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Edaphic arthropod diversity in intensive sugarcane production systems in North Western India

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Abstract

The diversity of soil arthropod fauna from sugarcane fields from four districts of Punjab *viz.*, Gurdaspur, Shaheed Bhagat Singh Nagar (SBS) Nagar, Patiala and Fazilka was studied during the year 2016 and 2017. A total of five orders of soil arthropods were extracted. At one inch sampling depth, the locations in decreasing order of abundance were SBS Nagar (35 %) > Fazilka (24 %) > Patiala (21 %) > Gurdaspur (20 %). At three inch sampling depth, locations in decreasing order of abundance were SBS Nagar (32 %) > Patiala (21 %), Gurdaspur (23 %) > Fazilka (22 %). Among the soil arthropods, Coleoptera had highest numerical abundance followed by Acarina, Collembola, Hymenoptera and Diptera at one inch sampling depth. However, at three inch sampling depth, order Hymenoptera had highest numerical abundance followed by Acarina, Coleoptera, Diptera and Collembola. Overall diversity index showed that at one inch depth, diversity of soil arthropods was maximum at SBS Nagar (0.67) while minimum diversity was recorded at Patiala (0.64). At three inch depth, maximum soil arthropod diversity was observed at Gurdaspur (0.62) while minimum diversity was observed at SBS Nagar (0.57).

Keywords: soil arthropods, diversity, collembola, sugarcane

Introduction

Soil arthropods are invertebrates having jointed legs, can be microscopic or quite large. They perform different functions in the soil community. They can be classified into micro arthropods (0.2-2 mm) and macroarthropods (>2 mm). Soil arthropods primarily fall under Class Insecta (Protura, Diplura, Collembola and larger insects), Class Myriapoda (Symphyla and Paupoda), Class Crustacea (Tardigrada, Copepoda and Isopoda) and class Arachnida (Pseudoscorpiones, Araneae and Acari) (Sharmilla Roy *et al.* 2018)^[17]. In terms of number of individuals and species, the most abundant soil micro arthropods are Acari (mites) and collembolans (springtails). Soil arthropods primarily facilitate nutrient acquisition, regulate flow of nutrient through decomposition, mineralization, immobilization. They breakdown organic matter which can influence soil structure further affecting water availability and modify plant health (Swift *et al.* 1979; Hunt and wall 2002)^[18, 9]. Soil arthropods in sugarcane ecosystem are affected by soil type and cultural practices (Eg Ants; Ali *et al.* 1986; Saad *et al.* 2017); irrigation pattern affecting soil moisture regime (Rana *et al.* 2006)^[15]; fire i.e. burning of trash prior to harvesting and pesticide usage pattern (Pasqualin *et al.* 2012; Benazzi *et al.* 2013)^[13, 4] and resource availability, soil pH, disturbance, climatic factors (Bini *et al.* 2016)^[5]. Soil arthropods play critical role in soil food web, thus serve as a useful monitoring tool for biological intervention and effective functioning of soil ecosystem. Sugarcane receives high dosages of fertilizers and also a considerable number of pesticides (foliar/soil as emulsifiable concentrates and granular formulations) are applied by the farmers. The inputs are being added irrespective of the faunal richness of soil. There is need to document the below ground diversity of the arthropods to develop fertilizers/insecticide application schedules commensurate with arthropod richness and abundance at different locations. Also since granular applications are done at planting stage, the role of soil fauna in degradation of the chemicals is an important concern. There is an ardent need to study soil arthropod diversity and dynamics in the context of maintenance of soil health and regulation of sugarcane production systems for soil quality improvement. The present study envisages documenting the soil arthropod diversity in intensively cultivated high input sugarcane production systems practiced in North Western India.

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Materials and methods

Study sites

The study was carried out in sugarcane fields at four districts of Punjab viz., Gurdaspur, SBS Nagar, Patiala and Fazilka covering three important agro-climatic zones where sugarcane is cultivated extensively (Table 1). The spots for sample collection were carefully chosen (though random) such that

areas being close to the field bunds were avoided. Samples were collected with fields neither too dry nor too wet. The present study was conducted during the period of April to October for two consecutive years 2016 and 2017. These months were chosen because maximum fertilizer/insecticide applications take place during this phase.

