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Evaluation of the effects of edaphic factors on population diversity of soil arthropods: A case study of Punjab (India)

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Abstract

The study assessed the soil arthropod diversity and its abundance concerning edaphic factors. The soil arthropods were collected using Tullgren equipment from two different sites, Site I (Bhogpur) and Site II (Kartarpur), from January to June 2019. Aspects such as seasonal changes and edaphic factors affect soil arthropod abundance and diversity. For example, increasing moisture content and temperature contribute to the increased abundance of arthropods from January to April, compared to May and June 2019. A total of 1373 soil arthropods were collected during the study period. Out of this, 685 individuals were collected from Site I, and 688 from Site II, respectively. In Site, I and Site II, an arthropod sequence consisting of Collembola > Acari> Coleoptera > Hymenoptera were observed. Comparative analysis of Site I and Site II revealed a non-significant difference between the orders mentioned above, with a higher diversity index of 0.799 (Site I) and 0.776 (Site II). Evenness ranged from 0.576 (Site I) to 0.56 (Site II) in the agriculture field, with a species richness value of 4. Research conducted evaluates the potential of these arthropods to serve as useful indicators of changing environmental conditions affecting agroecosystems.

Keywords: arthropods, diversity, soil, *Collembola, Acari*

Introduction

Arthropods that live in the soil play an essential role in ecological processes (Meloni *et al.*, 2020) [1]. The diversity of aboveground plants can be influenced by factors such as the type of vegetation, soil conditions, and organic matter content (Magdoff, 2018) [2]. Soil fauna also plays a critical role in the aboveground and belowground processes (Briones, 2018) [3]. Soil provides a natural habitat for organisms and helps establish and maintain various ecosystem functions. It also fills several ecological niches under the surface (Garibaldi *et al.*, 2019) [4]. Arthropods in soil litter contribute to soil nutrient cycles through nutrient mineralization and litter feeding and help create soil structures by mixing soil, creating soil openings, and producing soil aggregates (Nsengimana, 2018; Sofo *et al.*, 2020) [5, 6]. As "ecosystem engineers" and "litter transformers", soil arthropods contain fungi, bacteria, and other species, while similarly controlling the availability of resources within the soil. Organic matter is broken down by soil organisms and improves soil health and condition by providing minerals and nutrients to plants (Mekonen Ertiban, 2019) [7]. They deliver nutrients and minerals by digesting dead, decayed organisms (Bertola *et al.*, 2021) [8]. As a result, these arthropods are essential for the breakdown of complex organic compounds and the maintenance of soil productivity and fertility. Changes in plant quantity and quality and soil physicochemical features impact the variety and number of soil arthropods (Lakshmi *et al.*, 2020) [9]. The number of soil arthropod species linked with various vegetation types (crops or plants) is the most significant element in determining species diversity and a crucial ecological variable in studies of essential biotic processes and connections for biodiversity conservation (Lupardus *et al.*, 2021) [10]. Many factors determine how many species are found in soil, such as ecological diversification, density, biochemical composition, geographical extent, physiological and chemical characteristics (such as the weather and climate), efficiency, and biological interactions (Wagner, 2019) [11]. Arthropods have a very high reproductive rate and are quite diverse, which means pollutants, urbanization, industry, change, and habitat loss have only a small effect on them (Baardsen *et al.*, 2021) [12]. A lack of knowledge concerning this arthropod's abundance and diversity necessary to the soil environment is still prevalent in the Jalandhar region. With these factors in mind, the present study has been designed to understand better the seasonal variation of soil arthropods in number and diversity in Bhogpur and Kartarpur, Jalandhar, India.

Materials and methods
Study area
The research was done in Jalandhar, Punjab, India, on agriculture (Bhogpur, i.e., Site I and Kartarpur, i.e., Site II). Bhogpur is situated at 31° north latitude and 75° east longitude, with a usual elevation of 232 meters. Summers in Bhogpur are hot, humid, and clear, while winters are mild, dry, and generally clear. Throughout the year, temperatures range from 41 °F to 103 °F, with temperatures seldom dropping below 36 °F or exceeding 110 °F. Kartarpur is located at 31.407293°N, 75.5102°E, with a 235-meter average elevation. The summers are humid and hot, while the winters are mild. Summer lasts from April to June, and winter lasts from November to February. In July - August, a short period of southwest monsoon rain impacts the climate. Approximately 70 cm of precipitation falls each year.

Collection of Soil sample
The diversity of soil arthropods was assessed every month from January to June 2019. Soil samples were collected from both sites once a month. A total of 72 soil samples were taken from both locations and placed in labelled zip lock bags before being transported to the laboratory for extraction and analysis.

