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FLORISTIC COMPOSITION AND POLLEN MORPHOLOGY OF NAYACHAR: A NEWLY DEVELOPED ESTUARINE ISLAND OF WEST BENGAL, INDIA

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ABSTRACT
The present study aimed to determine floristic composition and pollen morphology of Nayachar Island, a recently developed estuarine island of West Bengal, India. The study revealed 85 plant species belonging to 35 families. Fabaceae is the most preponderant family, whereas the members of Poaceae and Cyperaceae were with higher densities. Trees were predominant life forms, which demonstrate a typical mangrove ecosystem. Among the identified taxa, 15 were true mangroves, 29 were mangrove associates and remaining 41 taxa were of other types. Regarding the pollen morphology, mangroves exhibits diversified pollen morphological characters. All the pollen types were radially symmetrical except the members of Arecaceae. Among the studied species, pollen shape classes also greatly varied with prolate, sub prolate, prolate spheroidal, spheroidal, oblate spheroidal, sub oblate and oblate types. The amb (equatorial outline viewed from pole) was also varied between circular, triangular, sub triangular and rarely tetra angular. Apertural patterns were predominantly of trizonocolporate type. The commonest forms of surface ornamentations are reticulate, punctate or psilate type.

KEY WORDS: Mangrove species, Nayachar Island, pollen morphology.

INTRODUCTION

Nayachar is a recently appeared estuarine Island (Majumdar *et al*., 2012) and made its first emergence during 1941 as congregated sediment forming sandbar. As being the part of deltaic environment, the halophytic species including mangroves become the important floristic component of the Island. Mangroves are salt tolerant higher group of flowering plants (Naskar and Mandal, 1999) that occur in relatively sheltered areas along estuaries, coastal lagoons and backwaters. They are generally inundated and exposed during regular high and low tides, respectively. They are nurtured by a mixture of fresh water from rains and land drainage with coastal marine water (Banerjee *et al*., 2002). The plants of mangrove vegetation are relatively poor in species diversity and show similarities in their general architecture and physiological adaptations. Typical mangrove species usually have pneumatophores, stilt roots, knee roots, viviparous germination, xerophyllous leaves and salt excretory glands (Tomlinson, 1986). They provide ecosystem functions on tropical coasts (Gilman *et al*., 2008; Walters *et al*., 2008), including protection against the disasters like tsunamis (Kathiresan and Rajendran, 2005; Alongi, 2008). Despite its ecological and economical values, in the last two decades global mangroves have witnessed annual loss of between 0.16 and 0.39% due to rapid coastal development (Hamilton and Casey, 2016). The species richness of mangroves in many geographical regions is decreasing with time as a result of the destruction of mangrove forests and exposure to various anthropogenic stresses (Hamilton and Snedaker, 1984). Therefore, mangrove aforestation programmes are as important as habitat conservation and need to be considered as an important approach to increasing the productivity of intertidal lands along the coast, the deltas of major river system, river banks and be managed as a major component of ecosystem development. The past and present distribution of mangrove species on a global scale has been reviewed by several authors (Tomlinson, 1986; Duke *et al*., 1998; Wang *et al*., 2003; Spalding *et al*., 2010). Because of unique ecology and floristic composition of mangrove vegetation, it is a suitable ecosystem to use palynology in tracing the history and evolution (Blasco, 1984). Few palynological works on mangrove species were already done from Sundarban mangrove swamps (Das and Ghose, 1990; Gupta *et al*., 2008) and Kerala mangrove swamps (Lovly and Merlee Teresa, 2016; Surya and Hari, 2017). However, there is a paucity of data regarding pollen morphology of various plant species grown in Nayachar Island of West Bengal.
The present study aims to investigate the floristic composition with a note on pollen morphology of Nayachar Island in Purba Medinipur district of West Bengal, India, which has received very little attention.

MATERIALS & METHODS

Study area

The study was conducted in Nayachar Island which is located (21°54′ and 22°01′ N latitudes, 88°02′ and 88°08′ E longitudes) at the middle part of the estuarine section of Hooghly River in Purba Medinipur district of West

Bengal, India (Figure 1). The Island is spindle shaped and extended towards the south-west to north-east direction. It covers an area of 64 km^2 and become second largest Island of Hoogly estuary (Bandyopadhyay *et al*., 1998). The Island exhibits rich biodiversity in terms of salt marsh grasses and swampy mangrove plant species. The surface characteristic of this Island are much diversified due to its dynamic landscape behaviour.

