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Monocot pollen flora of Paschim Medinipur District, West Bengal, with a note on pollen dispersal mechanism

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ABSTRACT

During the present investigation, pollen morphological studies of 66 species belonging to 19 families of monocots in Paschim Medinipur District have been worked out by light microscopy. The studied families are Agavaceae, Amaryllidaceae, Arecaceae, Asphodelaceae, Cannaceae, Colchicaceae, Commelinaceae, Costaceae, Cyperaceae, Hemerocallidaceae, Hydrocharitaceae, Iridaceae, Liliaceae, Limnocharitaceae, Musaceae, Poaceae, Pontederiaceae, Typhaceae, and Zingiberaceae. The apertural patterns mostly belong to two different categories, viz., monosulcate form (Agavaceae, Amaryllidaceae, Arecaceae, Asphodelaceae, Colchicaceae, Commelinaceae, Costaceae, Hemerocallidaceae, Hydrocharitaceae, Iridaceae, Liliaceae, Limnocharitaceae, Musaceae, Poaceae, and Pontederiaceae) and anaporate type (Cyperaceae, Poaceae, and Typhaceae). The shape of the pollen grains with monosulcate apertures is mostly oblate to peroblate type, whereas taxa showing anaporate apertures are more or less spheroidal. Regarding the mode of pollen dispersal plant taxa with monosulcate apertures and apiculate surface ornamentations (e.g. reticulate, rugulate, spinulate, and verrucate) are entomophilous (mainly melittophilous), while anaporate with smooth or minutely apiculate surface features are anemophilous. Here, entomophilous taxa provide reward as pollen grains and nectar to the honeybee species, and therefore, contribute as resource mobilizer for sustenance of honeybee colonies.

KEY WORDS: Anemophily, entomophily, monocot, pollen, porate, sulcate

INTRODUCTION

Unlike dicots, the pollen of monocots has received very little attention. Pollen morphological data were used by Dahlgren and Clifford (1982) and Dahlgren *et al*. (1985) during comparative studies and toward a more natural, phylogenetic classification of the monocotyledons. Zavada (1983) summarized the apertures and wall structures of monocot pollen and discussed evolutionary trends for those characters. Since then there has been a gradual increase in the use of pollen morphological data in phylogenetic analyses. A number of authors studied different groups of monocot pollen, viz., Wodehouse (1935), Jones and Newwell (1948), Sampath and Ramanathan (1951), Erdtman (1952), Ethirajan (1953), Rowley (1960), Nair and Sharma (1965), Thanikaimoni (1965), Gornall (1977), Meerow and Dehgan (1985), Siddiqui and Qaiser (1988), Goldblatt *et al*. (1991), Chaturvedi *et al*. (1998), and Furness and Rudall (2000, 2003). This study deals with a comprehensive approach regarding the pollen morphological studies of monocots with all its aspects in Paschim Medinipur district, West Bengal.

The District Paschim Medinipur is situated in the south-western side of West Bengal. The district lies between 21°47′ and 23°N latitude and between 86°40′ and 87°52′E longitude. It has an area of 929528 hectors. The climate is tropical and land surface is characterized by hard rock uplands, lateritic covered area, flat alluvial and deltaic plains. This area is predominantly covered by *Shorea robusta*. The forest type is tropical dry deciduous type. The usual associates of *S. robusta* are *Bombax ceiba*, *Madhuca latifolia*, *Pterocarpus marsupium*, *Schleichera oleosa, Terminalia arjuna,* and *Terminalia belerica*. Plantation mostly includes *Eucalyptus globulus*, *Acacia auriculiformis,* and *Anacardium occidentale* (Ghosh and Karmakar, 2012). Besides, a large number of grasses, sedges and other monocots are found in the district. Kangsabati, Silabati, Subarnarekha, Dulongs, Keleghai and their tributaries are the main rivers of the

district. The district is also a lead producer of flowers such as Tuberose, Gladiolus, and Marigold. Arabari forest range which was the site of India's first Joint Forest Management scheme is only 30 km away from the district town.

According to APG III system of classification (2009), there are 60,000 species of monocots occurring globally belonging to 78 families and 12 orders. Prain (1903) reported 241 genera and 740 species of monocots from West Bengal. In the present investigation, pollen grains of 54 genera and 66 species belonging to 19 families were collected from different parts of Paschim Medinipur district and simultaneously analyzed. The study was aimed at improving the general knowledge of the palynology and mode of pollen dispersal in this plant group and to contribute toward the constitution of a regional pollen flora in this part of the country which has received exceptionally modest consideration. Regarding the manner of pollen dispersal, sedges and grasses are anemophilous while the majority of the taxa with monosulcate pollen morphotypes are entomophilous and mostly dispersed by the different honeybee species, therefore, families producing such type of pollen grains are also adding themselves as potential bee plants for sustenance of honeybee hives of wild and managed varieties.

MATERIALS AND METHODS

During the present study, fresh polleniferous materials were collected from the different regions of Paschim Medinipur district, West Bengal. Polleniferous materials were preserved in formalin-acetic acid-alcohol solution, and the corresponding herbarium sheets were prepared. Plant specimens were identified by the scientists (Monocot section) of Botanical Survey of India, Kolkata. Palynological preparation of pollen samples was done using acetolysis method (Erdtman, 1960). First, anthers were dissolved in acetic acid, crushed and transferred to centrifuge tubes through proper mesh size. Pollen material was centrifuged at 2500 rpm for 10 min and decanted off. 5 ml of acetolysis mixture (acetic anhydride and concentrated sulfuric acid in a ratio of 9:1) was then added in the tubes containing pollen pellet. After thoroughly mixing, the mixture containing tube was placed in a water bath (at 80°C) for 3-4 min. After cooling, it was again centrifuged at 2500 rpm for 10 min. Again 5 ml of glacial acetic acid was poured in the sediment and centrifuged. A mixture was prepared having 2 ml of glacial acetic acid, 2-3 drops of saturated sodium chlorate solution followed by 1-2 drops of concentrated HCl. Such prepared chlorination mixture was then supplemented in the tubes containing pollen material (Nair, 1970), used to bleach the pollen samples for better understanding of the pollen walls. Finally, the polleniferous materials were washed with distilled water and centrifuged again. The pollen sediment was taken on a small piece of glycerine jelly and transferred to the center of a glass slide. Then, warmed gently to melt the jelly containing pollen sediment and covered by cover glass. The cover glass was sealed with paraffin wax. Microscopy was done using Leica DM1000, and photomicrographs of suitable magnifications were made with Leica DFC295 Digital camera. Pollens were described using standard terminologies (Erdtman, 1952; 1960; Kremp, 1965; Faegri and Iversen, 1975; Walker and Doyle, 1975). The collected families are Agavaceae, Amaryllidaceae, Arecaceae, Asphodelaceae, Cannaceae, Colchicaceae, Commelinaceae, Costaceae, Cyperaceae, Hemerocallidaceae, Hydrocharitaceae, Iridaceae, Liliaceae, Limnocharitaceae, Musaceae, Poaceae, Pontederiaceae, Typhaceae, and Zingiberaceae. Besides, melissopalynological observations (Pal and Karmakar, 2012; Layek *et al.*, 2015; Layek and Karmakar 2016) and field observations were also noted regarding the mode of pollen dispersal.

RESULTS

The different palynological features of the studied taxa are presented in Table 1. Text figures and photographs are displayed in Plates 1-5. Pollen morphological variation was described for size and shape, the number, position, and type of apertures and pattern of exine ornamentation.

Description of Pollen Grains

Alliaceae: *Allium cepa* L. [Pl.I:1, Pl.IV:1]

Pollen grains bilaterally symmetrical, oblate (20 µm × 41 µm); amb elliptic, monosulcate, sulcus narrowly elliptic, ends of the sulcus acute, exine ±1 µm thick, sexine tegillate, as thick as nexine, surface striate-perforate.

Agavaceae: *Polianthes tuberosa* L. [Pl.I:17, Pl.IV:21]

Pollen grains bilaterally symmetrical, peroblate (18 µm × 28 µm); equatorial outline oval-elliptic, monosulcate, sulcus narrowly elliptic, exine about 2 µm thick, surface with densely arranged reticulate ornamentation.

