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Seasonal Changes in Abundance and Distribution of the Soil Litter Micro-arthropods in a Tropical Forest, with Special Reference to Collembola

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Abstract
The population study was made on the basis of comparison of seasonal changes of Collembola in relation with the gradient of edaphic factors which include moisture, temperature, pH, organic carbon, inorganic nitrogen, phosphorus, sodium and potassium contents of a tropical forest, in West Bengal, India. The variations in abundances have significant values during the study period. The higher numbers of insects were collected in December and July. This was in winter and monsoon seasons in the first and second study year respectively, while the lowest numbers were collected in May and June. These were in the summer and early monsoon season, in the first and second study year respectively. During this period soil moisture, temperature, pH, organic carbon, inorganic nitrogen, phosphorus, sodium and potassium content had shown remarkable variations. It is observed from Pearson's correlation of study and canonical corresponding analysis (CCA) that the population abundance did not show the same results in response to all edaphic factors.

Keywords: *Canonical correspondence analysis (CCA), Collembola, Pearson's correlation study, population abundance, seasonal variation*

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INTRODUCTION
The amount of litter fall may change on a seasonal basis or based on the forest vegetation type resulting in litter depth peaking perhaps once or twice through the year [1]. Litter fall forms a protective layer on the soil surface and helps in nutrient and carbon cycling that also regulates microclimatic conditions of soil.

The decomposition of such organic matters starts with the infestation of microorganisms. Their activities help to change the chemical composition of the litter soil as well as decaying organic matter. Collembola together with other soil arthropods such as *Acari* constitute an important component of soil mesofauna in almost all terrestrial ecosystems [2], and are indispensable in decomposition of organic matter, maintenance of soil physical structure and efficient nutrient cycling. Identification of the ecologically meaningful causal factors are essential in order to explain variation in insect species. Edaphic factors include the composition and structure of soil along with its physical and chemical properties. Factors such as litter temperature, moisture, and other edaphic factors and slope of the terrine have been shown to be influencing abundance and distribution of the litter insects [3–7]. In some tropical dry forest, an inhibition of decomposer community results in a transient accumulation of litter on the forest floor during the dry season [8]. These generally occur due to seasonal variation. During the wet season, condition for growth and activity of soil microorganisms are improved, thus increasing the decomposition rate. Studies on soil invertebrates show that during the dry season the soil fauna move deeper in the soil [9]. Soil moisture gradient and changes in soil temperature were observed to play a significant role in seasonal fluctuation and distribution of Collembola [10]. Among Collembola the population of family Entomobryidae, Hypogasturidae, Neanuridae and Sminthuridae are found in forest litter where Entomobryidae exhibits maximum varieties of species during the study periods (Table 1). Present investigation has been initiated with the objectives like to know the diversity of Collembolan insects and its seasonal variations in forest litter ecosystem in respect of edaphic factors in this study area. The study will also highlight that out of the eight parameters taken which one will be the most controlling factor of the collembolan population fluctuation.

MATERIALS AND METHODS

The present study has been carried out in Bibhutibhushan sanctuary (District North 24 parganas) which is categorized as a northern tropical moist deciduous forest. The geographical location is between 88.45°east longitude and 23.12°north latitude. It is characterized by an oppressive hot summer and high humidity all around the year, particularly during the rainy season. The average annual soil temperature varies from 17.7°C–38.5°C. Higher moisture percentage in soil is observed during end of monsoon, autumn months and comparatively less percentage during summer months. Each study year had been divided into four seasons such as winter (December to February), summer (March to May), monsoon (June to August) and finally autumn (September to November). A seasonal collection of samples regarding soil was carried out for each of the four seasons for both cyclic years, i.e., from December to November, taken fortnightly.

The mean values observed in six seasonal samples were used to measure how much of insect's fauna was there for a particular season. For the analysis of edaphic factors as well as for a population study, litter soil was collected from each plot throughout the period of sample collection. Not only some important factors like temperature, pH, soil moisture content and some in organic factors as sodium (Na), potassium(K), phosphorus(P) and nitrogen(N) were analyzed but also an important organic element like 'carbon' was analyzed with the help of standard methods. Temperature of the soil was measured by a centigrade thermometer inserting directly into the soil at each sampling plot. Its pH value was measured in room temperature by using a digital pH meter (Systematics-121, India). For analyzing carbon (organic) matter, Walky and Black method was applied. Total nitrogen content of the soil was analyzed using micro-Kjeldahl distillation method [11]. Phosphate content of the soil was determined by molybdate-stannous chloride method [11]. Potassium and sodium content were analyzed by flame photometry method of ASA [12].

