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A preliminary study of the modern pollen of Tripura, Northeast India

NIVEDITA MEHROTRA* AND SANTOSH K. SHAH

Birbal Sahni Institute of Palaeosciences, 53 University Road, Lucknow 226 007, India.
**Corresponding author: nivedita_mehrotra23@hotmail.com*

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ABSTRACT

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The vegetation distribution in Tripura, Northeast India was studied from the modern pollen assemblages at various sites in the region. Sediment samples and moss cushions were collected along transects from North to South Tripura to assess the modern pollen taxa dominant in the region. A number of taxa showing a modern day distribution of moist deciduous mixed vegetation dominant in Tripura were observed in the modern pollen data. Statistical significance of the modern–pollen data was verified using one–way ANOVA technique. Despite the limited pollen taxa recorded in the surface samples the analysis proved the potential of the pollen data and scope for future palynological studies. The impact of anthropogenic activity is clearly visible through the low sample yield and presence of taxa such as Poaceae, Amaranthaceae, Solanaceae, etc. Other factors such as entomophilous tendency and/or low yield of pollen in tropical plants, excessive rainfall, sediment distribution and *jhum* cultivation could contribute to the lack of pollen preservation in the region.

Key–words—Modern pollen, Vegetation, Anthropogenic impact, Tripura, Northeast India.

त्रिपुरा, उत्तरपूर्व, भारत के आधुनिक पराग का प्रारंभिक अध्ययन

निवेदिता मेहरोत्रा एवं संतोष के. शाह

सारांश

अंचल में अलग–अलग स्थलों पर आधुनिक पराग समुच्चयों से प्राप्त त्रिपुरा, उत्तरपूर्व भारत में वनस्पति वितरण का अध्ययन किया गया। अंचल के प्रभावी आधुनिक पराग टैक्सा निर्धारित करने को उत्तर से दक्षिण त्रिपुरा तक वनस्पति पट्टी के समानांतर अवसाद नमूने और मॉस कुशन (तल्प) संगृहीत किए गए । आधुनिक पराग ऑकड़े में त्रिपुरा में प्रभावी आर्द्र पतझड़ी मिश्रित वनस्पति के आधुनिक दिन के वितरण दर्शाते हुए तमाम टैक्सा अवलोकित की गई हैं। एकांगी एनोवा तकनीक प्रयुक्त करते हुए आधुनिक पराग आंकड़ा की सांख्यिकीय महत्ता साबित की गई। पृष्ठीय नमूनों में अभिलिखित सीमित पराग टैक्सा के होते हुए भी विश्लेषण ने पराग आंकड़े की संभावना एवं भावी परागाणविक अध्ययनों हेतु गुंज़ाइश साबित की। कम नमूना प्राप्ति एवं पोआसी, अमरेंथेसी, सोलनेसी, इत्यादि जैसी टैक्सा की विद्‌यमानता से मानवजनिक हलचल स्पष्टतः दृष्टिगोचर होती है। अंचल में कीटपरागीय प्रवृत्ति तथा/या उष्णकटिबंधीय पादपों में पराग की कम प्राप्ति, बेहद बरसात, अवसाद वितरण ओर झूम खेती जैसे अन्य कारक पराग परिरक्षण के अभाव में योगदानी रहे होंगे।

सूचक शब्द—आधुनिक पराग, वनस्पति, मानवजनिक प्रभाव, त्रिपुरा, उत्तरपूर्व भारत।

INTRODUCTION

THE study of surface sample for pollen analysis provides most precise method of the interpretation of pollen assemblages in terms of modern vegetation of the study area and a reference for the plausible past vegetation. It provides basic information of pollen rain beneath a range of vegetation types, which is a useful source of information upon which the fossil pollen assemblages can be interpreted (Wright, 1967; Flenley, 1973; Moore & Webb, 1978; Birks & Birks, 1980; Liu & Lam, 1985; Fall, 1992; Davis *et al*., 2013).

Significant relationship between vegetation and pollen accumulation and distribution in various regions of Northeast India has been demonstrated in several modern pollen studies (Gupta & Sharma, 1985; Bera, 2000; Basumatary & Bera, 2007; Dixit & Bera, 2012a, b; Basumatary *et al*., 2013; 2014; 2017; Bera *et al*., 2014, Tripathi & Bera, 2014). These studies are generally concentrated in the central and northern parts of Northeast India such as Assam, Meghalaya, Arunachal Pradesh and Darjeeling and few surface pollen studies have been published from southern parts of Northeast India which include Tripura and Mizoram.

Here we make a preliminary attempt to study the modern vegetation distribution in this tropical region of Northeast India. The Tripura State which has a moderate forest cover and simultaneously dominant agricultural activities in a monsoon dominated warm and humid climate. The palynological analysis of surface sediments and moss cushions was carried out and statistical analysis of the pollen data revealed the present state of vegetation distribution. We also try to examine the anthropogenic impact on the pollen yield and thereby the plant taxa dominant in surface sediments collected from different parts of Tripura.