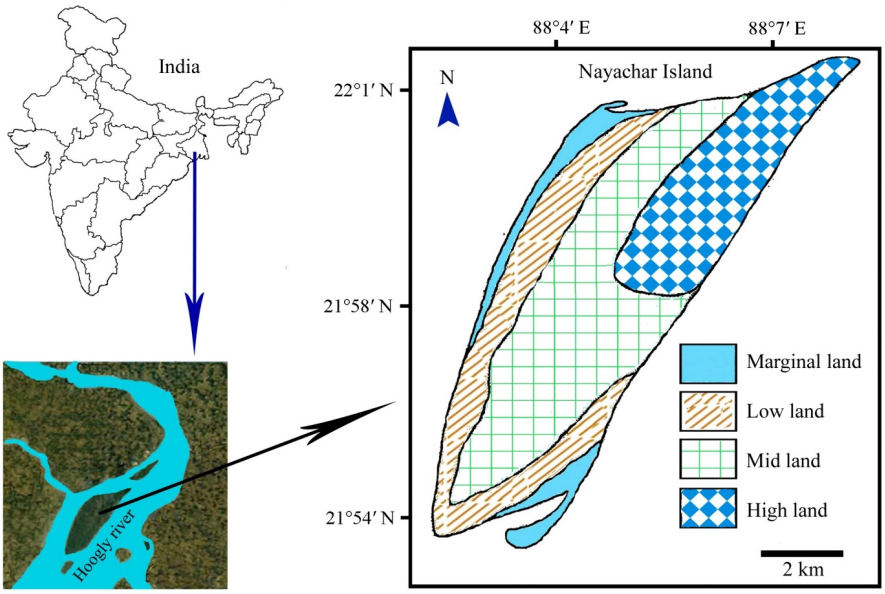

FIGURE 1: Location map of the study area

Data collection about floristic composition

We carried out random sampling of the area by quadrats of 5 m x 5 m. In our survey, we divided the Island into 4 vegetation zones viz. zone I (marginal land), zone II (low land), zone III (mid land) and zone IV i.e. high land (Table 1, Figure 1). For each zone 10 quadrats were taken into consideration. From each quadrat sample the obtained plant species were identified and counted separately. Then various parameters like Frequency, Abundance, Density, Maturity Index Value and Simpson's Diversity Index were calculated as follows:

$$\text{Frequency} = \frac{\text{Number of occurrences of a species}}{\text{Total number of site samples taken}} \times 100$$

$$\text{Abundance} = \frac{\text{Total number of individuals of a species}}{\text{Number of sampling units of occurrence}}$$

$$\text{Density} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrats sampled}}$$

$$\text{Maturity Index Value} = \frac{\text{Frequency of all species}}{\text{Number of species studied}} \times 100$$

$$\text{Simpson's Index of Diversity, D} = \frac{\sum n(n-1)}{N(N-1)}$$

Where, n is the number of individuals of each species and N is the total number of individuals of all species.

Collection of pollen samples

We collected anthers from mature flower buds just before anthesis by using clean forceps and preserved with FAA solution in a glass vial. Then anthers were crushed with a glass rod and filtered with a sieve.

Analyses of pollen samples

Each filtrated pollen sample was centrifuged at 2500 rpm for 10 minutes. Then 10 ml of acetolysis mixture (acetic anhydride and concentrated sulphuric acid in a ratio of 9:1) is added to the sediment (Erdtman, 1960). After thoroughly mixing, the mixture containing tube was placed in a water bath (at 100^{o}C) for 3 minutes. After cooling it was again centrifuged at 2500 rpm for 10 minutes. Again 5 ml of glacial acetic acid was added to the sediment and centrifuged at 2500 rpm for 10 minutes. After decanting, distilled water is added to the sediment and centrifuged twice at 2500 rpm for 10 minutes. The pollen sediment was taken on a small piece of glycerine jelly and transferred to the centre 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. Pollen grains were described using standard terminologies (Erdtman, 1952; Faegri and Iversen, 1975; Hesse *et al*., 2009; Punt *et al*., 2007).

RESULTS

Angiosperm flora in Nayachar Island

The outer most vegetation zone I is mostly mudflats and water logged of the Island. This part of the Island is colonized by *Cyperus rotundus* and *Porteresia coarctata*. Besides, *Avicennia marina* also frequently noted (Plate 1A).

PLATE 1: A-B. Marginal land vegetation with *Avicennia marina* and *Porteresia coarctata* respectively. C-D. Low land vegetation of *Cryptocoryne ciliata* and *Sonneratia apetala* respectively. E. Mid land vegetation of *Acanthus ilicifolius*. F-G. High land vegetation of *Heritiera fomes* and *Rhizophora mucronata* respectively

This part exhibits lowest plant diversity as well as lower maturation index value (Table 1). In zone II, *Aeluropus lagopoides*, *Aeluropus littoralis*, *Myriostachya wightiana* and *Porteresia coarctata* occurred frequently. Zone III dominated by *Aeluropus lagopoides*, *Aeluropus littoralis*, *Excoecaria agallocha* and *Myriostachya wightiana*. The zone IV is fringed by zone III, colonized by *Aegiceras corniculatum*, *Aeluropus lagopoides*, *Aeluropus littoralis*, *Ceriops tagel*, *Excoecaria agallocha* and *Sonneratia apetala*. The plant diversity and maturation index value are gradually increased from zone I to zone IV.

When we considered all the vegetation zones together, a total of 85 angiosperm plant species belongs to 35 families were recorded (Table 2). Most represented families were Fabaceae (15 taxa), followed by Amaranthaceae, Arecaceae, Poaceae (each family with 5 taxa), Acanthaceae, Euphorbiaceae, Meliaceae, Moraceae and Rhizophoraceae (each family with 4 taxa). However frequency, abundance and density were higher in case of

Poaceae (mainly given by *Porteresia coarctata*, *Aeluropus littoralis* and *Aeluropus lagopoides*) and Cyperaceae (mainly given by *Cyperus rotundus*). Among the identified taxa, 15 were true mangroves, 29 were mangrove associates and remaining 41 taxa were other types. The true mangroves were *Acanthus ilicifolius*, *Aegiceras corniculatum*, *Avicennia alba*, *Avicennia marina*, *Avicennia officinalis*, *Bruguiera gymnorrhiza*, *Ceriops tagel*, *Excoecaria agallocha*, *Heritiera fomes*, *Nypa fruticans*, *Rhizophora apiculata*, *Rhizophora mucronata*, *Sonneratia apetala*, *Xylocarpus granatum* and *Xylocarpus moluccensis*. According to life form of the identified plant species, most were trees (47 taxa), followed by herbs (23 taxa), shrubs (9 taxa) and climbers (6 taxa). Regarding worldwide conservation status of the Nayachar flora, most of them belong to Least Concern (LC) category. Only *Heritiera fomes* belongs to Endangered (EN) category. However, some of them are rare in West Bengal regional perspective.

