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A PALYNOLOGICAL SURVEY OF WETLAND PLANTS OF PUNJAB, PAKISTAN

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Abstract

Pollen of 34 aquatic plants distributed in 13 dicotyledonous and 7 monocotyledonous families of Punjab (Pakistan) have been investigated by Light and Scanning Electron Microscopy. Pollen are generally free in most of the aquatic plants, rarely united in tetrads such as in Juncaceae and Typhaceae. Most of the pollen are radially symmetrical, isopolar-apolar, often heteropolar as in *Trapa bispinosa* Roxb., *Nymphaea alba* L., *Eichhornia crassipes* (Mart.) Roxb., *Cyperus* species, oblate-prolate spheroidal, infrequently prolate-subprolate. Non aperturate, poroid (false apertures), both simple (porate and colpate) and compound (colporate) apertures have been observed. Aquatic families also exhibit a great variation in tectum types varying from scabrate, reticulate to rugulate, verrucate, echinate, striate, sub-psilate punctuate, finely reticulate with muri patterns, areolate and scabrate-areolate punctate. The pollen characteristics are quite distinct for the identification of species. Five distinct types are recognized on the basis of tectum and apertural types i.e., Non-aperturate, Porate, Colpate, Colporate and Miscellaneous.

Introduction

Aquatic angiosperms are defined as blatant plants that lived in water bodies e.g., ponds, lakes and stream. An aquatic plant may also be delimited as a plant that grows near the banks of running and standing water (Arber, 1963; Sculthorpe, 1967; Cook, 1974). Aquatic plants are essential to prevent undue turbidness and erosion of soil and to maintain fragile balance of nutrients in water. Vegetation along the banks of ponds offers habitat for water fowl, protection to fishes, and enhanced the plankton density (Nazir & Younas, 1979). Water plants play an important role in maintaining healthy ecosystems while providing food, medicines and building materials. Aquatic angiosperms are a significant part of the World's flora.

Lindley (1830) was probably the first person to make use of pollen characters in the classification of Orchidaceae and later the significance of pollen morphology in plant taxonomy has been stressed by several workers, notably by Mohl (1835), Fritzsche (1832), Fischer (1890), Selling (1946-47), Cranwell (1952) and Erdtman (1952). Realizing its importance, palynology was recognized for the first time as a separate section of the International Botanical Congress in Stockholm Sweden in 1950.

However, the literature dealing with the palynology of aquatic and semi aquatic plants is limited. The pollen morphology of few of the wetland plants has been carried out e.g., Pontederiaceae (Raj & Saxena, 1966), Lemnaceae (Aiken, 1978; Landolt, 1986), Typhaceae (Cook, 1988), Potamogetonaceae (Sorsa, 1988), Eriocaulaceae (Borges *et. al*., 2009) and Podostemaceae (Sa-Haiad *et al*., 2010) A palynological study of an aquatic medicinal plant of Mimosaceae has been done by Bhunia and Mondal (2012). In Pakistan the first contribution was done by Perveen (1999). The morphological, palynological, ethnobotanical and anatomical features of 23 aquatic plants in Hazara Divison have also been studies by Ayub *et al*., (2012). However, at present there is no separate documentation on the palynology of aquatic and semi-aquatic plants of Punjab, so the present work is especially designed to enlist and describe the Wetland Pollen Flora of the Punjab. The major objectives of this study is to provide detailed account of the pollen morphology and structure of exine pattern of aquatic and semiaqutic plants by Light and Scanning Microscopy.

Materials and Methods

Flowering part of the aquatic plants containing pollen were obtained from water bodies and their adjoining areas of Punjab. In the absence of fresh anthers, pollen were obtained from the herbarium specimens of Herbarium of Centre of Plant Conservation (KUH), University of Karachi. The voucher specimens of freshly collected plants are deposited in Sultan Ahmad Herbarium, GC University Lahore. The material was acetolyzed according to the methods of Erdtman (1952) for observations by microscopy. The material containing pollen was transferred on a glass slide having unstained glycerin jelly (made by Kisser's Method, 1937) and allowed to dry. The slide was studied in a light microscope of Nikon (Type-2) using a 10x eye piece. For study in scanning microscope the pollen material was mixed in water and shifted to a metallic stub by a fine pipette with double-sided adhesive tape. The stub with pollen material was placed overnight to dry at room temperature and then covered with gold in a sputtering chamber using Ion-sputter JFC-1100. Coating be limited to 150°A and observed on Scanning Electron Microscope of Jeol (JSM-6380).

To avoid shrinkage of pollen of some plants (especially Gramineae and Cyperaceae), pollen was suspended in distilled water instead of acetolysis mixture. For each species 2-3 specimens were studied and the measurements were based on 10-15 pollen per specimen (Tables 1-5). Pollen size including polar axis or length (P) and equatorial axis or diameter (E) as well as aperture size, exine thickness, colpi length and spine length were computed. The terms used in the present study are according to the Wodehouse (1928); Erdtman (1952); Faegri & Iversen (1964); Kremp (1965) and Walker & Doyle (1976). Artificial key to the families based on pollen characters have been prepared.

Table 1. General pollen characters of species found in pollen Type-I.

Name	Family	Shape	Polar length in µm (P)	Equatorial diameter in µm (E)	Aperture	Exine Thickness (µm)	Tectum
Juncus articulatus Linn.	Juncaceae	Tetrahedral united in tetrads	(25.82-) 28.62±0.95 (-31.62)	(14.49-) 18.66±1.03 (-21.08)	Non aperturate	(1.43-) 2.32±1.27 (-3.25)	Lophate-reticulate with fine scabrae
Juncus maritimus Lam.	Juncaceae	Tetrahedral united in tetrads	(36.85-) 41.71±1.12 (-44.79)	(36.85-) 39.29±0.66 (-42.18)	Non aperturate	(1.95-) 2.48±0.49 (-3.91)	Sub-psilate
Potamogeton nodosus Poir.	Potamogetonaceae	Spheroidal	(17.45-) 21.61±1.04 (-23.72)	(17.13-) 19.92±1.97 (-23.72)	Non aperturate	(1.64-) 2.16±1.16 (-2.96)	Reticulate having irregular pattern of muri

Table 2. General pollen characters of species found in pollen Type-II.