Table 1: Field statistics for soil samples collection areas

Location	Agroclimatic zone	Latitude	Longitude	Altitude (feet)	Geographical area (sq. km)	Major Soil type	Soil texture
Gurdaspur	Sub-mountain undulating zone	32.033°N	75.5167°E	793	3513	Reddish chestnut and tropical arid soil	Clayey
SBS Nagar	Undulating plain zone	31.8°N	76.70°E	839	1267	Reddish chestnut, tropical arid brown soil (weakly solonized)	Loamy sand to sandy loam
Patiala	Central plain zone	30.32°N	76.40°E	820	3218	Tropical arid brown	Sandy loam to clayey
Fazilka	Western plain zone	30.403°N	74.025°E	597	3113	Desert soil	Sodic and saline

Sampling method

Soil samples were collected during the active growing season of sugarcane at fortnightly intervals from all the locations with the help of tube auger from two depths i.e. 1 inch and 3 inch. The samples were taken in 'W' pattern from the fields (one acre) randomly from fifty spots/field. It was ensured that the soil samples were devoid of any crop residues or weeds. Uniform soil with adequate moisture was collected to avoid desiccation. The collected samples were packed in a polythene bags and were taken to the laboratory for invertebrate extraction, identification and further analysis.

Extraction and preservation

Soil arthropods are both photophobic and hydrophilic. This knowledge makes the Berlese funnel extraction apparatus suitable for use to extract the soil arthropods. The field collected samples from all locations were cleaned for any crop residues/weeds. The samples were kept in the Berlese funnel for 24 hrs (Fig.1). The apparatus consisted of a light source (60-Watt incandescent bulb) situated at the top and a soil containing funnel (240 mesh) which is fitted at the bottom. At the narrow mouth end of the funnel, a glass container with 70 per cent ethyl alcohol is placed which acts as a receptor for the arthropods. The soil arthropods are photophobic and hydrophilic thus the light generated from the bulb diverts them to move downwards and fall into the alcohol containing container. After the extraction is complete the samples were labeled and kept for further assessment. The sorting of soil arthropods into their major groups was done by using the binocular microscope (under 40 x magnification). The arthropods extracted were categorized based on the diagnostic characteristics of the order or family to which they belonged and total number of each one was recorded.

Statistical analysis

The total number of specimens collected was counted order wise for each depth (1 inch & 3 inch) at each sampling date. This was done for fortnightly intervals and for the period of seven months across the locations. The data recorded was analyzed to calculate (i) Percentage seasonal abundance for the whole season across the locations (ii) Proportion of the arthropods belonging to a order across the locations (iii) Monthly variation in arthropods at 1 inch and 3 inch depth

across locations (iv) Diversity indices (a) Shannon-Weiner Index (b) Pielou Evenness Index

The Shannon-Weiner's diversity index (Shannon and Weiner 1963) was used to calculate the diversity of soil invertebrates collected.

$$\text{Shannon Weiner's index } (H') = -\sum p_i \log_e p_i$$

Where, p_i = proportion of individuals of species i (n_i/N)

n_i = number of individuals in the i^{th} species

N = total number of individuals of all the species

The evenness index (Pielou 1966) was calculated to determine the equal abundance of soil