Physicochemical analysis of the soil
Standard procedures were used to determine soil physicochemical parameters (Wright, 1939; Sarkar and Haldar, 2012) [13, 14].

Extraction of Soil arthropods
According to (Crossley and Blair, 1991) [15], the Tullgren funnel is an integral part of the extraction process. The Tullgren funnel was invented by Berlese to gather soil arthropods from soil samples (Fenton, 1947) [16]. One 60-watt light bulb was utilized for 6-7 days as a heat and light source. We gathered the separated species in vials, subjected them to 70% ethanol and a few drops of glycerol, and then examined them using a stereo zoom microscope (Nsengimana, 2018) [5].

Soil arthropod identification
The collected species were examined for basic identification using a Stereo zoom Microscope and categorized using a variety of taxonomic keys at the order or family level (Bellinger *et al*., 1996-2022).

Statistical analysis
Shannon Diversity Index (H) and percentage Abundance were calculated along with the evenness and richness of the species (Bhagawati *et al*., 2020) [31].

Results and discussions
A total of 1373 arthropods were collected, representing three classes and four orders. At Site, I, only 685 arthropods were collected (Fig. 1), while at Site II, 688 were collected (Fig. 2). The Site I experienced the most orders for *Collembola* (51.82 %), *Acari* (45.83 %), Ground *Beetles* (1.751 %), and *Ants* (0.583 %) (Table 2). Table 2 shows that *Collembola* (51.01 %) is the most abundant order at Site II, followed by *Acari* (47.33 %), while Ground *Beetle* (1.453 %) and *Ants* (0.290 %) are the least abundant. A total of 685 arthropod species were collected from Site I, with *Collembola* accounting for the most species, followed by *Mesostigmatids*, *Oribatids*, *Coleoptera*, and *Hymenoptera*. At Site II, 688 soil arthropods were collected, with *Collembola* the dominant type with 351 species, Acari with 325 species, Coleoptera with 10 species, and *Hymenoptera* with about two species (Table 1b).
For Site, I (Table 1a)
Shannon's diversity index = 0.799, Evenness = 0.576, Richness (number of species) = 4, total number of individuals = 685 and average population size = 171.
For Site II (Table 1a)
Shannon's diversity index = 0.776, Evenness = 0.56, Richness (number of species) = 4, total number of individuals = 688 and average population size = 172.

Table 1a: Diversity index and evenness of Soil arthropods in Agriculture land (Site I and Site II)

Soil arthropods	January		February		March		April		May		June	
	Site I	Site II	Site I	Site II	Site I	Site II	Site I	Site II	Site I	Site II	Site I	Site II
Collembola	80	88	81	82	81	81	62	57	40	37	11	06
Acari	60	69	72	78	58	63	82	73	33	35	09	07
Ground beetles	07	03	-	-	-	-	05	07	-	-	-	-
Ants	-	-	-	-	-	-	04	02	-	-	-	-
Total Number of Individuals	147	160	153	160	139	144	153	139	73	72	20	13
Average Population Size	49	53.3	76.5	80	69.5	72	38.3	34.8	36.5	36	10	6.5
Shannon Diversity Index (H)	0.842	0.766	0.691	0.693	0.679	0.685	0.907	0.915	0.689	0.693	0.688	0.69
Evenness	0.766	0.697	0.998	1	0.98	0.989	0.655	0.66	0.99	0.99	0.99	0.99
Richness	3	3	2	2	2	2	4	4	2	2	2	2

Table 1b: Relative Abundance of Soil arthropods in Agriculture land (Site I and Site II)

Month, 2019	Sub-phylum	Class	Order	Superorder	Common Name	Site I	Site II
January	*Hexapoda*	*Entognatha*	*Collembola*		Springtails	80	88
	Chelicerata	*Arachnida*	*Acari*	*Mesostigmatids Oribatids*	Mite	60	69
		Insecta	*Coleoptera*		Ground Beetle	07	03
February	*Hexapoda*	*Entognatha*	*Collembola*		Springtails	81	82
	Chelicerata	*Arachnida*	*Acari*	*Mesostigmatids Oribatids*	Mite	72	78
March	*Hexapoda*	*Entognatha*	*Collembola*		Springtails	81	81
	Chelicerata	*Arachnida*	*Acari*	*Mesostigmatids Oribatids*	Mite	58	63
April	*Hexapoda*	*Entognatha*	*Collembola*		Springtails	62	57
	Chelicerata	*Arachnida*	*Acari*	*Mesostigmatids Oribatids*	Mite	82	73
		Insecta	*Coleoptera*		Ground Beetle	05	07
		Insecta	*Hymenoptera*		Ants	04	02
May	*Hexapoda*	*Entognatha*	*Collembola*		Springtails	40	37
	Chelicerata	*Arachnida*	*Acari*	*Mesostigmatids Oribatids*	Mite	33	35
June	*Hexapoda*	*Entognatha*	*Collembola*		Springtails	11	6
	Chelicerata	*Arachnida*	*Acari*	*Mesostigmatids Oribatids*	Mite	9	7
					Total	685	688

