Journal of Entomology and Zoology Studies 2018; 6(1): 1119-1125

Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(1): 1119-1125

Received: 16-11-2017
Accepted: 21-12-2017

**Md. Shahinur Islam**
Institute of Food and Radiation Biology, Atomic Energy Research Establishment, G.P.O. Box-3787, Dhaka-1000, Bangladesh

**Mosharrof Hossain**
Department of Zoology, University of Rajshahi, Rajshahi-6205, Bangladesh

**M Hossain**
Institute of Food and Radiation Biology, Atomic Energy Research Establishment, G.P.O. Box-3787, Dhaka-1000, Bangladesh

**M Yasmin**
Institute of Food and Radiation Biology, Atomic Energy Research Establishment, G.P.O. Box-3787, Dhaka-1000, Bangladesh

**Correspondence**
**Md. Shahinur Islam**
Institute of Food and Radiation Biology, Atomic Energy Research Establishment, G.P.O. Box-3787, Dhaka-1000, Bangladesh

# Impact of climatic factors and soil quality on the abundance and population density of Collembola in the Rajshahi University Campus, Bangladesh

**Md. Shahinur Islam, Mosharrof Hossain, M Hossain and M Yasmin**

**Abstract**
The present study was conducted to know the impact of abiotic factors on the abundance and density of the collembolan population in the Rajshahi University Campus from March 2012 to February 2013. A total of 3749 individuals of Collembola were collected and they were identified into three families and five species and three genera, *viz*; *Entomobyra albocincta*, *Dicranocentroides indicus*, *Seira indica*, *Lepidocyrtus lignorum, Lepidocyrtus sp* (Entomobryidae), *Salina sp*. & *Salina tricolor* (Paronellidae), and *Tomocerus sp* (Tomoceridae). Five different habitats; Open grassland, Shady grassland, Crop field margin, Roadside vegetation and Pondside vegetation were selected for the collection of Collembola. The temperature was positively correlated with abundance and density of Collembolan population ($r = 0.622$, $P<0.05$) and where relative humidity ($r = -0.114$, $P>0.05$) and rainfall ($r = - 0.06$, $P>0.05$) was negatively correlated. The abundance of soil Collembola population were indicated strong positive correlation with Organic materials ($r = 0.618$, $P>0.05$), Nitrogen ($r = 0.607$, $P>0.05$), Phosphorus ($r = 0.927$, $P<0.05$), Potassium ($r = 0.824$, $P<0.1$), Sulfur ($r = 0.663$, $P>0.05$) and very week negative correlation with Zinc ($r = -0.383$, $P>0.05$) and $P^H$ ($r = -0.301$, $P>0.05$) respectively. The highest mean abundance of vegetation dwelling collembolan was recorded in the Roadside vegetation (44.15±14.53) and lowest was in Shady grassland (11.12±4.17); however, maximum soil living Collembola was found in the Crop field margin (44±14.84) and minimum was in the Open grassland (27±8.36).

**Keywords:** Climatic factors, Collembola, Population density, Rajshahi University, Springtails, Abundance, Rainfall

## 1. Introduction

Collembola apterygote insect commonly known as springtails and are the most common ubiquitous groups of micro arthropods found predominantly in the soil and in leaf litter. There are approximately 7500~8000 described collembolan species worldwide [1, 2]. Certain species are found on grasses, in flowers and under the bark of trees [3]. Soil fauna constitute 23% of the total diversity of living organisms [4]. Among these soil fauna, Collembola is reported to dominate in most kinds of soils [5-7]. Collembola are particularly sensitive to environmental changes, and therefore thought to be an excellent bio indicator [8]. Collembolan is the generally sensitive indicator of disturbance and therefore has a value in environmental assessment. Abiotic factors are good predictors of collembolan community structure. Collembola constitute a well investigated and diverse microarthropods group which members may be affected by changes in soil conditions and vegetation cover [9-11]. Their high abundance makes them significant contributors to several processes of soil, such as material and energy cycles, and formation of soil [12]. Environmental changes such as variation in the soil moisture, precipitation, drought, global warming, soil pH and temperature are likely to cause changes in the density, diversity, survival, behavior, activity and reproduction of Collembola [13-18]. Temperature and moisture are two of the most important environmental factors affecting populations of soil-dwelling Collembola. In general, collembolan development and reproduction are so strongly regulated by temperature [17]. Many studies have proven the direct or indirect contribution of Collembola to belowground process. Many of these studies included N mineralization, soil respiration or leaching of dissolved organic carbon [19]. Environmental factors such as temperature, soil moisture, and pH commonly affect the biology of soil microarthropods [20, 21]. Soil organic matter [22- 24], relative humidity [25], soil pH [26], rainfall [27, 28] vegetation cover [29, 30] are greatly influenced the abundance and density of Collembolan community.