Name	Family	Shape	Polar length in µm (P)	Equatorial diameter in µm (E)	Aperture	Colpus length in µm	Mesocolpium (µm)	Apocolpium (µm)	Exine thickness (µm)	Tectum
Eichhornia crassipes (Mart.) Sloms	Pontederiaceae	Oblong	(28.99-) 32.41±0.84 (-34.26)	(28.99) 35.31±2.30 (-44.86)	Mono-bicolpate	(18.45-) 25.30±2.70 (-34.26)	-	-	(2.64-) 4.01±0.43 (-5.25)	Areolate
Nasturtium officinale R. Br.	Brassicaceae	Sub-prolate	(21.08-) 24.24±1.30 (-28.99)	(18.45-) 20.55±0.84 (-23.71)	Tricolpate	(13.18-) 14.97±0.43 (-15.81)	(8.43-) 9.59±0.33 (-10.54)	(5.25-) 6.72±0.36 (-7.64)	(2.37-) 2.95±0.24 (-3.95)	Coarsely reticulate
Nelumbo nucifera Gaertn.	Nelumbonaceae	Sub-prolate	(50.07-) 62.50±2.39 (-65.87)	(47.43) 56.94±2.30 (-63.25)	Tricolpate	(39.53-) 45.33±1.64 (-50.07)	(34.26-) 41.11±2.07 (-47.43)	(5.25-) 8.44± 0.84 (-10.50)	(2.64-) 4.85± 0.63 (-7.11)	Rugulate
Nymphaea alba Linn.	Nymphaceae	Bilateral boat shaped	(26.35-) 31.20±1.05 (-34.26)	(31.38-) 32.75±0.62 (35.57)	Monocolpate	(17.13-) 20.45±0.83 (-24.40)	-	-	(1.29-) 2.56±0.87 (-3.05)	Rough reticulate
Ranunculus muricatus Linn.	Ranunculaceae	Prolate spheroidal	(23.32-) 25.01±0.98 (-28.99)	(21.08-) 22.08± 0.78 (-27.35)	Tricolpate	(13.17-) 15.52± 0.83 (-18.45)	(11.54-) 13.85±0.50 (-15.17)	(5.36-) 6.95±0.40 (-7.90)	(2.64-) 3.48±0.22 (-3.95)	Verrucate to scabrate
Spergularia marina (Linn.) Criscb.	Caryophyllaceae	Prolate-spheroidal	(21.08-) 27.83±2.21 (-36.85)	(18.45-) 24.77±2.30 (-34.26)	Pantocolpate	(13.17-) 16.55±0.82 (-18.45)	-	-	(2.64-) 3.43±0.37 (-5.01)	Finely scabrate

Table 3. General pollen characters of species found in pollen Type-III.

Name	Family	Shape	Polar length in µm (P)	Equatorial diameter in µm (E)	Aperture	Pore diameter (µm)	Exine Thickness (µm)	Tectum
Alternanthera sessilis (Linn.) DC.	Amaranthaceae	Spheroidal	(21.08-) 27.83±2.21 (-36.85)	(18.45-) 21.87±1.20 (-26.35)	Panto-porate	(5-) 6.85±0.76 (-9.7)	(3.43-) 4.21±1.6 (-5.25)	Scabrate spinulose
Desmostachya bipinnata (Linn.) Stapf.	Poaceae	Spheroidal	-	(18.44-) 27.14±2.99 (-39.53)	Mono-diporate	(2.11-) 2.95±0.34 (-4.21)	(0.79-) 1.63±0.27 (-2.64)	Areolate
Dichanthium annulatum (Forssk.) Stapf.	Poaceae	Spheroidal	-	(18.45-) 26.35±2.92 (-36.89)	Monoporate	(1.32-) 2.27±0.26 (-2.90)	(0.79-) 1.37±0.33 (-2.90)	Areolate cum scabrate
Echinochloa crus-galli (Linn.) P. Beauv.	Poaceae	Spheroidal	-	(21.08-) 24.51±2.11 (-34.26)	Monoporate	(2.64-) 3.06±0.23 (-3.95)	(2.64-) 2.90±0.14 (-3.43)	Areolate
Ipomea aquatica Forsk.	Convolvulaceae	Oblate-spheroidal	(60.60-) 69.56±2.06 (-81.69)	(63.24-) 73.52±2.19 (-84.32)	Pantoporate	(5.25-) 8.17±0.44 (-9.90)	(3.43-) 4.80±0.37 (-6.06)	Echinate
Ipomea carnea Jacq.	Convolvulaceae	Oblate-spheroidal	(65.88-) 77.47±2.70 (-84.32)	(68.51-) 74.83±2.07 (-81.69)	Pantoporate	(7.90-) 9.75±0.45 (-10.45)	(3.95-) 3.48±0.33 (-6.06)	Echinate
Lemna aequinoctialis Welw.	Lemnaceae	Spheroidal	Very small	-	Monoporate	-	-	Spinulose punctate
Lemna gibba Linn.	Lemnaceae	Spheroidal	Very small	-	Monoporate	-	-	Spinulose
Persicaria amphibia (Linn.) A.Gray	Polygonaceae	Oblate-spheroidal	(44.80-) 55.45±3.29 (-68.50)	(42.18-) 54.75±3.00 (-63.25)	Polypantoporate	(6.12-) 9.44±1.02 (-10.45)	(1.64-) 3.22±0.38 (-4.25)	Scabrate
Persicaria glabra (Willd.) Gomes	Polygonaceae	Oblate-spheroidal	(44.79-) 58.21±3.68 (-79.05)	(50.07-) 61.18±3.17 (77.73)	Polypantoporate	(7.91-) 11.97±0.53 (-15.8)	(3.64-) 5.32±0.34 (-7.25)	Finely Scabrate
Setaria pumila (Poir.) Roem. & Schult.	Poaceae	Spheroidal	-	(26.35-) 35.31±2.61 (-44.80)	Monoporate	(2.64-) 2.97±0.14 (-3.43)	(2.64-) 2.79±1.09 (-3.16)	Areolate
Typha domigensis Pers.	Typhaceae	Spheroidal	(18.45-) 21.24±1.97 (-24.03)	(18.45-) 23.08±1.17 (-25.35)	Monoporate	(5.25-) 6.17±0.32 (-7.38)	(2.64-) 3.48±0.23 (-4.22)	Reticulate with irregular muri

Table 4. General pollen characters of species found in Type-IV.

