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Modern pollen and vegetation relationship in the teak deciduous forest in Sehore District, Madhya Pradesh

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ABSTRACT

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Pollen analyses of 19 surface soil and mud samples in and around Kusumelli Swamp near Shahganj, Sehore District of Madhya Pradesh were carried out to understand modern pollen and vegetation relationship in the dry deciduous teak dominated forest region. The palynological assemblage demonstrates pervasiveness of non–arboreal (herbs) forms in comparison to arboreal (trees and shrubs) taxa. Maximum arboreal pollen are recorded in forest floor (average 37%) in comparison to lake floor sediments (average 33%) followed by forest vicinity mud (average 29%) and forest edge open area (average 24%). The most common constituent of modern forest floristic, i.e. teak (80–90%) is recorded by average of 1% in lake, forest and adjoining floor sediments. The other members such as *Madhuca indica* (average 2.1%), *Syzygium* sp. (average 1.6%), *Terminalia* sp. (average 1.4%), *Butea monosperma* (average 1%), *Embilica officinalis* (average 0.7%), *Diospyros* sp. and *Lannea grandis* (average 0.6%) are also recorded in low frequencies. This discrepancy in the pollen deposition pattern is possibly due to their low pollen production and partial preservation in sediments. Stumpy pollen frequency of Sal (average 0.4%) recovered in open area and lake floor sediments could be ascribed to its anemophilous mode of pollination and transportation through low turbulent winds and water from nearby area. However, better representation of *Holoptelea* (average 4.4%) and *Buchanania lanza* (average 3.8%) in all sediment samples can be substantiated through their huge pollen production and higher dispersal efficiency. In addition, non–arboreal representatives such as Asteraceae (Tubuliflorae and Liguliflorae), Caryophyllaceae, Malvaceae, Brassicaceae, Chenopodiaceae/Amaranthaceae and Cannabinaceae, etc. more or less reflect actual composition of the ground flora. The comparative database generated on pollen–vegetation spectra will serve a modern pollen analogue for factual appraisal of fossil pollen successions deposited during Quaternary Period in the region.

Key–words—Pollen deposition, Pollen spectra, Tropical deciduous forest, Kusumelli Swamp, Madhya Pradesh.

जनपद सिहोर, मध्य प्रदेश के सागौन पतझड़ी वन में आधुनिक पराग एवं वनस्पति संबंधता

पूनम वर्मा एवं एम.आर. राव

सारांश

शुष्क पतझड़ी सागौन प्रभावी वन अंचल में आधुनिक पराग एवं वनस्पति संबंधता समझने हेतु मध्य प्रदेश के सेहोर जनपद, शाहगंज के नजदीक कुसुमेल्लि दलदल में एवं चहुंओर 19 पृष्ठीय मृदा व पंक नमूनों के पराग विश्लेषण किए गए। परागाणविक समुच्चय वृक्षीय (वृक्षों एवं झाड़ियों) टैक्सा की तुलना में गैर-वृक्षीय (शाक) प्ररूपों की व्याप्ति दर्शाती है। वन सामीप्य पंक (औसतन 29 प्रतिशत) व वन किनारे खुला क्षेत्र (औसतन 24 प्रतिशत) के अनुगामी झील पृष्ठ अवसादों (औसतन 33 प्रतिशत) की तुलना में वन पृष्ठ (औसतन 37 प्रतिशत) अधिकतम वृक्षीय पराग अभिलिखित किए गए हैं। आधुनिक वन पादपअध्ययन की ज्यादातर सर्वनिष्ठ वस्तुएं अर्थात झील, वन एवं समीपवर्ती पृष्ठ अवसादों में 1 प्रतिशत के औसतन से सागौन (80-90 प्रतिशत) अभिलिखित की गई है। *मधुका इंडिका* (औसतन 2.1 प्रतिशत), *सायज़ीजियम* जाति (औसतन 1.6 प्रतिशत), *टर्मिनेलिया* जाति (औसतन 1.4 प्रतिशत), *ब्यूटिया मोनोस्पर्मा* (औसतन 1 प्रतिशत), *एम्बिलिका ऑफिसिनेलिस* (औसतन .7 प्रतिशत), *डायोस्पायरॉज* जाति एवं *लन्निया ग्रांडिस* (औसतन .6 प्रतिशत) जैसे अन्य सदस्य भी अल्प आवृत्तियों में अभिलिखित किए गए हैं। पराग निक्षेपण प्ररूप में यह विसंगति संभवतः उनके अल्प पराग उत्पादन और अवसादों में आंशिक परिरक्षण के कारण है। खुले क्षेत्र एवं झील पृष्ठ अवसादों से प्राप्त साल (औसतन .4 प्रतिशत) की ठूंठदार पराग आवृत्ति नजदीकी क्षेत्र से प्राप्त निम्नतर प्रक्षुब्ध वायु व जल के माध्यम से परागण एवं परिवहन की अपनी वायुपरागित प्रावस्था को आरोपित की जा सकी। फिर भी सभी अवसाद नमूनों में *होलोप्टेलिया* (औसतन 4.4 प्रतिशत) और *बुचनेनिया लेन्ज़ा* (औसतन 3.8 प्रतिशत) का बेहतर प्रतिरूपण उनके बृहत पराग उत्पादन

व उच्च परिक्षेपण दक्षता से प्रमाणित किया जा सकता है। इसके अलावा एस्टेरेसी (ट्यूब्लीफोरे व लिगुलिफ्लोरे), कैरियाफायल्लेसी, मालवेसी, ब्रसीकेसी, कीनोपोडिएसी/अमरेन्थेसी व कन्नबीनेसी इत्यादि जैसे गैर वृक्षीय निरूपक स्थल वनस्पतिजात का कम या ज्यादा वास्तविक संगठन प्रतिबिंबित करते हैं। क्षेत्र में चतुर्थमहाकल्प अवधि के दौरान निक्षेपित जीवाश्म पराग अनुक्रमों के तथ्य मूल्यांकन हेतु पराग-वनस्पति स्पेक्ट्रा पर जनित तुलनात्मक आंकड़ा आधार आधुनिक परागअनुरूप मुहैया कराएगा।