Only a few mentionable works in Bangladesh have been done on Collembola. Kabir *et al*. describe, 4 genera fewer than 4 families [31], Prevalence of springtail (Collembola) in the cultivated maize fields [32], Collembolan fauna of Rajshahi University Campus [33], Taxonomy of Collembola (Insecta: Apterygote) using morphological and chaetotaxy characters [34], and Abundance and habitat diversity of springtails (Insecta: Collembola) of Rajshahi City Corporation [35]. But intensive ecological and taxonomical works of Collembolan are remaining undone in our country. In the present study, seasonal variation, and population dynamics of collembolan population in the different habitats, their abundance and density against variety of abiotic factors have been investigated.

## 2. Materials and methods

### 2.1. Study area

Collembola were collected from Rajshahi University Campus area. RU is located in Rajshahi, a city in north-western Bangladesh. The geographical distribution of Rajshahi is 24° North and 89° east. It is situated in the South-Western part of Rajshahi division and lies between 24°6′ M and 25°13′ M latitude and between 44°02′ E and 49°21′ E longitude. Area of RU is 753acres/303 hector. It lies on the northern bank of the river Padma.

### 2.2. Methodology and Data collection

In this study Collembola were collected from five different types of habitats; Open grassland, Shady grassland, Crop field margin, Roadside vegetation and Pondside vegetation. Collembola were collected by Aspirator and Berlese funnel. Vegetation living Collembola was collected by Aspirator and Collembola from soil was collected by Berlese funnel. In each habitat, soil cores of 100 cm3 were collected. Collembola were preserved in 70% alcohol in vial. The monthly data of temperature, relative humidity and rainfall were collected from the field observation through the hygrometer. The data of rainfall were collected from the Meteorological center of Rajshahi. For observing the relationship of soil Collembola population with soil elements we have performed soil test from five habitats in the Soil Institute of Rajshahi and analyzed following elements, Nitrogen (%), Phosphorus (ppm), Potassium (me/100g), Sulfur (ppm), Zinc (ppm), $P^H$, and Organic materials (%).

### 2.3. Taxonomical identification

Springtails were identified at the species level according to Key [1, 36] in this study. Taxonomic classification is based on the annotated checklist of the Indian collembolan [37] and checklist of collembolan of the world (www.collembola.org/).

### 2.4. Statistical analysis

Correlation was calculated at 5% level of significance. Regression (y) calculated in the Excel 2013 in according to methodology designated by [38].

## 3. Results

The abundance and density of Collembolan population were greatly influenced by the environmental temperature, humidity and rainfall. During the study period highest temperature were recorded in the month of May (32.06 ºC on an average) and the lowest temperature were found in the month of January (16.25 ºC on an average). The greater humidity recorded in the month of August (90.28% on an average) while the minutest recorded in the month of April (72.66% on an average). During the observation period; the maximum precipitation was recorded in the month of July (10.05mm) and minimum in the month of December (0.029mm) and there was no precipitation in the month of January. The highest number of Collembola were found in the month of May (57.79±32.14) and lowest number of Collembola were found in the month of January (16.46±4.49). In the present study we observed that the high abundance of collembolan population frequently occurred from March 2012 to June 2012 (33.93±9.56, 48.40±24.92, 57.79±32.14, 45.73±24.39) and highest density found in the month of May 2012 (57.79±32.14). The low abundance occurred from the month of November 2012 to January 2013 (25.13±10.54, 22.93±12.19, 16.46±4.49) and lowest density were found in the month of January (16.46±4.49) because the temperature suddenly falls. The abundance and density of collembolan population are strong positively correlated with temperature (r = 0.622, P<0.05) and very week negatively correlated with relative humidity (r = -0.114, *P*>0.05) and rainfall (r = -0.06, *P*>0.05) respectively (Table 2). The regression line (Fig 1: [A], [B] & [C]) and Fig 3: represent the relationship of Collembola with temperature, relative humidity and rainfall.