Name	Family	Shape	Polar length in µm (P)	Equatorial diameter in µm (E)	Aperture	Colpus length in µm	Mesocolpium (µm)	Apocolpium (µm)	Exine thickness (µm)	Tectum
Bacopa moneiri (Linn.) Pennell	Scrophulariaceae	Oblate-spheroidal	(13.18-) 21.52±1.94 (-26.39)	(15.80-) 24.51±2.58 (-34.26)	Tricolporate	(13.18-) 16.68±1.03 (-21.08)	(9.01-) 10.54±1.10 (-12.18)	(5.36-) 8.35±1.75 (-10.55)	(3.95-) 5.06± 0.56 (-7.91)	Coarsely reticulate
Eclipta alba Linn.	Compositae	Oblate-spheroidal	(26.35-) 32.36±1.05 (-39.56)	(18.45-) 24.72±1.30 (-34.26)	Tricolporate	(18.18-) 23.27±0.43 (-28.98)	(9.87-) 14.07±1.34 (-17.30)	(7.13-) 10.98±0.76 (-13.98)	(2.64-) 4.11±0.73 (-5.25)	Echinate
Centella asiatica (Linn.) Urban	Umbelliferae	Prolate	(16.01-) 20.55±0.25 (-23.71)	(11.86-) 12.98±1.42 (-13.49)	Tricolporate	(7.90-) 11.33±0.77 (-13.17)	(6.59-) 7.11±0.23 (-7.90)	(5.25-) 6.01±0.26 (-6.59)	(2.64-) 5.25±0.46 (-3.90)	Striate
Phyla nodiflora (Linn.) Greene	Verbenaceae	Sub-prolate	(23.72-) 27.14±1.04 (-30.30)	(18.45-) 23.19±1.44 (-27.67)	Tricolporate	(15.81-) 17.65±21.08 (-21.08)	(11.03-) 12.40±1.16 (-14.10)	(5.27-) 8.4±1.03 (-11.86)	(1.64-) 1.90±1.14 (-2.43)	Sub-psilate-punctate
Trapa bispinosa Roxb.	Trapaceae	Triangular obtuse	(36.89-) 47.64±2.54 (-55.33)	(28.91-) 46.11±3.94 (-57.97)	Tricolporate	(18.45-) 30.49±3.34 (-39.53)	(6.45-) 8.79±3.34 (-10.53)	(4.50-) 6.97±1.65 (-8.22)	(1.94-) 3.06±0.40 (-4.89)	Smooth-rugulate

Table 5. General pollen characters of species found in pollen Type-V

Name	Family	Shape	Polar length in µm (P)	Equatorial diameter in µm (E)	Aperture	Exine Thickness (µm)	Tectum
Cyperus arenarius Retz.	Cyperaceae	Heteropolar	(23.71-) 31.62±2.37 (-39.53)	(21.08-) 25.98±1.38 (-29.78)	Faintly marked Poroids	(2.64-) 4.64±0.56 (-6.58)	Scabrate
Cyperus conglomerates Rottbl.	Cyperaceae	Heteropolar	(21.08-) 25.48±1.18 (-28.72)	(17.12-) 20.03±0.96 (-23.71)	Faintly marked Poroids	(4.21-) 5.06±0.26 (6.06)	Areolate
Cyperus leavigatus Linn.	Cyperaceae	Heteropolar	(34.26-) 42.16±2.91 (-52.70)	(26.35-) 32.15±1.75 (-38.20)	Faintly marked Poroids	(2.64-) 3.11±0.18 (-3.69)	Scabrate
Cyperus rotundus Linn.	Cyperaceae	Heteropolar	(28.99-) 34.26±2.92 (-47.43)	(21.08-) 26.24±1.58 (-31.62)	Faintly marked Poroids	(5.01-) 6.27±0.41 (7.38)	Areolate
Eleocharis palustris (Linn.) Roem. & Schult.	Cyperaceae	Heteropolar	(23.71-) 30.99±2.43 (-39.53)	(18.18-) 23.08±1.32 (-26.35)	Faintly marked Poroids	(2.64-) 2.90±1.41 (-3.43)	Areolate
Schoenoplectus lacustris (Linn.) Palla	Cyperaceae	Heteropolar	(26.35-) 33.00±2.41 (-42.16)	(15.81-) 23.08±1.87 (-28.46)	Faintly marked Poroids	(2.48-) 3.98±1.34 (-4.25)	Areolate-punctate
Schoenoplectus litoralis (Schard.) Palla	Cyperaceae	Heteropolar	(31.62-) 35.84±1.14 (-39.53)	(21.08-) 23.50±0.73 (-26.35)	Faintly marked Poroids	(1.96-) 3.79±0.19 (-4.48)	Areolate having scabrae
Schoenoplectus mucronatus (Linn.) Palla	Cyperaceae	Heteropolar	(27.76-) 31.41±1.16 (-35.57)	(36.89-) 42.61±1.37 (-47.43)	Faintly marked Poroids	(2.95-) 3.88±0.49 (-4.38)	Areolate with scabrae

