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Modern pollen assemblages from teak (*Tectona grandis* Linn. F.) dominated tropical deciduous forest in southwestern Madhya Pradesh, India

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ABSTRACT

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This paper gives an account on the modern pollen rain–vegetation relationships, based on the pollen analysis of 12 surface samples, 2 samples each collected from the southern, northern, eastern and western flanks of Amjhera Swamp as well as 4 from the mixed tropical deciduous forests dominated by teak (*Tectona grandis*) in Hoshangabad District, southwestern Madhya Pradesh, India. The pollen assemblages demonstrate the dominance of arboreals (trees and shrubs) over non–arboreals (herbs). Among the tree taxa, *Madhuca indica* is constantly represented with average pollen frequency of 37.36% in most of the samples which could be attributed to the good preservation of its pollen in the sediments coupled with its high pollen dispersal efficiency. *Terminalia* (av. 5.1%) is also retrieved steadily. However, *Tectona grandis* is untraced in the samples despite being an enormous pollen producer and dominant forest component, which could be due to its low pollen dispersal efficiency and differential pollen preservation. Besides, *Adina cordifolia*, *Mitragyna parvifolia*, *Schleichera oleosa* and *Emblica officinalis* are present with average pollen frequencies of 8.1%, 7.8%, 6.69% and 1.126%, respectively, but only in a few samples. *Syzygium*, *Maytenus*, *Lagerstroemia*, *Lannea coromandelica*, etc. are also intermittently recovered in almost all the samples, but in varying frequencies (< 0.5%–7.91%) despite their frequent presence in the forest. This erratic display of all these taxa could be inferred to their low pollen productivity, since majority of the tropical trees portray a strong tendency of entomophily. The partial preservation of their pollen in the sediments cannot also be denied. The relatively meagre representation of grasses, sedges, Malvaceae, *Xanthium* except Tubuliflorae and culture pollen taxa such as Cheno/Am, Caryophyllaceae, Brassicaceae and *Cannabis sativa* are suggestive of poor herbaceous cover around the swamp and also in the mixed tropical deciduous forest. However, the record of Cerealia and other culture pollen taxa stamps the proximity of cultivated land and human habitation in and around the investigation site. The abundance of trilete fern spore as well as *Ceratopteris*, monolete fern spore and trilete with perine, though in relatively low values envisages their origin from the local sources as ferns and their allies flourish well in moist and shady habitats.

Key–words—Pollen analysis, Surface sediments, Mixed tropical deciduous forests, Hoshangabad, Madhya Pradesh, India.

दक्षिण पश्चिम मध्य प्रदेश, भारत में सागौन (*टेक्टोना ग्रांडिस* लिन.एफ.) प्रभावी उष्णकटिबंधीय पतझड़ी वन से प्राप्त आधुनिक पराग समुच्चए

एम.एफ. क़मर एवं एम.एस. चौहान

सारांश

यह शोध पत्र जिला होशंगाबाद दक्षिण पश्चिम मध्य प्रदेश, भारत में सागौन (*टेक्टोना ग्रांडिस*) मिश्रित उष्णकटिबंधीय पतझड़ी वनों से प्रभावित 4 के साथ-साथ दक्षिणी, उत्तरी, पूर्वी एवं अमझेरा दलदल के पश्चिमी पार्श्वों प्रत्येक से 2 संगृहीत, 12 पृष्ठीय नमूनों के पराग विश्लेषण के आधार पर आधुनिक पराग वर्षा-वनस्पति संबंधताओं पर विवरण प्रदान करता है। पराग समुच्चएं गैर-वृक्षीयों (शाक) पर वृक्षीयों (वृक्षों व झाड़ियों) की प्रभाविता दर्शाते हैं। वृक्ष टैक्सा में, अधिकांश नमूनों में 37.36 प्रतिशत की औसतन पराग आवृत्ति सहित *मधुका इंडिका* अनवरत रूप से रूपायित है जो अपने उच्च पराग निक्षेपण दक्षता से युग्मित अवसादों में अपने पराग के अच्छे परिरक्षण को आरोपित है। *टर्मिनेलिया* (औसतन 5.1 प्रतिशत) की भी अपरिवर्तित रूप से पुनः प्राप्ति हुई है। फिर भी, बृहत पराग उत्पादक एवं प्रभावी वन घटक होने के बावजूद भी नमूनों में *टैक्टोना ग्रांडिस* अनुपथ नहीं है जो कि इसकी अल्प पराग निक्षेपण