Table 2: Percentage abundance of Soil Arthropods in Agriculture land (Site I and Site II) during January-June, 2019

Soil Arthropods	Agriculture land (Site I) Number of species	Percentage	Agriculture land (Site II) Number of species	Percentage
Collembola	355	51.82	351	51.01
Acari	314	45.83	325	47.23
Ground Beetles	12	1.751	10	1.453
Ants	4	0.583	2	0.290
	Total=685		Total=688	

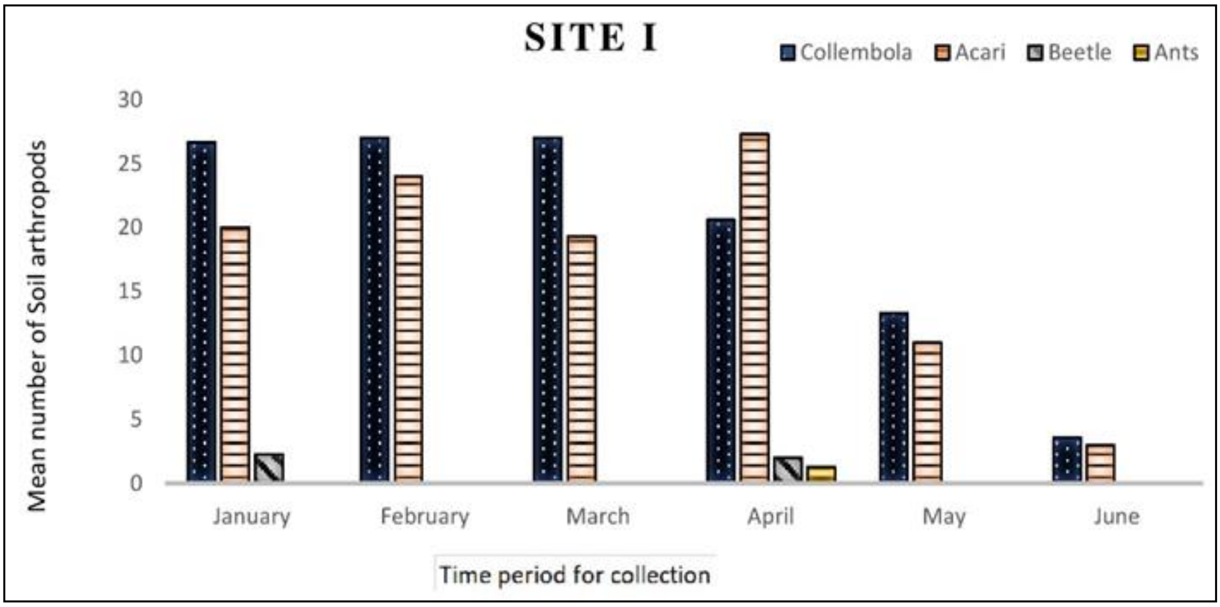

Fig 1: This bar graph represented the number of arthropods from the study area (Site I) for six months (2019)

