The Palaeobotanist 62(2013): 47–53
0031–0174/2013

Pollen rain deposition pattern in tropical deciduous Sal (*Shorea robusta* Gaertn.) forest in Shahdol District, Madhya Pradesh, India

M.S. CHAUHAN* AND M.F. QUAMAR

Birbal Sahni Institute of Palaeobotany, 53 University Road, Lucknow 226 007, India.
**Corresponding author: mschauhan_2000@yahoo.com*

(Received 18 January, 2012; revised version accepted 7 November, 2012)

ABSTRACT

Chauhan MS & Quamar MF 2013. Pollen rain deposition pattern in tropical deciduous Sal (*Shorea robusta* Gaertn.) forest in Shahdol District, Madhya Pradesh, India. The Palaeobotanist 62(1): 47–53.

The pollen rain–vegetation relationship study, based on pollen analysis of 6 surface samples from tropical deciduous Sal (*Shorea robusta* Gaertn.) forest at Khanaudi, Shahdol District reveals the relatively lower frequencies of arboreal taxa in contrast to non–arboreal taxa. Among the arboreals, *Shorea robusta*, a dominant forest constituent, is not represented appropriately in the pollen–rain and encountered with av. 2% pollen only in the sediments. The under–representation of *Shorea robusta* pollen, despite being high pollen producer, could be attributed to its poor preservation in the sediments as well as low dispersal efficiency. On the other hand, the consistent presence of *Madhuca indica*, a common associate of Sal, and Sapotaceae with high frequencies of average 19% and 6%, respectively corresponds more or less with their frequent presence in the forest coupled with good preservation of their pollen in the sediments. However, a large number of other associates of Sal, viz. *Terminalia*, *Lagerstroemia*, *Emblica officinalis*, *Syzygium*, *Holoptelea*, *Sterculia*, etc. occurring appreciably in the forest, denote sporadic presence with av. 10% pollen only owing to their low pollen productivity, since they are entomogamous. Thus, av. 39% arboreal pollen including av. 37% trees and av. 2% shrubs, though scanty, represent the modern Sal forest in the region. The abundance of pollen of grasses, sedges, Tubuliflorae, etc. corresponds with their composition in the ground flora. The consistently moderate frequencies of Cerealia and Cheno/Am coupled with sporadic pollen of *Artemisia*, *Cannabis sativa* and Caryophyllaceae indicate the proximity of cultivated land.

Key–words—Pollen–rain, Vegetation, Tropical deciduous Sal forest, Shahdol, Madhya Pradesh.

जिला शहडोल, मध्य प्रदेश, भारत में उष्णकटिबंधीय पतझड़ी साल (*शोरिया रोबस्टा* गारटेन) वन में पराग वर्षा निक्षेपण प्ररूप

एम.एस. चौहान व एम.एफ. क़मर

सारांश

खनौदी, जिला शहडोल में उष्णकटिबंधीय पतझड़ी साल (*शोरिया रोबस्टा* गारटेन) से प्राप्त 6 पृष्ठीय नमूनों के पराग विश्लेषण पर आधारित पराग वर्षा-वनस्पति संबंधता अध्ययन, गैर-वृक्षीयों के विपरीत वृक्षीयों की सापेक्षतया अल्प आवृत्ति उद्घाटित करता है। वृक्षीयों में प्रभावी वन अंतर्वस्तु *शोरिया रोबस्टा,* पराग-वर्षा में उपयुक्तता से रूपायित नहीं है तथा अवसादों में औसतन 2% पराग सहित ही समागमित है। उच्च पराग उत्पादक होने के बावजूद *शोरिया रोबस्टा* पराग का अल्प रूपायन अवसादों में अपने अल्प परिरक्षण के साथ-साथ अल्प परिक्षेपण क्षमता को आरोपित है। दूसरी तरफ, साल की सर्वनिष्ठ सहचारी *मुधका इंडिका* की अनवरत विद्यमानता तथा क्रमशः 19% व 6% औसतन की उच्च आवृत्ति सहित सपोटेसी अवसादों में अपने पराग के अच्छे परिरक्षण सहित युग्मित वन में अपनी यदा-कदा विद्यमानता सहित ज़्यादा या कम संगत होती है। फिर भी, साल के बड़ी संख्या में अन्य सहचारी अर्थात *टर्मिनेलिया , लेजरस्ट्रोमिया, एम्बलिका आफीसिनेलिस, सायज़ीजियम, होलोप्टेलिया, स्टेरकुलिया* इत्यादि वन में पर्याप्त रूप से उग रहे हैं चूंकि वे एंटोमोगामस हैं, अपनी अल्प पराग उत्पादकता के कारण औसतन 10% पराग के साथ ही विरल विद्यमानता इंगित करते हैं। इस प्रकार, अंचल में आधुनिक साल वन औसतन 37% वृक्ष एवं औसतन 2% यद्यपि विरल रूप से झाड़ियों सहित 39% वृक्षीय पराग रूपायित करता है। घासों, पृत्रणों, ट्यूबिफ्लोरी इत्यादि की प्रचुरता स्थलीय वनस्पतिजात में उनके संघटन के सुसंगत है। अनाज व *अर्टेमिसिया, कैन्नबिस सैटाइवा* के कदाचनिक पराग सहित युग्मित कीनो/एम और कैरीफिलेसी की अनवरत रूप से आधुनिक आवृत्तियां क्रस्ट भूमि की सामीप्यता इंगित करती हैं।