Table 1: *Seasonal Abundance of Collembolan species.*

Species	Winter		Summer		Monsoon		Autumn	
	2007	2008	2007	2008	2007	2008	2007	2008
Family-Entomobryidae								
Lepidocyrtus magnificus Carpenter	24	40	36	44	0	20	8	24
Lepidocyrtus medius Schaeffer	44	72	36	36	44	60	8	36
Lepidocyrtus indica carpenter	0	0	0	0	0	0	8	0
Entomobrya indica Baijal	44	44	16	20	32	62	32	56
Sinella curviseta Brook	44	56	16	24	32	56	32	52
Dicranocentrus indicus Bonet	8	0	4	0	4	4	0	8
Cyphodurus sarojinii Bhattacharjee	0	0	4	3	4	12	0	0
Dicranocentroides indica, Handschin	8	3	0	0	0	4	0	0
Dicranocentroides flavescens Yosii	4	4	0	0	0	8	0	0
Salina bengalensis Mitra	20	4	12	4	16	16	4	0
Salina indicaimms	0	12	0	8	8	4	0	16
Salina biformes Mitra	8	0	0	0	0	9	6	6
Homidiacingulla Borner	4	4	0	0	4	0	0	9
Family-Hypogastruridae								
Hypogastrura unguiculata Mitra	0	0	0	0	0	0	8	13
Family-Neanuridae								
Lobella assamensisYosii	8	4	0	0	0	0	0	16
Neanura muscorum Templeton	0	4	0	0	0	8	8	0
Family-Sminthuridae								
Sminthurides velli Prabhoo	4	4	0	0	4	4	0	9
Seira punctata Ritter	0	0	0	4	0	12	8	56

Statistical Analysis: An important technique namely Pearson's correlation technique was employed in this investigation which focused the difference in preferences towards edaphic factors of forest litters and in this way, it influences the insect's abundance on the variability of edaphic factors. Whereas, canonical correspondence analysis (CCA) actually able to describe the reason of seasonal fluctuation of insects' species.

This occurs due to different loading between species abundance and edaphic factors. CCA was used on transformed (square root of X+0.05) mean abundance data with many missing values for non-availability of all collembolan species where such analysis assumes Gaussian relationship between groups of variables.

When CCA was used, an assumption was made that species abundance in different population would be Gaussian function of environmental edaphic factors concentration. CCA technique using unimodal response model was followed to explain the species abundance concentration in response to different edaphic factors with the help of bi-plot type of scaling. A test of significance of both first canonical axis and all canonical axes were made under Monte Carlo test with 499 permutations under reduced model. Relationship of species abundance with environmental loading in different population has been presented in ordination diagrams (bi-plot) for first two axes.

Pearson's Correlation Study: Pearson's correlation of study (Table 2) reveals that, among the members of order Collembola the abundance of *Lepidocyrtus magnificus* showed significant correlation with carbon (C) at 1% level. *Lepidocyrtus indicus* showed significant correlation with moisture at 5% level. *Sinella curviseta* showed significant correlation with N at 5% level. Whereas, *Cyphodurus sarojinii* showed significant correlation with N at 1% level. *Dicranocentroides flavecens* showed significant correlation with N and K at 5% level. *Dicranocentroides indicus* showed significant correlation with P at 1% level. *Salina bengalensis* showed significant correlation with P at 5% level. *Salina indica* showed significant correlation with N at 1% level. *Hypogastrura unguiculata* showed significant correlation with moisture and K at 5% level and with Na at 1% level. *Lobella assamensis* showed significant correlation with Na at 5% level.

Canonical Correspondence Analysis: On the other hand, according to transformed values of CCA, Axis-1 of bi-plot (Table 3, Figure 1) revealed that high concentration of N is highly associated with the increasing population of *Dicranocentrus indicus, Lepidocyrtus magnificus, Dicranocentroides flavus, Salina indica, Cyphodurus sarojinii, Salina bengalensis, Homidia cingula and Lepidocyrtus medius* due to positive loading. At the same time, the population of *Dicranocentroides indica, Lobella assamensis, Sinella curviseta, Salina biformes, Lepidocyrtus indicus, Neanura muscorum, Entomobrya indica, Sminthurides velli, Hypogastrura unguiculata and Lobella assamensis* showed decreasing population in presence of high concentration of N and increasing population in presence of high concentration of C.