Amaryllidaceae: *Crinum asiaticum* L. [Pl.I:8, Pl.IV:10,11]

Pollen grains bilaterally symmetrical, peroblate (43 µm × 77 µm), amb elliptic, monosulcate, sulcus narrowly elliptic, extending from pole to pole, exine 2.5 µm thick, sexine as thick as nexine, surface distinctly

Table 1: The size, shape, apertural pattern and surface features of the studied monocot taxa

Families	Plant taxa	Shape of pollen	P×E (μM)	Apertural pattern	Surface features
Alliaceae	*Allium cepa*	Oblate	20×41	Monosulcate	Striate-perforate
Agavaceae	*Polianthes tuberosa*	Peroblate	18×28	Monosulcate	Reticulate
Amaryllidaceae	*Crinum asiaticum*	Peroblate	43×77	Monosulcate	Reticulate
Arecaceae	*Areca catechu*	Oblate	20×34	Monosulcate	Reticulate, heterobrocate, muri well developed
	Borassus flabellifer	Oblate	30×60	Monosulcate	Varrucate and gammate
	Cocos nucifera	Peroblate	26×55	Monosulcate	Psilate
	Phoenix sylvestris	Peroblate	18×36	Monosulcate	Faintly microreticulate
Asphodelaceae	*Aloe vera*	Oblate	26×44	Monosulcate	Rugulo-reticulate
Cannaceae	*Canna indica*	Spheroidal	Diameter 55	Inaperturate	Baculo-verrucate
Colchicaceae	*Gloriosa superba*	Oblate	18×28	Monosulcate	Reticulate
Commelinaceae	*Commelina benghalensis*	Oblate	60×130	Monosulcate	Spinulose
	Cyanotis axillaris	Oblate	40×82	Monosulcate	Rugulo-reticulate
	Murdannia nudiflora	Oblate	21×36	Monosulcate	Spinuloid-verrucoid type
Costaceae	*Costus speciosus*	Oblate	74×143	Monosulcate	Sporopollenin deposition occurred in lumps throughout the surface
Cyperaceae	*Cyperus cyperoides*	Spheroidal	Diameter 35	Monoporate	Microreticulate
	Cyperus haspan	Spheroidal	Diameter 40	Monoporate, operculate	Psilate
	Cyperus kyllinga	Spheroidal	Diameter 23	Monoporate, operculate	Psilate
	Cyperus paniculatus	Spheroidal	Diameter 20	Monoporate	Microreticulate
	Cyperus rotundus	Spheroidal	Diameter 35	Monoporate	Microreticulate
	Fimbristylis rugosa	Spheroidal	Diameter 17	Monoporate	Psilate
	Scirpus articulatus	Spheroidal	Diameter 13	Monoporate	Microreticulate
	Scirpus supinus	Spheroidal	Diameter 13	Monoporate	Microreticulate
Hemerocallidaceae	*Hemerocallis fulva*	Oblate	25×60	Monosulcate	Rugulo-reticulate
Hydrocharitaceae	*Hydrilla* sp.	Sub-oblate	28×35	Polyplicate	Psilate
Iridaceae	*Gladiolus communis*	Oblate	28×35	Monosulcate	Rugulo-reticulate
Limnocharitaceae	*Tenagocharis latifolia*	Spheroidal	Diameter 23	Tetra-hexazonoporate	Spinulate
Musaceae	*Musa sapientum*	Spheroidal	Diameter 55	Inaperturate	Psilate
Poaceae	*Avena sativa*	Spheroidal	Diameter 30	Monoporate, operculate	Psilate
	Bambusa arundinaceae	Spheroidal	Diameter 37	Monoporate, operculate	Granulate
	Brachiaria ramosa	Spheroidal	Diameter 26	Monoporate, operculate	Faintly Reticulate
	Chloris barbata	Spheroidal	Diameter 24	Monoporate, operculate	Punctate
	Chrysopogon aciculatus	Spheroidal	Diameter 26	Monoporate, operculate	Faintly microreticulate
	Coix lacryma-zobi	Spheroidal	Diameter 39	Monoporate, operculate	Psilate
	Cynodon dactylon	Spheroidal	Diameter 31	Monoporate, operculate	Microreticulate
	Desmostachya bipinnata	Spheroidal	Diameter 17	Monoporate, operculate	Reticulate
	Dicanthium annulatum	Spheroidal	Diameter 18	Monoporate, operculate	Faintly microreticulate
	Digitaria sanguinalis	Spheroidal	Diameter 12	Monoporate, operculate	Psilate
	Digitaria violascens	Spheroidal	Diameter 11	Monoporate, operculate	Very faintly microreticulate
	Echinochloa colona	Spheroidal	Diameter 39	Monoporate, operculate	Psilate
	Eleusine indica	Spheroidal	Diameter 22	Monoporate	Granulate
	Eragrostis tenella	Spheroidal	Diameter 10	Monoporate, operculate	Psilate
	Imperata cylindrica	Spheroidal	Diameter 25	Monoporate, operculate	Psilate
	Leptochola chinensis	Spheroidal	Diameter 11	Monoporte with Oncus	Microreticulate
	Oryza sativa	Spheroidal	Diameter 35	Monoporate, operculate	Psilate
	Panicum feanidum	Spheroidal	Diameter 11	Monoporate	Psilate
	Panicum notatum	Spheroidal	Diameter 13	Monoporate	Microreticulate
	Panicum plicatum	Spheroidal	Diameter 12	Monoporate	Microreticulate
	Paspalidium flavidum	Spheroidal	Diameter 11	Monoporate, operculate	Psilate
	Paspalum dilatatum	Spheroidal	Diameter 16	Monoporate, operculate	Microreticulate
	Paspalum scrobiculatum	Spheroidal	Diamtere 15	Monoporate, operculate	Faintly reticulate
	Pennisetum pedicellatum	Spheroidal	Diameter 13	Monoporate, operculate	Psilate
	Pennisetum polystachyon	Spheroidal	Diameter 16	Monoporate, operculate	Finely Microreticulate
	Pennisetum purpureum	Spheroidal	Diameter 30	Monoporate, operculate	Faintly reticulate
	Phalaris minor	Spheroidal	Diameter 17	Monoporate, operculate	Microreticulate
	Poa annua	Soheroidal	Diameter 13	Monoporate, operculate	Reticulate
	Poa gangetica	Spheroidal	Diameter 54	Monoporate, operculate	Faintly Microreticulate
	Saccharum spontaneum	Spheroidal	Diameter 38	Monoporate, operculate	Psilate
	Setaria glauca	Spheroidal	Diameter 40	Monoporate, operculate	Psilate
	Sporobolus diander	Spheroidal	Diameter 29	Monoporate, operculate	Psilate
	Triticum aestivum	Spheroidal	Diameter 48	Monoporate, operculate	Fanitly microreticulate
	Zea mays	Spheroidal	Diameter 104	Monoporate, operculate	Psilate
Pontederiaceae	*Eichhornia crassipes*	Peroblate	44×19	Dizonosulcate	Faintly rugulate
	Monochoria hastata	Oblate	24-30×47-72	Monosulcate	Granulose
Typhaceae	*Typha angustifolia*	Spheroidal	Diameter 21	Monoporate	Rugulo-reticulate
Zingiberaceae	*Hedychium coronarium*	Spheroidal	Diameter 13	Inaperturate	Rugulate
	Kaempferia galangal	spheroidal	Diameter 22	Inaperturate	Psilate