संकेत-शब्द—पराग-वर्षा, वनस्पति, उष्णकटिबंधीय साल वन, शहडोल, मध्य प्रदेश

INTRODUCTION

Reconstruction of past vegetation and climate necessitates the utilization of pollen analysis as the most widely used tool. However, prior to executing the analysis of sediment profile palynologically from any region, it is prerequisite to have a precise knowledge of the interplay of various constituents of pollen rain in relation to extant vegetation through the investigation of surface sediments. Considerable database has been generated concerning modern pollen rain vis–à–vis vegetation from the tropical regions comprising tropical evergreen forests in Sri Lanka (Bonnefille *et al*., 1999; Anupama *et al*., 2000; Barboni & Bonnefille, 2001), tropical deciduous forests in foothills of Himalaya (Sharma, 1985; Gupta & Yadav, 1992) and tropical scrub vegetation in Rajasthan desert (Singh *et al*., 1973). These studies have provided valuable information for the critical assessment of past vegetation scenario and climatic change from their respective regions. However, Madhya Pradesh, which possesses approximately 26% of the total forest floristics of the country and abounds with numerous potential sediment deposits for the Quaternary palaeofloristic studies, has not yet been given adequate 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 (Bera, 1990; Chauhan, 1994, 2008; Quamar & Chauhan, 2007). The available information on pollen–rain study from this region has served as significant modern analogue for the appropriate appraisal of the palaeovegetation scenarios, which also symbolize the climatic changes during the Quaternary Period (Chauhan, 1995, 2000, 2002, 2004, 2005; Chauhan *et al*., 2001; Chauhan & Quamar, 2010, 2012; Patnaik *et al*., 2009; Quamar & Chauhan, 2011; Shaw *et al*., 2007; Yadav *et al*., 2006). In the present paper, hence, an attempt has been made to bring about more data on this aspect through the analysis of surface sediments from Sal dominated tropical deciduous forest from Khanaudi in southeastern Madhya Pradesh in order to understand the interplay of Sal (*Shorea robusta*) and its allies in the pollen rain, their pollen dispersal efficiency and factors affecting the preservation of pollen/spores in the sediments. This study will further aid in assessing the vegetation dynamics during the Quaternary Period in central India as well as equivalent floristic regions.

