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## A Palynological Survey of Aquatic Flora of Karachi-Pakistan

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**Abstract:** The pollen morphology of 16 species of aquatic angiosperms, distributed in 14 families from Karachi was examined by light and scanning microscope. Pollen grains are usually free, rarely united, mostly radially symmetrical, isopolar-apolar, occasionally heteropolar. Simple aperturate (porate or colpate) pollen are more frequently found. Number of apertures varies from 1-3 or more than 30, rarely compound aperture as in *Enhydra fluctuans* Lour. Tectum of the families also is quite variable, ranging from reticulate to rugulate, striate, fossulate, echinate or scabrate/areolate. The pollen morphology of the families is significantly useful for characterizing the species. Apertural types and tectum types are the most significant pollen characters. On the basis of these characters 4 distinct pollen types are recognized.

**Key Words:** Aquatics; Flora Karachi, Pollen morphology.

### Karachi-PAKİSTAN Sucul Florası Üzerine Palinolojik Bir Araştırma

**Özet:** Karachi'de bulunan 14 familyaya dahil 16 sucul angiosperm türünün polen morfolojisi ışık ve taramalı elektron mikroskobu ile incelenmiştir. Polenler genellikle serbest (tek), nadiren birleşiktir, çoğunlukla radyal simetrik, izopolar-apolar, nadiren heteropolardır. Çoğunlukla basit apertürlü (porat ya da kolpat) polenler bulunmaktadır. Apertür sayısı 1 ile 3 arasındadır ya da 30'dan fazladır, *Enhydra fluctuans* Lour.'da olduğu gibi nadiren bileşik apertür bulunmaktadır. Familyaların tektumu da oldukça değişkendir; retikülat, rugulat, striat, fossulat, ekinat ya da skabrat/areolatdır. Familyaların polen morfolojisi türlerin karakterize edilmesine büyük ölçüde yardımcı olmaktadır. Apertür ve tektum tipleri en belirgin polen karakterleridir. Bu karakterleri temel alarak 4 polen tipi tanımlanmıştır.

**Anahtar Sözcükler:** Sucul bitkiler, Karachi Florası, polen morfolojisi.

### Introduction

Aquatic flowering plants represent a considerable part of the world's flora, About 79 families and 380 genera contain aquatic species (1). Because of their anatomical, morphological, reproductive and physiological peculiarities, the aquatic plants attract a special interest from biologists. However, literature dealing with the pollen morphology of aquatic flowering plants is rather scarce. Few reports are available on aquatic plants, such as the families *Typhaceae* (1, 2) and *Pontederiaceae* (3).

Some species of *Potamogetonaceae* have been examined by Sorsa (4). Landolt (5) examined the pollen morphology of *Lemnaceae*. The flora of Karachi is represented by 413 plant species of which 162 are monocots and 251 are dicots, distributed in 60 dicot and 15 monocot families (6). Of these about 20 species belonging to 18 families are aquatic in nature. There are no previous reports of palynological surveys of aquatic

plants from Karachi. The present report gives an account of the pollen morphology of 16 species, belonging to 14 genera distributed in 14 families.

### Materials and Methods

Pollen samples were obtained from the Karachi University Herbarium (KUH) or collected from the field. The list of voucher specimens is deposited in the KUH. The pollen grains were prepared for light (LM) and scanning microscopy (SEM) by the standard methods described by Erdtman (7). For light microscopy, the pollen grains were mounted in unstained glycerine jelly and observations were made with a Nikon Type-2 microscope, under E40, 0.65 and oil immersion (E100, 1.25), using a 10x eye piece. For SEM studies, pollen grains were suspended in a drop of water and directly transferred with a fine pipette to a metallic stub using double-sided adhesive tape and coated with gold in a

sputtering chamber (Ion-sputter JFC-1100). Coating was restricted to 150Å. The S.E.M examination was carried out on a Jeol microscope JSM-T200. The measurements were based on 15-20 readings from each specimen. Polar area index (P.A.I: Polar area index expressed by the ratio of the polar area dimension to the largest transverse dimension of the pollen grains) and coefficient of variation (coefficient of variation expresses the standard deviation as a percentage in terms of the arithmetic mean) are also given. Polar axis (P), equatorial diameter (E), colpi length, apocolpium, mesocolpium, spine length and exine thickness were measured.

The terminology used is in accordance with Wodehouse (8); Erdtman (7); Faegri and Iversen (9); Kremp (10) and Walker and Doyle (11).

## Observations

### General pollen characters of Aquatic Families

The pollen grains are mostly apolar or isopolar rarely heteropolar. The shape is commonly spheroidal or oblate-spheroidal rarely boat-shaped (*Nymphaea stellate* Willd.) and sub-prolate (*Nelumbo nucifera* Gaertn.). However, in the family *Juncaceae* and in the single species of *Typhaceae* (*Typha elephantina* Roxb.) pollen grains are united in tetrads. Similarly, exine sculpturing is also extremely varied, ranging from reticulate to rugulate, fossulate, foveolate, scabrate, echinate-spinulose or areolate. Apertures are mostly colpate or porate (number varies from 1-(3)-40). However, in few taxa non-aperturate pollen is also found (*Potamogeton* L., *Juncus* L.) rarely tricolporate as in *Enhydra fluctuans* Lour.

