The Palaeobotanist 64(2015): 169–176
0031–0174/2015

Pollen deposition pattern in Kathali wetland and its adjoining areas of Garo Hills, Meghalaya, northeast India

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(Received 31 November, 2015; revised version accepted 22 December, 2015)

ABSTRACT

Basumatary SK, Tripathi S, Jalil A & Rahman A 2015. Pollen deposition pattern in Kathali wetland and its adjoining areas of Garo Hills, Meghalaya, northeast India. The Palaeobotanist 64(2): 169–176.

This paper presents a palynological dataset on Kathali wetland and vicinity forest area to characterize the pollen depositional pattern in relation to existing vegetation. The overall palynodata is suggestive of the tropical deciduous forest admixture with the evergreen taxa which coheres with extant vegetation. Pollen clumping in the palynoassemblage was highly significant and suggests their local origin and entomophilous nature. The various pollen distributions were observed in continuation at study sites which confirmed that the pollen deposition pattern in wetland depends on parent plant growth, water level and surrounding vegetation. The main forest elements include *Syzygium*, *Salmalia*, *Lagerstroemia*, *Duabanga* and *Barringtonia* along with *Impatiens* in the palynoassemblage which strongly indicate the high rainfall in the region. Thus, the generated modern palynodata could be precisely utilized to reconstruct the palaeovegetation and past climate in relation to palaeomonsoonal activity through the pollen analysis of sedimentary core/profile from the region and its correlation with other tropical parts of India and Asia.

Key–words—Palynoassemblage, Pollen clumps, Pollen deposition, Kathali wetland, Meghalaya.

गारो पहाड़ियाँ, मेघालय, उत्तरपूर्व भारत की काठली आर्द्रभूमि एवं इसके सामीप्य वन में पराग निक्षेपणीय प्ररूप

एस. के. बासुमतारी, स्वाति त्रिपाठी, अब्दुल जलील एवं अज़ीज़ुर रहमान

सारांश

विद्यमान वनस्पति के संबंध में पराग निक्षेपणीय प्ररूप की विशेषता बताने को यह दस्तावेज काठली आर्द्रभूमि एवं सामीप्य वन क्षेत्र पर एक परागाणिक आँकड़ासमूह प्रस्तुत करता है। समग्र परागाणुआँकड़ा उष्णकटिबंधीय पतझड़ी वन अधिमिश्रण सदाहरित टैक्सा को सुझावित है जो मौजूदा वनस्पति के पूर्णतः सुसंगत है। परागाणुसमुच्चय में पराग गुच्छन अति सार्थक था तथा उनके स्थानीय उद्‌गम एवं कीटपरागित प्रकृति को जताता है। स्थलों के अध्ययन की अनवरतता में तमाम पराग वितरण प्रेक्षित किए गए थे जिससे साबित (सिद्ध) हुआ कि नम जमीन (आर्द्र भूमि) में निक्षेपण प्ररूप मूल पादप वृदधि जल स्तर और आस–पास की वनस्पति पर निर्भर करता है। मुख्य वन तत्वों में परागाणुसमुच्चय में *इम्पेशिएन्स* के साथ–साथ *सायज़ीजियम, साल्मेलिया, लेगरस्ट्रोमिया, दुआबंगा* एवं *बैरिंगटोनिया* सन्निहित हैं। जो अंचल में प्रबलतया उच्च वर्षा द्योतित करते हैं। इस प्रकार, अंचल से अवसादी क्रोड परिच्छेदिका के माध्यम से पुरामानसूनी सक्रियता के मामले में पुरावनस्पति और गत जलवायु की पुनर्रचना करने में यह जनित आधुनिक परागाणु आँकड़ा हूबहू तथा भारत व एशिया के अन्य उष्णकटिबंधीय भागों से इसके सहसंबंध में इस्तेमाल हो सकेगा ।

