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Studies on Pollen Rain vis-a-vis Vegetation Relationship and Thecamoebian Diversity in Bari Tal area, Lucknow District, Uttar Pradesh

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ABSTRACT: The paper embodies the modern pollen rain-vegetation relationship from sub-tropical belt, India. Palynological study was carried out on ten samples collected at sediment-water interface from lake-Bari Tal, Lucknow (UP). The quantitative and qualitative analysis of pollen and spores reveals the dominance of non-arboreals and relatively extremely low frequencies of arboreals (trees & shrubs). Among the tree taxa, *Madhuca indica* (av. 6.8%) and *Acacia* (av. 4.7%) are the major components and they are consistently represented with collectively av. 11.5% pollen, whereas rest of the trees viz., *Holoptelea*, *Bauhinia*, *Terminalia*, *Shorea robusta*, *Syzygium*, *Emblica officinalis*, members of Meliaceae, etc., are meagre although they are common in the region. The under-representation of all these taxa could be due to low pollen production and entomophilly. The partial preservation of their pollen in the sediments cannot be denied. In general, the trees taxa constitute av. 22.5% fraction of the total pollen rain and it does not reflect their actual composition in the extant vegetation, despite their sparse presence in the area. The representation of grasses, sedges, Cheno/Am, Caryophyllaceae, Brassicaceae, Asteraceae, etc. in the pollen spectra substantiates their actual composition in the herbaceous complex. The frequent encounter of Cerealia along with other culture pollen taxa viz., Cheno/Am, Brassicaceae, Caryophyllaceae, etc. depicts the proximity of cultivated land and human habitation to the study site. Fungal spores viz., *Glomus*, *Nigrospora*, *Tetraploa*, etc. are recorded in appreciable frequencies. Thecamoebians dominated by *Centropyxis laevigata* have also been discussed in ecological perspective and related to climate-vegetation equilibrium in the study area.

The recovery of the pollen/spores in the surface soil reveals the presence of the aerospora too, which could assist in divulging specific pollen/spores liable for allergic diseases. The thecamaebian concentration helps to surmise the stress level of the water bodies.

Keywords **:** Pollen rain, Pollen analysis, Surface samples, Bari Tal, Lucknow District (U.P.)

INTRODUCTION

Substantial data-grid has been generated on modern pollen rain-vegetation relationships for the tropical evergreen and deciduous forests in South India and Sri Lanka (Bonnefille *et al*., 1999; Anupama *et al*., 2000; Barboni and Bonnefille, 2001), tropical deciduous forests in the foothills of Himalaya (Sharma, 1985; Gupta and Yadav, 1992), northeast India (Basumatary and Bera, 2007), Madhya Pradesh (Chauhan, 1994, 2008) and tropical deciduous scrub vegetation in northwest desert (Singh *et al*., 1973). These studies have provided ample comparative data-base on the pollen rain vis-a-vis modern vegetation, which served as modern analogue for the factual appraisal of past pollen sequences from their respective regions in terms of vegetation dynamics and coeval climatic conditions during the Quaternary Period. However, the Ganga Plain with immense potential for the Quaternary palaeofloristic studies has not received much attention to understand the pollen deposition pattern of different plant taxa/plant groups, which is of utmost need prior to the investigation of sedimentary deposits from this region. On this aspect so far a maiden study has been executed from Jalesar, Unnao District in the Central Ganga Plain (Trivedi and Chauhan, 2012). In the present paper an endeavor has been made to generate more information on this aspect in order to evaluate the extent of representation of various regional and local taxa in the modern pollen rain and to understand their pollen dispersal efficiency as well as to unravel the possible factors affecting preservation of pollen/spores in the sediments through the pollen analysis of surface soil samples picked up from the surrounding of the Bari Tal

situated in the south of the Gohna Kala Village, Lucknow District in the Central Ganga Plain. Considerable efforts are being made world over for the use of thecamoebians as proxy for understanding ecology and palaeoecology, particularly induced by climatic fluctuations. We briefly describe here the thecamoebian community specific to a particular niche and relating it to vegetation-climate equilibrium through palynological study.

The knowledge of important pollen/spores in the surface soils also provides database on the allergic diseases caused by them. Besides, the quantitative and qualitative assessment of thecamaebians in the soils from the vicinity of aquatics ecosystem facilitates by understanding the stress level of lakes, ponds and other water bodies.

Bari Tal is situated about 20 km east of Lucknow city between 26° 58′19″ Latitude and 80° 57′35″ Longitude in the vicinity of the Gohna Kala Village (Fig. 1). The lake, Bari Tal is irregular in shape and quite large in dimension, measuring 100m in length and 50m in breadth at its widest. This perennial lake is highly waterlogged and overgrown with *Eichhornia crassipes* (water-hyacinth), a common noxious weed of ponds and lakes in the Central Ganga Plain, impeding the proliferation of other aquatic flora and fauna. During summer season the *Eichhornia crassipes* mat affixes the lake bottom due to low water level, but it becomes free-floating in monsoon season owing to inundation. The lake is largely fed by the subterranean water as well as by a brook on the western side. Most of the plain area on its west and south is an arable land. However, far-flung area beyond the cultivated land is marked by the presence of open *Acacia*-scrub vegetation.

