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Review Article

Abundance and diversity of soil Oribatid Mites (Acari: Oribatida) from North-East India- A review

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ABSTRACT

The diversity and abundance of soil organisms significantly contribute to the ecosystems as well as in human welfare as we are very much dependent on the productivity of the soil. The oribatid mites are one of the most abundant species of soil microarthropods, spread all over the world and their effective role in soil ecological processes is indeed significant. Moreover, North-East (N-E) India is a hub of diverse life forms and rich in endemism with comprehensive ecological habitats that make it suitable to harbour a large number of organisms. The richness of soil mites in this region of the country has not been explored adequately and most of the part remains unexplored due to lack of survey, awareness of its beneficial role and scientific vigilance. In spite of the richness and abundance of fauna in this part of Indian subcontinent the acarine fauna of this region remain unattended by the acarologists for the reasons best known to them. The present work is a review article on oribatid soil mites and is based mainly on the work done so far and recent studies from north-eastern states along with the records of its distribution and abundance to enhance the knowledge about this soil micro fauna, their distribution, impacts on soil health and gap areas that need to be explored in future.

Key words: North-East India, Oribatid mites, Diversity, Abundance, Distribution.

INTRODUCTION

The soil, domicile for a diverse form of life that supports different types of mesofauna. Soil Oribatida are generally known as 'moss mites' or 'beetle mites' and their body size usually range between 100-1000 µm. They explore almost all types of possible habitats and express the maximum degree of diversity in terms of abundance and species composition (Schneider *et al.,* 2004; Subías, 2004; Erdmann *et al.,* 2007; Sharma and Parwez, 2017). The N-E region of India includes eight states and part of the globally recognized Indo-Burma biodiversity hotspot. This province is categorised as one of the undisturbed part of the world harbouring a wide range of ecological habitats with diverse flora and fauna, along with rich endemic species (Tripathi *et al.,* 2016). A nationwide study from Great Britain reported that subclass Acari were the most abundant group of soil invertebrates in terms of distribution in the soil as recorded in 94% of all soil samples (Black *et al.,* 2003). Several studies reported mites as a potential bio-indicator of ecosystems; their composition reflects the state of stress in the ecosystems. Oribatida are extremely sensitive towards all sorts of soil disturbance, their long life span, gradual development, low fecundity and dispersion indicates the status of the environment. Structural changes in the dominance of mite communities proposed as a prior cautioning measure for the level of stress in mite communities (Gulvik, 2007). The anomalous taxonomical diversity of oribatids all around the globe and site-specific predominance strongly support their importance in the soil. In forest and grassland soils oribatids are the most numerically abundant group of soil mites under Acari. They play a significant role in the process of decomposition and mineralization through which promote sustaining agro-ecosystem and considered as most successful among all soil arthropods. They possess a diverse mode of feeding starting from the degraded plant materials to decaying faecal matter. However, most of the oribatid mites are either obligate or facultative fungivores (Anderson, 1975; Wallwork, 1983; Labandeira *et al.,* 1997; Culliney, 2013; Sharma and Parwez, 2017). Oribatids also play a crucial role in biodegradation through digesting the bulk amount of plant materials with the help of the enzymes produced by their gut microbiome. Organically rich excretory wastes of Oribatids accelerate soil fertility and enhance both plant growth and productivity (Haq, 2016). Moreover, soil mites were model organisms for toxicological tests due to their prominent attribute including diverse and cosmopolitan nature of distribution, smaller body size, utilization of specific soil niches, concise reproductive period, feeding habits etc. (Huguier *et al.,* 2015). Some of the important soil mite species standardised for soil ecotoxicity tests are *Mulierculain expectata* (Owojori *et al.,* 2019),

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Oppia nitens (Princz *et al.,* 2010; Owojori *et al.,* 2011), *Hypoaspis aculeifer* (Smit *et al.,* 2012), *Platynothrus peltifer* (Alves *et al.,* 2016). The predatory behaviour of soil mites provides an effective control against harmful arthropods and their use as biological control agents economically beneficial, environment friendly and more effective control than the chemical agents, because the pest does not build up any sort of resistance to predatory mites and crop yield increased without compromising the quality, they also generally do not disrupt plant, animal or human lives (Nafiu *et al.,* 2014). Besides, their contribution to the ecological services they can also be a vital tool in the forensic analysis in the future which is proved by a case study in northern Spain wherein crime cases for the estimation of the time of death aside from insects, mites (Acari) were also found to be capable of providing a timescale or to complement and reinforce insect information. Phoretic mites of forensic importance are highly specific, adding valuable information on a particular host or scavenger (Salona-Bordas and Perotti, 2014).Also there was a study which reported for the first time the use of soil mites for the localization of buried money (Hani *et al.,* 2018).

This present review article aims to give a concise assessment of soil mites study from N-E India and also accolade their importance. Perhaps it is the first review article on soil mites to summarize the works done so far in N-E Indian states on soil Oribatida and to picturesque the research gaps.

Oribatida in World and India

Till 2004 near about 10000 species of oribatid mites has been described from all over the world. Among the Zoogeographical realms of the world, the highest grade of oribatids diversity is reported from the Palaearctic region with 3620 species and lowest from Sub-Antarctic region with a total number of 118 species. Whereas, the Oriental, Ethiopian, Nearctic, Neotropical and Australian / Pacific regions were represented by 1900, 1453, 1117, 1848 and 1245 species respectively (Schatz, 2004). In India, till 2003, 425 species/subspecies of Oribatida were recorded and distributed over more than 200 genera under more than 75 families (Sanyal, 2003a).The European acarologist Pearce (1906) first made faunistic studies on the oribatid mites from soils of the Sikkim Himalaya. Later the knowledge was enriched to some extent by the works of Bayoumi and Mahunka (1979a, 1979b), Mishra, Bhaduri, Raychaudhuri (1982), Subias and Sarkar (1982, 1983, 1984), Sanyal (1988), Bodjema *et al.* (1991), Chakrabarty and Bhattacharya (1992) and Bhattacharya and Chakrabarti (1995).The major contribution on soil oribatid mites from North eastern states of Meghalaya, Tripura, Manipur and Nagaland were by Sanyal (1995, 2000, 2004, 2006). Numerous studies on the diversity and abundance of soil mites in relation to various edaphic and environmental factors of India has been found in the recent literature by various workers such as Banerjee *et al.* (2009), Moitra *et al.* (2012), Rakshit and Chanda (2017), Ghosh and Mandal (2017), Ghosh (2018). The distribution of oribatid families, genera and species in different states of India shows that 60% of the Indian oribatid fauna is recorded from West Bengal. But the data available is not sufficient to draw any inference about the faunal richness of the states, as all the states except West Bengal has been little explored, resulting in poor representation of the oribatids (Sanyal, 1992; Channa Basavanna and Viraktamath, 1989).