संकेत-शब्द—पराग निक्षेपण, पराग स्पेक्ट्रा, उष्णकटिबंधीय पतझड़ी वन, कुसुमेल्लि दलदल, मध्य प्रदेश।

INTRODUCTION

Modern pollen analysis from lake sediments and surface soil can provide a useful tool to interpret fossil pollen record for quantitative palaeovegetation and palaeoclimate reconstructions. Prior to determination of factual appraisal of pollen sequence from specific region, it becomes indispensable to understand the modern pollen deposition pattern of constituent plant taxa in regional vegetation. Substantial information on the same aspect was available from tropical evergreen and deciduous forests of south India and Sri Lanka (Bonnefille *et al.*, 1999; Anupama *et al.*, 2000; Barboni & Bonnefille, 2001; Barboni *et al.*, 2003); tropical deciduous scrub vegetation in Rajasthan desert (Singh *et al.*, 1973); Himalayan foot hills (Sharma, 1985; Gupta & Yadav, 1992). From central India, a few records are available to understand the pollen deposition pattern of tropical Sal forest in north eastern and south eastern Madhya Pradesh (Bera, 1990; Chauhan, 1994, 2005; Quamar & Chauhan, 2007). These modern pollen analogues are used for reconstruction of regional palaeovegetational dynamics during Holocene (Chauhan, 1995, 2000, 2002, 2004, 2005; Chauhan & Quamar, 2010; Yadav *et al.*, 2006). However, these types of records are deficient from teak deciduous forest of central Narmada Valley. The present study is based on pollen analysis of modern surface samples both mud and soil sediments in and around Kusumelli Swamp (22°54'05.5" N: 77°48'39" E) to establish representation of modern pollen of Teak, Sal and their associates in the sediments. The generated database could be treated as modern pollen analogue for factual assessment of fossil pollen successions to infer past vegetation and climate changes in the region.

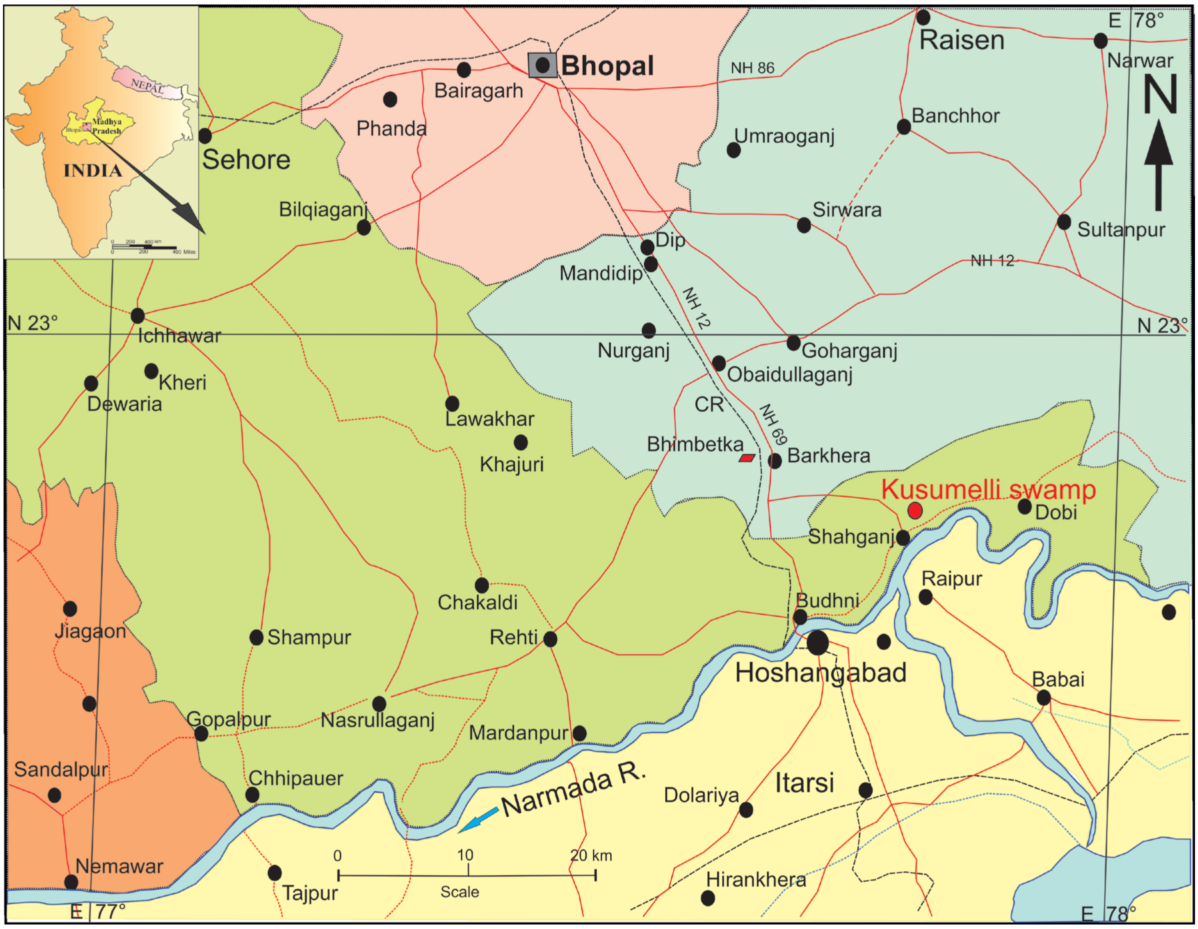


Fig. 1—Map showing the location of Kusumelli Swamp, Sehore District, M.P.

