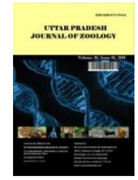
UTTAR PRADESH JOURNAL OF ZOOLOGY

41(23): 38-46, 2020
ISSN: 0256-971X (P)



SEASONAL INFLUENCE OF SOIL PROPERTIES ON POPULATION DENSITY OF *Bilobella braunerae* (DHERVANG 1981)- (COLLEMBOLA: NEANURIDAE) IN GRASSLAND OF SOUTHERN WESTERN GHATS

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between both authors. Author NT designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MGSK managed the analyses of the study. Both authors read and approved the final manuscript.

Article Information

Editor(s):
(1) Dr. Osama Anwer Saeed, University of Anbar, Iraq.
Reviewers:
(1) Zouidi Mohamed, University of Saïda, Algeria.
(2) Nuril Hidayati, Research Center for Biology-Indonesian Institute of Sciences, Indonesia.

Received: 10 October 2020
Accepted: 17 December 2020
Published: 11 January 2021

Original Research Article

ABSTRACT

The present study was conducted to understand the impact of soil physicochemical parameters on population density and vertical distribution pattern of a soil collembolan *Bilobella braunerae* in grasslands of Southern Western Ghats. The results revealed that maximum mean abundance of collembola was found during postmonsoon season (26.9) followed by monsoon (20.05) and premonsoon (7.1). Population density of organisms was high in 0-10 cm layer of soil during postmonsoon season. A vertical migration pattern was observed with increase in soil temperature and decreasing moisture content during premonsoon season. During monsoon season owing to heavy rainfall organism shows a vertical migration to 10-20 cm depth and thus lesser number of organisms were seen in 0-10 cm layer of soil .Seasons exerted a strong effect on the abundance of *B. braunerae* in grassland .Principal Component Analysis (PCA), was used to make the selection about soil components which directly influence the population. The first five principal components (PCs) explained more than 80% of the total variance in all seasons .The PCA showed significant effect of soil pH, organic carbon, soil moisture, temperature, phosphorous and potassium on the population density of *B. braunerae*.

Keywords: *Bilobella braunerae; physicochemical parameters; population density; vertical migration; Principal Component Analysis (PCA).*

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1. INTRODUCTION

Soil system represents a complex of abiotic and biotic factors that influence the biological community. Grasslands have soil which is different from those of forests and other vegetation types, though formed from the same parent materials. A key aspect of grasslands is their high shoots and root biomass, which results in high amount of organic matter at the soil surface. Among soil biota microarthropods are one of the very important biotic components of soil ecosystem as they do decomposition, nutrient cycling, increases soil fertility thus influences the overall soil quality. They are good biological indicators of soil conditions [1,2,3]. Collembolans are important microarthropod present in almost all terrestrial ecosystems. They are useful bio-indicators for land management practices because of high diversity, sensitivity to disturbance and ease of sampling and play a significant role in mineralization and humification of organic matter [4,5,6]. They are considered as the indicator organisms in studies of soil quality [7,8]. Soil fauna is largely influenced by physicochemical properties of soils. [9] studied the qualitative and quantitative composition of the soil fauna and their relation with the different soil factors in respect to their population size and distribution pattern. In soil ecosystems, the status of soil biota at local and regional scales is influenced by different driving forces, such as forestry, agriculture, urbanization and seasonal fluctuation. Seasonal differences in the abundance of soil arthropods have been studied and it was reported that micro arthropods undergo enormous fluctuations in densities, due to changes in microenvironment [10]. Extensive studies have been done on feeding behavior as it affects the microbial activity and soil biomass in ecosystem. Very fewer studies were conducted on population dynamics of Collembolans. Collembolan distribution is affected by micro and macrohabitats in forest ecosystem [11]. Soil fauna like collembolans cause nutrient mineralization and nutrient uptake in grassland ecosystem [12]. Collembolans vary in distribution pattern with season and soil type. So we need to understand the physicochemical properties of the soil to study the population dynamics of collembolans .Soil quality effects the growth of *Folsomia candida* in microcosm experiments [13]. The relationships between endogeic and epigeic collembolan species and chemical and microbiological top soil parameters revealed that the distribution of endogeic species of the collembolan fauna was related to organic matter content, as well as pH, C, N, and C/N ratio and epigeic species were influenced by available P and exchangeable K and Mg [14]. The condition of soil biota at local and regional scales is influenced by different driving forces, such as forest, agriculture, industrialization and seasonal variation. These forces causes changes in land use, soil moisture, temperature, bulk density and other physico-chemical factor which directly or indirectly affect density and diversity pattern of soil biota. Temperature fluctuation during different seasons commonly induces vertical movement of soil animals in the soil profile [15,16]. To avoid dry conditions in top layer of soil biota move vertically deeper and reorganize themselves in moisture patches present in deep layers of soil [15,17]. The principal component analysis showed significant effect of soil moisture and soil pH on the abundance of collembola while the effect of soil temperature, relative humidity and organic matter was non-significant. The abundance of Collembola was positively correlated with soil moisture and organic matter in all the crops, soil temperature in wheat, relative humidity in sugarcane and cotton, soil pH in cotton while negatively correlated with soil temperature in sugarcane, cotton and clover, relative humidity in clover and wheat, soil pH in sugarcane, clover and wheat [18]. Thus, the objectives of present work was to study the role of seasons on population density and vertical migration of *B. braunerae* and also to assess the principal components in soil which directly influence the population distribution.