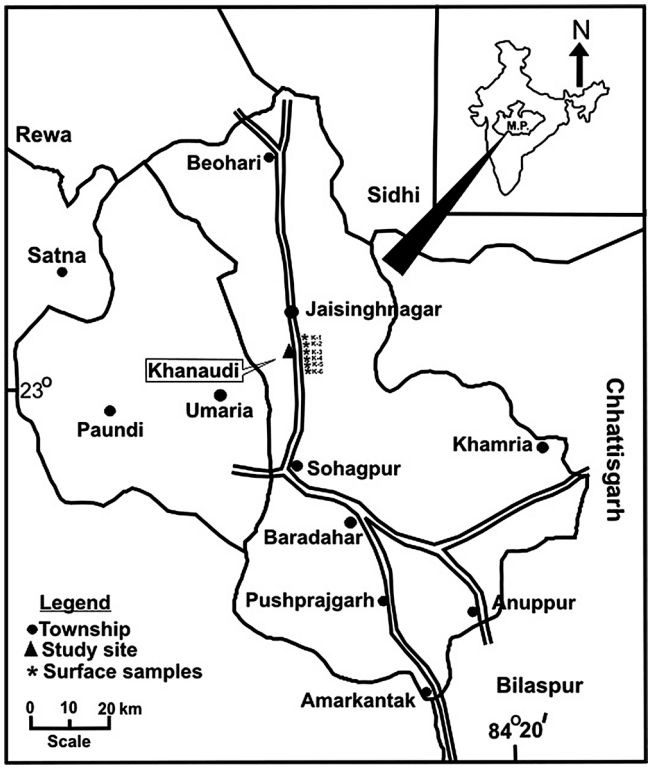

Fig. 1—Map showing the investigation site Khanaudi, Shahdol District, Madhya Pradesh.

PHYSIOGRAPHY

The investigation site–Khanaudi lies about 10 km south of Jaisinghnagar and 40 km north of Sohagpur Township between 84°E Long. and 23°N Lat. in the close vicinity of Khanaudi Village (Fig. 1). Physiographically, the adjoining area of the investigation site is marked by the presence of bumpy surface and deep gorges. The area is characterized by wide range of altitudes, i.e. 400' to 1500' amsl due to great variability of physiographical features. The flat–topped bouldery hillocks encircling the study site support the luxuriant tropical deciduous Sal forests. Most of the area in and around the investigation site is under intensive cultivation by the densely inhabited Gond, Bega, Panika and Kol tribals.

CLIMATE

The study area, in general, experiences a warm and moist climate, which is largely affected by southwest monsoon (Chauhan & Quamar, 2010). The mean minimum and maximum winter temperatures are 16.3°C and 21°C respectively. However, the lowest temperature of 1°C is recorded during the severe cold month of January. The mean minimum and maximum summer temperatures are 31.6°C and 34°C, respectively. The temperature seldom rises up to 44°C during the extreme hot month of June. The rainfall by and large occurs from southwest monsoon from mid June to September; however, major fraction of it takes place in July and August. The average annual precipitation recorded for the area is 1200 mm. Approximately 80% of the total precipitation occurs during the rainy season.

VEGETATION

The vegetation of the region is characterized by the dominance of tropical moist deciduous Sal forest with *Sho-*