Area	Geographical coordinates	Nature of samples	Samples	No. of samples
Kusumelli Swamp	22º54'05.5"N: 77º48'39"E	Lake floor mud	KMS1–KMS5	5
		Surface soil from forest edge	KMS6–KMS8	3
		Ditch mud	KMSa1–KMSa7	7
		Forest floor soil	KMSb1–KMSb4	4

Fig. 2—Details of surface samples collected from Kusumelli Swamp, Sehore District, Madhya Pradesh.

CLIMATE

The climate of Madhya Pradesh is by and large humid and tropical. It can be classified broadly into four seasons: (i) winter (January–February), (ii) hot summer (March–May), (iii) rainy south western monsoon (June–September) and (iv) post–monsoon, also known as northeast monsoon (October–December). The mean monthly temperature and precipitation data from AD 1901–1997, available from Hoshangabad climate station (22º46' N: 77º46' E) shows that May (34.4º C) and December–January (19.1º C) are the hottest and coldest months, respectively. July receives highest rainfall (408.8 mm) and April is the driest month having only 3.9 mm of precipitation (Shah *et al.*, 2007). According to CGWB report (2009) a major portion of the precipitation takes place during southwest monsoon (July to September) which accounts for about 92.8% of the total annual precipitation whereas, northeast monsoon is 7.2%. Average annual rainfall of the basin is 1225.9 mm (at Hoshangabad). The evaporation rates in the basin vary from 6 to 28 mm in summer (April to June) and 1 to 9 mm in winter (October to March) (Gupta & Chakrapani, 2005).

VEGETATION

The region represents the tropical dry deciduous forests along the Narmada River Valley and the edging Vindhyan Range. According to Champion and Seth (1968) the study area is marked by TYPE 5A/C1b dry teak forests and TYPE 5A/C3 southern dry mixed deciduous forests. Teak (*Tectona grandis*) is a ubiquitous species in the region, with presence ranging from a sporadic distribution in most parts of the study area to localized teak–dominated patches. Teak and associated taxa such as *Madhuca indica*, *Diospyros melanoxylon*, *Terminalia tomentosa*, *Holoptelea, Buchanania lanza*, *Lagerstroemia parviflora*, *Ougeinia dalbergoides*, *Hardwickia binata, Miliusa velutina* and *Lannea coromandelica. Acacia* spp. and *Ziziphus mauritiana* occur on flat terrain. The undulating terrain and hill slopes have patches of mixed forest dominated by *Boswellia serrata* and *Anogeissus latifolia*. Species like *Sterculia urens* and *Gardenia latifolia* are found scattered on rocky slopes. Bamboo forests occur in the hill slopes and along streams. Some of the open patches of the study area are covered with tall grasses interspersed with *Butea monosperma* and *Ziziphus mauritiana*. Evergreen tree species like *Terminalia arjuna*, *Syzygium cumini* and *Ixora parviflora* are found in riparian vegetation along channels and river banks.

MATERIAL AND METHOD

Kusumelli Swamp (22º54'05.5" N: 77º48'39" E, Fig.1) is located about 7 km northeast of Shahganj Township, Sehore District, Madhya Pradesh. Overall, 19 samples (Fig. 2) were collected for modern pollen and vegetation relationship, out of which 8 swamp floor sediment samples (KMS1 to KMS8) were collected in a linear transect at every 10 meter distance from lake margin towards forest edge, 7 mud samples (KMSa1–KMSa7) from a ditch in vicinity of forest and 4 surface soil samples (KMSb1 to KMSb4) from forest floor.

Extraction of pollen and spores from the sediments has been done by conventional method (Erdtman, 1943). 10% aqueous KOH solution, 40% HF and acetolysis mixture (9:1, acetic anhydride and conc. H_2SO_4) was employed to extract the palynomorphs from the sediments. A few recovered taxa are shown in Pl. 1. Total 266 to 555 palynomorphs were counted per sample and percentages of each have been calculated in terms of total terrestrial plant pollen. The palynomorphs have been grouped in an order of trees, shrubs, herbs (terrestrial, marshy and aquatic), ferns, algal and fungal remains in pollen spectra. The percentages of total arboreal, i.e. trees and shrubs and non–arboreal (terrestrial, marshy and aquatic herbs with ferns) pollen have also been calculated.

POLLEN ANALYSIS

Pollen spectra (Figs 3 and 4) from the lake floor sediments (KMS1 to KMS5, Fig. 5A) contain a rich pollen assemblage with 22–28% of trees. Among trees, *Buchanania lanza* (3–6.5%), *Holoptelea* sp. (3.5–5%), *Terminalia* sp. (1–3%), representatives of the Meliaceae family (0.5–2.5%), *Madhuca indica* (0.5–3.5%), *Syzygium* sp. and *Butea monosperma* (1–2% each) are the major taxa. In addition, *Shorea robusta, Tectona grandis, Ailanthus* sp., *Azadirachta* sp., *Lagerstroemia* sp. (up to 2% each), *Embilica officinalis, Lannea coromandelica* (1% each), *Diospyros* sp., *Acacia*