2. MATERIALS AND METHODS

2.1 Study Area

Soil samples were randomly collected from 20 different sites of 5X5 cm^2 area, from different places in Grassland area of Pachakanam latitude 9°27’49.41”N 77°08’43.94”E of Pathanamthitta District, Kerala using a soil augar. The soil through the study area is sandy loam. The soil samples were collected bimonthly for a period of one year from October 2017 to September 2018. Soil samples were collected from 0-10 10-20 and 20-30 cm layers of the soil pit random collected from each study area from different seasons. Temperature was recorded on site using soil thermometer. The soil samples were collected in a polythene bag, tied using rubber band, properly marked and taken to the laboratory. Samples were pooled, air dried, sieved through 2mm sieve. The sand, silt and clay contents were analyzed by Particle size analysis, pipette method. Soil pH measured by pH meter in water suspension (1:2 ratios). Organic carbon content by Walkley Black acid digestion method [19], total Nitrogen by Kjeldahl distillation method; Phosphorus content by Molybdate-Stannous chloride method; Potassium content by flame photometry method [20]; Exchangeable Acid, Exchangeable base, Calcium and Magnesium by the methods of [21]. Soil temperature was measured using a soil thermometer. Soil edaphic factors like moisture, pH, Organic Carbon were estimated as per the procedure of [22]. Twenty soil samples each were collected from study sites during pre monsoon (February to May), monsoon (June to September) and postmonsoon season (October to January). Mean value along with standard deviation was calculated then converted in to area into cm^2.

2.2 Population Density of Soil Fauna

Soil samples of 25 cm^2 area, from a depth of up to 30 cm were randomly collected using soil auger. Samples were collected in morning, between 8.00 am to 10.00 am, bimonthly for one year in labeled polythene covers and taken to the laboratory. Collected soil samples were transferred to the Berlese Tullgren funnel for extraction of *B. braunerae* overnight into picric acid medium.

2.3 Data Analysis

The density of the collembolan was calculated in 25 cm^2 area. The mean value of population in 20 sites along with standard deviation was calculated. Two way ANOVA was conducted to study variation in population density of the collembola between sites and seasons. PCA of soil was done using PAST 3 software.

