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Impact of soil physicochemical properties on the density and diversity of Collembola in Majuli river island, Assam, India

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Abstract
The present study was undertaken to know the density and diversity of collembolans in Majuli river island during 2015-16. Altogether 1354.55 individuals of Collembola were extracted, which revealed the presence of 5 species *viz*., *Cyphoderus* sp., *Entomobrya* sp., *Isotoma* sp., *Folsomia* sp. and *Hypogastrura* sp. belonging to 4 families *viz*., Cyphoderidae, Entomobryidae, Isotomidae and Hypogastruridae. *Cyphoderus* sp. was recorded to be the most abundant species contributing 37.74 percent of population. During the study period, the diversity was recorded to be higher during summer indicating the presence of relatively stable habitats as compared to other seasons. The highest density (196.36 nos./sq.m.) of Collembola was registered during the summer season and the lowest during the winter season (39.09 nos./sq.m.). Monthly variation of collembolan density revealed the maximum population of Collembola during the month of August (206.82 nos./sq.m.) whereas minimum was registered during February (27.27 nos./sq.m). Correlation studies revealed a significant positive correlation of collembolan density and diversity with soil moisture (Density, r= 0.929, 0.923, 0.824 and 0.945); (Diversity, r= 0.702, 0.867, 0.622 and 0.904) and organic carbon (Density, r= 0.873, 0.973, 0.787 and 0.915); (Diversity, r= 0.732, 0.667, 0.735 and 0.843) during all the seasons, respectively. Other soil physicochemical properties *viz*., sand, silt, clay, soil microbial biomass carbon, pH and bulk density did not exhibited any distinct relationship with both the density and diversity of the collembolans.

Keywords: Collembola, density, diversity, soil physicochemical properties

1. Introduction

Collembola commonly known as springtails are small apterygote insects mostly abundant in the top few centimetres of soils. These tiny insects are regarded as one of the most important inhabitants of soil worldwide as they have significant influences on soil genesis and soil microbial ecology. These group of insects are the most abundant insects in the world and regarded as one of the most potential bioindicators of soil health due to their quick response to environmental variations mainly those caused by anthropic modifications. Collembolans are also reported to be feed on various dead organic matter and decayed plant materials. Additionally, some collembolans are also found to be feeds on various soil microorganisms particularly on fungal hyphae and thereby plays a pivotal role in suppressing various fungal diseases in plants [2, 3]. A number of collembolans are also found to be carnivorous and feed on plant parasitic nematodes and rotifers whereas some are found to be influencing the growth of mycorrhizae in various habitats [4]. The collembolans have very diverse distribution occurring in all Zoo-geographical regions of the world inhabiting a wide range of ecological niche and climate. Approximately 8,143 species of collembolans belonging to 764 genera and 19 families are being reported from all over the world[5] whereas 301 species under 109 genera belonging to 19 families have already been reported from India [6]. Despite of having the immense potential of collembolans as “Ecosystem service providers”, practically very little information is available from North East India on collembolan diversity and their further exploration. Moreover, the north eastern region is widely considered as a “Biodiversity hotspot” as well as the “Organic hub” of India and hence a rich treasure in the form of collembolan diversity cannot be overlooked. Pertinent to above, an attempt was made to know the diversity and density of collembolans and their association with soil physicochemical properties in Majuli, Assam.

2. Materials and Methods

2.1 Study area

Majuli is the largest fresh water mid-river deltaic island in the world. The total geographical area of Majuli is 577 square km with a total net sown area of 30,584 hectares. Majuli falls under the tropical climate zone; however, the numerous wetlands, streams, etc. endow Majuli with a sub-tropical climate. The maximum summer temperature varies from 30-35 °C with a minimum temperature of 12 °C. The average annual rainfall ranges from 2000-2500mm with 80 percent relative humidity. The island is a biodiversity hotspot and has rich ecology with rare breeds of flora and fauna[7].

2.2 Collection of soil samples

Soil samples were collected from Majuli in four different seasons *i.e.*, spring, summer, autumn and winter during March, 2015 to February, 2016. The soil samples were collected with the help of a rectangular soil sampler (30cm×11cm×8cm) at a constant depth of 0-10cm [8]. During sampling at each season, ten samples were collected. The soil inside the sampler was taken out without disturbing the soil profile and then sealed, tagged and transported to the laboratory for the extraction of Collembola.