दक्षता व विभेदन पराग परिरक्षण की वजह से रहा होगा। इसके अलावा, लेकिन कुछेक नमूनों में ही, क्रमशः 8.1 प्रतिशत, 7.8 प्रतिशत, 6.69 प्रतिशत और 1.126 प्रतिशत की औसतन पराग आवृत्तियों सहित *एडिना कॉर्डिफोलिया, मित्रगायना पर्विफोलिया, सायलीचेरा ओलेओसा* व *एम्बिलिका ऑफीसीनेलिस* विद्यमान हैं। वन में उनकी कदाचनिक विद्यमानता के बावजूद किंतु परिवर्तनीय आवृत्तियों (> 0.5 प्रतिशत - 7.91 प्रतिशत) लगभग सभी नमूनों में *सायज़ीजियम, मेटेनस, लेजरस्ट्रोमिया, लेनिया कोरोमंडेलिका* इत्यादि भी आंतरायिक रूप से प्राप्त हुई हैं। चूंकि अधिकांश उष्णकटिबंधीय वृक्ष कीटपरागण की कठोर प्रवृत्ति चित्रित करते हैं ये समस्त टैक्सा विस्थापन प्रदर्शन उनकी अल्प पराग उत्पादकता को अनुमानित होंगे। अवसादों में उनके पराग के आंशिक परिरक्षण से भी इंकार नहीं किया जा सकता। कीनो/एम कैरियोफाइल्लेसी, ब्रासीकेसी व *कैन्नाबिस सैटाइवा* जैसे टुब्लीफ्लोरे एवं संवर्धित पराग टैक्सा के अलावा घासों प्रतृणों, मालवेसी, *जैन्थियम* के सापेक्षतया तनु निरूपण दलदल के चहुंओर और मिश्रित पतझड़ी वन में भी अल्प शाक आच्छादन को सुझावित हैं। फिर भी, अनाज व अन्य संवर्धन पराग टैक्सा का अभिलेख अन्वेषण स्थल में और चहुंओर कृष्ट भूमि और मानव आवास की सामीप्यता मुद्रांकित करता है। यद्यपि सापेक्षतया अल्प मानों में *सेराटॉप्टेरिस,* एकअरीय पर्णांग बीजाणु के साथ-साथ त्रिअरीय पर्णांग बीजाणु और परिचोल सहित त्रिअरीय की बहुलता स्थानीय स्रोतों से प्राप्त उनके उद्गम की परिकल्पना करते हैं क्योंकि पर्णांग व उनके उपवर्ग आर्द्र एवं छायादार आवासों में सुविकसित होते हैं।

संकेत-शब्द—पराग विश्लेषण, पृष्ठीय अवसाद, मिश्रित उष्णकटिबंधीय पतझड़ी वन, होशंगाबाद, मध्य प्रदेश, भारत।

INTRODUCTION

Pollen analysis is one of the widely used tools to reconstruct past vegetation and climate. The hypothesis behind the use of pollen analysis as a palaeoecological tool is that the relative pollen abundance in sediments is in some way proportional to the relative abundance of plants in a given landscape (Erdtman, 1943). Plants employ various means of dispersing pollen and, as such, pollen production and dispersal varies greatly between species (Tauber, 1965; Faegri, 1966). It follows that an understanding of the relationship between vegetation and modern pollen–rain is a vital and inevitable first step before attempting to interpret fossil pollen spectra (Janssen, 1973). In this perspective, extensive information has been generated from the tropical evergreen and deciduous forests in South India and Srilanka (Bonnefille *et al*., 1999; Anupama *et al*., 2000; Barboni & Bonnefille, 2001), foothills of the Himalaya (Sharma, 1985; Gupta & Yadav, 1992) and tropical deciduous scrub vegetation in Rajasthan desert (Singh *et al*., 1973) and a good understanding of the regional and local scale pollen rain–vegetation relationships has been garnered for these regions. These studies from different phytogeographical regions have generated valuable comparative database on the aspect of pollen rain/vegetation relationships for the factual appraisal of pollen sequences from their respective regions in terms of past vegetation dynamics and contemporary climatic trends during the Quaternary Period. However, Madhya Pradesh, which alone possesses approximately 26% of the total forests of the country with great potentiality for the Quaternary palaeofloristic studies has been given less attention to understand the pollen deposition pattern except for some work executed from the tropical deciduous sal (*Shorea robusta*) forests distributed in northeastern Madhya Pradesh (Chauhan, 1994, 2008). This paucity of modern pollen rain studies from this region is, therefore, a significant hindrance in resolving controversies concerning the Late Quaternary vegetation dynamics of the region. The study has also provided a valuable analogue for the precise reconstruction of the palaeovegetation scenarios from the tropical regions during the Holocene (Chauhan, 1995, 2000, 2002, 2004, 2005; Chauhan *et al*., 2001; Shaw *et al*., 2007; Yadav *et al*., 2006). In the present paper, hence, an attempt has been made to produce more data from teak (*Tectona grandis*) dominated mixed tropical deciduous forest in southwestern Madhya Pradesh in order to understand the interplay of teak and its associates in the modern pollen rain, their pollen dispersal efficiency and factors affecting the preservation of pollen/spores in sediments from the different forest areas at Amjhera, Hoshangabad District in southwestern Madhya Pradesh (India).

AREA OF STUDY

Amjhera Swamp falls about 23 km southwest of Itarsi Township and 31 km west of Hoshangabad between 77°50' E Long. & 22°30'25" N Lat. amidst dense mixed tropical deciduous teak forest in the close proximity of Chandkhar Village of Itarsi Forest Range (Fig. 1). The swamp proper and its immediate vicinity are almost flat and are surrounded by high plateaus, hillocks and have gentle slopes, attaining the elevations varying from 1500'–2000' amsl. It is big in expanse and measures about 300 m long and 150 m at its widest. The swamp is fed by rain as well as subterranean water. The swamp is perennial and highly waterlogged at the centre. Physiographically, most of the area adjacent to the investigation site is marked by high lands of low relief with deep gorges. The peripheral broader region of the swamp gets inundated during the rainy season and is under cultivation of conventional crops such as rice, wheat, barley and pulses by the Gond, Kurku tribals inhabiting therein. The soil in the swamp and adjoining cultivated area is generally blackish sticky clay with fine sand, whereas it is sandy clay in composition in rest of the regions. However, at certain places black cotton soil is found in patches.

