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Comparative Approach Towards the Collembolan Diversity in Different Urban Agro-Ecosystems and Their Use as Bioindicators for Soil Pollution

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KEYWORDS

Collembola, Relative Abundance, population dynamics, edaphic factor, seasonal variation

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ABSTRACT:

Introduction: Collembolans are good representatives of the diversity of soil fauna, playing a significant role in nutrient recycling and the decomposition of organic matter.

Objectives: The study evaluates the role of different edaphic factors and the diversity of the collembolan population in different agroecosystems. The inference gathered from this study may be helpful in the development of conformational strategies in agricultural practices and monitoring natural and human-impacted areas.

Methods: Seasonal soil sampling and collecting collembolans was done from November 2020 to October 2021 at four sites in Punchakari, Thiruvananthapuram. Extraction of collembolans was done, and specimens were identified using standard taxonomic keys. Relative abundance, seasonal fluctuations, and Diversity indices of the collembolan population were calculated. Correlation analysis was carried out to determine the impact of various soil Physico-chemical parameters on the population of collembolans.

Results: The Collembolan population showed irregular trends of fluctuations depending on temperature and monthly rainfall. A positive correlation can be stated between collembolan distribution and organic carbon content.

Conclusions: In light of the study's conclusions, collembolans can have their diversity examined to better understand the gradient of soil disturbances since they are reliable indicators of various farming techniques. Additionally, to safeguard soil biological communities and ecosystem resilience, alternative land use approaches for sustainable soil health management might be created.

Introduction

Soil is a highly dynamic, complex, and diverse system that supports the growth of a massive range of ecological niches. (Gardi and Jeffery, 2009) for a wide range of organisms. Agricultural practices influence the diversity, distribution and population dynamics of microarthropods. Without arthropods, most terrestrial ecosystems would rapidly collapse (Iloba and Ekrakene, 2008: Lavelle et al. 2006). Anthropogenic soil change, mainly due to land use activities, has led to biodiversity decline among soil dwellers. Land use activities repeatedly modify soil structure and chemo-edaphic variables, resulting in harmful effects on soil fauna. (Bhagawati et al. 2021).

Collembolans are soil and litter-dwelling arthropods. They are significant soil representatives of faunal diversity (Cassagne et al. 2003) and play a significant role in nutrient recycling, organic matter decomposition,

Journal of Chemical Health Risks

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and soil decomposition. In addition, because of their fast responses to numerous environmental changes, including human-induced disruptions, collembolans can be regarded as sensitive indicators among soil fauna.

There are around 8143 collembolan species worldwide, classified into 764 genera and 19 families, while the Indian Collembola fauna is represented by 301 species subdivided into 109 genera and 19 families. (Bhagawati et al. 2021). In India, only a tiny fraction of the Collembola population is documented. Studies on diversity and the distribution patterns of Collembola could serve as a potential bio-indicator of land use changes. Previous studies have noted that environmental factors influence soil arthropod distribution and diversity. The effect of environmental factors on collembolan populations is quantified in terms of species diversity and abundance.

In the present study, we evaluate the role of different edaphic factors and the diversity of the collembolan population in different agroecosystems. The inference gathered from this study may be helpful in the development of conformational strategies in agricultural practices and monitoring natural and human-impacted areas.

Materials and methods

Site description

The study was conducted on "Punchakari" (8.449077^0 N, 76.977309^{0}E), a vast area of Paddy fields, wetlands and other cultivations situated in Thiruvananthapuram, Kerala. The study site is situated very close to Vellayani Lake. The area has a highly suitable temperature with a minimum of 24°C at night, a maximum of 35°C during the day, and relative humidity of 76%. Four different sites from Punchakari was selected for the study, which includes two paddy fields and two plantain field. In each ecosystem, one follows organic cultivation (chemicals are not used), and the other follows conventional cultivation (synthetic chemicals such as fertilizer and pesticides, such as quinalphos, fipronil, spinosad etc are applied).

Collection of soil samples

From November 2020 to October 2021, soil samples were taken from each ecosystem during three seasons (pre-monsoon, monsoon, and post-monsoon). Soil collection was done at a depth of 0–10 cm using a soil sampler. After collecting the soil from the sampler, the samples were appropriately sealed, labeled, and transferred to the laboratory for Collembola extraction. Large arthropods were hand sorted and collected with the help of an aspirator. Micro-arthropods were extracted by a modified Berlese Tullgren funnel for 48-72 hrs. They were collected in collecting tubes that contained 70% ethyl alcohol. Collembolans were then observed under a stereo-zoom microscope and identified using a taxonomic key published by (Babenko et al. 1994; Christiansen and Bellinger, 1980; Prabhoo, 1971). The relative abundance and density of collembolans in each ecosystem and the seasonal variation of the overall collembolan population were calculated.