सूचक शब्द—परागाणुसमुच्चय, पराग संपुंजन, पराग निक्षेपण, काठली आर्द्रभूमि, मेघालय।

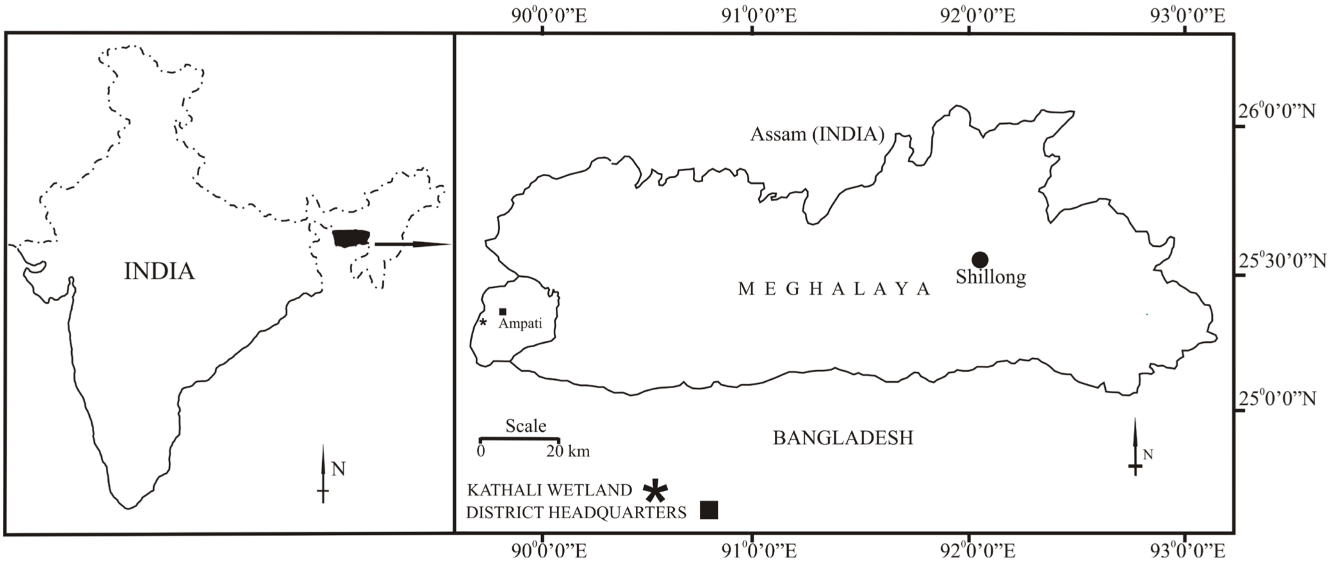

Fig. 1—Location map showing the study area.

INTRODUCTION

THE Garo Hills is located in the western part of the state of Meghalaya in northeast region of India (Lat. 26º48' and 27º53' N, Long. 93º42' and 94º20' E) (Fig. 1). The region is enriched with the diversified flora and fauna due to hilly terrain and high rainfall. The relationship between modern pollen and vegetation is well established and is prerequisite for palaeoecological reconstruction (Bent & Wright, 1963; Janssen, 1967; Wright, 1967; Overpeck *et al*., 1985; Prentice, 1985; Bunting *et al*., 2004; Gosling *et al*., 2009). A lack of many pollen species from the tropics are observed in surface and sedimentary basin samples, despite their high pollen production and dispersal to sample sites, but with the aid of modern pollen spectra, the modern pollen deposition pattern could be successfully related to the contemporary vegetation (Davies *et al*., 1971; Luly, 1997; Birks & Seppa, 2004; Wilmshurst & McGlone, 2005; Zhao *et al*., 2009). In general, five main sources have been observed for the accumulation of pollen grains into lake sediments: (1) atmosphere, (2) local plants (pollen directly transferred into the basin), (3) slope wash, (4) pollen in twigs and leaves washed into the lake basin and (5) river and streams entering the lake basin (Fall, 1992). It is also established that the large basin size accumulate more pollen grain from regional sources as reflected in their palynoassemblages, while the small basins are mostly affected by local vegetation (Bradshaw & Webb, 1985; Sugita, 1993).