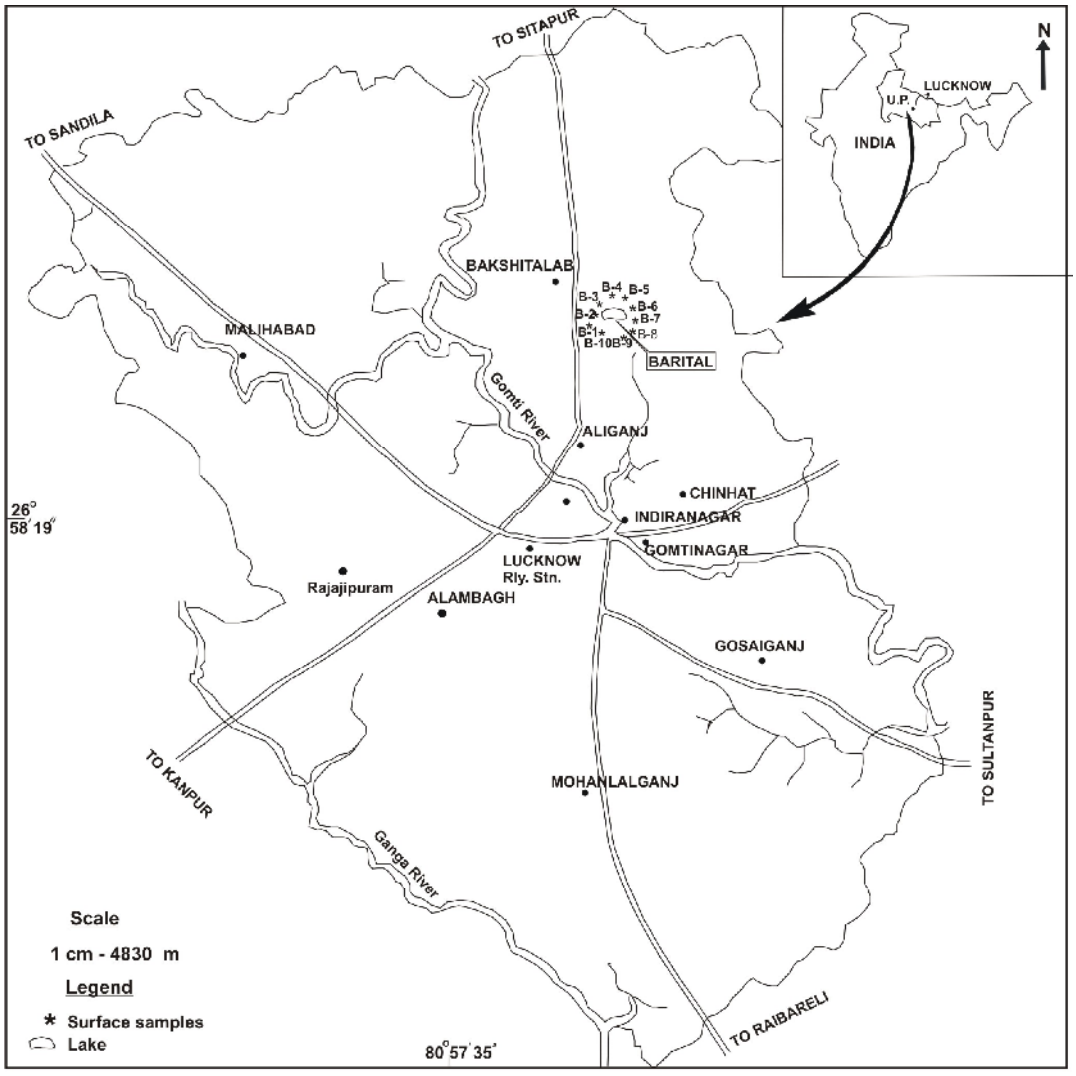


Fig. 1

Fig. 1. Map of Bari Tal, Lucknow District (U.P.) showing site of surface samples.

Presently, plantation of *Prosopis julifera* and *Acacia nilotica* has been made about 400m north of Gohna Kala Village in order to reclaim the wasteland under afforestation Program by Uttar Pradesh State Government. Recently, some plantation of *Eucalyptus globulus* has been raised along the roadside.

Climate of the region, in general, is humid and largely influenced by southwest monsoon (Chauhan *et al*., 1990). Winter season from November to February is characterized by average minimum and maximum temperatures of 7.6ºC and 21ºC respectively. The temperature seldom goes down to 0ºC during the extreme cold months of December and January. Summer season from March to June is marked by hot dry winds with average minimum and maximum temperatures of 27ºC and 32.5ºC respectively. The temperature ascends up to 46ºC in the month of June. Monsoon season begins in the mid-June and continues till mid-September. The weather becomes sultry during July to September.

The area in the vicinity of the lake has patchy occurrence of stands or groves of forest interspersed with stretches of open mixed savannah, dominated by grasses (Champion and Seth, 1968). Thus, the landscape imparts a view of open vegetation. The trees viz., *Acacia arabica*, *A. nilotica*, *Holoptelea integrifolia*, *Cordia dichotoma*, *Syzygium cumini*, *Madhuca indica*, *Capparis decidua*, *Butea monosperma*, *Symplocos* sp., *Ailanthus excelsa*, *Melia azardirach*, *Aegle marmelos*, *Bauhinia variegata*, *Albizia lebbek*, *Flacourtia indica*, *Terminalia arjuna*, *Dalbergia sissoo*, etc. together with thickets of *Ziziphus mauritiana*, *Carissa spinarum*, *Adhatoda vasica*, *Indigofera* sp., *Nyctanthes arbor-tritis*, etc. occur sparingly distributed in the scrub forests. However, in certain areas, *Acacia*-scrub forests dominated by *Acacia nilotica* with scattered shrubby elements of *Ziziphus mauritiana*, *Adhatoda vasica*, *Carissa spinarum*, *Ricinus communis*, *Mimosa* sp., *Abrus precatoris*, etc. can be seen in pockets. The herbaceous vegetation of terrestrial environment encompasses *Ageratum conyzoides*, *Euphorbia hirta*, *E. thymifolia*, *Mazus japonicus*, *Sonchus oleraceus*, *Oxalis acetosella*, *Chenopodium album*, *Sida rhombifolia*, *Micromeria biflora*, *Luecas aspera* and *Blumea eriantha*. *Cyperus rotundifolia*, *Scirpus mucronatus*, *Polygonum plebeium*, *Polygala chinensis*, *Ammania baccifera*, *Rotala rotundifola*, *Hygrophilla auriculata* and *Alternanthera sessilis* occur profusely in marshy place adjoining to the lake.