Invertebrates in each study site as follows:

$$\text{Evenness index } (J) = H' / \log_e S$$

Where, H' = Shannon Weiner's index

S = number of species

Results and Discussion

The fauna composed of 5 taxa of phylum arthropoda in four districts of Punjab. During the present study period, a total of 1007 specimens of soil arthropods [2016 & 2017] were extracted from collected soil samples from sugarcane fields at different locations of Punjab. However, only 891 were considered true soil inhabitants. Insects belonging to the orders Thysanoptera, Homoptera, Diptera and Hymenoptera (except Family Formicidae) were excluded in the analysis due to their life behavior. The taxa collected in this study belonged to Hymenoptera, Acarina, Collembola, Coleoptera and Diplura. Among the soil arthropods Hymenoptera was the most predominant group followed by Coleoptera whereas other groups were comparatively less in number. The locations in decreasing order of numerical abundance were SBS Nagar > Fazilka > Patiala > Gurdaspur. At one-inch sampling depth, the locations in decreasing order of abundance were SBS Nagar (36 %) > Fazilka (23 %) > Patiala (22 %) > Gurdaspur (19 %) (Fig.1). However, at three-inch sampling depth, locations in decreasing order of abundance were SBS Nagar (32 %) > Patiala (25 %) > Fazilka (23 %) > Gurdaspur (19 %) (Fig.1).

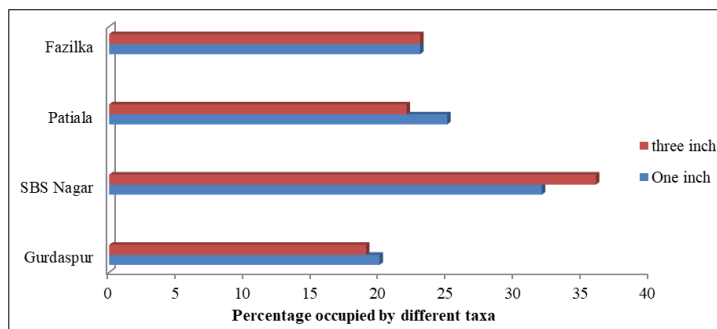


Fig 1: Collective soil arthropod abundance at varying depth across different locations of Punjab (2016-17)

At one inch sampling depth, maximum number of coleopterans, collembolans, acarina and hymenopterans were found in SBS Nagar (Fig. 2). At three inch sampling depth, maximum number of collembolans, acarina and hymenopterans were found in SBS Nagar (Fig. 3). Use of insecticides for the management of arthropods also influences the abundance and diversity (Bini *et al.* 2016) [5]. At SBS Nagar, chlorantraniliprole 18.5 SL was used which is a green chemistry molecule, thus explaining the higher abundance and diversity.

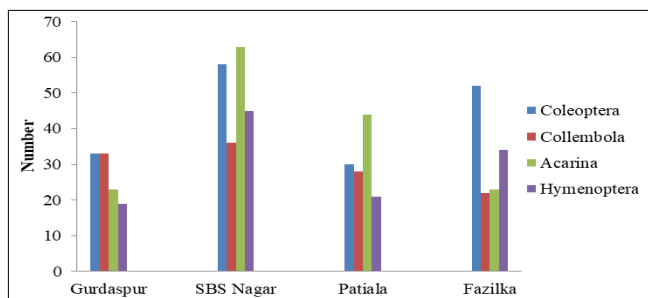


Fig 2: Number of different taxa at one inch sampling depth across different locations of Punjab (2016-17)

Diversity was more at one inch depth as compared to three inch depth across all the locations. Adis *et al.* (1987) [1] found 77 per cent of arthropods in uppermost layer (3.5 cm depth), 15 per cent below humus layer (3.5-7.5 cm depth) and only 8 per cent in 7-14 cm depth. Overall diversity index showed that at one inch depth, diversity of soil arthropods was maximum at SBS Nagar (0.67) while minimum diversity was recorded at Patiala ($H^2=0.64$) (Fig. 4). At three inch depth, maximum soil arthropod diversity was observed at Gurdaspur (0.62) while minimum diversity was observed at SBS Nagar (0.57). Species were more evenly distributed at Gurdaspur ($J=0.94$) followed by Fazilka (0.93) at one inch depth. Similarly, at three inch depth highest evenness index was recorded at Gurdaspur ($J=0.88$) followed by Patiala ($J=0.83$) (Fig. 5).