Several Botanists, Zoologists, Geologists, Ecologists and Palynologists studied on Northeast region of India due to its rich biodiversity, flood and earthquake prone areas. An extensive research work has been carried out in northeast India in order to establish modern pollen–vegetation relationship (Gupta & Sharma, 1985; Bera, 2000; Basumatary & Bera, 2007; Dixit & Bera, 2012; Bera *et al*., 2012, 2014; Basumatary *et al*., 2013). In Meghalaya, the well known Balpakram Valley, covering the southeastern part of Garo Hills has been studied for the detailed assessment of modern pollen deposition pattern. The palynoassemblage in Balpakram Valley reflects the vegetation similar to the Indo–Burmese vegetation except for a unique *Duabanga–Schima–Nepenthes* assemblage due to high monsoonal activity with a strong perennial river and streamlet system. Also, the presence of high frequencies of evergreen trees along with *Dendrophthoe*, Piperaceae and *Impatiens* are significant and suggestive of dense forest with high monsoonal activity (Basumatary *et al*., 2014). The palynoassemblage recovered from bat–guano and surface soil samples of Siju Cave, Meghalaya (also known as cave of bats) reflects a close similarity between the modern pollen and vegetation. The native flora in the area is dominated by riparian taxa like *Duabanga, Syzygium, Careya* and *Ficus*, along with evergreen and deciduous elements. The evergreen taxa like *Mesua, Elaeocarpus* and *Garcinia*, along with *Impatiens*, reflect the high precipitation in the region (Basumatary *et al*., 2015). Hitherto, the present study area, south–west Garo Hills District of Meghalaya has been untouched in the context of establishing the modern pollen deposition pattern. Thus, the main objective of this paper is to display the pollen deposition pattern in the Kathali wetland in relation to the current vegetation in the region which will be precisely utilized for the reconstruction of palaeovegetation and past climate in Garo Hills and its correlation with other parts of India.

STUDY SITE AND VEGETATION

The Kathali wetland (Lat. 27°12" N and Long. 94°02" E) is located in newly formed, the south west Garo Hills District of Meghalaya which lies at close proximity to

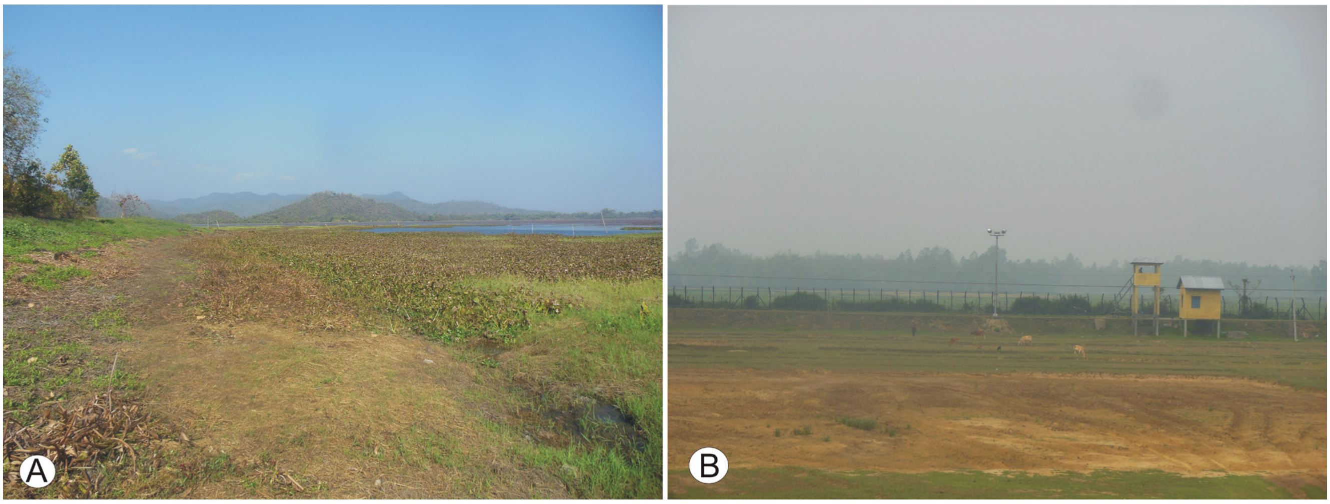

Fig. 2—A. View of a Kathali wetland. B. View of a India and Bangladesh border near Kathali wetland.