### *Eichhornia crassipes* (Mart.) Sloms (Fig. 1-2).

Pollen grains heteropolar, oblong, size: Length (37.07)-39.25±0.75 (-42.51) µm, C.V.11, and breadth (47.50-) 50.98±1.20 (-57.51) µm, C.V.10., monobicolpate, colpi (42.50-) 45.61±1.21 (-50.23) µm long, C.V.3.01. Exine (0.50-) 2.25±0.21 (-2.52) µm thick, C.V.4.91, sexine thinner than or as thick as nexine. Tectum areolate, areolae variable in size.

### *Enhydra fluctuans* Lour. (Figs. 3-4).

Pollen grains radially symmetrical, isopolar, oblate-spheroidal, size: polar axis P(13.21-) 19.32±0.40 (-21.11) µm, C.V. 6.62, and equatorial diameter E(19.61) 21.61±0.70 (-25.21) µm, C.V. 4.41. P/E ratio: 0.89. Tricolporate, trilobed, fossaperturate, colpi (14.31-) 14.90±0.46 (-15.41) µm long, C.V. 5.36, colpal membrane sub-psilate. Mesocolpium (15.41-) 16.50±0.34 (-18.21) µm, C.V. 6.65. Apocolpium (2.80)

4.02±0.44 (-7.11) µm, C.V. 21.08. Exine (1.68-) 1.72±0.07 (-2.12) µm thick, C.V. 11.04, sexine thicker than nexine. Tectum echinate, collumellae branched, spines pointed, (3.50-) 4.06±0.09 (-4.21) µm, C.V. 7.14.

### *Ipomoea aquatica* Forsk. (Figs. 5-7).

Pollen grains radially symmetrical, apolar, spheroidal, size: (64.62-) 70.23±2.97 (-82.57) µm in diameter, C.V. 20.30. pantoporate, pores 36-42 or more, ±circular (3.95-) 5.77±0.30 (-7.18) µm in diameter, C.V.16.6, pore plate with sparse puncta or granules. Exine (3.59-) 4.71±0.26 (-5.74) µm thick, C.V.18.01, sexine slightly thinner than nexine. Tectum echinate finely perforated with granules, spines uniformly distributed, with distinct perforated base, and blunt apices, (3.59-) 3.74±0.06 (-3.95) µm long, C.V. 5.04.

### *Juncus maritimus* Lam. (Figs. 8-10).

Pollen grains tetrahedral, tetrads, non aperturate, size: Length (32.50-) 40.25±2.88 (-42.51) µm, C.V. 20.61, and breadth (37.50-) 40.04±1.29 (-47.91) µm, C.V. 7.18. Exine (1.25-) 1.35±0.05 (-1.75) µm thick, C.V. 8.21, sexine thicker than nexine. Tectum lophate-reticulate, with fine scabrae.

### *Lemna gibba* L. (Fig. 11).

Pollen grains radially symmetrical, apolar, spheroidal, size: (20-) 21.13±0.37 (-22.51) µm in diameter, C.V.3.91. monoporate, pore±circular, c.0.5 µm in diameter. Exine (1.25-) 1.42±0.16 (-1.75) µm thick, C.V. 25.12, sexine thicker than nexine. Tectum spinulose.