Axis-2 of bi-plot (Table 3, Figure 1) revealed that the high values of C and N are highly associated with the increasing population of *Cyphodurus sarojinii, Dicranocentroides flavascens, Salina indica, Dicranocentrus indica, Homidia cingula, Dicranocentroides indica, Sinella curviseta, Lobella assamensis* due to positive loading, but *Salina biformes, Sminthurides velli, Entomobrya indica, Seira punctata, Lepidocyrtus magnificus, Salina indica, Neanura muscorum, Hypogastrura unguiculata and Lepidocyrtus indicus* and *Lepidocyrtus medius* showed decreasing population in presence of the same factors due to negative loading. In bi-plot, quadrant-wise position of species and nearness to each of these, describe the co-existence of those species in a given environment.

RESULTS

The seasonal variation showed significant relation throughout the study period and the abundance of total Collembola in the study area showed variation even in the same year. In order Collembola *Lepidocyrtus medius, Entomobrya indica and Sinella curviseta* show its maximum representation and *Dicranocentroides flavescens* shows its minimum representation in 1st study year. Whereas, *Lepidocyrtus medius, Entomobrya indica* and *Dicranocentroides indicus* shows its maximum and minimum representation respectively during 2nd study year. In the study area the wet period lasts for three months and the long duration of summer lasts for four months with short-spells of heavy rains followed by three months of wet and moderate rains.

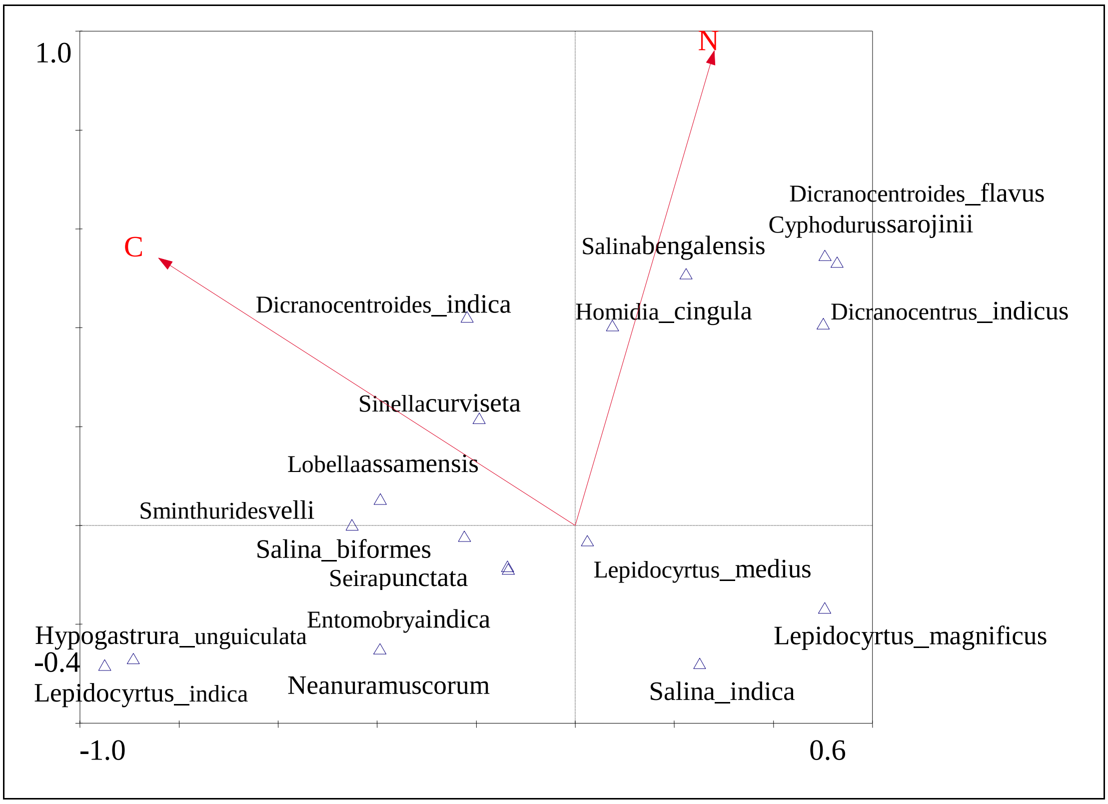

***Figure**. 1: Canonical correspondence analysis bi-plot (Transformed).*

***Table 2:** Correlation of abundance and edaphic factors and their level of significance at Bibhutibhushan sanctuary. Significant<0.05= * =Association/Correlation is Significant at 5%level. Significant<0.01= ** =association/correlation is significant at 1%.*