Bangladesh border (Fig. 2B). During summer, the wetland area increases due to heavy rainfall and during winter, it decreases due to low rainfall (Fig. 2A). The wetland vegetation is very rich and largely comprised of grasses, Cyperaceae, Polygonaceae, Onagraceae and Ranunculaceae, in the margin areas. The aquatic taxa namely *Nymphoides indica*, *Euryale ferox*, *Nymphaea nouchali*, *Lemna minor* and *Utricularia flexuosa* are growing luxuriantly in the centre of the wetland. Besides, aquatic angiosperms, some pteridophytic elements such as *Ceratopteris thalictroides*, *Marsilea minuta*, *Isoetes coromandelina*, *Pistia stratiotes* and *Azolla pinnata* are also luxuriantly growing within the swamp. However, other terrestrial ferns namely *Adiantum phillippense*, *Angiopteris evecta*, *Blechnum orientale* and *Equisetum diffusum* are growing at the periphery of the wetland along with other terrestrial herbs. Scattered deciduous forest occurs around the wetland composing of *Terminalia bellirica*, *Salmalia malabarica*, *Dillenia pentagyna*, *Careya arborea* and *Semecarpus anacardium*. Few evergreen taxa like *Schima wallichi*, *Elaeocarpus rogusus* and *Artocarpus chaplasha* are also growing in association with major deciduous elements in the vicinity of forest.

CLIMATE AND SOIL

The climate of the area is controlled by the southwest monsoon. During summer, it is hot and humid. The maximum temperature during summer reaches up to 35º C and during winter, the minimum temperature dips down to 3º C. The relative humidity is ranging from 75–98%. The annual rainfall in the region ranges from 1,494 to 2,552 mm. The soil of the wetland is alluvial fine loamy in nature and the forest soil is fine loam sandy in nature and rich in humus.

MATERIAL AND METHODS

Field Work

A total number of twelve surface samples were collected in a linear transect at approximately 50 meter intervals from the centre towards the margin of the Kathali wetland. A PVC pipe of 80 mm diameter was cored into the swamp bed and the upper 0.5 cm of sediment was collected for palynological examination. Six soil samples (K 1–6) were collected from the core location and six (K 7–12) from the margin areas of the wetland. Similarly eight (K 13–20) surface samples (soil and moss cushion) were also collected randomly at approximately 100 meter intervals from the adjoining forest.

Laboratory Work

The soil and moss cushion samples were processed employing standard acetolysis method (Erdtman, 1953). The samples were treated with 10% aqueous KOH solution to deflocculate the pollen/spore from the sediments followed by 40% HF treatment to dissolve silica content. Thereafter, the conventional procedure of acetolysis was followed using acetolysis mixture (9:1 anhydrous acetic acid and conc. H_2SO_4). Finally the material was kept in 50% glycerin solution with a drop of phenol. Temporary pollen slides were made for identification and counting of pollen and non–pollen palynomorphs (fungal remains) under Olympus BX 61 light microscope. Photography of same was performed through attached Olympus DP–25 camera (Pl.1). A total pollen sum of 300 to 345 was counted from each sample to make pollen spectra. The pollen taxa were categorized as arboreal taxa, nonarboreals, ferns and fungal remains excluding the high land taxa in the palynoassemblage. Pollen frequencies were done based on the total sum of palynomorphs.

RESULTS

The modern pollen spectra from Kathali wetland and nearby forest are discussed below and provide an overview of modern pollen deposition pattern in relation to extant vegetation and climate in the region (Fig. 3).