The aquatic elements including, *Trapa natans*, *Lemna polyrriza*, *Potamogeton cristatum*, *Nymphoides cristata* and *Nelumbo nucifera* are common in lakes, ponds and ditches.

MATERIAL AND METHOD

In all, 10 surface samples (B-1 to B-10) were collected at sediment-water interface from Bari Tal Lake. Palynological study in a trench profile from the central part of the lake is being analysed to reconstruct past vegetation and climate change. The surface samples were collected at an average of 100 m distance assuming that the major fraction of pollen gets accumulated within 100 m distance or so after getting discharged from the plants in open land conditions or cultivated area (Luna *et al*., 2002). The sampling strategy was planned in linear transect to understand the average representation of the prominent forest constituents/plant groups of the regional vegetation in the pollen rain.

Ten gram of samples were treated with warm 10% aqueous KOH followed by 40% HF treatment in order to remove humus and silica, respectively present in the sediment. Subsequently, the standard procedure of acetolysis (Erdtman, 1943) was followed to extract the pollen/spores from the samples. All the samples analysed were rich in pollen/spore content. The pollen sums range from 200 to 310, depending upon the pollen potential of the samples. Percentage frequencies of retrieved taxa have been calculated in terms of total terrestrial plant pollen, excluding the pollen of Poaceae, Cerealia, *Xanthium*, marshy, aquatic plants and spores of ferns and other lower cryptogams (algal remains) from the pollen sums because of their excessively high frequencies and origin from the local provenances. However, the percentage frequencies of all these have been calculated from the pollen sums for their representation in the pollen spectra. The plant taxa (Pollen plate) classified as trees, shrubs, herbs, ferns and algal remains and are arranged in the same sequence in the pollen spectra (Fig. 2).

During the course of palynological investigation we have come across a large number of testate amoebae (thecamoebians). The community assemblage from dessicated lake periphery to the moist middle and the central part (Fig. 3) was recorded during the month of June. The identification of the testate amoebae was executed by consulting the relevant literature (Ogden & Hedley, 1980; Leidy, 1879; Kumar & Dalby, 1988).

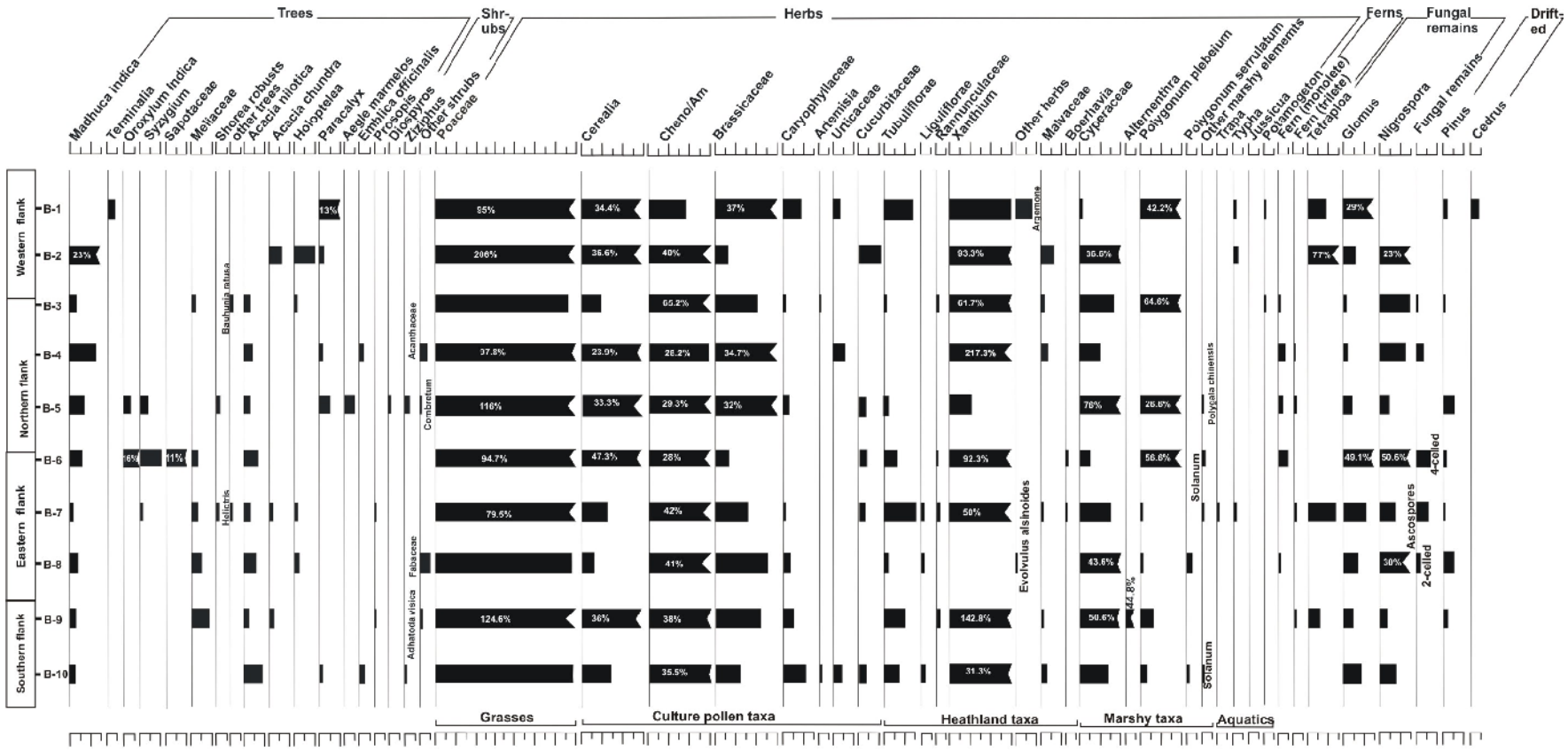


Fig. 2. Pollen spectra from Bari Tal, Lucknow District (U.P.)

