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Changes in the Structure of Microarthropods Population in Relation to Edaphic Factors in a Managed Ecosystem of Cachar District, North East India

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Abstract: Micro-arthropods are important bio-indicators of soil health and are an integral part of food web in soil ecosystems. The present study elucidates the extent to which the various soil parameters influence the structure of soil microarthropod community. Soil sampling was done on monthly intervals and modified Berlese Tullgren funnel method was applied for the extraction of soil microarthropods. Soil temperature was noted on the study sites while other parameters of soil were analyzed. Results showed that the Collembola was the most dominant microarthropod and the density of microarthropods was recorded highest in July 2016 and lowest in September 2016. Soil organic carbon showed a significant positive correlation while other parameters revealed a weak correlation with the microarthropods density. CCA analyses revealed the occurrence of the different microarthropod groups in correspondence with the various abiotic variables and were discussed based on the microarthropods position in the CCA plot. The relation of the different edaphic variables with the microarthropods indicates that the potential contribution of all these variables should be considered for assessing the different aspects of microarthropods ecology.

***Keywords*:** Correlation, CCA, Edaphic, Rubber, Soil microarthropods

Soil microarthropods are very much essential and plays indispensable role in the soil ecosystems. They are mainly responsible for the litter decomposition and nutrient mineralization (Cole et al 2006, Kaneda and Kaneko 2008, A'Bear et al 2012). Microarthropods inhabiting in soil are well known for maintaining the soil health and react very quickly to the different changes occurred in the soil environment thereby considered them as an excellent bio-indicator of the soil environment (Lavelle et al 2006, Aspetti et al 2010). Different groups of microarthropods are exists in soil such as mites, Collembola, Diplura, Chilopoda, Symphyla (Manu et al 2016) and amongst them, Collembola and Oribatid mites are the most dominant ones (Santos-Roch et al 2011). The overall density, diversity, reproduction and development of soil microarthropods were mostly affected by the various abiotic factors such as soil moisture, precipitation, drought, soil pH, soil temperature etc. (Choi et al 2002, Ke et al 2004, Salmon et al 2008). Likewise, different climatic variables were also responsible in the seasonal fluctuation of the soil dwelling micro arthropod population. Rubber (*Hevea brasiliensis*) is a well-known low input plantation crop with a unique economic value and importance. In the East, India is the first country to launch the commercial cultivation of rubber. Currently, these plantations support various industries all over the world. The latex extracted from the rubber plant is used for numerous purposes such as in the production of equipment in sports, weatherproofing garments, etc. (FAO 2013). Moreover, the rubber plant is also used as timber for making plywood and wooden furniture that indirectly lowers the pressure imposes on forest thereby helps in carbon sequestration (Diana 2007, Ziegler et al 2009, Sturgeon 2010). Rubber plant is grown in a closed environmental system with a regular uptake of nutrients from the soil and vise versa (Hammond and Zagat 2006). Different soil types nurtures different microarthropod communities with its unique abundances and diversities which in turn helps to regulate the soil nutrient values and supports the vegetation in it. Therefore, the present study intended to explore the microarthropod population in the selected rubber plantation. The variation in the soil microarthropod population with respect to different soil parameters (soil moisture content, temperature, pH, organic carbon, N, P and K) were also analyzed to validate the microarthropods as a bio-indicator of soil environment.

MATERIAL AND METHODS

Study site: The study area lies in the North Eastern part of India which is globally recognized as biodiversity hotspot. The studied rubber plantation (*Hevea brasiliensis* Muell. Arg.) belongs to Cachar district of Assam and lies between 92°45'34°E longitude and 24°57'35°N latitude with an approximate altitude of 174 feet above mean sea level.

Cachar district falls under the conditions of subtropical warm humid climate with an annual rainfall of approximately 3874.5mm (GWIBCA 2013, Singh and Ray 2015). The soil of the plantation site has high dominance of sand percentage and is mostly sandy loam in nature.