Soil samples collected from core of the wetland (K 1–K 6): The soil sample collected from the core portion of wetland showed that the non–arboreals (61.3%) are dominant over arboreal taxa (24.0%). The ferns and fungal remains are exhibited at the value of 9.5% and 5.3% respectively. The major arboreal taxa such as *Dillenia*, *Salmalia*, *Lagerstroemia*, *Semecarpus* and *Syzygium* are continuously represented within the ranges of 0.6–4.4% in the palynoassemblage. Among the non–arboreals, the Poaceae (non–cereal type) is recorded up to 12.7%. The other herbaceous associates such as Tubuliflorae, Liguliflorae, *Xanthium* and *Impatiens* also consistently present in the palynoassemblage. However, the marshy and aquatic taxa namely Cyperaceae, Onagraceae, Polygonaceae, *Nymphoides*, *Lemna* and *Nymphaea* are represented within the value of 1.2–6.2% in the palynoassemblage.

Soil samples collected from margin of the wetland (K 7–K 12): The pollen analysis of margin soil sample showed that the non–arboreals (71.4%) are dominant over arboreal taxa (18.4%). Ferns and fungal remains are exhibited at the value of 6.5% and 3.2% respectively in the palynoassemblage. Among the arboreal taxa, *Dillenia*, *Salmalia*, *Lagerstroemia*, *Semecarpus* and *Syzygium* are continuously represented within the ranges of 0–3.0% in the palynoassemblage. Among the non–arboreals, Poaceae (non–cereal type) is recorded up to 11.7% followed by Poaceae (cereal type) at the value of 4.4–6.1%. The other associates non–arboreals such as Tubuliflorae, Convolvulaceae, *Xanthium* and *Justicia* also consistently present in the palynoassemblage. However, the marshy and aquatic taxa namely Cyperaceae, Onagraceae, Polygonaceae, *Typha*, *Lemna* and *Nymphaea* are represented within the value of 1.0–9.2%.

Soil samples collected from forest floor (K 13–K 20): The pollen analysis of forest surface samples (soil and moss cushion) showed that the arboreal taxa (36.6%) are dominant over non–arboreals (44.8%). The ferns and fungal remains are exhibited at the value of 11.6% and 7.0% respectively. Among the arboreal taxa, *Dillenia*, *Salmalia*, *Lagerstroemia*, *Semecarpus* and *Syzygium* are continuously represented within the ranges of 0.7–5.5% in the palynoassemblage. Among the non–arboreals, Poaceae along with other associates such as Tubuliflorae, Liguliflorae, *Xanthium* and *Justicia* are consistently present in the palynoassemblage. However, the marshy taxa namely Cyperaceae, Onagraceae and Polygonaceae were recorded within the ranges of 0.7–3.0%, whereas the aquatic taxa namely *Typha*, *Lemna* and *Nymphaea* are exhibited at the sporadic value in the palynoassemblage.

DISCUSSION

The palynomorphs recovered from the sediments of Kathali wetland and vicinity forest was observed and strongly suggestive of the tropical deciduous forest under warm and humid climate. Among arboreal taxa, *Terminalia*, *Dillenia*, S*yzygium* and *Salmalia* were the major forest elements in and around the study site. The evergreen taxa namely *Elaeocarpus*, *Schima* and Magnoliaceae in the palynoassemblage are strongly suggestive of the high monsoonal activity in the region. The arboreal taxa in the wetland samples were mainly derived from the adjoining forest through in–wash water due to high rainfall and soil erosion. It was observed that the frequency and diversity of the arboreal taxa are comparatively higher in the core samples than in forest surface samples. The high pH value of soil as well as the microbial and chemical degradation of the pollen grains of these taxa might have been detrimental factors contributing to the scarcity of pollen of these plants in the forest soil (Sharma, 1985; Bera *et al*., 2008). The pH–value is one of the important features of soil and also one of the major factors to affect the pollen preservation. Higher pH values will damage pollen exine more easily. Dimbleby (1961) pointed out that the pollen concentrations will become very low, when soil pH values are over 5.5. Among non–arboreals, the terrestrial taxa namely Poaceae, Tubuliflorae, Liguliflorae and *Impatiens* were strongly indicative of the surrounding source because these taxa are luxuriantly growing in the vicinity of wetland. Generally, the surface samples from the wetland core accumulate pollen and