### *Lemna aequinoctialis* Welw.

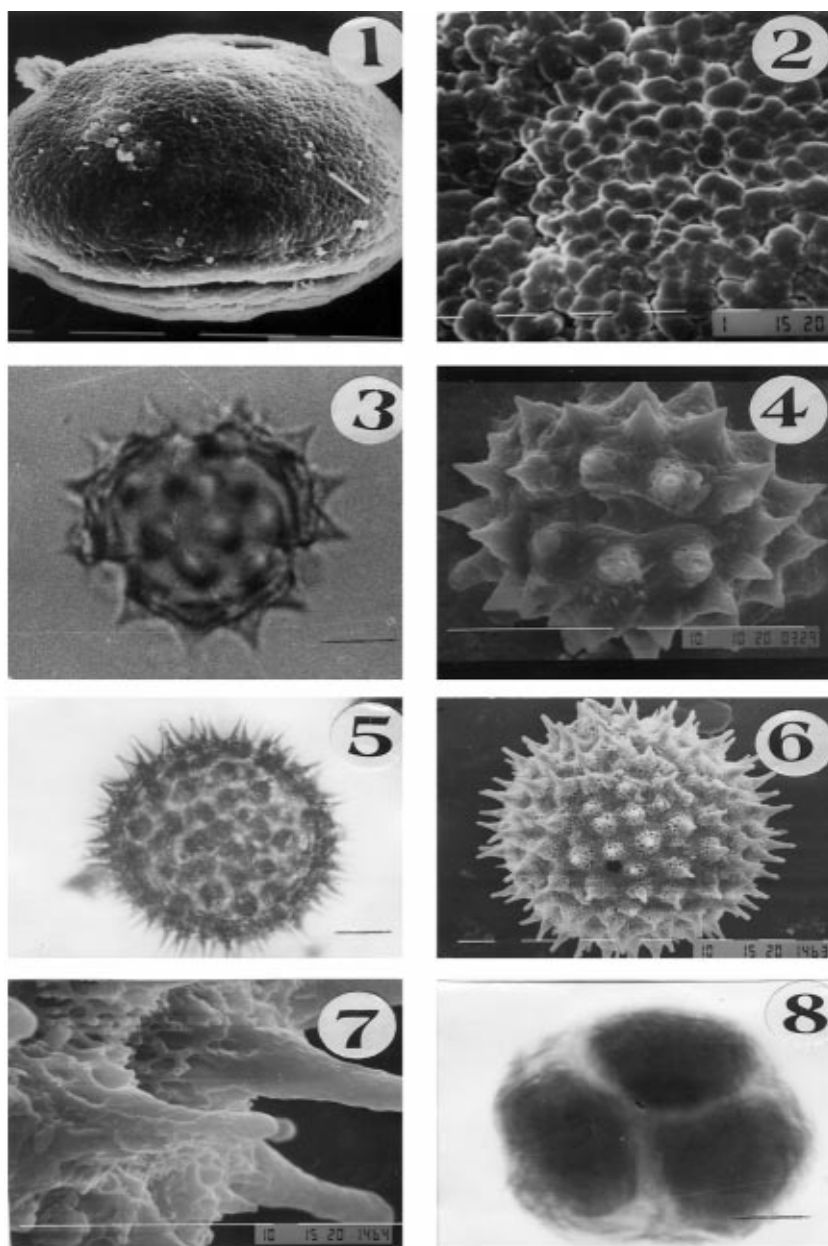
Pollen grains radially symmetrical, apolar, spheroidal, size: (19.69-) 21.22±0.62 (-23.97) µm in diameter, C.V.12. monoporate, pore very small. Exine (0.66-) 1.76±0.41 (-3.33) µm thick, C.V. 62.41, sexine as thick as nexine. Tectum spinulate-punctate.

### *Myriophyllum verticillatum* L. (Figs. 12-14).

Pollen grains radially symmetrical, isopolar, sub-oblate, size: Polar axis P(18.59-) 19.54±0.16(-20.02) µm, C.V. 3.27, and equatorial diameter E(21.54-) 23.64±0.23 (-24.31) µm, C.V. 3.84. 4-5 colpate, short colpi (1.43-) 2.86±0.13 (-3.95) µm long. Exine 1.43 µm thick, sexine thicker than nexine. Tectum scabrate-punctate, scabrae fine.

### *Nelumbo nucifera* Gaertn. (Figs.15-18).

Pollen grains radially symmetrical, isopolar, sub-prolate, size: Polar axis P(68.21-) 78.11±3.20 (-87.90) µm, C.V.9.11, and equatorial diameter E(55.61-)



Figs.1-2. *Eichhornia crassipes* (Mart.) Sloms  
 Figs.3-4. *Enhydra fluctuans* Lour.  
 Figs.5-7. *Ipomoea aquatica* Forsk.  
 Fig.8. *Juncus maritimus* Lam.  
 1, Pollen grain; 2, Exine pattern; 3, polar view (LM); 4, Equatorial view (SEM); 5, pollen grain (LM); 6, pollen grain (SEM); 7, Exine pattern (SEM); tetrads (LM).

$59.20 \pm 1.13$  ( $-61.03$ )  $\mu\text{m}$ , C.V.9.21. P/E ratio: 1.31. Tricolpate, rounded-trilobed, ( $50.20$ -)  $66.05 \pm 4.61$  ( $-78.91$ )  $\mu\text{m}$  long, C.V. 15.61, colpal membrane densely fossulate. Mesocolpium ( $50.26$ -)  $61.82 \pm 2.84$  ( $-71.82$ )  $\mu\text{m}$ , C.V.11.25. Apocolpium ( $3.61$ -)  $4.81 \pm 1.91$  ( $-7.18$ )  $\mu\text{m}$ , C.V. 4.33. Exine ( $3.61$ -)  $3.94 \pm 0.06$  ( $-4.31$ )  $\mu\text{m}$  thick, C.V. 3.94, sexine thicker than nexine. Tectum rugulate.