Result

Key to the families

1.	+	Pollen single 3
	-	Pollen united in groups 2
2.	+	Pollen monoporate ..... Typhaceae
	-	Pollen non-aperturate ..... Juncaceae
3.	+	Pollen aperturate 4
	-	Pollen non-aperturate ..... Potamogetonaceae
4.	+	Pollen colpate and colporate 5
	-	Pollen Porate 15
5.	+	Pollen colpate 6
	-	Pollen colporate 11
6.	+	Pollen mono-bicolpate 7
	-	Pollen tricolpate 8
7.	+	Tectum reticulate ..... Nymphaeaceae
	-	Tectum areolate ..... Pontederiaceae
8.	+	Tectum reticulate-rugulate 9
	-	Tectum Scabrate 10
9.	+	Tectum reticulate ..... Brassicaceae
	-	Tectum rugulate ..... Nelumbonaceae
10.	+	Pantocolpate, colpi narrow 13.17-18.45 µm long ..... Caryophyllaceae
	-	Tricolpate, colpi narrow with acute ends ..... Ranunculaceae
11.	+	Tectum echinate with sparsely punctate base ..... Compositae
	-	Tectum not as above 12
12.	+	Pollen oblate-spheroidal 13
	-	Pollen subprolate to prolate 14
13.	+	Tectum finely scabrate ..... Polygonaceae (P.P)
	-	Tectum coarsely reticulate with irregular muri pattern ..... Scrophulariaceae
14.	+	Pollen subprolate, Tectum sub-psilate-punctate ..... Verbenaceae
	-	Pollen prolate, Tectum striate ..... Umbellifereae
15.	+	Pollen mono-diporate 16
	-	Pollen pantoporate 17
16.	+	Tectum areolate or scabrate ..... Poaceae
	-	Tectum spinulose or spinulose punctuate ..... Lemnaceae
17.	+	Finely perforate echinate tectum with granules ..... Convolvulaceae
	-	Tectum not as above 18
18.	+	Tectum coarsely reticulate ..... Polygonaceae (P.P)
	-	Tectum not as above 19
19.	+	Pollen triangular 20
	-	Pollen spheroidal ..... Amaranthaceae
20.	+	Tectum areolate-punctuate or scabrate-punctuate ..... Cyperaceae
	-	Tectum twisted, smooth rugulate, perforated with germinal structures ..... Trapaceae

General pollen characters of aquatic and semi-aquatic families

Pollen grains are generally free, united in tetrads such as in Juncaceae. Exine patterns also varied in great extent, such as scabrate, reticulate to rugulate, verrucate, echinate, striate, sub-psilate punctuate, finely reticulate with muri patterns. Areolate and scabrate-areolate punctat. Sexine is thicker or thinner or equally thick to nexine. Both simple and compound apertures are found. However, non-aperturate pollen are also observed in some families of monocots such as Potamogetonaceae and Juncaceae. Following 5 pollen types based on apertures and shapes are recognized:

Key to the pollen types

1.	+	Pollen heteropolar ..... Type V
	-	Pollen not as above 2
2.	+	Non-aperturate pollen grains ..... Type I
	-	Aperturate pollen grains 3
3.	+	Pollen grains with simple apertures 4
	-	Pollen grains having compound apertures ..... Type IV
4.	+	Pollen grains colpate ..... Type II
	-	Pollen grains Porate ..... Type III

Description of pollen types

Type-I: Non-aperturate (Figs. 4A-D, 6F).
Size: 17.45-44.79 µm in length and 14.49-42.18 µm in diameter
Spheroidal, Tetrahedral, apolar, nexine thinner than sexine often thicker, Tectum reticulate to lophate reticulate, Obscure.
Species included: *Juncus articulatus* L., *Juncus maritimus* Lam**.,** *Potamogeton nodosus* Poir.

Type-II: Colpate (Figs. 1A-1E, 6B).
Size: 21.08-65.87 µm in length and 18.45-63.25 µm in diameter.
Pollen grains elliptic, heteropolar, Bilateral, Boat-shaped, Oblong, Sub-prolate to Prolate-spheroidal, monocolpate-bicolpate, tricolpate, pantocolpate, nexine thicker than sexine or thinner, Tectum rough reticulate, coarsely reticulate, rugulate, verrucate to scabrate, scabrate spinulose, areolate.
Species included: *Eichhornia crassipes* (Mart.) Sloms, *Nasturtium officinale* R. Br., *Nelumbo nucifera* Gaertn., *Nymphaea alba* L., *Ranunculus muricatus* L., *Spergularia marina* (L.) Criscb.

Type-III: Porate (Figs. 1E , 2A-2D, 3C-3D, & 6C-6D).
Size: 18.45-84.32 µm in length and 17.12-81.69 µm in diameter
Pollen grains prolate, oblate-spheroidal, spheroidal, apolar, Mono-diporate, pantoporate, poly-pantoporate, Operculate to non-operculate, Annulate, Sexine thicker than nexine or equally thick or thinner, Tectum spinulose scabrate, scabrate-punctate reticulate, echinate spines with blunt apices, areolate, areolate cum scabrate, spinulose, spinulose punctate, reticulate with irregular muri.
Species included: *Alternanthera sessilis* (L.) DC., *Desmostachya bipinnata* (L.) Stapf., *Dichanthium annulatum* (Forssk.) Stapf., *Echinochloa crus-galli* (L.) P. Beauv., *Ipomoea aquatica* Forsk., *Ipomoea carnea* Jacq., *Lemna aequinoctialis* Welw., *Lemna gibba* L., *Persicaria amphibia* (L.) A. Gray, *Persicaria glabra* (Willd.) Gomes, *Setaria pumila* (Poir.) Roem. & Schult., *Typha domigensis* Pers.

Type-IV: Colporate (Figs. 1F, 2E-2F, 3A-3B, 3E-F, 6A, 6G).
Size: 13.18-55.33 µm in length and 11.86-57.97 µm in diameter.
Triangular obtuse, wedge shaped with combined ridges, oblate-spheroidal, prolate-spheroidal, prolate, sub-prolate, apolar to heteropolar, Tricolporate, nexine thicker than sexine or thinner or as thick as sexine, Tectum twisted smooth-rugulate perforate with germinal structures at poles, striate, coarsely reticulate, echinate.
Species included: *Bacopa moneiri* (L.) Pennell, *Eclipta alba* L., *Centella asiatica* (L.) Urban, *Phyla nodiflora* (L.) Greene, *Trapa bispinosa* Roxb.

Type-V: Miscellaneous (Figs. 4C, E &F & 5A-F)
Size: 21.08-52.70 µm in length and 16.31-38.20 µm in breadth.
Pollen grains triangular to pear shaped, heteropolar, 1-4 faintly marked aperturates, in pear shaped grains one of aperture is always situated on the proximal face and is considered to be the germ pore (Dunbar, 1973), often tenui-exinous, sexine as thick as nexine or thicker than nexine. Tectum scabrate-punctate, or areolate-punctate.
Species included: *Cyperus arenarius* Retz., *Cyperus conglomerates* Rottbl., *Cyperus leavigatus* L., *Cyperus rotundus* L., *Eleocharis palustris* (L.) Roem. & Schult., *Schoenoplectus lacustris* (L.) Palla, *Schoenoplectus litoralis* (Schard.) Palla, *Schoenoplectus mucronatus* (L.) Palla.