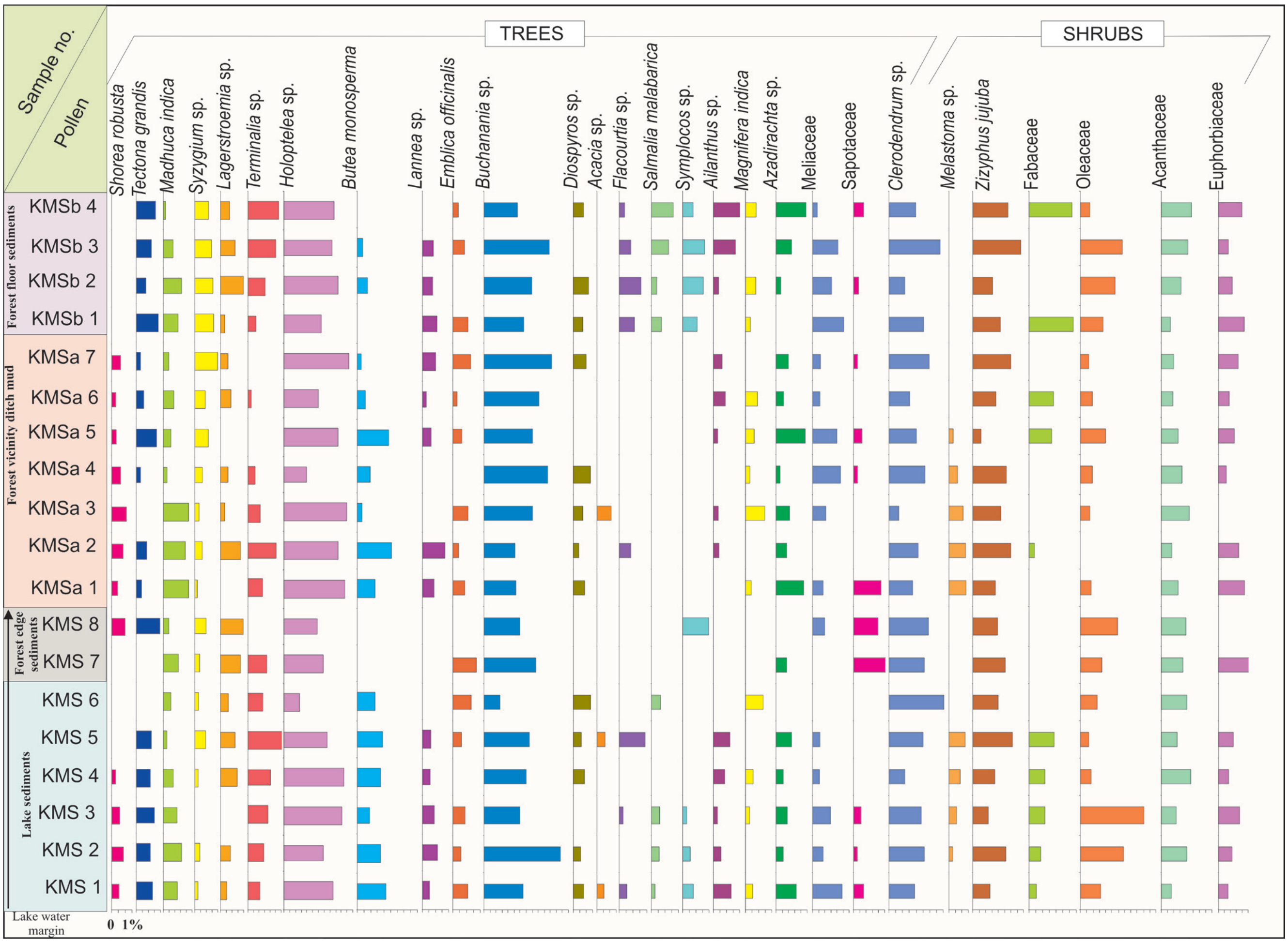


Fig. 3—Pollen spectra showing arboreal pollen percentages from Kusumelli Swamp, Sehore District, M.P.

sp., *Flacourtia* sp., *Salmalia* sp., *Symplocos* sp., *Mangifera indica* sp. and members of the Sapotaceae family are scarcely represented. Among the shrubs, *Zizyphus jujuba* (1–3%), Oleaceae (0.5–5%), Fabaceae (0.5–2%), Acanthaceae (1–2%) and *Melastoma* sp. (1%) are recorded. However, non–arboreal taxa of Poaceae (39–52%), Cyperaceae (12–32%), Tubuliflorae (4–10%), *Cannabis sativa* (2–10%), Brassicaceae (3–6%), Caryophyllaceae (2–3.2%) show their preponderance as compared to those of the families Chenopodiaceae /Amaranthaceae (0.9–3.8%), Malvaceae (0–2.5%) and Liguliflorae (0–1.5%) and the taxon *Artemisia* sp. (0–0.8%).

Pollen spectra (Figs 3 and 4) from the edge of the forest (KMS6–KMS8, Fig. 5B) exhibit a relatively lower terrestrial pollen sum (102–145) as well as low arboreal (12–18%) representation in comparison to non–arboreal taxa. *Buchanania lanza* and *Holoptelea* sp. (1–4% each), *Madhuca indica* (0.5–2.5%), *Syzygium* sp. (1–2%), *Terminalia* sp. (1–3%) are the major tree taxa. Meliaceae, *Butea monosperma*, *Tectona grandis, Ailanthus* sp.*, Azadirachta* sp.*, Lagerstroemia, Embilica officinalis, Lannea coromandelica, Diospyros* sp., *Acacia* sp.*, Flacourtia* sp.*, Salmalia* sp.*, Symplocos* sp.*, Mangifera indica* are noticed in low percentages (~ 1%). *Zizyphus jujuba* (2–3%), Oleaceae (1–3%), Acanthaceae (1–2%) *Melastoma* sp., Fabaceae (1% each) represent major shrubby vegetation. The non–arboreal members mainly comprise Poaceae (42–52%), Cyperaceae (32–50%), Tubuliflorae (2–4%), Brassicaceae (1–6%), Caryophyllaceae (2–5%), Chenopodiaceae/Amaranthaceae (3–5%), besides *Cannabis sativa* (2–7%).