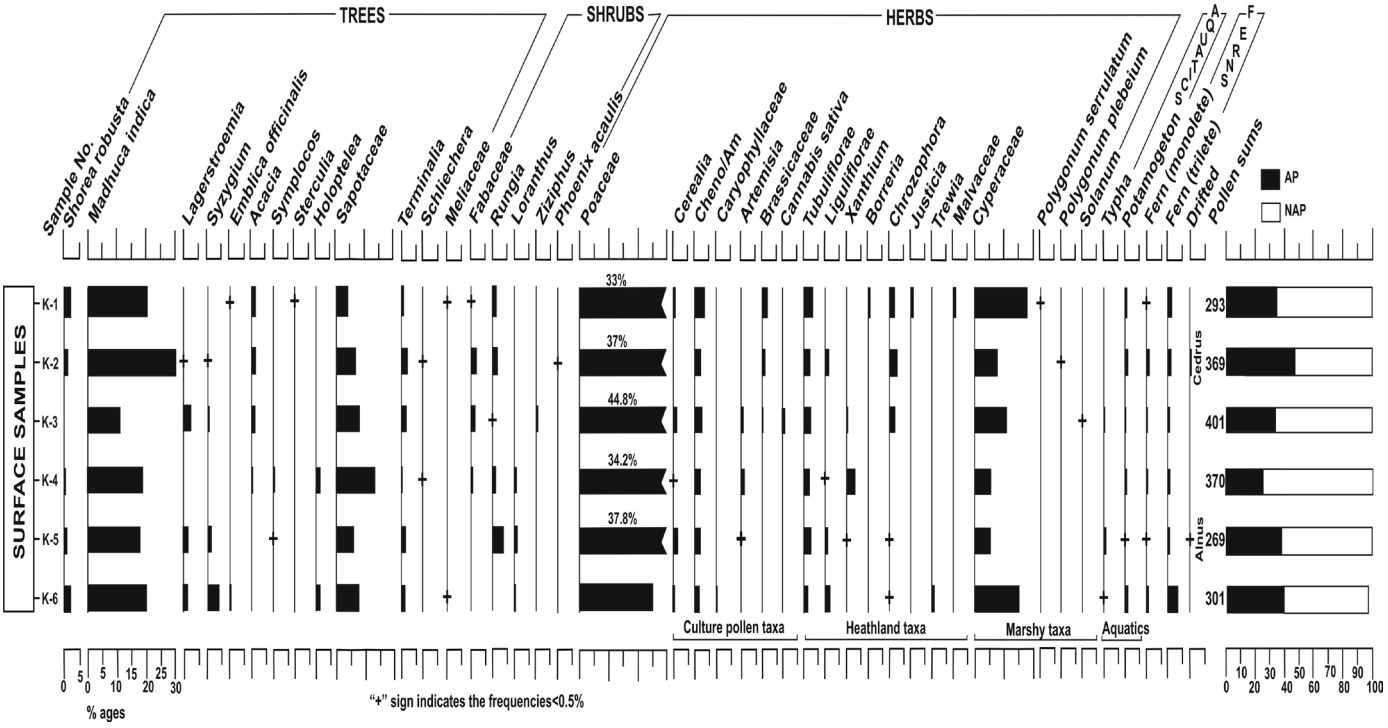

Fig. 2—Modern pollen spectra from Khanaudi, Shahdol District, Madhya Pradesh.

rea robusta being the dominant constituent (Champion & Seth, 1968). Besides Sal, *Madhuca indica*, *Syzygium cumini*, *Lagerstroemia parviflora*, *Careya arborea*, *Adina cordifolia*, *Gardenia latifolia*, *Terminalia arjuna*, *Anogeissus latifolia*, etc. also occur very commonly in the forest. However, *Madhuca indica* and *Syzygium cumini* can be seen locally in good numbers around the site of investigation. The shrubby vegetation comprises mainly *Carissa opaca*, *Woodfordia fruticosa*, *Ziziphus mauritiana*, *Holarrhena antidysenterica*, *Premna mucranata*, *Xeromphis uliginosa*, *X. spinosa*, etc. *Syzygium heyneanum* and *Vitex negundo* grow very profusely along the stream banks. A few stands of *Phoenix acaulis* are seen on the shady hill slopes.

The herbaceous vegetation is predominantly constituted of grasses together with *Ageratum conyzoides*, *Mazus japonicus*, *Sida rhombifolia*, *Justicia simplex*, *Chenopodium album*, *Amaranthus spinosa*, *Nepeta indica*, *Micromeria biflora*, *Urena lobata*, *Oldenlandia dichotoma*, *Hyptis suaveolens*, *Crotalaria juncea*, *Desmodium gangetica*, *D. triflorum*, *Zornia gibbosa*, *Flemingia bracteata*, *Aeschynomene indica*, etc. in the terrestrial habitats. *Cyperus corymbosus*, *Scirpus mucronatus*, *Ammania baccifera*, *Rotala rotundifolia*, *Eriocaulon quinquangulare*, *Jussieua repens*, *Hygrophila auriculata*, *Ocimum americanum* and *O. sanctum* are abundant over the swamps, marshes and in damp places along the stream banks. *Typha latifolia*, *Nymphoides indica*, *Potamogeton purpurascens* and *Lemna paucicostata* are the aquatic plants in the lakes and ponds. Ferns such as *Dryopteris prolifera*, *Adiantum philippensis*, *Diplazium esculentum*, etc. and lycopods, viz. *Selaginella semicordata*, *Lycopodium cernuum*, etc. are seen luxuriantly in damp and shady situations.