TABLE 2: Plant species found in Nayachar Island of West Bengal, India

Species	Habit	Plant type	Frequency	Abundance	Density
Acanthaceae					
Acanthus ilicifolius	Shrub	M	42.50	7	2.98
Avicennia alba	Tree	M	7.50	1.33	0.10
Avicennia marina	Tree	M	17.50	1.86	0.32
Avicennia officinalis	Tree	M	10	1.25	0.12
Aizoaceae					
Sesuvium portulacastrum	Herb	A	7.50	15.67	1.18
Amaranthaceae					
Alternanthera sessilis	Herb	O	37.50	13.87	5.20
Amaranthus viridis	Herb	O	7.50	9	0.68
Salicornia brachiata	Herb	A	7.50	19	1.42
Suaeda australis	Herb	A	12.50	6.40	0.80
Suaeda maritima	Herb	A	15	5.83	0.88
Amaryllidaceae					
Crinum viviparum	Herb	O	5	11	0.55
Anacardiaceae					
Lannea coromandelica	Tree	O	5	1	0.05
Mangifera indica	Tree	O	7.50	1	0.08
Apocynaceae					
Calotropis procera	Shrub	O	7.50	2.33	0.18
Cascabela thevetia	Tree	O	7.50	1	0.08
Sarcobolus carinatus	Climber	A	22.50	4.67	1.05
Araceae					
Cryptocoryne ciliata	Herb	A	25	4.30	1.08
Arecaceae					
Areca catechu	Tree	A	5	1	0.05
Borassus flabellifer	Tree	O	5	1	0.05
Cocos nucifera	Tree	A	7.50	1	0.08
Nypa fruticans	Shrub	M	5	5	0.25
Phoenix paludosa	Tree	A	12.50	3.60	0.45
Asteraceae					
Chromolaena odorata	Shrub	O	7.50	3.33	0.25
Bignoniaceae					
Dolichandrone spathacea	Tree	A	12.50	4.40	0.55
Spathodea companulata	Tree	O	5	1	0.05
Boraginaceae					
Heliotropium curassavicum	Herb	A	20	16.38	3.28
Cactaceae					
Opuntia stricta	Shrub	A	5	3.50	0.18
Casuarinaceae					
Casuarina equisetifolia	Tree	O	10	1	0.10
Cleomaceae					
Cleome viscosa	Herb	O	7.50	3	0.22
Combretaceae					
Terminalia arjuna	Tree	O	2.50	1	0.02
Convolvulaceae					
Ipomoea pes-caprae	Climber	A	5	2	0.10
Ipomoea violacea	Climber	A	5	1	0.05
Cyperaceae					
Cyperus rotundus	Herb	O	25	310.70	77.68
Fimbristylis ferruginea	Herb	O	27.50	14.91	4.10
Fimbristylis nutans	Herb	O	30	11.92	3.58
Euphorbiaceae					
Croton bonplandianum	Herb	O	7.50	8.67	0.65
Excoecaria agallocha	Tree	M	27.50	5.91	1.62

Jatropha gossypiifolia	Shrub	O	2.50	4	0.10
Tragia involucrata	Climber	A	10	1.25	0.12
Fabaceae					
Acacia auriculiformis	Tree	O	10	1.25	0.12
Albizia lebbeck	Tree	O	2.50	1	0.02
Albizia saman	Tree	O	2.50	1	0.02
Crotalaria pallida	Herb	O	7.50	1.33	0.10
Dalbergia spinosa	Tree	A	7.50	1	0.08
Delonix regia	Tree	O	2.50	1	0.02
Derris trifoliata	Climber	A	17.50	6	1.05
Guilandina bonduc	Shrub	O	7.50	3.67	0.28
Millettia pinnata	Tree	A	5	1	0.05
Peltophorum pterocarpum	Tree	O	5	1	0.05
Parkinsonia aculeata	Tree	A	5	1	0.05
Pithecellobium dulce	Tree	O	2.50	1	0.02
Prosopis juliflora	Tree	A	7.50	1	0.08
Tamarindus indica	Tree	O	2.50	1	0.02
Vachellia nilotica	Tree	O	2.50	1	0.02
Lamiaceae					
Volkameria inermis	Shrub	A	12.50	3.20	0.40
Lecythidaceae					
Barringtonia racemosa	Tree	A	2.50	1	0.02
Lythraceae					
Sonneratia apetala	Tree	M	25	1.80	0.45
Malvaceae					
Heritiera fomes	Tree	M	10	1.75	0.18
Hibiscus tiliaceus	Tree	A	10	1.25	0.12
Thespesia populnea	Tree	A	7.50	1.33	0.10
Meliaceae					
Azadirachta indica	Tree	O	5	1	0.05
Swietenia mahagoni	Tree	O	2.50	1	0.02
Xylocarpus granatum	Tree	M	7.50	1	0.08
Xylocarpus moluccensis	Tree	M	7.50	1.33	0.10
Moraceae					
Artocarpus heterophyllus	Tree	O	2.50	1	0.02
Ficus benghalensis	Tree	O	5	1	0.05
Ficus elastica	Tree	O	2.50	1	0.02
Ficus religiosa	Tree	O	10	1.25	0.12
Myrtaceae					
Eucalyptus globulus	Tree	O	7.50	1.33	0.10
Phyllanthaceae					
Phyllanthus reticulatus	Shrub	O	10	2.50	0.25
Plantaginaceae					
Bacopa monnieri	Herb	A	27.50	26.91	7.40
Poaceae					
Aeluropus lagopoides	Herb	A	47.50	53	25.18
Aeluropus littoralis	Herb	A	37.50	115.07	43.15
Cynodon dactylon	Herb	O	25	31.50	7.88
Myriostachya wightiana	Herb	O	17.50	140.57	24.60
Porteresia coarctata	Herb	A	45	395.67	395.67
Portulacaceae					
Portulaca oleracea	Herb	A	7.50	58	4.35
Primulaceae					
Aegiceras corniculatum	Tree	M	17.50	2.57	0.45
Rhizophoraceae					
Bruguiera gymnorrhiza	Tree	M	10	2.25	0.22
Ceriops tagel	Tree	M	15	3.17	0.48
Rhizophora apiculata	Tree	M	5	3	0.15
Rhizophora mucronata	Tree	M	10	1.80	0.18
Sapotaceae					
Mimusops elengi	Tree	O	5	1	0.05
Solanaceae					
Solanum surattense	Herb	O	10	8	0.80
Vitaceae					
Cayratia trifolia	Climber	O	12.50	7.25	0.72

M- true mangrove, A- mangrove associate, O- other

Pollen morphologies of mangrove plant species

Light microscopic views of selected mangroves and mangrove associates are given in Plate 2. The morphology of pollen grains of the studied species are described below and summarized in Table 3.