The study area, in general, experiences a warm and humid climate, which is largely influenced by the southwest monsoon. The mean minimum and maximum winter temperatures are 16.3°C and 21°C, respectively, however, lowest temperature of 1°C is recorded during the month of January. The mean minimum and maximum summer temperatures are 31.6°C and 34°C, respectively. During the extreme hot summer month of June, the temperature occasionally rises up to 44°C. The rainfall by and large occurs from mid June to September, however, major fraction of it falls in July and

August. The average annual precipitation recorded for the area is 1200 mm. Approximately 92% of the total precipitation occurs during the rainy season.

The vegetation around the swamp and the adjoining hill slopes is of mixed tropical deciduous teak forests type (Champion & Seth, 1968), which is quite luxuriant and diversified in their floristic composition. In addition to *Tectona grandis*, the prominent constituents of these forests, such as *Adina cordifolia*, *Lagerstroemia parviflora*, *Mitragyna parvifolia*, *Buchanania lanzan, Terminalia tomentosa, Anogeissus latifolia, Schleichera oleosa, Wrightia tinctoria, Kydia calycina, Bridelia retusa, Bauhinia retusa, B. integrifolia, B. malabarica, B. racemosa, B. purpurea*, *Elaeodendron glaucum, Aegle marmelos, Emblica officinalis, Chloroxylon sweitenia, Syzygium cumini, Melia azedarach*, *Ficus benghalensis, Acacia nilotica*, etc. occur frequently.

Stunted trees of *Butea monosperma* are seen sporadically along the border of the swamp and the open wasteland close to the forest. Around the village, *Mangifera indica, Melia azedarach*, *Butea monosperma*, *Azadirachta indica*, etc. can be seen frequently.

Ziziphus mauritiana, *Melastoma malabathricum*, *Woodfordia fruticosa*, *Strobilanthes* sp. are the common shrubs in the forest. *Ricinus communis*, *Adhatoda vasica*, *Carissa opaca*, etc. occur frequently around the habitations.

The herbaceous vegetation around the dried part close to the swamp chiefly comprises grasses, sedges, *Sida rhombifolia*, *Sida cordata*, *S. alba*, *S. cordifolia*, *Oxalis acetocella*, *Leucas aspera*, *Centella defformis*, *C. verticillata*, *Hydrocotyle sibthorpioides*, *Ammania baccifera*, *Ageratum conizoides*, etc. However, reed swamp grass–*Phragmites vulgaris*, *P. biflora*, *P. longivalvis* and *Typha latifolia* grow profusely over the swamp. *Hygrophila auriculata*, *Polygonum plebeium, Rotala rotundifolia*, *Cyperus rotundus, Carex speciosa*, *Scirpus triangulatus*, etc. are the other swampy taxa, which occur preponderantly in the highly waterlogged part of the swamp as well. Aquatic elements such as *Lemna paucicostata*, *L. perpusilla*, *Potamogeton nodosus*, *Nymphoides cristata*, *N.*