Discussion

In the present study, morphology and characteristics of pollen grains of 34 species of a total of 15 dicotyledonous and 19 monocotyledonous species of aquatic plants of Punjab has been investigated. Five distinctive pollen types are recognized on the basis of apertures. Species were easily separated on the basis of groups of apertures. Porate type pollen are mostly found in 11 aquatic and semi-aquatic species belonging to the families Amaranthaceae, Convolvulaceae, Poaceae, Lemnaceae and Typhaceae In 3 species of dicots, viz. *Alternanthera sessilis*, *Ipomea aquatica* and *Ipomea carnea* pantoporate porate type pollen grains are reported (Sengupta, 1972). *Persicaria glabra* is found with polypanto-porate pollen (Leeuwan *et. al.*, 1988). Monoporate pollen are observed mostly in the monocots as in Poaceae, Lemnaceae and Typhaceae (Cook, 1988; Landolt, 1986; Perveen & Qaiser, 2012). The species of the family Cyperaceae have been observed with 1-4 faintly marked poroid or elongate apertures, one at the thick end and three at lateral ends. Tricolporate pollen are only found in 6 species of aquatic Dicots viz. *Trapa bispinosa*, *Centella asiatica*, *Bacopa moneiri*, *Phyla nodiflora* and *Eclipta alba*.

Apolar-isopolar pollen commonly found, infrequently heteropolar as in Nymphaceae, Trapaceae of dicots and Pontederiaceae of monocot families. Oblate-prolate spheroidal shapes are common, prolate-subprolate (Nelumbonaceae), bilateral/boat shaped are rare as in Nymphaceae. Pollen of aquatic plants are single or united in groups, aperturate to non aperturate, operculate to non operculate, porlate to subprolate, oblate to prolate-spheroidal, triangular obtuse as in *Trapa bispinosa*. Tectum also shows a great variation i.e., areolate and scabrate-areolate punctate, scabrate, reticulate, rugulate, verrucate, echinate, striate, sub-psilate punctuate, finely reticulate with muri patterns. Many authors have studied the pollen morphology of some species of aquatic families such as Lemnaceae (Aiken, 1978), Hydrocharitaceae (Takahashi, 1994; Tanaka *et al*., 2004), Haloragaceae (Landolt, 1986; Sorsa, 1988; Perveen & Qaiser, 1996), Rubiaceae (Lacroix & Kemp, 1997; Perveen & Qaiser, 2007) and Callitrichaceae (Cooper *et al*., 2000). In Pakistan Pollen Flora of Aquatic Plants of Karachi has been studied by Perveen (1999).

Pollen of dicotyledons are much particular and show a large diversity in their morphology and characteristics e.g. in size, shape, polarity, apertures, exine and tectum patterns. However, pollen of monocots are least specialized due to their porate, monocolpate pollen with ill-defined apertures than dicotyledons. But the pollen grains of monocotyledons have also large distinctions in their exine patterns. Some dicotyledons with ancient monocolpate pollen type are considered as ancestors of monocots (Takhtajan, 1969).

Scanning electron micographs of pollen grains of dicots

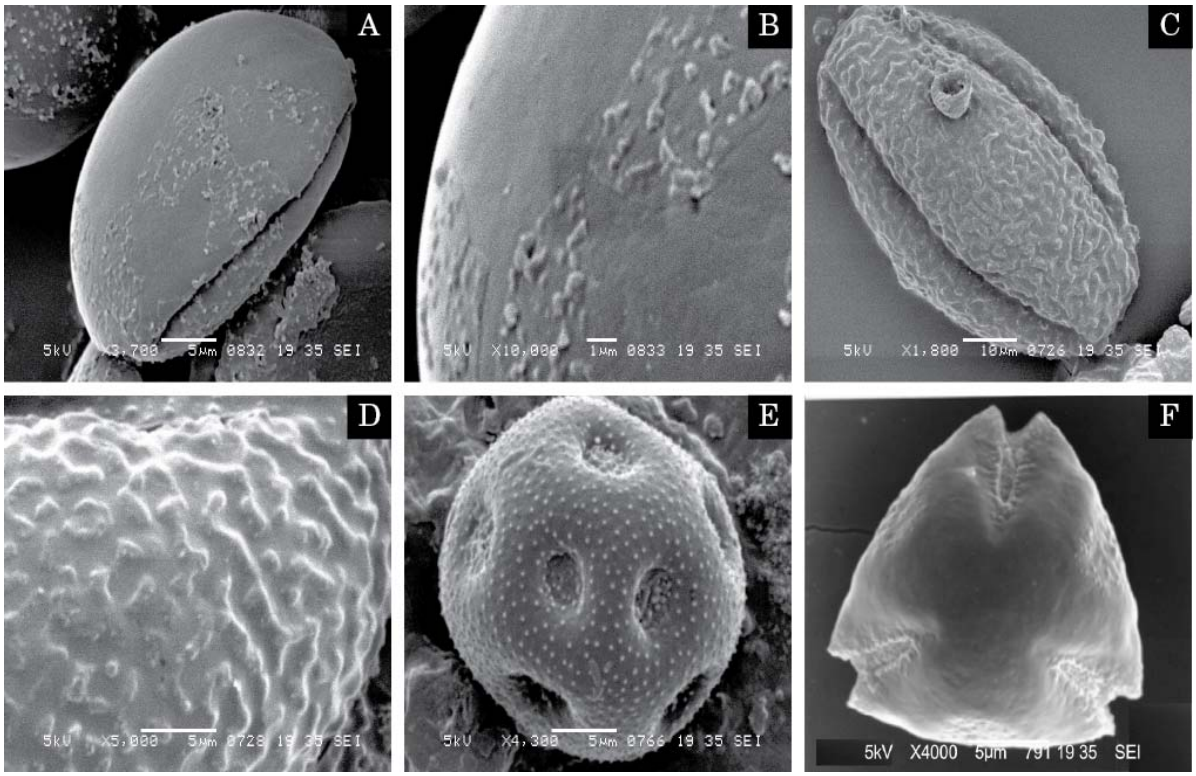

Fig. 1. *Nymphaea alba*: A. Pollen. B. Exine Pattern. *Nelumbo nucifera*: C. Pollen D. Exine pattern. *Spergularia marina*: E. Pollen grain *Phyla nodiflora:* F. Pollen grain.

