Pollen rain-vegetation relationship in the tropical deciduous teak (*Tectona grandis* Linn. F.) forest in south-western Madhya Pradesh, India

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ABSTRACT

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The paper deals with the modern pollen rain - vegetation relationship, derived from the pollen analysis of eight surface samples collected from the tropical dry deciduous teak (*Tectona grandis*) forest in Sehore District of Madhya Pradesh. The pollen assemblages reveal the dominance of non-arboreals over relatively low frequencies of arboreals. Among the tree taxa, teak (*Tectona grandis*), the principal arboreal component of modern forest (70-80%), is not represented precisely in the pollen rain studies from inside the forest and adjoining open areas. However, on an average 7.5% of its pollen is recovered in the sediments from the above two areas. In the pollen spectra from forest, it is low with 19.5% and declines severely even to 1-1.5% at the edge of forest as well as in open area, despite its being a high pollen producer. Irregular representation of teak pollen in the sediments is inferred to its poor preservation. On the other hand, the consistent recovery of pollen of *Madhuca indica* in moderate to high values in the forest area corresponds well with its actual representation in the forest. The values of *Madhuca indica* decrease at the edge of forest as well as in the open area. The other major associates of teak, viz. *Terminalia*, *Mitragyna parvifolia*, *Emblica officinalis*, *Holoptelea*, *Lannea coromandelica*, etc. in the extant forest remain under-represented attributed to their low pollen productivity. The representation of grasses, sedges, Asteraceae, Cheno/Am, Caryophyllaceae, *Xanthium*, etc. in the pollen spectra substantiates their actual composition in the ground flora besides, the presence of Cerealia pollen along with other culture pollen taxa, viz. Cheno/Am, Brassicaceae, *Artemisia*, *Cannabis sativa* and *Alternanthera*.

Key-words: Pollen rain, surface sediments, teak forest, south-western Madhya Pradesh

INTRODUCTION

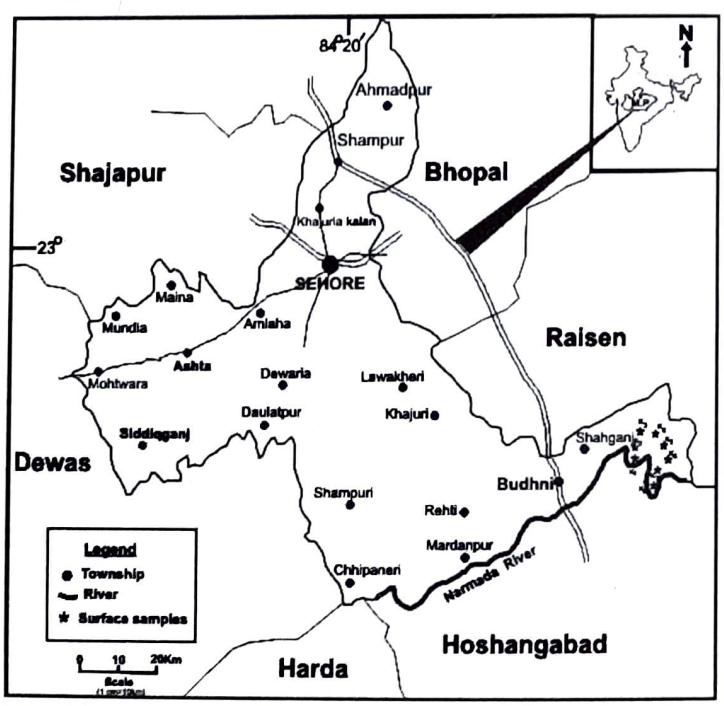
Considerable data on modern pollen rain-vegetation relationship has been generated for the tropical evergreen and deciduous forests in South India, Sri Lanka (Bonnefille et al. 1999, Anupama et al. 2000, Barboni & Bonnefille 2001), foothills of Himalaya (Sharma 1985, Gupta & Yadav 1992), North-east India (Basumatary & Bera 2007) and tropical deciduous scrub vegetation in Rajasthan desert (Singh et al. 1973). These studies provided valuable comparative data-base on the pollen rain vis-a-vis extant vegetation and serves as a modern analogue for the factual appraisal of pollen sequences from their respective regions in terms of past vegetation dynamics and contemporary climate during the Quaternary Period. However, Madhya Pradesh, which alone constitutes approximately 26% of the total forest floristic of the country with great potentiality for the Quaternary palaeofloristic studies has so far not been given enough attention to understand the pollen deposition pattern, except for some work executed from the tropical deciduous sal (*Shorea robusta*) forests distributed in north-eastern Madhya Pradesh (Chauhan 1994, 2008, Quamar & Chauhan 2007). The present study is an endeavor to generate data-base from teak (*Tectona grandis*) dominated tropical dry deciduous forest in south-western Madhya Pradesh purported to understand the interplay of *Tectona grandis* and its allies in the modern pollen rain, their pollen dispersal efficiency and assessment of possible factors affecting preservation of pollen/spores in the sediments through the pollen analysis of surface soil samples from the inside