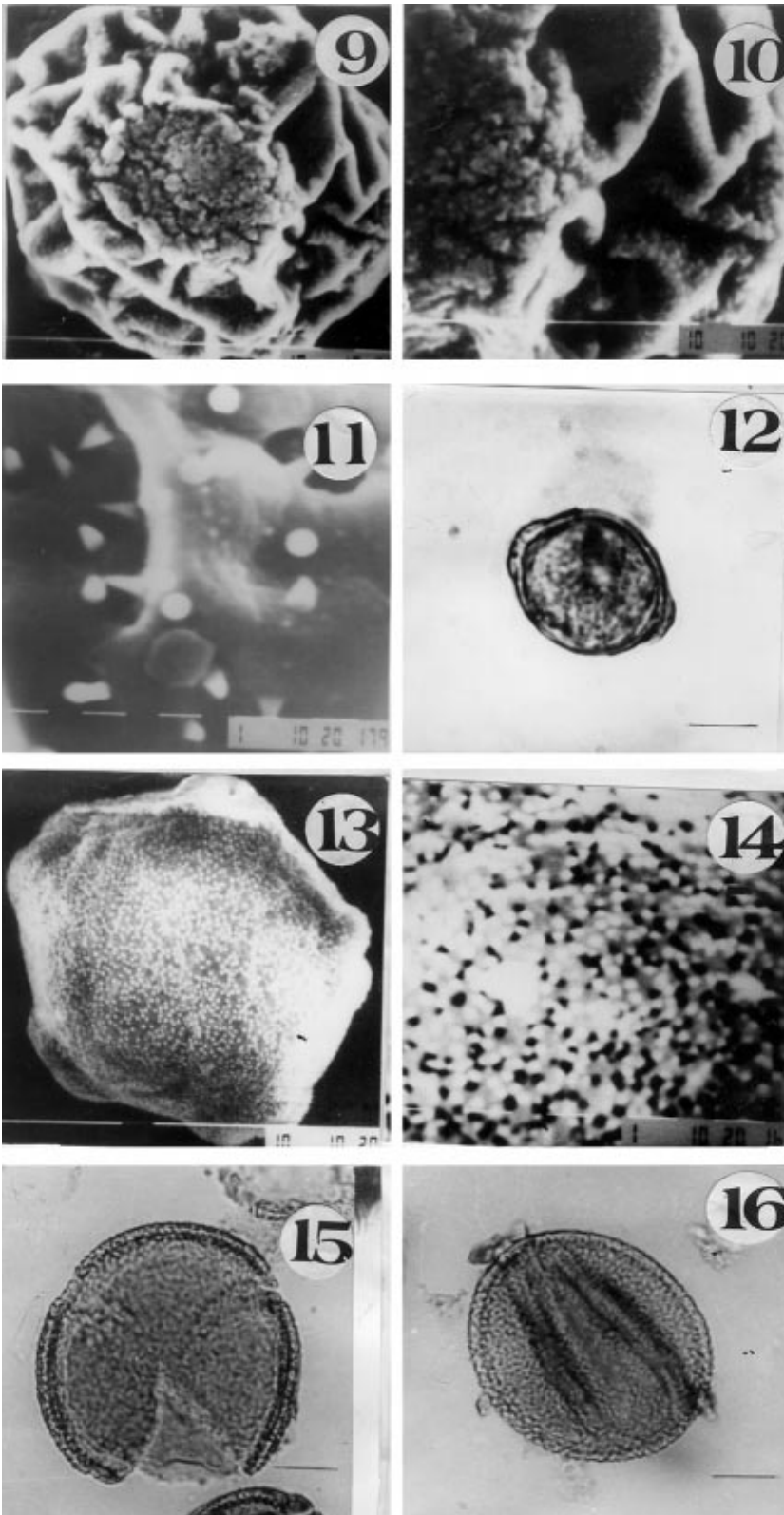
P.A.I: 1.04

*Nymphaea stellata* Willd. (Figs. 19-21).