3. RESULTS

3.1 Population Density and Distribution Pattern of *B. braunerae*

The mean population density of *B. braunerae* in grasslands of Southern Western Ghats were highest during postmonsoon period least during pre-monsoon (Fig. 1).The average number of organisms observed during post monsoon season were 26.9 with standard deviation of 1.774 and the during premonsoon season was (7.1±1.553). The two way anova results showed that there was significant variation in population density of *Bilobella braunerae* between seasons ($F= 926.9509$, F crit = 3.244818; $P<0.05$) but there was no significant variation between sites ($F= 1.342581$, F crit= 1.867332; $P>0.05$).

B. braunerae exhibits a vertical distribution pattern in grassland during various seasons. In postmonsoon an average of 13.25, 8.25and 5.25 organisms were observed at 0-10cms, 10-20 cm and 20-30 cms of vertical depth of soil respectively. During mosoon, the population density of organism was lesser than postmonsoon. The organism showed vertical distribution pattern in which their number was more in 0-10 cm followed by 10-20 cms of depth of soil. A slight variation was seen during premonsoon showing vertical migration of organisms from 0-10 cm layer to 10-20 cm due to less moisture and increase in soil temperature in top layer of soil. The two way anova results showed that there was a significant variation in population density of *B. braunerae* between increasing depth ($F=7.8189$, F crit =6.94427; $P<0.05$) and between different seasons ($F=12.7638$, F crit=6.94427; $P<0.05$).

3.2 Soil Physicochemical Parameters

The physicochemical parameters of soil considered for the present study to find out the factor which affects the distribution of *B. braunerae* in each season (Table 1). The soil parameters studied were moisture, temperature, pH, OC (organic carbon), EA(exchangeable acid), EB (Exchangeable Base), Sand (Sa), Silt (Si),Clay (Cla), Nitrogen (N),Phosphorous(P), Potassium(K), Magnesium (Mg), Calcium (Ca). Soil moisture was high in monsoon followed by post monsoon and less during pre-monsoon season. It ranged from 61% -89% in different seasons. The soil temperature was at an average of 23.02°C during monsoon and 30.33°C in premonsoon season. The pH of grassland soil was slightly acidic as it ranges between 6.24-6.61in different seasons. Organic carbon content was high in grassland soil and it was above 4 in all the sites in all seasons and it ranged between 4.38-4.65. Exchangeable acid was found in the range of 73.4% to 83.9% and exchangeable base between 14.8 % to 21.4%. The soil texture was found to be sandy loam base on the percentage of sand, silt and clay. As the percentage of sand and clay is high there is absence of luxuriant vegetation and community has degraded into grassland. Nitrogen, phosphorous and potassium) content was found to be low in soil and so luxuriant vegetation was not seen. High amount of calcium and magnesium in all the seasons suggest soil is not suitable for agricultural purpose.

3.3 PCA of Soil Parameters

PCA of soil edaphic and chemical properties of soil was done to know the principal component responsible for population density of *B. braunerae* in grassland ecosystem. Principal components with eigen values >1 are considered to be the most important components. PCA of soil in premonsoon season shows five components have eigen value >1 (Table 2). When the percentages of the total variances of the five extracted principal components were accumulated they account for 85.11% of the total variance of the original data. Thus, virtually the complete variance of the original data can be attributed to these five extracted component. First PC

1 accounts for 30.656% of variance which is mainly contributed by pH, OC, sand, silt and clay (Table 3). The first principal component is strongly correlated with five of the original variables. The first principal component increases with increasing pH, OC, sand, silt and clay scores. If one increases, then the remaining ones tend to increase as well. Furthermore, we see that the first principal component correlates strongly with the pH. Here pH, clay and OC has strong positive loading. In fact, we could state that based on the correlation of 0.916 that this principal component is primarily a measure of the pH. PC 2 accounts for 19.25% variance shows strong negative loading with temperature and moderate positive loading with exchangeable acid, moisture and potassium. PC 3 with 13.62% has strong negative loading for phosphorous and moderate positive correlation for EB. PC 4 explains 11.226% of variance, is moderately correlated to potassium (0.5673)and PC 5 explains 10.70% of variance, is high positive loading for potassium (0.52963) and negative loading for exchangeable base.

