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Vertical distribution of soil arthropods in apple ecosystem of Kashmir

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Abstract
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 ultimately changes the vertical distribution of soil fauna. The vertical distribution of arthropods extracted from soil in the apple ecosystem of Kashmir was investigated for the period of May 2013 to March 2014. Apple orchard soil was sampled at depths 0-15 cm, 16-30 cm and 31-45 cm. Population abundance of soil fauna showed maximum population in the upper depth in each month. Moreover, highest (16.33 individuals/sample) were reported in the month of August and lowest (1.33 individuals/sample) were recorded in February in the upper depth. Further, The mean monthly relative abundance of soil arthropods showed 46.15-66.66% population confined upto 0-15 cm depth followed by 16-30 cm depth 25.92-35.24% population and lowest percentage of population 12.90-21.43% was recorded at 31-45 cm depth.

Keywords: Abundance, ecosystem, soil arthropods, vertical distribution, depth

1. Introduction

Soil is the most composite, mixed, diverse and heterogeneous organization that leads to emergence of huge number of ecological niches and is abode of large number of living organisms that carry out crucial processes in the soil ecosystem [1]. In the soil, fauna perform important processes like degradation of organic biomass, mobilization of nutrients and enhancement of soil physicochemical properties [2]. Besides they regulate central functions vital to plants such as maintenance of pest populations below the economic injury levels and agrochemical disintegration. Soil fauna (micro fauna; protozoa, bacteria, meso fauna; Acarina, Symphyla, Collembola, Diplura and macro fauna; Chilopoda, Coleoptera, Orthoptera, Hymenoptera) interactions perform vital functions in a number of biological processes around the rhizosphere and within vicinity of decomposing organic matter.

Plant materials get incorporated into the soil through two modes viz. above-ground litter materials found on surface of the soil and through root system belowground [3]. 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 [4]. A considerable change in distribution of soil fauna has been found mainly by vertical stratification as compared to the horizontal or temporal variations [5]. But so far population abundance of soil fauna has been poorly studied, in spite of their role in understanding the interlink among surface litter and deeper soil layers [6]. Among the soil fauna, micro-arthropods and earthworms have received special emphasis for studying the vertical distribution [7, 8], only few studies are based on vertical distribution of macro arthropods [9, 10].

In a study on faunistic composition in different soils, Acarina and Collembola was recorded 67 per cent in upper 15 cm of soil, while 33 per cent in 15-30 cm horizon of soil [11]. On studying the vertical distribution of micro-arthropods in soil, 33% individuals were recorded upto 15.2 cm depth and 24% micro-arthropods were found at 15.2-30.5 cm depth, while 20% were recorded below 46 cm depth [12]. On sampling soil at depths 0-5 cm, 5-10 cm, 10-20 cm and litter, in order to investigate the seasonal and vertical distribution of Acarina fauna. Maximum percentage 43% of mites were collected from the litter layer followed by 20-36% individuals at 10-20 cm depth, while 12.8% Acarina fauna was recorded at 5-10 cm depth and 7.8% at 0-5 cm depth [13].

Among the various above surface and under surface pests and diseases in fruit ecosystem, some biological, taxonomic and management studies of above surface pests and diseases have been carried out but regarding under surface or underground pests especially important soil arthropods, there is no basic ecological information from planned as well as from unplanned (traditional) apple orchards. In addition, their role in fruit damage is scanty. By examining fruit ecosystems, it becomes clear that apple trees adapted to different seasonal changes at fruit developmental stages on the same land consistently for a long period provided, relatively, a suitable above surface and underground habitat offering good opportunities for harbouring arthropod fauna in abundance. In the soil different categories or groups of soil arthropods like beetles, worms, mites, centipedes, millipedes, crickets, springtails etc. are found which damage the root rhizosphere of various crops in constant ecosystem. Ecology study on soil ecosystems were found fruitful at the ecosystem level on nutrient cycling, influence of soil fauna on underground food webs, role of micro fauna on soil properties, rhizosphere dynamics and energy dynamics of soil systems [14, 15]. Abundant and diverse communities of soil macro fauna are considered as an important factor in the sustainability of agroecosystems [16].

For efficient and assured production of fruits, one requires sound ecological knowledge about the respective arthropod categories that inhabit the soil in fruit growing areas. Nutrient availability and crop performance have been found to be affected highly by soil fauna [17]. These soil arthropods in groups have several biological features that reinforce their use as bioindicators of soil to study the soil quality in relation to their abundance. Also the species richness of arthropods is reported to be basic for the management and preservation of biological diversity [18].

In view of paucity of information regarding vertical distribution in apple ecosystem, the present study was undertaken with an objective to ascertain the vertical distribution of soil arthropods in apple ecosystem of Kashmir

2. Materials and Methods

2.1 Study site

The investigation was carried out in apple orchards of Shopian district of Jammu and Kashmir. The district is having area of 30,741.6 hectares located at 33° 43' N to 33° 71' N latitude and 74° 50' E to 74° 83' E longitude and at an altitude of 2146 m above mean sea level.