The abiotic factors Nitrogen, Phosphorus, Potassium, Sulfur and Organic materials were positively correlated with soil Collembola population and Zinc and $P^H$ were negatively correlated. The abundance of soil Collembola population showed strong positive correlation with Organic materials (r = 0.618, *P*>0.05), Nitrogen (r = 0.607, *P*>0.05), Phosphorus (r = 0.927, P<0.05), Potassium (r = 0.824, *P*<0.1), Sulfur (r = 0.663, *P*>0.05) and very week negative correlation with Zinc (r = -0.383, *P*>0.05) and $P^H$ (r = -0.301, *P*>0.05) respectively (Table 2). Phosphorus and Potassium were significantly correlated with Soil Collembola population (Table 2). The regression line (Fig1: [D] & Fig 2: [E], [F], [G], [H], [I] & [J]) represent the relationship of Collembola with Nitrogen, Phosphorus, Potassium, Sulfur, Zinc, $P^H$ and Organic materials. Highest amount of Organic materials was found in the Roadside vegetation soil (2.51%) and lowest amount was found in the Open grassland soil (1.00%). Utmost amount of Nitrogen (0.12ppm) was found in the Roadside vegetation soil and limited (0.05ppm) was found in the Open grassland soil. Highest amount of Phosphorus and Potassium were recorded (47.3ppm, 0.93me/100g,) in the Crop field margin and lowest were (8.7ppm, 0.24 me/100g) in the Open grassland soil respectively. Maximum amount of Sulfur, Zinc and $P^H$ were recorded from the Pondside soil (7.55ppm, 8.0, 27.5ppm) and minimum amount of Zinc, $P^H$ and Sulfur were found in the Crop field margin soil (0.77ppm, 7.7) and Open grassland soil (8.8ppm) respectively. Among the surface dwelling collembolan the maximum number were recorded in the Roadside vegetation (44.15±14.53), second highest occurred in the Crop field margin (43.05±27.55) and lowest number (11.12±4.17) were found in the Shady grassland (Table 1). The highest soil living collembolan population were recorded in the Crop field margin soil (44± 14.84), Roadside (43± 14.84) soil and lowest number (27± 8.36) were recorded in the Open grassland soil respectively (Table 1). In the present study prevalence of finding species was *Entomobyra albocincta* (18.08%), *Dicranocentroides indicus* (16.06%), *Seira indica* (15.87%), *Lepidocyrtus lignorum* (13.90%) *Salina sp*

(13.26%), *Salina tricolor* (12.67%), *Lepidocyrtus sp* (5.42%) and *Tomocerus sp* (4.75%). The highest species were recorded from the Roadside vegetation (31.34%) and lowest from Shady grassland (8.40%) rest were Open grassland (26.54%), Crop field margin (17.81%) and Ponside vegetation (15.89%). The highest prevalence of *Seira indica* (58.82%), *Lepidocyrtus lignorum* (57.58%), *Tomocerus sp* (28.08%) and *Salina sp* (39.63%) were recorded in the Roadside vegetation and lowest prevalence (3.83%, 11.23%, 4.20% & 4.02%) were recorded Shady grassland habitat. The highest prevalence of *Salina tricolor* (65.26%), *Lepidocyrtus sp* (44.33%) were found in Open grassland and lowest in Pondside vegetation (3.16%) and Crop field margin (4.93%). The highest number of *Dicranocentroides indicus* (45.68%) was found in the Ponside vegetation and lowest was found in the (4.48%) in the Shady grassland. The maximum number of *Entomobyra albocincta* (38.05%) was found in the Crop field margin and lowest in Roadside vegetation (15.48%).

**Table 1:** Comparative collembola population (Mean ±SD) collected from surface vegetation and from the soil.

| Habitat | Vegetation Collembola (Mean ±SD) | Soil Collembola (Mean ±SD) |
|---|---|---|
| Open grassland | 26.45± 8.24=290 | 27± 8.36=297 |
| Shady grassland | 11.12± 4.17=122 | 28± 5.25=308 |
| Crop field margin | 43.05± 27.55= 473 | 44± 26.92=484 |
| Roadside vegetation | 44.15± 14.53=484 | 43± 14.84=473 |
| Pondside vegetation | 42.45± 21.64= 466 | 32± 10.18=352 |

**Table 2:** Correlation between Collembolan population with environmental and edaphic factors.

| Correlation | r- value | P- value | Regression equation |
|---|---|---|---|
| Collembola population with temperature | 0.622 | $P<0.05$ | y = 0.2546x+18.653 |
| Collembola population with RH | -0.114 | $P>0.05$ | y = -0.0665x+85.628 |
| Collembola population with Rainfall | -0.06 | $P>0.05$ | y = -0.0232x+4.1672 |
| Collembola population with Nitrogen | 0.607 | $P>0.05$ | y = 0.0022x+0.01 |
| Collembola population with Phosphorus | 0.927 | $P<0.05$ | y = 1.7528x-35.457 |
| Collembola population with Potassium | 0.824 | $P<0.1$ | y = 0.0370x-0.6165 |
| Collembola population with Sulfur | 0.663 | $P>0.05$ | y = 0.6498x- 3.4522 |
| Collembola population with Zinc | -0.383 | $P>0.05$ | y = -0.1354x+7.5874 |
| Collembola population with PH | -0.301 | $P>0.05$ | y = -0.0048x+7.987 |
| Collembola population with organic materials | 0.618 | $P>0.05$ | y = 0.519x+0.027 |