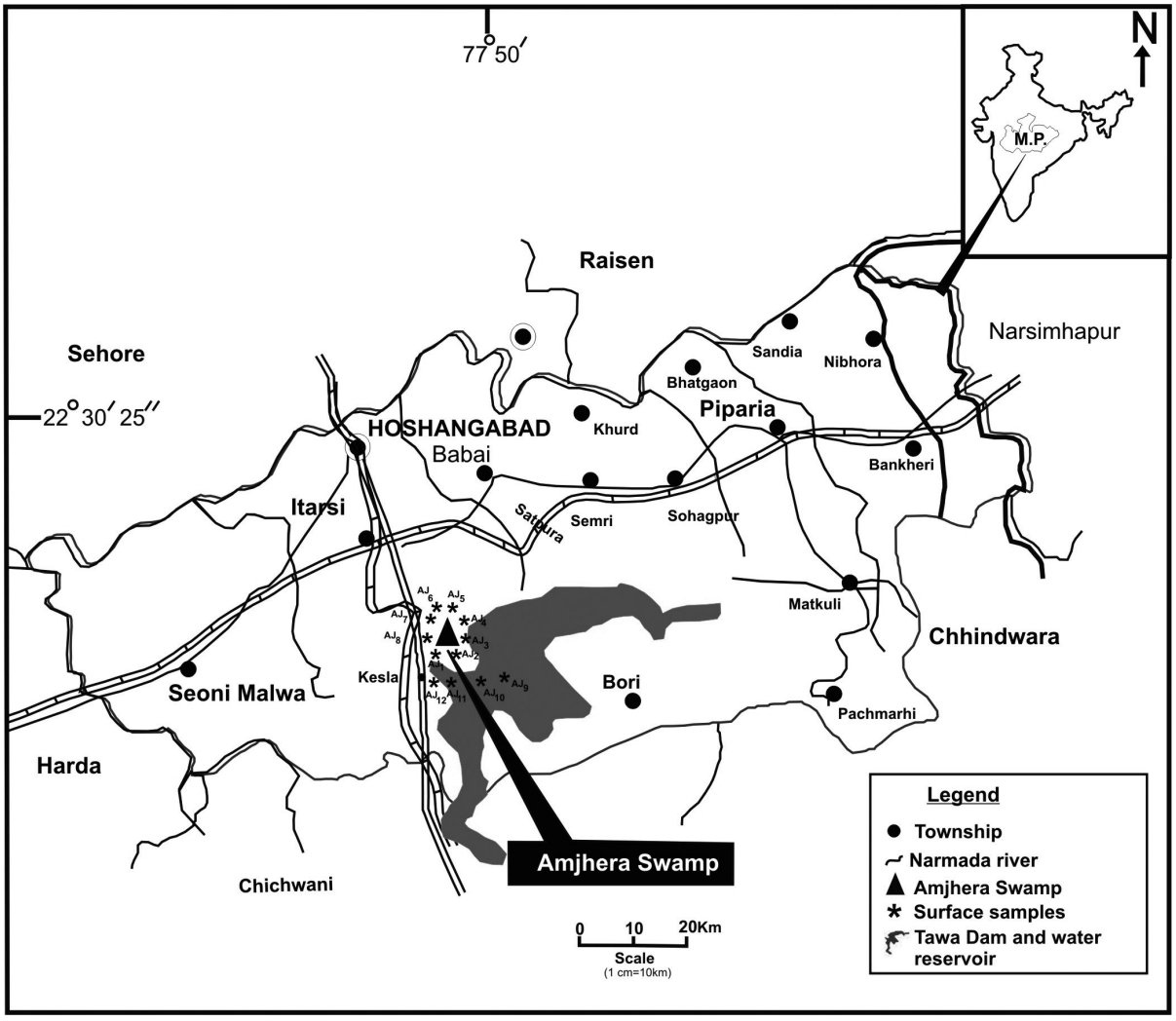

Fig. 1—Map showing the investigation site at Amjhera, Hoshangabad District, southwestern Madhya Pradesh.

stellata, etc. also occur frequently in ditches and water accumulated areas around the swamp. The common pteridophytic taxa growing in and around the swamp include *Adiantum philippense*, *Dryopteris prolifera*, *Ceratopteris thelictroides*, *Ophioglossum reticulatum*, *Equisetum debile*, *Selaginella lepidophylla*, *Lycopodium clavatum*, etc.

MATERIAL AND METHODS

A total number of 12 surface samples were collected in linear transects from the different flanks of the swamp as well as from the mixed tropical deciduous forests at Amjhera, Hoshangabad District at 100 m interval each to study the interplay between modern pollen deposition patterns with the vegetation in the region. While sampling it was surmised that a major fraction of pollen gets deposited within a distance of 100 m or so immediately after their discharge from the parent plants as the dense canopied forest prohibits their easy and longer exit, contrary to that of the open cultivated area (Luna *et al*., 2002), where a distance of 200 m from the source has been observed to be the normal range for the deposition of bulk pollen load after dispersal. The sampling strategy was planned in transects to understand the average representation of the prominent forest constituents/plant groups of the regional vegetation in the pollen rain across the forest area.

Ten grams of surface samples were boiled in 10% aqueous KOH solution for 5 minutes to deflocculate the pollen from the sediments and to dissolve the humus. This is followed by treatment of the samples with 40% HF solution in order to remove the silica. Thereafter, the samples were acetolysed (Erdtman, 1943), using the acetolysing mixture (9:1 ratio of acetic anhydride and concentrated sulphuric acid, respectively). Finally, the sample was prepared in 50% glycerine solution for microscopic examination.

The pollen sums range from 214 to 411 depending upon their yield. The percentage frequencies of the recovered taxa have been calculated in terms of total terrestrial plants pollen. The pollen of aquatic plants and fern spores have been excluded from the pollen sums because of their origin from the local sources. For the precise identification of fossil palynomorphs in the sediments the reference pollen slides available at BSIP Herbarium as well as the pollen photographs in the published literature (Nayar, 1990; Chauhan & Bera, 1990) were consulted. The plant taxa categorized as trees, shrubs, herbs, ferns, fungal spores and drifted and have been arranged in the same sequence in the pollen spectra. The pollen frequencies of < 0.5% are indicated by '+' sign in the pollen spectra.

RESULTS

In all, 8 surface samples (AJ–1 to AJ–8) including 2 each from southern (AJ–1 & AJ–2), eastern (AJ–3 & AJ–4), northern (AJ–5 & AJ–6) and western (AJ–7 & AJ–8) flanks of the swamp as well as 4 samples (AJ–9 to AJ–12) from inside the forest were analyzed to study the pollen rain composition in relation to local vegetation. The pollen rain compositions from different flanks of the swamp as well as from the mixed tropical deciduous forests are described separately in Fig. 2.

Pollen spectra from the southern flank (AJ–1 and AJ–2) of the swamp reveal the dominance of arboreals (trees & shrubs) and very low frequencies of non–arboreals (herbs). Among the arboreals, *Mitragyna parvifolia* dominates with highest frequency in sample AJ–2 (65.45%), followed by *Schleichera oleosa*, *Madhuca indica*, *Terminalia*, *Syzygium*, *Adina cordifolia*, *Grewia*, *Emblica officinalis* and Meliaceae with average total pollen frequencies of 46.15%. However, the rest of the trees are scant. The shrubby elements, such as *Triumfetta*, Acanthaceae and *Petalidium* are extremely low.