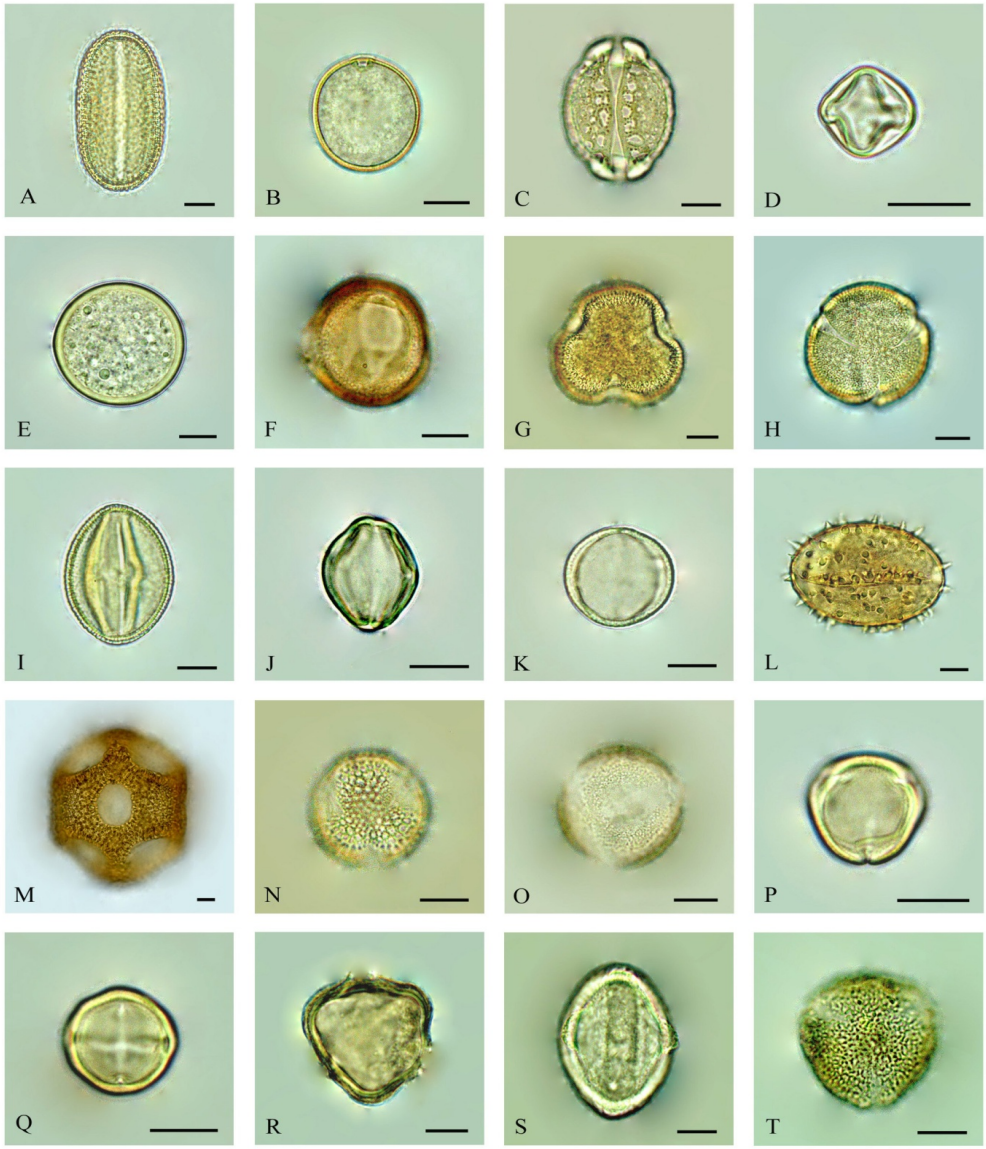

PLATE 2: Pollen grains of mangrove flora. A. *Acanthus ilicifolius*. B. *Aeluropus lagopoides*. C. *Barringtonia racemosa*. D. *Bruguiera gymnorrhiza*. E. *Cryptocoryne ciliata*. F. *Derris trifoliata*. G. *Dolichandrone spathacea*. H-I. *Excoecaria agallocha*. J. *Heliotropium curassavicum*. K. *Heritiera fomes*. L. *Nypa fruticans*. M. *Opuntia stricta*. N. *Parkinsonia aculeata*. O. *Prosopis juliflora*. P-Q. *Rhizophora mucronata*. R-S. *Sonneratia apetala*. T. *Tragia involucrata*