MATERIAL AND METHODS

A total number of six surface samples (moss pollsters) were collected in a linear transect along the edge of Sal forest on the left side of Satna–Sohagpur Highway adjoining to Khanaudi Village, Shahdol District to study the pollen deposition pattern in the region. The sampling was carried out at 100 m interval each as it has been observed that a major fraction of pollen gets deposited within a short distance of 100 m or so in the forested region immediately after their discharge from the parent plants. This happens because of the dense canopy of the forest, which prohibits the easier and longer exit of the pollen grains (Luna *et al*., 2002). The sampling strategy was planned in transect from the transition zone between the forest and adjoining open area to understand the average representation of the prominent forest constituents/plant groups of the regional vegetation in the pollen rain across the edge of the forest, covering a linear distance of 500 m. The sample collection was made during the peak flowering (March–April) of Sal and its other associates so that a factual evaluation of the pollen rain vis–à–vis the forest floristic could be achieved.

Ten gram samples were boiled in 10% aqueous KOH solution for 5 minutes to deflocculate the pollen from the sediments and to dissolve the humus. This was followed by

treatment of the samples with 40% HF solution in order to remove the silica. Thereafter, the samples were acetolysed (Erdtman, 1943), using acetolysing mixture (9:1 ratio of acetic anhydride and concentrated sulphuric acid). Finally, the macerals of the samples were prepared in 50% glycerin solution for microscopic examination.

POLLEN ANALYSIS

The pollen sums range from 269 to 401 in the samples analysed palynologically, depending upon their yield. The percentage frequencies of the recovered taxa have been calculated in terms of total terrestrial plant 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 appropriate identification of the palynomorphs (Pl. 1) retrieved in the samples, the reference pollen slides available at the sporothek of 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 and drifted are arranged in the same manner in the pollen spectra. The pollen frequencies < 0.5% are indicated by '+' sign in the pollen spectra. The sample numbers are prefixed with the initial "K" after the name of study site–Khanaudi.

Modern pollen rain composition: In order to understand the deposition pattern of various regional and local floristic constituents in the pollen rain at the study site, 6 moss pollsters (surface samples K–1 to K–6) were analyzed along the edge of Sal forest at Khanaudi (Fig. 2), since they serve as the actual source of pollen, prior getting accumulated in the sedimentary bed. The pollen assemblage has unravelled the dominance of non–arboreal pollen (NAP) and relatively lower frequencies of arboreal pollen (AP). *Madhuca indica* (16.9–30%) followed by Sapotaceae (3.74–13.2%) are recorded consistently with high frequencies. *Shorea robusta* (0.81–2.3%), *Lagerstroemia* (0.49–1.85%), *Terminalia* and *Syzygium* (0.50–1.65% each) have moderate values, despite their sporadic presence. *Acacia* (0.54–1.02%), *Holoptelea* (1.35%), *Symplocos*, *Emblica officinalis* (0.34–0.66% each), Meliaceae, *Schleichera* and *Sterculia* (< 0.5% each) are extremely low and sporadic. Among the shrubs, *Rungia* (1.62–3.31%) and Fabaceae (0.34–1.98%) are the major elements as marked by their steady presence in moderate values, whereas *Ziziphus* (1%) and *Phoenix acaulis* (0.5%) are met with sporadically. Epiphyte–*Loranthus* (1–2.3%) is also recovered in some samples in low frequencies. The drifted taxa, *Cedrus* (1%) and *Alnus* (0.33%) are recorded meagrely.

The non–arboreals are characterized by the steady presence of Poaceae (30–44.8%) in much higher frequencies. Likewise, Cheno/Am (2–3.74%) and Tubuliflorae (1.08–4.09%), which are also the principal components of the pollen rain, are encountered constantly in moderate values. Liguliflorae, *Xanthium* (0.27–2.97% each), Caryophyllaceae, *Chrozophora* (0.33–2.48%), Cerealia (0.27–1.49%), *Artemisia*, Brassicaceae (0.49–1.7% each), *Borreria* and *Trewia* (1.02% each) are met with sporadically in variable frequencies, whereas Malvaceae, *Justicia* (0.54–1.02%) and *Cannabis sativa* (2%) are scanty. Among the marshy elements, Cyperaceae (sedges 4.83–16.3%) is marked by its consistent presence in fluctuating moderate to high frequencies. *Solanum*, *Polygonum serrulatum* and *P. plebeium* (< 0.5% each) are recorded occasionally in extremely low frequencies. The aquatic element, *Potamogeton* (< 0.5–2.3%) is retrieved steadily compared to *Typha* (< 0.5–1.7%), which is very sporadic. Fern spores (monolete and trilete < 0.5–2.97% each) are encountered in moderate frequencies. The fungal spores (excluded in pollen counts and pollen sums) such as *Glomus*, *Tetraploa*, *Nigrospora*, *Cookeina*, etc. have also been recovered while examining the surface samples.