Diversity and distribution of soil Oribatida in North-East India

The geographical area of N-E India is 262,180 km^2 covered by about 8% of the country's total area. The eight states of N-E India include Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Nagaland, Sikkim and Tripura. Diversity in soil, slope and altitudes with vast ecological conditions makes this region expedite to support a wide range of life (Roy *et al.,* 2015). The diversity of soil organisms significantly contribute to ecosystems as well as in human welfare as we are very much dependent on the productivity of land and soil, since these small arthropods play a profound role in soil formation and stabilization processes (Culliney, 2013).

Meghalaya

Oribatid mites of Meghalaya were first explored by W. Wittmer, Natural History Museum Basel, who first collected a specimen of oribatid mite from the state of Meghalaya and first studied by Bayoumi and Mahunka (1979a, 1979b) upon receiving it in 1979. Subsequently, they described the specimen *Hoplophthiracarus indicus* as new to science. Later Sanyal (1988) took on the mantle and recorded seven species belonging to seven genera under six families from Meghalaya. Of these, three species viz*., Mesotritia indica*, *Euphthiracarus meghalayensis* and *Eremobelba shillongensis* were described as a new record and four other species *Rhysotritia ardua*(Koch) *var.otaheitensis*, *Dolicheremaeus coronarius*, *Suctobelba quadricarina* and *Galumna crenata* were noted as new to the state. Then in 1995 gave a consolidated account of the oribatids of Meghalaya surveyed by him and his associates in 1991 and the previous work done by him and other researchers in the state of Meghalaya in the State Fauna Series 4: Fauna of Meghalaya, Part 2 in which he included 42 species belonging to 32 genera under 22 families. Of these, 34 species, 25 genera and 16 families were reported for the first time from Meghalaya. They also reported the genus *Phyllocarabodes* with one species as the first record from India. The species studied were deposited in the National Zoological Collection, Zoological Survey of India. This compiled account provided by Sanyal (1995) showed that 12.5% of Indian oribatid fauna was known from Meghalaya. It was also reported that the genus *Phyllocarabodes* and five other species were to be considered as endemic. Furthermore, the species viz., *Allonothrus russeolus*, *Tectocepheus velatus*, *Scheloribates parvus*, *S. saswatii*, *Rostrozetes foveolatus*, *Xylobates seminudus*, *Unguizetes clavatus and Lamellobates palustris* were considered to be common and abundant. The account showed that the soil oribatid faunal richness of the East

Garo Hills district occupied the highest position in respect of faunal composition.

In between this works mentioned above, researchers like Paul and Alfred (1984, 1995), Reddy (1984), Hattar *et al.* (1992) also worked upon the soil microarthropods of the state of Meghalaya. Reddy (1984) investigated the seasonal fluctuations of soil and litter microarthropod populations in a pine plantation of Meghalaya. One interesting observation from the study was that there was a negative correlation between the Collembola and Acarina groups which may be due to an antagonistic relationship between the two, due to predation of mites on Collembola (Nijima, 1971; Reddy, 1980). Another study on soil microarthropods in the state of Meghalaya was conducted by Hattar *et al.* (1992) who tried to compare the distribution and diversity of mesofauna with particular reference to Collembola and Acarina of pine forest soil and adjacent cultivated land at four different soil depths. Altogether 8 species of Acarina were recorded in pine forest whereas 5 species of Acarina were recorded in the cultivated land. In a pine forest, the species *Scheloribates albialatus* was found to be dominant in the upper 0-10 cm and 10-20 cm soil depth whereas in the 20-30 cm and 30-40 cm soil depths the most dominant species found were *Scheloribates huancayensis* and *Epilohmannia* spp. respectively. In cultivated land, on the other hand, *Parasitus divortus* was found to be dominant in both these depths. Results also indicated a higher density, lower abundance (no. of species) and greater species richness of soil mesofauna in the forest as compared to cultivated land.

Tripura

Subías and Sarkar (1982) first initiated the study of oribatid mites in Tripura and described three new species. Since then, many studies regarding soil mites of Tripura had been done by various researchers like Sarkar and Subías (1982,1983,1984), Sarkar (1983,1992), Subías and Sarkar (1983, 1984), Bhattacharya and Halder (1984), Bhattacharya *et al.* (1985), Boudjema *et al.* (1991), Chakrabarty and Bhattacharya (1992), Saha and Sanyal (1996), Sanyal and Saha (1996), Cencela da Fonseca and Sarkar (1998) and Sanyal *et al.* (2000) but most of the works were restricted to the western and southern parts of Tripura and reported a considerably high number of genera and species. Bhattacharya and Chakrabarty (1995) showed the vast abundance of soil mite species in an old rubber plantation and adjacent wasteland area in Ballamukha village of Belonia, South Tripura. Altogether 46 oribatid species under 37 genera and 21 families were recorded from the study sites and reported as a dominating group of soil arthropods over the two study area. *Scheloribates praencisusinterruptus* was the most common species in both the sites in terms of abundance followed by *Haplochthonius simplex* in the wasteland and *Cosmochthonius lanatus diversiseta* in the rubber plantation. Wasteland area had a significantly higher species diversity index (H) then the rubber plantation plot.