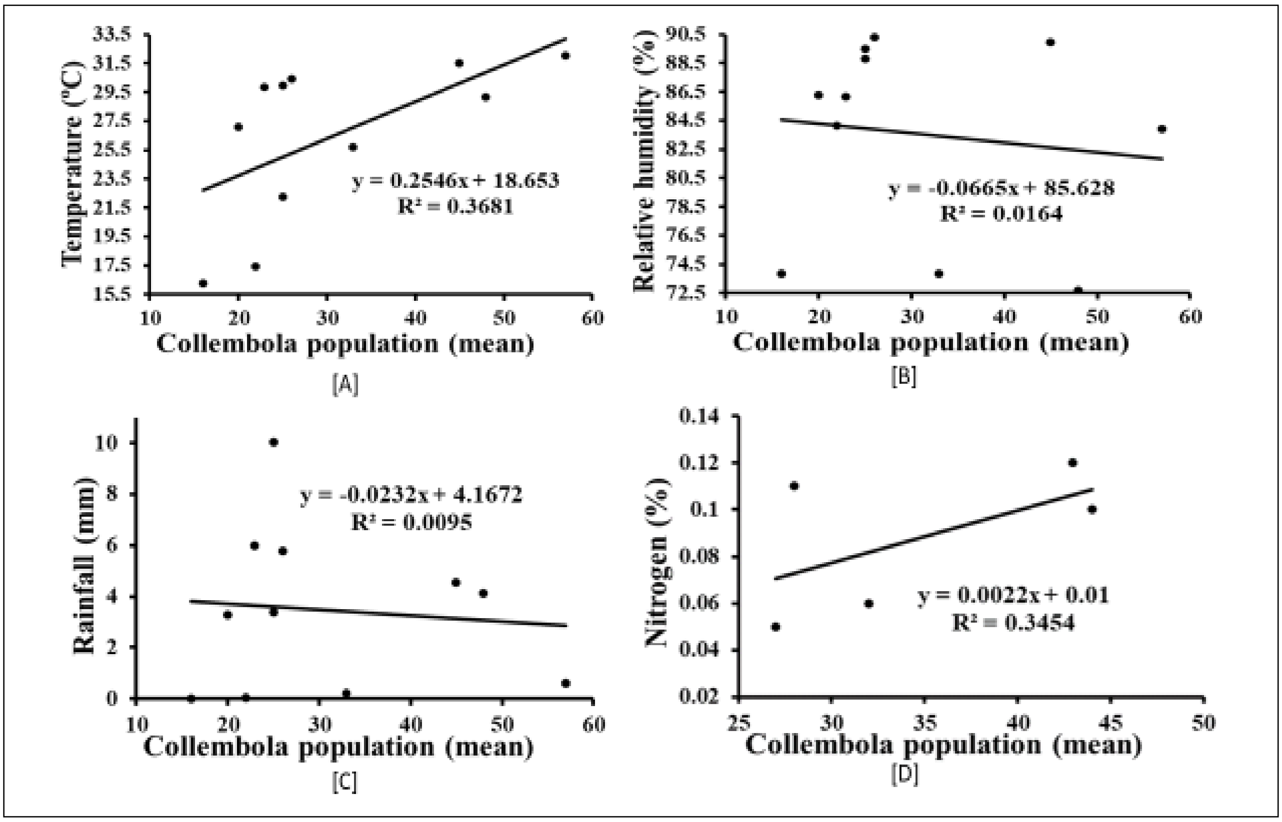


**Fig 1:** Showing the linear regression between abiotic factors (temperature, relative humidity, rainfall and Nitrogen) with Collembola population.