REGIONAL SETTING

The densely populated state of Tripura is in the hinterland of Northeast India and bordering the Bay of Bengal (Fig. 1). The state has a dense forest cover of about 6292 sq. km., (as per Forest Survey of India Report, 1999) with number of reserve forests and national parks but agricultural practices range from regular crop plantation to commercial rubber, bamboo and timber wood plantations.

Vegetation

The vegetation of Tripura, Northeast India was studied in detail by Deb (1983), who observed that the vegetation is comprised of evergreen forest and moist deciduous forest. Moist deciduous forests are further divided in two categories, namely moist deciduous Sal forests and moist deciduous mixed forest. Swamp vegetation, bamboo forest and cane brakes also occupy parts of the region. The planted rubber forests, bamboo forests, tea plantations along with other commercial crops are heavily developed throughout the state in the present day. There are about 379–tree species, 320–shrubs, 581–herbs, 165–climbers, 16–climbing shrubs, 35–ferns, 45–epiphytes and 4–parasites and about 266 species of medicinal plants (http: //tfdpc.tripura.gov.in).

Climate

The Tropical climate conditions prevailing in Tripura are generally hot and humid. The nearest meteorological station is in Agartala records annual minimum and maximum temperature between 8º C and 36º C respectively. The average annual rainfall varies between 2,250 mm and 2,500 mm (Bhattacharyya *et al*., 2011). The CRU TS 3.22 climate data set (Harris *et al*., 2014) extends from the year 1901–2013 and is an interpolation of 5 degrees of latitude-longitude climate data. Four grid points (Fig. 1) around the present sampling site were selected for calculation of regional mean temperature and precipitation. The Walter and Leith Climate diagram (Walter & Leith, 1967) based on CRU TS 3.22 climate shows that the average maximum temperature of the warmest month was 32.1°C and average minimum temperature of the coldest month was 11.7°C and the total annual precipitation is 2586 mm during the years 1901-2013 (Fig. 2). This climate diagram represents a tropical summer rain type curve according to Walter & Leith (1967).

MATERIAL AND METHODS

Palynological sampling and Analysis

A collection of 39 samples was made from Tripura, which included around 37 surface sediment samples and 2 moss cushion samples. The details of the sampling sites and the sample types are given in the Table 1 and the location of these sites is shown in the Fig. 1. The common dominant tree elements observed in sampling sites are *Terminalia bellirica, Polyalthia longifolia, Lagerstroemia parviflora, Michelia champaca, Syzygium cumini, Schima wallichii, Mesua ferrea, Delonix regia, Grewia microcos, Caesalpinia pulcherrima, Cassia fistula, Elaeis guineensis, Aphanamixis polystachya, Artocarpus chaplasha, Adenanthera pavonina, Shorea robusta, Dalbergia sissoo, Taraktogenos kurzii, Anthocephalus chinensis, Bombax ceiba, Pongamia pinnata* and *Acacia catechu.*

The samples were processed using standard methodology for palynological studies (Erdtman, 1943; Faegri & Iversen, 1989). We have counted minimum 150–200 pollen grains per sample. The palynomorphs counts were then represented as estimation of the abundance of individual pollen type and are expressed by its relative percentage. The relative percentage of individual pollen type of arboreal and non arboreal taxa was calculated using "Pollen Sum" that excludes the fern spores and aquatic /marshy taxa. The relative percentage of aquatic/marshy and ferns was calculated using "Total pollen count" which includes pollen of arboreal and non arboreal taxa along with aquatic/marshy and fern spore. The pollen percentage diagrams were constructed using computer program, the TILIA version. 2.0.2 (Grimm, 2004). Some of the pollen taxa were identified as extra local elements in the pollen percentage. These mostly include the taxa which grow at comparatively higher elevations at temperate and upper level of sub–alpine forest and may be carried to the site by wind and water.

