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Full Length Article

Morphological studies of the pollen grains for some hydrophytes in coastal Mediterranean lakes, Egypt

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ARTICLE INFO

Article history:

Received 3 March 2015

Received in revised form

5 April 2015

Accepted 7 April 2015

Available online 24 April 2015

Keywords:

Palynology

Northern lakes

Hydrophytes

Nile Delta

Key pollen

ABSTRACT

The pollen grains of forty species of the aquatic flowering plants (6 floating, 6 submerged and 28 emergent species) naturally growing in the four coastal Mediterranean lakes of Egypt were investigated during January–August 2012. These species belong to 17 families. Morphologically, the investigated pollen grains are mostly prolate-spheroidal, spheroidal or triangular, rarely prolate or elongated, tectum psilate, granulate, reticulate or micro-echinate. On the basis of aperture types pollen grains of most families are grouped under three distinct types, namely colpate, colporate and porate. On the other hand, pollen grains of some families e.g. Cyperaceae, Juncaceae, Potamogetonaceae and Ruppiaceae are inaperturate. It is worth stating that from a phylogenetic and evolutionary point of views, polarity, symmetry, apertural types and exine sculpturing are the most important characters to differentiate between the different pollen types. The identified pollen grains, conserved in the herbarium of Botany Department, Faculty of Science, Mansoura University, Mansoura, Egypt, as reference key pollen in the northern lakes for palynologists, ecologists, taxonomists etc.

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1. Introduction

Through the palynology we can get tremendous knowledge from a little material in a short time [1]. Palynology is used in several applications such as a survey of atmospheric pollen, spore production and the archaeological excavation of shipwrecks. The earliest investigation to use the morphological diversity of pollen directly concerned with the classification of plants [2]. Lindau [3] used a greater number of pollen

characters including shape and ornamentation as well as aperture number, to define a range of pollen types.

Morphology of pollen is involved in solving some taxonomic problems on the family, generic or specific level and has become part of the multidisciplinary and collaborative approach in plant systematic and evolution [4–6]. The sculpturing of the exine and the constant features make pollen grains appreciably recognizable feature through which parent genera or even species can be recognized [7,8].

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Peer review under responsibility of Mansoura University.

<http://dx.doi.org/10.1016/j.ejbas.2015.04.001>

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Several papers are published on pollen morphology of some dicots families from various parts of the world. Anacardiaceae, Bignoniaceae, Caricaceae, Myrtaceae, Moringaceae, Meliaceae, Rhamnaceae and Zygophyllaceae have been studied by [9]. Palynology of families Apocynaceae has been investigated by Schill and Leuenberger [10] and Van Campo et al. [11]. The families Caesalpiniaceae and Mimosaceae have been reported by Guinet [12] and Lock [13]. Morphology of pollen six aquatic angiosperms from Saudi Arabia has been studied by Perveen and Qaiser [14]. The main aims of this study are to contribute to our understanding the pollen morphology of aquatic plants naturally growing in four northern Mediterranean lakes of Egypt namely: Mariut, Idku, Burullus and Manzala by light microscopy and to be used as additional tool for plant taxonomy.

2. Materials and methods

2.1. Study area

The studied northern coastal Mediterranean lakes of Egypt are Lake Manzala, Lake Burullus, Lake Idku and Lake Mariut (Fig. 1). They are separated from the sea by strips of land that are very narrow in several places and are connected with the sea through narrow outlets (straits). Three lakes (Manzala, Burullus, Idku) receive the main bulk of the drainage water from the Nile Delta.

Lake Manzala (Long. $31^{\circ} 50' - 32^{\circ} 15' E$ and Lat. $31^{\circ} - 31^{\circ} 30' N$) is the largest of the northern deltaic lakes of Egypt. Its area is about 1400 km^2 [15]. Lake Burullus lies on the eastern side of the Rosetta Branch of the River Nile occupying a central

position along the Mediterranean coast of the Nile Delta. It extends eastwards from Longitudes $30^{\circ} 35'$ to $31^{\circ} 8' E$ and northwards from Latitudes $31^{\circ} 21'$ to $31^{\circ} 37' N$. It is the second largest natural lake in Egypt, with an area of about 410 km^2 [16]. Lake Idku is situated west of the River Nile delta between Longitudes $30^{\circ} 8'$ to $30^{\circ} 28' E$ and Latitudes $31^{\circ} 10'$ to $31^{\circ} 8' N$. Lake Mariut (Long. $29^{\circ} 89' E$ and Lat. $31^{\circ} 15' N$) is the smallest of the northern Mediterranean lakes of Egypt.