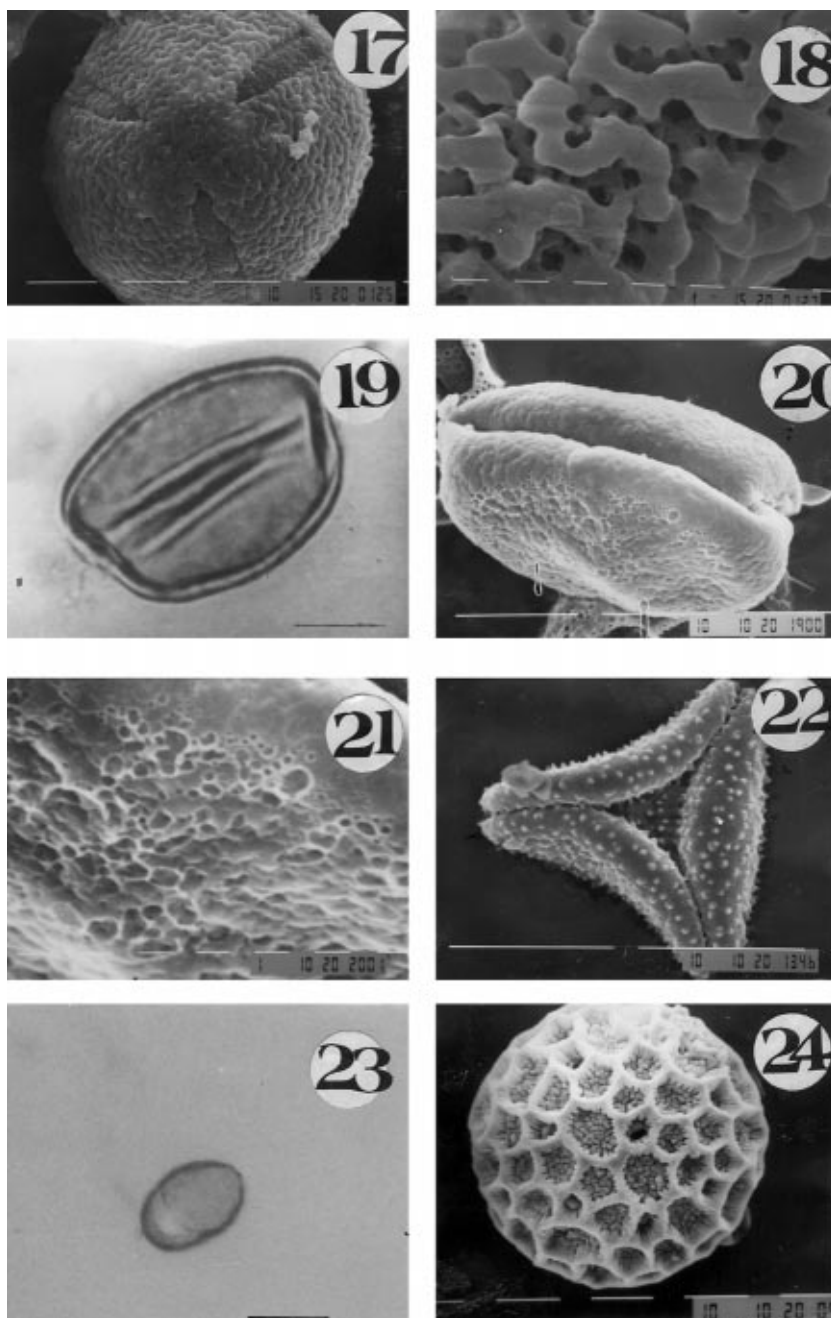
Pollen grains bilateral, heteropolar, boat-shaped, size: Length ( $25.13$ -)  $28.07 \pm 0.58$  ( $-32.31$ )  $\mu\text{m}$ , C.V.7.66, and breadth ( $32.80$ -)  $37.61 \pm 3.71$  ( $-41.04$ )  $\mu\text{m}$ , C.V.6.27. monosculate, colpi ( $32.31$ -)  $35.51 \pm 0.89$  ( $-39.40$ )  $\mu\text{m}$  long, C.V.21.92, sexine thinner than nexine. Tectum rough reticulate.

*Nymphoides cristata* (Roxb.) O. Ktze. (Figs. 22-23).

Pollen grains heteropolar, oblate, size: Polar axis P( $17.91$ -)  $20.93 \pm 0.84$  ( $-25.13$ )  $\mu\text{m}$ , C.V. 9.98, and equatorial diameter E( $25.13$ -)  $31.54 \pm 0.65$  ( $-35.91$ )  $\mu\text{m}$ , C.V. 7.95. A/E ratio: 0.64 Tricolpate, triangular, with



Figs.9-10. *Juncus maritimus* Lam.  
 Fig.11. *Lemna gibba* L.  
 Figs.12-14. *Myriophyllum verticillatum* L.  
 Figs.15-16. *Nelumbo nucifera* Gaertn.  
 9, Tetrads (SEM), 10, Exine pattern (SEM); 11, Exine pattern: 12, Equatorial view (LM); 13, polar view (LM); 14, Exine pattern (SEM); 15, polar view (LM); 16, Equatorial view (LM).  
 Scale bar= 9, 10, 12 & 13 = 10 =  $\mu$ m; 15&16=20  $\mu$ m; 11&14=1  $\mu$ m.