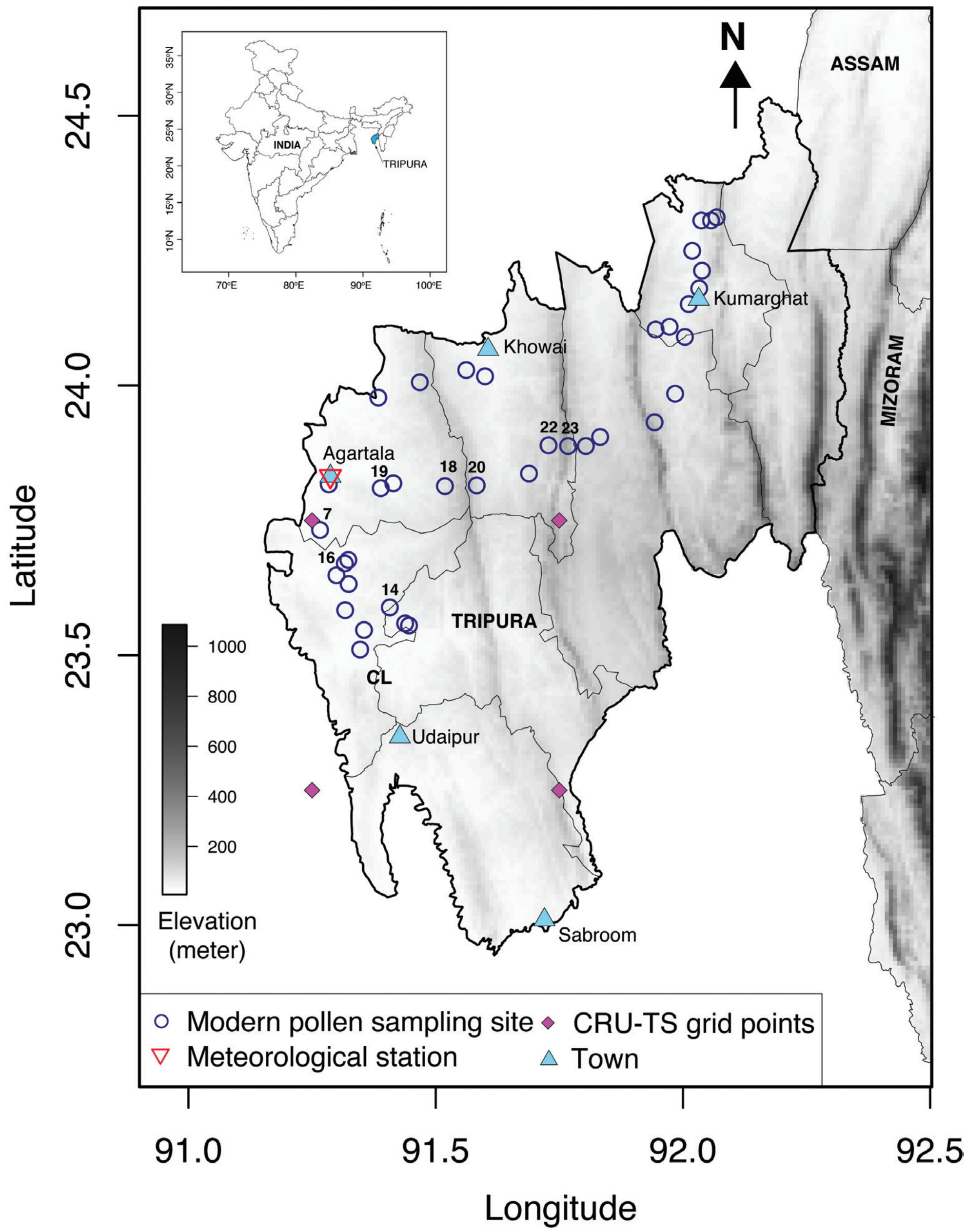

Fig. 1—a) Map of India showing Northeast India (Square block) and Tripura (marked in blue). b) Map of Northeast India: Tripura State shaded in blue. c) Map of Tripura including modern pollen sampling site, CRU–TS grid points and Meteorological station. The samples that yielded modern pollen are numbered and marked as circle, while the remaining sampling sites are shown as only circles.

Statistical analysis of palynological data–ANOVA

For the present study, in all the samples having palynological data, the taxa observed were clubbed as trees, shrubs and herbs, aquatic and marshy, and ferns. These samples were collected from sites at variable distances among each other and which had slightly different vegetation in their individual surroundings. The one–way ANOVA test was applied considering the samples as groups and clubbed taxa as the population within the samples, using data analysis tool pack in Microsoft Excel. Analysis of Variance (ANOVA) involves the separation of the total variance in a collection of measurements into various components or sources (Davis, 2002; Keller & Warrack, 1997). The alpha value 0.05 was taken for the analysis, i.e. 95% confidence level or as the significance level. We analyzed the Excel output (Table 2) for the SS–values, p–values, the F–values and F–test to finally obtain the inference of the One–way ANOVA analysis on the means and variance of theses set of surface samples collected from Tripura.

Table 1—Details of the various samples collected from different sites in Tripura.

