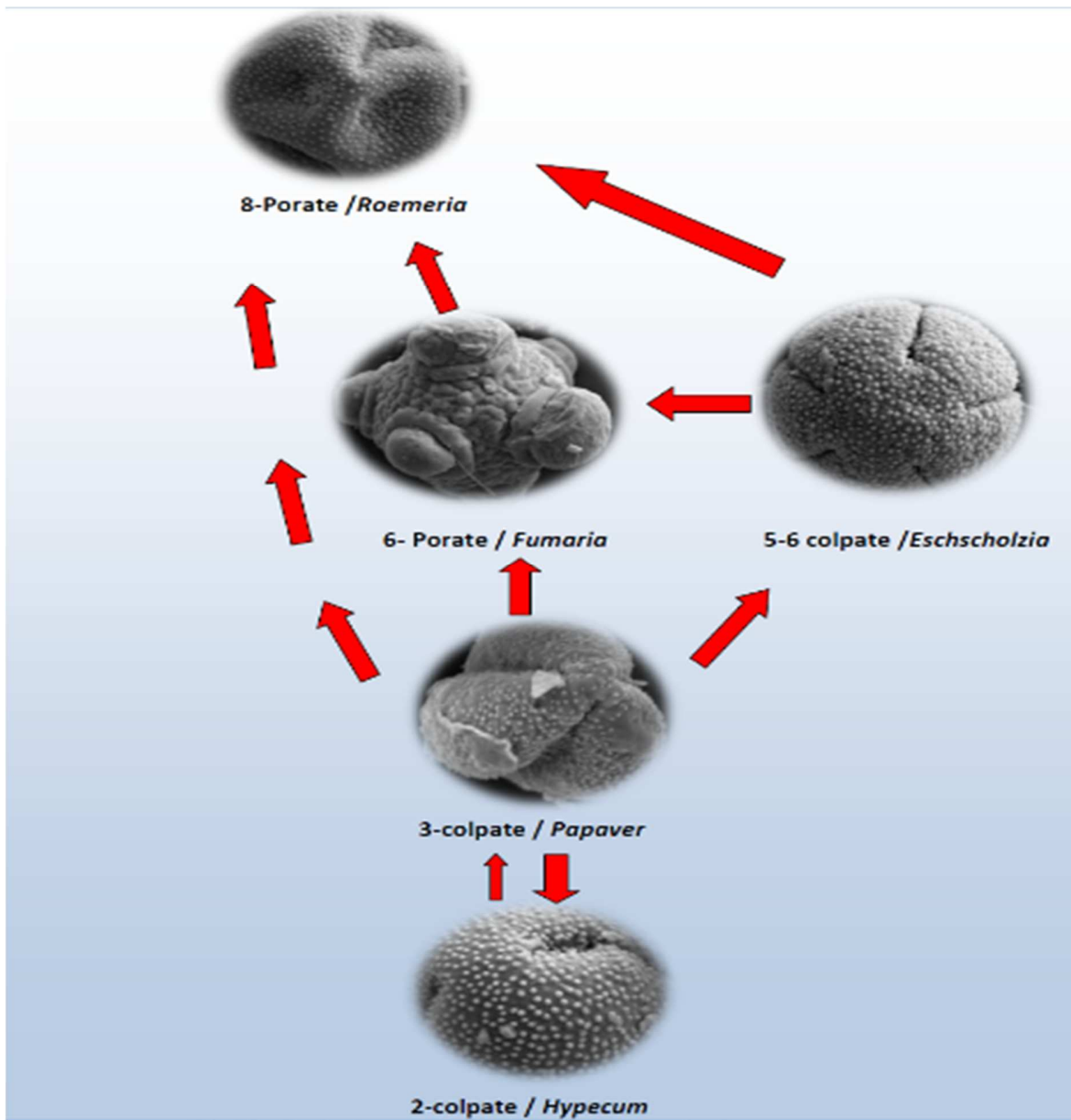
The palynological information available now support the proposal that Papaveraceae and Fumariaceae should be united under the same family.

Evolutionary trends:

As shown in Figure 87. the results indicate the evolutionary trends in the genera that were studied of this family in Iraq, it seems that the 3- colpate type represented by the species *P. rhoeas* is the primitive type and that may have been derived from it the rest of the types. This is consistent with this primitive character in all eudicot as confirmed by Walker and Doyle (1975). Accordingly, the 5-6 colpate type that representative by *E. californica* was derived from it evolutionary,

and maybe this type was evolution by reducing the dimensions of colps to the type 6-porate which representative by *R. hybrid* type. The last type led to polyporate by continues reducing the size of apertures. Or maybe the 5-6 colpate directly evolutionary by continue

reducing the size and number of apertures to polyporate. There is another suggestion that the type polyporate was derived directly from the primitive type 3- colpate or from the transitional patterns representative by *P.argemone* type.