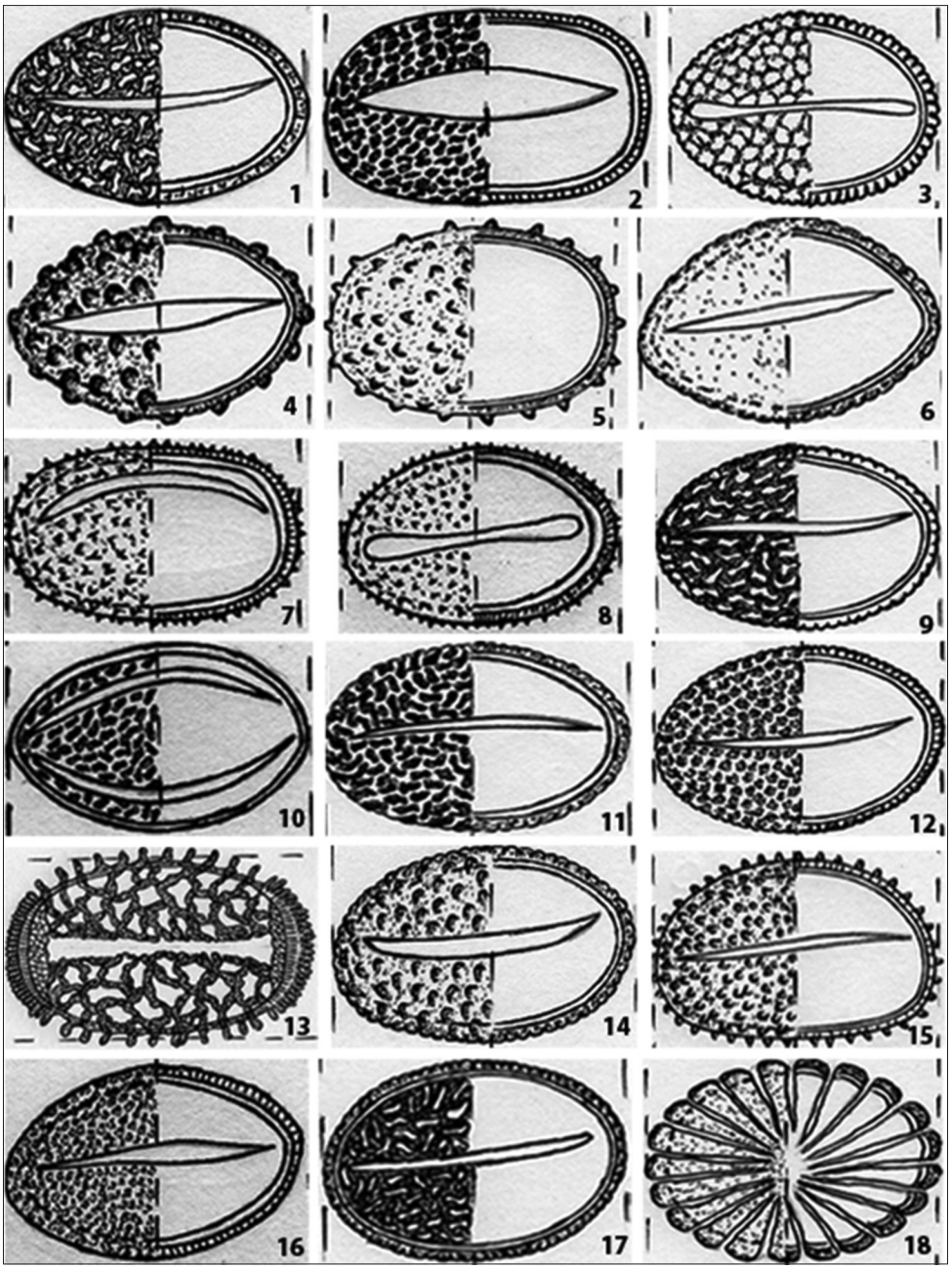

Plate 1: (1) *Allium cepa*; (2) *Aloe vera*; (3) *Areca catechu*; (4) *Borassus flabellifer*; (5) *Canna indica*; (6) *Cocos nucifera*; (7) *Commelina benghalensis*; (8) *Crimm asiaticum*; (9) *Cyanotis axillaris*; (10) *Eichhornia crassipes*; (11) *Gladiolus communis*; (12) *Gloriosa superba*; (13) *Hemerocallis fulva*; (14) *Monochoria hastata*; (15) *Murdannia nudiflora*; (16) *Phoenix sylvestris*; (17) *Polyanthes tuberosa*; (18) *Hydrilla*

reticulate, heterobrocate, muri well developed, lumina polygonal.

Arecaceae: *Areca catechu* L.; *Borassus flabellifer* L.; *Cocos nucifera* L.; *Phoenix sylvestris* (L.) Roxb.

Areca catechu L. [Pl.I:3, Pl.IV:3]

Pollen grains bilaterally symmetrical, oblate (20 µm × 34 µm), amb elliptic, monosulcate, crassimarginate, exine 1.5 µm thick, sulcus extending from pole to pole, sexine tegillate, thicker than nexine, surface densely reticulate, homobroate, muri well developed, lumina polygonal.

Borassus flabellifer L. [Pl.I:4, Pl.IV:4]

Pollen grains bilaterally symmetrical, oblate (30 µm × 60 µm), amb oval-elliptic, anasulcate, sulcus narrowly elliptic, sulcus ends acute, tenuimarginate, exine ±3 µm thick, sexine tegillate, as thick as nexine, surface with sparsely distributed verrucae and gammae, ±3.5 µm in diameter.

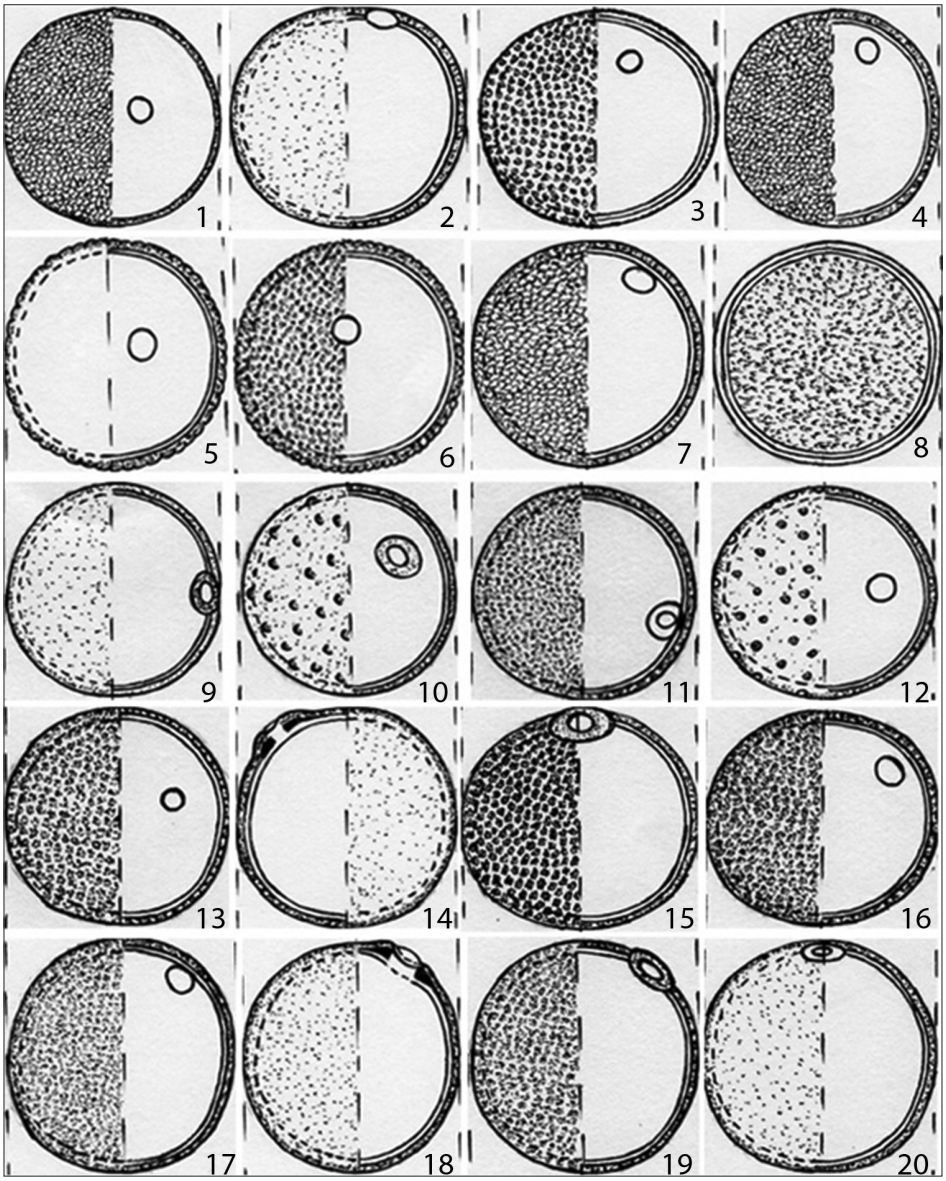

Plate 2: (1) *Cyperus cyperoides*; (2) *Cyperus kyllinga;* (3) *Cyperus paniculatus;* (4) *Cyperus rotundus;* (5) *Fimbristylis rugosa*; (6) *Scirpus articulatus;* (7) *Scirpus supinus;* (8) *Musa;* (9) *Avena sativa*; (10) *Bambusa*; (11) *Brachiaria ramosa*; (12) *Chloris barbata*; (13) *Chrysopogon aciculatus*; (14) *Coix lacryma-jobi*; (15) *Cynodon dactylon*; (16) *Desmostachya bipinnata;* (17) *Dicanthium annulatum*; (18) *Digitaria sanguinalis;* (19) *Digitaria violescens;* (20) *Echinochloa colona*

Cocos nucifera L. [Pl.I:6, Pl.IV:6]

Pollen grains bilaterally symmetrical, peroblate (26 µm × 55 µm), amb oval-elliptic, anasulcate, sulcus narrowly elliptic, ends pointed, exine about 2 µm thick, sexine as thick as nexine, surface psilate.

Phoenix sylvestris (L.) Roxb. [Pl.I:16, Pl.IV:20]

Pollen grains bilaterally symmetrical, peroblate (18 µm × 36 µm), amb elliptic, anasulcate, sulcus linear, exine about 1.5 µm thick, sexine tegillate, as thick as or slightly thicker than nexine, surface faintly microreticulate.