forest, edge of forest and open land at Kishanpur, Sehore District in the south-western Madhya Pradesh (Text-figure 1).

The study area is located about 10 km east of Budhni township, between 22°39′ and 22°45′ north latitudes and 77°45′ and 77°55′ east longitudes, on the right flank of Narmada river in Sehore District, Madhya Pradesh. Topographically, most of the area at Kishanpur is characterized by flat or bumpy land. The hillocks on the north are of moderate-size with gentle slopes occupied by boulders. Average altitude of the region varies from 244m to 458m a.m.s.l. The flat ground is mostly under intensive agricultural practice, whereas the valleys and gorges have groves of teak as well as mixed scrubs dominated by scattered *Acacia nilotica* (babul). The hillocks along the road side from Budhni to Shahganj area abound with *Tectona grandis* forest.

CLIMATE

Climate of Sehore District exhibits distinct seasonal variability. Summer season is characterized by high temperatures with average annual minimum and maximum of 24°C and 30.6°C, respectively. However, temperature seldom reaches up to 43°C during May and June. Winter season from November to January is marked by cold climate with the average minimum and maximum temperatures of 7°C and 17°C, respectively and the temperature descends as low as 1°C during the extreme cold months of December and January. The average annual precipitation varies from 1150-1200mm for the nearest township, Hoshangabad.



Text-figure 1. Map of Sehore District, Madhya Pradesh, showing site of surface samples.

VEGETATION

The vegetation of the area is characterized by tropical dry deciduous teak (*Tectona grandis*) dominated forests associated with *Diospyros melanoxylon*, *Madhuca indica*, *Buchanania lanzan*, *Sterculia urens*, *Emblica officinalis*, *Holoptelea integrifolia*, *Schrebera oleosa*, *Terminalia arjuna*, *T. bellerica*, *Aegle marmelos*, etc. (Champion & Seth 1968). The moist habitat elements such as *Adina cordifolia*, *Feronia lemonia*, *Mitragyna parvifolia*, *Lagerstroemia parviflora*, *Syzygium cumini*, etc., occur infrequently. *Butea monosperma* and *Acacia nilotica* are two prominent elements growing abundantly in the open land along the edge of forest, especially on rocky plateaus and wasteland adjoining to the cultivated fields mixed with scattered trees of *Bombax malabaricum*. The common trees seen around human habitations are *Madhuca indica*, *Butea monosperma*, *Melia azedarach*, *Mallotus philippensis*, *Acacia nilotica*, *Ficus infectoria*, *F. benghalensis*, *Annona squamosa*, etc.

The scattered shrubby elements seen in the teak forest comprise *Ziziphus mauritiana*, *Carissa opaca*, *Melastoma malabathricum*, *Osbekia* sp., *Nyctanthes arbor-tristis*, *Adhatoda vasica*, *Woodfordia fruticosa*, etc. *Phoenix acaulis*, *Dendrocalamus strictus* and *Bambusa* sp. thickets can be seen in groves around the forest skirt and valley areas.