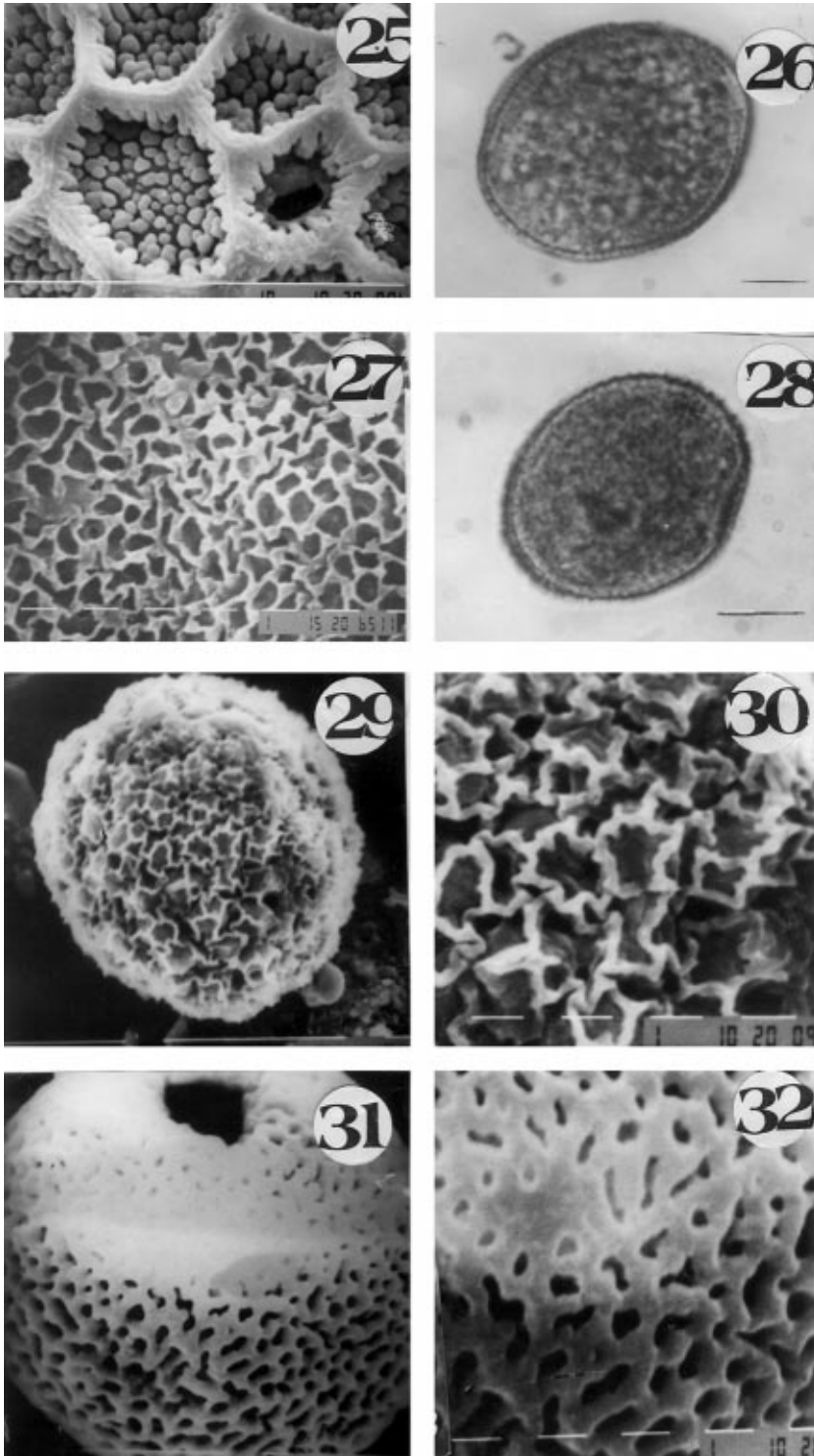
Figs.17-18. *Nelumbo nucifera* Gaernt.Figs.19-21. *Nymphaea stellata* Willd.Figs.22-23. *Nymphaea stellata* (Roxb.) O. Ktze.Figs.24. *Persicaria glabra* (Willd.) Gomes  
17, pollen grain (SEM), 18, Exine pattern (SEM); 19, pollen grain (LM); 20, pollen grain (SEM); 21, Exine pattern (SEM); 22, polar view (SEM); 23, pollen grain (LM); 24, pollen grain (SEM).Scale bar= 17, 20, 22 & 24= 10=  $\mu\text{m}$ ; 19 & 23= 20  $\mu\text{m}$ ; 18, 21= 1  $\mu\text{m}$ .

apertures on the sides of an angular grain in polar view, colpi (19.74-) 23.03 $\pm$ 1.07 (-23.32)  $\mu\text{m}$  long, C.V. 11.33. Mesocolpium (21.51-) 24.30 $\pm$ 0.56 (-26.72)  $\mu\text{m}$ , C.V. 7.61, para syncolpate (frequently syncolpate) leaving triangular apocolpium area. Exine (0.35-) 0.79 $\pm$ 0.06 (-0.89)  $\mu\text{m}$  thick, C.V. 26.52, sexine thicker than nexine. Tectum densely spinulose, unequal in size with acute tips.

*Persicaria glabra* (Willd.) Gomes (Figs. 24-25).

Pollen grains radially symmetrical, apolar, spheroidal,

size: (78-) 50.26 $\pm$ 0.77 (-60.26)  $\mu\text{m}$  in diameter, C.V. 6.01. polyantoporate, pore $\pm$ oblong, c. 1.87  $\mu\text{m}$  in diameter. Exine (5.38-) 6.31 $\pm$ 0.21 (-7.18)  $\mu\text{m}$ , C.V. 10.76, sexine thicker than or as thick as nexine, consisting of densely spaced bacula. Tectum very coarsely reticulate, with regular muri patterns, lumina hexagonal in shape, provided with intra-luminal bacula which completely fills the luminal space, lumina shorter towards the pores, 6.42-7.85  $\mu\text{m}$  in diameter.



Figs. 25. *Persicaria glabra* (Willd.) Gomes

Figs. 26-27. *Potamogeton pectinatus* L.

Figs. 28-30. *Potamogeton perfoliatus* L.

Figs. 31-32. *Typha angustifolia* L.