2.3 Extraction of collembolans from collected soil samples

"Tullgren funnel" was used to extract the collembolans from soil samples. The instrument was operated by using 40 Watt Tungsten electric bulbs, keeping in high light intensities for 72 hours of exposure [9]. The extracted soil microarthropods were collected in collecting tubes (40ml) containing 70 percent ethyl alcohol and was transferred into a clean petridish (15cm diameter) for the separation of collembolans. The collembolans were then cleaned, categorized and counted with the help of a Stereozoom Microscope (Model: Carl Zeiss Stemi 2000-C) in the laboratory. The population of extracted collembola were then estimated in numbers/sq.m. by following standard methodology [10].

2.4 Identification of collembolans

The collembolans collected were examined under Stereozoom Microscope (Magnification: 5X and above) for the preliminary basic characters and identified by using standard taxonomic keys [11]. Relative abundance of the different species of collembolans were worked out by using the following formula and expressed in percent.

$$\text{Relative abundance of species A} = \frac{\text{Number of species A}}{\text{Total number of collembola collected}} \times 100$$

2.5 Soil physicochemical properties

While collecting the soil samples for extracting the collembolans, additionally another three soil samples per season were also collected for the analysis of physicochemical properties. After collection, soil samples were sealed, tagged and brought carefully to the laboratory. The Physical and chemical properties of soil samples were determined in the laboratory of All India Coordinated Research Project on Water Management, Assam Agricultural University (26.7229°N, 94.1957°E), Jorhat, Assam. The details methodology used for this purpose is presented in Table 1.

2.6 Statistical analysis

2.6.1 Diversity indices

2.6.1.1 Shannon-Weiner Index (H')

Shannon-Weiner Index is calculated by following the standard formulae [12].

$$H' = \frac{s}{i=1} - \sum \text{Pi} \log 2 \text{ pi}$$

Where,

Pi= The proportion of the i^{th} species (n_i/N)
s= The number of species

2.6.1.2 Simpson Diversity Index (1-D)

Simpson Diversity Index was measured as per standard protocol [13].

$$D = \sum[n_i (n_i-1)]/N(N-1)$$

Where,

n_i = The total number of individuals of a particular species
N = The total number of individuals of all species

2.6.1.3 Species Evenness (E_H)

Evenness was calculated out by following the standard protocol [14]

$$E_H = H'/H'_{max} = H/\ln S$$

Where,

H' = The number derived from the Shannon diversity Index
H'_{max} = The maximum possible value of H'
S = The total number of species

2.6.2 Simple correlation and regression analysis

A simple correlation analysis was made between the mean population of collembola and independent variables (physical and chemical parameters of soil) to find out the relationship of soil physical and chemical parameters and the collembolan population.

2.6.3 Completely Randomized Design

The density data of collembolans were analyzed through Fisher's method of analysis of variance (ANOVA) which was employed for statistical analysis of the quantitative data using Completely Randomized Design (CRD) [15].

3. Results and Discussion

3.1 Composition and abundance of collembolans in Majuli

Soil samplings carried out in four different seasons *i.e.*, spring, summer, autumn and winter revealed the presence of 5 species of Collembola *viz.*, *Cyphoderus* sp., *Entomobrya* sp., *Isotoma* sp., *Folsomia* sp. and *Hypogastrura* sp. belonging to 4 different families *viz.*, Cyphoderidae, Entomobryidae, Isotomidae and Hypogastruridae. The percent relative abundance of collembolans recorded were graphically presented in Fig. 1. Out of the five species recorded, the most abundant species was found to be *Cyphoderus* sp. (37.74%) followed by *Isotoma* sp. (24.53%) and *Entomobrya* sp. (15.09%). Both the *Hypogastrura* sp. and *Folsomia* sp. contributed 11.32 percent of the total population. Similar findings were also reported by Santeshwari *et al.* [11] who recorded 13 dominant genera of collembolans *viz.*, *Cyphoderus*, *Isotoma*, *Entomobrya*, *Hypogastrura*, *Folsomia*, *Folsomides*, *Isotomurus*, *Seira*, *Salina*, *Lepidocyrtus*, *Neelus*, *Sminthurides* and *Sminthurinus* belonging to 8 families *viz*., Cyphoderidae, Entomobryidae, Hypogastruridae, Isotomidae, Paronellidae, Neelidae, Sminthurididae and Katiannidae from diverse habitats of Varanasi, India. The present findings also corroborate the findings of Guru and Mohanty [16] who reported that the most dominant species of Collembola was *Cyphoderus javanus* contributing 31.81 percent of population followed by *Isotoma* sp. (24.60%) and *Hypogastrura* sp. (15.65%) in the upper 5-10cm layers of soil.