→

Plate 1

1-2. *Tectona grandis*. 3-4. *Acacia*. 5. *Madhuca indica*. 6-7. *Grewia*. 8-9. *Lannea coromandelica*. 10. *Aegle marmelos*. 11. *Holoptelea*. 12. *Terminalia*. 13. *Syzygium*. 14. *Schleichera*. 15. *Mitragyna*. 16. *Emblica officinalis*. 17. *Rungia*, 18. Cheno/Am. 19. Caryophyllaceae. 20. *Borreria*. 21.*Cannabis sativa*. 22-23. Brassicaceae. 24-25. *Artemisia*. 26. *Xanthium*. 27. Tubuliflorae. 28. Liguliflorae cf. *Vernonia*. 29. Poaceae. 30. Cerealia. 31. Cyperaceae.

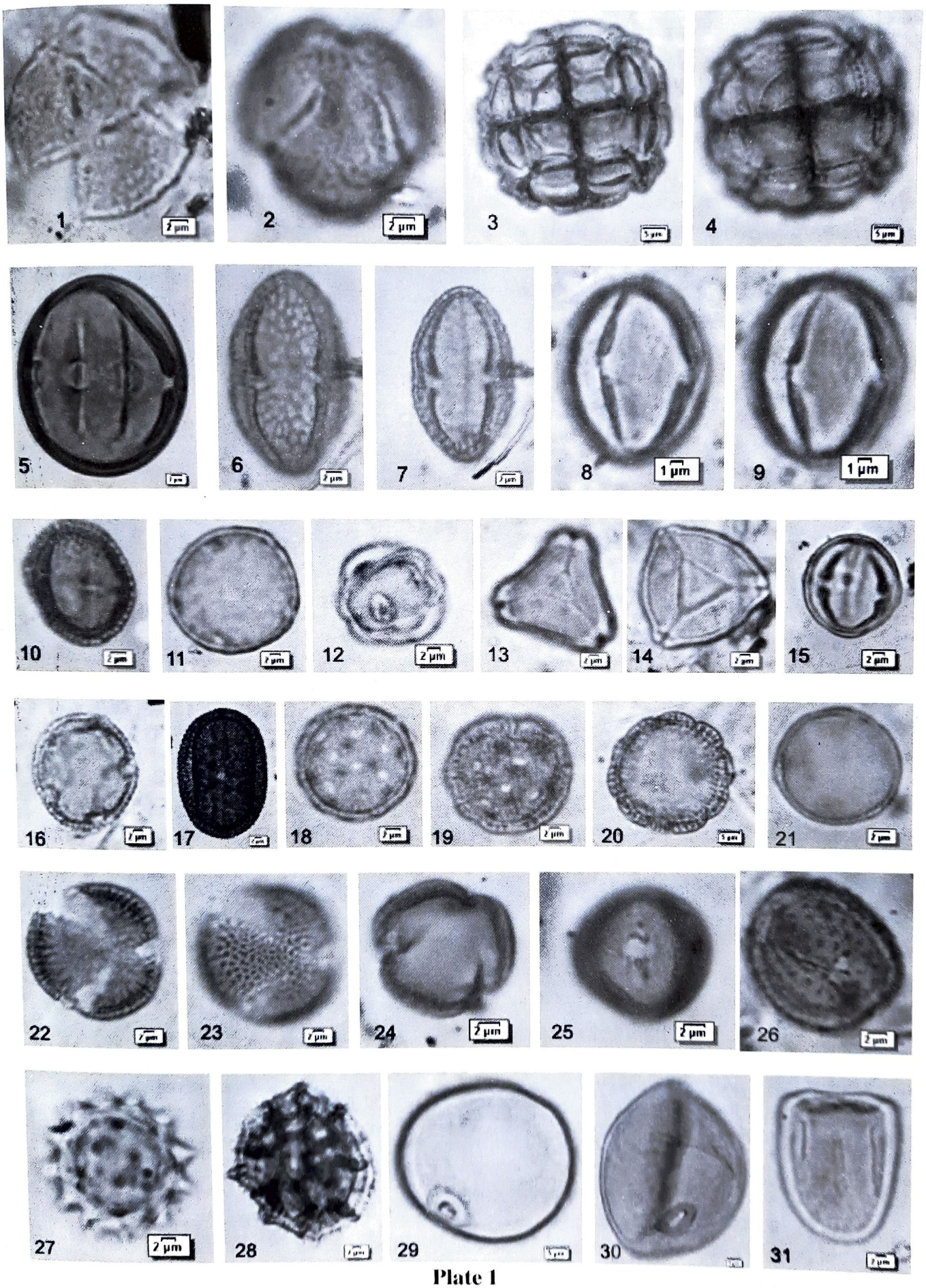

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Plate 1

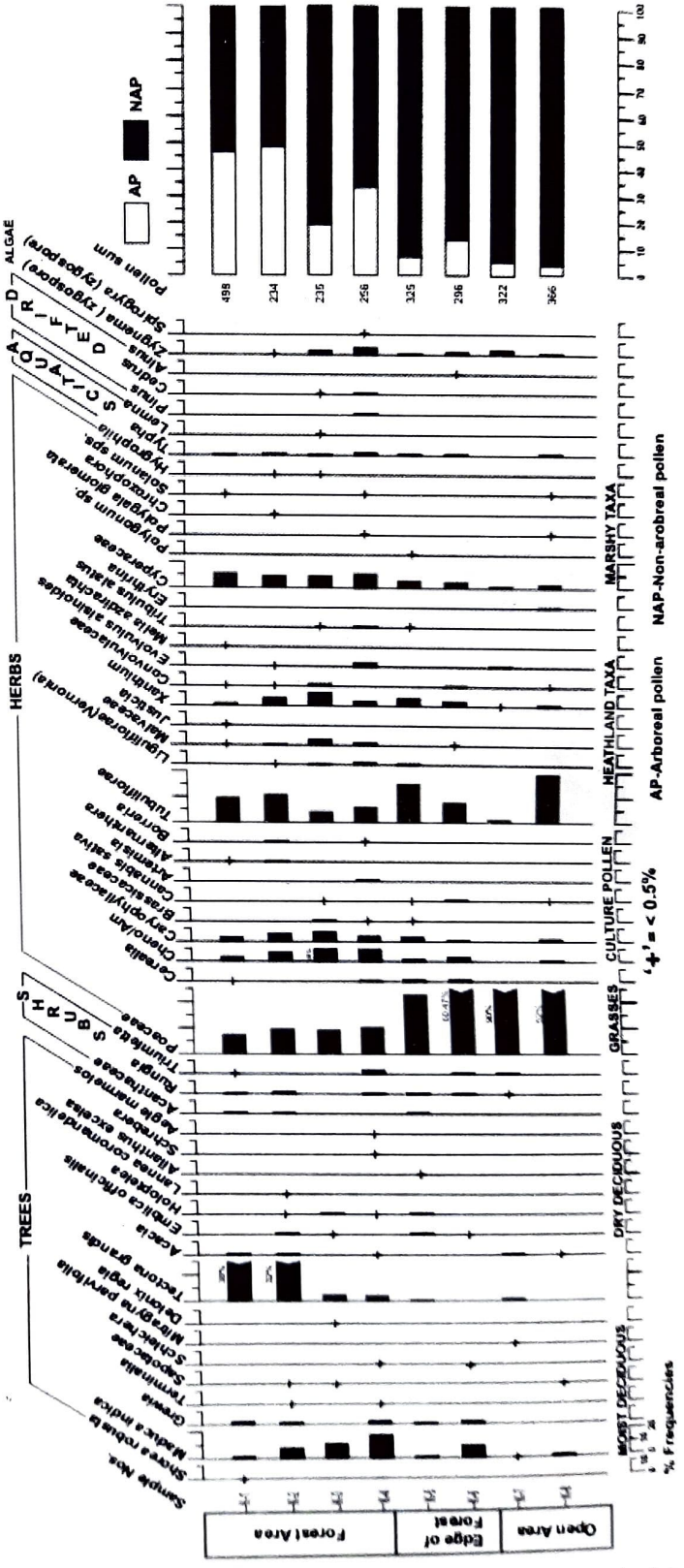
The herbaceous vegetation in the forest comprises mainly grasses, *Ageratum conyzoides*, *Blumea* spp., *Leucas aspera*, *Micromeria biflora*, *Mazus japonicus*, *Sida rhombifolia*, *Sonchus* spp., *Oxalis acetosella*, etc. The marshy vegetation along the water courses is dominated by *Polygonum serrulatum*, *P. plebeium*, *Polygala glomerata*, *Ammania baccifera*, *Rotala rotundifolia*, *Hydrocotyle sibthorpioides*, *Eriocaulon quinquangularis*, *Hygrophila* spp. and *Solanum xanthocarpum*. *Nelumbo nucifera*, *Nymphaea* sp., *Lemna* sp., *Typha latifolia*, *Potamogeton* sp., etc. flourish well in ponds, lakes and other water bodies. Ferns and their allies are restricted in damp and shady places, especially along the stream banks.