Asphodelaceae: *Aloe vera* (L.) Brum.f. [Pl.I:2, Pl.IV:2]

Pollen grains bilaterally symmetrical, oblate (26 µm × 44 µm), amb elliptic, monosulcate, tenuimarginate, ends acute, exine 1 µm thick, sexine distinctly tegillate, as thick as nexine, surface densely rugulo-reticulate, homobrocate.

Cannaceae: *Canna indica* L. [Pl.I:5, Pl.IV:5]

Pollen grains radially symmetrical, prolate-spheroidal, diameter of the grain 55 µm, inaperturate, exine 0.8 µm thick, surface baculo-verrucate, hight of the baculii 1.7 µm and width of the baculii 1.9 µm.

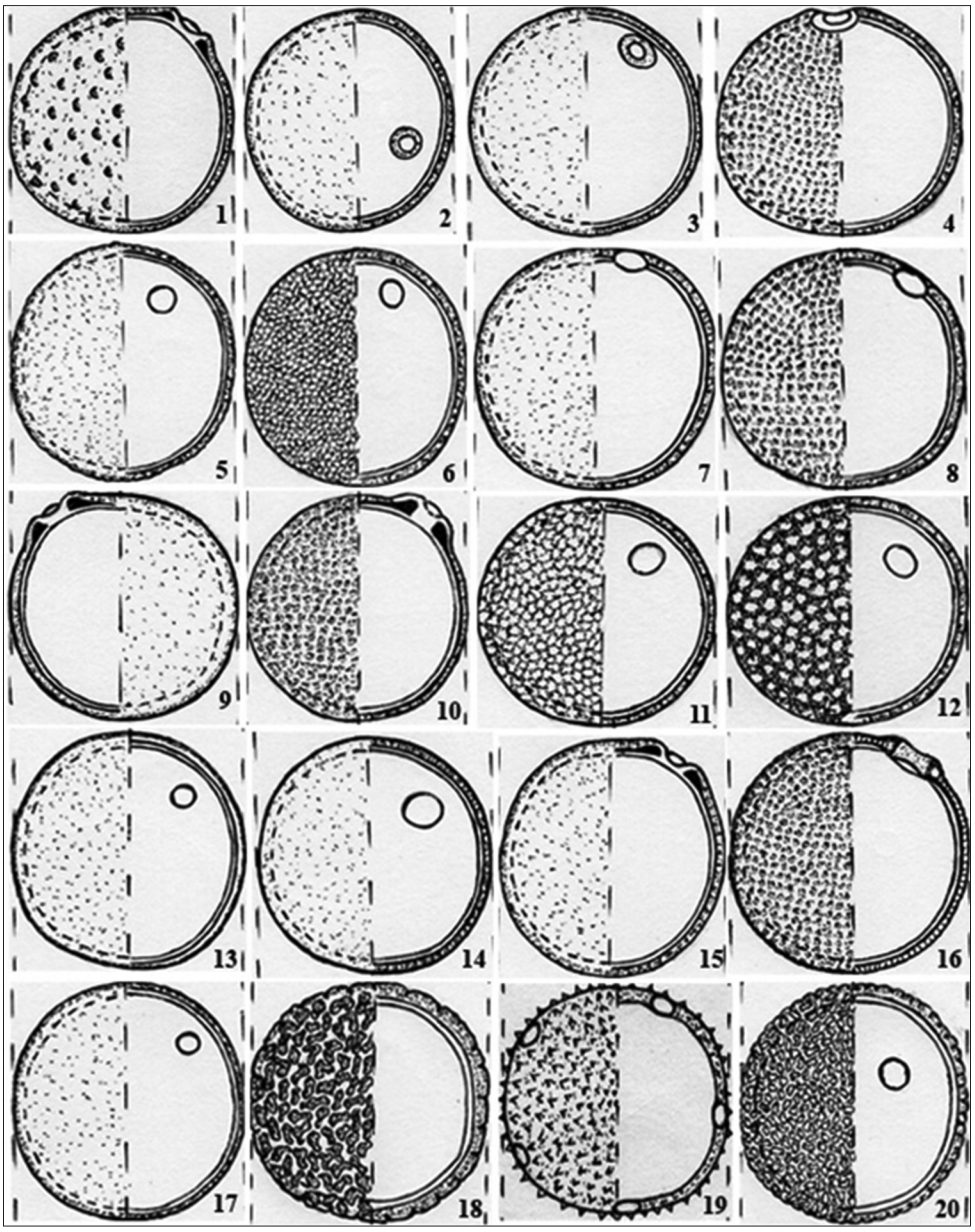

Plate 3: (1) *Eleusine indica*; (2) *Eragrostis tenella*; (3) *Imperata cylindrica*; (4) *Leptochola chinensis*; (5) *Oryza sativa*; (6) *Panicum plicatum;* (7) *Paspalidium flavidum;* (8) *Paspalum dilatatum;* (9) *Pennisetum pedicellatum;* (10) *Pennisetum polystachyon;* (11) *Phalaris minor;* (12) *Poa annua;* (13) *Saccharum spontaneum*; (14) *Setaria glauca;* (15) *Sporobolus diander;* (16) *Triticum aestivum;* (17) *Zea mays;* (18) *Hedychium coronarium;* (19) *Tenagocharis latifolia*; (20) *Typha angustifolia*

Colchicaceae: *Gloriosa superba* L. [Pl.I:12, Pl.IV:15]

Pollen grains bilaterally symmetrical, oblate (18 µm × 28 µm), amb elliptic, monosulcate, sulcus extended from pole to pole, sulcus narrowly elliptic, exine 1.2 µm thick, sexine distinctly tegillate, as thick as nexine, surface reticulate.

Commelinaceae: *Commelina benghalensis* L.; *Cyanotis axillaris* (L.) D. Don; *Murdannia nudiflora* (L.) Brenan

Commelina benghalensis L. [Pl.I:7, Pl.IV:7]

Pollen grains bilaterally symmetrical, oblate (60 µm × 130 µm), amb oval-elliptic, monosulcate, sulcus narrowly elliptic, ends pointed, exine 1.5 µm thick, surface spinulose-baculoid.

Cyanotis axillaris (L.) D. Don [Pl.I:9, Pl.IV:12]

Pollen grains bilaterally symmetrical, oblate (40 µm × 82 µm); amb elliptic, monosulcate, sulcus narrowly elliptic, tenuimarginate, ends pointed, exine about 1 µm thick, surface rugulo-reticulate.