Sample no.	Location Name	Sample type	Latitude (°N)	Longitude (°E)
TR–01	College Tila Lake, Agartala	Soil	23° 49' 0.764"	91° 17' 0.911"
TR–02	Melagarh	Soil	23° 30' 41"	91° 20' 50.1"
TR–03	Nalchor	Soil	23° 32' 49.7"	91° 21' 17.7"
TR–04	Bishramganj	Soil	23° 37' 53.9"	91° 19' 25.4"
TR–05	Bastali, Bairamura	Soil	23° 35' 0.745"	91° 19' 0.274"
TR–06	Sipaijala	Soil	23° 38' 54.2"	91° 17' 54.9"
TR–07	Sekarkot	Soil	23° 43' 55.2"	91° 15' 59.3"
TR–08	Laltila	Soil	24° 01' 0.797"	91° 36' 0.065"
TR–09	Padmabil	Soil	24° 01' 43.1"	91° 33' 43.5"
TR–10	Baramura	Soil	24° 00' 20"	91° 28' 5.6"
TR–11	Sidhai	Soil	23° 58' 41.2"	91° 23' 2"
TR–12	Tepania, Udaipur	Soil	23° 33' 18.9"	91° 26' 46.2"
TR–13	Bagma	Soil & Moss cushion	23° 33' 31.4"	91° 26' 15.8"
TR–14	Bagma	Soil	23° 35' 19.6"	91° 24' 25.7"
TR–15	Sepaijala, Wild Life Sanctuary	Soil	23° 40' 38"	91° 19' 21.2"
TR–16	Sepaijala, Wild Life Sanctuary	Soil	23° 40' 12"	91° 18' 56.5"
TR–17	Madhav Bari–Tripura–Shillong Hig	Soil	23° 49' 7.2"	91° 24' 48.9"
TR–18	Baramura–after Champak Nagar	Soil	23° 48' 49.4"	91° 31' 9.2"
TR–19	Baramura–14 km before Teliamura	Soil	23° 48' 35.3"	91° 23' 19"
TR–20	Baramura–8 km before Teliamura	Soil	23° 48' 52.3"	91° 34' 59.3"
TR–21	Chakmaghat–4 km before Teliamura	Soil	23° 50' 11.7"	91° 41' 20.4"
TR–22	Athermunga	Soil	23° 53' 21.2"	91° 43' 39.2"
TR–23	Mungaikami	Moss cushion	23° 53' 15.8"	91° 46' 4.7"
TR–24	Ambasa Forest Division	Soil	23° 53' 17"	91° 48' 13.4"
TR–25	2 km from Ambasa	Soil	23° 54' 16.4"	91° 49' 58.7"
TR–26	Jawahar Nagar	Soil	23° 55' 25.5"	91° 56' 30.1"
TR–27	Rantalai Valley	Soil	23° 55' 55.5"	91° 56' 34.1"
TR–28	3 km from Manu	Soil	23° 59' 4.9"	91° 59' 1.9"
TR–29	Kanchanchera	Soil	24° 05' 25.6"	92° 00' 14"
TR–30	Laljhuri, Kumarghat	Soil	24° 06' 13.9"	91° 56' 41.3"
TR–31	Paschim Kanchanbari	Soil	24° 06' 32.7"	91° 58' 22.5"
TR–32	Sonaimuri	Soil	24° 12' 47.9"	92° 02' 21.2"
TR–33	3 km from Kumarghat	Soil	24° 10' 48.5"	92° 01' 58.5"
TR–34	1 km from Unnakoti	Soil	24° 18' 42.2"	92° 04' 3"
TR–35	Chinibagan, Unnakoti	Soil	24° 18' 21.1"	92° 03' 25.2"
TR–36	Bhagwan Nagar	Soil	24° 18' 20.6"	92° 02' 14.3"
TR–37	Dalugaon	Soil	24° 15' 0.2"	92° 01' 9.5"
TR–38	Rajendra Nagar	Soil	24° 09' 4.8"	92° 00' 43"

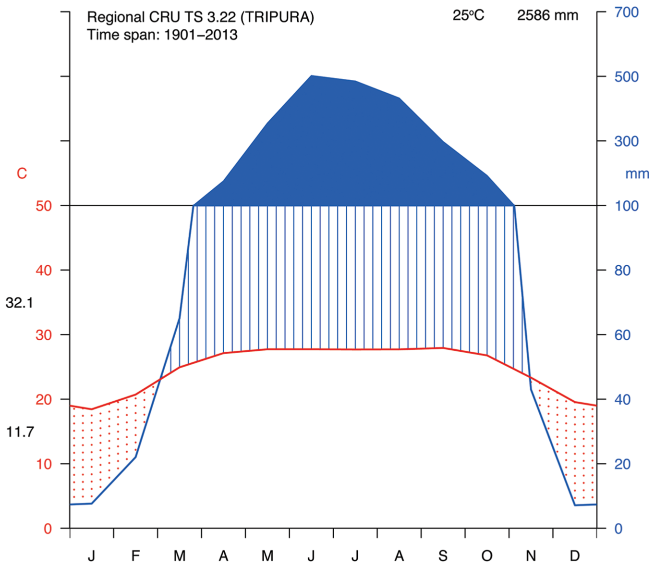

Fig. 2—Climate diagram of Tripura regional climate based on CRU TS 3.22 climate records for the period 1901–2013. Blue line represents precipitation curve and red line represent temperature. The diagram shows mean maximum temperature of the warmest month, mean minimum temperature of the coldest month. Upper right corner of the diagram is showing annual average of temperature and annual total precipitation. Climate diagram is based on Walter and Lieth (1967).