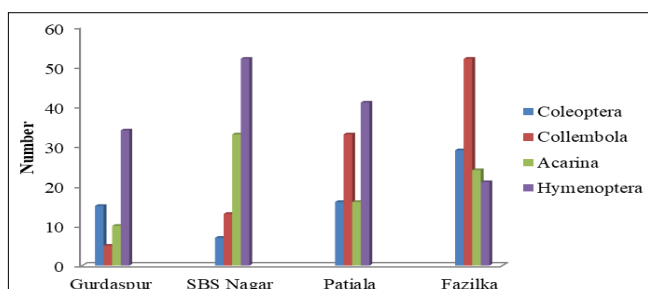


Fig 3: Number of different taxa at three inch sampling depth across different locations of Punjab (2016-17)

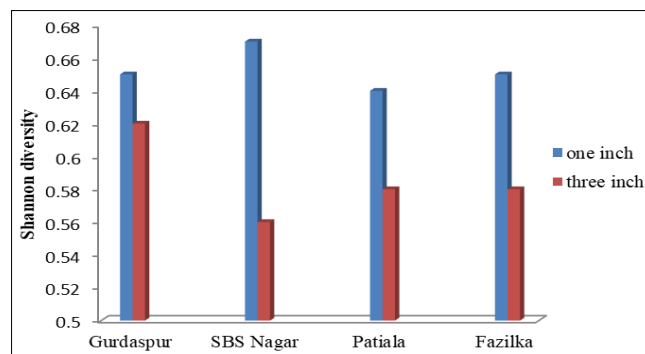


Fig 4: Soil arthropod diversity across different locations at one inch and three inch sampling depth (2016-17)

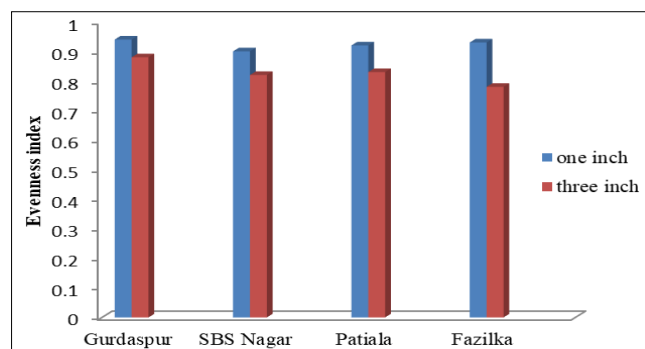


Fig 5: Evenness index of soil arthropods across different locations at one inch and three inch sampling depth (2016-17)

Seasonal abundance of soil arthropods at one inch and three inch depth across different locations

The total soil arthropod population showed fluctuations from month to month during the period of study. Bhattacharya and Bhattacharya (1987) [3] observed that rainfall and soil moisture were the major factors affecting the temporal variation in the micro arthropod abundance. Abundance of soil arthropods were more at one inch sampling depth as compared to three inch depth. At one inch sampling depth, maximum population of soil arthropods was observed during August at Gurdaspur (Fig 6) and Fazilka. At rest of the locations, maximum population of soil arthropods was observed during September (Fig 7, 8). Mahajan and Singh (1981) [11] found higher population of Collembolans during monsoon months (July-September) when soil temperature was low but soil moisture was high. Similarly, Banerjee (1982) [2] observed irregular fluctuations in the composition of oribatid mites; higher in July-August, lower in May and constant in December-January. Higher population of soil arthropods (at 1 inch depth) was observed at Gurdaspur during August owing to comparatively milder climate (lower mean temperature, Relative Humidity high) and higher moisture content of soil

(being clayey the soil at Gurdaspur has higher moisture retention capacity). However, at other sites soil was light textured with low moisture retention ability.