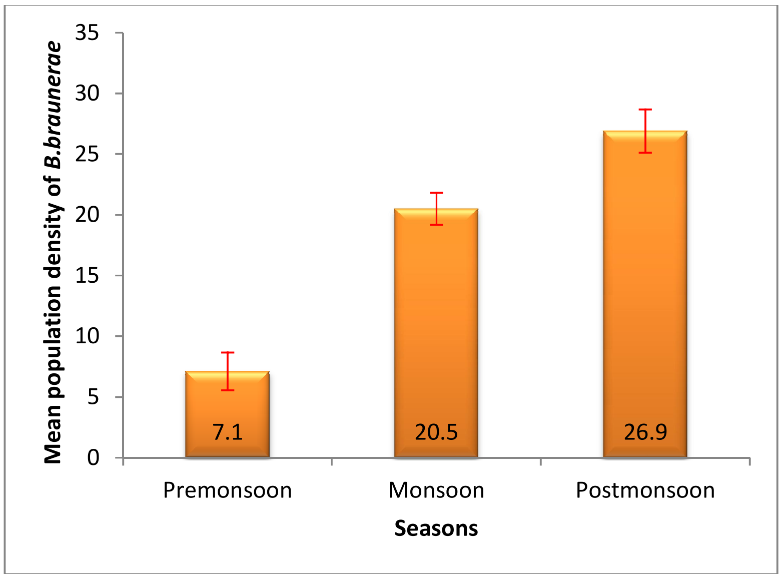

Fig. 1. Graph showing mean population density of *B.braunerae* in grassland during various seasons (25 cm^2 area)

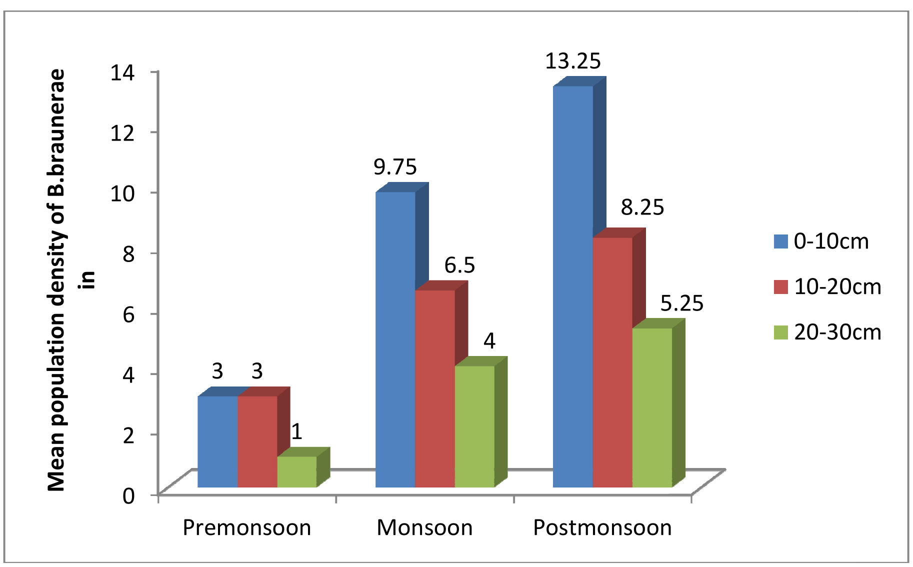

Fig. 2. Vertical distribution pattern of *B. braunerae* in Grassland during different seasons (25cm^2 area)

Table 1. Soil properties during various seasons in grassland habitat of Pachakanam (Mean ± SD)