Among the non–arboreals, Tubuliflorae (1.46–4.37%), Cheno/Am (2.91–3.51%) and Brassicaceae (1.70–3.22%) are encountered in moderate values. Poaceae (1.46–1.70%) is recovered in low frequencies, whereas *Xanthium*, *Artemisia* and Malvaceae (< 0.5%–approx 1% each) are sporadic. Cyperaceae (0.29–1.70%), the sole representative of the marshy vegetation, has low values. The aquatic components, viz. *Typha* and *Lemna* (< 0.5% each) are meagre. Fern producing trilete spores (1.75–9.24%) have moderate to high values. *Pinus* (< 0.5%) is scarce and denotes its transportation by winds from the Himalayan region. Fungal spores such as *Glomus*, *Nigrospora*, *Diplodia*, *Cookeina* and *Curvularia* are also recorded in variable frequencies.

Pollen rain composition from the eastern flank (AJ–3 & AJ–4) of the swamp also exhibits the relatively better representation of arboreals over non–arboreals. *Madhuca indica* (53.75–65.57%) shows high frequency. *Terminalia*, *Maytenus* and *Aegle marmelos* are also common but in moderate values of 14%. *Grewia* (2.63%) is recorded in AJ–4 only, whereas the rest of the tree taxa contributed with average pollen frequencies of 11.33% in the total pollen rain. Acanthaceae (0.72–1.12%) is the only representative of the shrubby vegetation. Tubuliflorae (2.89–9.39%) and Cheno/Am (1.08–7.14%) are the major herbs. Poaceae (1.50–5.43%) is somewhat better represented. Brassicaceae and Caryophyllaceae have reduced considerably as compared to the southern flank. *Xanthium* and *Evolvulus alsinoides* (< 0.5–1% each) are scarce. Cyperaceae (1.87–2.89%) is retrieved consistently. *Typha* (< 0.5%) is extremely sporadic. *Ceratopteris* (0.37%) is met with in AJ–4 only. Barring *Glomus* (5–59.25%), other fungal spores, viz. *Nigrospora*, *Cookeina*, Microthyriaceae and *Diplodia* are present in low frequencies.

Pollen rain composition from the northern flank (AJ–5 & AJ–6) of the swamp also portrays the dominance of arboreals and low frequencies of non–arboreals. *Madhuca indica* (41.78–50.78%) again shows relatively much higher frequencies in contrast to other trees which contributed with the av. total pollen frequencies of 8% in the total pollen rain. Acanthaceae (1%) and *Petalidium* (0.34%) are present intermittently in low values. Among the herbaceous taxa,