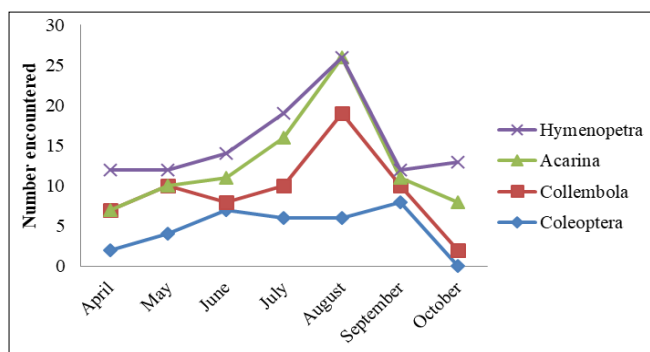


Fig 6: Seasonal abundance of soil arthropods at one inch sampling depth at Gurdaspur (2016-17)

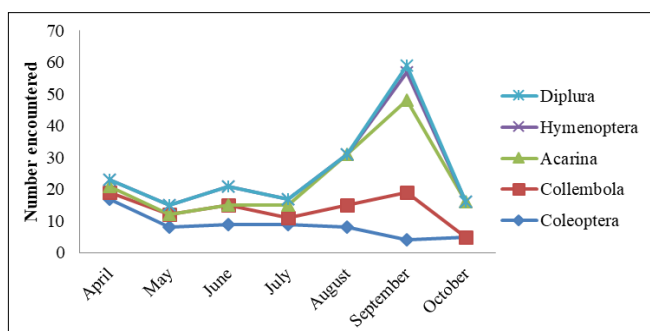


Fig 7: Seasonal abundance of soil arthropods at one inch sampling depth at SBS Nagar (2016-17)

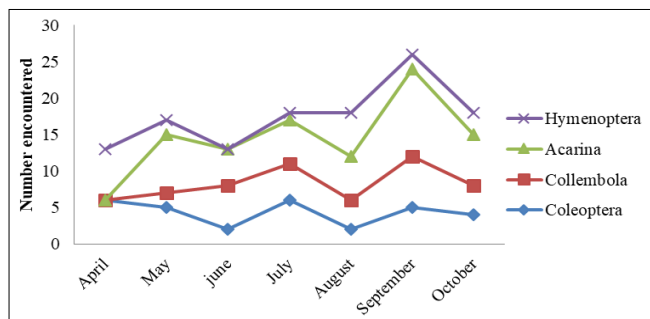


Fig 8: Seasonal abundance of soil arthropods at one inch sampling depth at Patiala (2016-17)

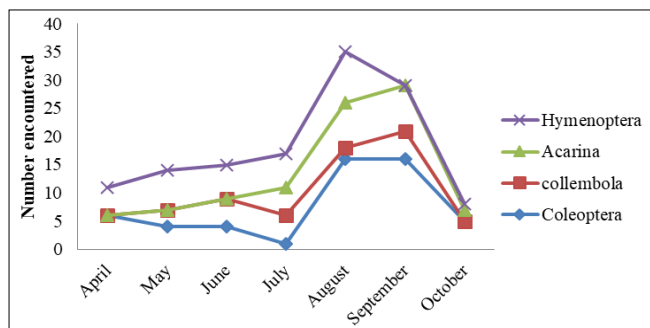


Fig 9: Seasonal abundance of soil arthropods at one inch sampling depth at Fazilka (2016-17)

The abundance increased later in the season when the climate was milder (low temperature, high Relative humidity) due to monsoon onset. Maximum population of soil arthropods was found in post monsoon and monsoon seasons and minimum in

summer season. Soil temperature influences the distribution of soil arthropods. As temperature increases, soil micro arthropod population decreases because soil arthropods migrate into the deeper layer of soil profile. Similarly, Narula *et al.* 1998^[12] found that abrupt increase in soil temperature and moisture resulted in decline in soil arthropod abundance.