Till 2003, the total numbers of taxa of oribatid mites known from the soils of Tripura were 160 species belonging to 98 genera under 44 families and representing nearly 40% of the total Indian oribatid fauna and occupying the second position among the Indian states. The distribution of soil oribatids in Tripura shows that they have adapted themselves to live in different habitats like grassland, forest, cropland and fallow land. On the basis of data available Sanyal (2003a) reported the account of the diversity of soil oribatid mites in the Records of the Zoological Survey of India, in which it is mentioned that out of the 36 species of oribatid mites that were endemic to India, 24 of them were from this state. In addition, it is also reported that 72 species across 42 genera were not found anywhere in India other than Tripura though found elsewhere in the world. The oribatid species recorded from Tripura exhibited maximum similarity with species of the Pacific region. The other regions in order of degree of similarity are Neotropical, Ethiopian, Palaearctic and Nearctic. Only four genera viz., *Trimalaconothrus*, *Oppia*, *Scheloribates* and *Galumna* were found to occur both in Tripura and Antarctica though there is no species similarity found. Sanyal (2003a) also showed that there is a very little exploration of these mites in the Northern district of Tripura compared to the southern and western districts as only 15 species were recorded from the northern part whereas the Southern and Western districts recorded 83 and 108 species respectively. Western district alone represented 72.7% of families, 65.3% of genera and 68.0% of species out of the total soil oribatid taxa known from Tripura and occupied numerically the highest position among the districts. Among all the genera recorded *Scheloribates*, *Galumna* and *Lamellobates* were found to be numerically dominant and *Scheloribates praeincisus interruptus*, *S. jimbriatoides*, *Galumna flabellifera*, *Lamellobates palustris*, *Xylobates seminudus*, *Oppia yodai*, *Archegozetes magnus longisetosus* were considered to be numerically the most dominant species in Tripura (Sanyal, 2003a). The current diversity and abundance of soil mites in Tripura must take into account the recent studies and surveys conducted such as Sanyal *et al.,* in 2006 and 2008 reported the presence of two new oribatid species *Unguizetes grallulatus* and *Eremulus indicus* belonging to families Mochlozetidae and Eremulidae respectively from Tripura. The type specimens were deposited in the National Zoological Collection, Zoological Survey of India, Kolkata. *Eremulus indicus* closely resembles the species *E. berlese* from Geneva. The genera *Eremulus* has seven species recorded from all over India, from which three species viz., *E. jyotsnai*, *E. nigrosetosus*, *E. truncatus* are known from the state of Tripura.

Recently, work from the northern part of the state by Ghosh' (2018) attempts to explore the North district of Tripura by recording 14 mite species under 12 genera where the genera *Scheloribates*, *Protoribates* and *Galumna* were the major contributors representing 34.27%, 16.93% and 7.58% of the total population, respectively. He also studied various soil variables which could influence the soil mite diversity, distribution and abundance and found that there was an irregular and significant trend of fluctuation in oribatids abundance

with a maximum in winter and a minimum in the monsoon period. Besides the vegetation cover and edaphic variables also either singly or conjointly exerted significant impacts on the distribution as well as the diversity of the oribatid fauna.

Sikkim

Pearce (1906) introduced the study of Oribatid fauna and recorded 18 species of mites from Sikkim Himalaya. After his tremendous work, Dhali and Bhaduri(1980) resumed the study on oribatids and reported 4 species belonging to 3 genera under 3 families. Among them three species of oribatids *viz. Seheloribates sikkimensis*, S. *saswatii* and *Chaunoproctus longisetosus* were described as new to science, whereas *Paralamellobates bengalensis* introduced as new to the state. Sanyal and Party in two of their surveys in 1990 and 1998 explored few more species which were published in state fauna series 9, Fauna of Sikkim. Where they explained altogether 85 oribatid species belonging to 63 genera and 45 families including works done by others earlier and recorded 3 species and 2 genera for the first time from India and 64 species, 53 genera and 33 families as the first record from the state of Sikkim (Sanyal, 2003b).

Manipur

Oribatid mites of Manipur were first studied by Misra *et al.*(1982). They reported *Atropacarus* (*Hoplophorella*) *manipurensis* as new to science and recorded three other species viz., *Atropacarus* (*Hoplophorella*) *scapellatus*, *Atropacarus* (*Hoplophorella*) *singularis* and *Hoplophthiracarus kugohi siamensis* from Manipur. Afterwards, Sanyal published a compiled account of the oribatid mites of Manipur surveyed by him and his associates in 1992 and the work done by Misra *et al.,* in 1982. Altogether 28 species belonging to 20 genera and 17 families were incorporated in the paper taking into account the four species reported by Misra *et al.* (1982). All the species studied by Sanyal (2004) were deposited in the National Zoological Collection, Zoological Survey of India. This compiled account provided by Sanyal showed that 7% of Indian oribatid fauna are known from the State of Manipur. It also reports the presence of two species *Atropacarus* (*Hoplophorella*) *manipurensis* and *Hoplophthirocarus kugohi siamensis* that were known only from Manipur in India. Since then some works has been taken up by other workers regarding different aspects of soil microarthropods in the recent past such as Sitlhou and Singh (2019) investigating the post-fire soil microarthropod abundance in the disturbed forest ecosystem of Koubru Hills, Manipur. The study showed that wildfire had a significant effect on soil microarthropod abundance which was found to be lower in the burned area compared to the adjacent unburned area. Though Collembola was found to be the most abundant group, Acari stood close second followed by other soil microarthropods in both burned and unburned areas. Acari and Collembola consisted of 44.3% and 45.2%, respectively in total numbers while others constituted only about 10% of the total population. Waikhom and Singh (2018) studied the abundance and relationship of Acarines and Collembolas with the organic carbon, Cu, Fe, Zn and Mn of phumdi soil of Keibul Lamjao National Park (KLNP), Manipur. In this study, Acari had a higher population density than Collembola as the correlation coefficient of Collembola with all C, Cu, Fe, Zn and Mn were found to be negatively correlated. Whereas with Acari significant positive correlations were obtained with Cu, Fe and Zn.