Species		Temp	Moist.	pH	N	P	K	Na	C
Lepidocyrtus magnificus	Corr.	-0.211	-0.192	0.184	0.053	0.060	-0.232	-0.172	-.47**
Lepidocyrtus medius	Corr.	-0.181	-0.169	-0.059	0.198	-0.153	0.084	-0.130	-0.003
Lepidocyrtus indicus	Corr.	0.041	0.298*	-0.106	-0.084	0.104	0.184	0.213	0.110
Entomobrya indica	Corr.	0.072	0.177	-0.170	0.005	-0.009	0.211	0.211	0.142
Sinella curviseta	Corr.	0.017	0.154	0.028	0.286*	-0.038	0.076	0.184	0.212
Dicranocentrus indicus	Corr.	-0.018	0.126	0.013	0.271	0.139	0.062	-0.019	-0.086
Cyphodurus sarojinii.	Corr.	0.209	-0.009	-0.196	0.403**	0.004	-0.003	0.234	0.003
Dicranocentroides flavescens	Corr.	-0.023	0.025	-0.159	0.320*	-0.041	0.289*	0.190	-0.035
Dicranocentroides indicus	Corr.	-0.221	-0.106	-0.011	0.119	0.446**	0.115	0.003	0.103
Salina bengalensis	Corr.	-0.090	-0.126	0.032	-0.086	-0.288*	-0.040	-0.209	-0.255
Salina indica	Corr.	-0.007	0.074	0.078	0.432**	0.275	0.049	0.034	0.082
S alinabiformes	Corr.	-0.004	0.222	0.193	0.013	-0.092	0.269	0.115	0.095
Hypogastrura_unguiculata	Corr.	0.107	0.303*	-0.039	-0.182	0.164	0.327*	0.440 **	0.233
Lobelia assamensis	Corr.	-0.143	0.005	0.110	0.009	-0.173	0.133	0.297*	0.171
Sminthurides velli	Corr.	0.089	0.216	-0.161	-0.011	-0.172	0.145	0.154	0.191
Seira punctata	Corr.	0.085	0.144	-0.145	0.112	0.115	0.080	0.002	0.113
Homidia cingula	Corr.	-0.139	-0.019	0.182	0.216	-0.109	0.028	-0.128	0.067
Neanura muscorum	Corr.	0.014	0.214	-0.102	-0.079	0.035	0.279	-0.002	0.082

During summer, high temperature is a normal occurrence (Table 4). While the winter period is restricted only 2–3 months and the occurrence of low soil temperature (17ºC) retain for a very short period. A sharp reduction in abundance during the dry season seems to be restricted to tropical habitats that have a severe dry season which concur with the opinion of [13, 14].

During the dry season several groups of insects decline in number (Figure 2) where the onset of rain is the major factor. This imposes direct effect on the population of insects. This population study also revealed that the family Entomobryidae is most abundant group of insects which showed its lowest abundance during late summer.

Several groups of insects are known to decline during the wet season (Table 1). In such cases, rainfall did not have a significant effect directly on faunal abundance in the study area, there may be indirect effect, i.e., by the influence of rainfall on plant phenology (litter fall and litter depth) and habitat microclimatic conditions (litter moisture, humidity conditions) [15]. In the study area *Lepidocyrtus medius, Entomobrya indica* and *Sinella curviseta* showed the highest population (Figure 3). Their peak in population level in pre-summer and winter could be linked to the well-known migratory behavior of Collembola to favorable litter moisture conditions following the monsoon season also to the same behavior when habitat becomes excessively wet [16]. The similar picture has been found in the present investigation (Figures 4 and 5). The general tendency of soil arthropods to attain maximum population during monsoon and minimum during summer as reported by some workers like [17, 18]. The present investigation showed almost similar picture (Figures 4 and 5). Although it is observed that soil arthropods had the capability to augment their population in accordance with the physicochemical conditions of soil [19, 20] (Table 5).