Soil parameters	Pre Monsoon Mean±SD	Monsoon Mean±SD	Post Monsoon Mean±SD
Temperature	30.33±1.354	23.02±1.041	26.59±1.003
pH	6.61±0.0612	6.24±0.07601	6.436±0.0523
Moisture%	61.3±2.110	88.7±1.6363	82.4±2.270
Exchangeable acid%	83.9±0.0617	73.4±0.1.6465	77.1±2.1832
Exchangeable Base%	21.4± 2.2211	19.2±0.1.3984	14.8±1.1352
Sand%	69.7±2.869	74.2±1.9888	71.9±3.414
Silt%	6.96±0.2065	7.88±0.1316	7.27±0.3056
Clay %	23.3±1.636	21.1±2.685	22.9±1.7288
Organic Carbon%	4.531±0.05606	4.656±0.01577	4.389±0.0672
Nitrogen (ppm)	1034.4±4.0331	1021.3±1.885	1020.9±2.6012
Potassium(ppm)	115.9±2.3309	108.5±2.121	117±.1.8257
Phosphorous (ppm)	4.48±1.1813	4.69±0.1370	4.28±0.1549
Magnesium (ppm)	288.2±4.39	286.5±2.7588	283.3±4.0565
Calcium (ppm)	1604±2.460	1532±4.1304	1564.6± 2.2110

Table 2. Eigen value of PC in grassland during premonsoon

PC	Eigen value	%variance
1	4.292	30.65
2	2.772	19.80
3	1.979	14.14
4	1.605	11.47
5	1.265	9.037
6	0.895	6.40
7	0.577	4.120
8	0.399	2.86
9	0.214	1.53

Table 3. Principal components coefficient value of soil properties during premonsoon in grassland

Soil parameters	PC 1	PC 2	PC 3	PC 4	PC 5
Moisture	-0.18141	0.312	0.094	0.376	-0.1635
Temperature	0.00500	-0.505	0.22141	0.0325	0.0475
pH	0.4424	0.044	0.04274	-0.121	-0.0293
Organic Carbon	0.3825	0.0618	0.221	0.0619	-0.180
Exchangeable Acid	0.27281	0.398	0.2850	-0.0993	-0.145
Exchangeable Base	0.158	0.0926	0.2764	0.4817	-0.498
Sand	0.332	0.0329	0.15024	0.32944	0.3850
Silt	0.3423	0.0114	0.3340	-0.12861	0.1802
Clay	0.412	-0.0213	0.0601	0.088	0.0640
Nitrogen	-0.290	0.0713	0.304	0.368	0.0359
Phosphorous	0.178	-0.276	0.5484	0.094	0.009
Potassium	-0.1031	0.3102	0.2769	-0.125	0.530
Magnesium	0.0304	0.2124	0.3535	0.440	0.4222
Calcium	0.0351	-0.5001	-0.0394	0.333	0.1517

The percentages of the total variances of the first five principal components during monsoon in grassland account for 85.45% of the total variance. First PC 1 accounts for 30.916% of variance (Table 4) which is mainly contributed by phosphorous, magnesium, clay and pH (Table 5). Here phosphorous, magnesium, clay and pH has strong positive loading. PC 2 accounts for 19.63% variance strong positive loading with potassium and calcium. PC 3 with 16.62% has strong negative loading for silt and moderate positive correlation for organic carbon and sand. PC 4 explains 10.56% of variance, is moderately correlated to nitrogen and calcium PC 5 explains 8.36% of variance, is high positive loading for pH and exchangeable acid and negative loading for temperature.