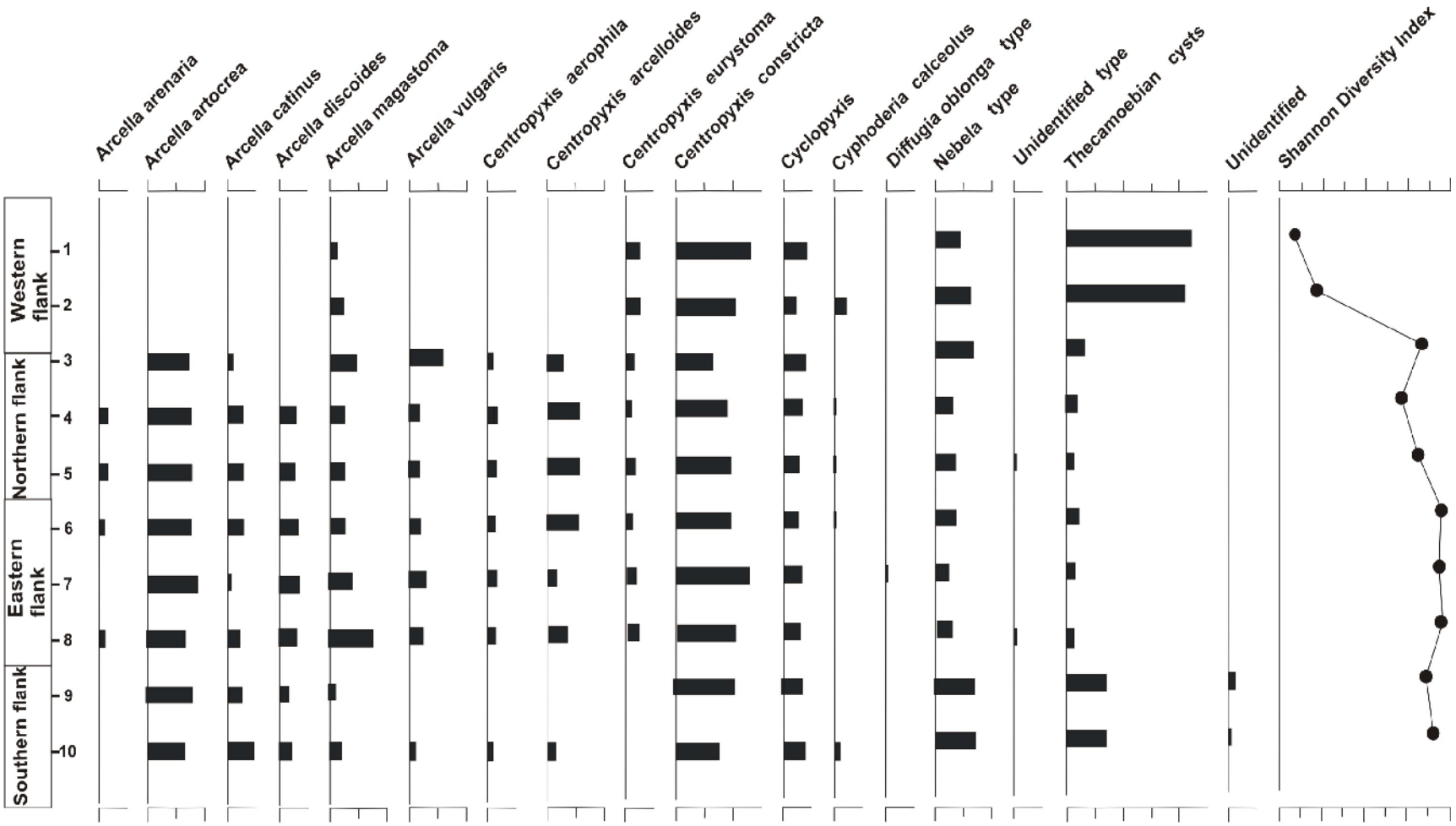
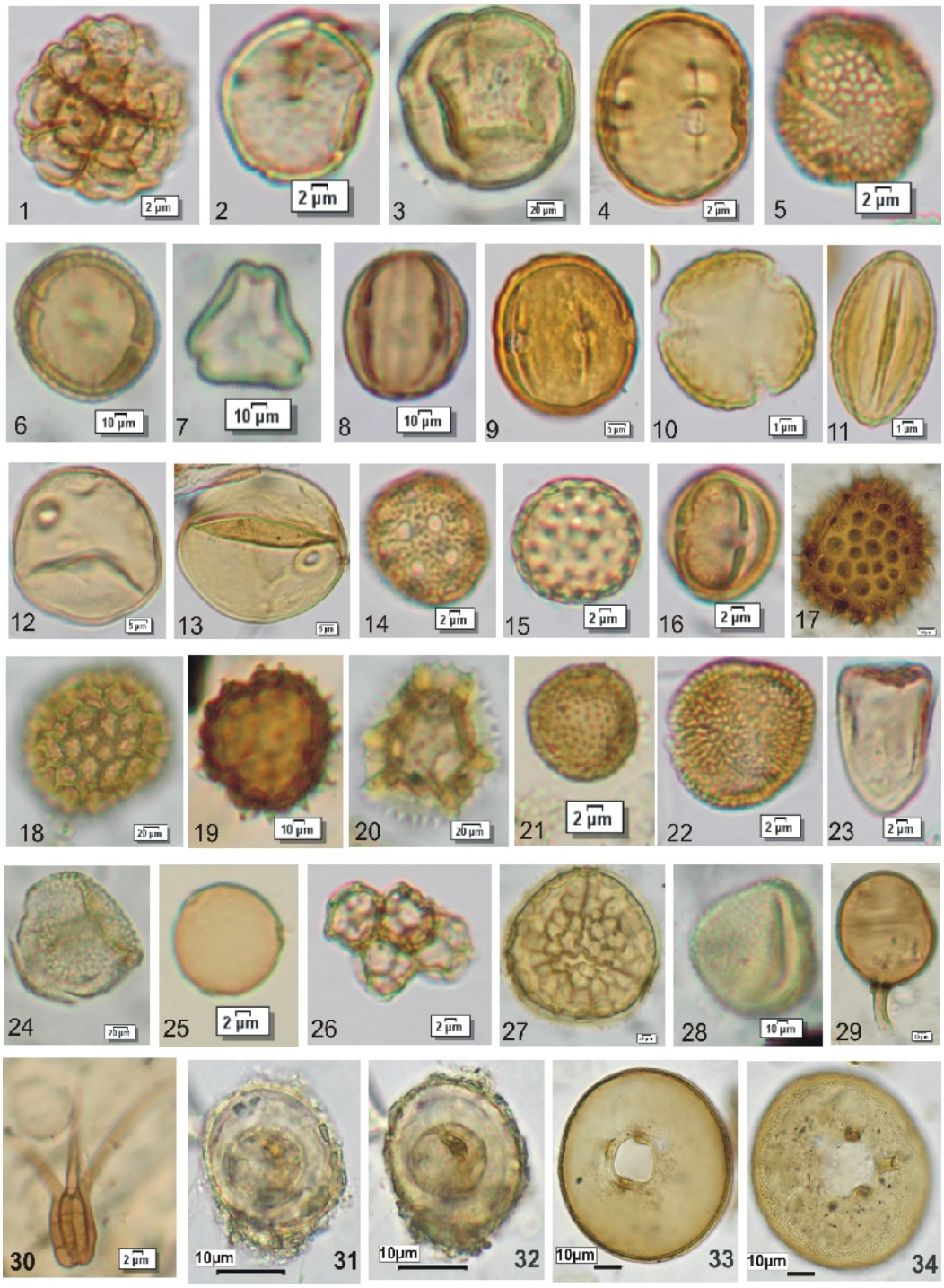