3.2 Seasonal fluctuation of collembolan diversity and density in Majuli

Analyses of collembolan diversity showed higher species diversity in Majuli during all the seasons which indicated finely distributed individuals of different species. During the period of investigation, the Shannon-Wiener Index was recorded to be higher (H'=1.55) in summer indicating the presence of relatively stable habitats as compared to spring (H'=1.49), autumn (H'=1.43) and winter (H'=1.40) suggesting relatively disturbed habitats (Table 2). The Simpson Index of Diversity values ranged between 0.71-0.93 (>0.5) indicating high species richness during all the seasons. Moreover, evenness of the recorded species also registered the values closer to 1 (E= 0.81-0.97) which indicated equal distribution of the individuals during all the seasons. A seasonal trend of increasing values of the diversity of collembolans from spring to summer and autumn and then decreased during winter was also reported earlier by Wiwatwitaya and Takeda (2005) [17], Muturi *et al*. (2009) [18] and Paul *et al*. (2011) [8]. Higher diversity of collembolans during summer as compared to other seasons may be due to the presence of soil moisture and temperature at a higher range which maximize the rate of litter and organic matter decomposition and thereby provide a favourable ecological niche.

Season wise variation of collembolan density revealed that the highest density (196.36 nos./sq.m.) was registered during the summer season followed by autumn (150.91 nos./sq.m.) and spring (70.00 nos./sq.m.), however, the lowest density was recorded during the winter season (39.09 nos./sq.m.) (Table 2). The monthly variation of collembolan density (nos./sq.m.) is graphically depicted in Fig. 2 and data revealed that the maximum population of Collembola was recorded during the month of August (206.82) followed by July (206.06) and June (172.73). The minimum population was registered during the month of February (27.27 numbers/sq. m.). The results obtained in the present study confirm the findings of Mandal and Suman[19] who observed the maximum percent of collembolans during the month of July. It was due to the coincidence of collembolan population with the maximum proportion of soil moisture and organic carbon. The present findings are also in accordance with the work of Saikia[20] who observed the quantitative distribution of soil microarthropods in forest, agro and fallow land ecosystem and recorded the highest population of soil microarthropods in the month of August (2989.81/sq.m) and lowest during the month of April (525.21/sq.m.).

3.3 Correlation between collembolan density and diversity with soil physicochemical properties of Majuli river island

Correlation studies between the density and diversity of collembolans with different physicochemical properties of river island soil are presented in Table 3-5. Experimental data revealed a significant (P<0.01 and P<0.05) positive correlation of collembolan density with soil moisture (r= 0.929, 0.923, 0.824 and 0.945) and organic carbon (r= 0.873, 0.973, 0.787 and 0.915) content of the soil during all seasons respectively. The diversity of collembolans in river island ecosystem also exhibited significant (P<0.01 and P<0.05) positive correlation with soil moisture (r= 0.702, 0.867, 0.622 and 0.904) and organic carbon (r= 0.732, 0.667, 0.735 and 0.843) during spring, summer, autumn and winter, respectively. Other soil physicochemical properties *viz*., sand, silt, clay, Soil Microbial Biomass Carbon, pH and bulk density of river island ecosystem showed positive but non-significant relationship with both the density and diversity of the collembolans.

The present findings are in conformity with Bhattacharya and Raychoudhuri [21] who reported that some edaphic factors *viz*., temperature, moisture content of the soil and rainfall of the previous month showed a significant positive correlation with the total soil microarthropods population. In a similar line of study carried out by Hazra [22] reported a strong positive correlation between soil moisture and collembolan population and considered it as the principal factor for growth and development as well as population fluctuation. Organic matter and water content of soil together exerted direct or indirect influence on the microbial floral and faunal population by maintaining soil reaction, controlling humification and stimulating the growth of micro and macro flora. The increased population of Collembola with the increase in organic matter content of soil as observed in the present investigation was also reported by many researchers [23, 24]. This may due to the fact that the availability of the sufficient amount of litter in to the top soil which not only served as a source of food but also influenced the amount of living space available for many soil organisms. Dhillon and Gibson [25] also made similar line of study and reported that approximately 85-90 percent of Collembola congregated in the first 0-10cm of soil layer due to the higher concentration of organic matter and availability of sufficient amount of moisture for their growth and survival. While studying the effect of pH and bulk density on collembolan population, Hazra [26] also reported that the pH and bulk density did not show any strong positive correlation and not exhibited any direct influences on the population growth of Collembola.