The pollen assemblage (Figs 3 and 4) of the ditch mud samples (KMSa1–KMSa7, Fig. 5C) in forest vicinity is more or less similar to the lake sediments. The arboreal taxa (by an average of 29%) are better represented in comparison to forest edge sediments. *Buchanania lanza* (3–6%), *Holoptelea* sp. (2–6%), *Madhuca indica* (1–4.5%), *Syzygium* sp. (0.5–4%), *Butea monosperma* (0.5–3%), *Azadirachta* sp., (0.5–2% *), Shorea robusta* (0.5–1%) are recorded from all the samples whereas, *Terminalia* sp. (0.5–3%), *Tectona grandis, Lagerstroemia* sp., *Lannea coromandelica ,* Meliaceae, Sapotaceae (each up to 2%), *Embilica officinalis*, *Diospyros* sp., *Acacia* sp., *Ailanthus* sp., *Flacourtia* sp. and *Mangifera indica* (up to 1%) are also recorded in some samples. Non–arboreal taxa such as

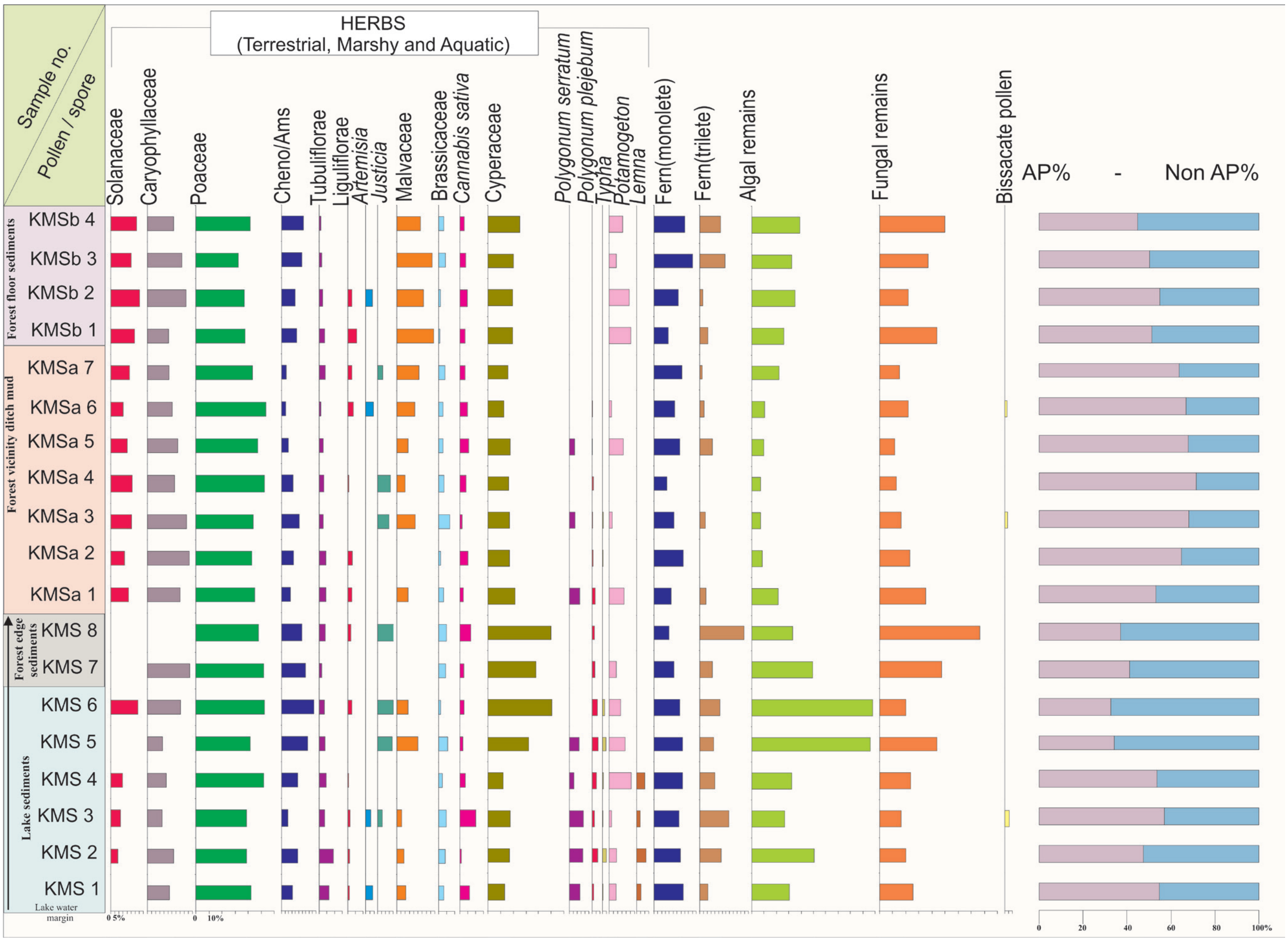


Fig. 4—Pollen spectra showing non–arboreal pollen / spores percentages from Kusumelli Swamp, Sehore District, M.P.

members of the Poaceae (43–54%), Cyperaceae (13–22%), Cannabinaceae(1.5–6%), Brassicaceae, Tubuliflorae (1–4%), Caryophyllaceae (3–5%) Chenopodiaceae/Amaranthaceae (1–3%) in addition to exhibited high frequencies.

Pollen spectra (Figs 3 and 4) from the forest floor sediments (KMSb1 to KMSb4, Fig. 5D) show highest percentage of tree pollen. However, *Shorea robusta* is not recorded but the frequencies of *Tectona grandis* (1–2%), *Syzygium* sp. (2.5–3.3%) and *Lagerstroemia* sp. (1–2%) are comparatively enhanced. Shrubs are also recorded with maximum average of 10% in forest floor sediments. Among herbs, Poaceae family members is recorded at an average of 37%. Other herbs (average terrestrial 25%, aquatics 22%) follow the same trend as on other sites.

In addition, all the samples have yielded fern spores, both trilete (1–6%) and monolete (2–5%) with algal (7–98%) and fungal remains (12–77%).