Ayyad et al. [17] stated that, the Mediterranean coastal region of Egypt belongs to the dry arid climatic zone of Koppen's [18] classification system. The study area lies in Meig's warm coastal deserts [19] in which summer is warmest month with mean monthly temperature less than $30^{\circ} C$, and winter is coldest month with mean monthly temperature above $10^{\circ} C$.

2.2. Pollen extraction

Pollen grains were extracted from fresh flowers of thirty seven aquatic species collected from the northern Mediterranean lakes during March–August 2012. Extraction and chemical preparations procedures of the flowers and pollen used is that described by Moore et al. [20]. Also, original pollen grains sizes were the mean values of the longest axis of 15 measured grains. The herbarium specimens of the studied plants were kept and well preserved at the herbarium of the Faculty of Science, Mansoura University, Mansoura, Egypt. Material for LM was acetolysed according to Erdtman [21]. Before acetolysis the pollens were boiled in 10% KOH for about 8 min, causing the apertures to open and making them easier to investigate [22]. The acetolysed pollens were mounted in glycerin jelly on glass slides. The pollen was examined using a

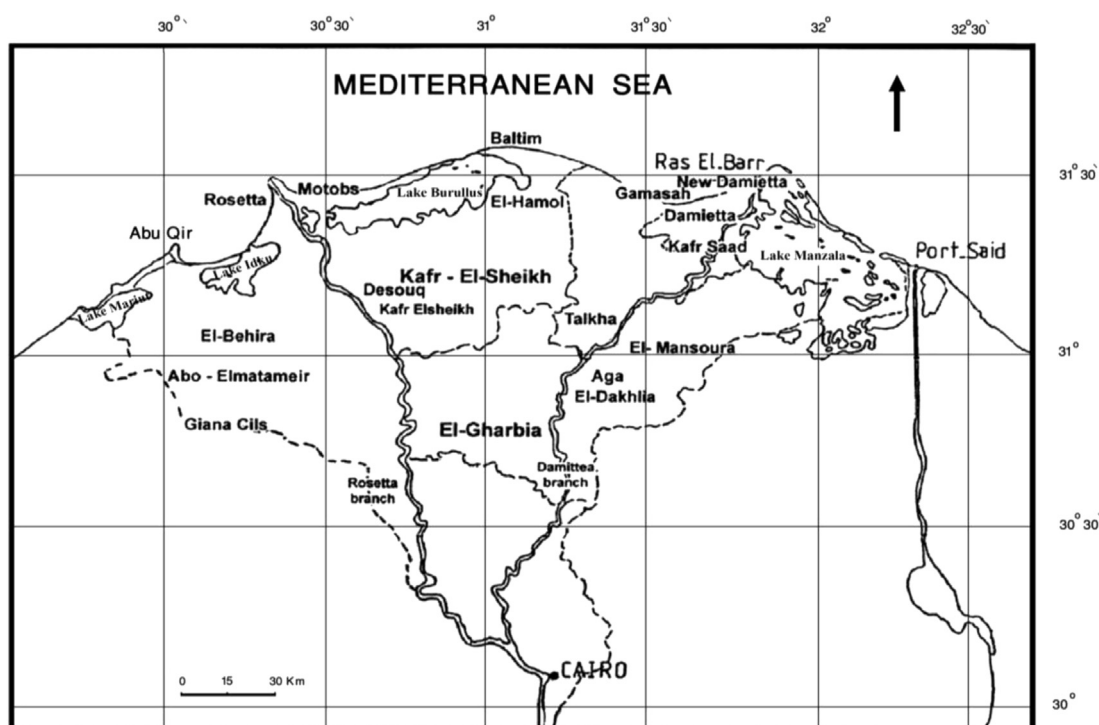


Fig. 1 – Map of the Nile Delta showing the coastal Mediterranean lakes of Egypt.

Leitz Laborlux D microscope fitted with a 40× and 100× oil immersion objectives, using 10× eyepieces.

The pollen identification and description were according to Moore et al. [20], Faegri and Iversen [23], Erdtman [9], Reitsma [24] and Punt et al. [25]. The terminology used is in accordance with Faegri and Iversen [26]; Kerp [27]; Walker and Doyle [1] and Solomon [28].