Fig. 3. Percentage occurrence and Shannon diversity index values of testate amoebae communities in surface samples of Bari Lake.

Plate 1



PLATES: 1. *Acacia nilotica*, 2. *Holoptelea*, 3&4. *Madhuca indica*, 5&6. *Aegle marmelos*, 7. *Syzygium*, 8. *Terminalia*, 9. Meliaceae, 10&11. *Prosopis spicigera*, 12. Poaceae, 13. Cerealia, 14. Caryophyllaceae, 15. Cheno/Am, 16. *Artemisia*, 17. Malvaceae, 18. *Polygonum serrulatum*, 19. Tubuliflorae, 20. Liguliflorae, 21. *Xanthium*, 22. Brassicaceae, 23. Cyperaceae, 24. *Potamogeton*, 25. Urticaceae, 26. *Alternanthera*, 27. Fern trilete spore, 28. *Typha*, 29. *Glomus*, 30. *Tetraploa*, 31&32. Thecamoebian Cyst, 33&34. *Centropyxis laevigata*.

POLLEN RAIN COMPOSITION

Out of 10 surface samples analysed, B-1& B-2 are from the western flank; B-3, B-4 & B-5 are from northern flank, B-6, B-7 & B-8 are from eastern flank and B-9 & B-10 are from southern flank of the lake. The pollen rain compositions of the samples from different flanks (Fig. 2) are described as below:

POLLEN SPECTRA (B-I & B-2) from western flank of the lake reveal the dominance of non-arboreals and relatively reduced frequencies of arboreals (trees and shrubs). The tree taxa, *Madhuca indica* (av. 11.66%), *Acacia nilotica* (3.33%) are constantly recorded in moderate frequencies. *Paracalyx* (8.27%), Sapotaceae (2.04%), *Acacia chundra* (3.3%), *Terminalia* (1.8%), *Syzygium* and *Holoptelea* (5% each) are recorded in moderate to low values, though sporadically. The herbaceous vegetation is characterized by the high frequencies and consistent presence of Poaceae (150.74%), Cerealia (35.6%), Brassicaceae (22.2%) and *Xanthium* (61.7%), whereas Caryophyllaceae (4.7%), Cucurbitaceae (5%), *Argemone* (4.7%), Urticaceae (1.9%), Malvaceae (3.3%) and Tubuliflorae (6.6%) are sporadic with moderate values. The marshy elements, Cyperaceae (19.19%) and *Polygonum plebeium* (24.1%) are retrieved in moderate to high frequencies.
Typha (2.58%) and *Potamogeton* (0.86%) represent the aquatic flora. The fungal remains, *Glomus* (17.9%), *Tetraploa* (42.6%), *Nigrospora* (11.6%) and fungal spores (1.93%) are very frequent. The Himalayan elements, *Pinus* and *Cedrus* (1.72% each) are also met with occasionally.