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PLATE 1

The palynoassemblage recovered from the Kathali wetland →

1. *Lagerstroemia*
2. *Salmalia*
3. *Barringtonia*
4. *Shorea robusta*
5. *Terminalia*
6. *Elaeocarpus*
7. *Duabanga*
8. *Pinus*
9. *Alnus*
10. Chenopodiaceae
11. Convolvulaceae
12. Amaranthaceae
13. Onagraceae
14. Clumps of *Xanthium* pollen
15. Clumps of Poaceae pollen
16. Cyperaceae
17. *Polygonum*
18. Clumps of *Lemna* pollen
19. Trilete
20. Monolete
21. *Alternaria*
22. *Meliola*

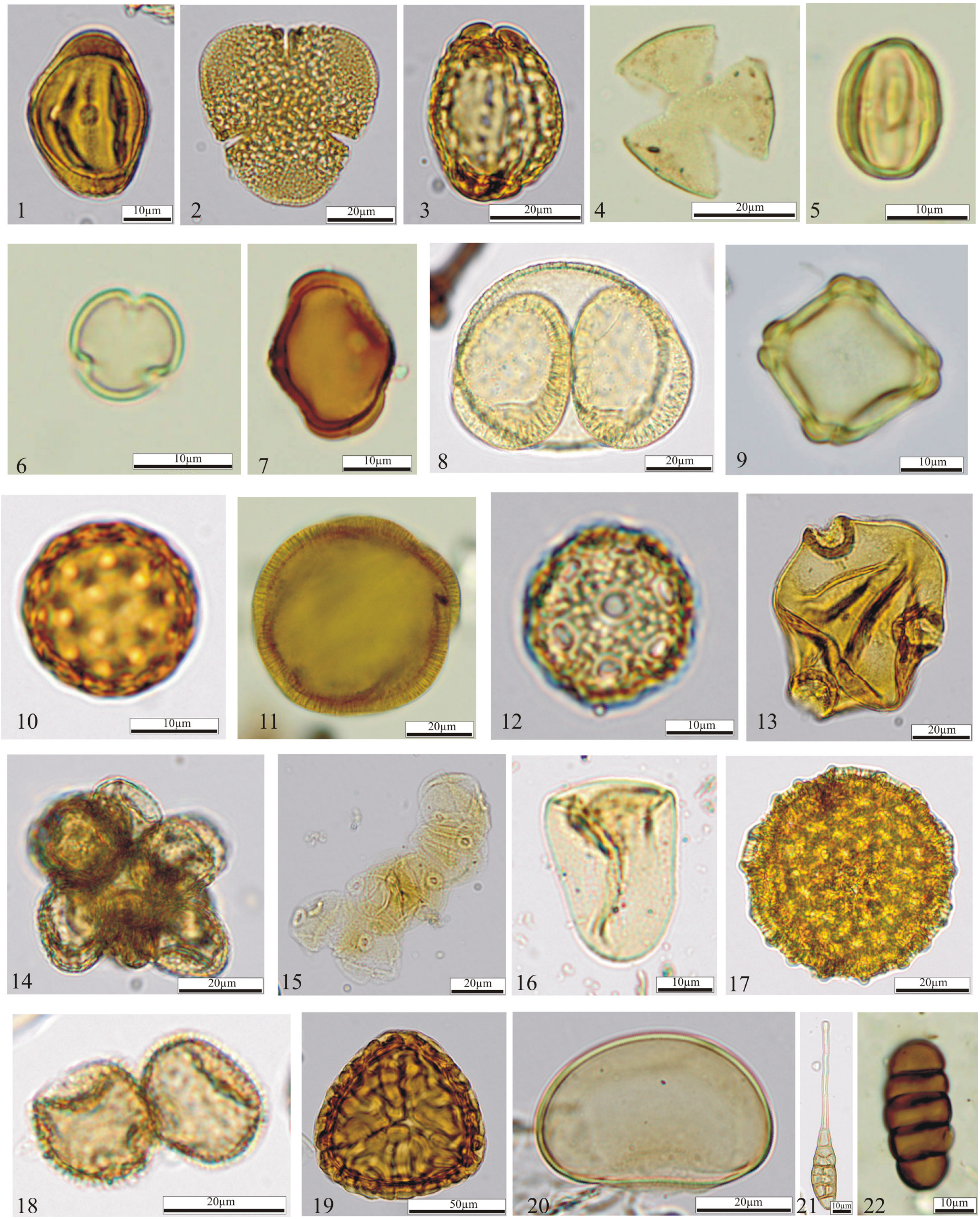
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PLATE 1