Table 1: Details of methodology used for analysis of soil physicochemical properties

Soil properties	Methodology
Mechanical analysis	International pipette method [27]
Soil Moisture	AOAC [28]
Organic Carbon	Dichromate oxidation [29]
Soil Microbial Biomass carbon	Fumigation–Extraction method [30]
pH	1:2 soil water suspension using Beckman glass electrode
Bulk density	Soil cores[31]

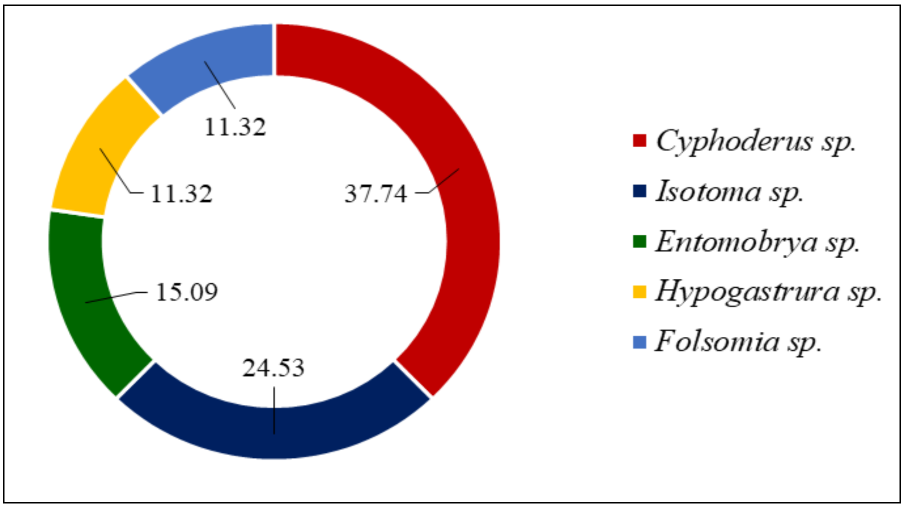

Fig 1: Relative abundance (%) of collembolans in Majuli river island during 2015-16

Table 2: Seasonal fluctuation of collembolan diversity in Majuli during 2015-16

Season	Shannon Wiener (H')	Simpson Index (D)	Simpson Index of Diversity (1-D)	Evenness (E)	Density (Nos./ sq.m.)
Spring	1.49	0.14	0.86	0.93	70.00
Summer	1.55	0.07	0.93	0.97	196.36
Autumn	1.43	0.19	0.81	0.81	150.91
Winter	1.40	0.29	0.71	0.97	39.09