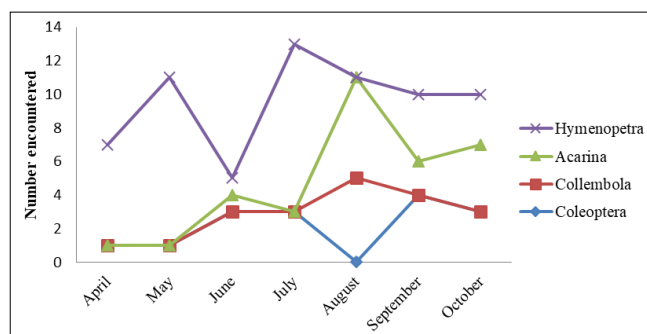


Fig 10: Seasonal abundance of soil arthropods at three inch sampling depth at Gurdaspur (2016-17)

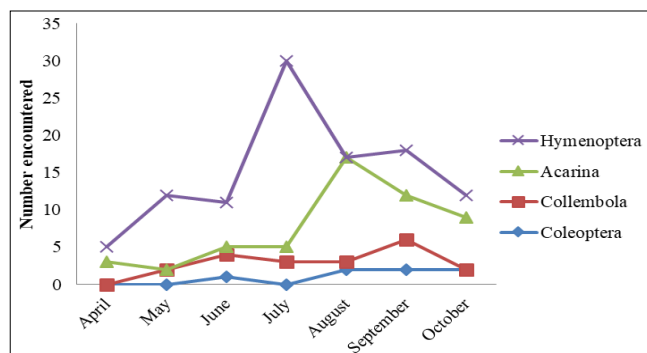


Fig 11: Seasonal abundance of soil arthropods at three inch sampling depth at SBS Nagar (2016-17)

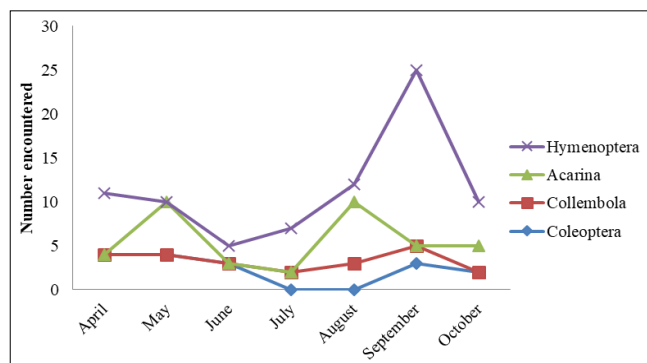


Fig 12: Seasonal abundance of soil arthropods at three inch sampling depth at Patiala (2016-17)

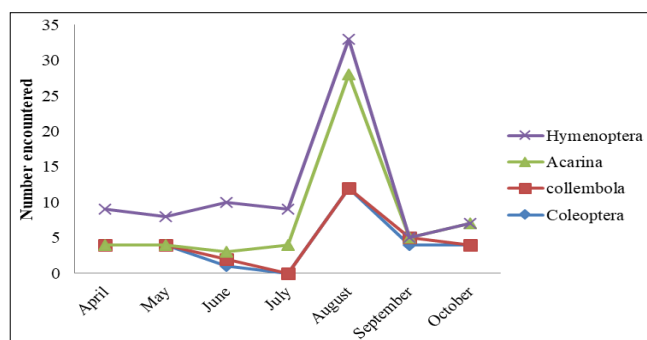


Fig 13: Seasonal abundance of soil arthropods at three inch sampling depth at Fazilka (2016-17)

However, at three inch sampling depth, maximum population of soil arthropods was observed during July at Gurdaspur (Fig 10) and SBS Nagar (Fig 11), September at Patiala (Fig 12) and during August at Fazilka (Fig 13). As the depth increases (3 inch depth) the soil is comparatively moister than 1inch depth. Soil arthropods being hydrophyllic tend to congregate at places with higher moisture (Bini *et al.* 2016, Bhattacharya *et al.* 1980)^[5, 6].

Conclusion

Present results suggested that intensive production systems in sugarcane affect the community structure, dynamics and abundance of soil fauna due to modifications of soil environment. The diversity/abundance varies with type of soil climate, taxonomic/functional groups of arthropods and cropping system. There is a need to understand the spatial and temporal distribution of key species. Further studies covering detailed traits of cropping systems and the associated above and below ground arthropods fauna need to be conducted. The comprehensive information generated therein will help manage sugarcane production systems with healthy soil environment.

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