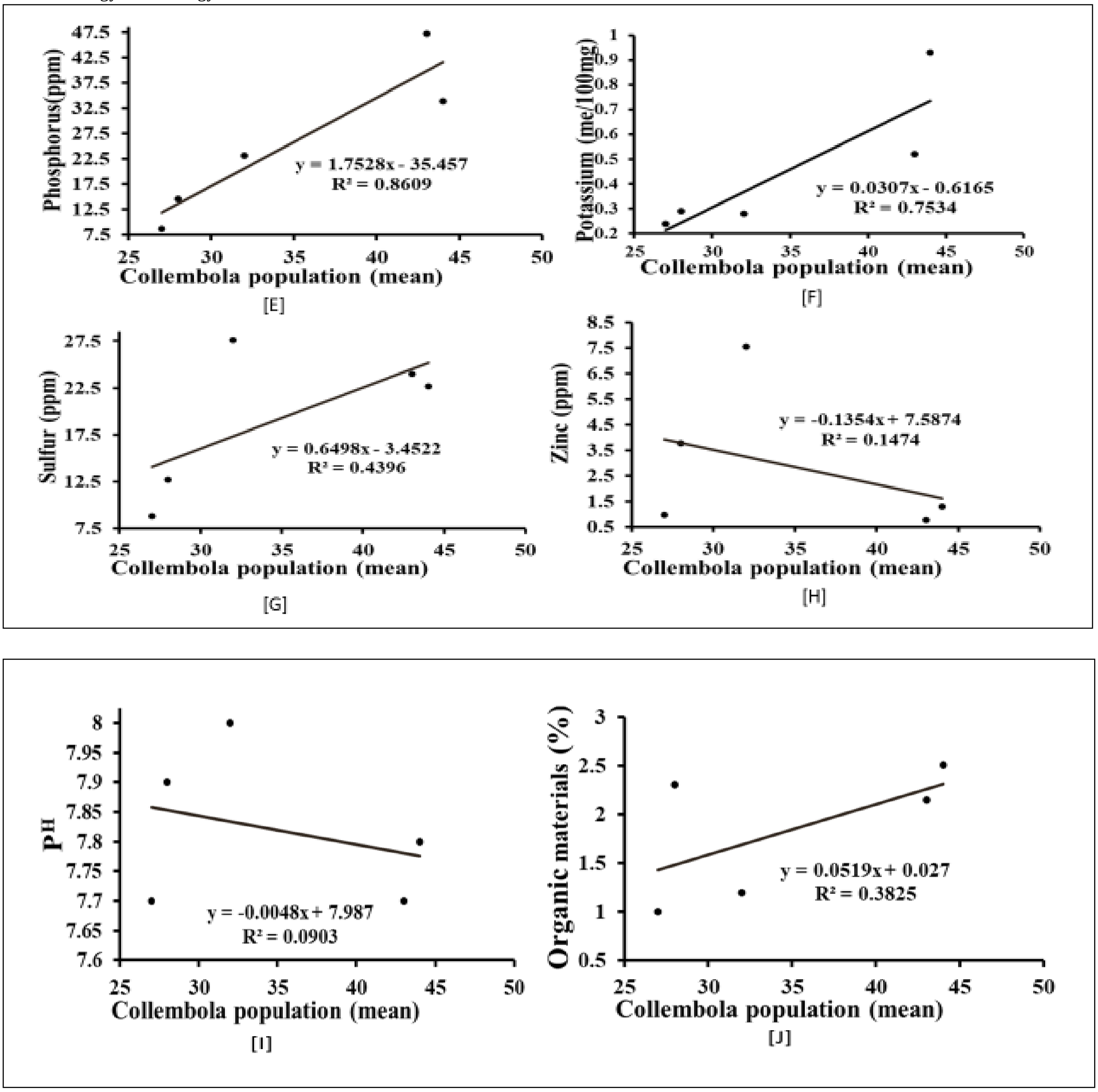


**Fig 2:** Showing the linear regression between abiotic factors (Phosphorus, Potassium, Sulfur, Zinc, P[H] and Organic materials) with Collembola population.