POLLEN SPECTRA (B-3, B-4 & B-5) from northern flank of the lake also exhibit relatively much reduced frequencies of arboreals as compared to the non-arboreals. The trees taxa such as *Shorea robusta* (0.44%), *Acacia nilotica* (2.64%), *Madhuca indica* (8.0%), *Oroxylum* (0.88%), *Paracalyx* (2.9%), *Aegle marmelos* (1.77%) and Meliaceae (0.39%) are recorded in moderate values. The rest of the trees viz., *Diospyros*, *Bauhinia* (0.44% each) and *Emblica officinalis* (0.72%) are very sporadic and low. The shrubby elements viz., Acanthaceae (1.44%) and *Combretum* (0.44%) are extremely sporadic. In all, the arboreals constitute *ca*. 5.23% part of the total pollen rain.

The non-arboreals as usual are characterized by the high frequencies of Poaceae (93.8%) followed by Cheno/Am (40.95%), *Xanthium* (92.38%), Brassicaceae (29%) and Cerealia (22.07%) in appreciable frequencies. Tubuliflorae (2.93%), Caryophyllaceae (1.28%), Urticaceae (2.2%), Ranunculaceae (0.59%), *Artemisia* (0.19%), Malvaceae (1.84%) and Cucurbitaceae (0.88%) are also retrieved sporadically in extremely low values. The marshy vegetation is marked by high values of Cyperaceae (34.9%) and *Polygonum plebeium* (30.44%), whereas *Polygala chinensis* (0.44%) is recorded scantily. The aquatic element, *Jussieua* (0.44%) is meagre. Fern spores (monolete 2.7% & trilete 0.92%) are also present moderately. Fungal spores such as *Glomus* (av. 2.4%) and *Nigrospora* (10.87%) together with 4-celled fungal spores (1.8%) are frequent. Drifted pollen of *Pinus* (3.06%) are noticed in one sample only.

POLLEN SPECTRA (B-6, B-7& B-8) from eastern flank of lake demonstrate an av. 7.67% arboreal pollen, which is much lower than the non-arboreals. *Madhuca indica* (3.9%) and *Acacia nilotica* (5.2%) are consistent recorded in moderate values. Meliaceae (4.3%), Sapotaceae (3.5%), *Syzygium* (3.7%) and *Holoptelea* (1.4%) are encountered sporadically in moderate to low values. Others such as *Acacia chundra* and *Prosopis* (0.5% each) are met with scantily. Meagre shrubby vegetation is represented by Fabaceae (1.8%) in one sample only.

Among the terrestrial herbs, Poaceae (81%), Cheno/Am (31.7%) and Brassicaceae (29%) are the most prominent. Others viz., Cerealia (22.2%) and Tubuliflorae (29.0%) are recovered in moderate to high frequencies. *Xanthium* (31.5%), Malvaceae (0.26%), Liguliflorae (2.4%), Cucurbitaceae (2.2%), *Boerhavia* (1%) and *Evolvulus alsinoides* (0.46%) are encountered rarely. The marshy element, Cyperaceae (21.6%) attains the high values, whereas *Polygonum plebeium* (19.6%) and *P. serrulatum* (0.96%) have high to low values respectively. *Solanum* (0.8%) is noticed in sample B-8 only. The aquatic element *Trapa* (0.25%), *Typha* (0.5%) and *Potamogeton* (3.03%) are occasional. Fern spores (monolete 2.2% & trilete 0.5%) are feeble. Fungal spores such as *Tertaploa* (4.5%), *Glomus* (23.2%) and *Nigrospora* (30.65%) show appreciable frequencies in contrast to other flanks. Drifted pollen of *Pinus* (3.1%) have increased frequencies.

POLLEN SPECTRA (B-9 & B-10) from southern flank are characterized by the relatively lowest diversity of both arboreals and non-arboreals compared to seen so far. The tree taxa, *Madhuca indica* (3.9 %) is consistently recorded in low values followed by *Paracalyx* (0.65%), *Acacia nilotica* (5.9%) and Meliaceae (3.9%) in moderate frequencies. *Shorea robusta*, *Prosopis* (0.64% each), *Emblica officinalis* (1.3%) and *Acacia Chundra* (5.9%) are

sporadically represented. The shrubby elements, *Adhatoda vasica* (0.68%) is met with intermittently.

Among the non-arboreals, Poaceae (96%) has the highest frequency in contrast to *Xanthium* (87.2%), Cerealia (25%), Cheno/Am (36.59%) and Brassicaceae (18.27%). Caryophyllaceae (9.16%) have moderate to high frequencies. Others such as Urticaceae (3.98%), Malvaceae (2.6%), Tubuliflorae (9.14%), Cucurbitaceae, Liguliflorae (1.9% each) and Ranunculaceae (1.2%) are recorded sporadically. Cyperaceae (21.6%) is represented by the highest frequencies. *Alternanthera* (22%), *Polygonum plebeium* (5.8%), *P. serrulatum* and *Solanum* (0.6% each) are met with occasionally. *Potamogeton* (1.2%) is the only representative of aquatic flora. Fern trilete (0.6%) and *Pinus* (1.2%) are encountered scantily in one sample each. However, there is a decline in diversity and frequencies of fungal spores comprising *Tetraploa* (2.5%), *Glomus* (7.2%) and *Nigrospora* (6.5%) with moderate values.

THECAMOEBIANS COMPOSITION

During the course of pollen analytical investigation of surface samples from different flank of the lake we have come across a large number of diverse Thecamoebians. The assemblages obtained in different samples bring out a wide range of variability of Thecamoebians in terms of their numbers and species, which could be an outcome of local microecological variability on the different flanks of the lake. The compositions of the samples are dealt as below (Fig. 3).