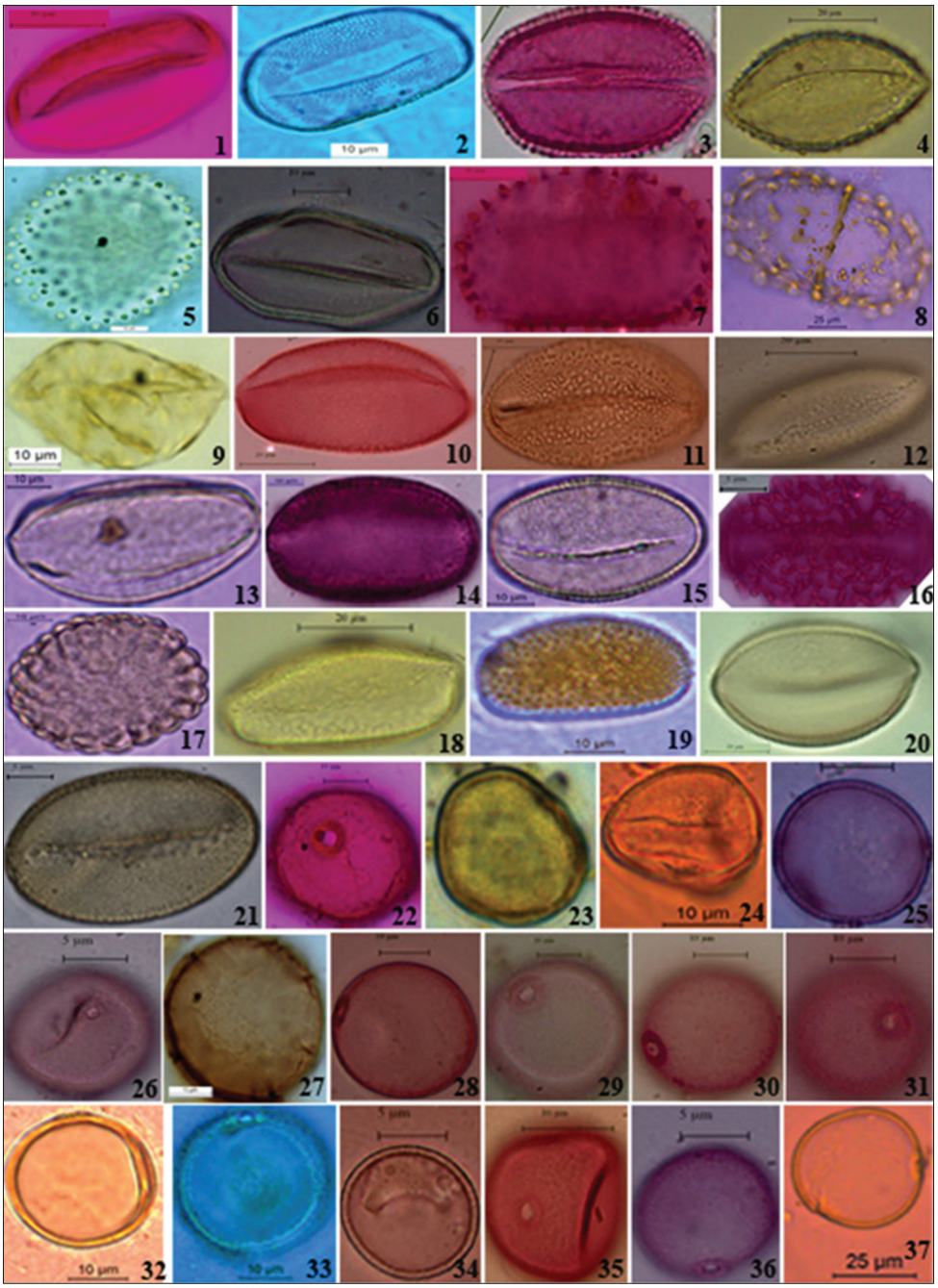

Plate 4: (1)*Allium cepa*; (2) *Aloe vera*; (3) *Areca catechu*; (4) *Borassus flabellifer*; (5) *Canna indica*; (6) *Cocos nucifera*; (7) *Commelina benghalensis*; (8) *Costus speciosus;* (9) *C. speciosus;* (10) *Crimm asiaticum;* (11) *C. asiaticum;* (12) *Cyanotics axillaris; (13) Eichhornia crassipes;* (14) *Gladiolus communis;* (15) *Gloriosa superba;* (16) *Hemerocallis fulva;* (17) *Hydrilla;* (18) *Monochoria hastate;* (19) *Murdannia nudiflora;* (20) *Phoenix sylvestris;* (21) *Polyanthes tuberosa;* (22) *Cyperus haspan;* (23) *Cyperus kyllinga;* (24) *Cyperus paniculatus;* (25) *Cyperus rotundus;* (26) *Scirpus articulates;* (27) *Musa sapientum;* (28) *Avena sativa;* (29) *Bambusa;* (30) *Brachiaria ramosa;* (31) *Chloris barbata;* (32) *Chrysopogon aciculatus;* (33) *Cynodon dactylon;* (34) *Desmostachya bipinnata;* (35) *Dicanthium annulatum;* (36) *Digitaria violescens*; (37) *Echinochloa colona*

Murdannia nudiflora (L.) Brenan [Pl.I:15, Pl.IV:19]

Pollen grains bilaterally symmetrical, oblate (21 µm × 36 µm), amb oval elliptic, monosulcate, exine 0.8 µm thick, sexine distinctly tegillate, slightly thicker than nexine, surface spinuloid-verrucoid type.

Costaceae: *Costus speciosus* (J.Koenig) Sm. [Pl.IV:8,9]

Pollen grains bilaterally symmetrical, oblate (74 µm × 142 µm), amb elliptic, monosulcate, exine very thin, sporopollenin deposition occurred in lumps throughout the surface.

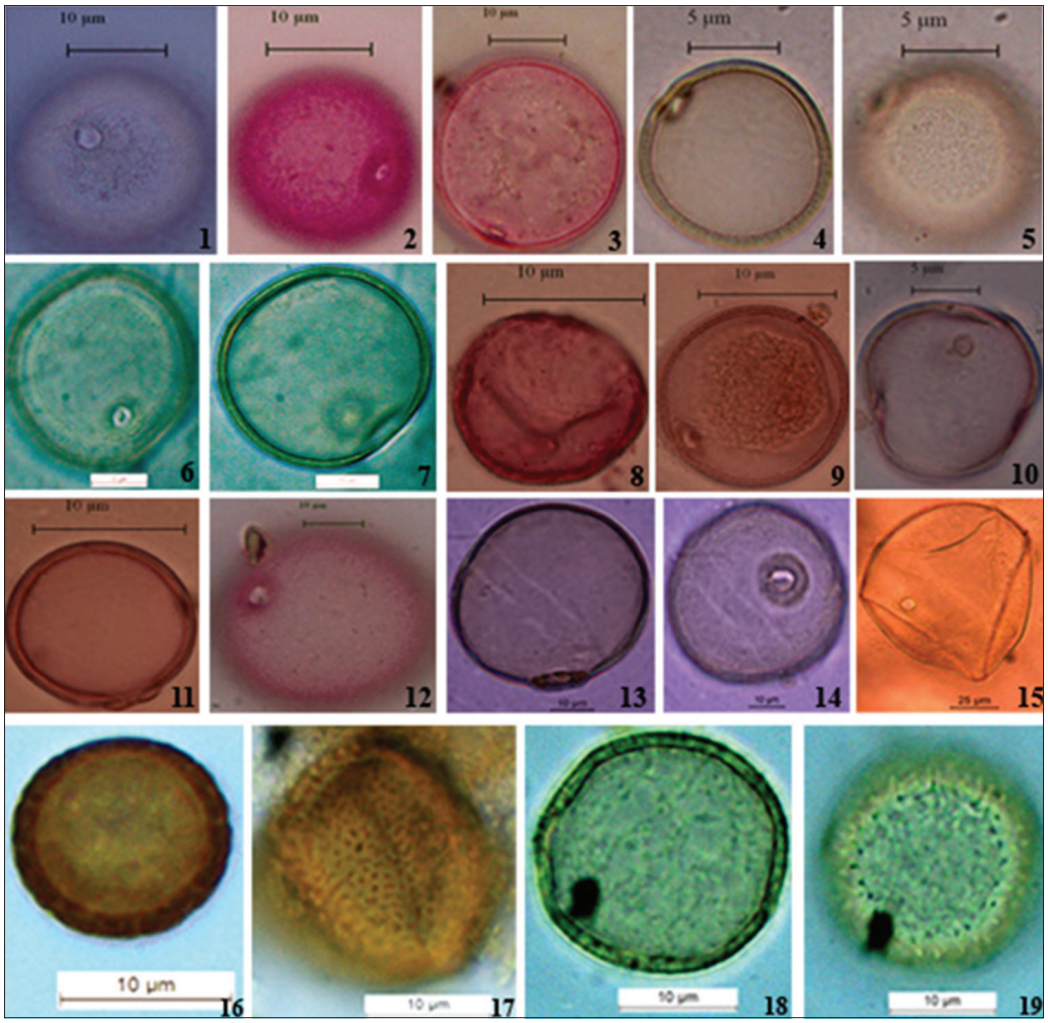

Plate 5: (1) *Eleusine indica*; (2) *Eragrostis tenella*; (3) *Imperata cylindrica*; (4) *Leptochola chinensis*; (5) *L. chinensis* (6) *Oryza sativa*; (7) *O. sativa;* (8) *Panicum plicatum;* (9) *P. plicatum;* (10) *Paspalum dilatatum;* (11) *Pennisetum pedicellatum;* (12) *Setaria glauca;* (13) *Triticum aestivum;* (14) *T. aestivum;* (15) *Zea mays;* (16) *Hedychium coronarium;* (17) *Typha angustifolia;* (18) *Tenagocharis latifolia;* (19) *T. latifolia*

Cyperaceae: *Cyperus cyperoides* (L.) Kuntze; *Cyperus haspan* L.; *Cyperus kyllinga* Endl.; *Cyperus paniculatus* D.Don; *Cyperus rotundus* L.; *Fimbristylis rugosa* Govind.; *Scirpus articulatus* L.; *Scirpus supinus* L.

Cyperus cyperoides (L.) Kuntze [Pl.II:1]

Pollen grains radially symmetrical, spheroidal, diameter 35 µm, monoporate, exine 1.5 µm thick, surface microreticulate.

Cyperus haspan L. [Pl.IV:22]

Pollen grains radially symmetrical, spheroidal, amb circular, diameter 40 µm, monoporate, annulate, operculate, pore diameter 2.2-3.5 µm, exine 1 µm thick, surface psilate.

Cyperus kyllinga Endl. [Pl.II:2, Pl.IV:23]

Pollen grains radially symmetrical, spheroidal, diameter 23 µm, amb circular, monoporate, annulate, operculate, exine 1 µm thick, surface psilate.