DISCUSSION

The overall pollen rain composition of the surface samples analysed along the edge of Sal forest at Khanaudi, Shahdol District thus, has revealed the relatively lower frequencies of arboreals (trees & shrubs) compared to non–arboreals. *Shorea robusta* (Sal), a dominant forest constituent, is recovered

PLATE 1

1. *Shorea robusta*
2. *Madhuca indica*
3. *Lagerstroemia*
4. *Holoptelea*
5. *Schleichera*
6. *Terminalia*
7. *Syzygium*
8. *Emblica officinalis*
9. *Acacia*
10. *Rungia*
11. Poaceae
12. Cerealia
13. Tubuliflorae
14. Liguliflorae
15. Cheno/Am
16. Caryophyllaceae
17. Malvaceae
18. Brassicaceae
19. *Cannabis sativa*
20. *Alternanthera*
21. *Artemisia*
22. *Borreria*
23. *Xanthium*
24. Cyperaceae
25. *Polygonum plebeium*
26. *Loranthus*
27. *Typha*
28. *Potamogeton*
29. *Chrozophora*
30. Fern trilete

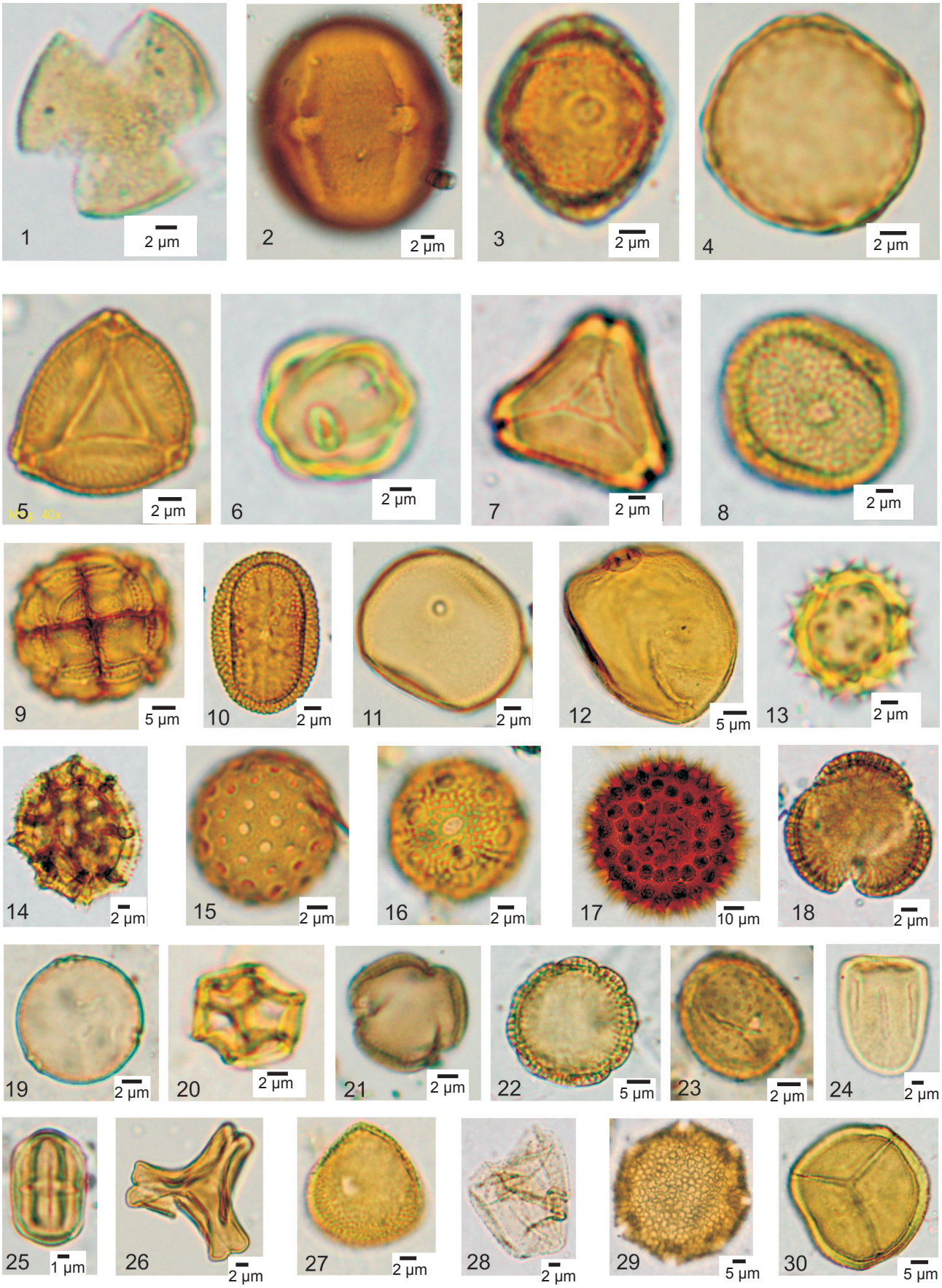
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PLATE 1