3. Results and discussion

The pollen grains of thirty seven species of the four northern Mediterranean lakes were investigated. The studied

thirty seven species are classified into three groups namely: submerged, floating and emergent hydrophytes. The investigated pollen morphological characters were: pollen unit, dimensions, shape class, polarity and symmetry, apertures, sculptures and exine texture (Tables 1 and 2; Plates 1 and 2).

3.1. Pollen unit and dimensions

The pollen grains at anthesis were found to be solitary (monads) in all the studied taxa. The mean length of the polar axis varied from 24.3 μm in *Veronica anagallis-aquatica* to 106.4 μm in *Ludwigia stolonifera*. The mean of equatorial diameter varied

Table 1 – Dimensions and shape classes variation in pollen grains of the hydrophytic taxa, of the Coastal Mediterranean lakes, Egypt. P/E = Polar axis/Equatorial axis.

No.	Pollen characters	Dimensions (μm)				P/E	Shape class
		Polar axis (P)		Equatorial axis (E)			
	Taxa	Mean	Range	Mean	Range		
Floating hydrophytes							
1	<i>Eichhornia crassipes</i> (Mart.) Solms	74.3 ± 4.7	50.0–87.5	58.6 ± 3.7	47.5–75.0	1.31	Prolate
2	<i>Lemna gibba</i> L.	47.5 ± 4.2	32.5–60.0	43.6 ± 1.7	30.0–40.0	1.40	Spheroidal
3	<i>L. minor</i> L.	37.5 ± 0.8	35.0–40.0	36.1 ± 0.5	35.0–37.5	1.00	Spheroidal
4	<i>L. perpusilla</i> Torr.	40.5 ± 0.9	36.5–45.0	39.0 ± 1.2	36.0–42.0	1.04	Spheroidal
5	<i>Ludwigia stolonifera</i> (Guill. & Perr.) Raven	106.4 ± 2.1	87.5–97.5	95.7 ± 9.5	95.0–110.0	1.11	Triangular
6	<i>Marsilea aegyptiaca</i> Willd.	37.1 ± 2.7	27.5–45.0	33.9 ± 2.9	27.5–45.0	1.10	Prolate spheroidal
Submerged hydrophytes							
1	<i>Ceratophyllum demersum</i> L.	38.2 ± 1.3	32.5–42.5	37.1 ± 0.9	32.5–40.0	1.03	Prolate spheroidal
2	<i>C. submersum</i> L.	36.1 ± 1.3	32.5–40.0	33.6 ± 1.4	30.0–40.0	1.07	Prolate spheroidal
3	<i>Myriophyllum spicatum</i> L.	30.7 ± 05	30.0–32.5	35.0 ± 2.9	27.5–47.5	0.88	Oblate spheroidal to Oblate
4	<i>Potamogeton crispus</i> L.	38.2 ± 1.5	35.0–45.0	32.9 ± 1.5	30.0–37.5	1.16	Spheroidal
5	<i>P. pectinatus</i> L.	42.9 ± 2.2	32.5–50.0	30.0 ± 2.2	20.0–35.0	1.43	Spheroidal
6	<i>Ruppia maritima</i> L.	65.4 ± 3.9	50.0–75.0	35.4 ± 2.5	22.5–42.5	1.84	Elongated
Emergent hydrophytes							
1	<i>Alternanthera sessilis</i> (L.) DC.	17.9 ± 1.2	15.0–22.5	18.6 ± 1.0	15.0–22.5	1.00	Spheroidal to Polyhedral