References

- Abou El-Naga, A.Z. (1982). Palynological and cytological studies on the Papaveraceae in Egypt. M.Sc. Thesis. University of Mansoura. Faculty of Science. Department of Botany. Egypt.
- Al-Qura'n, S. (2010). Pollen characteristics of three *Papaver* species and the observation of polyphylla fullo as the main pollen collector. Pakistan Entomologist. 32, 2.
- Candau, P. and Fernandez-Paniagua, I. (1985). Pollen en Papaveraceae. An. Asoe. Palinol. Leng. Esp, 2: 25-34.
- Chaturvedi, M., Datta, K. and Pal, M. (1999). Pollen anomaly-a clue to natural hybridity in *Argemone* (Papaveraceae). Grana, 38: 339-342.
- Cullen, J. (1965). Papaveraceae. In: Flora of Turkey, Vol. 1. Eds. P.H. Davis, pp: 213-248. Edinburgh at the University Press.
- El-Ghazaly, G.A. (1992). Pollen Flora of Qatar. Scientific and Applied Research Center, University of Qatar.
- Erdtman, G. (1971). Pollen Morphology and Plant Taxonomy. Hafner. New York.
- Fazal, H., Ahmad, N. and Abbasi, B.H. (2013). Identification, characterization, and palynology of high-valued medicinal plants. The Scientific World Journal. Vol. 2013. Araticale ID 283484.
- Gran, A. and Sharifnia, F. (2008). Micro-macromorphological studies of the genus *Glaucum* (Papaveraceae) in Iran. Iran Journ. Bot. 14, (1): 23-38.
- Hanif, U., Mazhar, M. and Sardar, A.A.(2013). Palynomorphological studies of some ornamental plants of Mall Road, Lahore. Bio. Pakis. 59(1): 147-156.
- Kadereit, J.W. (1993). A revision of *Papaver* L. section *Meconidium*. Edinb. J. Bot. 50, (2): 125-148.
- Kalaf, Y.N. (2012). Palynological study of wild plants in Southern and Western regions of Basrah. M.Sc. Thesis. College of Education University of Basra. (In Arabic).
- Keshavarzi, M., Arai, E., Habibi, T.F. and Sheidaii, M. (2011). Pollen morphology of the genus *Fumaria* L.(Papaveraceae) in Iran. Iran. Journ. Bot. 17, (1), 98-104.
- Layka, S. (1976). Le polymorphisme pollinique dans le genre *Argemone* (Papaveraceae). Pollen et Spores, 18 (3): 351-375.
- Mazari, P., Ajabkhan, M., Ali, B., Mangi, J.D., Bux, H., Yasmin Khan, K., Mughal, S., Ahmad, M., Zafar, M. and Akhter, A. (2012). Palynological diversity in selected medicinal

- plant species of Asteraceae (Compositae) from flora of Kaghan valley. *Journal of Medicinal Plant Research*, 6(14): 2747-2753.
- Mohl, H. 1834. Beiträge zur anatomie und physiologie der gewächse. Erstes Heft, Über den Bau und die Formen der Pollenkörner. Bern, Fischer.
- Moore, P.D., Webb, J.A. (1978). An illustrated guide to pollen analysis. Hodder and Stroughton, London.
- Ownbey, G. B. 1958. Monograph of the genus *Argemone* for North America and the West Indies. - Mem. Torrey Bot. Club 1: 1-159.
- Ownbey, G. B. 1961. The genus *Argemone* in South America and Hawaii. - *Brittonia* 13: 91 - 109.
- Perven, A. and Qaiser, M. (2004). Pollen flora of Pakistan-XL. *Fumariaceae*. *Pak. J.* 36, (3): 467-473.
- Rachele, L.D. (1974). Pollen morphology of the *Papaveraceae* of the northeastern United States and Canada. *Bulletin of the Torrey Botanical Club*, 101: 152-159.
- Rechinger, K.H. (1964). *Flora of Lowland Iraq*. New York, Harner, Publishing Co.
- Romero, A.T., Salins, M.J. and Fernandez, M.C. (2003). Pollen well development in *Hypocoum imberbe* Sm. (*Fumariaceae*). *Grana*, 42: 91-101.
- Tavakkoli, Z., and Assadi, M. (2013). Comparison of morphological and micromorphological studies in the genus *Papaver* sect. *Oxytona* (*Papaveraceae*) and interspecific hybrids. *Iran. J. Bot*, 19(2): 235-249.
- Townsend, C.C. (1980). *Fumariaceae*. In: *Flora of Iraq*. Vol. 4. Part 2. Eds. C.C. Townsend and E. Guest, pp: 815-827. Ministry of Agriculture and Agrarian Reform Republic of Iraq.
- Walker, J.W. and Doyle, J.A. (1975). The bases of angiosperm phylogeny, palynology. *Ann. Missouri Botanical Garden*, 62: 664-723.
- Zohary, M. (1966). *Flora palaestina*. Part 1.