RESULTS

Although many samples were collected but most soil samples had minimal pollen yield after processing. All the samples were observed for palynomorphs present but only 7 soil samples yielded palynomorphs (Fig. 3). Among the two moss cushions, sample number (TR–23) yielded sufficient pollen taxa. The results of this study are promising and further analysis of more moss cushions and sediment samples may give a clear picture of the modern pollen assemblages. The samples which yielded pollen taxa are described below.

Modern pollen assemblages in Surface samples

TR–7–The site at Sekarkot was near a cultivated land, which had a high pollen sum. It recorded few tree pollen of namely *Palmae* (1.05%), *Acacia* (1.05%), Elaeocarpaceae (4.21%). The shrubs and the herbs such as Solanaceae (9.47%) Asteraceae (Tubuliflorae) (5.26%), and large amounts of grass pollen, i.e. Poaceae (<50 µ) (50.53%) and (> 50 µ) (28.42%) were found. Aquatic and marshy taxa such as Cyperaceae (25.47%) and *Potamogeton* (0.94%) were also present. Ferns in this sample were Trilete (1.89%) and *Lycopodium* (7.55%).

TR–14–This surface soil sample was collected near a rubber tree plantation site at Bagma. It recorded no tree taxa, no ferns and aquatic or marshy taxa. With only very few counts of shrubs and herbs such as Solanaceae (11.11%), Amaranthaceae (22.22%) and Poaceae (<50µ) (66.67%) were found in the sample.

TR–16–This surface sample was collected at Sepaijala Wild Life Sanctuary forest area. The tree pollens dominating this sample were Saxifragaceae (5%), Elaeocarpaceae (5%), Theaceae (15%), *Shorea robusta* (37.50%) and *Salix* (2.5%). Shrubs found were Solanaceae (20%), Malvaceae (5%), Rosaceae (2.5%) along with herbs such as Asteraceae (Tubuliflorae) (2.5%) and Poaceae (< 50 µ) (5%). Among the fern spores only Monolete (2–44%) was observed.

TR–18–This sample collected near Baramura, after the Champak Nagar forest area also lacked any tree pollen. Among the shrubs, Solanaceae (5.26%) and Malvaceae (31.58%), were recorded along with herbs namely Polygonaceae (15.79%), Poaceae (<50µ) (47.37%), Ferns such as Monolete and Trilete were about 4.76% each.

TR–19–It was collected at Baramura forest area about 14 km from Teliamura. The trees found in this sample were *Pinus* (16.67%). The herbs recorded were Asteraceae (Tubuliflorae), (16.67%) and Poaceae (<50 µ) (66.67%). No ferns, aquatic taxa were recorded.

TR–20–This sample collected 8 km before Teliamura, at Baramura recorded few trees such as Palmae (2.38%), Elaeocarpaceae (2.38%) and *Shorea robusta* (2.38%). The shrubs and herbs dominating the sample were *Symplocos* (4.76%), Solanaceae (11.90%), Malvaceae (14.29%), Asteraceae (Tubuliflorae) (2.38%), Euphorbiaceae (7.14%), Amaranthaceae (7.14%), Poaceae (< 50 µ) (38.10%) and Poaceae (>50 µ) (7.14%). Aquatic and marshy taxa were only Cyperaceae (10.71%). The ferns were abundant included Monolete (7.14%), Trilete (5.36%) and *Lycopodium* (1.79%).

TR–22–This sample was collected near Atheramunga, Munga Bari forest and was devoid of any tree taxa. The shrubs and herbs found were Solanaceae (28.57%), Euphorbiaceae (14.29%), Poaceae (<50 µ) (57.14%). There were no aquatic or marshy taxa recovered in this sample. The ferns found were Monolete (13.33%) and Trilete (40%).

TR–23–This moss cushion sample collected 3 km after Mungai kami had a good count of trees namely *Pinus* (2.04%), Palmae (10.20%), Elaeocarpaceae (4.08%). The

Table 2—ANOVA of modern pollen data from Tripura.

Source of Variation	SS	df	MS	F	P–value	F crit
Between Groups	32129.88	7	4589.982	1.21951	0.330536	2.422629
Within Groups	90331	24	3763.792			
Total	122460.9	31				

lower element such as *Symplocos* (2.04%), Solanaceae (14.29%), Rosaceae (4.08%), Asteraceae (Tubuliflorae), (22.45%), Euphorbiaceae (10.20%), Acanthaceae (2.04%) and Poaceae (<50 μ) (28.57%). Aquatic and marshy taxa such as Cyperaceae (0.49%) and *Potamogeton* (1.47%) were found. The ferns observed were Monolete (7.35%), Trilete (78.43%) and *Lycopodium* (0.25%).