2	<i>Carex extensa</i>	40.7 ± 1.4	37.5–50.5	34.6 ± 1.2	32.5–40.0	1.18	Pear-shaped
3	<i>Cyperus alopecuroides</i> Rottb.	31.4 ± 0.8	30.0–35.0	25.4 ± 0.7	22.5–27.5	1.24	Pear-shaped
4	<i>C. articulatus</i> L.	32.5 ± 0.8	30.0–35.0	22.9 ± 1.1	20.0–27.5	1.41	Pear-shaped
5	<i>C. laevigatus</i> L.	31.8 ± 1.1	27.5–35.0	28.2 ± 1.3	25.0–32.5	1.13	Pear-shaped
6	<i>Echinochloa colona</i> (L.) Link	35.5 ± 0.8	32.5–37.5	30.4 ± 1.0	27.5–32.5	1.15	Prolate spheroidal
7	<i>E. crus-galli</i> (L.) P. Beauv.	29.9 ± 0.7	27.5–33.5	28.0 ± 0.5	26.5–30.0	1.08	Prolate spheroidal
8	<i>E. stagnina</i> (Retz.) P. Beauv.	40.0 ± 1.6	35.0–47.5	38.2 ± 1.8	32.5–45.0	1.05	Prolate spheroidal
9	<i>J. bufonius</i> L.	42.5 ± 0.8	39.5–45.0	40.5 ± 0.5	38.5–43.5	1.05	Prolate spheroidal
10	<i>J. subulatus</i> Forssk.	39.3 ± 2.1	35.0–50.0	37.5 ± 2.5	30.0–47.5	1.05	Prolate spheroidal
11	<i>Leersia hexandra</i> Swartz	38.6 ± 1.9	32.5–45.0	35.7 ± 2.1	30.0–45.0	1.08	Prolate spheroidal
12	<i>Leptochloa fusca</i> (L.) Kunth.	35.4 ± 1.1	32.5–40.0	33.2 ± 1.3	27.5–37.5	1.06	Prolate spheroidal
13	<i>Panicum repens</i> L.	34.4 ± 1.1	31.5–39.0	31.2 ± 1.3	27.5–35.5	1.10	Prolate spheroidal
14	<i>Paspalidium geminatum</i> (Forssk.) Staff in prain	34.6 ± 1.2	30.0–37.5	33.2 ± 1.1	30.0–37.5	1.04	Prolate spheroidal
15	<i>Paspalum distichum</i> L.	37.9 ± 0.9	35.0–40.0	36.1 ± 1.3	32.5–40.0	1.05	Prolate spheroidal
16	<i>Persicaria salicifolia</i> (willd.) Assenov	55.4 ± 1.6	50.0–62.5	55.0 ± 1.8	47.5–60.0	1.01	Prolate spheroidal
17	<i>P. lapathifolia</i> (L.) Gray	54.6 ± 1.8	50.0–62.5	53.6 ± 1.3	50.0–57.5	1.02	Prolate spheroidal
18	<i>Phragmites australis</i> (Cav.) Trin.ex Steud.	28.9 ± 0.8	27.5–32.5	28.6 ± 0.5	27.5–30.0	1.01	Prolate spheroidal
19	<i>Ranunculus sceleratus</i> L.	26.4 ± 1.0	22.5–30.0	23.2 ± 0.8	20.0–25.0	1.14	Subprolate
20	<i>Rorripa palustris</i> (L.)Besser.	26.0 ± 1.2	20.0–30.0	21.5 ± 0.9	17.5–25.0	1.21	Subprolate
21	<i>Saccharum spontaneum</i> L.	45.0 ± 2.0	40.0–50.0	42.5 ± 2.0	37.5–50.0	1.06	Prolate spheroidal
22	<i>Schoenoplectus maritimus</i> L.	46.4 ± 1.6	40.0–50.0	28.2 ± 1.7	22.5–35.0	1.65	Pear-shaped
23	<i>S. litoralis</i> (Schrad.) Palla	28.6 ± 1.4	22.5–32.5	23.2 ± 1.3	22.5–27.5	1.23	Pear-shaped
24	<i>Typha domingensis</i> (Pers.) Poir. ex Steud.	28.9 ± 0.8	27.5–32.5	28.6 ± 0.5	27.5–30.0	1.01	Spheroidal
25	<i>Veronica anagallis-aquatica</i> L.	24.3 ± 0.8	22.5–27.5	21.4 ± 1.0	17.5–25.0	1.13	Subprolate