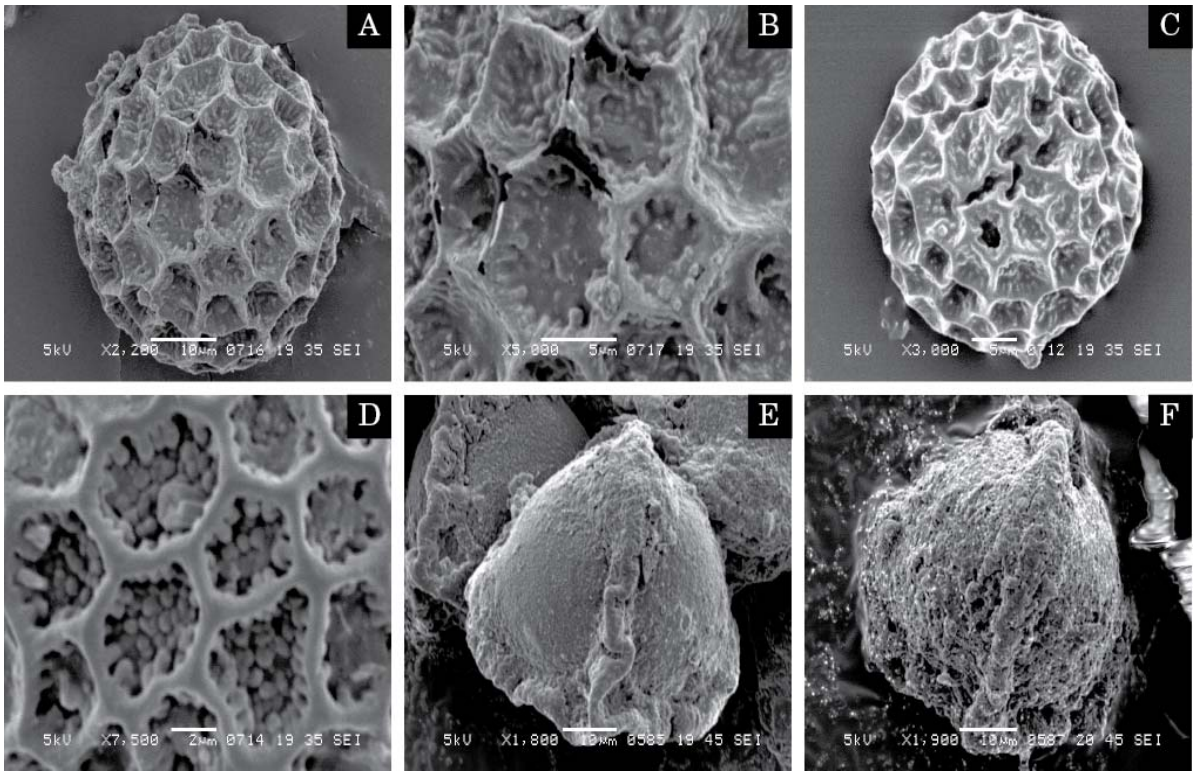

Fig. 2. *Persicaria glabra*: A. Pollen. B. Exine Pattern. *P. amphibium*: C. Pollen D. Exine pattern. *Trapa bispinosa*: E. Pollen. F. Exine Pattern.

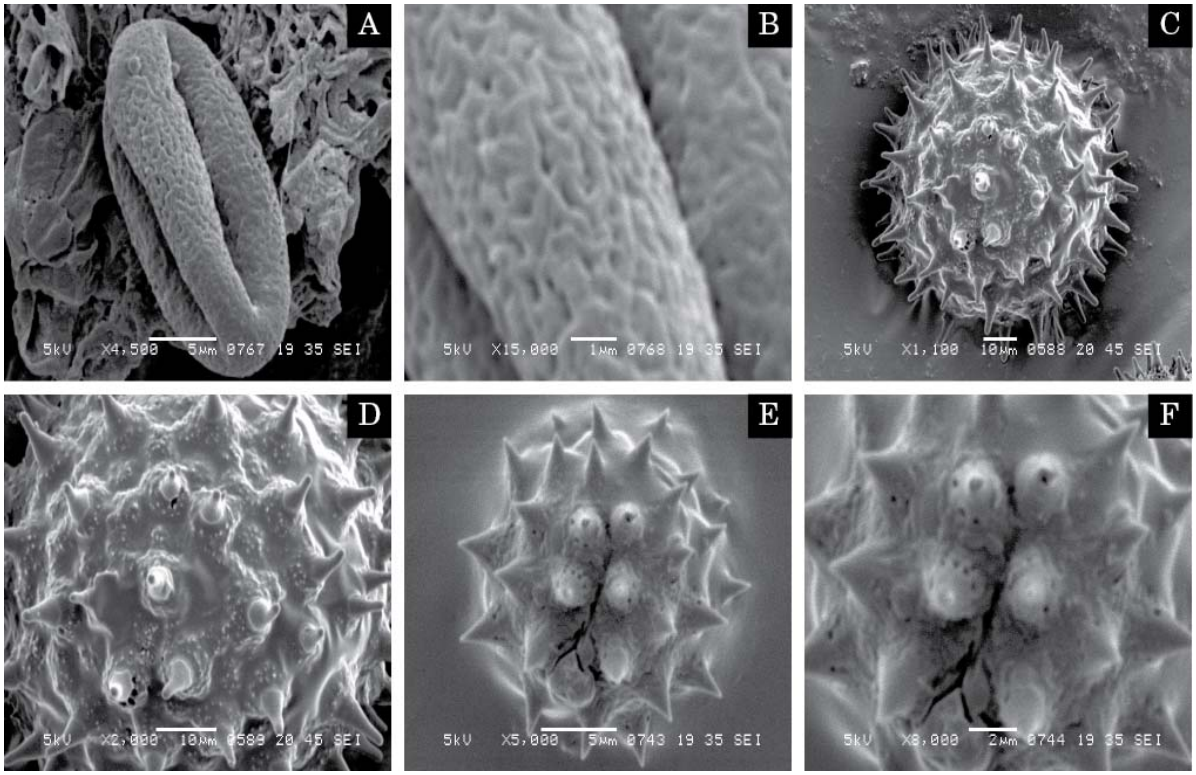

Fig. 3. Scanning electron micographs of Pollen grain. *Bacopa moneiri*: C. Pollen D. Exine pattern. *Ipomea aquatica*: C. Pollen D. Exine pattern. *Eclipta alba* Linn: E. Pollen F. Exine Pattern.