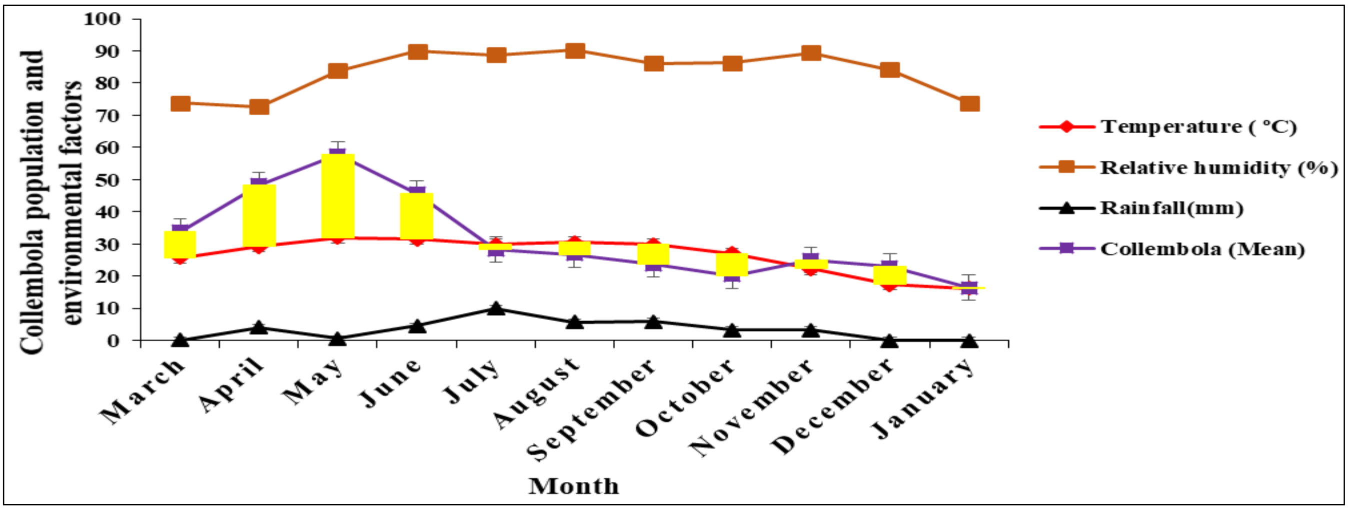


**Fig 3:** Showing the relationship between Collembola population with temperature, relative humidity and rainfall.

## 4. Discussion

Among abiotic factors, temperature and relative humidity stand out as the most important ones constraining abundance and distribution of insect. Furthermore, it is well documented that abiotic factors, especially temperature, regulate the ecology of insect communities. In the present study the abundance of Collembola were greatly influenced in response to abiotic factors and their density was not always equal throughout the year has been observed. The highest mean abundance of Collembola was found in the month of May and lowest mean abundance was found in the month of November to January respectively which gets similarity with Hossain *et al* [32]. Temperature are positively correlated with abundance of Collembola population where relative humidity and rainfall were negatively correlated with Collembola population in the present investigation. Insects are all poikilothermic, that is, they have no precise mechanism for regulating the temperature of their bodies. Their body temperatures closely related to surrounding environment. Temperature acts on insects in two-fold manners by acting directly on survival, development and indirectly through food, humidity, rainfall, wind, and atmospheric pressure. Survival is indirectly affected by extremely high humidity conditions. If the temperature, RH and rainfall was presence good in conditions then the highest abundance of Collembola exist in their niche. But high temperature with low RH, high RH with low temperature, high rainfall after high temperature was greatly disturbed the abundance and density of Collembola population. We observed that seasonally variance of Collembola population occurred in a year. Our statement agree 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 (Den linger,1980) [39]. The community responses of soil Collembola population are strongly controlled by both temperature and precipitation which gets resemblance with Jucevica and Melecis [40]. 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* [41]. 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 Collembola population and negatively with $P^H$ this investigation gets similar with findings revealed by Abbas and Parwez [42]. Low population of Collembola recorded in our study indicated that low amount of Organic materials and Nitrogen. High amount of Nitrogen and organic materials indicated that the high mean abundance Collembola in the roadside vegetation and Margin of the crop field which gets support from Christiansen *et al*. observation [43] and Dhillon and Gibson observation [44]. Choudhuri and Banerjee asserted high organic matter raising the population [45]. Zinc also negatively correlated with Collembola population and can create detrimental effect on population density which could be supported by Richard *et al* [46]. High amount of Zinc and $P^H$ indicated the lowest population of Collembola in our present findings. High amount of Zinc increases the toxicity for the soil dwelling micro arthropods. Hazra, A.K. observed the effect of $P^H$ on the insect fauna of uncultivated field suggesting that pH of soil between of 6.3-7.5 were probably ideal for most of the species [47]. Here Phosphorus, Sulfur and Potassium were positively correlated with soil Collembola population. But Scientist found that the greater diversity loss was associated with soil P, S, K, pH and percentage sand in the soil. This evidence only can be true if the application of P,S & K related fertilizer in the agricultural practice which increasing the amount of P, S & K in the soil. Otherwise it is not applicable for general habitats where agricultural practice never done. Our opinion disagree with this findings. In the present study the highest mean number of Collembola was recorded from the roadside vegetation lowest mean number was in the Shady grassland. In case of soil Collembola maximum mean abundance occurred in the cropland margin and lowest was in open grassland. The highest species of Collembola was found in the roadside vegetation and lowest species was in Shady land. The highest prevalence was *Entomobyra albocincta species* and lowest prevalence was *Tomocerus sp*. Here we also observed that without temperature and relative humidity two factors grazing and mowing of the grass in the field also influenced the abundance and density of the collembolan population. Therefore, this finding may subsidize the abundance and diversity of collembolan and their role as a decomposer and bio-indicator. Furthermore, research is prerequisite for the study of different constraints such as the soil chemistry, edaphic factors and their consequence on the diversity of soil micro arthropods in relation to soil excellence.

## 5. Conclusion

In the study we observed that both climatic factors and soil properties have the cumulative effect on the density of Collembola population. Seasonal patterns drastically influenced the both surface and soil dwelling Collembola. Surface and Soil living Collembola showed a consistent but fluctuations occurred with the changing of climate. However, Collembola population can adjust to these changes successfully. Collembola population was available with more nitrogen and organic materials content soil which indicates their role in the decomposing process. In our mediocre study, we try to evaluate the impact of abiotic factors on collembolan population density and their abundance in leaf litter and soil.