Table 2 – General pollen characters of hydrophytic taxa, of the coastal Mediterranean lakes, Egypt.

No.	Pollen characters Taxa	Polarity	Symmetry	Apertures	Sculpture type	Exine texture
Floating hydrophytes						
1	<i>Eichhornia crassipes</i> (Mart.) Solms	Isopolar	Bilateral symmetric	Monosulcate	Psilate-granulate	Thick
2	<i>Ludwigia stolonifera</i> (Guill. & Perr.) Raven	Heteropolar	Radiosymmetric	Trizonoporate	Psilate	Moderate
3	<i>Marsilea aegyptiaca</i> Willd.	Apolar	Radiosymmetric	Trizonocolpate	Psilate-granulate	Thick
4	<i>Lemna gibba</i> L.	Apolar	Radiosymmetric	Monoporate	Psilate	Thick
5	<i>L. minor</i> L.	Apolar	Radiosymmetric	Monoporate	Psilate	Thick
6	<i>L. perpusilla</i> Torr.	Apolar	Radiosymmetric	Monoporate	Psilate	Thick
Submerged hydrophytes						
1	<i>Ceratophyllum demersum</i> L.	Apolar	Radiosymmetric	Trizonoporate	Psilate	Thick
2	<i>C. submersum</i> L.	Apolar	Radiosymmetric	Trizonoporate	Psilate	Thick
3	<i>Myriophyllum spicatum</i> L.	Isopolar	Radiosymmetric	Tetra-zonoporate	Microechinate	Thick
4	<i>Potamogeton crispus</i> L.	Apolar	Radiosymmetric	Inaperturate	Reticulate	Thick
5	<i>P. pectinatus</i> L.	Apolar	Radiosymmetric	Inaperturate	Semitectate	Thick
6	<i>Ruppia maritima</i> L.	Isopolar	Bilateral symmetric	Inaperturate	Reticulat – Psilate	Thick
Emergent hydrophytes						
1	<i>Alternanthera sessilis</i> (L.) DC.	Apolar	Radiosymmetric	Polyantoporate	Microechinate	Thick
2	<i>Carex extensa</i>	Heteropolar	Radiosymmetric	Ulcerate	Granulate	Thick
3	<i>Cyperus alopecuroides</i> Rottb.	Heteropolar	Radiosymmetric	Ulcerate	Granulate	Thick
4	<i>C. articulatus</i> L.	Heteropolar	Radiosymmetric	Ulcerate	Granulate	Thick
5	<i>C. laevigatus</i> L.	Heteropolar	Radiosymmetric	Ulcerate	Granulate	Thick
6	<i>Echinochloa colona</i> (L.) Link	Apolar	Radiosymmetric	Monoporate	Psilate	Thick
7	<i>E. crus-galli</i> (L.) P. Beauv.	Apolar	Radiosymmetric	Monoporate	Psilate	Thick
8	<i>E. stagnina</i> (Retz.) P. Beauv.	Apolar	Radiosymmetric	Monoporate	Psilate	Thick
9	<i>J. bufonius</i> L.	Apolar	Radiosymmetric	Inaperturate	Psilate	Thin
10	<i>J. subulatus</i> Forssk.	Apolar	Radiosymmetric	Inaperturate	Psilate	Thin
11	<i>Leersia hexandra</i> Swartz	Apolar	Radiosymmetric	Monoporate	Psilate	Thick
12	<i>Leptochloa fusca</i> (L.) Kunth.	Apolar	Radiosymmetric	Monoporate	Psilate	Thick
13	<i>Panicum repens</i> L.	Apolar	Radiosymmetric	Monoporate	Psilate	Thick
14	<i>Paspalidium geminatum</i> (Forssk.) Staff in prain	Apolar	Radiosymmetric	Monoporate	psilate	Thick
15	<i>Paspalum distichum</i> L.	Apolar	Radiosymmetric	Monoporate	Psilate	Thick
16	<i>Persicaria salicifolia</i> (willd.) Assenov	Isopolar	Radiosymmetric	Trizonocolporate	Reticulate	Thick
17	<i>P. lapathifolia</i> (L.) Gray	Isopolar	Radiosymmetric	Trizonocolporate	Reticulate	Thick
18	<i>Phragmites australis</i> (Cav.) Trin.ex Steud.	Apolar	Radiosymmetric	Monoporate	Psilate	Thick
19	<i>Ranunculus sceleratus</i> L.	Isopolar	Radiosymmetric	Trizonocolpate	Granulate	Thick
20	<i>Rorripa palustris</i> (L.) Besser.	Isopolar	Radiosymmetric	Trizonocolpate	Reticulate	Thick
21	<i>Saccharum spontaneum</i> L.	Apolar	Radiosymmetric	Monoporate	Psilate	Thick
22	<i>Schoenoplectus maritimus</i> L.	Heteropolar	Radiosymmetric	Ulcerate	Granulate	Thick
23	<i>S. litoralis</i> (Schrad.) Palla	Heteropolar	Radiosymmetric	Ulcerate	Granulate	Thick
24	<i>Typha domingensis</i> (Pers.) Poir. ex Steud.	Apolar	Radiosymmetric	Monoporate	Microreticulate	Thick
25	<i>Veronica anagallis-aquatica</i> L.	Isopolar	Radiosymmetric	Trizonocolporate	Perforate	Thick

from 18.6 μm in *Alternanthera sessilis* to 95.7 μm in *L. stolonifera*. Pollen grains can be categorized into small-sized (10–25 μm), medium-size (25–50 μm), large-size (50–100 μm) and very large-size (100–200 μm) [27]. In this connection Ramamoorthy [29]; Ezcurra [30]; Bank et al. [31] and Ueckermann and Rooyer [32] suggested that small-sized pollen enhances the insect pollination whereas large-sized pollen enables moth or bat pollination.