Sampling, extraction, and identification of soil microarthropods: Soil samples from the selected ecosystem were collected at monthly intervals over a period of one year (April 2016 to March 2017) from a depth of 0-10 cm in the morning hours between 8am-9am by using simple random technique methods. On each survey, ten soil replicates were collected for the microarthropods extraction whereas five replicates for the preparation of composite soil mixture. Altogether 120 samples were collected during the study period and all the samples were kept in the modified Berlese Tullgren funnel apparatus for the purpose of microarthropods extraction. The samples were kept in the Tullgren funnel under 25-watt of electric bulb for more than 72 hours depending upon the moisture content of the soil (Murphy 1962). The vials containing 75% ethanol were fixed beneath each funnel. The extracted microarthropods were than identified under the stereoscopic binocular microscope (10x X 40x).

Analyses of edaphic variables: Soil samples of the composite mixture were air-dried and grinded for further physico-chemical analyses except in case of soil moisture content and soil temperature. Various methods were undergoes for the analyses of the edaphic variables such as temperature, moisture content, pH, organic carbon, nitrogen (N), phosphorus (P), and potassium(K) . A digital soil thermometer was inserted directly in the sampling plots (0-10cm depth) for the measurement of the soil temperature. Soil moisture content was estimated by following the oven-dry method while soil pH of the studied ecosystem was determined by a digital pH meter (Systronics). For the determination of soil organic carbon, the Walkley and Black's rapid titration method (Jackson 1958) was followed while parameters like N, P, K were assessed by Kjeldahl method, molybdenum blue and flame photometer method, respectively (Allen et al 1974).

Statistical analyses: The microarthropod population along with the different edaphic variables was subjected to statistical analysis by using various statistical software. The microarthropods density was calculated by following Singh et al (1978) in MS Office Excel-2007 software while the diversity index and regression analysis were estimated by using the PAST (version 3.05) and SPSS® (version 18.0), respectively. Canonical correspondence analysis (CCA) was performed using CANACO for windows 4.5 to illuminate the relationships between species and their environmental variables (Leps and Smilauer 2003). CCA is used as a method to find out the relationship between soils parameters with the microarthropods groups.

RESULTS AND DISCUSSION

Percent contribution of the extracted soil microarthropod groups: From the overall soil samples, a total number of 16 groups of soil microarthropods were extracted during the study period. Collembola (28.33%) and Oribatid mites (25.78%) were the most dominated groups and representing almost half of the total population sampled throughout the year. Other microarthropod groups such as Hymenoptera (13.66%), Mesostigmatid mites (10.52%), Prostigmatid mites (5.87%) were also shared a maximum contribution. Conversely, the least percentage was contributed by Isopoda with 0.05% (Fig. 1). Many pedologist reported similar findings although their studied ecosystem were different as observed in paddy field (Pator and Ray 2020), urban environment (Mcintyre et al 2001), agricultural field (Shakir and Ahmed 2015) and forest-steppe ecotone (Zhu et al 2010). Mcintyre et al (2001) observed that Collembola, Acarina, and Hymenoptera were extremely ubiquitous and almost represents 92% of the total microarthropods found in soil. Their dominancy was linked with the resistant capacity to different stress of water and temperature in the soil and litter environment (Lavelle and Spain 2001).

Density and diversity of microarthropod population: Effect of the climatic variations was clearly visible in the studied ecosystem. The maximum numbers of soil microarthropod populations were observed during May to

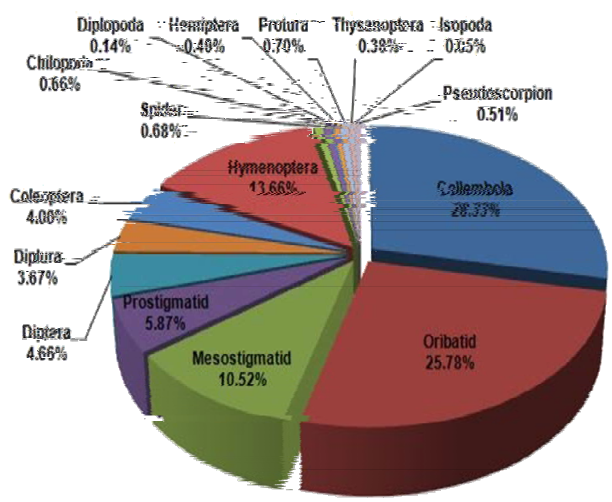

Fig. 1. Pie chart representing the percent contribution of the soil microarthropod groups during the study period (April 2016-March 2017)