TABLE 3: Summary of pollen characters

Taxa	Aperture	Ectoaperture (µm)	Endoaperture (µm)	PA (µm)	ED (µm)	Ornamentation
Acanthus ilicifolius	3-colpate	24.4 x 1.2	-	61	32	Reticulate
Aegiceras corniculatum	3-colporate	18.7 x 3.9	2.7 x 8.2	32	27	Punctate
Aeluropus lagopoides	1-porate	2.9 x 2.9	-	27	27	Psilate
Aeluropus littoralis	1-porate	2.7 x 2.7	-	25	25	Psilate
Areca catechu	1-sulcate	24.3 x 3.8	-	23	41	Finely reticulate
Avicennia alba	3-colporate	19.3 x 9.4	8.2 x 4.4	24	23	Reticulate
Avicennia marina	3-colporate	16.7 x 6.4	6.5 x 6.9	42	37	Reticulate
Avicennia officinalis	3-colporate	24 .0x 10.7	10.7 x 9.7	47	50	Reticulate
Bacopa monnieri	3-colpate	14.2 x 11.7	-	28	29	Reticulate
Barringtonia racemosa	3-syncolpate	37 x 4.6	-	37	30	Reticulate
Bruguiera gymnorrhiza	3-colporate	11.0 x 1.6	2.4 x 6.4	13	14	Psilate
Ceriops tagel	3-colporate	8.6 x 0.5	1.7 x 5.1	10	11	Punctate

Cocos nucifera	1-sulcate	22.3 x 3.4	-	20	35	Finely reticulate
Cryptocoryne ciliata	Inaperturate	-	-	37	37	Psilate
Dalbergia spinosa	3-colporate	15.3 x 1.6	5.8 x 5.8	19	15	Punctate
Derris trifoliata	3-colporate	15.4 x 2.2	5.1 x 2.2	27	27	Reticulate
Dolichandrone spathacea	3-colporate	22.2 x 7.6	7.4 x 7.4	42	42	Reticulate
Excoecaria agallocha	3-colporate	26.2 x 4.3	5.2 x 2.1	36	34	Reticulate
Heliotropium curassavicum	3-colporate	14.3 x 2.4	2.4 x 2.4	18	20	Psilate
Heritiera fomes	3-colporate	18.1 x 3.3	4.1 x 3.2	22	23	Reticulate
Hibiscus tiliaceus	Pantoporate	6.3 x 6.3	-	117	117	Echinate
Ipomoea pes-caprae	Pantoporate	5.5 x 5.5	-	77	77	Echinate
Ipomoea violacea	Pantoporate	3.4 x 3.4	-	33	33	Echinate
Millettia pinnata	3-colporate	22.4 x 3.6	3.4 x 3.6	35	27	Psilate
Nypa fruticans	1-sulcate	51.0 x 1.5	-	47	57	Echinate
Opuntia stricta	6-porate	25.0 x 22.0	-	90	84	Reticulate
Parkinsonia aculeata	3-colporate	18.3 x 9.4		21	24	Reticulate
Phoenix paludosa	1-sulcate	21.6 x 2.8	-	16	24	Finely reticulate
Porteresia coarctata	1-porate	2.2 x 2.2	-	35	35	Granulate
Portulaca oleracea	Pantocolpate	11.0 x 5.0	-	73	73	Granulate
Prosopis juliflora	3-colporate	24.7 x 6.3	6.2 x 6.2	30	30	Finely reticulate
Rhizophora apiculata	3-colporate	19 .0 x 0.8	2.8 x 2.8	19	17	Punctate
Rhizophora mucronata	3-colporate	16.2 x 0.8	1.9 x 1.9	16	16	Finely reticulate
Salicornia brachiata	Pantoporate	3.8 x 3.8	-	28	28	Microechinate
Sarcobolus carinatus	Pollinial form	-	-	-	-	-
Sesuvium portulacastrum	3-colpate	13.6 x 2.2		13	12	Punctate
Sonneratia apetala	3-porate	5.0 x 5.0	-	39	31	Reticulate
Suaeda australis	Pantoporate	1.7 x 1.7	-	22	22	Microechinate
Suaeda maritima	Pantoporate	1.6 x 1.6	-	17	17	Microechinate
Thespesia populnea	Pantoporate	9.2 x 9.2	-	73	71	Echinate
Tragia involucrata	3-colporate	11.3 x 1.8	1.7 x 1.7	27	27	Reticulate
Volkameria inermis	3-colpate	22.4 x 4.2	-	54	41	Echinate
Xylocarpus granatum	3,4-colporate	12.3 x 1.2	4.0 x 4.3	33	33	Punctate
Xylocarpus moluccensis	4,5-colporate	9.4 x 1.0	2.2 x 2.4	30	30	Punctate

PA- polar axis length, ED- equatorial diameter

***Acanthus ilicifolius*:** Pollen grains are radially symmetrical and prolate (PA: 61 µm, ED: 32 µm) in shape. Amb is circular. The apertural pattern is trizonocolpate type with narrowly elliptic colpi (24.4 µm x 1.2 µm) which extending from pole to pole. Exine is 1.9 µm thick, sexine distinctly tegillate and thicker than nexine. Exine ornamentation is reticulate-homobrochate type.

***Aegiceras corniculatum*:** Pollen grains are radially symmetrical and prolate spheroidal (PA: 32 µm, ED: 27 µm) in shape. Amb is circular. The apertural pattern is trizonocolporate type. Ectoaperture is narrowly elliptic colpi (18.7 µm x 3.9 µm) which extending from pole to pole. Endoaperture is elliptic (2.7 µm x 8.2 µm). Exine is 1.4 µm thick, sexine distinctly tegillate and thicker than nexine. Exine ornamentation is punctate type.

***Aeluropus lagopoides*:** Pollen grains are radially symmetrical and spheroidal (27 µm in diameter) in shape. Amb is circular. The apertural pattern is monoporate type. Pore is circular with 2.9 µm in diameter. Exine is 1.8 µm thick and sexine thicker than nexine. Exine ornamentation is psilate type.

***Aeluropus littoralis*:** Pollen grains are radially symmetrical and spheroidal (25 µm in diameter) in shape. Amb is circular. The apertural pattern is monoporate type. Pore is circular (2.7 µm in diameter). Exine is 1.8 µm thick and sexine thicker than nexine. Exine ornamentation is psilate type.