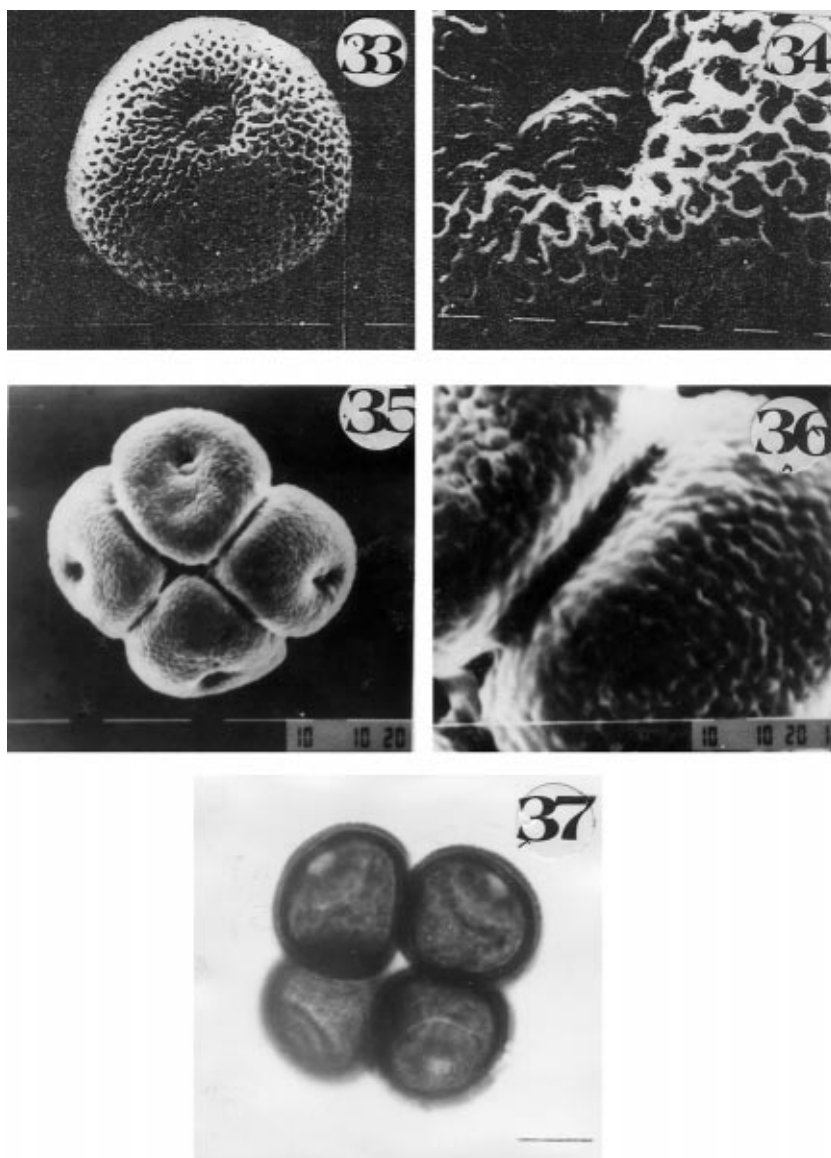
25. Exine pattern (SEM); 26, pollen grain (LM); 27. Exine pattern (SEM); pollen grain (LM); 29, pollen grain (SEM); 30, Exine pattern (SEM); 31, monad (SEM); 32. Exine pattern (SEM).

Scale bar= 25, 26, 28, 29 & 31= 10=  $\mu\text{m}$ ; 27, 30 & 32= 1  $\mu\text{m}$ .

*Potamogeton pectinatus* L. (Figs. 26-27).

Pollen grains radially symmetrical, apolar, spheroidal, size: (32.50-) 35.11 $\pm$ 1.87 (-37.51)  $\mu\text{m}$  in diameter, C.V.

16.11 nonaperturate. Exine c. 0.12  $\mu\text{m}$  thick, sexine thicker than or as thick as nexine. Tectum coarsely reticulate with irregular pattern of muri, lumina variable in size and shape, 0.22  $\mu\text{m}$  in diameter.

Figs. 33-34. *Typha domingensis* Pres.Figs. 35-37. *Typha elephantina* Roxb.

33, monads (SEM); 34, Exine pattern (SEM); 35, Tetrads (SEM); 36, Exine pattern (SEM); 37, tetrad (LM).

Scale bar= 33, 34, 35 & 36= 10- $\mu$ m; 37= 20  $\mu$ m.**Potamogeton perfoliatus** L. (Figs. 28-30).

Pollen grains radially symmetrical, apolar, spheroidal, size: (21.25-) 24.28 $\pm$ 0.71 (-30.11)  $\mu$ m in diameter, C.V. 8.93. nonaperturate. Exine (0.50-) 0.83 $\pm$ 0.22 (-1.25) $\mu$ m thick, C.V. 5.01, sexine slightly thicker than nexine. Tectum coarsely reticulate with irregular pattern of muri, lumina 0.41-2.11  $\mu$ m in diameter.

**Typha angustifolia** L. (Figs. 31-32).

Pollen grains radially symmetrical, apolar, spheroidal, size: (22.50-) 23.11 $\pm$ 0.38 (-25.11)  $\mu$ m in diameter, C.V. 4.71. monoporate, pore $\pm$ circular (3.01-) 4.12 $\pm$ 0.70 (-5.11)  $\mu$ m in diameter, C.V. 39, sexine thicker than nexine.

Tectum reticulate-rugulate.