2.2 Data collection

For soil sampling three fruit belts of the district were selected and the locations were Jamnagar (with orchard locations; J_1) Vehil (V_1) and Pinjora (P_1). During the survey 9 soil samples were collected in each month from J_1, V_1, and P_1 orchard locations, three samples from three depths d_1= 0-15 cm, d_2 = 16-30 cm and d_3 = 31- 45 cm at each location and total 99 samples were collected during study period. The soil samples were taken from the selected orchards regularly throughout the study period beginning from May 2013 to March 2014. The trees under which soil samples were taken had been selected randomly. For the collection of soil samples a soil coring tool, measuring 7.6 cm × 7.6 cm across and 45 cm tall was used as employed by [19] 19 Singh and Mukharji (1971). The soil samples after removing from coring tool were placed in sealed polythene bags with relevant recorded information and taken to laboratory for extraction of soil arthropods. Care was taken to keep the samples cool and prevent moisture loss during transportation.

The extraction of soil arthropods from the collected sample was done using Berlese funnel apparatus as followed by many other workers [20-22]. The funnels were fabricated locally and the heat source was provided by 100 W electric bulbs. The funnel works on the principle that soil arthropods are photophobic i.e. repelled by light and the temperature gradient forces arthropods downwards. The arthropods from soil samples migrate through sieves of different mesh size and were collected in the beakers containing 70% ethyl alcohol. Also the hand sorting of soil arthropods was done i.e. for separation of large size arthropods, they were separated by hand from sample [23].

The soil arthropods extracted were observed under stereo binocular microscope, sorted and counted at order level or higher taxonomic levels such as Acarina, Collembola, Symphyla, Chilopoda, Hymenoptera, Orthoptera, Heteroptera, Isopoda and Dermaptera [20]. The different chemicals used for the purpose included 70% ethyl Alcohol, glycerine, Kevin's fluid, 1% glacial acetic acid, lacto phenol (50:50) and Hoyer's medium.

2.3 Data analysis

The number and type of soil arthropods extracted from each sample were recorded, counted per sample, per depth and analysed statistically.

Population Abundance = mean number of individuals per sample.

Relative abundance

The relative abundance of the soil arthropods at various locations was determined to know about the variation of faunal composition with depth. The abundance of the soil arthropods was determined with the help of following formula:

$$\text{Relative abundance} = \frac{\text{Abundance of particular depth}}{\text{Total abundance}} \times 100$$

The relative abundance was determined from the samples collected at d_1= 0-15 cm, d_2 = 16-30 cm and d_3 = 31- 45 cm.

3. Results

3.1 Taxonomic composition of soil arthropods

The fauna composed of 10 taxa of phylum Arthropoda in three fruit belts of district Shopian. The taxa collected in this study belonged to Acarina, Collembola, Symphyla, Chilopoda, Isopoda, Hymenoptera, Coleoptera, Orthoptera, Heteroptera and Dermaptera. Among the Arthropods Acarina were the most predominant group followed by Collembola whereas other groups were comparatively less in number. Symphyla are soil-dwelling, centipede like creatures, whitish in colour having less than 10 mm body length, represented mainly by the garden symphylans, *Scutigerella* sp. Among the macro arthropods hymenopterans were the most predominant group followed by Chilopoda, Coleoptera Heteroptera and Orthoptera. Dermaptera represented a small group present in soil. Class Chilopoda represented by the order Geophilomorpha includes centipedes which posses dorsoventrally flattened body, first pair of trunk appendages modified into poison claw, one pair of legs on every segment. Isopods have 8 pairs of an equal number of legs with all legs similar to one another and dorso-ventrally flattened body, sharply-angled antennae, color varies from dark gray to white with or without pattern. They were widely represented by the genus *Armadillidium* and genus *Porcellio.* In addition to this, a number of other organisms, Protura, Diplura, larvae, grubs and pupae were encountered during the study period.

3.2 Population abundance

Data obtained on the abundance of arthropods from the apple orchards were compared using means and Standard error values (SE at 95% Confidence limits). Based on the soil core samples The basic data of nine samples collected around the apple trees from three orchard locations (Jamnagar, Vehil, Pinjora) in three fruit belts viz. Reshinagar, Kachidora and Shopian at three vertical depths 0-15 cm, 16-30 cm, and 31-45 cm are presented in (Table 1). Perusal data revealed that population abundance (mean/sample) was mostly confined at 0-15 cm followed by 16-30 cm and 31-45 cm. Differences were found between the upper soil layers and the lower layers.

Table 1: Mean monthly population abundance (number of individuals/sample) of soil arthropods (SE at 95% Confidence limits).