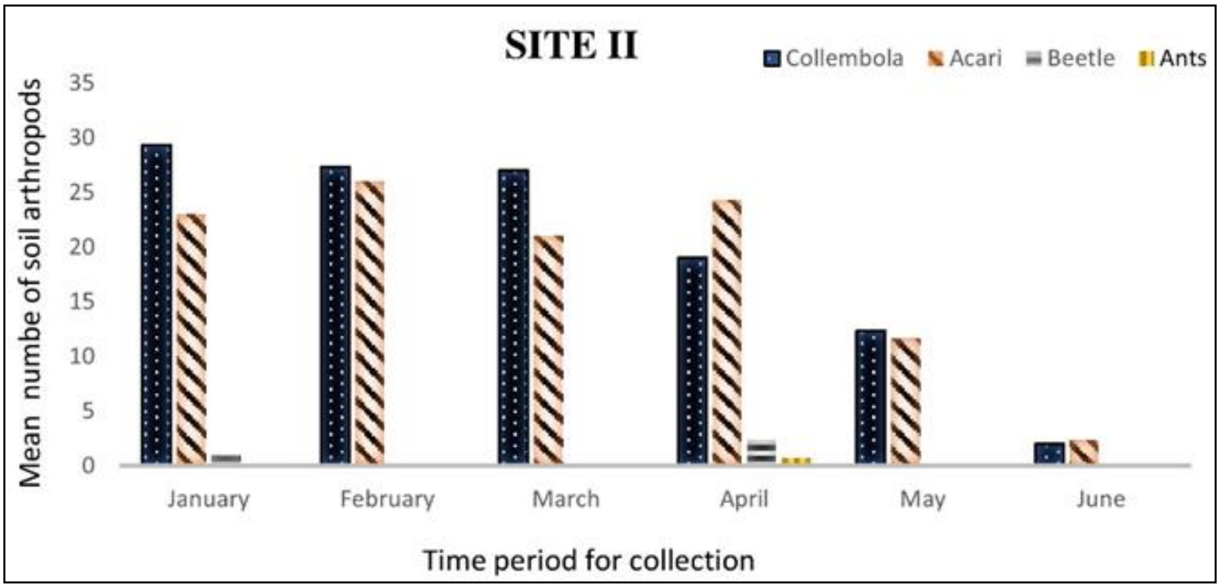

Fig 2: This bar graph represented the number of arthropods from the study area (Site II) for six months (2019)