DISCUSSION

The study of modern–pollen and vegetation relationship provides a potentially valuable pollen analogue to evaluate palynological fossil record for quantitative assessment of palaeovegetation and palaeoclimate. The database is generated through the pollen analysis of different types of samples, i.e. surface soil, lake and ditch mud which will be useful to avoid bias of preferential pollen preservation in different types of sediments. The pollen assemblages from all the sites (Fig. 5) have provided a general dominance of non–arboreals over arboreals, however, the soil sediments from forest floor near Kusumelli Swamp also showed dominance of arboreal pollen (average 36.8%, Fig. 5D) especially tree components (average 27.2%, Fig. 5). The low values of Teak (0–2%) and Sal (0–1%) have been recorded from all types of samples except forest floor samples which yielded Teak pollen (1.4%) but not Sal. The erroneous behaviour of Teak which is the major component of forest in the area could be ascribed to its entomophilous nature (Bryndum & Hedegart, 1969; Hedegart, 1973; Egenti, 1978) with low pollen production rate, i.e. 2100 ± 170 per

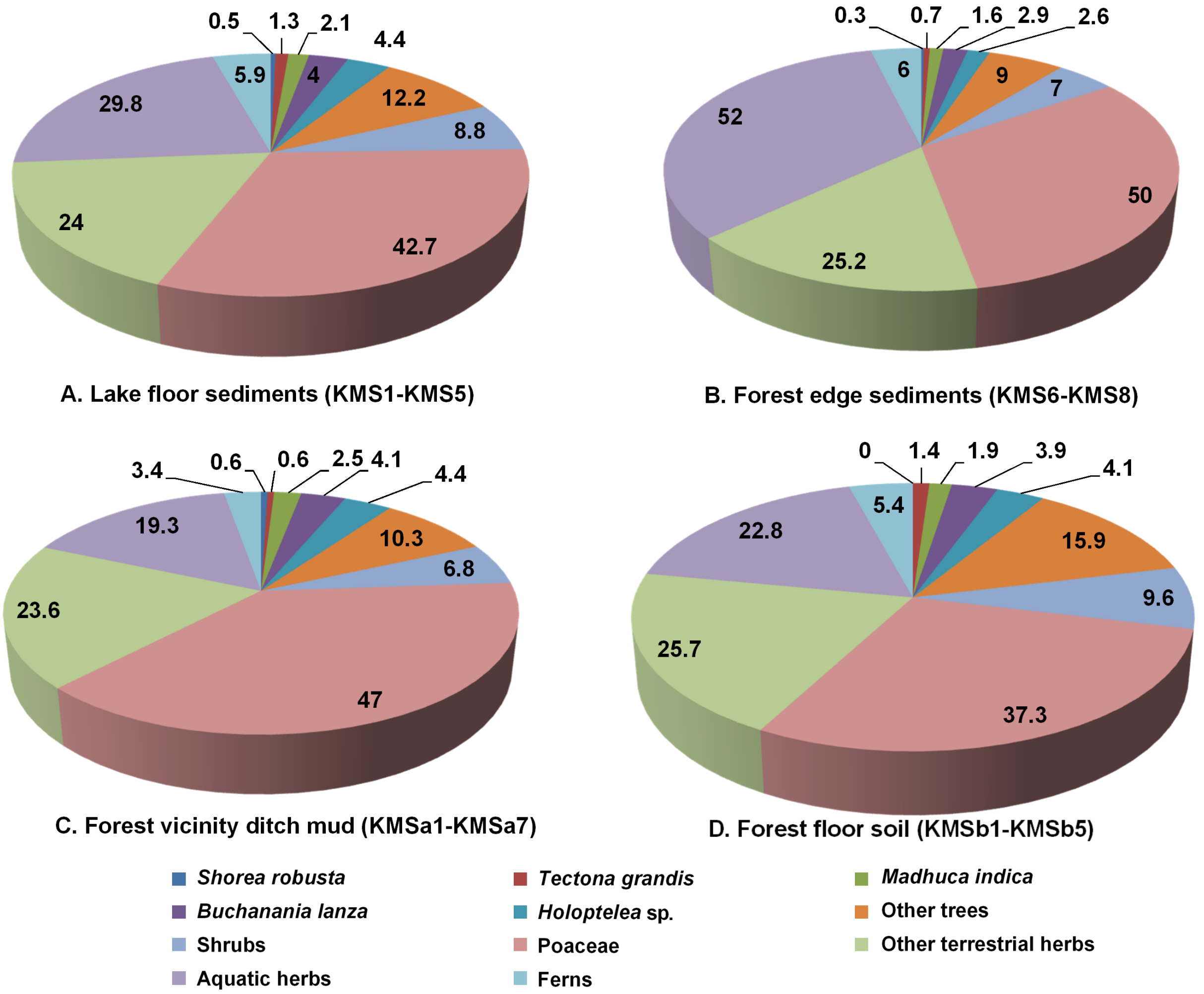


Fig. 5—Composite pie diagram Lake floor sediments (KMS1–KMS5); Forest edge sediments (KMS6–KMS8); Forest vicinity ditch mud (KMSa1–KMSa7); Forest floor soil (KMSb1–KMSb5) of Kusumelli Swamp, Sehore District, M.P.

anther (or ~12600 pollen per flower) and less efficient pollen dispersal (Tangmitcharoen & Owens, 1997).

In case of *Shorea robusta* pollen, although provenance is far away, yet very low values of pollen representation could be due to its anemophilous nature and high pollen production (61200–94600 per flower; Bera, 1990; Chauhan, 1994; 59500 per flower, Atluri *et al.*, 2004). *Shorea robusta* pollen can be transported to longer distance depending upon its height and moderate turbulent atmospheric condition. The high pollen concentration in air, i.e. 300–1800 per m^3, its viability of 50 hrs and its grain size of 24–28 × 28–33 µm, and canaliculated exine sculpture support the above view (Atluri *et al.*, 2004; Bera, 1990). Irrespective of all these factors, it contributes only an average of 10% pollen in pond sediments near Sal