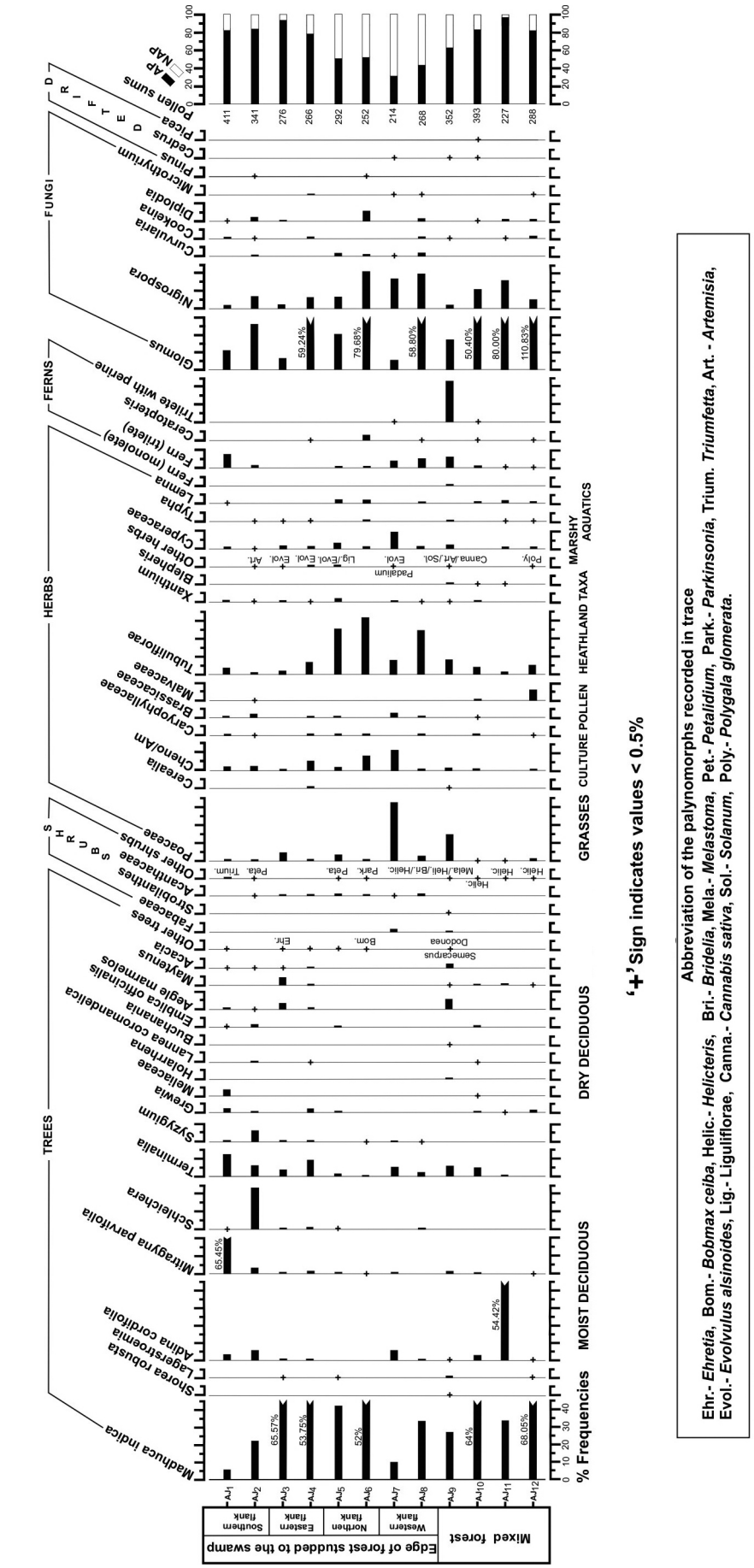

Fig. 2—Modern pollen spectra, Hoshangabad District, southwestern Madhya Pradesh.

Tubuliflorae (31.84–40.47%) has high values. Cheno/Am (2.39–7.19%) and Poaceae (1.19–4.79%) are constantly recorded in moderate values. *Xanthium* (2.39%) and Cerealia (1.36%) are recorded in sample AJ–5 only. Caryophyllaceae, Brassicaceae, Liguliflorae and *Evolvulus alsinoides* (< 1% each) are sporadic. Cyperaceae (1.58–4.45%) along with aquatic elements such as *Lemna* (2.73–2.77%) and *Typha* (1.19%) have improved values than witnessed ever. Fern spores particularly trilete spores (0.68–0.79%) and *Ceratopteris* (3.75%, only in sample AJ–6) are present in low to high values. *Pinus* (0.39%) is scarce. Fungal spores, viz. *Glomus*, *Nigrospora*, *Curvularia* and *Diplodia* are also represented in variable frequencies.

Pollen spectra from the western flank (AJ–7 & AJ–8), unlike other flanks of the swamp exhibit comparatively low frequencies of arboreals. *Madhuca indica* (12.14–40.67%) maintains its high frequencies in the pollen rain. *Terminalia* (2.98–7%) and *Adina cordifolia* (1.11–7.47%) are much better represented than *Schleichera oleosa* (1.80%) and *Mitragyna parvifolia* (1.40%), which are recorded only in pollen spectra AJ–8 & AJ–7, respectively. *Syzygium* (< 1%) is sparse. Acanthaceae (0.46–2.23%) and Fabaceae (2.23%) represent the shrubby vegetation. Poaceae (3.35–40.18%), Tubuliflorae (9.81–30.59%) and Cheno/Am (10.74–14.55%) are represented consistently in high frequencies as compared to the other flanks of the swamp. Brassicaceae (1.11–3.73%) and *Xanthium* (0.37–1.40%) are also recorded in moderate values. Caryophyllaceae and *Evolvulus alsinoides* are sporadic (< 1%). Cyperaceae (1.49–11.68%) shows fluctuating high frequencies as compared to eastern and northern flanks of the swamp. *Lemna* (1.11%) is in low value in sample AJ–8 only. Trilete fern spores (4.67–6.34%) have moderate values, whereas *Ceratopteris* (< 0.5% in AJ–8 only) is sparse. *Cedrus* (0.46%) is meagre.

Pollen spectra (AJ–9 to AJ–12) from the mixed tropical deciduous forest exhibit the dominance of trees and shrubs over herbs. *Madhuca indica* (33.60–68.05%) is the principal component of the pollen rain here too, however, the contribution of the rest of the tree taxa in the total pollen rain from the forest area is 22.21%. The shrubby taxa, viz. *Triumfetta* (0.5–6.49%) and *Helicteres* (0.5–1%) are present consistently in high to low frequencies, whereas *Bridelia retusa*, *Helixanthera*, *Strobilanthes* and *Melastoma* have values < 0.5–2.29%. Poaceae (0.5–18.36%) has good representation in the total pollen rain followed by Tubulifloreae (2.2–9%). Cheno/Am (1–2.25%) is reduced in comparison to the previous pollen spectra. Caryophyllaceae, *Xanthium* and *Blepharis* (0.5–1% each), *Artemisia* and *Cannabis sativa* (1% each), Cerealia and Brassicaceae (< 0.5% each) have low values. However, Malvaceae (1–7.29%) exhibit moderate to high values in samples AJ–10 & AJ–12. Cyperaceae (1–2.8%) shows moderate values, whereas *Solanum* and *Polygala* (< 0.5% each) are extremely low. *Lemna* (1–1.76%) and *Typha* (0.5–1%) are present sporadically. Trilete fern spores (4.5–7.34%) and trilete spores with perine (0.5–28.53%) are recorded consistently in good frequencies. *Ceratopteris* and monoletes (0.5% each) are extremely low. Fungal spores are marked by the exceptionally high values of *Glomus* (20–111%) followed by *Nigrospora* (5–15%). The others, viz. *Cookeina*, *Diplodia* and Microthyriaceae are infrequently present. *Picea* and *Cedrus* (0.5% each) are recovered occasionally.