SPECTRA B-1 & B-2 show six species of thecamoebians from the western flank of the lake. The average values in these two samples are *Arcella megastoma* (3.8%), *A. vulgaris* (1.2%), *Centropyxis laevigata* (23.5%), *Centropyxis* species (5.0%), *Cyclopyxis* (4.7%), *Corythion* (6.5%), *Nebela* (11.3%), *Heleopera* (1.2%) and Cysts (42.8%). The increased percentage of *C. laevigata* is directly proportional to increased percentage of cyst forms.

SPECTRA B-3 to B-5 depict thirteen species of thecamoebians were recorded from the northern flank of the lake. These comprise *Arcella artocrea* (16.1%), *A. megastoma* (6.7%), *A. vulgaris* (6.6%), *A. arenaria* (2.8%), *Centropyxis arcelloides* (10.4%), *C. eurystoma* (5.0%), *C. laevigata* (18.5%) and *Centropyxis* spp. (3.2%), *C. aerophila* (3.2%), *C. ecornis* (1.7%), *Cyclopyxis* (7.9%), *Nebela* (9.8%), *Heleopera* (2.7%) and cysts (5.2%).

SPECTRA B-6 to B-8 encompass sixteen species of thecamoebians from eastern flank of the lake. These comprise of *Arcella artocrea* (16.7%), *A. megastoma* (10.4%), *A. vulgaris* (5.4%), *A. arenaria* (1.9%), *Centropyxis arcelloides* (7.8%), *C. eurystoma* (3.9%), *C. laevigata* (23.8%) and *Centropyxis* spp. (4.3%), *C. aerophila* (2.1%), *C. ecornis* (3.5%), *Cyclopyxis* (6.5%), *Difflugia* (0.7%), *Corythion* (0.5%), *Trinema* (0.5%), *Nebela* (6.5%), *Heleopera* (1.6%) and cysts (3.8%).

SPECTRA B-9 & B-10 reveal thirteen species of thecamoebians from southern flank of the lake. These comprise *Arcella artocrea* (15.7%), *A. megastoma* (3.5%), *A. vulgaris* (2.1%), *Centropyxis arcelloides* (2.1%), *C. eurystoma* (7.7%), C. *laevigata* (20.4%) and *C. aerophila* (2.1%), *Cyclopyxis* (7.3%), *Corythion* (2.1%), *Trinema* (2.0%), *Nebela* (15.8%), *Heleopera* (4.0%) and cysts (15.1%).

DISCUSSION

The study of pollen rain-vegetation relationship is indispensable prior to analysis of sedimentary deposits because it provides the modern analogue for the appropriate assessment of changing vegetation scenarios and contemporary climate variability during the past. Hence, to generate the comparative database on this aspect in order to divulge the pollen deposition pattern of various regional and local plant taxa/plant groups the investigation of surface sediments was executed at Bari Tal in the Central Ganga Pain, from where the investigation of sediment profile for the reconstruction of past vegetation and climate change is in progress. The pollen rain study conducted on the 10 surface samples garnered from different flanks of Bari Tal, Lucknow District (Fig. 2) has revealed the dominance of non-arboreals (herbs) and relatively low number and frequencies of arboreals (trees & shrubs). Among the trees, *Madhuca indica* with av. 6.8% pollen is consistently represented. It attains the highest value of 23.3% at densely inhabited western flank (B-2), probably due to its local abundance as it is conserved by the local populace for its multifaceted use. However, it is recorded with low frequencies on eastern flank, where most of the area is under habitation. Besides, *Acacia nilotica* and *A. chundra* with av. 4.7% pollen are recorded with the highest value of 9% at southern flank. Collectively, these taxa constitute a fraction of av. 11.45% of the total arboreal pollen. The rest of the trees such as *Holoptelea*, *Syzygium*, *Paracalyx*, *Aegle marmelos*, *Emblica officinalis*, Meliaceae, etc. are recorded sporadically in extremely low frequencies, despite being common in the region. In all, they constitute av. 11% pollen out of av. 22.5% arboreal pollen retrieved in the pollen rain. The under-representation of these taxa in the pollen rain could be attributed to their low pollen

productivity since most of the tropical trees exhibit a strong tendency of entomophilly (Chauhan, 2008). Similar observations have also been made concerning the ambiguous behavior of tropical trees in the pollen rain from Jalesar in Unnao District (Trivedi & Chauhan, 2011) and Madhya Pradesh (Chauhan, 1994, 2008) as well as from tropical forests from South Africa (Vincens *et al*., 1997). Partial preservation of their pollen and microbial degradation cannot be denied since a large number of fungal spores viz., *Nigrospora*, *Tetraploa*, *Glomus*, etc. have also been recovered substantially in the sediments. The sparse shrubby vegetation in the region is truly reflected by the intermittent pollen of a few taxa viz., *Ziziphus*, *Adhatoda*, Fabaceae, etc.

The non-arboreal vegetation is characterized by the steadily high frequencies of grasses (Poaceae) and Cerealia, which are non-pollen sum components, have high frequencies with av. 102%, 26% pollen respectively, besides, Cheno/Am and Brassicaceae with average maximum values of 36.5% and 21.7% respectively. Their preponderance could be due to their local abundance in the area adjoining to study site. Further, they are much better represented in northern and western flanks in contrast to other. The recovery of these taxa along with Cucurbitaceae and Caryophyllaceae infers that most of the area in the vicinity of the lake is under intensive agricultural practice as well as some other sort of human activities. In addition, among the heathland elements, *Xanthium* is retrieved consistently high frequency of average 65% owing its gregarious presence in the region. Others such as Asteraceae (Tubuliflorae & Liguliflorae), Ranunculaceae, Malvaceae, etc. are infrequent. The good encounter of sedges (Cyperaceae), *Polygonum plebeium* and *Alterenanthera* in fluctuating moderate to high frequencies demonstrates the prevalence of marshy condition along the lake margin. In general, the representation of non-arboreal pollen assemblage implies a close coherence with the ground flora in the region. Furthermore, the aquatic elements viz., *Potamogeton*, *Typha* and *Trapa*, despite their low pollen production, are recorded scarcely, depicting thereby the proximity of lake and other water-bodies, from where their pollen get trapped in the surface sediments. The pronounced damp condition along lake margin also favours the propagation of fungi such as *Glomus*, *Tetraploa*, *Nigrospora* and fungal spores of uncertain affinities as evidenced from their frequent presence in almost all the samples. However, fungal spores diversity is more at eastern flank probably owing to more-damp condition in contrast to other flanks. They decline sharply in number and frequencies on the southern and western flanks because of prevailing dry condition.