Scanning electron micographs of pollen grains of monocots

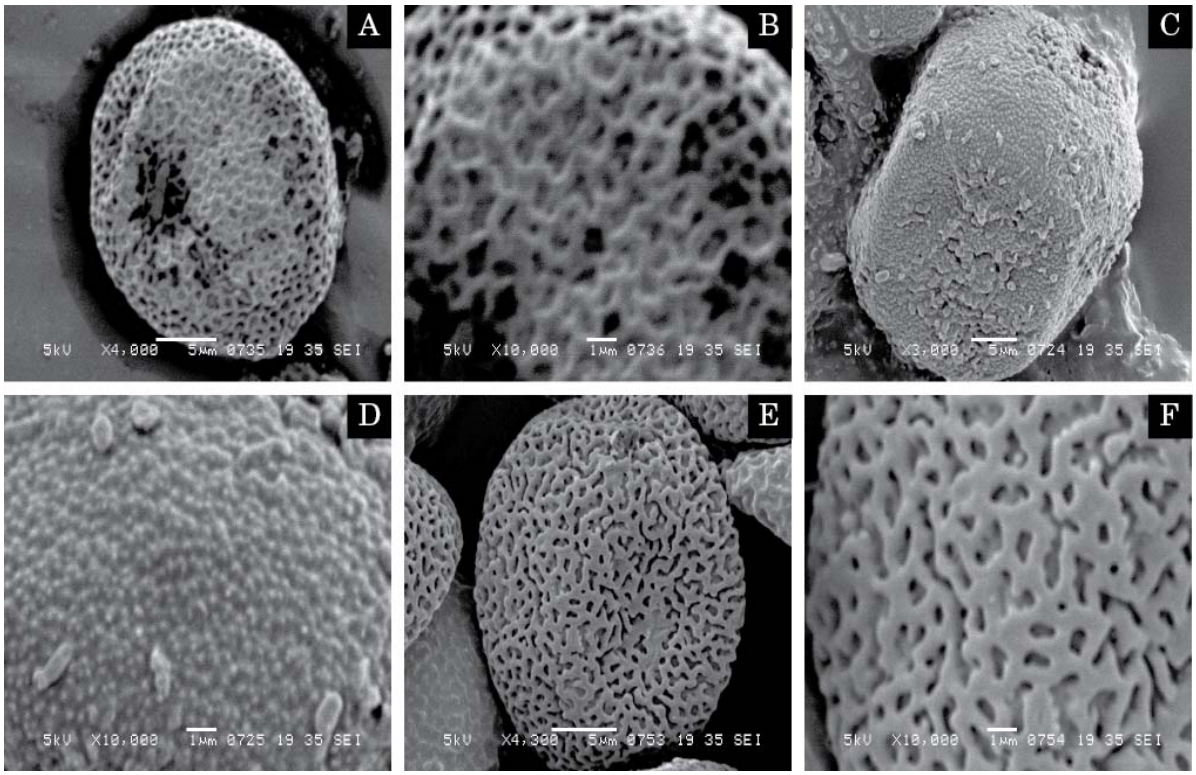

Fig. 4. *Potamogeton nodosus*: A. Pollen. B. Exine Pattern. *Schoenoplectus mucronatus*: C. Pollen D. Exine pattern. *Typha domigensis*: E. Pollen F. Exine pattern.