Triticum aestivum, *Hordeum vulgare*, *Sesamum indicum*, *Brassica campestris*, *Cajanus cajan* and *Oryza sativa* are the conventional crops being practised by the local people.

MATERIAL AND METHOD

Eight surface soil samples were collected in a linear transect from the forest area (K-1 to K-4), the edge of forest (K-5 & K-6) and open area (K-7 & K-8) at Kishanpur area each at 100 m interval. While picking the samples it was surmised that a major fraction of pollen gets deposited within 100 m distance or so after getting discharged from the plants since the dense canopied forest prohibits their easy and long distance transport contrary to that of the open land conditions or cultivated area (Luna et al. 2002), where 200m distance has been observed to be a normal range for the deposition of bulk pollen load after discharge from the source plants. The sampling strategy was planned in a transect to understand the average representation of the prominent forest constituents/plant groups of the regional vegetation in the pollen rain across the forest region, edge of forest and open area. In addition, the sampling was done during the mid-September to early October, when most of the tropical trees and herbs are in full blossom.

The standard technique of pollen analysis (Erdtman 1943) using 10% aqueous KOH and 40% HF solutions, in order to remove humus and silica present in the sediments, respectively and acetolysing mixture (9:1, acetic anhydride and concentrated sulphuric acid) was followed to extract the pollen/spores from the



Text-figure 2. Pollen spectra from Kishanpur, Sehore District, Madhya Pradesh.

sediments. Finally, the samples for microscopic examination were prepared in 50% glycerin solution.

Analyzed pollen sums range from 234 to 498 in the samples, depending upon their potential. Percentage frequencies of recovered taxa have been calculated in terms of total terrestrial plant pollen. Pollen of aquatic plants and spores of ferns and other lower cryptogams have been excluded from the pollen sums owing to their local origin. The plant taxa (Plate 1) categorized as trees, shrubs, herbs, ferns, drifted and algal remains are arranged in the same sequence in the pollen spectra (Text-figure 2). The pollen frequencies <0.5% are indicated by '+' sign.

POLLEN RAIN COMPOSITION

Pollen spectra of K-1 to K-4 samples from inside the forest depict the dominance of non-arboreals over relatively lower frequencies of arboreals (trees & shrubs). Among the trees, *Tectona grandis* (4-38%), the chief ingredient of the pollen rain present consistently, attains high frequencies of 38% and 32% in the pollen spectra K-1 and K-2, respectively. *Madhuca indica* (2-10%) shows steadily moderate values. *Grewia* (0.42-2%) is recorded consistently in fluctuating low frequencies, whereas *Emblica officinalis* (0.42-1.28%), *Acacia* and *Holoptelea* (0.42-1% each) have sporadically reduced values. Other trees, viz. *Shorea robusta*, *Terminalia*, Sapotaceae, *Schleichera*, *Delonix regia*, *Lannea coromandelica*, *Schrebera*, *Melia azedarach* and *Aegle marmelos* (<0.5% each) are encountered very scarcely. *Triumfetta* (0.40-2.34%), Acanthaceae (1.28-2.2%) and *Rungia* (0.60-2.13%) are recovered sporadically.