Discussion

Arthropods in soil are affected by various factors, including climate change, soil pollution, tillage processes, herbicides and pesticides, and other grazing management practices. Arthropods in the soil are indicators of soil health and fertility, and their presence has direct effects on plant productivity (Mahdi *et al*., 2017) [17]. Numerous studies have demonstrated that the richness and diversity of soil habitats disturb the abundance and diversity of soil arthropods (Esenowo *et al*., 2017) [18]. We can infer from the differences in the number of soil arthropods from both the sites of agricultural land that agricultural areas attract more soil arthropods and create an appropriate environment (Table 1b). There were commonly *Collembola* in agricultural land, followed by *Acari, Beetles, and Ants*. The *Collembola* is a significant bioindicator of the health of the soil and is easily affected by changes in soil habitat (Fusaro *et al*., 2018) [19]. The majority of collembola are carnivorous, feeding on fungi hyphae, dead organic matter in the soil, and decaying organic material (Fusaro *et al*., 2018) [19]. *Collembola* and *Acari* contain nearly all soil arthropods, as they flourish in all tropic levels of the soil's belowground detritus food web (Liu *et al*., 2016) [21]. The soil microarthropods included in the present study were *Collembola*, the most abundant and dominant species over *Acari, Coleoptera, Hymenoptera*, etc. (Table 1a & 1b). Studies have shown that the *Collembola* and *Acari* species displayed a reliable and similar pattern of seasonal variations (Bhagawati *et al*., 2018; Bhagawati *et al*., 2020; Esenowo *et al*., 2017; Fusaro *et al*., 2018) [20,, 31, 18, 19]. Several factors contribute to the density of soil arthropods, such as soil pH, temperature, and food availability (Abbas and Parwez, 2020; Bhagawati *et al*., 2020) [25, 31]. According to studies on soil arthropods, both population abundance and diversity are affected by edaphic factors and seasonal changes. A higher Collembolan diversity revealed more species diversity at Site I & II (Fig. 1 & 2) throughout all seasons, indicating finely distributed individuals of different species (Esenowo *et al*., 2017) [18]. The present findings are in accordance with the work of (Bhagawati *et al*., 2018) [20], that the presence of higher moisture content and temperature conditions, which accelerate the amount of organic material and litter decomposition and provide a preferable environment, may explain the increased diversity of *Collembolans* and *Acari* from January to April, particularly when compared to May and June 2019 (Bhagawati *et al*., 2018; Bhagawati *et al*., 2020) [20, 31]. As the soil's organic matter and moisture content change, it, directly and indirectly, affects the microbe community by improving the soil interaction, monitoring humification, and fostering macro- and microflora development. The monthly variation of arthropod diversity revealed that the highest density was recorded in April, January, February, and March, followed by May, and the lowest density was recorded in June 2019 (Table 1a). In soil collected in May and June 2019, soil-litter arthropods were found in low abundance and diversity (Table 1b). Low abundance and diversity may be linked to land use management. We found that the most critical condition during May and June is hot and dry during field data collection. Although fertilizer application is essential for increasing crop yields, it impacts soil qualities by changing the biodiversity and amounts of leaf litter, which changes the diversification and concentration of soil fauna populations. Soil-litter arthropods are sensitive to changes in soil physicochemical composition caused by chemical fertilizers due to their great relationship with soil nutrient levels. *Collembola* and *Acari* were plentiful in soils and were collected at the sampling site (Fig. 1 & 2). The feeding activities of soil arthropods substantially affect the functioning of decomposer flora. They are the primary mechanism for releasing nutrients contained in waste material. Collembola, Mites, Millipedes, Pseudoscorpions, Isopods, Centipedes, Symphyla, Diplura, Protura, Hymenoptera, and larvae of numerous more orders are commonly found among the soil arthropods. Acarina and Collembola dominate the landscape of every continent in terms of arthropod variety and abundance (Liu *et al*., 2016; Chown and Convey, 2016; Schuster *et al*., 2019) [21, 22, 23]. According to scientists, Acari's dominant position in the soil is due to their physiological and morphological adaptive responses. Acari mites have sclerotized exoskeletons, a wide range of feeding preferences, and a long lifespan, with an average life expectancy of several months to two years from the time of hatching to adulthood. Springtails have a rapid reproductive rate and can produce multiple generations over a year, explaining why they are so prevalent in the soil environment (Abbas and Parwez, 2020; Shakir and Ahmed, 2014) [25, 33]. The temperature of the soil affects the spread of soil arthropods. As the temperature rises, the number of soils microarthropods falls as soil arthropods migrate to the deeper layers of the soil profile (Menta and Remelli, 2020) [28]. Thus, a rapid increase in soil temperature and moisture led to decreased soil arthropods (Shakir and Ahmed, 2014) [33]. Mites and collembolans are among the arthropods that have great potential as bioindicators of our environmental conditions, particularly land use intensification. Approximately 72 to 97 % of the arthropods found on Indian soils are mites and collembolans (Kumar and Singh, 2016) [24], and this work is similar to our findings where we found 97% of Collembolans and Mites taken together (Table 2). Several types of Acari include parasitoids, predators, fungal feeders, parasites, dead plant feeders, algal feeders, root feeders, bacterial feeders, scavengers, and omnivores. In addition to feeding on a wide variety of organisms in the system, Acarina can catalyze microbial activity in the soil and decompose organic matter. Acarine is required for decomposition and nutrient cycling. Collembola plays an important role in the decomposition of organic matter, the cycle of nutrients, and the formation of soil and influencing the fungi. Although collembolans are comparable to oribatids, their ecological roles are different. They are primarily fungivores and detrivores; as a result, collembolans can adapt more quickly to ecosystem disruptions than oribatids (Menta and Remelli, 2020) [28]. The collembola and acari were relatively abundant (Table 2), whereas the other two groups were scarce and did not appear in most of the collections made during the different months. The findings of (Abbas and Parwez, 2020; Bhagawati *et al*., 2018; Bhagawati *et al*., 2020; Chown and Convey, 2016; Dey and Hazra, 2021; Kaur and Sangha, 2020; Krishnapriya and Binoy, 2020; Kumar and Singh, 2016; Liu *et al*., 2016; Menta and Remelli, 2020; Shakir and Ahmed, 2014; Uthappa and Devakumar, 2021) [25, 20, 31, 22, 29, 27, 32, 24, 21, 28, 33, 26] follow this observation.

Conclusion

The research indicates a higher diversity of species and density of collembola and acari, including both Jalandhar, Punjab sites. Furthermore, based on the findings presented above, it can be concluded that soil moisture and temperature played critical roles in regulating the abundances and variety of arthropods, particularly *Collembola* and *Acari* since they demonstrated a high positive and significant association with these populations. The seasonality changes, soil physicochemical features, land-use categories, and land-use types all influenced soil arthropods' population abundance and dynamics. The month of January through April recorded the most significant number of individuals compared to May and June. Soil arthropods differed according to the season in terms of diversity, richness, abundance, and evenness. Arthropods play a significant role in the trophic interactions of soil biota, which control soil nutrients available for plant growth.

Furthermore, they are vital for the breakdown of plant litter and the formation of soil microstructure. More extensive studies on *collembolan* and *acari* fauna documentation using molecular and conventional taxonomy are needed to aid in the digital encoding file on the diversity of arthropods in North India. This understanding will be crucial to designing a sustainable production system.

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Author Contributions

The published version of the manuscript has been read and approved by all the authors.

Conflicts of Interest

The authors declare no conflict of interest.

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