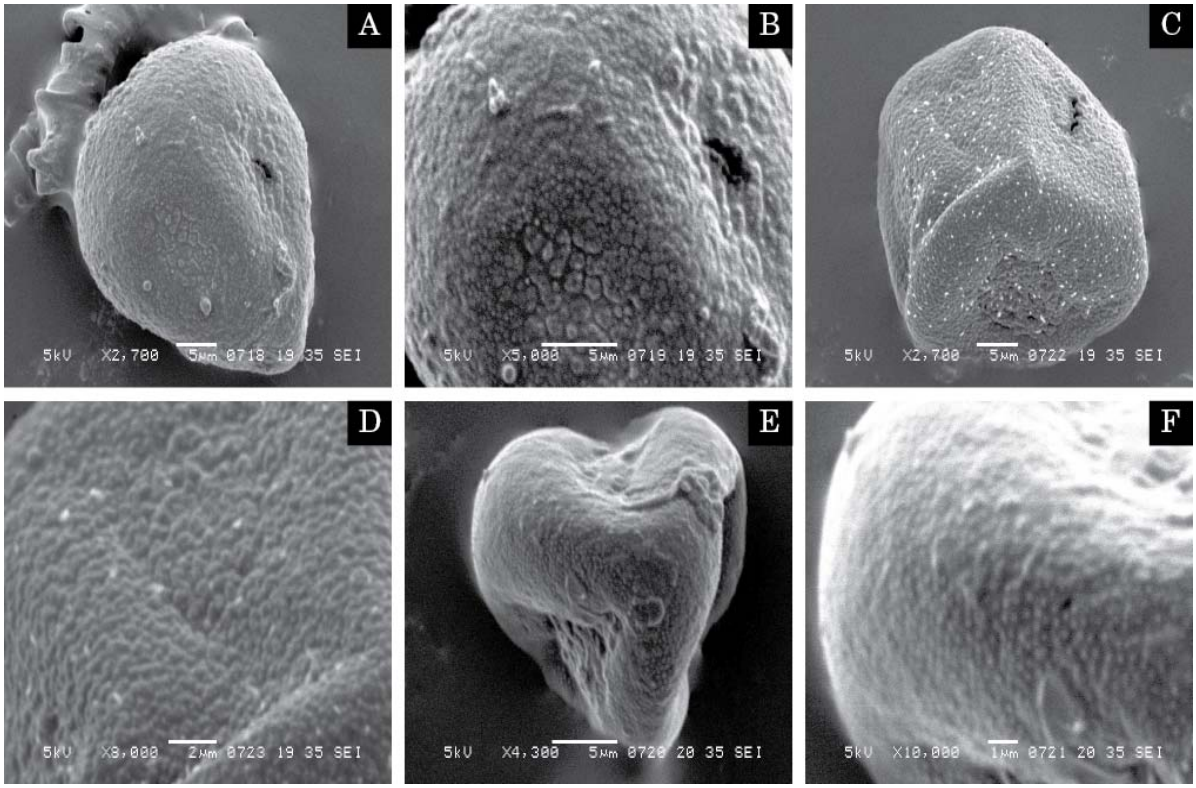

Fig. 5. *C. rotundus*: A. Pollen. B. Exine Pattern. *Schoenoplectus litoralis*: C. Pollen D. Exine pattern. *C. conglomerates*: E. Pollen F. Exine Pattern.

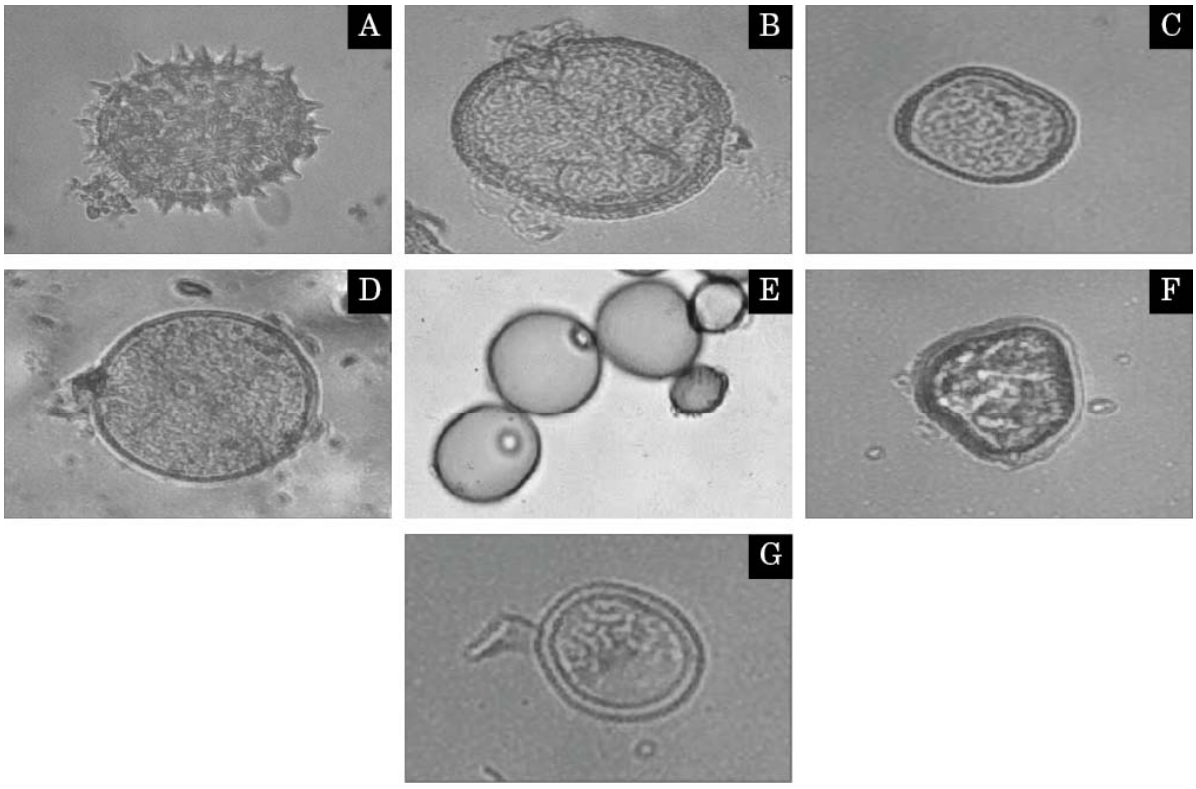

Fig. 6. Light Microscopy Micographs of Pollen Grains. A. *Eclipta alba* B. *Nelumbo nucifera* C. *Typha domigensis* D. *Persicaria glabra* E. *Dichanthium annulatum* F. *Potamogeton nodosus* G. *Trapa bispinosa*.

In the present study panto-colpate pollen are only found in the family Caryophyllaceae. In family Nelumbonaceae belonging to a monotypic order Nelumbonales, pollen of *Nelumbo nucifera* has been examined. Pollen grains are usually tricolpate, isopolar, sub-prolate, sexine thicker than nexine. Erdtman (1952) and Walker (1974) also made similar observations on the other species of *Nelumbo*. Previously, families Nelumbonaceae and Nymphaeaceae were considered as a single entity, but now treated as two distinct families and even placed under two separate orders i.e. Nelumbonales and Nymphaeales (Cronquist, 1968; Takhtajan, 1969). Pollen morphology also confirms them as two distinct entities. Where as in Nymphaeaceae the pollen are monocolpate. The monotypic order Polygonales (Polygonaceae) one of the most palynologically diverse order in dicotyledons, as indicated by Nowicke & Skvarla (1977, 1979) has been examined amongst dicots. In the present study Polygonales is represented by two species. Polygonaceae depicts considerable variations in apertures, surface sculpturing, and size of the grains.

Monocots were suggested as monosulcate group by Walker & Doyle (1975). In the current study, pollen morphology of 4 sub classes of monocots belonging to seven orders has been described. Each order is represented by a single family. The species of Juncaceae and Potamogetonaceae have non-aperturate pollen. But the pollen of *Potamogeton* is in monads (Pettite & Jermy, 1975; Cook, 1988; Sorsa, 1988) and in Juncaceae are united in tetrads. The colpi number ranges from mono-pantocolpate. The aquatic monocot *Eichhornia crassipes* has mono-bicolpate pollen (Horn, 1987; Barrett, 1988).

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