The non-arboreals are marked by consistently good frequencies of Poaceae (15-20%) together with Tubuliflorae (3-11 %), Cheno/Am (3.2-18%), *Xanthium* (1.40-13.19%) and Caryophyllaceae (2.81-6.80%), whereas Malvaceae (0.40-4%) is present in low to moderate values. *Convolvulus* (0.20-0.78%) is present consistently, though in very low frequencies. Cerealia pollen (0.40-0.78%), Liguliflorae cf. *Vernonia*, *Tribulus* (0.42-1% each), *Artemisia* (0.78%), *Alternanthera*, *Borreria* (0.39-0.84% each), Brassicaceae (0.39-0.85%), *Evolvulus alsinoides*, *Cannabis sativa*, *Solanum*, *Chrozophora* and *Justicia* (<0.5% each) are extremely sporadic. Cyperaceae (sedges 8.51-10.84%) is retrieved more or less uniformly in high values. Other marshy elements, viz. *Hygrophila*, *Chrozophora* and *Polygala glomerata* (<0.5% each) show their stray presence. Among the aquatic elements, *Typha* (0.60-1.56%) is recorded steadily, whereas *Lemna* (<0.5%) is feebly present. Algal remains, zygospores of *Zygnema* (0.42-5.46%) are recorded in good numbers and zygospores of *Spirogyra* (<0.5%) are rare. Fungal spores such as *Glomus*, *Diplodia*, *Curvularia*, *Nigrospora*, *Cookeina*, Microthyriaceae as well as bi-celled ascospores are also met with in variable numbers. The two Himalayan elements - *Pinus* and *Cedrus* (0.42-1% each) are also occasionally encountered.

Pollen spectra of samples K-5 & K-6 from the edge of the forest also portray the dominance of non-arboreals over arboreals, but trees are fewer in numbers and with lesser frequencies than what is seen in the four samples from inside the forest. *Madhuca indica* (1.23-9.45%), one of the major forest constituents is recorded here in relatively higher values. *Grewia* (1.68%) is steadily represented in moderate values and *Emblica officinalis*, *Holoptelea* and *Tectona grandis* (0.33-1% each) are consistent with much reduced values. *Schleichera*, *Acacia* and *Ailanthus excelsa* (<0.5% each) are extremely sporadic. *Rungia* (0.66-1.23%) is better represented in contrast to *Triumfetta* and Acanthaceae (1% each).

Poaceae (45-60.47%) followed by Tubuliflorae (16-30%) have much higher frequencies amongst non-arboreals in comparison to the pollen spectra from inside the forest. Cerealia pollen (1.53-1.68%) depict improved values, whereas Cheno/Am (2-3%) and Caryophyllaceae (0.66-2.46%) show good frequencies compared to inside the forest. *Xanthium* (0.31-3%) portrays its consistent presence in moderate frequencies. *Cannabis sativa* (0.30-0.66%) is recorded constantly in somewhat increased values contrary to the forest area. Malvaceae (0.30-0.66%) is scanty, whereas other herbaceous taxa, viz. *Convolvulus*, Liguliflorae cf. *Vernonia* (1% each), Brassicaceae and *Tribulus* (<0.5% each) exhibit much

reduced frequencies. Cyperaceae (4-5.23%) is marked by the considerably reduced frequencies, whereas *Polygonum* sp. (<0.5%) is meagerly present. *Typha* (1%) despite its steady presence has decreased values. Algal remains such as zygospores of *Zygnema* (0.92-1.35%) are marked by lower values than is witnessed in the forest area. Fungal spores such as *Nigrospora*, *Curvularia*, *Glomus*, *Diplodia* and bi-celled ascospores are also retrieved in moderate to high frequencies. Retrieval of stray pollen of temperate element- *Alnus* (<0.5%) depicts its transport from Himalayan region.

Pollen spectra (K-7 & K-8) of the surface samples from open area adjoining the forest again exhibit the dominance of non-arboreals compared to much reduced frequencies of arboreals. The major forest elements, viz. *Tectona grandis, Madhuca indica* (2% each) and *Erythrina* (1%) are recorded in low to moderate frequencies. They are recovered in relatively much reduced values in contrast to the spectra from inside the forest and edge of the forest. *Acacia* (0.27-0.62%) is consistently present, though in low frequency. The other tree taxa, viz. *Mitragyna* and Sapotaceae (<0.5% each) are occasionally present. *Rungia* (<0.5%) and *Triumfetta* (0.62%) are retrieved feebly.