***Areca catechu*:** Pollen grains are bilaterally symmetrical and oblate (PA: 23 µm, ED: 41 µm) in shape. Amb is elliptic. The apertural pattern is monosulcate type. Sulcus is 24.3 µm in length and 3.8 µm in width. Exine is 1.7 µm thick. Exine ornamentation is finely reticulate type.

***Avicennia alba*:** Pollen grains are radially symmetrical and prolate spheroidal (PA: 24 µm, ED: 23 µm) in shape. Amb is circular. The apertural pattern is trizonocolporate type. Ectoaperture is narrowly elliptic colpi (19.3 µm x 9.4 µm) and endoaperture is oval (8.2 µm x 4.4 µm) in shape. Exine is 2.0 µm thick, sexine distinctly tegillate and thicker than nexine. Exine ornamentation is reticulate-homobrochate type.

***Avicennia marina*:** Pollen grains are radially symmetrical and prolate spheroidal (PA: 42 µm, ED: 37 µm) in shape. Amb is circular. The apertural pattern is trizonocolporate type. Ectoaperture is narrowly elliptic colpi (16.7 µm x 6.4 µm) and endoaperture is oval (6.5 µm x 6.9 µm) in shape. Exine is 2.5 µm thick, sexine distinctly tegillate and thicker than nexine. Exine ornamentation is reticulate-homobrochate type.

***Avicennia officinalis*:** Pollen grains are radially symmetrical and prolate spheroidal (PA: 47 µm, ED: 50 µm) in shape. Amb is circular. The apertural pattern is trizonocolporate type. Ectoaperture is narrowly elliptic colpi (24 µm x 10.7 µm) and endoaperture is oval (10.7 µm x 9.7 µm) in shape. Exine is 2.5 µm thick, sexine distinctly tegillate and thicker than nexine. Exine ornamentation is reticulate-homobrochate type.

***Bacopa monnieri*:** Pollen grains are radially symmetrical and oblate spheroidal (PA: 28 µm, ED: 29 µm) in shape. Amb is triangular. The apertural pattern is trizonocolpate type with broadly elliptic colpi (14.2 µm x 11.7 µm). Exine is 1.9 µm thick. Exine ornamentation is reticulate type.

***Barringtonia racemosa*:** Pollen grains are radially symmetrical and sub prolate (PA: 37 µm, ED: 30 µm) in shape. Amb is sub triangular. The apertural pattern is trizonosyncolpate type. Colpi are narrow and covering the whole polar axis. Polar ends compressed and forms the polar cushions. Mesocolpium is bulged. Exine is 2.6 µm thick. Sexine is thicker than nexine. Exine ornamentation is coarsely reticulate adjacent to colpi and in sub polar areas, psilate elsewhere.

***Bruguiera gymnorrhiza*:** Pollen grains are radially symmetrical and oblate spheroidal (PA: 13 µm, ED: 14 µm) in shape. Amb is circular. The apertural pattern is trizonocolporate type. Ectoaperture is narrowly elliptic colpi (11 µm x 1.6 µm) and endoaperture is oval (2.4 µm x 6.4 µm) in shape. Exine is 0.5 µm thick and sexine thicker than nexine. Exine ornamentation is psilate type.

***Ceriops tagel*:** Pollen grains are radially symmetrical and oblate spheroidal (PA: 10 µm, ED: 11 µm) in shape. Amb is circular. The apertural pattern is trizonocolporate type. Ectoaperture is narrowly elliptic colpi (8.6 µm x 0.5 µm) and endoaperture is elliptic (1.7 µm x 5.1 µm). Exine is 0.9 µm thick, sexine distinctly tegillate and thicker than nexine. Exine ornamentation is punctate type.

***Cocos nucifera*:** Pollen grains are bilaterally symmetrical and oblate (PA: 20 µm, ED: 35 µm) in shape. Amb is elliptic. The apertural pattern is monosulcate type. Sulcus is 22.3 µm in length and 3.4 µm in width. Exine is 1.7 µm thick. Exine ornamentation is finely reticulate type.

***Cryptocoryne ciliata*:** Pollen grains are radially symmetrical and spheroidal (37 µm in diameter) in shape. Amb is circular. The pollen grains are inaperturate. Exine is 1.5 µm thick and sexine thicker than nexine. Exine ornamentation is psilate type.

***Dalbergia spinosa*:** Pollen grains are radially symmetrical and sub prolate (PA: 19 µm, ED: 15 µm) in shape. Amb is sub triangular. The apertural pattern is trizonocolporate type. Ectoaperture is narrowly elliptic colpi (15.3 µm x 1.6 µm) and endoaperture is more or less circular with 5.8 µm in diameter. Exine is 1.2 µm thick. Sexine is thicker than nexine. Exine ornamentation is punctate type.

***Derris trifoliata*:** Pollen grains are radially symmetrical and spheroidal (27 µm in diameter) in shape. Amb is circular. The apertural pattern is trizonocolporate type with narrowly elliptic colpi. Exine is 2.0 µm thick and sexine thicker than nexine. Exine ornamentation is reticulate-homobrochate type.

***Dolichandrone spathacea*:** Pollen grains are radially symmetrical and spheroidal (42 µm in diameter) in shape. Amb is circular. The apertural pattern is trizonocolporate type with narrowly elliptic colpi. Exine is 2.5 µm thick and sexine thicker than nexine. Exine ornamentation is reticulate-homobrochate type.

***Excoecaria agallocha*:** Pollen grains are radially symmetrical and prolate spheroidal (PA: 36 µm, ED: 34 µm) in shape. Amb is circular. The apertural pattern is trizonocolporate type with narrowly elliptic colpi which extending from pole to pole. Exine is 2.0 µm thick and sexine thicker than nexine. Exine ornamentation is reticulate-homobrochate type.

***Heliotropium curassavicum*:** Pollen grains are radially symmetrical and oblate spheroidal (PA: 18 µm, ED: 20 µm) in shape. Amb is circular. The apertural pattern is trizonocolporate type with narrowly elliptic colpi. Exine is 1.1 µm thick and sexine thicker than nexine. Exine ornamentation is psilate type.