Analysis of Soil Physico-chemical Properties

For the analysis of soil parameters, soil samples were collected from each of the ecosystems during different seasons using Standard V-Method. Physico-chemical factors like soil pH (using a digital pH meter), soil temperature, soil moisture by Oven-dry method (Dowdeswell, 1959), and organic carbon content by Walkley-Black procedure (Walkley and Black, 1934) were estimated during the period of study. The Seasonal precipitation data of the prescribed study period were collected from India Meteorological Department.

Statistical Analysis

The Shannon-Wiener's diversity index (Krebs, 1999) was used to calculate the diversity of collembolans. The formula of the Shannon-Wiener's diversity index (H') used is;

$$H' = \sum_{i=1}^{S} (pi)\,(lnpi)$$

Where H' is the species diversity index, s is the number of species, and pi is the proportion of the total sample belonging to i^{th} species.

The evenness index (J') (Krebs, 1999) was calculated to determine the equal abundance of collembolans in each study site as follows:

$$J' = \frac{H'}{H'\,MAX}$$

Journal of Chemical Health Risks
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Where H´ is the observed species diversity index, and H´MAX is the maximum possible diversity index. The impact of several soil Physico-chemical parameters on the collembolan population was investigated using simple correlation.

Result

A total of 748 collembolans were collected from all the sites and identified up to the genus level. 15.6% of collembolans belonged to Site A (Conventional paddy field), where Entomobrya showed the highest and Cyphoderus showed the lowest frequency of occurrence. 28.87% were collected from Site B (Organic paddy field); Lepidocyrtoides showed the highest frequency of occurrence, followed by Isotomurus (Figure 1).

Soil Property	Conventional Paddy Field			Organic Paddy Field			Conventional Plantain farm			Organic Plantain farm		
	Pre-Monzoon	Monzoon	Post-Monzoon	Pre-Monzoon	Monzoon	Post-Monzoon	Pre-Monzoon	Monzoon	Post-Monzoon	Pre-Monzoon	Monzoon	Post-Monzoon
Density (No./m²)	33.80 ± 11.43	22.80 ± 5.80	84 ± 12.145	61 ± 13.638	37.6 ± 7.021	131.40 ± 29.66	44 ± 9.67	35.4 ± 6.92	92.2 ± 10.2	85.6 ± 17.8	47.2 ± 8.07	150.8 ± 23.6
Diversity(H')	1.78 ± 0.01	1.39 ± 0.01	1.89 ± 0.01	1.75 ± 0.01	1.54 ± 0.01	1.83 ± 0.01	1.88 ± 0.01	1.87 ± 0.01	1.97 ± 0.01	1.98 ± 0.01	1.89 ± 0.01	2.10 ± 0.01
Soil Temperature (°C)	28.33 ± 1.22	27.66 ± 1.154	29.66 ± 0.577	28.52 ± 1.31	27.68 ± 1.54	29.66 ± 0.57	30.33 ± 0.58	29 ± 1	30.68 ± 0.59	29.91 ± 0.58	29.33 ± 0.54	30 ± 0.25
Soil pH	4.6 ± 0.251	4.5 ± 0.17	4.3 ± 0.28	4.6 ± 0.08	4.5 ± 0.11	4.4 ± 0.05	5.3 ± 0.18	5.1 ± 0.08	5.4 ± 0.21	5.4 ± 0.07	5.3 ± 0.03	5.4 ± 0.05
Moisture (%)	10.94 ± 0.897	15.87 ± 0.668	12.54 ± 0.706	11.10 ± 0.832	13.76 ± 0.52	13.27 ± 0.491	7.36 ± 0.687	7.42 ± 0.563	7.35 ± 0.331	7.54 ± 0.83	8.01 ± 0.32	7.82 ± 0.54
Organic Carbon(g/kg)	5.05 ± 0.476	4.84 ± 0.446	6.06 ± 0.228	5.62 ± 0.341	4.8 ± 0.325	6.232 ± 0.134	4.18 ± 0.182	3.89 ± 0.226	5.06 ± 0.143	4.9 ± 0.312	4.13 ± 0.17	5.38 ± 0.342

Table (1) showing Species composition of Collembolans in Different Ecosystems

18.44% of the population was constituted by the collembolans collected from Site C (Conventional Plaintain farm).Here Isotomurus species showed the highest, and Pararrhophalites showed the least frequency of occurrence. 37.03% of the total specimen were collected from Site D (Organic Plantain Farm). In these, Proisotoma showed the highest and Seira showed the least frequency of occurrence (Figure.2). Collembolan population was lower in Site A & C, where Conventional farming using chemical fertilizers and pesticides was done, compared to Site B and Site D.