August 2016 showing their more abundance in July 2016. The calculated population density for the month was 3.73 $No.m^{-2}X100^{2}$. The lowest population was in September 2016 (0.33 $No.m^{-2}X100^{2}$) (Table 1). Many reports were consistent with the findings of the present study, however, the sampling sites were different (Singh et al 2012, Singh and Ray 2015, Lakshmi and Joseph 2016, Pator and Ray 2020). Zhu et al (2010) observed that the soil microarthropods population was enhanced in the middle of the rainy season as compared to the early or late periods. Ali-Shtayeh and Salahat (2010) reported that the higher air temperature may be associated with the higher arthropod population during the summer season while the lower temperature was linked with the lower population in the winter months. At the end of August, the effect of the seasonal variation was observed on the soil inhabiting arthropod community that leads to a shifting in the community structure.

The diversity index of the microarthropod groups was highest in April 2016 (2.01) with lowest in November 2016 (1.51) (Fig. 2). Yang and Tang (2004) also observed the richness, abundance, and diversity of the soil dwelling arthropods communities were mostly higher in the dry or early rainy season as compared to the middle of the rainy season. The April is basically a wet month as dominated by high precipitation which in turn provides a suitable environment for the growth of the microarthropod population.

Edaphic factors and their correlation with soil microarthropods: During the study period, various soil parameters (soil moisture content, temperature, pH, organic carbon, N, P and K) were analyzed and correlated with the soil-dwelling microarthropods population. Depending on the

Table 1. Population density of total microarthropod groups in the soil samples of rubber plantation

Months	Rubber plantation (TM)
April, 2016	1.55±0.42
May, 2016	2.22±0.75
June, 2016	1.63±0.23
July, 2016	3.73±0.23
August, 2016	2.41±0.47
September, 2016	0.33±0.07
October, 2016	1.96±0.36
November, 2016	1.41±0.31
December, 2016	0.82±0.24
January, 2017	0.51±0.18
February, 2017	2.20±0.23
March, 2017	1.85±0.26

TM: Total micro arthropod population extracted month wise (April 2016-March 2017) Values are the population density ($No./m^{2}x100^{2}$)

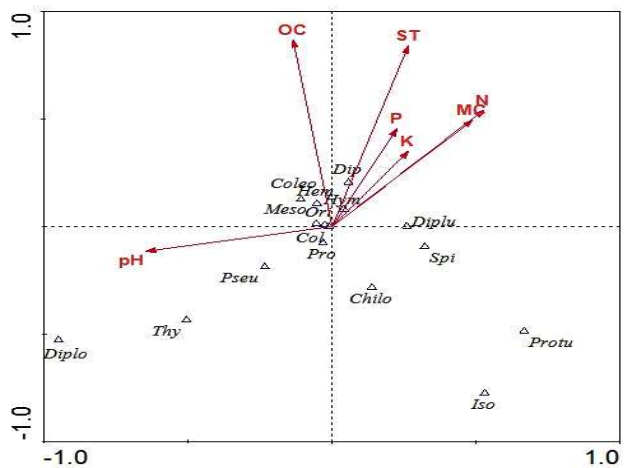

Fig. 3. Canonical correspondence analysis (CCA) biplot ordination graph of rubber plantation. MC-Moisture content, ST-Soil temperature, OC-Organic carbon, pH-Soil pH, N-Nitrogen, P-Phosphorous, K-Potassium, Ori-Oribatid mites, Col-Collembola, Meso-Mesostigmatid mites, Pro-Prostigmatid mites, Dip-Diptera, Hym-Hymenoptera, Diplu-Diplura, Protu-Protura, Chilo-Chilopoda, Diplo-Diplopoda, Iso-Isopoda, Spi-Spider, Pseu- Pseudoscorpion, Hem-Hemiptera, Thy-Thysanoptera, Coleo-Coleoptera