PLATE 1

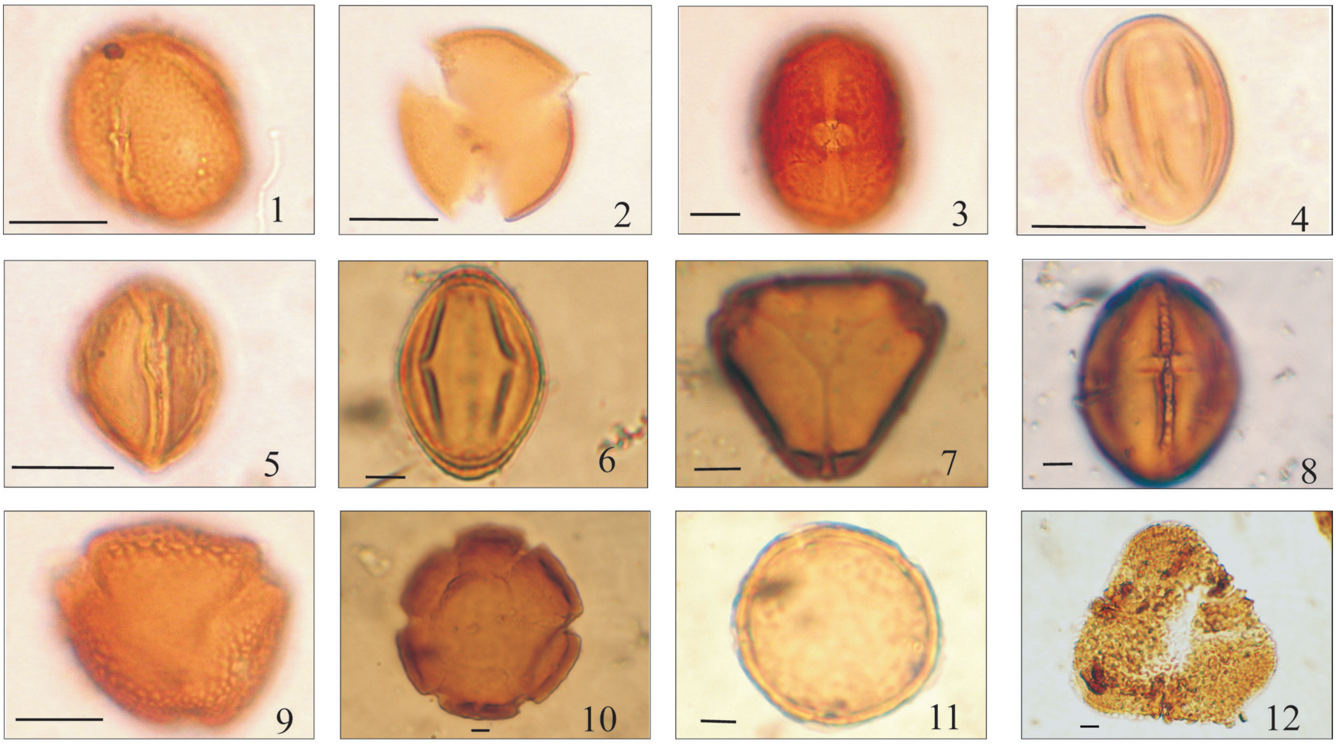
(The bar in figures is equal to 10 µm) ⟶

1. *Shorea robusta*
2. *Tectona grandis*
3. *Madhuca indica*
4. *Terminalia* sp.
5. *Lannea coromandelica*
6. *Lagerstroemia* sp.
7. *Syzygium* sp.
8. *Diospyros* sp.
9. *Butea monosperma*
10. Meliaceae
11. *Holoptelea* sp.
12. Bombacaceae
13. *Cerealia*
14. Poaceae
15. *Polygonum* sp.
16. Solanaceae
17. Brassicaeae

18., 19. Asteraceae

20. Chenopodiaceae/ Amaranthaceae
21. *Cannabis sativa*
22. *Chrozophora* sp.
23. *Justica* sp.
24. Malvaceae
25. Cyperaceae