*Data are mean of 10 samples

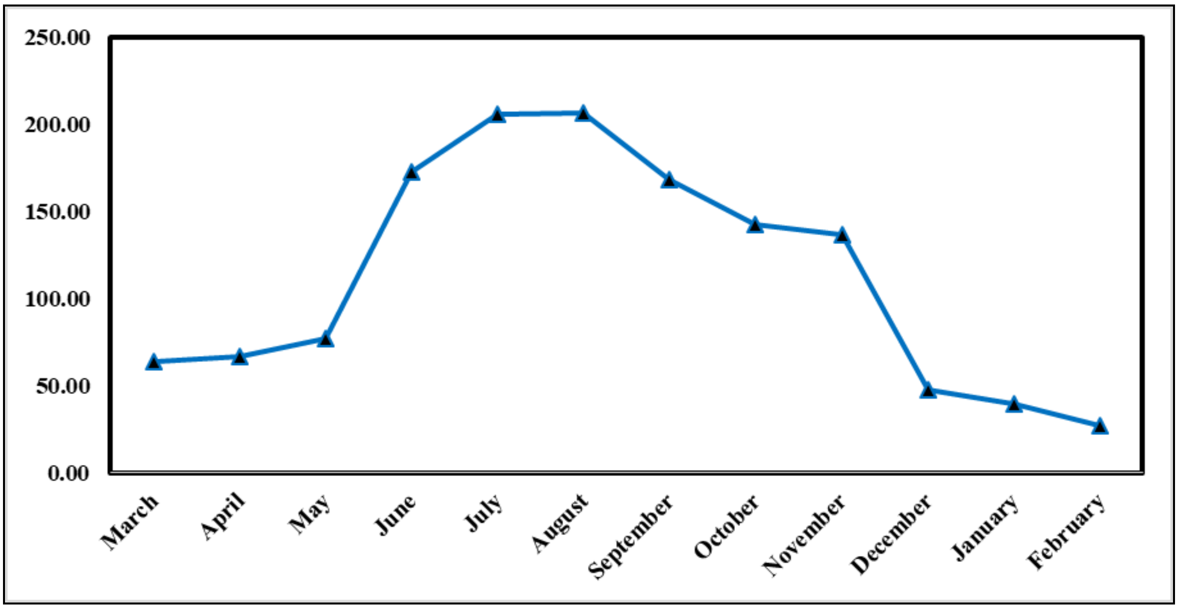

Fig 2: Monthly variation of collembolan density in Majuli River Island during 2015-16

Table 3: Details of soil physicochemical properties of Majuli, Assam during 2015-16

Season	Density (No/ sq.m.)	Diversity (1-D)	Sand (%)	Silt (%)	Clay (%)	Soil moisture (%)	Organic carbon (%)	SMBC (µg/g)	pH (1:2.5)	BD (g/cc)
Spring	70.00	0.86	74.0	11.0	13.5	25.19	0.69	89.22	6.3	1.41
Summer	196.36	0.81	72.4	9.6	16.0	28.72	0.77	97.61	6.4	1.37
Autumn	150.91	0.71	75.2	9.6	13.2	26.18	0.71	83.82	6.8	1.39
Winter	39.09	0.93	70.4	21.4	7.2	21.88	0.62	74.93	6.1	1.43

Data are mean of 3 samples

Table 4: Correlation studies between collembolan densities with soil physicochemical properties of Majuli, Assam

Season		Sand (%)	Silt (%)	Clay (%)	Soil moisture (%)	Organic carbon (%)	SMBC (µg/g)	pH (1:2.5)	BD (g/cc)
Spring	r	0.050	0.314	0.462	0.929**	0.873*	0.700	0.340	0.108
	p	0.704	0.511	0.619	0.001	0.023	0.216	0.589	0.571
Summer	r	0.484	0.308	0.124	0.923*	0.973**	0.287	0.643	0.442
	p	0.299	0.593	0.724	0.042	0.001	0.529	0.221	0.365
Autumn	r	0.533	0.296	0.237	0.824*	0.787*	0.314	0.104	0.594
	p	0.224	0.651	0.842	0.022	0.027	0.757	0.762	0.120
Winter	r	0.212	0.367	0.278	0.945**	0.915*	0.193	0.341	0.311
	p	0.708	0.518	0.512	0.001	0.021	0.444	0.495	0.334

**Significant at 1 percent probability level $p \leq 0.01$
* Significant at 5 percent probability level $p \leq 0.05$

Table 5: Correlation studies between collembolan diversity with soil physicochemical properties of Majuli, Assam

Season		Sand (%)	Silt (%)	Clay (%)	Soil moisture (%)	Organic carbon (%)	SMBC (µg/g)	pH (1:2.5)	BD (g/cc)
Spring	r	0.047	0.024	0.787	0.702*	0.732*	0.016	0.323	0.111
	p	0.610	0.715	0.234	0.032	0.026	0.832	0.516	0.735
Summer	r	0.143	0.358	0.157	0.867*	0.667*	0.147	0.428	0.206
	p	0.348	0.522	0.821	0.021	0.041	0.713	0.235	0.653
Autumn	r	0.540	0.602	0.442	0.622*	0.735*	0.205	0.537	0.583
	p	0.238	0.382	0.643	0.042	0.032	0.413	0.216	0.285
Winter	r	0.277	0.179	0.024	0.904**	0.843*	0.189	0.251	0.200
	p	0.492	0.759	0.733	0.003	0.032	0.738	0.618	0.762

**Significant at 1 percent probability level $p \leq 0.01$
* Significant at 5 percent probability level $p \leq 0.05$

4. Conclusion
The study revealed a higher species diversity and density of collembolans in Majuli river island of Assam. However, more extensive studies on the documentation of collembolan fauna by both molecular and conventional taxonomy is required which would further help in creating a digital database on collembolan fauna of North East India. Moreover, from the above findings it can be concluded that out of all the soil physicochemical parameters, the soil moisture and organic carbon content played pivotal roles in controlling the population densities and diversity of Collembola as they showed high positive significant correlation with Collembola population.

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