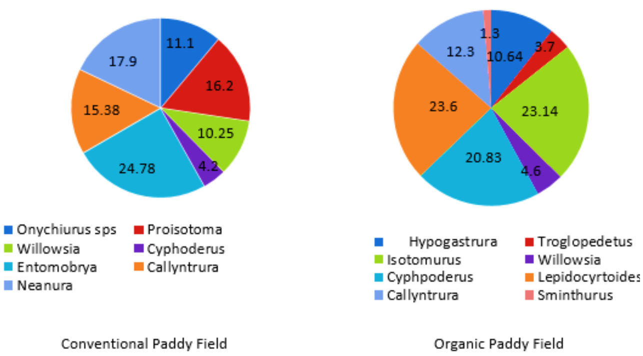

Figure 1; Pie Chart showing Relative Abundance of Collembolans in Conventional and Organic Paddy field

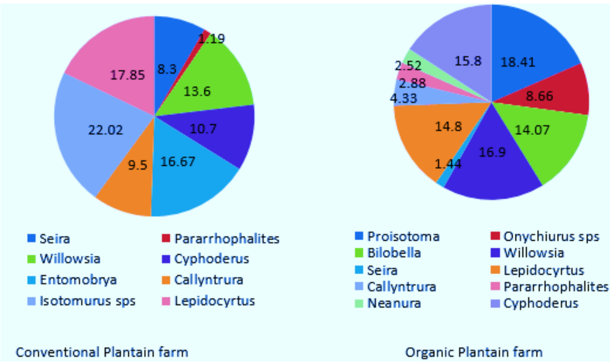

Figure 2: Pie chart showing Relative Abundance of Collembolans in Conventional and Organic Plantain farm

A total of 16 genera of collembolans were recorded from all the study sites. The species composition was found to be different in all four agroecosystems. Willowsia, Cyphoderus, and Callyntrura species were collected from all four ecosystems. However, Hypogastrura, Trogolopedetes, Sminthurus, and Lepidocyrtoides were only collected from the Organic Paddy field. Seira, Pararrhophalites, Bilobella, and Lepidocyrtus were the four genera observed in the Plantain ecosystem, of which Bilobella and Lepidocyrtus were collected only from the Organic Plantain farm. Entomobrya species were recorded in conventional Paddy field and Plantain farm, indicating their high tolerance to chemicals and pesticides .

The diversity of collembolans in all the agroecosystems exhibits a seasonal trend. The value decreased from the pre-monsoon period to the monsoon and then showed an increase from the monsoon to the post-monsoon period. Shannon-Weiner Index showed a sharp decline from pre-monsoon to monsoon in the Paddy ecosystem (Value decreased from 1.78 to 1.39 in Site A and 1.75 to 1.54 in Site B) than Plantain farms. Conversely, the value showed a sharp increase (1.39 to 1.89 in Site A and 1.54 to 1.83 in Site B) from monsoon to post-monsoon (Figure 3). Compared to Paddy ecosystems,

Journal of Chemical Health Risks
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JCHR (2024) 14(1), 1034-1040 | ISSN:2251-6727

Plantain fields exhibited only a slight variation in the index value. Evenness values were closer to one, indicating that collembolans were distributed evenly throughout all the ecosystems at all seasons (E = 0.85–0.96). The highest density and diversity were recorded in the post-monsoon period, followed by the pre-monsoon period, while lowest density was recorded during the monsoon period (fig4).