Nagaland

In this state Ghosh and Bhaduri (1979) explored the Oribatid fauna for the first time and recorded five species, among them species *Eremobelba indica* and *Allonothrus monensis* were found new to science. Later Darlong and Alfred (1993) continued investigations and reported 11 species, mostly identified up to generic level. The oribatids of Nagaland has so little been explored that out of more than 400 species of oribatids known so far from India (Alfred *et al.*, 1998; Sanyal, 2006a) only 16 species belonging to 15 genera under 14 families are known from Nagaland (Sanyal 2006a). But works are being taken up in the recent past by researchers like Tsurho and Ao (2014) who carried out the community analysis of Acari in a natural forest and jhumland ecosystem of Mokokchung in Nagaland from January 2009 to December 2011. The vertical distribution and abundance of total soil Acarina were found to be more in the natural forest ecosystem than jhum land ecosystem and showed a significant decrease from the upper layer to deeper layers (0 cm to 30 cm). A total of 15 soil Acarina species were identified from the two study sites i.e. forest and jhum land ecosystems. Following species of oribatid mites had been found in Nagaland from the records of the zoological survey of India namely *Haplacarus foliatus bengalensis*, *Allonothrus monensis*, *Eremulus avenifer*, *Eremobelba indica*, *Brachychthonius* sp. *Rhysotritia* sp., *Platynothrus Peltifer*, *Dolicheremaeus brueiensis*, *Oppia* spp., *Ramusella* sp., *Suctobelba* spp., *Neoribates* spp., *Haplozetes* sp., *Scheloribates* sp., *Galumna* sp. (Sanyal and Bhaduri,1986; Sanyal, 2006a).

Arunachal Pradesh

Sanyal *et al.* (2006b) gave an overall view of the Oribatid fauna of Arunachal Pradesh which included the work done by him and his associates in the collection of oribatids during the years 1997 and 1999. They reported the presence of a total of 35 species belonging to 30 genera under 21 families recorded till then from the state. All the taxa were reported for the first time from the state of Arunachal Pradesh, besides 3 species were likely to be new species. This account provided by Sanyal *et al.* (2006b) showed that 8.6% of Indian Oribatid fauna are known from the State of Arunachal Pradesh and 5 species under 5 genera reported from the state were not yet known from outside India. Afterwards, Ermilov in his venture of Indian Oribatid mites added several other species to the already existing database. For instance, Ermilov and Kaluz (2013) reported the presence of two new oribatids from Arunachal Pradesh, viz., *Epidamaeus parayunnanensis* sp.nov. (Niphocepheidae) and *Taiwanoppia (Taiwanoppia) paraflagellifera* sp. nov. Also, it's a very first record when the genera

Epidamaeus and *Taiwanoppia* had been reported in India. Similarly, Ermilov and Kaluz (2014) again reported three new species *Allogalumna asetosa* spec. nov., *Galumna paraweni* spec. nov. and *Heterogalumna minima* nov. of the family Galumna from the Hunli region of Arunachal Pradesh. In 2014 itself, Ermilov *et al.* (2014a) reported three new species of oribatid mites of the genus *Pergalumna* from the region of Tippi, Arunachal Pradesh viz., *Pergalumna paraclericata* sp., *Pergalumna minipora* sp. and *Pergalumna paracattienica* sp. Lastly to conclude their venture Ermilov *et al.* (2014b) reported a new species of the genus *Niphocepheus* and gave an annotated checklist of three sites of India among which two sites were from Arunachal Pradesh which included 66 species out of the 71 species collected in total. Out of which 29 of the oribatid species were recorded for the first time in India. Five of the species/subspecies- *Trhypochthonius tectorum stercus*, *Hermanniella aliverdievae*, *Sphodrocepheus tridactylus*, *Caenosamerus spatiosus*, *Dolicheremaeus distinctus* were recorded for the first time in the Oriental region. The holotype of all these collected species was deposited in the collection of the Zoological Institute of the Russian Academy of Sciences, St. Petersburg, Russia.

Mizoram

Oribatid fauna of Mizoram has been little explored and only one major work has been found which was published by Sanyal (2009) in the state fauna series 14, the fauna of Mizoram, part-2. This study of Sanyal (2009) took into account the Mizoram surveys undertaken by B.K. Biswas and party in 1994 and A.K. Sanyal and party in 1995. Altogether 40 species were recorded belonging to 29 genera and 22 families. All the species incorporated were reported for the first time from the State of Mizoram. All the species studied in this work were deposited in the National Zoological Collection, Zoological Survey of India. Oppiidae, Scheloribatidae and Galumnidae were found to be the most dominant families of oribatid mites in the State of Mizoram. This account provided by Sanyal showed that 9.5% of Indian oribatid fauna are known from the State of Mizoram.

Assam

Though concrete evidence is not available regarding the time at which the study of soil mites began in Assam, but it can definitely be said that it is not a recently found area of research. According to Luxton (1966), some species of acari were highly selective in their choice of food and it mainly controls their zonal distribution. Since then different works has been done on the soil fauna especially in the early 2000s and at the beginning of this decade by researchers like Gope and Ray (2006), Bhattacharyya *et al.* (2013), Borah and Kakati (2014), Ermilov *et al.* (2014b). Gope and Ray (2006) reported the population dynamics at two sites of Dorgakona Village, Silchar, Assam in which Cryptostigmata constituted more than 50% of the total acari population. Bhattacharyya *et al.* (2013) worked on the quantitative distribution of soil microarthropods from three different ecosystems viz. agro-ecosystem, forest ecosystem, and fallow land of the district Jorhat of Assam. Maximum numbers of soil arthropods were collected from the forest ecosystem. The presence of higher numbers of soil arthropods in forest ecosystem may be due to the fact that the forest soils were healthy and virtually free from the risk of pesticides and other heavy metal deposits. Among all the soil arthropods, soil mites were found to be the most dominant in all the ecosystems. Population density of soil Acari in two sampling sites viz., natural and degraded forest sites were studied for one year at Dulung Reserve Forest of Lakhimpur district, Assam by Borah and Kakati (2014). Vertical and seasonal distribution of total soil Acari were more in natural forest and there was a significant decrease from the upper layer to deeper layers. Acarina was found to be a dominant group comprising 39.26% and 37.51% of the total soil microarthropods in natural and degraded sites respectively. Ermilov *et al.* ,(2014b) reported some oribatid species collected by L. Dembický and O. Šauša from the soil of Bhalukpong, Assam. *Nothrus phylliformis*, *Archegozetes longisetosus*, *Mixacarus (Phyllolohmannia)* sp., *Epidamaeus parayunnanensis*, *Sphodrocepheus tridactylus(*)*,*Zetorchestes saltator*, *Eremobelba indica*, *Lasiobelba remota(*)*, *Constrictocepheus orientalis*, *Eurostocepheusmahunkai*, *Lamellobates molecula*, *Rykellaasiatica* (*), *Zetorchellasottoetgarciai*, *Perscheloribates minutes(*)*, *Scheloribates fimbriatus*, *Scheloribates latipes*, *Acrogalumna bipartite(*)*, *Galumna levisensilla(*)*, *Pergalumna paratsurusakii* were some of the species reported by him (* Indicates that the species is recorded for the first time in India). Most recently, Pator and Ray (2018) reported a significant size of both the Collembola and Oribatid mites population in the extracted soil samples of the Acacia plantation site within the Assam University Campus of Cachar District, Assam, India.