One–way ANOVA analysis of palynological data

Although the samples having palynological data and/or the ones that yielded palynomorphs were very few in the present study. We attempted to bring out the statistical significance of the data set and the samples under consideration. The clubbed taxa of the sample population included the trees, shrubs and herbs, aquatics, and ferns distributed throughout Tripura (Fig. 4). The population of these taxa in each sample had equal mean and similar variance which was the null hypothesis for the one–way ANOVA test (Table 2). The *p*–value was greater than the α–value of 0.05 and the data was statistically significant. Hence we further looked at the $F_{critical}$ value which was higher than the $F_{calculated}$ value. Therefore in accordance with the null hypothesis being true, the population means of the samples were equal and or similar and the variance among the samples was similar too. Thus the one–way ANOVA test brought out the statistical significance of the data. The vegetation recorded in the samples was normally distributed throughout the study area. Given the fact that although the samples are less but the analysis proved the potential of the data recorded and scope for future studies.

DISCUSSION

The surface sediment samples collected across Tripura clearly indicate the dominance of moist deciduous mixed vegetation in the region. The most commonly occurring taxa in the surface samples were *Shorea robusta, Palmae, Salix, Symplocos,* Elaeocarpaceae, Solanaceae, Malvaceae, Rosaceae, Poaceae, Amaranthaceae along with marshy and/or aquatic species and fern spores (Fig. 3). The surface sediment samples having very low yield of palynomorphs could be attributed to various reasons. The lack of palynomorphs yield in sediment samples could be due to low pollen productivity tendency of the tropical species in the region. Similar occurrence of low pollen yield was recorded in surface pollen based modern vegetation studies in other tropical regions of India. Modern pollen rain studies from Ganga plain area (Trivedi & Chauhan, 2011) and Madhya Pradesh and Chhattisgarh in central India (Chauhan, 1994, 2008; Quamar & Bera, 2014a, b; Quamar & Chauhan, 2007, 2010, 2011) reported the low yield of palynomorphs due to the tendency of low pollen productivity of similar tropical species as growing in Tripura. Tropical regions of India have many

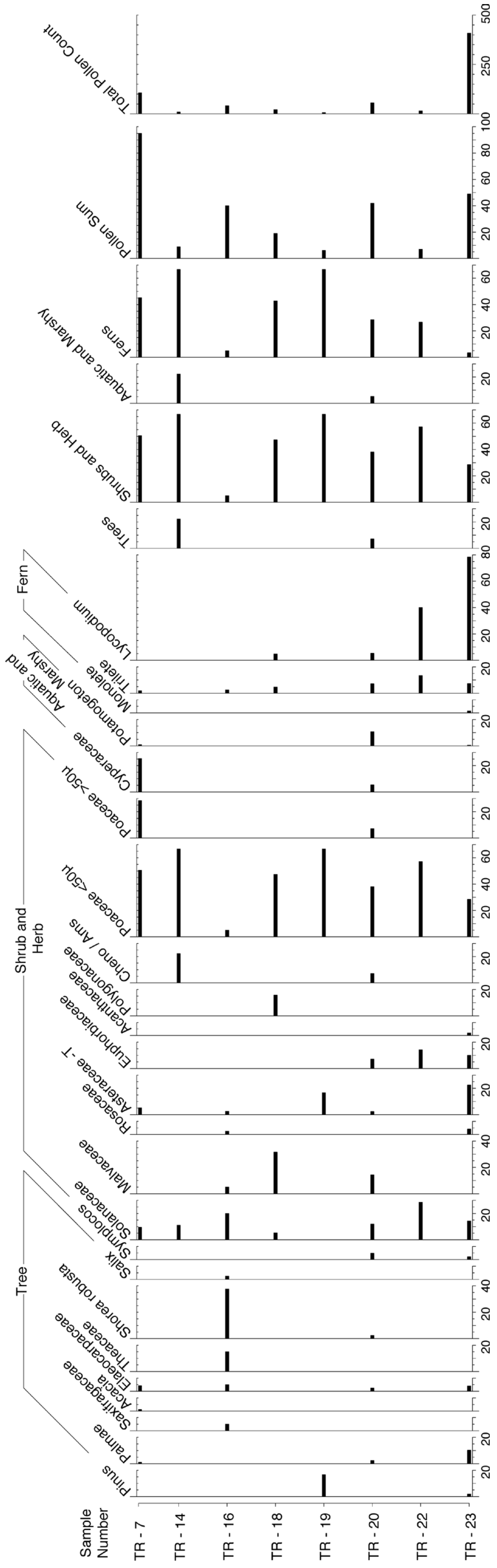

Fig. 3—Pollen diagram showing the percentage of taxa recovered in surface samples.