Cyperus paniculatus D. Don [Pl.II:3, Pl.IV:24]

Pollen grains radially symmetrical, spheroidal, diameter 20 µm, monoporate, pore diameter 1.5 µm, exine 1 µm thick, surface microreticulate.

Cyperus rotundus L. [Pl.II:4, Pl.IV:25]

Pollen grains radially symmetrical, spheroidal, amb circular, diameter 35 µm, monoporate, pore diameter 3 µm, surface microreticulate.

Fimbristylis rugosa Govind. [Pl.II:5]

Pollen grains radially symmetrical, spheroidal, amb circular, diameter 17 µm, exine 0.5 µm thick, anaporate, pore diameter 1.5 µm, surface psilate.

Scirpus articulatus L. [Pl.II:6, Pl.IV:26]

Pollen grains radially symmetrical, spheroidal, amb circular, diameter 13 µm, anaporate, exine 0.8 µm thick, sexine distinctly tegillate, surface microreticulate.

Scirpus supinus L. [Pl.II:7]

Pollen grains radially symmetrical, spheroidal, amb circular, diameter 13 µm, exine 1 µm thick, anaporate, sexine distinctly tegillate, surface microreticulate.

Hemerocallidaceae: *Hemerocallis fulva* L. [Pl.I:13, Pl.IV:16]

Pollen grains bilaterally symmetrical, oblate (25 µm × 60 µm), amb oblong, monosulcate, sulcus extended from pole to pole, sulcus narrowly elliptic, sexine distinctly tegillate, as thick as nexine, surface rugulo-reticulate, lumina polygonal, muri well developed, surface on both the colpi ends densely microrugulate.

Hydrocharitaceae: *Hydrilla* Casp. [Pl.I:18, Pl.IV:17]

Pollen grains are radially symmetrical, sub-oblate, 28 µm × 35 µm, amb circular, polyplicate with ridges and furrow, exine 1 µm thick, surface psilate.

Iridaceae: *Gladiolus communis* L. [Pl.I:11, Pl.IV:14]

Pollen grains bilaterally symmetrical, oblate (28 µm × 35 µm), amb elliptic, monosulcate, sulcus narrowly elliptic, tenuimarginate, exine 1.5 µm thick, sexine distinctly tegillate, surface rugulo-reticulate.

Limnocharitaceae: *Tenagocharis latifolia* (D.Don.) Kunth [Pl.III:19, Pl.V:18,19]

Pollen grains radially symmetrical, spheroidal, 23 µm in diameter, tetra-hexazonoporate, pore very small, exine 1.2 µm thick, sexine distinctly tegillate, slightly thinner than nexine, surface spinulose.

Musaceae: *Musa sapientum* L. [Pl.II:8, Pl.IV:27]

Pollen grains radially symmetrical, spheroidal, diameter of the grain 55 µm, inaperturate, exine 2 µm thick, surface psilate.

Poaceae: *Avena sativa* L.; *Bambusa arundinaceae* Retz.; *Brachiaria ramosa* (L.) Stapf.; *Chloris barbata* Sw.; *Chrysopogon aciculatus* (Retz.) Trin.; *Coix lacryma-jobi* L.; *Cyanodon dactylon* (L.) Pers.; *Desmostachya bipinnata* (L.) Stapf.; *Dichanthium annulatum* (Forssk.) Stapf; *Digitaria sanguinalis* (L.) Scop.; *Digitaria violascens* Link; *Echinochloa colona* (L.) Link; *Eleusine indica* (L.) Gaertn.; *Eragrostis tenella* (L.) Roem. Schult.; *Imperata cylindrica* (L.) P.Beauv.; *Leptochola chinensis* (Roth.) Nees; *Oryza sativa* L.; *Panicum feanidum* L.; *Panicum notatum* Retz.; *Panicum plicatum* Roxb.; *Paspalidium flavidum* (Retz.) A.Camus; *Paspalum dilatatum* Poir.; *Paspalum scorbiculatum* L.; *Pennisetum pedicellatum* Trin.; *Pennisetum polystachyon* (L.) Schult.; *Pennisetum purpureum* Schumach.; *Phalaris minor* Retz.; *Poa annua* L.; *Poa gangitica* Roxb.; *Saccharum spontaneum* L.; *Setaria glauca* Kunth; *Sporobolus diander* P.Beauv.; *Triticum aestivum* L.; *Zea mays* L.

Avena sativa L. [Pl.II:9, Pl.IV:28]

Pollen grains radially symmetrical, spheroidal, diameter 30 µm, amb circular, monoporate, annulate with operculum, surface psilate.

Bambusa arundinaceae Retz. [Pl.II:10, Pl.IV:29]

Pollen grains radially symmetrical, spheroidal, 37 µm in diameter, amb circular, monopororate, annulate, operculate, pore diameter 4 µm, ora 3 µm, surface granulate.

Brachiaria ramosa (L.) Stapf. [Pl.II:11, Pl.IV:30]

Pollen grains radially symmetrical, spheroidal, diameter 26 µm, amb circular, monoporate, annulate, operculate, surface faintly reticulate.

Chloris barbata Sw. [Pl.II:12, Pl.IV:31]

Pollen grains radially symmetrical, spheroidal, diameter 24 µm, amb circular, monoporate, annulate, operculate, exine 1.5 µm thick, sexine tegillate, as thick as nexine, surface punctuate.

Chrysopogon aciculatus (Retz.) Trin. [Pl.II:13, Pl.IV:32]

Pollen grains radially symmetrical, spheroidal, 26 µm in diameter, amb circular, monoporate, annulate, operculate, pore diameter 2 µm, exine 1.8 µm thick, sexine distinctly tegillate, surface faintly microreticulate.

Coix lacryma-jobi L. [Pl.II:14]

Pollen grains radially symmetrical, spheroidal, 39 µm in diameter, amb circular, monoporate, annulate, operculate, exine 1.8 µm thick, surface psilate.

Cyanodon dactylon (L.) Pers. [Pl.II:15]

Pollen grains radially symmetrical, spheroidal, 31 µm in diameter, monoporate, annulate, operculate, exine 2 µm thick, surface microreticulate.

Desmostachya bipinnata (L.) Stapf. [Pl.II:16, Pl.IV:34]

Pollen grains radially symmetrical, spheroidal, diameter 17 µm, amb circular, monoporate, annulate, operculate, exine 0.6 µm thick, sexine distinctly tegillate, surface reticulate.

Dichanthium annulatum (Forssk.) Stapf [Pl.II:17, Pl.IV:35]

Pollen grains radially symmetrical, spheroidal, diameter 18 µm, amb circular, monoporate, annulate, operculate, exine 1 µm thick, sexine distinctly tegillate, surface faintly mictoreticulate.

Digitaria sanguinalis (L.) Scop. [Pl.II:18]

Pollen grains radially symmetrical, spheroidal, diameter 12 µm, amb circular, monopororate, annulate, operculate, exine 1 µm thick, sexine distinctly tegillate, surface psilate.

Digitaria violascens Link [Pl.II:19, Pl.IV:36]

Pollen grain radilly symmetrical, spheroidal, diameter 11 µm, amb circular, pororate, annulate, operculate, pore diameter 1 µm, ora diameter 0.8 µm, exine 0.6 µm thick, surface very faintly microreticulate.

Echinochloa colona (L.) Link [Pl.II:20, Pl.IV:37]

Pollen grains radially symmetrical, spheroidal, diameter 39 µm, amb circular, monoporate, annulate, operculate, exine 1.3 µm thick, surface psilate.

Eleusine indica (L.) Gaertn. [Pl.III:1, Pl.V:1]

Pollen grains radially symmetrical, spheroidal, diameter 22 µm, amb circular, monoporate, diameter of pore 2 µm, surface granulate.

Eragrostis tenella (L.) Roem. Schult. [Pl.III:2, Pl.V:2]

Pollen grains radially symmetrical, spheroidal, amb circular, diameter 10 µm, monopororate, annulate, operculate, sexine tegillate, as thick as nexine, surface psilate.

Imperata cylindrica (L.) P.Beauv. [Pl.III:3, Pl.V:3]

Pollen grains radially symmetrical, spheroidal, amb circular, diameter 25 µm, monopororate, annulate, operculate, sexine tegillate, as thick as nexine, surface psilate.

Leptochola chinensis (Roth.) Nees [Pl.III:4, Pl.V:4,5]

Pollen grains radially symmetrical, spheroidal, diameter 11 µm, amb circular, monoporate, oncus present, exine 1 µm thick, sexine tegillate, as thick as nexine, surface microreticulate.

Oryza sativa L. [Pl.III:5, Pl.V:6,7]

Pollen grains radially symmetrical, spheroidal, 35 µm in diameter, monoporate, annulate, operculate, exine 1.5 µm thick, surface psilate.