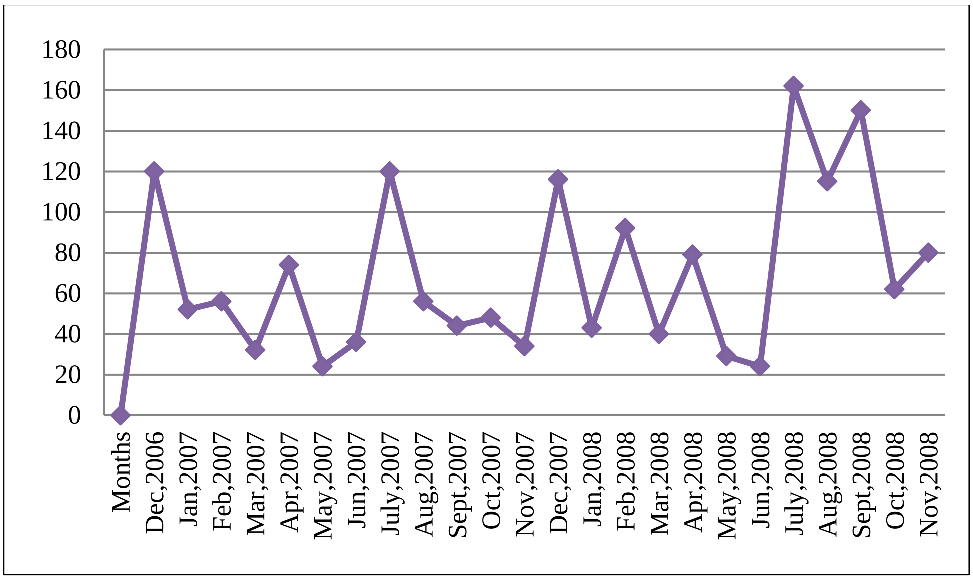

Fig. 2: *Seasonal fluctuation of population of Collembola at Bibhutibhushan sanctuary.*

Table 3: *Canonical Correspondence Analysis (CCA) results involving effect of edaphic factors on abundance of species under Collembola.*

	Axis-1	**Axis-2**	**Axis-3**	**Axis-4**
Sum of all Eigen values=2.029				
Env. vs Abundance correlation	0.67	0.69	0.0	0.0
Cumulative percentage variance				
Abundance of species	6.1	9.1	20.7	30.8
Abundance-Env. relation	67.8	100	0.0	0.0
P value=0.018				
Inflation factors<20				
Omitted env. Variables: Temperature. Na, K, pH and moisture.				