Fig. 4—Diagrammatic representations of the clubbed taxa data of selected modern samples for One–way ANOVA.

species which have a tendency to be entomophilous which was also presented as a reason for the low occurrence of pollen taxa in the surface samples of these studies from tropical India (Chauhan, 1994, 2008; Quamar & Bera, 2014a, b; Quamar & Chauhan, 2007, 2010, 2011; Trivedi & Chauhan, 2011). Our study is based on the results from few surface samples but it is first such representation of modern vegetation occurring in Tripura. But modern pollen rain studies of tropical regions of central India have been based on 5–10 samples having low pollen counts and successfully demonstrated modern vegetation in the regions (Chauhan, 1994, 2008; Quamar & Bera, 2014b; Quamar & Chauhan, 2007, 2010, 2011; Trivedi & Chauhan, 2011). Modern pollen taxa from Tripura were higher in yield from moss cushion sample in Tripura but the lack of proper pollen preservation in surface sediment samples could be due to anthropogenic activity and environmental factors also.

There have been reports from China where abundance of some pollen taxa were associated with human activities and anthropogenic influences (Li *et al*., 2008; Li *et al*., 2014, 2015; Zhang *et al*., 2010.). Li *et al*., (2015) demonstrated that human impact can cause bias in the modern pollen distribution and climate relationship which together also affected the spatial distribution of modern pollen data in China. Li *et al*., (2014) had created a quantitative calibration model of the human influence index (HII; developed by Sanderson *et al*., 2002) along with two climate variables in China. They analyzed modern pollen data sets from different biomes of entire China and shown that the impact of human influence index on modern pollen data was highest in east central China where there has been major settlement since the last 3000 years. Consequently the natural vegetation of this region of China has been disturbed and mostly replaced by cultivated fields dominated by wheat, rice and corn. The high level of HII was mostly caused by the steady occurrence of pollen types such as *Artemisia*, Chenopodiaceae (Amaranthaceae) and Poaceae in this Tianchi Lake pollen record. These pollen types belong to the taxa that are natural plants in the dry climatic regions of north–western China, but are anthropogenic indicators in the more humid, deforested regions of eastern China. It is possible that before 3000 cal. yr BP they might represent either the natural plants typical to the semi–open vegetation in the vicinity of Lake Tianchi or the long–distance transported pollen from the steppe regions farther north and west of the lake. Our study also records similar taxa such as Chenopodiaceae (Amaranthaceae), Poaceae and Solanaceae in the surface sediment samples indicating a possible anthropogenic influence on the modern vegetation of Tripura.

Spatio–temporal variability in vegetation is a combined product of human activities and natural environmental changes throughout the Holocene (e.g. Ruddiman, 2003; Fyfe *et al*., 2013; Trondman, 2014; Trondman *et al*., 2015; Xu *et al*., 2016). We have known records of human occupancy of Tripura since the prehistoric times who have been said to migrate from the Burma (Myanmar) based on similar stone tools found in both the regions (Ramesh, 1986). Thus human impact has been disturbing the vegetation and Quaternary sediments in the Tripura region since a very long time. Nevertheless factors such as agricultural practices, deforestation, irrigation, plant introduction, and urbanization, strongly impact the natural vegetation–climate relationship during the entire Holocene (Li *et al*., 2014).

Tripura is subjected to extensive agricultural activities which included a common practice of *Jhum* (Slash and burn) in hill areas where forest clearing is followed by burning and later plantation of mixed crops (Bhattacharyya *et al*., 2011). The lower altitudes and river valleys have paddy and vegetable grown as crops (Bhattacharyya *et al*., 2011) which require a lot of tilling and irrigation practices. A number of sites where the sampling was carried out had agricultural lands in close vicinities. The samples which yielded palynomorphs were from forested area, rubber–plantation areas, wild life sanctuaries and hilly terrains with minimal human impact. Since anthropogenic activity in the state of Tripura is extensive this might have caused the discrepancies in the sample yield. There could be possibly more reasons for lack of pollen preservation in the region. These could be due to both external and factors inherent to the pollen grains themselves. Most of the tree taxa although widely distributed throughout the state are low in counts in the samples. This could be due the fact that tropical trees have entomogamous tendencies hence leading low pollen production (Quamar & Chauhan, 2014a, b). The low sporopollenin content of the pollen and soil environment of preservation might also have a detrimental impact on the pollen preservation (Sangster & Dale, 1965; Havinga, 1967). The high soil pH values along with oxidation, high temperature, microbial and chemical action in sediments could also have caused the lack of pollen present in the sediments (Havinga, 1967). The average annual rainfall in Tripura being high could probably cause excessive sediment weathering, water logging and soil degradation. A report by National Bureau of Soil Survey & Land Use Planning states that about 60 percent of total geographical area (approximately 6.28 Lac Ha.) of Tripura is subjected to various types of soil degradation (Bhattacharyya *et al*., 1996). Tripura soils are subjected to two major processes of degradation, first due to displacement of soil material by water, and secondly due to internal soil degradation. The internal soil degradation is due to loss of nutrients (chemical deterioration) or by physical processes such as water–logging and flooding (physical deterioration).