Panicum feanidum L. [Pl.V:8]

Pollen grains radially symmetrical, spheroidal, diameter 11 µm, amb circular, monoporate, annulate, exine 0.5 µm thick, sexine distinctly tegillate, surface psilate.

Panicum notatum Retz.

Pollen grains radially symmetrical, spheroidal, diameter 13 µm, amb circular, monoporate, annulate, exine 0.8 µm thick, surface microreticulate.

Panicum plicatum Roxb. [Pl.III:6, Pl.V:9]

Pollen grains radially symmetrical, spheroidal, diameter 12 µm, amb circular, monoporate, annulate, exine 0.8 µm thick, surface microreticulate.

Paspalidium flavidum (Retz.) A.Camus [Pl.III:7]

Pollen grains radially symmetrical, spheroidal, diameter 11 µm, amb circular, monoporate, annulate, operculate, exine 1 µm thick, surface psilate.

Paspalum dilatatum Poir. [Pl.III:8, Pl.V:10]

Pollen grains radially symmetrical, spheroidal, diameter 16 µm, amb circular, monoporate, annulate, exine 1 µm thick, surface microreticulate.

Paspalum scorbiculatum L.

Pollen grains radially symmetrical, spheroidal, amb circular, diameter 15 µm, exine 0.8 µm thick, monoporate, annulate, operculate, surface faintly reticulate.

Pennisetum pedicellatum Trin. [Pl.III:9, Pl.V:11]

Pollen grains radially symmetrical, spheroidal, diameter 13 µm, amb circular, exine 1 µm thick, monoporate, annulate, operculate, surface psilate.

Pennisetum polystachyon (L.) Schult. [Pl.III:10]

Pollen grains radially symmetrical, spheroidal, diameter 16 µm, amb circular, anaporate, annulate, operculate, exine 0.8 µm thick, surface finely microreticulate.

Pennisetum purpureum Schumach.

Pollen grains radially symmetrical, spheroidal, diameter 30 µm, amb circular, anaporate, annulate, operculate, sexine tegillate as thick as nexine, surface faintly reticulate.

Phalaris minor Retz. [Pl.III:11]

Pollen grains radially symmetrical, spheroidal, diameter 17 µm, amb circular, monoporate, annulate, operculate, pore diameter 1.7 µm, sexine distinctly tegillate, surface microreticulate.

Poa annua L. [Pl.III:12]

Pollen grains radially symmetrical, spheroidal, diameter 13 µm, amb circular, monoporate, annulate, operculate, pore diameter 1.6-2.5 µm, pore oval in shape, exine 0.7 µm thick, surface distinctly reticulate, homobrocate.

Poa gangetica Roxb.

Pollen grains radially symmetrical, spheroidal, 54 µm in diameter, amb circular, monoporate, annulate, operculate, pore circular to oval in outline, ±3 µm in diameter, crassimarginate, exine about 2 µm thick, sexine as thick as nexine, surface faintly microreticulate.

Saccharum spontaneum L. [Pl.III:13]

Pollen grains are radially symmetrical, spheroidal, diameter 38 µm, amb circular, monoporate, annulate, operculate, exine 1.2 µm thick, surface psilate.

Setaria glauca Kunth [Pl.III:14, Pl.V:12]

Pollen grains radially symmetrical, spheroidal, amb circular, diameter 40 µm, monoporate, annulate, operculate, pore diameter 2.5-3.5 µm, exine 1.5 µm thick, surface psilate.

Sporobolus diander P.Beauv. [Pl.III:15]

Pollen grains radially symmetrical, spheroidal, amb circular, diameter 29 µm, monoporate, annulate, operculate, sexine distinctly tegillate, surface psilate.

Triticum aestivum L. [Pl.III:16, Pl.V:13,14]

Pollen grains radially symmetrical, oblate-spheroidal (47 µm × 49 µm), monoporate, annulate, operculate, pore diameter 6.5-7 µm, exine 1.5 µm thick, sexine distinctly tegillate, as thick as nexine, surface faintly microreticulate.

Zea mays L. [Pl.III:17, Pl.V:15]

Pollen grains radially symmetrical, spheroidal, diameter of the grain 104 µm, monoporate, pore diameter 7.5 µm, exine 0.8 µm thick, surface psilate.

Pontederiaceae: *Eichhornia crassipes* (Mart.) Solms; *Monochoria hastata* (L.) Solms

Eichhornia crassipes (Mart.) Solms [Pl.I:10, Pl.IV:13]

Pollen grains bilaterally symmetrical, peroblate (19 µm × 44 µm), amb elliptic, dizonosulcate, sulcus narrowly elliptic, exine tenuimarginate, exine about 1.3 µm thick, surface faintly rugulate.

Monochoria hastata (L.) Solms [Pl.I:14, Pl.IV:18]

Pollen grains bilaterally symmetrical, oblate (24-30 µm × 47-72 µm), amb elliptic, anasulcate, sulcus broad, occupying almost whole length of the grain, exine tenuimarginate, exine 1.5 µm thick, sexine as thick as nexine, surface granulose.

Typhaceae: *Typha angustifolia* L. [Pl.III:20, Pl.V:17]

Pollen grains bilaterally symmetrical, spheroidal, diameter of the grain 21 µm, amb circular, monoporate, exine 0.8 µm thick, sexine distinctly tegillate, as thick as nexine, surface rugulo-reticulate.

Zingiberaceae: *Hedychium coronarium* J. Koenig; *Kaempferia galanga* L.

Hedychium coronarium J. Koenig [Pl.III:18, Pl.V:16]

Pollen grains radially symmetrical, spheroidal, diameter of the grain 13 µm, amb circular, inaperturate, exine 1 µm thick, sexine distinctly tegillate, as thick as nexine, surface rugulate.

Kaempferia galanga L.

Pollen grains radially symmetrical, spheroidal, diameter 22 µm, amb circular, inaperturate, exine 0.8 µm thick,

sexine distinctly tegillate, slightly thinner than nexine, surface psilate.

DISCUSSION

Altogether, pollen morphological studies of 66 species belong to 19 monocotyledon families (Table 1) in Paschim Medinipur District have been worked out. Among those, 34 species belongs to Poaceae followed by 8 species to Cyperaceae, 4 species to Arecaceae, 3 species to Commelinaceae, 2 to Pontederiaceae and Zingiberaceae each. The rest of the families are represented by a single species. Pollen grains are radially symmetrical in Cannaceae, Cyperaceae, Hydrocharitaceae, Limnocharitaceae, Musaceae, Poaceae, Typhaceae, and Zingiberaceae where apertural patterns are either inaperturate or monoporate or pantoporate and the shape is mostly spheroidal. Families having pollen grains with sulcus apertures (Halbritter and Hesse, 1993) and peroblate to oblate in shape, viz., Alliaceae, Agavaceae, Amaryllidaceae, Arecaceae, Asphodelaceae, Colchicaceae, Commelinaceae, Costaceae, Hemerocallidaceae, Iridaceae, and Pontederiaceae are bilaterally symmetrical. Among the monosulcate pollens, the species can be taxonomically differentiated from each other either by their surface features or nature of sulcus or length of polar and equatorial axes of the pollen. Surface of *A. cepa* is striate-perforate. Since *P. tuberosa* (Pt), *G. superba* (Gs) and *G. communis* (Gc) exhibit more or less uniform sulcus apertural pattern and surface features, therefore, palynological separation of those taxa are rather cumbersome and needs a detailed Scanning Electron Microscopy (SEM) study. *C. asiaticum* (Ca) shows a distinct reticulate surface with narrowly elliptic sulcus extending up to two ends of the equatorial outline with acute ends. In *C. speciosus,* there is a single slit-like furrow and the exine is not divisible into nexine and sexine, rather, sporopollenin deposited in lumps looks like beads distributed throughout the surface. *H. fulva* reveals a unique surface with wide muri and broad lumina, sulcus wide at the poles. *B. flabellifer* is characterized by distinct verrucate surface ornamentations with a sulcus that tapers both the ends. In *C. nucifera,* the surface is psilate. Although *A. catechu* displays reticulate surface, however, sulcus is distinct from Pt, Gs, Gc, and Ca. The ED of *C. benghalensis* (130 µm) is much longer than the ED of *M. nudiflora* (36 µm) otherwise both exhibit spinuloid ornamentations. *E. crassipes* shows dizonosulcate apertural pattern while *M. hastata* displays granulate surface with one sulcus.