Poaceae (52-90%) portrays excessively higher frequencies followed by considerably low to high values of Tubuliflorae (1.86-38%) and low values of Caryophyllaceae, *Xanthium* (1.36% each) and Cheno/Am (0.81%). Other herbaceous taxa such as *Solanum*, *Cannabis sativa* and *Convolvulus* (<0.5% each) are recorded intermittently in reduced frequencies. *Evolvulus alsinoides* (1%) is met with occasionally. Cyperaceae (1.24-2.18%) depicts reduced frequencies, though consistently. *Polygala glomerata* (<0.5%) is rare. *Typha* (0.54%) only, represents the aquatic vegetation. Algal bodies-*Zygnema* zygospores (0.54-2.48%) are marked by their good frequencies compared to at the edge of forest. Fungal spores such as *Nigrospora*, *Glomus* and *Curvularia* denotes their much fluctuating frequencies.

DISCUSSION

The study of pollen rain-vegetation relationship provides potentially valuable modern analogue required for proper appraisal of the chronological changing vegetation scenarios during the Quaternary Period. The investigation of surface samples provides the insight about the influx of pollen deposited in the sediments in relation to the existing vegetation cover in an area. The pollen assemblage of the investigated site, in general, reveals the dominance of non-arboreals (NAP) over comparatively low representation of arboreal pollen (AP). Among the tree taxa, *Tectona grandis* which constitutes approximately 70-80% of the total forest floristic is represented very poorly on an average of 7.5% pollen deposited in forested as well as adjoining open area. However, *Tectona grandis* has on average 19.7% pollen in the spectra from forested region alone, despite its being an enormous pollen producer (Bhattacharya et al. 1999). Its under-representation in the modern pollen rain could be attributed to the poor preservation in the sediments. Hence, it is presumed that this fraction of the total tree pollen influx in the surface sediments symbolizes the dense teak dominated forest as well as the present existing climatic condition in the region. It declines considerably and is recovered with an average value of 1% at the edge of forest and remains as low as of 1.5% in the open area barely at a distance of 100 to 200m from the adjoining forest. This sharp decline in *Tectona grandis* could be inferred to its very low pollen dispersal efficiency. The high pH value of the soil and microbial degradation of its pollen in the sediments might have been a detrimental factor for poor recovery of teak pollen in the sediments. *Madhuca indica*, a close associate of teak, is consistently recorded in the spectra from the forested area compared to spectra from forest edge and in the bordering open land.

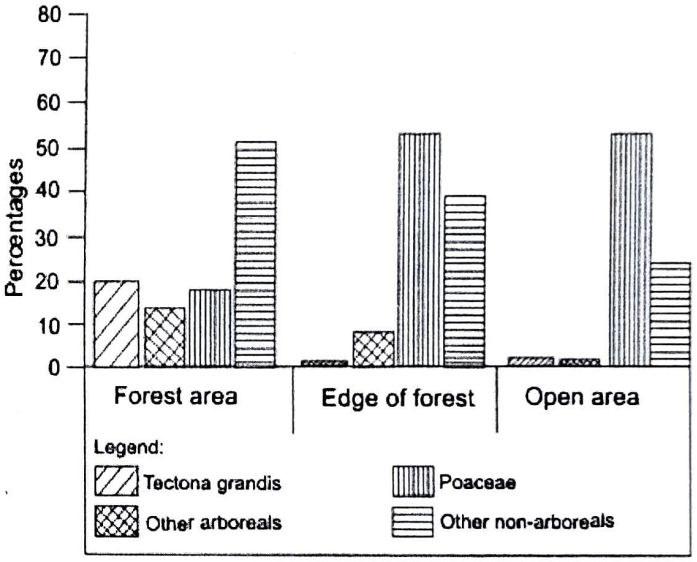
Apart from *Tectona grandis* and *Madhuca indica*, other common forest constituents such as *Terminalia*, *Schleichera*, *Mitragyna*, *Emblica officinalis*, *Holoptelea*, *Lannea coromandelica*, etc. demonstrate their presence sporadically and in extremely low frequencies. *Grewia* and *Acacia*, despite their local frequent distribution in the forest are marked by their sporadic pollen in the spectra. All the above trees constitute 13.5% and 12% of total arboreal pollen retrieved from the forest and edge of the forest spectra, respectively. Their frequencies, however, decline sharply