## 6. Acknowledgements

The authors expressing sincere thanks and gratefulness to the anonymous reviewers for critical and constructive suggestions on the manuscript. The authors like to thank the Chairman, Department of Zoology, University of Rajshahi for providing laboratory facilities. We also thanked The Director, Soil Test Department, Fruit Research Institute, Binodpur, Rajshahi for their soil components analysis. The first author is also grateful to the Ministry of Science and Technology, People's Republic of Bangladesh for financial support in MS thesis grant.

## 7. References

1. Hazra AK, Mandal GP. Pictorial Handbook on Indian Collembola (Part-1). Zoological Survey of India, Kolkata, 2007, 1-34.
2. Bellinger PF, Christiansen KA, Janssens F. Checklist of the Collembola of the World. Available at http://www.collembola.org. 2017.
3. Weis- Fogh T. Ecological investigations on mites,

collemboles in the soil. Natura Jutlandicae. 1948; 1:135-270.

4. Decaens T, Jimenez JJ, Gioia C, Measey G, Lavelle P. The values of soil animals for conservation biology. Eur. J Soil Biol. 2006; 42:23-38.
5. Brahmam P, Sravanthy C, Laxman P, Samatha C, Sammaiah C. Biodiversity of soil arthropods in Bt-cotton fields of Warangal, Andhra Pradesh, India. Bioscan. 2010; 5:159-160.
6. Zhu X, Gao B, Yuan S, Hu Y. Community structure and seasonal variation of soil arthropods in the forest-steppe ecotone of the mountainous region in Northern Hebei, China. J. Mountain Sci. 2010; 7:187-196.
7. Abbas MJ. Seasonal diversity of Collembola assemblages in two different habitats of Aligarh. Indian J. Fund. Appl. Life Sci. 2012; 2:18-25.
8. Hopkin SP. Biology of the Springtails (Insecta: Collembola). Oxford University Press, UK. 1997, 330.
9. Kaczmarek M. An analysis of Collembolan communities in different pine forest environments. Ekol. Polska. 1975; 23:265-293.
10. Hagvar S. Collembola in Norwegian coniferous forest soils. I. Relations to plant communities and soil fertility. Pedobiologia. 1982; 24:255-296.
11. Chauvat M, Ponge JF, Wolters V. Humus structure during a spruce forest rotation: quantitive changes and relationship to soil biota. Eur. J Soil Science. 2006; 58(3):625-631.
12. Vu QM, Nguyen TT. Micro arthropod community structures (Oribatei and Collembola) in Tam Dao national park, Vietnam. J. Bioscience. 2000; 25:379-386.
13. Loring SJ. Response of Hypogastrura nivicola (Collembola: Hypogastruridae) to variable relative humidity. Pedobiolgia. 1981; 22:167-171.
14. Bauer R, Christian E. Adaptations of three springtail species to granite boulder habitats (Collembola). Pedobiolgia. 1993; 37:280-290.
15. Wolters V. Long-term dynamics of a collembolan community. Appl. Soil Ecol. 1998; 9:221-227.
16. Pflug A, Wolters V. Influence of drought and litter age on Collembola communities. Eur. J Soil Biol. 2001; 37:305-308.
17. Choi WI, Ryoo MI, Kim J. Biology of Paronychiurus kimi (Collembola: Onychiuridae) under the influences of temperature, humidity and nutrition. Pedobiologia. 2002; 46:548-557.
18. Ke X, Yang YM, Yin WY, Xue LZ. Effects of low pH environment on the collembolan Onychiurus yaodai. Pedobiolgia. 2004; 48:545-550.
19. Filser J. The role of Collembola in carbon and nitrogen cycling in soil. Pedobiologia. 2002; 46:234-245.
20. Van Gestel CAM, van Diepen AMF. The influence of soil moisture content on the bioavailability and toxicity of Cadmium for Folsomia candida Willem (Collembola: Isotomidae). Ecotoxicol Environ Saf. 1997; 36:123-132.
21. Cassagne N, Gers C, Gauquelin T. Relationships between Collembola, soil chemistry and humus types in forest stands (France). Biol Fertil Soils. 2003; 37:355-36.
22. Mussury RM, Scalon SPQ, Silva SV, Soligo VR. Study of Acari and Collembola populations in four cultivation systems in Dourados-MS. Braz. Arch. Biol. Technol. 2002; 45:257-264.
23. Muturi JJ, Mbugi JP, Mueke JM, Lagerlof J, Mungatu JK, Nyamasyo D *et al*. Collembola density and diversity along a gradient of land-use types in Embu district, Eastern Kenya. Trop. Subtrop. Agroecosyst. 2009; 11:361-369.
24. Karoline U, Frouz J, Drapela T. Distribution patterns of Collembola affected by extensive grazing in different vegetation types. 19th World Congress of Soil Science, Soil Solutions for a Changing World 1–6 August. Brisbane, Australia. 2010.
25. Gope R, Ray DC. Seasonal distribution of Isotomina thermophilan in a secondary succession and a homegarden in Cachar, Assam. J Environ. Biol. 2012; 33:181-186.
26. Begum F, Bajracharya RM, Sitaula BK, Sharma S, Ali S, Ali H. Seasonal dynamics and land use effect on soil microarthropod communities in the mid-hills of Nepal. Int. J. Agron. Agri. Res. 2014; 5:114-123.
27. Ferguson SH, Joly DO. Dynamics of springtail and mite populations: the role of density dependence, predation, and weather. Ecol. Entomol. 2002; 27:565-573.
28. Lensing JR, Todd S, Wise DH. The impact of altered precipitation on spatial stratification and activity-densities of springtails (Collembola) and spiders (Araneae). Ecol. Entomol. 2005; 30:194-200.
29. Hansen RA. Effects of habitat complexity and composition on a diverse litter microarthropod assemblage. Ecology. 2000; 81:1120-1132.
30. Bandyopadhyaya I, Choudhuri DK, Ponge JF. Effects of some physical factors and agricultural practices on Collembola in a multiple cropping programme in West Bengal (India). Eur. J. Soil Biol. 2002; 38:111-117.
31. Kabir SMH, Ahmad M, Ahmed ATA, Rahman AKA, Haque EU, Ahmed ZU *et al* Encyclopedia of Flora and Fauna of Bangladesh Apterygota and Pterygota(Part). Asiatic Society of Bangladesh, Dhaka. 2008; 19:275.
32. Hossain M, Rahman S, Islam MS, Papia S, Faruki SI. Prevalence of springtail (Collembola) in the cultivated maize fields at Puthia Upazila, Rajshahi district, Bangladesh. Journal of Entomology and Zoology Studies. 2017; 5(1):186-190.
33. Hossain M. Collembolan fauna of Rajshahi University Campus. Journal of Life and Earth Science. 2010; 5:33-35.
34. Islam MS, Alim MA, Hossain M. Taxonomy of Collembola (Insecta: Apterogota) using morphological and chaetotaxy characters. University Journal of Zoology, Rajshahi University. 2014; 33:107-111.
35. Hossain M, Mirjahan, Faruki SI. Abundance and habitat diversity of springtails (Insecta: Collembola) of Rajshahi City Corporation. Journal of Life and Earth Science. 2012; 7:119-120.
36. Greenslade PJ. Collembola (Sprigtails). In: Insects of Australia: A Textbook for Students and Research Workers (ID Neumann ed.), Melboune University Press, Australia. 1991, 252-264.
37. Mitra SK. Chaetotaxy, Phylogeny and Biogeography of Paronellinae (Collembola: Entomobryidae). Calcutta Laser Graphics Pvt. Ltv. India. 1993, 100.
38. Prasad S. Elements of Biostatistics. 2nd edition. Rastogi publication. 2007, 236-259.
39. Linger DLD. Seasonal and annual variation of insect abundance in the Nairobi National Park, Kenya. *Biotropica.*1980; 12:100-106.
40. Jucevica E, Melecis V. Global warming affect Collembola community: A long term study. Pedobiologia. 2006; 50(2):177-184.