DISCUSSION

The pollen rain study has revealed the dominance of relatively much higher frequencies of arboreals (trees & shrubs) as compared to the non–arboreal taxa. Among the tree taxa, *Madhuca indica* is consistently represented with high values, which coincides to a greater extent with its actual composition in the extant forest. The high values of *Madhuca indica* could also be attributed to good preservation of its pollen in the sediments as well as high pollen dispersal efficiency. In addition, the steady retrieval of *Terminalia* is suggestive for its being one of the common constituents in the forest. However, *Tectona grandis* is untraceable in the samples, despite being a high pollen producer and also the dominant forest constituent (75–90% of the total floristics), which could be assigned to low pollen dispersal efficiency and differential preservation of its pollen in the sediments. Others such as *Adina cordifolia* and *Mitragyna parvifolia* are also recovered in almost all the samples. However, the excessively high frequency (54.42%) of *Adina cordifolia* in AJ–11 and *Mitragyna parvifolia* (65.5%) in AJ–1 from mixed forest and southern flank, respectively could be ascribed to the local abundance of these taxa. The much higher frequency of *Schleichera oleosa* (25%) and appreciable value of *Syzygium* (8%) in AJ–2 depicts the frequent presence of these taxa in the southern flank in contrast to other areas, where they are recorded sporadically. However in the eastern flank, *Madhuca indica* (59.6%) exclusively constitutes the major portion of the pollen rain, whereas the rest of the trees are lowly represented with 10% pollen only. On the other hand, the southern flank with 45% and eastern flank with average 69.85% contributed the largest portion of the pollen influx in the total pollen rain, whereas the tree pollen declines severely in the northern and the western flank with average percentages of 48% and 31%, respectively, except *Madhuca indica* which is marked by the excessively high frequencies (48% and 25%, respectively) compared to other forest constituents of the swamp. A large number of forest elements, viz. *Lagerstroemia parviflora*, *Holarrhena*, *Grewia*, *Lannea coromandelica*, *Emblica officinalis*, *Maytenus*, *Shorea robusta*, etc. are intermittently recovered in almost all the samples from different flanks, despite their frequent occurrence in the floristics. This under representation of all these taxa is inferred to their low pollen productivity since they exhibit a strong tendency of entomophily (Chauhan, 1994, 2008; Vincens *et al*., 1997; Quamar & Chauhan, 2007, 2009, 2011). The partial preservation of their