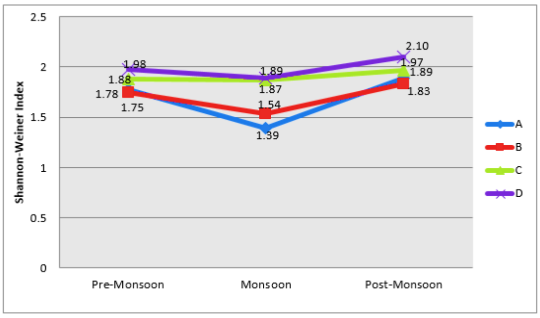

Figure 3; Graph showing Shannon-Weiner Index of Collembolan populations during different seasons

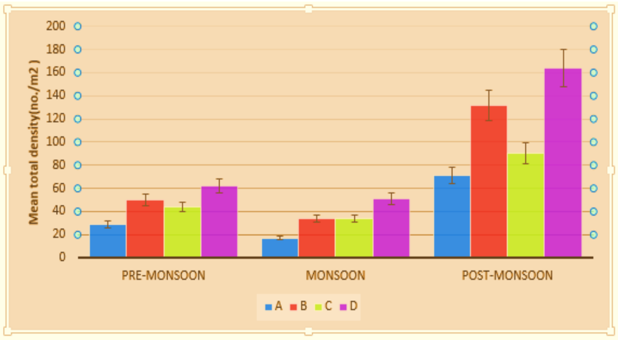

Figure 4; Graph showing Mean Total Density of Collembola in different Agro-Ecosystems

Role of Physicochemical Properties of Soil on Collembolan Density

The density of collembolans in each ecosystem was correlated with important soil chemo-edaphic factors. In all ecosystems and seasons, the density of collembolans indicated a significant positive correlation ($p < 0.05$ and $p < 0.01$) with soil moisture and organic carbon. However, except for soil ph (r = 0.905,0.878) of organic paddy field and organic plantain farm, during post-monsoon, which showed a remarkable positive relation ($p < 0.05$) with collembolan density, the other soil physicochemical characteristics were not significantly correlated.

Role of Precipitation on Collembolan Density

The Density of Collembola in each ecosystem was compared with the Season-wise Mean precipitation value. It was noted that Minimum precipitation was recorded during the Pre-Monsoon period (77.88 mm in Paddy fields and 72.38 mm in Plantain farms) and Maximum during the Monsoon period (305.03 mm in Paddy fields and 256.19 mm in Plantain farms) as shown in Figure 5 and Figure 6.

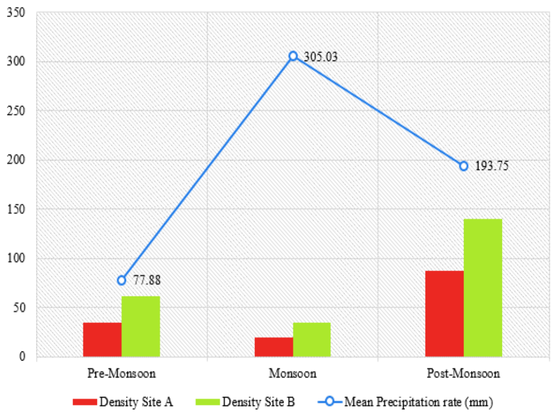

Figure 5: Graph showing Relation between Mean Precipitation rate and Mean density of Collembola at Conventional & Organic Paddy Field (Site A & B)

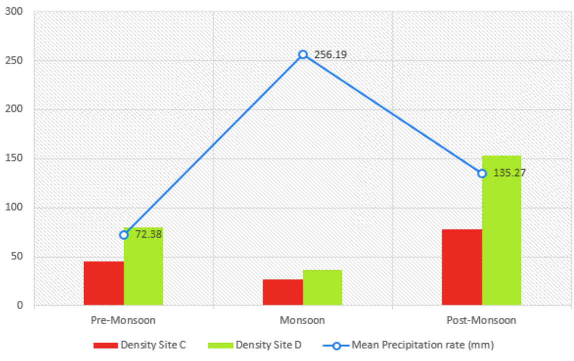

Figure 6: Graph showing Relation between Mean Precipitation rate and Mean density of Collembola at Conventional & Organic Plantain Farm (Site C & D)

From the current study, we observed that the Mean precipitation value has a negative effect on the Mean density of the Collembolan population. As the precipitation rate increase, the Collembolan density exhibits a sharp decline.