spore greater than the surface soils and moss cushion from adjoining forest floor (Wilmshurst & McGlone, 2005) which is well evident in palynoassemblage of Kathali wetland. However, the over representation of aquatic taxa namely *Nymphaea*, *Lemna* and *Potamogeton* in the core sediments was observed in comparison to the margin site owing to the difference in proximity of the parent plants growth, its deepness and proper settlement in the wetland basin. However, pollen sedimentation is strongly influenced by pollen yield, blooming season, transport and the distance between pollen sources and the lake shore (Xiao *et al*., 2011). The abundance of pollen clumping both in the forest and wetland samples was observed which strongly suggest their local origin and entomophilous nature. However, the consistent appearance of highland taxa such as *Pinus*, *Betula* and *Alnus* in the palynoassemblage was indicative of the strong wind activity in and around the study area. The frequencies of marshy taxa such as Cyperaceae, Polygonaceae and Onagraceae were comparatively higher in wetland margin samples as compare to the core site samples. The reason for this is due to luxuriant growth of marshy taxa near the margin areas of the wetland. The pollen accumulation in the lake sediments depend on the size of Lake basin, dispersal and depositional characteristic (Prentice, 1987; Sugita, 1993; Borstrom *et al*., 2008). The presence of cerealia along with *Brassica* was strongly indicative of the human activity in the region. The abundance of fern spores, especially *Dryopteris*, *Polypodium* and *Pteris* in the palynoassemblage is due to their local origin and suggestive of the warm and humid climatic condition in and around the region. The presence of fungal remains especially *Helminthosporium* and *Alternaria* shows the open–land vegetation as they are the common pathogens of herbaceous plants, particularly grasses.

Similar inferences have been drawn from the studies conducted on modern pollen rain–vegetation relationship in other regions of the tropical belts of the country with deciduous forest having similar and/or varied vegetation composition (Dixit & Bera, 2011; Quamar & Bera, 2014; Tripathi *et al*., 2015).

CONCLUSIONS

The modern pollen deposition at Kathali wetland and adjoining forest areas primarily reflects a tropical deciduous forest admixture with the evergreen elements in response to the high rainfall under warm and humid climate in the region. It is confirmed that the depositional pattern in core and margin site of Kathali wetland depends on the growth of nearby parent plant taxa. The water level and proper settlement in the soil