3.2. Shape class

The morphology of a pollen grain was measured by the ratio of the length of the polar axis (an imaginary straight line connecting the two poles) to the equatorial diameter (P/E) according to Erdtman [9]. Table 1 shows that the shapes of pollen grain are spheroidal (7 taxa), prolate-spheroidal (19 taxa) except in *Myriophyllum spicatum* is oblate-spheroidal,

triangular (8 taxa), subprolate (3 taxa), prolate in *Eichhornia crassipes* or elongated in *Ruppia maritima*.

3.3. Polarity and symmetry of pollen grains

The pollen grains examined were usually radially symmetrical (except in *Eichhornia* and *Ruppia*, both with bilateral symmetric), apolar, few taxa are isopolar and heteropolar (Plates 1 and 2). However, heteropolar grains were commonly found in monocotyledonous families (e.g. Cyperaceae) compared to dicot ones. Pollen grains of dicot families were usually apolar or isopolar. Pollen grains are usually categorized largely on the basis of their shape, size, apertural types, symmetry, polarity and exine sculpturing. However, from a phylogenetic and evolutionary point of view, polarity, symmetry, apertural types and exine sculpturing are the most important pollen characters [1].

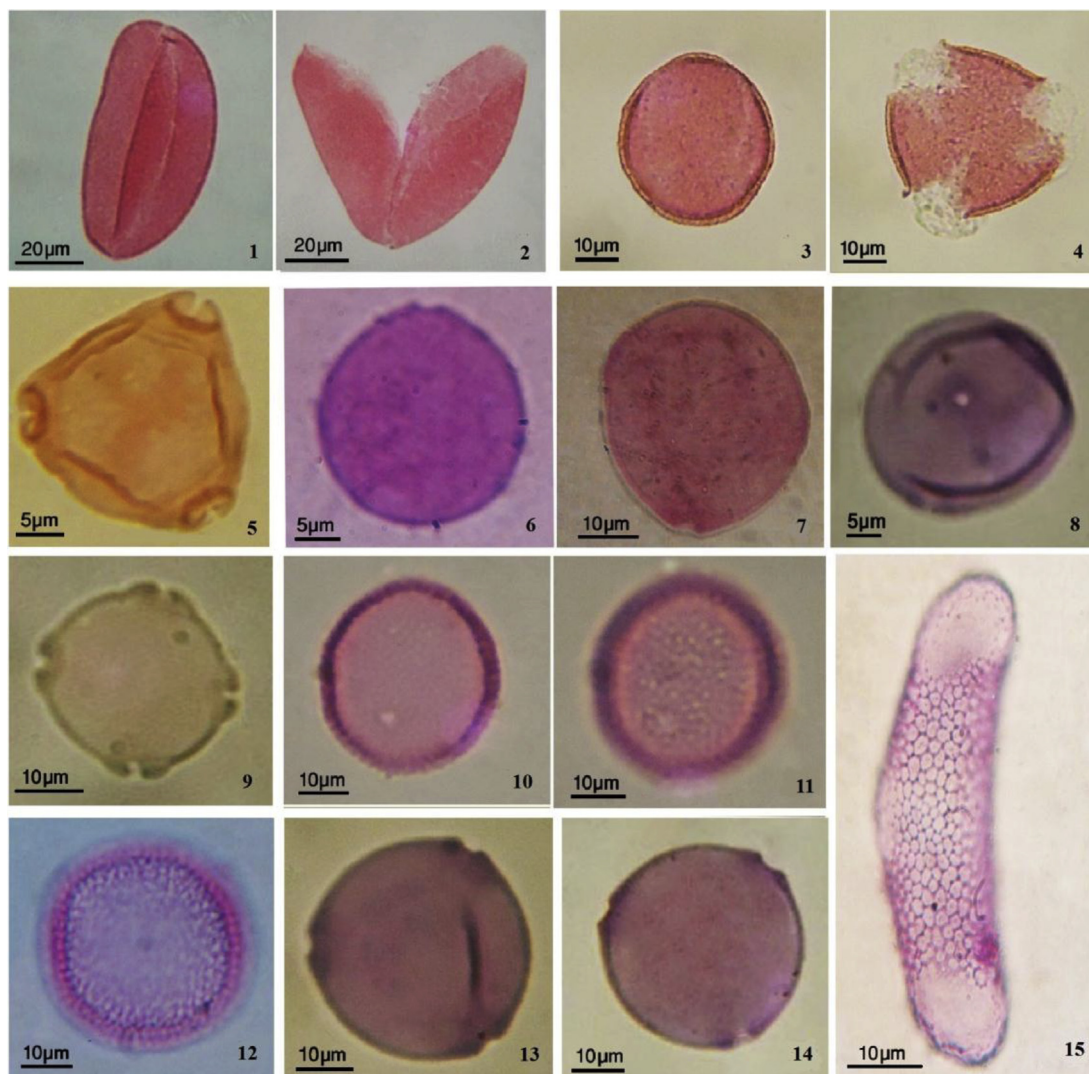


Plate 1 – Microphotographs showing the morphological shapes for pollen grains of submerged and floating hydrophytic taxa in the coastal Mediterranean lakes, Egypt. 1 and 2. *Eichhornia crassipes*, 3 and 4. *Marsilea aegyptiaca*, 5. *Ludwigia stolonifera*, 6. *Lemna gibba*, 7. *L. minor*, 8. *L. perpusilla*, 9. *Myriophyllum spicatum*, 10 and 11. *Potamogeton crispus*, 12. *P. pectinatus*, 13. *Ceratophyllum demersum*, 14. *Ceratophyllum submersum*, 15. *Ruppia maritima*.

3.4. Aperture characters