***Heritiera fomes*:** Pollen grains are radially symmetrical and oblate spheroidal (PA: 22 µm, ED: 23 µm) in shape. Amb is circular. The apertural pattern is trizonocolporate type with narrowly elliptic colpi. Exine is 1.3 µm thick and sexine thicker than nexine. Exine ornamentation is reticulate type.

***Hibiscus tiliaceus*:** Pollen grains are radially symmetrical and spheroidal (117 µm in diameter) in shape. Amb is circular. The apertural pattern is pantoporate type. Aperture operculate with pore diameter of 6.3 µm. Exine is 6.3 µm thick and sexine is much thinner than nexine. Exine ornamentation is echinate type. The spines are 20 µm in length and 6.3 µm in width.

***Ipomoea pes-caprae*:** Pollen grains are radially symmetrical and spheroidal (77 µm in diameter) in shape. Amb is circular. The apertural pattern is pantoporate type. Pori are 5.5 µm in diameter. Exine is 3.6 µm thick and sexine thinner than nexine. Exine ornamentation is echinate type. The spines are 10.8 µm long, broad and bulbous at base, and gradually tapering towards the apex with a more acute tip.

***Ipomoea violacea*:** Pollen grains are radially symmetrical and spheroidal (33 µm in diameter) in shape. Amb is circular. The apertural pattern is pantoporate type. Pori are 3.4 µm in diameter. Exine is 1.8 µm thick and sexine thinner than nexine. Exine ornamentation is echinate type. The spines are 4.7 µm long, slender and blunt at the ends.

***Millettia pinnata*:** Pollen grains are radially symmetrical and sub prolate (PA: 35 µm, ED: 27 µm) in shape. Amb is triangular. The apertural pattern is trizonocolporate type. Ectoaperture is narrowly elliptic colpi (22.4 µm x 3.6 µm). Endoaperture is oval (3.4 µm x 3.6 µm) and lalongate. Exine is 1.2 µm thick. Sexine is thicker than nexine. Exine ornamentation is psilate type.

***Nypa fruticans*:** Pollen grains are bilaterally symmetrical and sub oblate (PA: 47 µm, ED: 57 µm) in shape. Amb is elliptic. The apertural pattern is monosulcate type. Exine is 1.2 µm thick and sexine thicker than nexine. Exine ornamentation is echinate type. The spines are 3.5 µm in height with slightly wide base and acute apex.

***Opuntia stricta*:** Pollen grains are radially symmetrical and prolate spheroidal (PA: 90 µm, ED: 84 µm) in shape. Amb is tetra angular. The apertural pattern is hexaforate type. Pores are oval shaped (25 µm x 22 µm). Exine is 7.6 µm thick. Exine ornamentation is reticulate-heterobrochate type.

***Parkinsonia aculeata*:** Pollen grains are radially symmetrical and oblate spheroidal (PA: 21 µm, ED: 24 µm) in shape. Amb is circular. The apertural pattern is trizonocolporate type with narrowly elliptic colpi. Exine is 1.9 µm thick and sexine thicker than nexine. Exine ornamentation is reticulate-homobrochate type.

***Phoenix paludosa*:** Pollen grains are bilaterally symmetrical and oblate (PA: 16 µm, ED: 24 µm) in shape. Amb is oval. The apertural pattern is monosulcate type. Sulcus is 21.6 µm in length and 2.8 µm in width. Exine is 1.0 µm thick. Exine ornamentation is finely reticulate type.

***Porteresia coarctata*:** Pollen grains are radially symmetrical and spheroidal (35 µm in diameter) in shape. Amb is circular. The apertural pattern is monoporate and annulate type. Pore diameter is 2.2 µm. Exine is 1.8 µm thick and sexine thicker than nexine. Exine ornamentation is granulate type.

***Portulaca oleracea*:** Pollen grains are radially symmetrical and spheroidal (73 µm in diameter) in shape. Amb is circular. The apertural pattern is pantocolpate type. Colpi are broadly elliptic (11 µm x 5 µm). Exine is 4.2 µm thick and sexine thicker than nexine. Exine ornamentation is granulate type.

***Prosopis juliflora*:** Pollen grains are radially symmetrical and spheroidal (30 µm in diameter) in shape. Amb is circular. The apertural pattern is trizonocolporate type with narrowly elliptic colpi. Exine is 2.0 µm thick and sexine thicker than nexine. Exine ornamentation is finely reticulate type.

***Rhizophora apiculata*:** Pollen grains are radially symmetrical and prolate spheroidal (PA: 19 µm, ED: 17 µm) in shape. Amb is triangular. The apertural pattern is trizonocolporate type. Ectoaperture is narrowly elliptic colpi (19 µm x 0.8 µm) and endoaperture is circular (2.8 µm in diameter). Exine is 1.4 µm thick, sexine distinctly tegillate and thicker than nexine. Exine ornamentation is punctate type.

***Rhizophora mucronata*:** Pollen grains are radially symmetrical and spheroidal (16 µm in diameter) in shape. Amb is circular. The apertural pattern is trizonocolporate-synorate type. Ectoaperture is narrowly elliptic colpi (16.2 µm x 0.8 µm) and endoaperture is circular (1.9 µm in diameter). Exine is 1.5 µm thick and sexine thicker than nexine. Exine ornamentation is finely reticulate type.

***Salicornia brachiata*:** Pollen grains are radially symmetrical and spheroidal (28 µm in diameter) in shape. Amb is circular. The apertural pattern is pantoporate type. Aperture is circular (3.8 µm in diameter). Exine is 1.6 µm thick. Exine ornamentation is microechinate type.