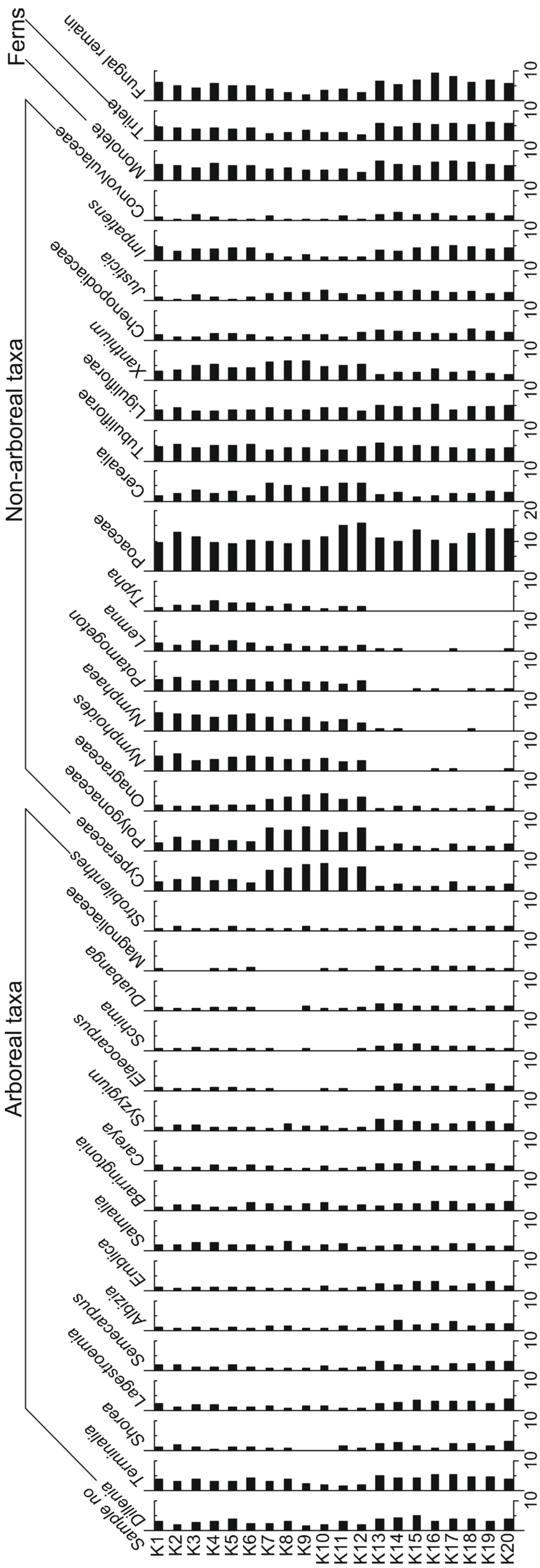

Fig. 3—Pollen spectra from the different sites of Kathali wetland and its adjoining forest areas of Garo Hills, Meghalaya.
Legends K1-K6: Core; K7-K12: Margin; K13-K20: Forest floor

are essential factors for the production and dispersal of pollen grains. The present communication summarized the following beneficial cessations which must be taken into consideration whilst dealing with the modern pollen–vegetation studies.

1. The influence of soil pH values is most important observation in context to pollen preservation. The statistical analysis shows that soil pH values have negative correlations with pollen total concentrations at exponential form. When soil pH values are higher than 7.6, the pollen total concentrations decrease sharply (Li *et al*., 2005).
2. Sub–aerial exposure created an opportunity for oxidation and degradation of pollen grains and possibly for further degradation by bacteria or fungi (Elsik, 1971).
3. Flowering age and forest structures play a crucial role in the calculation of pollen productivity estimates for some taxa. A gradual increase has been recorded in the amount of pollen produced in a single year in most trees with age. A free–standing tree produces more pollen compared to that growing within a dense stand (Abay, 1994).
4. Difference between various habitats also affects the total pollen production. This means that the total amount of pollen shed into the atmosphere varies from area–to–area (Prieto–Baena *et al*., 2003).
5. Effect of human pressure on the pollen spectra is realized by the presence of high values of Cereal and *Xanthium* pollen in wetland soil samples (open–land area) (Gupta & Yadav, 1992).
6. Establishing modern pollen rain/vegetation relationship, could also be of great help in resolving the controversies, if any, regarding the vegetation dynamics of the Late Quaternary Period in the region, as well as the other equivalent floristic regions of the country, as the scarcity of modern pollen–rain data constitutes a significant hindrance in understanding the Late Quaternary vegetation history of the tropical and sub tropical forest regions.

Acknowledgements*—We thank Professor Sunil Bajpai, Director, Birbal Sahni Institute of Palaeobotany, Lucknow, India for providing laboratory facilities and kind permission to publish the paper.*

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