In apertural types, the investigated pollens are mostly colpate, colpate, porate rarely non-aperturate grains were observed. The colpate aperture is tricolpate with free apices in three taxa (*Marsilea aegyptiaca*, *Ranunculus sceleratus* and *Rorripa palustris*). The colpate aperture type is tricolpate in three taxa (*Persicaria* spp and *V. anagallis-aquatica*). The porate type is monoporate (14 taxa), triporate (3 taxa), tetraporate as in *M. spicatum* and polyporate as in *A. sessilis*. The inaperturate pollen (14 taxa) as in *Cyperaceae*, *Juncaceae* and *Potamogeton* spp. In *E. crassipes* the aperture is monosulcate.

Walker and Doyle [1] and Moore et al. [20] considered that the line of evolution in pollen class as from inaperturate pollen (without aperture) vs aperturate pollen and the latter is from monoaperturate to polyaperturate. Thus, as the majority of the studied taxa have porate or inaperturate, rarely colpate

and colpate pollen grains, thus are considered the line of evolution between the primitive type and advanced pores. The pollen in monocots are less specialized than that of dicots, particularly in their apertural types [33].

3.5. Pollen surface sculpture

The pollen grains examined were usually thick in exine texture except these of family *Juncaceae*. The following pollen surface patterns were recorded; psilate (22 taxa), granulate (8 taxa), microechinate (*A. sessilis* and *M. spicatum*), reticulate (5 taxa), only that of *Typha domingensis* is microreticulate in pattern. *V. anagallis-aquatica* pollen are perforate sculpture but those of *R. maritima* have exine which is reticulate in pattern in the central portion of the grain and appears smooth at the extremities. Walker and Doyle [1] on angiosperms and Furness [34] on *Acanthaceae* considered that the psilate pollen surface is the primitive case.