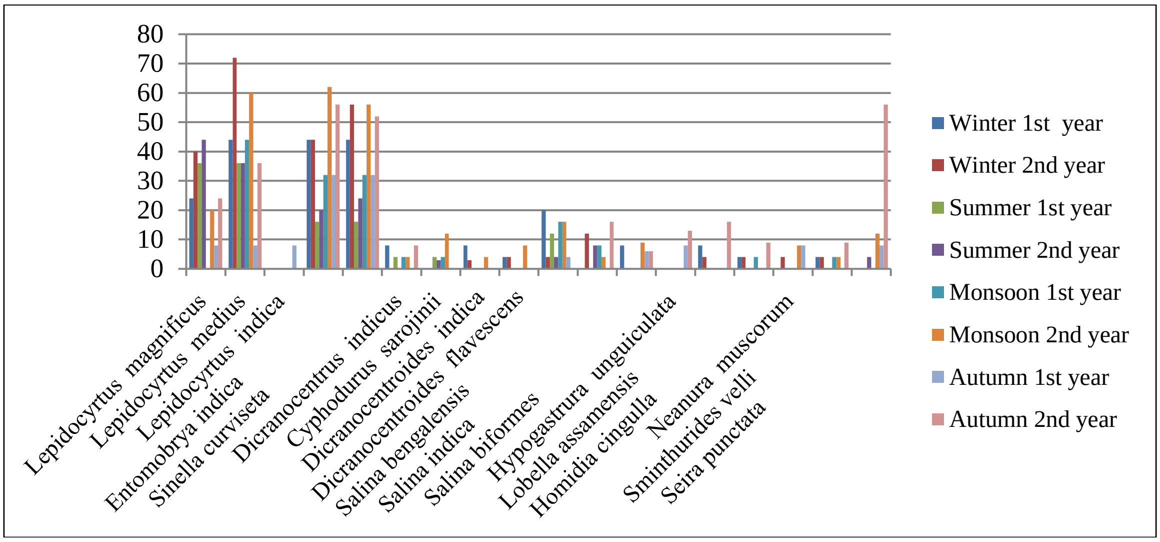

***Fig*. 3:** *Seasonal fluctuation of population of different species in Collembola.*

Table 4: *Month wise occurrence of soil edaphic factors at Bibhutibhushan sanctuary.*

Month	Temperature ^{0}C	Moisture %	pH	Na mg/kg	K mg/kg	P mg/kg	N %	C %
Dec.2006	17.75	19.0	7.84	15	86	45	3.40	4.2
Jan,2007	18.0	11.5	7.13	10	90	39	1.95	4.7
Feb,2007	20.75	17.75	7.9	12	91	54	0.81	3.4
March,2007	25.25	14.75	7.3	16	80	55	0.84	1.4
April,2007	28.5	11.5	7.29	11	78	56	1.10	2.9
May,2007	28.75	10.1	7.0	17	79	55	1.94	4.5
June,2007	29.75	13.75	6.8	20	86	52	2.25	5.2
July,2007	31.0	20.25	6.7	32	89	55	3.05	5.0
Aug,2007	38.5	24.1	6.75	103	93	56	4.08	4.8
Sept,2007	36.0	34.0	6.77	162	90	57	0.77	5.6
Oct,2007	27.75	35.5	6.73	128	96	58	1.02	5.3
Nov,2007	27.0	29.3	7.77	17	92	58	2.18	5.0
Dec,2007	18.0	18.0	7.93	07	88	60	13.65	4.8
Jan,2008	18.25	14.3	7.2	08	91	56.5	2.17	5.4
Feb,2008	21.0	18.1	7.04	11	96	55	0.77	3.8
March,2008	26.25	12.6	7.14	09	85	56	0.86	2.8
April,2008	29.25	12.0	7.08	08	77	57	1.33	3.4
May,2008	29.75	11.5	7.05	16	84	56	2.17	4.8
June,2008	29.5	12.0	6.85	22	89	55	2.65	5.6
July,2008	30.25	19.0	6.78	38	94	53	3.37	5.0
Aug,2008	32.0	22.0	6.72	152	95	54	13.51	5.2
Sept,2008	30.25	20.0	6.82	160	91	56	1.15	5.4
Oct,2008	28.0	30.1	7.0	139	99	57	0.49	5.2
Nov,2008	24.75	27.5	7.38	08	90	61	10.92	5.1

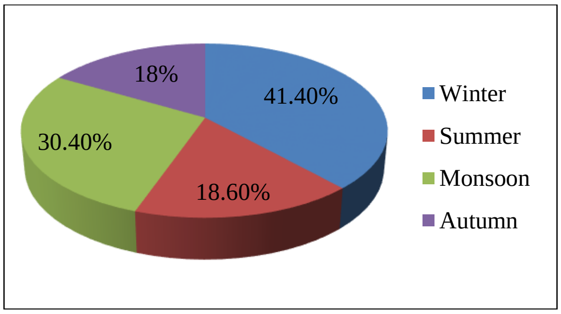

***Fig*. 4:** *Seasonal variation of collembola in first study year.*

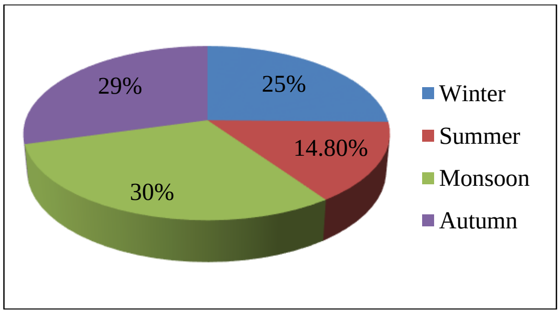

Fig. 5: *Seasonal variation of collembola in Second study year.*

Table 5: *Month wise occurrence of collembola in both the study years.*

Orders	Collembola
Months	
Dec,2006	120
Jan,2007	52
Feb,2007	56
Mar,2007	32
Apr,2007	74
May,2007	24
Jun,2007	36
July,2007	120
Aug,2007	56
Sept,2007	44
Oct,2007	48
Nov,2007	34
Dec,2007	116
Jan,2008	43
Feb,2008	92
Mar,2008	40
Apr,2008	79
May,2008	29
Jun,2008	24
July,2008	162
Aug,2008	115
Sept,2008	150
Oct,2008	62
Nov,2008	80