**Typha domingensis** Pers. (Figs. 33-34).

Pollen grains radially symmetrical, apolar, monads, spheroidal, size: (20.11-) 22.61 $\pm$ 0.43 (-25.11)  $\mu$ m in diameter, C.V. 5.88, monoporate, pore $\pm$ circular (4.75-) 5.32 $\pm$ 0.36 (-7.51)  $\mu$ m, diameter, C.V.15. Exine (1.01-) 1.15 $\pm$ 0.13 (-1.25)  $\mu$ m thick, C.V. 25, sexine thicker than nexine. Tectum coarsely reticulate, with $\pm$ irregular pattern of muri, lumina 0.2-1  $\mu$ m in diameter.

**Typha elephantina** Roxb. (Figs. 35-37).

Pollen grains tetragonal tetrads, size: Length (33.21-) 35.12 $\pm$ 1.19 (-40.11)  $\mu$ m, C.V.10, and breadth (35.21-



)  $38.33 \pm 1.15$  (-40.12)  $\mu\text{m}$ , C.V.11, monoporate, single grain spheroidal, C.20  $\mu\text{m}$  in diameter, C.V. 24.11 Exine (2.01-)  $2.25 \pm 0.14$  (-2.61)  $\mu\text{m}$  thick, C.V.16, sexine thicker than nexine. Tectum densely foveolate.

#### Key to the species and species groups

1. + Pollen grains non-aperturate 2  
- Pollen grains aperturate 3
2. + Pollen grains single *Potamogeton*-group  
(*P. perfoliatus*, *P. pectinatus*)  
- Pollen grains tetrads *Juncus maritimus*
3. + Pollen grains porate 4  
- Pollen grains colpate or colporate 7
4. + Pollen grains monoporate 5  
- Pollen grains pantoporate 6
5. + Pollen grains spinulose *Lemna*-group  
(*L. aequinoctiales*, *L. pectinatus*)  
- Pollen grains rugulate reticulate *Typha*-group  
(*T. angustifolia*, *T. domingensis*, *T. elephantina*)
6. + Tectum echinate *Ipomoea aquatica*  
- Tectum reticulate *Persicaria glabra*
7. + Pollen grains colporate *Enhydra fluctans*  
- Pollen grains colpate 8
8. + Pollen grains monocolpate 9  
- Pollen grains 3-5-colpate 10
9. + Tectum areolate *Eichhornia crassipes*  
- Tectum rough reticulate *Nymphaea stellata*
10. + Pollen 4-5 colpate *Myriophyllum verticillatum*  
- Pollen colpate 11
11. + Pollen grains syncolpate *Nymphoides cristata*  
- Pollen apocolpate *Nelumbo nucifera*

#### Discussion

Aquatic angiosperms exhibited great diversity in their pollen characters, such as in shape, size, apertures, polarity and tectum type. However, the exine pattern and

apertural types are the most significant pollen characters. On the basis of apertural type 4 distinct pollen types are recognized.

Pollen type-I is characterized by its non-aperturate pollen. Two species of *Potamogeton* L., and *Juncus maritimus* have non-aperturate pollen. However, in *Potamogeton*, monods are found (1, 4, 12), whereas in *Juncus maritimus*, tetrahedral tetrads are found.

Pollen type-II is readily delimited by having colpate pollen the number of colpi varies from mono-pantocolpate. In the present study aquatic monocots have mono-bicolpate pollen i.e., *Eichhornia crassipes* (13, 14). In 2 species of *Myriophyllum verticillatum* (15-17), *Nelumbo nucifera* (18, 19), and *Nymphoides cristata*, 3-5-colpate pollen is observed (20).

Pollen type-III is easily recognized by having porate pollen. Seven species are included in this pollen type. Monoporate pollen is mostly found in aquatic monocots as in *Typha* L., and *Lemna* L. (1, 5), whereas pantoporate pollen is found in aquatic dicots, such as *Persicaria glabra* (21, 22) and *Ipomoea aquatica* (23).

Pollen type-IV is characterized by its tricolporate pollen. Only a single species, *Enhydra fluctans*, (24) has tricolporate pollen.

It is very interesting to note that the most of the aquatic taxa are wind pollinated. Some aquatic dicots like *Nymphaea stellata* (25) *Nelumbo nucifera* (25), *Persicaria glabra* (25) *Ipomoea aquatica* (25) and *Enhydra fluctans* (25) are pollinated by insects. There is a correlation between pollen morphology and pollination mechanism.

A definite relationship is exhibited between pollen characters and pollination types especially in entomophily and anemophily. Pollen grains of entomophilous taxa are characterized by compound apertures i.e., 3-colporate, prolate-spheroidal shape, generally large, thick-walled, sticky and with reticulate tectum, while pollen grains of anemophilous taxa are with simple apertures i.e., monoporate, spheroidal, small, thin-walled, dry and with scabrate-areolate tectum (25).

Pollen grains of hydrophilous taxa are spheroidal, non-aperturate coarsely reticulate tectum with (0.5  $\mu\text{m}$  thick) thin exine (as in *Potamogeton*). The thin elastic exine and reduced or omniapertures (non-aperture) are considered characters of hydrophilous taxa by Punt (26),

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