Table 4. Eigen value of PC in grassland during monsoon

PC	Eigenvalue	% variance
1	4.328	30.915
2	2.749	19.639
3	2.324	16.603
4	1.472	10.516
5	1.171	8.365
6	0.733	5.235
7	0.670	4.786
8	0.330	2.359
9	0.221	1.579

Table 5. Principal components value of soil properties during monsoon in grassland

Soil parameters	PC 1	PC 2	PC 3	PC 4	PC 5
Moisture	-0.292	0.236	0.347	-0.034	-0.042
Temperature	-0.294	0.244	-0.068	0.350	-0.429
pH	0.3192	0.080	0.176	-0.179	0.511
Organic Carbon	-0.097	-0.039	0.480	0.3800	0.3200
Exchangeable Acid	-0.289	-0.235	0.020	-0.091	0.469
Exchangeable Base	-0.330	0.0257	-0.001	0.067	-0.027
Sand	0.033	0.3708	0.4407	-0.2212	-0.270
Silt	0.113	0.31845	-0.414	0.2944	0.248
Clay	0.333	0.20464	0.303	-0.178	-0.249
Nitrogen	0.304	0.07223	0.259	0.418	-0.063
Phosphorous	0.395	0.12214	-0.266	-0.157	-0.165
Potassium	0.0687	0.51723	-0.07761	0.3570	-0.015
Magnesium	0.3450	0.20663	0.0938	0.177	0.0287
Calcium	0.162	0.458	0.051021	0.402	-0.0330

The percentages of the total variances of the first five principal components during postmonsoon account for 80.11% of the total variance. First PC 1 accounts for 22.69% of variance (Table 6) which is mainly contributed by organic carbon, nitrogen, sand and calcium. Here organic carbon, nitrogen, sand and calcium has strong positive loading (Table 7). PC 2 accounts for 18.33% variance strong positive loading with potassium and exchangeable base. It has negative loadings for magnesium. PC 3 with 17.33% has strong negative loading for sand and moderate positive correlation for moisture and potassium. PC 4 explains 13.57% of variance, is moderately correlated to temperature and calcium PC 5 explains 10.49% of variance, is high positive loading for pH, exchangeable acid and base.

Table 6. Eigen value of PC in grassland during post monsoon

PC	Eigen value	% variance
1	3.178	22.699
2	2.565	18.322
3	2.427	17.333
4	1.900	13.573
5	1.469	10.497
6	1.158	8.276
7	0.698	4.987
8	0.487	3.482
9	0.1161	0.830

Table 7. Principal components value of soil properties during post monsoon in grassland

Soil parameters	PC 1	PC 2	PC 3	PC 4	PC 5
Moisture	0.246	0.0227	**0.439**	0.042	-0.145
Temperature	0.178	0.0707	0.080	**0.558**	0.20
pH	-0.227	0.292	-0.222	-0.152	**0.517**
Organic Carbon	**0.453**	0.113	-0.138	-0.234	0.039
Exchangeable Acid	0.207	-0.189	0.218	-0.21	**0.41**
Exchangeable Base	0.249	**0.342**	0.158	0.153	**0.445**
Sand	**0.347**	0.0431	-0.205	-0.300	0.209
Silt	0.288	-0.288	0.285	-0.127	0.392
Clay	0.1556	-0.376	-0.377	0.236	0.175
Nitrogen	0.3612	0.253	-0.225	0.1384	0.133
Phosphorous	0.251	0.292	0.0493	0.301	0.038
Potassium	0.1108	**0.404**	**0.43**	0.002	-0.071
Magnesium	0.108	**-0.45237**	0.322	0.21	0.195
Calcium	**0.315**	-0.050	-0.205	**0.469**	-0.002