There are several quantitative techniques used to analyze modern pollen spectra and climate data required along with fossil pollen–based for climate inferences and reconstruction (Li *et al*., 2015) (e.g., Seppä *et al*., 2004; Whitmore *et al*., 2005; Shen *et al*., 2006; Finsinger *et al*., 2007; Minckley *et al*., 2008; St. Jacques *et al*., 2008; Williams and Shuman, 2008; Salonen *et al*., 2012; Zhao *et al*., 2012; Schäbitz *et al*., 2013; Wen *et al*., 2013; Tian *et al*., 2014; Xu *et al*., 2016). There are various quantitative reconstruction methods and models which were created to reconstruct past vegetation and climate using fossil pollen data (Xu *et al*., 2016); these were namely the transfer function method (e.g. Webb, 1974; Song *et al*., 1997; Birks *et al*., 2010), the modern analog technique (e.g. Overpeck *et al*., 1985; Williams & Shuman, 2008), the biomization approach (e.g. Prentice & Solomon, 1992), the ERV models (e.g. Andersen, 1970; Parson & Prentice, 1981; Prentice & Parsons,1983), and the Landscape Reconstruction Algorithm (LRA including the REVEALS and LOVE models) (Sugita, 2007a,b). Among these the most frequently used techniques for past climate reconstruction based on pollen is the Modern Analogue Technique (MAT; e.g. Overpeck *et al*., 1985; Guiot, 1990; Nakagawa *et al*., 2002) and the transfer function method (Weighted Averaging and Weighted Averaging Partial Least Squares, WA and WAPLS; e.g., terBraak & Juggins, 1993; ter Braak, 1995; Seppä *et al*., 2004). Although there have been very few studies in which ANOVA analysis have been carried out on modern pollen samples (e.g., Amami *et al*., 2010; Hill, 1996; Ding *et al*., 2011; Mazier *et al*., 2012) to understand modern vegetation and/or climate in a region. Variation of palynomorphs was studied in a population of individually collected samples of climatically different regions or varying vegetation zones using ANOVA along with other quantitative techniques (Goring, 2012; Hill, 1996; Ding *et al*., 2011; Mazier *et al*., 2012).

We make an attempt to understand the statistical significance of the samples drawn from various parts of Tripura by one–way ANOVA analysis of taxa type clubbed together in these samples. The trees, shrubs and herbs, ferns, and aquatic taxa were distributed throughout the study area about evenly. The vegetation of the sampling region did not have a large difference as shown by the one–way ANOVA analysis. The sample means of these clubbed taxa were equal and the variance was similar. The variability in the distribution of the taxa was observed to be statistically significant by the one–way ANOVA test. Hence there is further scope of more sampling for modern pollen studies in Tripura. The results were not very exuberant but statistical significant. Thus further quantitative studies can provide a better understanding of the vegetation distribution and climate variations based on modern pollen data. But this was the first attempt to carry out such sampling and modern pollen studies in the region. Future studies should concentrate more on sampling moss cushions as these had more chances of good pollen yield and/ or preservation.

The review from China (Xu *et al*., 2016) addressed the extensive work on vegetation and climate reconstruction based on modern pollen–climate relationship and fossil pollen data. But there are a number of issued such as the quantification of wind–born against water–born pollen deposition in lake sediments and discrepancy in preservation of pollen grains in alluvial or lake sediments (Xu *et al*., 2016). It is important to consider such issues to understand about pollen assemblages. There have been extensive studies in North America (Traverse, 2007), Europe (Bessedik, 1985) on vegetation reconstruction based on pollen data and pollen productivity estimation and have been initiated in China (Xu *et al*., 2016 and references there in). Extensive pollen based environmental analysis throughout the world has generated and verified model based precise reconstruction of palaeovegetation and climate (Xu *et al*., 2016). But in Northeast India still not much work has been initiated in this direction of pollen based study (Mehrotra *et al*., 2014). Further involvement of model–based quantitative climate reconstruction and vegetation studies need to be carried out in India.

CONCLUSIONS

The modern pollen assemblages indicate moist deciduous mixed vegetation occurring in Tripura. We have attempted to start a basic quantitative and or statistical significance analysis of pollen data. But due to lack of palynomorphs in the sediments collected were unable to carry out any advanced statistical or multivariate analysis. This is the first study of modern pollen data from Tripura and a lot needs to be done in future in this monsoon dominated region. It is empirical that the results of this study showed the impact of natural and anthropogenic factors causing the low yield of pollen taxa in surface sediments. But this study enlightens the potential of the modern pollen studies that can be carried out in Tripura. This region has a strong influence of South–west monsoon, Bay of Bengal and Tropical environment. Although the pollen yield was low but future extensive and selective sampling should be carried out. An advanced quantitative analysis of modern pollen data along with modern climate records can bring out more information regarding the modern vegetation vis–à–vis modern climate variations in the region.

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