The retrieval of pollen of *Pinus* and *Cedrus* in the sediment envisages their transportation mainly by watercourse as well as by winds from the temperate and subtropical belts of the Himalaya, where these taxa grow profusely. Their presence also infers the Himalayan connection of wind circulation pattern of the Ganga Plain.

The total number of species (diversity of thecamoebians) is inversely proportional to the percentage of thecamoebian cysts. Therefore, the high ratio (18-25) of the total thecamoebians verses cysts in a sample indicates favourable conditions for the thecamoebians. The lower the ratio of total thecamoebians verses cyst indicates unfavourable and vulnerable conditions. Out of all the species, *Centropyxis laevigata* is the most dominant and thus, shows its adaptability to stressed conditions such as desiccation and expansion of the lake water level. Testate amoebae, being inherently aquatic, can be classified into ecological groups according to their requirements concerning moisture (hygrophiles, hydrophiles and xerophiles), pH (acidophiles and calciophiles), habitat preferences (sphagnophiles, soil-inhabiting and aquatic) (Mazei & Tsyganov, 2007; Farooqui *et al*., 2012). About 16 species or sub-species have been identified in the studied samples. More than half of the taxa belong to hygro-hydrophilic species of the genera *Centropyxis*, *Arcella* and *Difflugia*. Most of the identified species belong to cosmopolitan group. Among these eurybiontic species are *Centropyxis aerophila*, *C. constricta*, *C. aerophila*, *C. aerophila 'sylvatica'*, *Cyclopyxis* and *Trinema*. The dominance of hydro-hygrophilic species such as *Centropyxis laevigata* is interestingly unique. Dominance of *C. laevigata* in sediment thus provides a valuable clue to understand the climate induced increase or decrease in the lake water level and subsequently subjected to stressed conditions. The palynological assemblages in the sediment recorded here are categorized as dry-deciduous vegetation meaning thereby, that the number of dry months per annum is more than 7-8 months. Therefore, it is likely that such an assemblage of thecamoebian community could be recorded with areas dominated by climatic conditions favouring dry-deciduous vegetation. The significance of thecamoebians for palaeoecological studies is based on the fact that these are permanently affixed to the substrate. Their shells are normally destroyed if the sediments are redeposited. Therefore, thecamoebians have an advantage to directly indicate the palaeoenvironmental conditions during the sediment formation, unlike many other biological remains.

CONCLUSION

The comparative assessment of AP and NAP ratio from Bari Tal reveals av. 22.5% arboreals (trees & shrubs) mainly comprised of dry-deciduous vegetation. The pollen assemblage is in equilibrium with the annual precipitation range (100-200cm). Highest pollen influx of *Madhuca indica* is av. 6.8% and *Acacia* av. 4.7% is recorded. The rest of the trees represent av. 11% pollen. Among the non-arboreals grasses (Poaceae) are recorded with av. 105% of pollen together with Cerealia av. 26.2% pollen and X*anthium* av. 65%, which are non-pollen sum components are recovered in excessively high frequencies due to their local abundance in the wasteland adjoining to the lake. On the whole the terrestrial herbs constitute the largest fraction of pollen rain. The other heathland taxa with av. 75.3 % pollen, barring grasses, Cerealia and *Xanthium*, truly reflect their factual presence in the area. The marshy comprising sedges and others (non-pollen sum elements) are encountered with av. 53% pollen, depicting close proximity of the lake or marshy condition to the study site. Therefore, it is deduced that this comparative database on pollen rain vis-à-vis vegetation is to be taken as a modern analogue for the scrupulous evaluation of vegetation dynamics of the past while interpreting the pollen sequences from the Central Ganga Plain and other region with similar extant floristic composition. The pollen rain data-grid also signifies the prevailing present climatic condition in the study area. The physiognomic aspects of the trees 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 pollen assemblage as well as empirical climatic data for the region. Thecamoebians are abundant in aquatic ecosystem and their solid shells are preserved long after the death. These are potential indicators of palaeoecology and in association with palynological data serve as palaeoclimate and palaeovegetation markers. Thecamoebians are substrate specific and respond quickly to hydrological changes in very short-duration. The study here provides a glimpse of pollen rain data of sub-tropical climate supporting dry-deciduous vegetation and significant marker assemblages of stressed thecamoebian community particularly, *Centropyxis laevigata*.

In addition, the meticulous retrieval of pollen/spores in the surface soils aids in discerning the various plant species/groups contributing to the aerospora of the region. Because after emission of pollen from the flowers and spores from the fruiting bodies remain suspended in the atmosphere prior to settling down along with dews and rain water. This information provides awareness among the people concerning the important pollen/spores in the milieu so that the precautionary measures to be taken against the allergic diseases caused by them. Further, the quantitative and qualitative assessment of thecamoebians in the surface soils from the proximity of the aquatic ecosystem enables in deciphering the stress level of the lakes, ponds and other potable water bodies.

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