with av. 2% pollen only in the sediments, merely at a distance of 100 m from the dense forest; despite being a high pollen producer (Bera, 1990). The under–representation of *Shorea robusta* pollen could be attributed to its poor preservation in the sediments as well as low dispersal efficiency. Similar observations have also been made regarding the ambiguous behaviour of Sal pollen at the edge of forest from Sidhi and Umaria districts, Madhya Pradesh with the frequency of av. 1% only (Chauhan, 1994, 2008; Quamar & Chauhan, 2007). The high pH value of the soil and microbial degradation might have been detrimental factors for the paucity of *Shorea robusta* pollen in the sediments (Gupta & Yadav, 1992). On the other hand, the consistent retrieval of *Madhuca indica*, a common associate of Sal, and Sapotaceae (cf. *Mimusops elangi* and *Manilkara hexandra*) in the surface sediments with the av. 19% and av. 6% pollen as well as with highest frequencies of 30% and 13% respectively, suggests the local abundance of these taxa around the investigation site coupled with good preservation of their pollen in the sediments. Besides, the conservation of *Madhuca indica* tree by the local folks for its multifaceted uses also facilitates its better presentation in the pollen rain. However, a number of trees such as *Terminalia*, *Lagerstroemia*, *Emblica officinalis*, *Syzygium*, *Holoptelea*, *Sterculia*, etc. occurring very frequently in the forest, are characterized by the sporadic presence of their pollen in the sediments. In all, they constitute merely av. 10% chunk of the total pollen influx. The under–representation of these taxa could be attributed to low pollen productivity, since they exhibit a strong tendency of entomogamy (Chauhan, 1994, 2008; Quamar & Chauhan, 2007, 2010). The partial preservation of their pollen in the sediments cannot be overlooked. The irregular representation of tropical trees in the pollen rain has also been recorded from south Indian mountains (Anupama *et al*., 2000) and tropical forests of east African (Vincens *et al.*, 1997). In addition, a large number of trees, viz. *Diospyros melanoxylon*, *Boswellia serrata*, *Adina cordifolia*, *Mitragyna parvifolia*, *Lannea coromandelica*, etc. also occurring in the forest, though sparsely, are untraceable in the sediments. Possibly, the microbial degradation of their pollen can not also be denied since a considerable number of fungal remains, viz. *Glomus*, *Nigrospora*, *Tetraploa*, *Cookeina*, etc. have come across in the sediments during the course of investigation. The shrubs are few in the forest and they are truly represented by merely av. 2% pollen encompassing *Rungia*, Fabaceae, *Ziziphus*, *Loranthus* and *Phoenix acaulis*.

Hence, from the above given account it is deduced that a fraction of average av. 37% trees, including the locally preponderant *Madhuca indica* pollen and av. 2% shrubby pollen, reflect the modern forest floristic in the study area and this also symbolizes the present climatic conditions, more particularly average annual precipitation and temperature of the region.