4. DISCUSSION

In the present study the abundance of Collembola were greatly influenced by abiotic factors and soil properties. Their density was not always equal throughout the year. The highest mean abundance of Collembola was found in the month of October to November and lowest mean abundance was found in the month of April to May respectively. *B. braunerae* shows a vertical migration in soil during various seasons. During monsoon season to escape flooding they usually move to deeper layers wheras in premonsoon increasing soil temperature and decreasing moisture in top layer of soil compel them to move to deeper layers. Insects are all poikilothermic and their body temperatures closely related to surrounding environment. Temperature has two-fold effect on collembolans by acting directly on survival, development and indirectly through food and rainfall. When the temperature and rainfall was present good in conditions in postmonsoon then the abundance of Collembola was high. But high temperature, high rainfall greatly disturbed the abundance and density of Collembola population. There was seasonal variance of Collembola population all throughout the year. This is in agreement with other researchers that seasonal variability of micro arthropods can be extremely high, reflecting period, food supplies or environmental changes such as rainfall and temperature [23]. Among three factors rainfall are leading factors which abruptly change the number of vegetation and soil living Collembola. Because the precipitation decreased the amount of habitable air-filled pore space, which mesofauna such as Collembola rely on which gets support from Matthew et al. [24]. Collembola represent one of the most abundant groups of animal inhabiting soil and may play a dominant role in soil formation, nutrient cycling and decomposition. Collembola play an important role in plant litter decomposition processes and in forming soil microstructure. The present studies have indicated the nitrogen and organic material positively correlated with *B. braunerae* population during post monsoon season and negatively with pH. Similar with findings revealed by [25]. Low population of Collembola recorded during monsoon(June- July) indicated that low amount of organic materials. Soil arthropod population abundance in soil relies on the number of factors- biotic interactions such as competition and predation, presence or absence of organic matter, physiochemical features of the soil such as temperature, moisture, compaction and pH which change from layer to layer in soil, these factors lead in vertical stratifications and changes the vertical distribution of soil fauna [26]. Among the soil microarthropod groups, Collembola and Acari are the most often studied group, due to their high abundance and diversity, important role in key biological processes such as, catalyzing organic matter decomposition and central role in the soil food web, making them suitable organisms for soil quality indicator. Collembola are low during drought conditions because of less humidity and is the most important factor determining distribution, abundance, and survival of soil Collembola intropical forest. High predation and low organic matter also caused low population abundance of Collembola in the tropical habitat [27]. Drought appeared to have a negative impact on soil microarthropod fauna, but the effects of climate change on soil fauna may vary with the soil type [28]. [29] noted that moisture content and temperature of soil, rainfall showed significant positive correlation with the total soil micro arthropods population. Collembolans are likely to be more dependent on temperature and availability of water (soil moisture) than on food supply as they have cosmopolitan diet [30]. Low densities of *B. braunerae* during the pre-monsoon month of February to May was probably due to low soil moisture content and high soil temperature with the dry conditions. But the most important reason could be scarcity of food material. As in dry conditions the humus layer becomes dry and the growth of fungal mycelia is also retarded. The absence of fungal population in the soil may be one of the causes responsible for less number oforganism in 0-10cm layer of soil [31]. Generally, grasses and legumes affected Collembola density and diversity in spring and autumn. In the presence of small herbs the density of hemiedaphic Collembola and the diversity of Isotomidae increased in spring whereas they decreased in autumn. Increased density of collembolan is likely due to increased root and microbial biomass, and elevated quantity and quality of plant residues serving as food resources[31]. During postmonsoon season because of high organic and moisture content in 0-10 cm depth of soil density of organism was high. But towards the end of postmonsoon season that is during December to January a vertical migration was observed and more organisms were seen in 10-20 cm depth. In monsoon seen less number of *B. braunerae* was observed in 0-10 cm depth .Especially in June and July their number was very less in 0-10 cm layer and more in 10-20 cm depth. This may be due to water retainability in 0-10 cm depth due to heavy rainfall in grasslands. In conclusion there is a strong correlation between organic content, moisture, pH and collembolan population.

5. CONCLUSION

In the study it was observed that both climatic factors and soil properties have the cumulative effect on the density and distribution pattern of *B. braunerae*. Collembola population was more when organic content of soil was high during postmonsoon season which indicates their role in the decomposing process. *B. braunerae* population was highest in postmonsoon, followed by monsoon and lowest during the pre-monsoon. The seasonal variations in population were largely due to climatic changes which directly affects the soil properties and thus the distribution pattern of organism under study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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