Pollen of Arboreal taxa



Pollen of Non Arboreal taxa

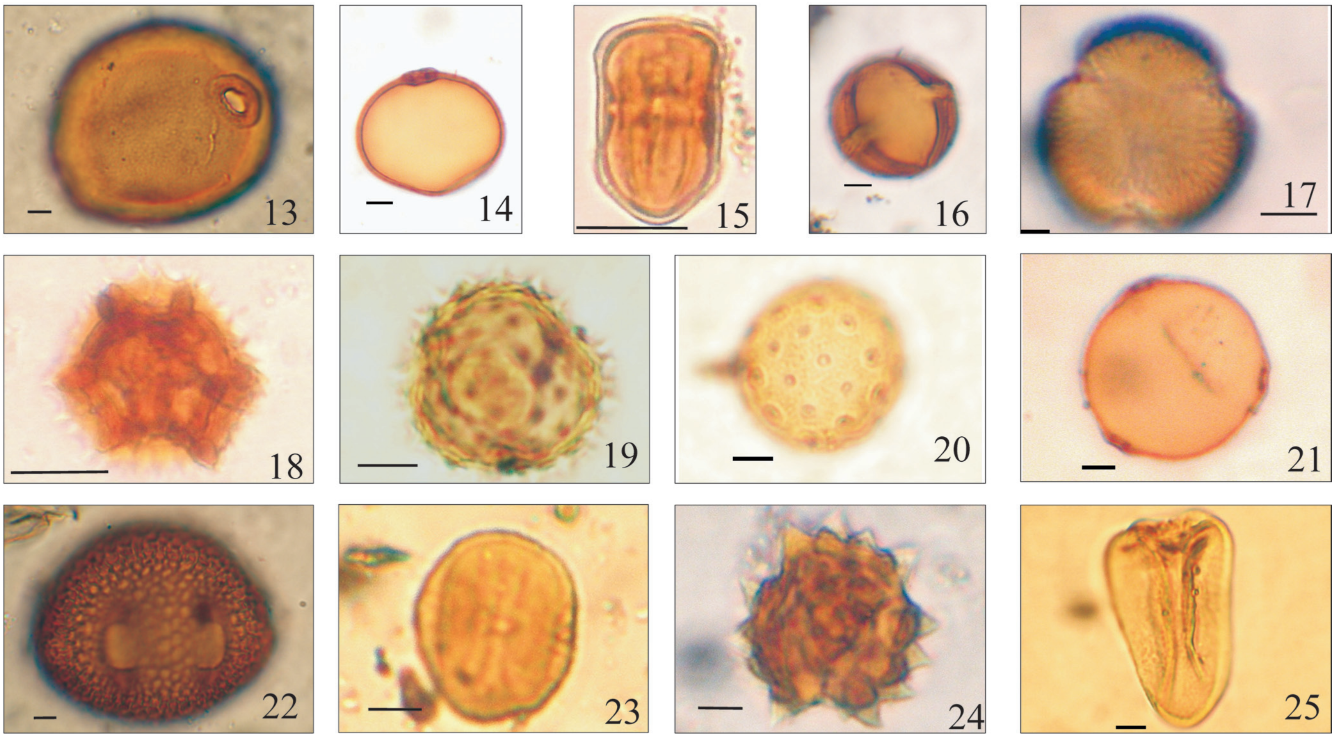


PLATE 1

forest (Chauhan, 1994). In the present study, the Sal pollen is considered to approach from nearby areas through winds.

Likewise, *Madhuca indica*, *Terminalia*, *Butea monosperma*, *Embilica officinalis*, *Diospyros*, *Flacourtia*, *Lannea*, *Syzygium* and the major constituents of dry deciduous tropical forest are poorly represented in the sediments. The low representation of these taxa is attributed to their less pollen productivity because majority of tropical trees have strong tendency of entomophilous mode of pollination. Better representation of *Holoptelea* and *Buchanania lanza* in all the types of sediment samples could be attributed to their huge pollen production. The similar annotations have been made through modern pollen and vegetation studies on surface sediments from tropical deciduous forest from Madhya Pradesh, India (Bera, 1990; Chauhan, 1994, 2005; Quamar & Chauhan, 2007, 2010) and south Indian mountains (Anupama *et al.*, 2000; Barboni & Bonnefille, 2001). Further, a few trees such as *Boswellia serrata*, *Manilkara hexandra*, *Mimusops elangi*, *Dalbergia sissoo*, *Kydia calycina*, etc. are common in forest but could not be recovered from the sediments. The possible reason for this discrepancy could be the limited discernibility beyond family level due to overlapping morphological characters of pollen of close species and genera under the light microscope. Besides, the microbial degradation and partial preservation of pollen in different sediments cannot be ruled out as good number of fungal spores such as *Tetraploa, Alternaria*, *Glomus* and others are recorded.

Among the non–arboreal representatives, Poaceae has consistently been recorded with high percentages from all sites denoting the dominance among terrestrial herbaceous flora. However, the maximum values of Poaceae (50%) are marked in forest edge soil samples which could be attributed to their profound growth in open area. It is recorded by an average of 37.3% from forest floor, i.e. minimum value. The overall dominance of Poaceae over the arboreal taxa in forest area also is due to high pollen production and anemophilous nature in contrast to the low pollen producing, entomophilous tropical trees. In addition, other representatives such as members of Asteraceae (Tubuliflorae and Liguliflorae), Caryophyllaceae, Malvaceae besides *Justicia*, *Cannabis sativa,* etc. reflect the composition of the ground flora. The culture pollen taxa such as Brassicaceae (0.7–7%), Chenopodiaceae/ Amaranthaceae (0.6–4.7%) and *Artemisia* (0–0.9%) could be suggestive of agricultural practice and human habitation in the region (Chauhan, 1994). The abundance of Cyperaceae (sedges) indicate damp and marshy habitat and other aquatic herbs indicate prevalence of water logged body in vicinity of sample collection site.

The consistent presence of fern spores is ascribed by persistent growth of ferns and allies in damp and shady habitat in the forest or along the water course. The low values of temperate elements, viz. *Betula, Alnus, Pinus* and *Abies* are the exotic pollen from high altitude, transported through wind possibly from the Himalayas.

It is apparent from the above discussion that the pollen deposition pattern and floristic composition of vegetation of respective regions does not necessarily correspond to each other. Therefore, prior to the determination of any palaeovegetation and palaeoclimate inference of Quaternary Period, it becomes inevitable to establish a modern pollen analogue of the respective region. The main reason for pollen and vegetation incongruity is largely due to different pollen production capacity of different taxa. The dispersal and depositional patterns also influence the distribution pattern of pollen. This may be due to the sculpture of pollen and spores, media of dispersion, geographical causes, atmospheric influences or a combination of these causes. The preservational factors also play their role. The degradation of pollen and spores may also be attributed to micro biota and saprophytic fungi. A major cause could be anthropogenic interference in nature.

CONCLUSIONS

Present pollen and vegetation relationship from dry deciduous teak forest of Madhya Pradesh reveals that the arboreal pollen composition is over masked by non–arboreal pollen/spores. The arboreal taxa in pollen spectra are not fully corresponding to their actual composition as in the forest floristic. The major constituent of the forest, i.e. Teak (*Tectona grandis*) is represented by an average of 2% where as Sal (*Shorea robusta),* growing in remote area is recorded by an average of 1% except the forest floor. Similarly, other major components of the forest such as *Madhuca indica*, *Terminalia*, *Butea monosperma*, *Embilica officinalis*, *Diospyros*, *Flacourtia*, *Lannea coromandelica*, *Syzygium,* etc. also show pollen / vegetation anomalies. These anomalies pertaining to pollen and vegetation incongruity could be attributed to their poor pollen productivity, dispersal efficiency and preservation potential, etc. In addition, presence of some locally copious non–arboreal taxa should also be deciphered carefully while interpreting the pollen spectra. Hence, in the translation of fossil pollen records in term of past vegetation and climate, all the above criteria should be considered.

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