DISCUSSION

This current review provides a succinct glance on the study of soil mites (Oribatida) which has been done in N-E India. Among them, Tripura has the highest grade of Oribatid abundance by contributing nearly 40% of the total Indian oribatid fauna, in contrast, Nagaland has the lowest abundance, contributing only 4%. Whereas the states of Arunachal Pradesh, Manipur, Meghalaya and Mizoram contribute 8.6%, 7%, 12.5% and 9.5% respectively. But no such records were available from Assam and Sikkim. A precise state wise graphical representation regarding the numerical abundance of Oribatid family, genus and species has been provided in Figure 1. In Assam due to lack of conspicuous evidence, it is very difficult to set forth the accurate year in which mite research actually begun in this state. However, extensive literature study indicates that mite research initiated in the late 1900s and picked up pace in the early 2000s. The Oribatid mites were the most prominent group of Acari documented from the soil of Assam. Few studies support the high abundance of soil mites in this state with a diverse pattern of distribution. However, some species were also reported as newer to India. Similarly, the state of Sikkim has also been scarcely explored and apart from the records of Zoological Survey of India and a couple of works dated way back in the 20th century no other works

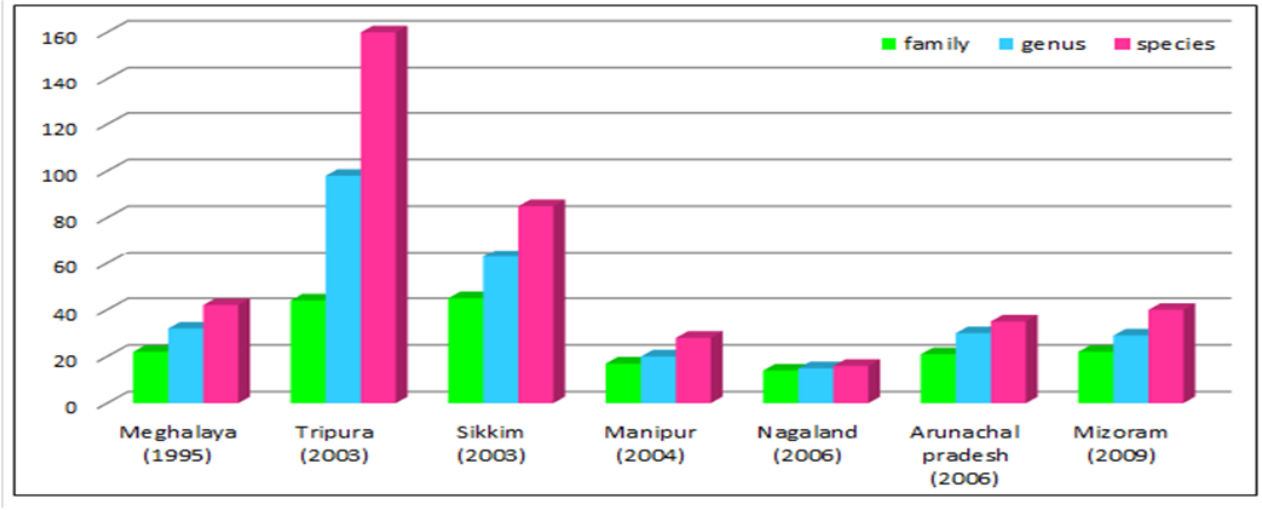

Figure 1. Numerical representation of Oribatida (Acari) family, genus and species for N-E states of India (excluding Assam). Data were taken from state fauna series published by Zoological Survey of India.

regarding the soil mite have been done in spite of having a good amount of soil oribatid richness as evident from the very few surveys in the state so far, thus this state needs special attention in terms of survey and exploration to evaluate the faunal richness. In Arunachal Pradesh major works were done by Sanyal *et al.* (2006) in their records of the Zoological Survey of India where number of new species were discovered and in few surveys of Ermilov with his associates. Besides, there were not many notable works found in the literature and thus there is a huge need for extensive exploration of soil mites in this state. Meghalaya holds second highest oribatid richness among the N-E states. A compiled account of the oribatid mites of Meghalaya was provided by Sanyal way back in the year 1995 in the state fauna series with records of genus *Phyllocarabodes* and five species endemic to the state, thus there is still room for further exploration and documentation. In Manipur, mite research was started by Mishra and his co-workers in 1982, since then only a few works has been found in the literature. Very recently, works done by Sitlhou and Singh (2019) was in Kourbu Hills but most part of the state remains unexplored. Likewise, a very minimal number of works has been reported from Mizoram and it's not sufficient to conclude the oribatid richness of the state although this state holds third most rank regarding oribatid richness among the N-E states. According to the current records found in the state fauna series of Nagaland published by the Zoological Survey of India in 2006, it is found that Nagaland contributes the least to the Indian oribatid fauna and has the lowest oribatid faunal richness among the states of N-E. Although, several researchers are trying to explore the unexplained and unsurveyed areas of the state. In case of Tripura however, the scenario is quite different Subías and Sarkar (1982) took the initiative to explore the soil mite community of the state and since then many more works had been done by various authors and as a result, this state holds the highest rank in oribatid richness among all North-Eastern states. The western part of the state is very well surveyed and explored though major portion of the northern part still remains unexplored. Most recently, Ghosh's (2018) attempt from the northern part of the state is a timely kick start in the path to explore more from this unsurveyed region of the state of Tripura and also focused extensive research is needed in this region.