41. Matthew S, Turnbull, Lindo z. Combined effects of abiotic factors on Collembola communities reveal precipitation may behave as a disturbance. Soil Biology & Biochemistry xxx. 2014; 1-8.
42. Abbas MJ, Parwez H. Impact of edaphic factors on the diversity of soil micro arthropods in an agricultural ecosystem at Aligarh. Indian Journal of Fundamental and Applied Life Sciences. 2012; 2(1):1-7.
43. Christiansen K, Willson M, Tecklin I. The Collembola of Hunters cave, with a preliminary study of the micrarthropods ecology of Hunter cave. Bull. Net. Speleogical Soc. 1961; 23:59-69.
44. DhiJllion BS, Gibson NHE. A study of Acarina and Collembola of agricultural soils. Pedobiologia. 1962; 1:189-209.
45. Choudhuri DK, Banerjee S. Qualitative composition of Acari and Collembola in relation to soil organic matter-microbes complex. Orient. Ins. 1975; 9(3):313-316.
46. Richard D, Sandifer, Hopkin SP. Effects of Temperature on the Relative Toxicities of Cd, Cu, Pb, and Zn to Folsomia candida (Collembola). Ecotoxicology and Environmental Safety. 1997; 37:125-130.
47. Hazra AK. Influence of soil pH on the Collembolan fauna of two uncultivated fields of Gangetic West Bengal (In collabor). J Bioi. Sci. 1976; 19(1):19-24.