to an av. value of 3.5 % in the adjoining open area, merely at a distance of 100 to 200m. This erratic display of all these taxa could be ascribed to their low pollen productivity, entomophilous mode (Vincens et al. 1997) of pollination, low dispersal efficiency and poor preservation of their pollen in the prevailing soil conditions. Similar conclusions have been drawn for the investigated surface samples from north-eastern Madhya Pradesh (Chauhan 1994, 2008, Quamar & Chauhan 2007) and South Indian mountains (Anupama et al. 2000). The microbial degradation of the pollen can not be denied as fungal spores, viz. *Glomus*, *Curvularia*, *Nigrospora*, *Diplodia* and *Cookeina* have been retrieved frequently in the sediments.

Among the non-arboreals Poaceae, Cyperaceae, Asteraceae (Tubuliflorae), Cheno/Am, Caryophyllaceae, *Xanthium*, etc. with consistently much higher frequencies in the pollen spectra infer the profuse growth of these taxa. Grasses, the dominant constituent of ground vegetation, exhibit relatively lower values in the forested area in contrast to forest edge and open areas, where they progressively increase in their frequencies, possibly owing to the light factor and availability of more space for their growth. Other herbaceous elements exhibit an inverse trend as they could not withstand the harsh edaphic conditions at the latter two situations. In totality, representation of non-arboreals in the pollen spectra portrays a close coherence in terms of their composition in the ground flora. The presence of Cerealia along with other culture pollen taxa such as Cheno/Am, *Cannabis sativa*, *Artemisia*, *Xanthium*, *Alternanthera*, etc., though sporadically, implies the proximity of cultivated land and human habitation to the study area. The relatively high values and consistent presence of Asteraceae pollen, particularly in the forest, suggests the intensive pastoral activity in and around the investigation site as the members of this family escape grazing because they are least palatable to cattle and goats (Mooney 1997, Mazier et al. 2006).

The occurrence of pollen of subtropical and temperate elements such as *Pinus*, *Cedrus* and *Alnus* in the sediments reveals their exclusive wind-transport from the Himalaya.

Hence, it can be concluded that the pollen/spore deposition pattern in the surface samples does not correctly demonstrate the actual floristic composition of the region. The pollen rain-vegetation relationship drawn from the present pollen analysis should be taken into consideration very cautiously while making any assessment of the pollen assemblage recovered in the sedimentary deposits in terms of past vegetation and corresponding climate.



Text-figure 3. Composite pollen spectra from teak forests in Sehore District, Madhya Pradesh.

CONCLUSION

The comparative assessment of AP and NAP ratio from forest, forest edge and open area reveals av.16% arboreal pollen of total pollen rain and out of that teak alone has av. 7.5% pollen. The rest of the trees are represented by an average of 10% pollen only. Teak, constituting 70-80% woody taxon of the total forest floristic despite being a high pollen producer is recorded only with av. 19.5% in the forest area and as low as 1-1.5% at the forest edge and adjoining open area, demonstrating its poor pollen preservation in the sediments coupled with its low pollen dispersal efficiency (Text-figure 3). The extremely poor representation of other tree taxa with only av. 9% of the pollen rain contrary to their frequent presence in the forest could be attributed to their low pollen productivity. They have been recorded in a declining trend with the values of 13.5%, 11% and 2% in the

forest, forest edge and open area, respectively. The non-arboreals attain an average high value of 80% (65.5%-96.5%) and form a major portion of the pollen rain. Out of this, grasses (Poaceae) constitute 18% in the forest area and exhibit an increasing trend at forest edge and open area with the values of 53% and 71%, respectively. It is concluded that this comparative database on pollen rain vis-à-vis vegetation should be taken as a modern analogue for the careful delineation of vegetation scenarios of the past while interpreting the pollen diagrams from the tropical deciduous teak dominated forests in central India, and other equivalent floristic region. The physiognomic aspects of the forests whether they are dry, moist or evergreen can be determined from the available information by seeing the climatic requirements of the retrieved plant taxa in the floristic assemblage of the sediments.

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