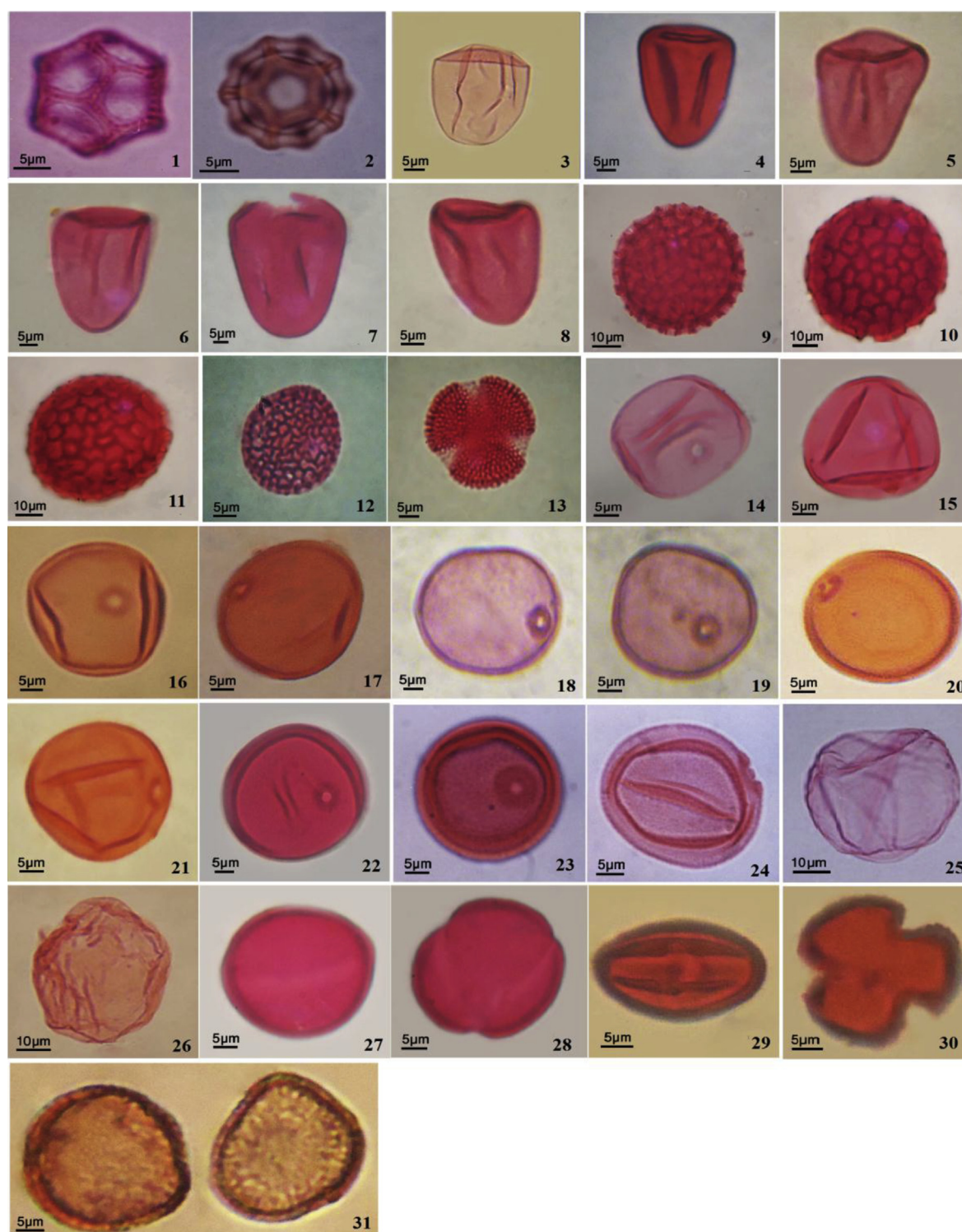


Plate 2 – Microphotographs showing the morphological shapes for pollen grains of emergent hydrophytic taxa in the coastal Mediterranean lakes, Egypt. 1 and 2. *Alternanthera sessilis*, 3. *Carex extensa*, 4. *Cyperus alopecuroides*, 5. *C. articulatus*, 6. *C. laevigatus*, 7. *Schoenoplectus maritimus*, 8. *S. litoralis*, 9 and 10. *Persicaria salicifolia*, 11. *P. lapathifolia*, 12 and 13. *Rorripa palustris*, 14. *Echinochloa colona*, 15. *E. crus-galli*, 16. *E. stagnina*, 17. *Leersia hexandra*, 18. *Leptochloa fusca*, 19. *Panicum repens*, 20. *Paspalidium geminatum*, 21. *Paspalum distichum*, 22. *Saccharum spontaneum*, 23 and 24. *Phragmites australis*, 25. *J. subulatus*, 26. *J. bufonius*, 27 and 28. *Ranunculus sceleratus*, 29 and 30. *Veronica anagallis-aquatica*, 31. *Typha domingensis*.

Acknowledgements

The author is deeply indebted to Prof. M.A. Zahran, Faculty of Science, Mansoura University for revising the manuscript and for his constructed advice.

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