Cyperaceae and Poaceae are relatively stenopalynous taxa (Sharma, 1967; Chaturvedi *et al*., 1998, Kawarase and Kunjalwar, 2016). Pollen grains of both the families are spheroidal in shape and exhibit distally placed single porate aperture (anaporate). According to Erdtman (1952) pollen grains of Cyperaceae are 1-4 aperturate. However, dizonocolpoidate nature of exine was described by Nair (1990) in *Cyperus exaltatus*, *Fuirena ciliaris,* and *S. articulatus*. Our study reveals that *S. articulatus* is monoporate with microreticulate sculpturing. In *C. haspan* and *C. kyllinga* annulate pore with operculum is seen. All the members of Poaceae show anaporate operculate aperture with annulus except *E. indica* and species of *Panicum* where only pores are found. In *E. indica,* oncus is present over the intine. Regarding surface features among the 34 species of Poaceae, 14 are psilate type, 12 shows microreticulate type, 5 exhibit reticulate ornamentations, 2 are granulose, and one reveals punctate type of surface features. Thus, regarding the surface features, little variations have been observed in grass family. Further, light microscopic and SEM studies for pollen exine surface features significantly widen the purpose of these pollen features at a number of taxonomic levels in the members of poaceae to a greater extent (Andersen and Bertelsen, 1972; Kohler and Lange, 1979; Chaturvedi *et al*., 1994, 1998; Perveen, 2006). Monoporate aperture with reticulate surface and thick exine is seen in *T. angustifolia*. Polyplicate apertural pattern with ridges and furrows is observed in *Hydrilla*. *T. latifolia* is characterized by tetra-hexazonoporate with spinulate exine. Taxa without any aperture are studied in *C. indica, M. sapientum, H. coronarium,* and *Kaempferia galangal*.

CONCLUSION

From the pollen analyses of honey samples and pollen loads made by different honeybee species, viz., *Apis dorsata, A. florea,* and *A. mellifera*, it was found the presence of following pollen taxa, viz., *Allium* of Aliaceae, Pt of Agavaceae, *Borassus, Cocos* and *Phoenix* of Arecaceae, *Commelina* and *Cyanotis* of Commelinaceae, and Gc of Iridaceae. Besides, field works ensure that Gs of Colchicaceae*, C. speciosus* of Costaceae and *H. fulva* of Hemerocallidaceae are also pollinated by insects. Here, all the above-mentioned species comprising monosulcate type of pollen apertures. Therefore, monosulcate apertural pattern with elaborate surface features correspond with entomophily which is an evolutionary evolved character with respect to pollination. The pollen grains in the members of Cyperaceae and Poaceae are extensively used in wind pollination. Pollen grains are dry rather than sticky due to poor development of pollenkitt or completely lacking leading to reduce clumping (Willmer, 2011). Surface patterns are relatively unsculptured (Crane, 1986; Linder, 1998) and a reduction in size and number of apertures, may help to reduce the water loss. Hence, along with the reduction in the size and

number of floral parts, the key evolutionary adaptations in the grasses include the development of wind pollination by virtue of their simple pollen morphotypes.

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REFERENCES

Andersen ST, Bertelsen F. Scanning electron microscope studies of pollen of cereals and other grasses. Grana 1972;12:79-86.

APG III. An update of the angiosperm phylogeny group classification for the orders and families of flowering plants: APG III. Bot J Linn Soc 2009;161:105-21.

Chaturvedi M, Yunus D, Datta K. Pollen morphology of *Sorghum* moench-Sections *Eu-sorghum* and *Para-sorghum*. Grana 1994;33:117-23.

Chaturvedi M, Datta K, Nair PK. Pollen morphology of *Oryza* (*Poaceae*). Grana 1998;37:79-86.

Crane PR. Form and function in wind dispersed pollen. In: Blackmore S, Ferguson IK, editors. Pollen and Spores: Form and Function. London: Academic Press; 1986. p. 179-202.

Dahlgren RM, Clifford HT. The Monocotyledon, a Comparative Study. New York: Academic Press; 1982.

Dahlgren RM, Clifford HT, Yeo PF. The Families of the Monocotyledons. Berlin: Springer; 1985.

Erdtman G. Pollen Morphology and Plant Taxonomy. Stockholm: Almqvist & Wiksell; 1952.

Erdtman G. The acetolysis method - A revised description. Sven Botan Tidskr 1960;54:561-4.

Ethirajan AS. Pollen grains in *Saccharum* and certain allied genera. Curr Sci 1953;22:385-6.

Faegri K, Iversen J. Textbook of Pollen Analysis. Copenhagen, Denmark: Munksgaard; 1975.

Furness CA, Rudall PJ. Aperture absence in pollen of monocotyledons. In: Harley MM, Morton CM, Blackmore S, editors. Pollen and Spores: Morphology and Biology. Kew: Royal Botanical Gardens; 2000. p. 249-57.

Furness CA, Rudall PJ. Aperture with lids: Distribution and signifcance of operculate pollen in monocotyledons. Int J Plant Sci 2003;164:835-54.

Ghosh A, Karmakar P. Studies in the pollen morphology of some members of *Acanthaceae* in Paschim Medinipur District, West Bengal. Indian J Biol Sci 2012;18:26-34.

Goldblatt P, Manning JC, Bari A. Sulcus and operculum structure in the pollen grains of *Iridaceae* subfamily *Ixioideae*. Ann Mo Bot Gard 1991;78:950-61.

Gornall RJ. Notes on the size and exine ornamentation of *Avena* pollen grains. Can J Bot 1977;55:2622-9.

Halbritter H, Hesse M. Sulcus morphology in some monocot families. Grana 1993;32:87-99.

Jones MD, Newwell LC. Size variability and identification of grass pollen. J Am Soc Agron 1948;40:136-43.

Kawarase AD, Kunjalwar SG. Pollen morphological studies in five species of *Cyperus* from Cyperaceae of Wardha district, Maharashtra, India. Int J Sci Res 2016;5:2106-9.

Kohler E, Lange E. A contribution to distinguishing cereal from wild grass pollen grains by LM and SEM. Grana 1979;18:133-40.

Kremp GO. Encyclopaedia of Pollen Morphology. Tucson, USA: University of Arizona Press; 1965.

Layek U, Bhakat RK, Karmakar P. Foraging behavior of *Apis florea* Fabricius during winter and spring-summer in Bankura and Paschim Medinipur districts, West Bengal. Glob J Biosci Biotech 2015;4:255-63.

Layek U, Karmakar P. Bee plants used as nectar sources by *Apis florae* Fabricius in Bankura and Paschim Medinipur districts, West Bengal. Geophytology 2016;46(1):1-14.

Linder HP. Morphology and the evolution of wind pollination. In: Owens SJ, Rudall PJ, editors. Reproductive Biology in Systematics, Conservation and Economic Botany. London: Royal Bot Gard Kew; 1998. p. 123-35.

Meerow AW, Dehgan B. The auriculate pollen grain of *Hymenocallis quitoensis* her. (*Amaryllidaceae*) and its systematic implications. Am J Bot 1985;72:540-7.

Nair PK, Sharma M. Pollen morphology of *Liliaceae*. J Palynol 1965;1:38-61.

Nair PK. Pollen Morphology of Angiosperms: A Historical and Phylogenetic Study. Lucknow: Scholar Publishing House; 1970.

Nair TS. Pollen Flora of Maharashtra State, India. New Delhi: Today & Tomorrow's Printers and Publishers; 1990.

Pal PK, Karmakar P. Pollen analysis in understanding the foraging behaviour of *Apis mellifera* in Gangetic West Bengal. Geophytology 2013;42:93-114.

Perveen A. A contribution to the pollen morphology of family gramineae. World Appl Sci J 2006;1:60-5.

Prain D. Bengal Plants. Vol. I and Vol. II. Calcutta: Printed by West, Newman & Co; 1903.

Rowley J. Exine structure of cereal and wild type grass pollen. Grana Palynol 1960;2:9-15.

Sampath S, Ramanathan K. Pollen grain sizes in *Oryza*. J Indian Bot Soc 1951;30:40-8.

Sharma M. Pollen morphology of Indian monocotyledons. J Palynol Spec Vol 1967:97.

Siddiqui T, Qaiser M. A palynological study of the family gramineae from Karachi. Pak J Bot 1988;20:161-76.

Thanikaimoni G. Contribution to the pollen morphology of *Eriocaulaceae*. Pollen et spores 1965;7:181-291.

Walker JW, Doyle JA. The bases of angiosperm phylogeny: Palynology. Ann Miss Bot Gard 1975;62:664-723.

Willmer P. Pollination and Floral Ecology. Princeton: Princeton University Press; 2011.

Wodehouse RP. Pollen Grains: Their Structure Identification and Significance in Science and Medicine. New York: Hafner; 1935.

Zavada MS. Comparative morphology of monocot pollen and evolutionary trends of apertures and wall structure. Bot Rev 1983;49:331-79.