climatic variation, the edaphic variables were fluctuated in a regular pattern. The moisture content of the soil samples showed a wide range of variation, highest in the June 2016 (24.30%) and lowest in January 2017 (19.45%). However, soil temperature ranged between 18.3ºC (January 2017) to 28.8ºC (July 2016). The soil pH of all the samples was acidic and did not show any wide range of variation lies between 4.61 (September 2016) to 5.15 (July 2016). The amount of soil organic carbon was varied between 0.59% (December 2016) to 0.95% (April 2016). Soil total nitrogen ranged between 0.04% (October 2016) to 0.11% (July 2016) while potassium showed a broad range of 46.32 kg ha^{-1} (November 2016) to 308.69 kg ha^{-1} (April 2016). The amount of phosphorus content in the soil varied between 13.37 kg/ha (November 2016) to 30.09 kg/ha (April 2016). Soil moisture content revealed a positive correlation with the microarthropod population but without any significant effect (Table 2). Shakir and Ahmed (2015) also reported a positive correlation between soil moisture with the microarthropod population but the data obtained were insignificant. Soil microarthropods showed a positive correlation with the temperature of the soil but the correlation was insignificant. Similar observation was reported by Asif et al (2016) in wheat crops, Pator and Ray (2018) in paddy field. They reported that the abundance of Collembola showed an insignificant positive correlation with the soil temperature. Shakir and Ahmed (2015) observed that the soil temperature had a positively significant correlation with the density of micro arthropods. Soil organic carbon was found as the most influencing factor in the density of microarthropods. Here, a strong significant positive correlation was observed in between the soil organic carbon and microarthropod population (Table 2). Similar observations regarding organic carbon with the microarthropod population were also reported earlier by Klausman (2006) and Ghosh (2018). All the physical, chemical and biological properties of soil were closely attached with the soil organic carbon and thereby their concentration in the soil environment affects the microarthropods population dwelling in the soil. Soil pH in the study sites was positively correlated although the correlation was weak. In support of these findings, weak positive correlation between collembola abundance and soil pH in a cotton crops was reported by Asif et al (2016). A contradictory result of negative weak correlation of soil pH was observed by Shakir and Ahmed (2015) and Klausman (2006) in soil and litter microarthropods, respectively.

Other parameters like total nitrogen (N), phosphorous (P), and potassium (K) also revealed a weak positive correlation with the microarthropods population (Table 2). A similar observation of all the three chemical parameters (NPK) having positive correlation with the microarthropods was reported by Gope and Ray (2012) but with a significant effect. The result of nitrogen is in line with the findings of Parwez and Abbas 2012, Verma et al 2014 whose work also reveals a positive non-significant correlation with the soil microarthropods. Ray et al (2012) and Islam et al (2018) analyzed the effect of potassium and phosphorous on soil microarthropods, respectively and observed an insignificant correlation between the population and selected chemical parameters.

Table 2. Correlation and regression values of different soil parameters in relation to microarthropods population

Soil parameters	Rubber plantation		
	r value	p value	Regression equation
Moisture	0.243	0.447	y = 0.1408x - 1.363
Temperature	0.470	0.123	y = 0.1198x - 1.2293
Organic carbon	0.634	0.027*	y = 5.1618x - 2.3553
pH	0.289	0.363	y = 1.5361x - 5.7353
Nitrogen	0.113	0.727	y = 8.249x + 1.3735
Phosphorous	0.205	0.523	y = 0.0386x + 1.0026
Potassium	0.550	0.064	y = 0.0058x + 0.8354

Values are significant at $p<0.05$ (*)

Table 3. Canonical Correspondence Analysis (CCA) for rubber plantation

System	Rubber plantation	
Axes	1	2
Eigenvalues	0.084	0.060
Species-environment correlations	0.976	0.964
Cumulative percentage variance of species data	19.3	33.1
Cumulative percentage variance of species-environment relation	30.1	51.8
Sum of all eigenvalues	0.435	
Sum of all canonical eigenvalues	0.278	

Canonical correspondence analysis between soil parameters and microarthropods groups: Microarthropod groups were subjected to Canonical Correspondence Analysis (CCA), a direct gradient analysis method that summarizes the relationship between the soil parameters with the microarthropods groups (Table 3). The eigenvalues for axes 1 and 2 were 0.084 and 0.060, respectively. Cumulative percentage variance of species-environment relation for axes 1 and 2 were depicted as 30.1 and 51.8. Moreover, the species environment correlations for both the axes1 and axes 2 were found as 0.97 and 0.96 respectively, indicating that the arthropods group data were strongly correlated with the soil parameters (Table 3).