Month	Depth		
	d_1 = 0-15 cm	d_2 = 16-30 cm	d_3 = 31-45 cm
May 13	12.33 (11.68-12.99)	6.33 (4.60-8.06)	3.33 (2.03-4.64)
June 13	16 (14.87-17.13)	7.67 (5.31-10.02)	4.67 (4.01-5.32)
July 13	14 (12.87-15.13)	10 (7.74-12.26)	6.33 (5.68-6.99)
August 13	16.33 (14.60-18.06)	7 (5.87-8.13)	3.67 (3.01-4.32)
Sept 13	15 (59.21-13.87)	6.67 (26.31-6.01)	3.67 (14.47-3.01)
Oct 13	12.67 (12.01-13.32)	6.67 (6.01-7.32)	5 (3.87-6.13)
Nov 13	12.67 (9.21-16.12)	8.33 (6.60-10.06)	5.33 (4.68-5.99)
Dec 13	6.67 (6.01-7.32)	4.33 (3.68-4.99)	3 (1.87-4.13)
Jan 14	2.67 (0.93-4.39)	2 (0.87-3.13)	1 (0.13-2.13)
Feb 14	1.33 (0.68-1.99)	0.66 (0.013-1.32)	0.00
Mar 14	6(4.87-7.13)	3 (1.87-4.13)	1.33 (0.68-1.99)

3.3 Relative abundance

The mean monthly relative abundance expressed as percentage abundance of different soil arthropod categories (Table 2) in the present study revealed that maximum percentage of soil arthropods remained mostly confined at depth 0-15 cm, representing 46-66% of the total fauna in each month, while the depth16-30 cm constituted about 26-35% and the depth 31-45 cm contributed only 12-21%. Therefore, it was clear that first two depths constituted the major portion (85%) of fauna found in the soil, while meager soil fauna remained confined in the third layer

Table 2: Percentage relative abundance (RA) of soil arthropod taxa in different months.

Depth	Month										
	May 13	June 13	July 13	Aug13	Sep 13	Oct 13	Nov 13	Dec 13	Jan 14	Feb 14	Mar 14
d_1= 0-15 cm	56.06	56.47	46.15	60.49	59.21	52.05	48.10	47.61	47.06	66.66	58.06
d_2= 16-30 cm	28.79	27.05	32.97	25.92	26.31	27.40	31.64	30.95	35.29	33.33	29.03
d_3= 31-45 cm	15.15	16.47	20.88	13.58	14.47	20.55	20.25	21.43	17.65	-	12.90

4. Discussion

The widely accepted assertion that the soil is our basic source had evoked a thought about the organisms that inhabit soil. The population of the soil arthropods is in dynamic equilibrium, the activity of some surges in one month, that of others in other month. Population changes occur mostly and rapidly on or near the root tip surfaces in the rhizosphere zone. Soils of natural ecosystems and the animal life in them greatly influence the physiochemical and biological properties of soil.

Acarina was the most dominant group of soil arthropods followed by Collembola and Hymenoptera while other groups like Symphyla, Coleoptera, Chilopoda, Orthoptera, Heteroptera and Dermaptera were marginally less in number. The reason for the Acari predominance in the soil is attributed to their morphological and physiological adaptations as mites possess sclerotised exoskeletons, diverse feeding preferences and adult mites are long-lived with an average lifespan of several months to 2 years from egg to adult. Springtails have higher reproductive rate and produce many generations over a year that might be the reason of being predominant in the soil. These findings are in conformity with the findings of many workers [24], who reported Acarina as the most dominant group, when they collected Acari, Collembola, Pseudoscorpians and Araneida from Holland and New Zealand soils. Moreover, Hymenoptera was found the most representative group followed by Coleoptera, while centipedes and earwig were recorded low in number in the Olive grove ecosystem [1]. In Indo-Gangetic plains of North Bihar similar population dynamics of Collembola and Acari in croplands was recorded [25]. The above findings also receive support from many workers who reported that out of the total soil arthropods under study, Acarina and Collembola dominated in faunistic composition studied in different ecosystems [19-21, 26, 27].

The vertical distribution of soil arthropods revealed that population abundance (mean number of individuals/sample) was 12.33 at 0-15 cm comparatively higher than 6.33 at 16-30 cm and 3.33 at 31-45cm in May. The pattern of population abundance was similar for all the months i.e. the maximum population remains confined in the upper 0-15 cm of soil followed by depth of 16-30 cm and minimum portion of population was found at a depth of 31-45 cm. Also the relative abundance expressed as percentage was highest 56.06% at 0-15 cm, 28.79% at 16-30 cm, 15.15% at 31-45 cm. Many workers observed similar patterns in the vertical distribution with higher densities of micro-arthropods population confined in the upper layers of the soil [28, 29]. Also maximum population of Arthropods during rainy season and decreasing trend with the onset of winter was noted by many workers [30, 31]. The reason may be that soil-inhabiting micro arthropods usually are most abundant near the surface, as upper layers are characterized by adequate living space, favorable moisture conditions, aeration rates and rich accumulations of organic debris, also most soil fauna are unable to actively burrow in the soil, therefore, and they use existing pore spaces. The above findings receive support from the results of many workers [12, 11, 32-34].

5. Conclusion
This study comprises one of the first works on the arthropod fauna associated with a apple orchard ecosystem and also is one of the few contributions on this topic in India. The results showed that 0-15 cm depth was having maximum population followed by 16-30 cm depth and minimum at 31-45 cm depth.

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