CONCLUSION

The field of mite research has a great potential in ecological perspective. The pattern of mite distribution, species richness act as an indicator for determination of soil quality including toxicity status of a particular area. However, the work that had been done in the N-E India is not enough to completely understand the pattern of soil mite distribution and diversity as majority parts of the N-E. India remain unexplored. Thus further multi-scale works are required to get an overall picture of every aspect of oribatid mite communities in this part of country. It may result in the discovery of newer and endemic mite species to N-E, India with their specific beneficial impact on edaphic ecology.

REFERENCES

Alfred, J.R.B., Das, A.K. and Sanyal, A.K. 1998. Faunal Diversity in India. Zool Surv India 2:1-495.

Alves, P.R. and Cardoso, E.J. 2016. Overview of the standard methods for soil ecotoxicology testing. Invertebrates experimental models in toxicity screening. In Tech, Croatia 10:35-56. http://dx.doi.org/10.5772/62228

Anderson, J.M. 1975. Succession, diversity and trophic relationships of some soil animals in decomposing leaf litter. J Ani Ecol 44(2):475-495. https://doi10.2307/3607

Banerjee, S., Sanyal, A. and Moitra, M. 2009. Abundance and group diversity of soil mite population in relation to four edaphic factors at Chintamani Abhayaranya, Narendrapur, South 24-Parganas, West Bengal. Proc Zool Soc 62(1):57-65. https://doi.org/10.1007/s12595-009-00082

Bayoumi, B.M. and Mahunka, S. 1979a. Ergebnisse der Bhutan Expedition 1972 des Naturhistorischen Museums in Basel-Acari: Oribatida (Part I). Entomol Basili 4:13-24.

Bayoumi, B.M. and Mahaunka, S. 1979b. Ergebrisse der Bhutan-Expedition 1972 des Naturhistorischen Museums in Basel-Acari: Oribatida (Part II). Entomol Basili 4:24-30.

Bhattacharya , T. and Chakrabarti, P. 1995. Community structure of soil Oribatida of a young rubberplantation and an adjacent wasteland in Tripura (India). In: Mishra *et al.* (ed) Advances in ecology and environmental sciences. Ashish Publishing House, New Delhi, pp 65-77.

Bhattacharya, T. and Halder, G. 1984. New records of soil oribatid mite from Tripura. Entomon 9(4):293–294.

Bhattacharya, T., Halder, G. and Saha, R.K. 1985. Soil microarthropods of a rubber plantation and a natural forest. Envi Ecol 3(2):143–147.

Bhattacharyya, B., Pujari, D., Handique, G., Bhuyan, U. *et al.,* 2013. Distribution of soil arthropods in different ecosystems of Assam. Curr Adv Agri Sci 5(2):242-244.

Black, H.I.J., Parekh, N.R., Chaplow, J.S., Monson, F. *et al.,* 2003. Assessing soil biodiversity across Great Britain: national trends in the occurrence of heterotrophic bacteria and invertebrates in soil. J Env Manag 67(3):255-266. https://doi:10.1016/S0301-4797(02)00178-0

Borah, M. and Kakati, L. 2014. Population dynamics of soil Acarina in natural and degraded forest ecosystem at Pathalipam, Lakhimpur, Assam. J Env Sci Tox Food Tech 8:45-50.

Boudjema, G., Julien, J.M., Sarkar, S. and Cancella da Fonseca, J.P. 1991. Etude par l'analysestatistiquemultidineaire de l'impact des facteursphysicochimiquessurl'abondance des Microarthropdsedaphiquesd'uneforet de mousson en Indeorientale. Rev Eco Bio Sol 28(3):303-322.

Cencela da Fonseca, J.P. and Sarkar, S. 1998. Soil microarthropods in two different managed ecological system (Tripura, India). Appl Soil Ecol 9:105 –107.

Chakraborti, P. and Bhattacharya, T. 1992. Soil microarthopods of a rubber plantation and an adjacent waste land in Tripura, India. Proc Zool Soc 45(2):163-172.

ChannaBasavanna, G.P. and Viraktamath, C.A. (eds). 1989. *Progress in acarology*. Brill Archive.

Culliney, T.W. 2013. Role of arthropods in maintaining soil fertility. Agriculture, 3(4):629-659. https://doi.org/10.3390/ agriculture 3040629

Darlong, V.T. and Alfred, J.R.B. 1993. Micro-arthropod diversity in some soils of North-east India with special reference toeffect of shifting cultivation. Himalayan Biodiversity: Conservation Strategies (ed U. Dhar), pp 331-23.

Dhali, S. and Bhaduri, A.K. 1980. Taxonomic investigations of soil oribatid mites (Acari) of Sikkim Himalaya. Indian J. Acar 5:50-55.

Erdmann, G., Otte, V., Langel, R. and Scheu, S. 2007. The trophic structure of bark- living oribatid mite communities analyzed with stable isotopes (N-15 C-13) indicates strong niche differentiation. ExpApplAcar 41:1-10. https://doi.org/10.1007/s10493-007-9060-7

Ermilov, S.G. and Kalúz, S. 2014. New species of oribatid mites of the genera *Allogalumna*, *Galumna* and *Heterogalumna* from India (Acari, Oribatida, Galumnidae). Spixiana 37(1):73-80.

Ermilov, S.G., Kalúz, S. and Martens, J. 2014b. Additions to the Indian oribatid mite fauna, with description of a new species of the genus *Niphocepheus* (Acari, Oribatida). Sys Appl Acar 19(1):58-67.

Ermilov, S.G. and Kalúz, S. 2013. Two new species of oribatid mites (Acari: Oribatida) from India. Труды Зоологического института РАН 317(2):176-184.

Ermilov, S.G., Chatterjee, T., Das, M. and Bordoloi, S. 2014a. Three new species of oribatid mites of the genus Pergalumna (Acari: Oribatida: Galumnidae) from India. Biologia 69(4):489-497.doi:10.2478/s11756-014-0332-5

Ghosh, A.K. and Bhaduri, A. 1979. Studies on the oribatid mites (Acari: Oribatei) of Nagaland, India. Indian J. Acar 3(2):51-57.