***Sarcobolus carinatus*:** Pollen grains are aggregated into pollinia. The pollinium sac is oval (102 µm x 53 µm) in shape. The caudicle is 82 µm in length and 30 µm in breadth. The corpusculum is 80 µm in length and 32 µm in breadth.

***Sesuvium portulacastrum*:** Pollen grains are radially symmetrical and prolate spheroidal (PA: 13 µm, ED: 12 µm) in shape. Amb is sub triangular. The apertural pattern is trizonocolpate type. Colpi are narrowly elliptic (13.6 µm x 2.2 µm). Exine is 1.7 µm thick. Exine ornamentation is sparsely punctate type.

***Sonneratia apetala*:** Pollen grains are radially symmetrical and sub prolate (PA: 39 µm, ED: 31 µm) in shape. Amb is triangular and planaperturate. The apertural pattern is trizonoporate type. Aperture is circular (5 µm in diameter). Exine is 4.5 µm thick and sexine thicker than nexine. Exine ornamentation is reticulate-homobrochate type.

***Suaeda australis*:** Pollen grains are radially symmetrical and spheroidal (22 µm in diameter) in shape. Amb is circular. The apertural pattern is pantoporate type. Aperture is circular (1.7 µm in diameter). Exine is 1.9 µm thick. Exine ornamentation is microechinate type.

***Suaeda maritima*:** Pollen grains are radially symmetrical and spheroidal (17 µm in diameter) in shape. Amb is circular. The apertural pattern is pantoporate type. Aperture is circular (1.6 µm in diameter). Exine is 1.8 µm thick. Exine ornamentation is microechinate type.

***Thespesia populnea*:** Pollen grains are radially symmetrical and prolate spheroidal (PA: 73 µm, ED: 71 µm) in shape. Amb is circular. The apertural pattern is pantoporate type. Pori are circular (9.2 µm in diameter). Exine is 3.9 µm thick. Exine ornamentation is echinate type. Spines are 8 µm in length and 2.8 µm in width.

***Tragia involucrata*:** Pollen grains are radially symmetrical and spheroidal (27 µm in diameter) in shape. Amb is circular. The apertural pattern is trizonocolporate-synorate type with narrowly elliptic colpi. Exine is 2.0 µm thick and sexine thicker than nexine. Exine ornamentation is reticulate-homobrochate type.

***Volkameria inermis*:** Pollen grains are radially symmetrical and sub prolate (PA: 54 µm, ED: 41 µm) in shape. Amb is sub triangular. The apertural pattern is trizonocolpate type. Colpi are narrowly elliptic (22.4 µm x 4.2 µm). Exine is 2.6 µm thick. Exine ornamentation is echinate type.

***Xylocarpus granatum*:** Pollen grains are radially symmetrical and spheroidal (33 µm in diameter) in shape. Amb is circular. The apertural pattern is tri to tetrazonocolporate type. Ectoaperture is narrowly elliptic colpi (12.3 µm x 1.2 µm) and endoaperture is oval (4.0 µm x 4.3 µm). Exine is 1.0 µm thick, sexine distinctly tegillate and thicker than nexine. Exine ornamentation is punctate type.

***Xylocarpus moluccensis*:** Pollen grains are radially symmetrical and spheroidal (30 µm in diameter) in shape. Amb is circular. The apertural pattern is tetra to pentazonocolporate type. Ectoaperture is narrowly elliptic colpi (9.4 µm x 1.0 µm) and endoaperture is oval (2.2 µm x 2.4 µm). Exine is 1.2 µm thick, sexine distinctly tegillate and thicker than nexine. Exine ornamentation is punctate type.

DISCUSSION

Nayachar Island comprises of different types of plants species including true mangroves, mangrove associates and others plant species. The mangrove species were already documented from India (Das *et al*., 1997; Mandal and Naskar, 2008; Barik and Chowdhury, 2014) as well as from other countries (Satyanarayana *et al*., 2010). The number of identified true mangrove taxa from Nayachar Island was quite lower than the other mangrove vegetation sites like Andaman Island (Singh and Garge, 1993) and Sundarban Delta (Barik and Chowdhury, 2014). The island exhibits moderate biodiversity in terms of salt marsh grasses. Though, the vegetation of marginal and low land area of the Island showed little plant diversity. The maturity index values were also lower in these two vegetation zones. This finding was matched with the previous observations made by Bandyopadhyay *et al*. (1998). The lower maturity index indicate that Nayachar is a newly growing Island.

Pollen morphologies greatly varied from species to species. This is due to variation of taxa in different ranks included in this study. pollen grains of all the studied taxa were monad of type, with one exception viz. *Sarcobolus carinatus* (a member of Asclepiadoideae of Apocynaceae)

where pollen grains are aggregated forming pollinia. Majority of the pollen grains were radially symmetric except the members of Arecaceae. Most members of the family are characterized by bilaterally symmetrical grains having monosulcate aperture (Rodríguez and Oliver, 2002). Apertural patterns were also greatly varied. The most common type was trizonocolporate, as consistent with previous studies (Lovly and Merlee Teresa, 2016). *Cryptocoryne ciliata*, a member of Araceae showed inaperturate type of pollen grains. Pollen shape classes also greatly varied from prolate, sub prolate, prolate spheroidal, spheroidal, oblate spheroidal to sub oblate types. Most pollen types were with circular, triangular and sub triangular amb. Tetra angular amb is rare in occurrence, only in case of *Opuntia stricta*. Surface ornamentation predominantly of reticulate type, followed by punctate, psilate, microechinate and granulate types. Dominance of reticulate type ornamentation of mangrove species was also reported by Surya and Hari (2017). Members of Amaranthaceae were with microechinate surface ornamentation.

The comprehensive information about the floristic composition of Nayachar Island provided here will help in the long term monitoring of mangrove species and formulating species specific conservation strategies. Moreover, the short descriptions of pollen can be used as a tool to identify plant species to which unknown pollen grains belong.

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