Among the non–arboreals, the high frequencies of grasses with av. 33% pollen followed by Tubuliflorae, Cheno/Am, *Chrozophora*, etc. and other terrestrial herbs (culture and heath land taxa) with av. 18% frequency correspond more or less with their factual composition in the herbaceous vegetation. The constant record of Cerealia and other culture pollen taxa reflects a close proximity of investigation site to the habitation. Further, the substantial presence of sedges with av. 10% pollen together with other scanty marshy taxa, viz. *Polygonum plebeium* and *Polygonum serrulatum* with av. 2% pollen as well as aquatic elements, *Typha* and *Potamogeton* reflects the intermittent wetlands in the forest. The occurrence of pollen of temperate elements, *Cedrus* (1%) and *Alnus* (< 0.5%), though sporadically, suggests their exclusively long distance wind transportation as there is no any watercourse leading to central India from the Himalaya. Their retrieval also confirms the Himalayan connection of regional wind circulation pattern. The ferns inhabit frequently the moist and shady niches as portrayed by the moderate frequencies of monolete and trilete spores.

Hence, from the aforementioned discussion, it is inferred that the pollen rain data don't fully cohere with the present day vegetation set–up in the region. For this reason, the derived comparative database on the pollen rain–vegetation relationship and all limiting factors drawn from the pollen analysis should be taken into consideration with care while assessing the pollen assemblage recovered in the sediment deposits in terms of past vegetation and climate.

CONCLUSIONS

The comparative evaluation of AP and NAP ratios in the surface samples analysed from the edge of Sal forest at Khanaudi, Shahdol District demonstrates av. 39% arboreal pollen (Fig. 3) out of the total pollen influx. However, *Shorea robusta* is recorded merely with av. 2% pollen, despite its being a high pollen producer. *Madhuca indica* and Sapotaceae with av. 19% and 6% pollen respectively are veraciously represented in accordance to their occurrence in the forest. Nonetheless, the rest of the trees are represented by av. 10% pollen only. This extremely poor representation of other tree taxa in the pollen rain, contrary to their factual presence in the forest could be ascribed to their low pollen productivity. Thus, from the above given account, it is evident that av. 39% arboreal pollen comprising av. 37% trees and barely av. 2% shrubby pollen denote the tropical deciduous Sal forest in the region. This fraction of the forest ingredients also signifies the existing climatic conditions in the study area as dealt elsewhere in the text. Among the non–arboreals, grasses are recorded with av. 33% pollen, whereas Cerealia and other culture pollen taxa as well as heath land taxa collectively constitute av. 18% of the pollen rain. Overall the terrestrial herbs constitute the largest fraction of av. 51% pollen. In general, the non–arboreals with av. 61% pollen including av. 10% marshy herbs infact reflect the ground flora. Further, the substantial frequencies of sedges coupled with other stray marshy and aquatic elements reveal the intermittent wetlands in the for-

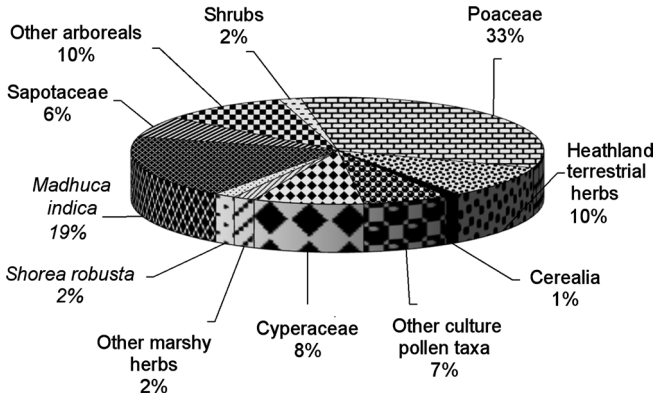

Fig. 3—Composite pollen spectrum showing the major plants/groups in the pollen rain of Sal forest in Shahdol District, Madhya Pradesh.

est. The agrarian activity in the study area is manifested by the consistent presence of Cerealia and other culture pollen taxa. Thus, this comparative database on pollen rain vis–à–vis vegetation is to be taken as modern analogue for the ingenious assessment of pollen sequences from the sediment deposits in terms of past vegetation and climate from the study area and other identical floristic regions.

Acknowledgement—*We are grateful to the Director, Birbal Sahni Institute of Palaeobotany, Lucknow for providing research facilities to accomplish this work.*

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