Ghosh, T.C., Mandal, S. 2017. Distribution and seasonal abundance of acarine community (Arachnida: Acari) in a Zoological Park of Darjeeling Himalayas, West Bengal, India. Per J Acar 6(1):1-10. http://dx.doi.org/10.22073/pja.v6i1.26053

Ghosh, T.C. 2018. Impact of macro vegetation and edaphic variables on the distribution and diversity of Oribatida (Acari) in Northern Tripura, India. Biologia 73(12):1229-1236. https://doi.org/10.2478/s11756-018-0142-2

Gope, R., Ray, D. 2006. Dynamics of Soil Acari (Arthropoda: Arachnida) under Managed and Unmanaged Landuse of Barak Valley, Assam (North Eastern India). Bull NatInsEcol 17:17-23

Gulvik, M.E. 2007. Mites (Acari) as indicators of soil biodiversity and land use monitoring: a review. Pol J Ecol 55:415-440.

Hani, M., Thieven, U., and Perotti, M. A. 2018. Soil bulb mites as trace evidence for the location of buried money. Forensic science international, 292: e25-e30.

Haq, M.A. 2016. Oricultural farming practice: a novel approach to agricultural productivity. J. Acar Soc Jpn 25(S1):51-75. https://doi.10.2300/acari.25.suppl 51

Hattar, S., Alfred, J. and Dartong, V. 1992. Soil acarina and collembola in forest and cultivated land of KhasiHills, Meghalaya. Rec Zool Surv India 92:89-97. https://doi10.3390/agriculture3040629

Huguier, P., Manier, N., Owojori, O.J. and Bauda, P. *et al.,* 2015. The use of soil mites in ecotoxicology: a review. Ecotoxicology 24(1):1-8. https://doi 10.1007/s10646-014-1363-y

Labandeira, C.C., Phillips, T.L. and Norton, R.A. 1997. Oribatid mites and the decomposition of plant tissuesin Paleozoic coal- swamp forests. Palaios 12(4):319-353.

Luxton, M. 1966. Laboratory studies on the feeding habits of saltmarsh acarina, with notes on their behaviour. Acarologia 8:163-175.

Misra, B., Bhaduri, A.K. and Raychaudhuri, D. 1982. Oribatid mites of Manipur, India-I, Family Phthiracaridae. Indian J Acar 7:73-78

Moitra, M., Sanyal, A. and Chakrabarti, S. 2012. On diversity and abundance of soil acarines with special reference to oribatid mites (Acari, Oribatida) at different altitudes in the Eastern Himalaya, India. Biodiversitat und Naturausstattung im Himalaya IV:107-119.

Nafiu, B., Dong, H, and Cong, B. 2014. Principles of biological control in integrated pest management. Inter J Appl Res Tech 3:104-116. doi 10.13140/RG.2.2.36522.41922

Nijima, K. 1971. Seasonal changes in Collembolan populations in a warm temperate forest of Japan. Pedobiologia 11:11-26.

Owojori, O.J., Ademosu, O.T., Jegede, O.O. and Fajana, H.O. 2019. Tropical oribatid mites in soil toxicity testing: Optimization of test protocol and the effect of two modelchemicals (cadmium and dimethoate) on Mulierculainexpectata. Chemosphere 218:948-54. https://doi.org/10.1016/j.chemosphere.2018.11.173

Owojori, O.J., Healey, J., Princz, J. and Siciliano, S.D. 2011. Can avoidance behavior of the mite Oppianitens be used as a rapid toxicity test for soils contaminated with metals or organic chemicals?.Env tox chem 30(11):2594-2601. https://doi 10.1002/etc.658

Pator, R.C. and Ray, D.C. 2018. Role of Edaphic Factors on the Population Density of Soil Inhabiting Collembola and Oribatidmites in Acacia Plantation of Cachar District, Assam. Int J Adv Sci Res&Manag 3(10):75-78.

Paul, D. and Alfred, J.R.B. 1984. A comparative study of soil microarthropods in three disturbed habitats of Meghalaya, North-East India, Orient. Ent. Symp. Assoc. Adv. Ent., University of Kerala, India, pp 221-227.

Paul, D. and Alfred, J.R.B. 1995. Soil arthropod fauna of three agroecosystems as compared to that of undisturbed forests of Meghalaya, N.E. India, J Soil Biol Ecol 15:52-65.

Pearce, N.D.F. 1906. VII. On some Oribatidœ from the Sikkim Himalaya. Journal of the Royal Microscopical Society 26(3):269-273.

Princz, J.I., Behan-Pelletier, V.M., Scroggins, R.P. and Siciliano, S.D. 2010. Oribatid mites in soil toxicity testing-the use of Oppianitens (CL Koch) as a new test species. Env tox chem29 (4):971-979. https://doi10.1002/etc.98

Rakshit, M.D. and Chanda, A. 2017. Oribatid faunal abundance: an indicator for evaluation of environmentalharshness in agro-ecosystem. J Entomol Zool Stud 5(2):92-96.

Reddy, M.V. 1980. Arthropod faunal structure of soil surface under stone habitats at Berhampur, Orissa. Newsl Soi Bio Ecol 1:18-19

Reddy, M.V. 1984. Seasonal fluctuation of different edaphic microarthropod population densities in relation to soil moisture and temperature in a pine, Pinus kesiya Royle plantation ecosystem.Inter j biome 28(1):55-59.

Roy, A., Das, S.K., Tripathi, A.K. and Singh, N.U. 2015. Biodiversity in North East India and their conservation. J Prog Agri 6(2):1-6.

Saha, S. and Sanyal, A.K. 1996. Two new species of the genera Malaconothrus (Acari: Oribatei) from Tripura. India Entomon 21(1):105-109.

Saloña-Bordas, M. I. and Perotti, M. A. 2014. First contribution of mites (Acari) to the forensic analysis of hanged corpses: A case study from Spain. Forensic science international, 244: e6-e11.

Sanyal, A.K. 1988. Some oribatid mites (Acarina: Cryptosigmata) from Meghalaya with description of three new species. Rec zool surv India 85(2):225-235.

Sanyal, A.K. 1992. Oribatid mites (Acari). In: Fauna of West Bengal, Part 3, State Fauna Series 3:213-356.