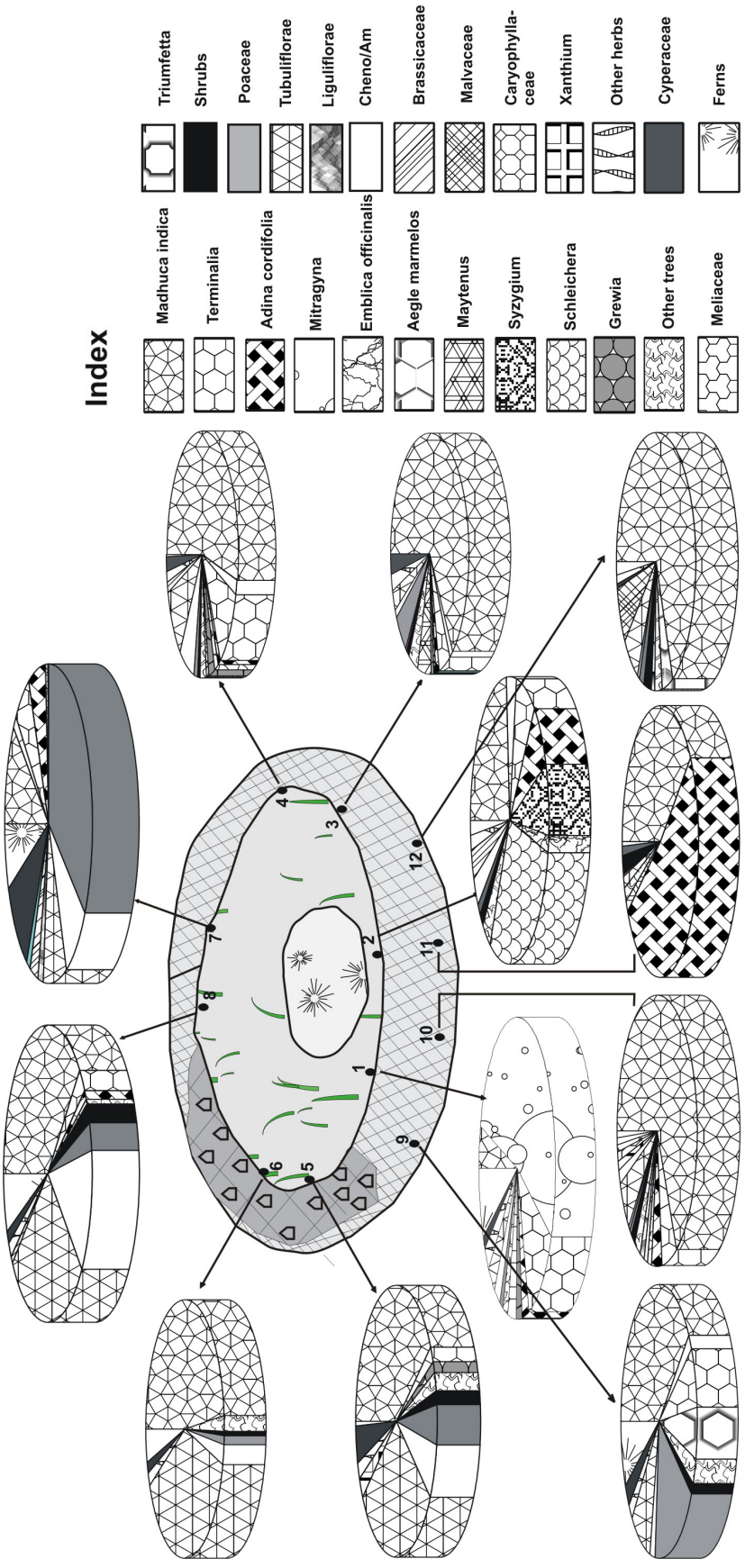

Fig. 3—Pollen Deposition Model, southwestern Madhya Pradesh.

pollen in the samples as well as differential recognition of poorly preserved grains cannot also be ruled out. The high pH value of soil and microbial degradation of their pollen in the sediments might have been detrimental factors for the scarcity of pollen of these plants in the sediments (Gupta & Yadav, 1992). Besides, good number of trees such as *Bombax ceiba*, *Dalbergia sissoo*, *Albizia lebbeck*, *Anogeissus latifolia*, *Flacourtia indica*, *Nyctanthes arbortritis*, *Diospyros*, *Butea*, *Ailanthus excelsa*, etc. occurring in good proportion in the forest remain untraceable in the samples, possibly due to their insect–pollinated nature, low pollen production or microbial degradation of their pollen (Sharma, 1985) since a considerable number of fungal remains, viz. *Glomus*, *Nigrospora*, *Diplodia*, *Curvularia*, *Cookeina*, Microthyriaceae, etc. have come across in the samples during investigation. The shrubby vegetation in the forest is very scarce, constituting a small fraction of 2.26% of the total pollen rain.

The non–arboreals are relatively poorly retrieved with low frequencies in contrast to the arboreals in most of the samples. Average 6.74% pollen frequency of Poaceae in the pollen rain could be attributed to the meagre occurrence of the members of this family owing to much open forest cover as these areas are under human habitation, whereas Cerealia and other culture pollen taxa contributed with average 7.53% pollen in the pollen rain. Tubuliflorae with average 12.89% pollen has comparatively good value, amply depicting the intense pastoral activities in the area of investigation as members of this family escape grazing because of its unpalatable nature to cattle and goats (Mazier *et al*., 2006). *Xanthium* has average low value of 0.87% pollen. The sporadic record of Malvaceae, *Blepharis*, Liguliflorae, etc. compares with their scanty presence in the herbaceous complex. The scarce pollen of sedges and *Typha* in most of the samples reflects the lack of marsh and distant location of Amjhera Swamp. However, the moderate frequency of sedges in AJ–7 only signifies the close proximity of the swamp.

The encounter of trilete spores in moderate values in a few samples only from southern and western flanks and mixed forest depicts the localized presence of ferns and their allies under moist and shady conditions.

The plentiful record of the fungal spores, viz. *Glomus* and *Nigrospora*, in particular, together with sporadic presence of *Curvularia*, *Cookeina*, *Diplodia* and Microthyriaceae implies the availability of rich decaying organic matter on the forest floor for their propagation and dissemination.

The representation of important and major forest constituents in the pollen rain has been shown in the pollen deposition model (Fig. 3).

CONCLUSIONS

It is , thus, concluded that the southern flank with 45.29% tree pollen is followed by the eastern flank and mixed deciduous forest with an average of 69.85% and 79.97%, respectively contribute the largest proportion of the pollen influx in the pollen rain as these areas are densely occupied by the forests. However, the tree pollen influx declines severely in the northern and western flanks since most of the areas there are under human habitation and agricultural activities. In contrast, the non–arboreals portray a reverse trend as they have been noticed with reduced average frequencies of 10.4%, 14.7% and 21.1% in the southern and eastern flanks and mixed forests, respectively. Contrary to this, the northern and western flanks have much higher frequencies of 49% and 60%, respectively owing to much open nature of forest as most of the area there is under human habitation. For the areas where most of the landscape is under thick forest cover, trees in totality constitute an average 68% of the total pollen influx with a minor fraction of 2% pollen of shrubby vegetation, whereas, the non–arboreals are marked by an average value of 30% pollen only, indicating the deficient ground flora on the forest floor. This comparative database on pollen rain–vegetation relationship serves as a modern analogue for the precise appraisal of fossil pollen diagram in terms of past vegetation and climate in the area of investigation. The study also symbolizes the prevailing climatic condition in the area of investigation. In addition, the physiognomic aspects of trees, i.e. whether they are dry, moist or evergreen can be determined from the available information.

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