In this multivariate analysis, the multicolinearity between the studied parameters was checked by applying the sign rule. In the produced CCA diagram, the length of the arrows of the given soil parameters indicates the importance on CCA plot. Microarthropod groups plotted close to the soil parameters have a strong relationship with them. Taking account of these relationships, the CCA ordination diagram revealed that the soil organic carbon (OC), soil temperature (ST), nitrogen (N), pH and moisture content (MC) were the most important variables for soil-dwelling microarthropod populations. The CCA graph showed that the axes 1 mainly correlated with the soil pH while axes 2 with the soil temperature (ST) and organic carbon (OC). Coleoptera, Oribatid, and Mesostigmatid mites were showed a strong correlation with soil organic carbon (OC) whereas Collembola, Pseudoscorpion, and Prostigmatid mites showed towards the soil pH. However, the groups such as Protura, Isopoda, and Chilopoda showed a negative relation with the soil organic carbon. Among all the soil parameters, Potassium (K) and Phosphorous (P) were the two least contributing factors that showed a weak correlation with the soil microarthropods population (Fig. 3).

The CCA revealed that soil moisture content was positively correlated with Oribatid and Hymenoptera groups. A contradictory result of the negative correlation of soil moisture with Oribatida and Hymenoptera was reported by

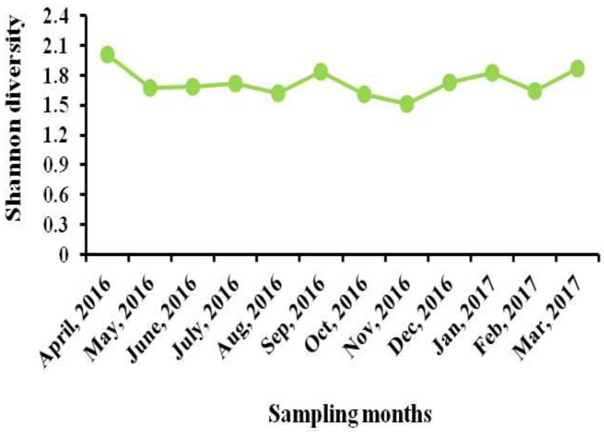

Fig. 2. Soil microarthropod diversity across the year

Duyar and Makineci (2016). CCA diagram also revealed that the arthropods groups such as Protura, Pseudoscorpion, and Thysanoptera had a negative correlation with the soil temperature. Similar observations were also reported by Duyar and Makineci (2016) from a Bornmulleriana forests in Turkey. In the study site, the biplot ordination graph also revealed that the Oribatid mites and Diptera were correspondence towards the soil temperature (Fig. 3). The results were in consistent with the findings of Pator and Ray (2020) and reported that both these groups were in close association with the soil temperature. The multivariate analysis showed that Chilopoda and Diplopoda were negatively correlated with soil temperature and soil organic carbon. A conflicting result of Myriapoda closely associated with soil temperature and soil organic matter reported by Shakir and Ahmed (2015). The CCA diagram also revealed a negative correlation between the microarthropods population and soil pH which is contradictory with the findings reported by Shakir and Ahmed (2015).

CONCLUSION

Soil microarthropods and their function in the soil ecosystem are vital for the global functioning. This paper provides a conceptual outline to understand the role of soil microarthropods and their responses to different abiotic factors. From the study, it was clearly observed that the Collembolans and Oribatid mites were highly dominant groups in the studied ecosystem and the soil parameters have exerted an impact on the microarthropods population and control their diversity, distribution and overall density of the soil microarthropods. Parameters like soil organic carbon were suitable and showed a positive significant effect on the microarthropods while other parameters in a collective way also play a major role but not proved statistically. CCA revealed that all the correlations between the microarthropods groups and abiotic variables are specific. Thus, it can be concluded that the edaphic factors either directly or indirectly exert impact on the density and diversity of soil microarthropods thereby play a vital role in maintaining the microarthropods community in the soil.

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