Sanyal, A.K. 1995. Oribatid Mites (Acari: Cryptostigmata). In: Fauna of Meghalaya, Part 2, State Fauna Series 4:51-91.

Sanyal, A.K. 2000. Oribatid Mites (Acari: Cryptostigmata). In: Fauna of Tripura, Part 2, State Fauna Series 7:33-112.

Sanyal, A.K. 2003a. Diversity in soil oribatid (Acari) mites of Tripura. Rec Zool Surv India 101:55-60.

Sanyal, A.K. 2003b. Oribatid mites (Acari: Oribatida). In:Fauna of Sikkim, Part 2, State Fauna Series 9: 37 -66.

Sanyal, A.K. 2004. Oribatid mites(Acari). Fauna of Manipur, State fauna Series, 10:1-13.

Sanyal, A. K. 2006a. Oribatid mites(Acari). Fauna of Nagaland, State fauna Series, 12:389- 392.

Sanyal, A.K. 2006b. Oribatid Mites (Acari: Oribatei). In: Fauna of Arunachal Pradesh, Part2, State Fauna Series13: 467-478.

Sanyal, A.K. 2009. Oribatid mites (Acari: Oribatei). In: Fauna of Mizoram, State Fauna Series 14: 1-17.

Sanyal, A. and Bhaduri, A. 1986. Check list of oribatid mites (Acari) of India, pp 1-76

Sanyal, A.K. and Saha, S. 1996. A new species of the genus *Peloribates* (Acari: Oribatei) from Tripura, India. Hexapoda 8(2):71-76.

Sanyal, A., Saha, S. and Chakraborty, S. 2006. A new species of the family Mochlozetidae (Acarina, Oribatida) from Tripura, India. Rec Zool Surv. India 106(2):99-104.

Sanyal, A.K., Sengupta, D., Saha, S. and Chakrabarti, S. 2000. The genus Arcoppia(Acari, Oribatei, Oppiidae) from Indian soils. Rec Zool Surv India 98(2): 99-118.

Sanyal, A., Saha, S. and Chakrabarti, S. 2008. A new species of the genus Eremulus (Acari: Oribatei) from Tripura, India. Acarologia 48(1-2):115-117.

Sarkar, S. 1983. New representatives of oribatid mites (Acari: Oribatei) from soil of Tripura, India. Orient Zool 3:91-98.

Sarkar, S. 1992. Three new species of the genus Microzetes (Acarina: Oribatida: Microzetidae) from the soil of Tripura. New record of the genus *Schizozetesin* India. Bull. Life Sci 2(31-39):143-154.

Sarkar, S. and Subías, L.S. 1982. Some new macropylinesoribates (acarida) from India. (Hypochthoniidae, Cosmochthonoidea and Epilomanniidae). Eos 58(1-4):311–318

Sarkar, S. and Subías, L.S. 1983. Papillonotustricarinatus sp.nov.from India (Acarina: Oribatida, Oppiidae). Bull Inst Cat Hist Nat 49(Sec Zool 5):85-86.

Sarkar, S. and Subías, L.S. 1984. New Lohmannids (Acarina: Oribatida) from India. Orient Insects 18:25-30.

Schatz, H.E. 2004. Diversity and global distribution of oribatid mites (Acari, Oribatida) evaluation of the present state of knowledge. Phytophaga 14:485-500.

Schneider, K., Migge, S., Norton, R.A. and Scheu, S. 2004. Trophic niche differentiation in soil microarthropods (Oribatida : Acari): evidence from stable isotope ratios (N-15/N-14). Soil Biol Biochem 36:1769–1774. https://doi.org/10.1016/j.soilbio.2004.04.033.

Sharma, N. and Parwez, H. 2017. Population density and diversity of Soil mites (Order: acarina) in agroforestry habitat: Relationship to Soil temperature and Soil moisture. Int JAppl Env Sci 12 (7):1449-1460.

Sitlhou, A. and Singh, T.B. 2019. Wildfire effect on soil Microarthropod abundance in the subtropical forest ecosystem of Koubru Hills, Manipur (North-East India). Inter J Sci Res Pub 9(1):446-463.

Smit CE, Moser T, Römbke J (2012) A new OECD test guideline for the predatory soil miteHypoaspisaculeifer: Results of an international ring test. Ecotoxicology and environmental safety 82:56-62. http://dx. doi.org/10.1016/j. ecoenv.2012.05.009

Subías, L.S. 2004. ListadoSistematico, Sinonimico Y, Biogeografico De, Los Acarosoribatidos. (Acariformes, Oribatida) Del Mundo (1758-2002). Graellsia 60:3-305.

Subías, L.S. and Sarkar, S. 1982. New representatives of nothroides oribatids (acarida) from India (Trhypochthoniidae and Malaconothridae). Redia 65:39–49.

Subías, L.S. and Sarkar, S. 1983. Some new Oppiidae from India (Acarida, Oribatida). Redia 66:435-447.

Subías, L.S. and Sarkar, S. 1984. Three new species of ptyctimines Oribates (Acari) from India (Mesoplophoridae and Phthiracaridae). Folia Ent Hung 45(1):215-220.

Tripathi, S.K., Roy, A., Kushwaha, D. and Lalnunmawia, F. 2016. Perspectives of Forest Biodiversity Conservation in Northeast India. J Biodiv Biopros Dev. 3(157):2376-0214. http://doi10.4172/2376-0214.1000157

Tsurho, K. and Ao, B. 2014. Community Analysis of Soil Acarina in a Natural Forest and Jhum Land Ecosystem of Mokokchung, Nagaland. IOSR J Appl Phys(IOSR-JAP) Ver. II, 6(4):50-54.

Waikhom, M.D. and Singh, T.B. 2018. Abundance & Relationship Of Acarines And Collembolas With The Organic Carbon, Cu, Fe, Zn and Mn of phumdi Soil of Keibul Lamjao National Park (KLNP), Manipur. Inter J Sci Res & Education, 6 (5):7945-7949. http://dx.doi.org/10.18535/ijsre/v6i5.05

Wallwork, J.A. 1983. Oribatids in forest ecosystems. Annu. Rev. Entomol. 28:109-130. https://doi.org /10.1146/ annurev. en. 28.010183.000545