Discussion

Agricultural soil is an essential natural resource that needs careful management for various purposes such as plant cultivation, nutrient cycling, etc. Soil microarthropods are significant indicators of soil quality and productivity, mainly due to their interactions with edaphic factors. Also, the study points out that the soil at sites B and D (organic cultivation sites) included a rich composition of collembolan species compared to locations used for conventional cultivation (Sites A and C). Furthermore, the density and diversity analyses supported this finding that plantain plantations had higher densities and more diversity of collembolans than paddy fields. However, agricultural soil is often exposed to stressful disturbances such as tillage operations and thrashing, which lead the uppermost layers to dry up and the litter removed from the soil surfaces, making the ecological niche unfit for soil fauna (Singh, 2018; Fiera et al. 2020). Several studies support that organic fertilization methods in agricultural lands can produce variable effects on soil organisms, including collembolans (Gergócs et al. 2022; de Graaff et al. 2019). Adopting chemo-centric agriculture and using synthetic pesticides carelessly alter the chemical properties of soil and have a fatal impact on collembolan populations. (Tsiafouli et al. 2015; Harta et al. 2020). Temperature, optimal precipitation rates, and soil moisture during the post-monsoon enhanced the pace of decomposition of organic matter and litter, releasing carbon from the soil and creating a condition that was favorable for collembolan assemblages (Abbas and Parwez, 2020; Liu et al. 2019). The abundance of soil-dwelling collembolans was considerably affected by a temporal rise in soil temperature during the post-monsoon period (Holmstrup et al. 2018). Hazra and Bhattacharyya reported in 2003 that an elevation in the Collembola population is associated with increased soil organic matter. Since the seasonal soil samples gathered from the four study sites were mainly acidic, they may not have had a direct effect on the collembolan population (Bhagawati, 2018, 2020, 2021)

The collembolan density had a substantial positive correlation with soil moisture and organic carbon content in all four ecosystems during all seasons, which is another important finding in this study. The role of collembolans in decomposing dead organic materials may explain the link between the collembolan community and soil moisture and organic carbon concentration (Ghiglieno et al. 2020). It is also evident that the community response of the population of Collembola is strongly controlled by both temperature and precipitation (Jucevica and Melecis, 2006). Precipitation is a major factor regulating other environmental factors, such as temperature and soil moisture. The effects of precipitation on soil moisture will directly affect plant and soil organisms' water utilization. The population dynamics of collembolans collected from the paddy fields show noticeable fluctuations following the seasonal variations along with the precipitation rate (Widyastuti, 2005). Most of the conducted studies show that Changes in Precipitation can directly affect Collembolans' diversity and Community composition (Wu et al. 2020).

Collembolans have a significant ecological association with biotic and abiotic factors and often respond strongly to environmental and geographical conditions. The current study demonstrates that collembolans are useful markers of various land use practices; hence, their species richness can be investigated to comprehend the gradation in soil disturbances better. With this knowledge, sustainable soil health management approaches might be developed to safeguard soil biological populations and ecosystem stability.

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References

1. Abbas MJ, Parwez H. 2012. Impact of edaphic factors on the diversity of soil microarthropods in an agricultural ecosystem at Aligarh. *Indian J. Fundam. Appl. Life Sci*, *2*: 185-191.
2. Abbas MJ, Parwez H. 2019. Effect of habitat quality, microclimatic conditions and wastewater contamination on diversity & distribution of Collembola community. *bioRxiv* 668749.
3. Babenko AB, NM Chernova, MB Potapov, SK Stebaeva. 1994. Collembola of Russia and adjacent

Journal of Chemical Health Risks

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JCHR (2024) 14(1), 1034-1040 | ISSN:2251-6727

countries: Family Hypogastruridae. – Nauka, Moscow 336 pp..