DISCUSSION

From mean abundance indifferent of location, it reveals that only the mean observed values of temperature showed significant differences throughout the year. So, the seasonal abundance of insects' species become positively affected by the temperature. In the study areas, the maximum soil temperature ranges from 31°C to 38.5°C during July to September in both the study years (Table 4). Whereas, minimum (18°C to 21°C) during December to February in both the year (Table 4). Mean abundance of observed values of moisture showed significant differences in various season. Moisture showed maximum range during October 30.1% to 35.5% and minimum 10% to 11% during May in both the years and study areas (Table 4). So, the values of moisture have a positive effect over the population of insects. Collembolan recorded a bimodal peak in abundance in pre-summer and in southwest monsoon season [21]. Though mean observed pH values showed significant differences in various seasons. In spite of these differences the population of insects in different season did not show any significant relationship with the pH value of the soil (Table 4, Figure 2). Nitrogen content of the litter recorded various mean observed values in different seasons. Its concentration increased slightly during the experiment. The abundance of various collembolan species is significantly related with N content (Table 4, Figure 2). N concentration in leaf litter increased to a maximum range during August, then declined and again increased in December which is significantly related to the rising population of some collembolan species (Table 4, Figure 2). Though its concentration in second study year was much more than that of first year. The lowest concentration of N was noticed during February though it did not show any relationship with the population abundance (Table 4, Figure 2). Increase in the N concentration of leaf litter have also been found in other studies [22, 23]. The abundance of various species is significantly related with these factors. Nitrogen is one of the most common factors, limiting litter decomposition as it determines the growth and turnover of microbial biomass mineralizing the organic carbon [24]. Carbon showed no significant differences in its concentration in both the study period with a few exceptions. Soil organic carbon showed the highest concentration during June and September and lowest during March (Table 4). Soil organic carbon content exhibited a strong positive correlation with collembolan population (Table 4, Figure 2). The quantitative increase in population with increased concentration of organic carbon has been reported in different ecosystem [25]. Mean observed values of phosphorus revealed that significant differences are recorded in different season (Table 4). Higher values in P concentration were observed during May, September and June which is related to the increase of the population abundance of a few species. The higher K concentration was initiated from August to September and thereafter declined in all the sites (Table 4). The mean observed values of sodium and potassium revealed significant difference in its concentration throughout the study period. Its (Na) concentration rises from August and retained up to October then declined (Table 4). Na has the significant effect on the abundance of two species of Collembola (Table 4). Potassium being very mobile, less bound to nutrient and insects have little impact on potassium depletion. According to Pearson's correlation of study, species abundance showed variation in response to the variations of concentration of inorganic carbon, nitrogen, moisture, phosphorus, and sodium and potassium factors (Table 2). Whereas, according to the transformed values of CCA, it was revealed that the variation of species abundance was strongly related with the variation of concentration of carbon and nitrogen only (Table 3, Figure 1), which were more specific. The present conception about microhabitat of individual species can be made by this study. This investigation provides knowledge on seasonal variation of Collembolan population in response to physicochemical structure of forest litter. The result can help to initiate further studies on litter insects in different forest types in presence or absence of different edaphic factors.

CONCLUSION

This investigation can provide knowledge on seasonal variation of collembolan populations in response to physicochemical factors of forest litter as evidenced by the statistically significant correlations between the two entities, which has been seen in the study area although different statistical analysis has given different results of population abundance with respect to edaphic factors. Finally, it is hoped that the present investigation may provide a base line data to the future workers and can help to formulate in a more sophisticated pattern of investigation. Among the collembolan species recorded *Lepidocyrtus medius, Entomobrya indica, Sinella curviseta* contributed a relatively high percentage to total density in both the study years. They were evident throughout the sampling period but for a few instances, this suggests that these species dominate the entire recorded population of Collembola. It has a wide range of tolerance to the existing soil physicochemical factors.

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