4. Bhagawati S, Bhattacharyya B, Medhi BK, Bhattacharjee S, Mishra H. 2020. Diversity and density of Collembola as influenced by soil Physico-chemical properties in fallow land ecosystem of Assam, India. *J. Environ. Biol 41*: 1626-1631..
5. Bhagawati S, Bhattacharyya B, Medhi BK, Bhattacharjee S, Mishra H. 2018. Impact of soil Physico-chemical properties on the density and diversity of Collembola in Majulli, river island, Assam, India. *Journal of Entomology and Zoology studies 6*: 837-842..
6. Bhagawati S, Bhattacharyya B, Medhi BK, Bhattacharjee S, Mishra H. 2021. Diversity of Soil Dwelling Collembola in a Forest, Vegetable and Tea Ecosystems of Assam, India. *Sustainability 13*(22): 12628..
7. Cassagne N, Gers C, Gauquelin T. 2003. Relationships between Collembola, soil chemistry and humus types in forest stands (France). *Biology and Fertility of Soils 37*(6): 355-361.
8. de Graaff MA, Hornslein N, Throop HL, Kardol P, van Diepen LT. 2019. Effects of agricultural intensification on soil biodiversity and implications for ecosystem functioning: a meta-analysis. *Advances in Agronomy155*: 1-44.
9. Fiera C, Ulrich W, Popescu D, Buchholz J, Querner P, Bunea, CI, Zaller JG. 2020. Tillage intensity and herbicide application influence surface-active springtail (Collembola) communities in Romanian vineyards. *Agriculture, Ecosystems & Environment 300*: 107006.
10. Gardi C, Jeffery S. 2009. Soil biodiversity. European commission joint research centre. *Institute for Enviromental and Sustainability, Land Management and Natural Hazards Unit*.
11. Gergócs V, Flórián N, Tóth Z, Szili-Kovács T, Mucsi M, Dombos M. 2022. Crop species and year affect soil-dwelling Collembola and Acari more strongly than fertilisation regime in an arable field. *Applied Soil Ecology 173*: 104390.
12. Ghiglieno I, Simonetto A, Orlando F, Donna P, Tonni M, Valenti L, Gilioli G. 2020. Response of the arthropod community to soil characteristics and management in the Franciacorta Viticultural Area (Lombardy, Italy). *Agronomy 10*(5): 740.
13. Gonçalves MF, Pereira JA. 2012. Abundance and diversity of soil arthropods in the olive grove ecosystem. *Journal of Insect Science 12*(1): 20.
14. Harta I, Simon B, Vinogradov S, Winkler D. 2021. Collembola communities and soil conditions in forest plantations established in an intensively managed agricultural area. *Journal of Forestry Research 32*(5): 1819-1832.
15. Hazra AK, Bhattacharyya B. 2003. *Studies of Collembola from Agricultural fields and waste disposal sites of West Bengal with special reference to their microbial association*. Zoological Survey of India.
16. Hazra AK, Choudhuri DK. 1990. Ecology of subterranean macro and micro arthropod fauna in different degraded and polluted soil environment of West Bengal, India.
17. Holmstrup M, Ehlers BK, Slotsbo S, Ilieva-Makulec K, Sigurdsson BD, Leblans NI, Berg MP. 2018. Functional diversity of Collembola is reduced in soils subjected to short-term, but not long-term, geothermal warming. *Functional Ecology 32*(5): 1304-1316.
18. Iloba BN, Ekrakene T. 2008. Soil micro arthropods recovery rates from 0–5 cm depth within 5 months period following endosulfan (organochlorine pesticide) treatment in designated plots in Benin City, Nigeria. *Acad J Entomol 1*: 36-44.
19. Janssens F, Christiansen KA. 2011. Class Collembola Lubbock, 1870. In: Zhang, Z.-Q.(Ed.) Animal biodiversity: An outline of higher-level classification and survey of taxonomic richness. *Zootaxa*, *3148*(1):192-194.
20. Jucevica E, Melecis V. 2006. Global warming affect Collembola community: A long-term study. *Pedobiologia 50*(2): 177-184.
21. Liu Y, Wang L, He R, Chen Y, Xu Z, Tan B, Zhang J. 2019. Higher soil fauna abundance accelerates litter carbon release across an alpine forest-tundra ecotone. *Scientific reports9*(1): 1-12.
22. Prabhoo NR. 1971. Soil and litter Collembola of south India I-Arthropleona. *Oriental insects 5*(1): 1-46.

23. Prabhoo, NR. 1971. Soil and litter Collembola of south India II-Symphypleona. *Oriental Insects 5*(2): 243-262.
24. Singh J. 2018. Role of earthworm in sustainable agriculture. In *Sustainable Food Systems from Agriculture to Industry* pp. 83-122. Academic Press.
25. Tsiafouli MA, Thébault E, Sgardelis SP, De Ruiter PC, Van Der Putten WH, Birkhofer K, Hedlund K. 2015. Intensive agriculture reduces soil biodiversity across Europe. *Global change biology 21*(2): 973-985.
26. Widyastuti R. 2005. Population dynamics of microarthropods (Oribatida and Collembola) in rainfed paddy field ecosystem in Pati, Central Java. *Jurnal Ilmu Tanah dan Lingkungan 7*(1): 11-14.
27. Wu K, Xu W, Yang W. 2020. Effects of precipitation changes on soil bacterial community composition and diversity in the Junggar desert of Xinjiang, China. *PeerJ 8*: e8433.