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POPULATION ABUNDANCE AND DIVERSITY OF SOIL ARTHROPODS IN APPLE ECOSYSTEM OF KASHMIR

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ABSTRACT

A survey was carried out to record the population abundance, diversity of soil arthropods in the apple ecosystem of Kashmir. During study the most predominant group recorded was Acarina closely followed by Collembola and Hymenoptera. The other categories such as Chilopoda, Coleoptera Isopoda, Orthoptera, Heteroptera and Dermaptera showed low abundance. The highest population density of soil arthropods was recorded in June (3670.69 individuals/m^2) and the lowest in the February (231.03 individuals/m^2). The mean monthly relative abundance of different soil arthropod categories revealed that Acarina constituted about 42.27 per cent followed by Collembola (33.14%), Hymenoptera (7.66%) and Chilopoda (4.23%) of total fauna per soil sample. The other groups such as Coleoptera, Orthoptera, Heteroptera, Isopoda, Symphyla and Dermaptera constituted less than 5 per cent relative abundance per soil sample. The highest Shannon-Wiener diversity index value was recorded in June (1.56) while the lowest in February (0.86). The highest Evenness (0.95) was observed in February 2014 while lowest (0.66) in August 2013. The highest richness (2.01) was observed in June 2013 and the lowest (1.08) in February 2014

INTRODUCTION

The soil an extremely dynamic, complex and highly heterogeneous system that allows the development of an exceedingly large number of ecological habitats; is the home of an array of living organisms, and performs important functions for the ecosystem (Gonclaves and Pereira, 2012). In the soil, these organisms have central functions in organic matter decomposition, nutrient cycle, enhancement of soil structure and control of soil organisms including crop pests (Moore and Walter, 1988). Besides they perform a number of key functions essential to plants, such as disease regulation, agrochemical degradation. Soil fauna (micro fauna; protozoa, bacteria, meso fauna; Acarina, Symphyla, Collembola, Diplura and macro fauna; Chilopoda, Coleoptera, Orthoptera, Hymenoptera) interactions play a critical role in a variety of biological functions both in the rhizosphere and near decomposing residues.

Mir (2000) concluded the abundance and distribution of the soil fauna is influenced by geographical location, climate, physical properties of soil, type and depth of litter and many other abiotic factors like moisture, temperature, light *etc*. Ouedraogo *et al*. (2006) reported macrofauna are highly affected by cultural and agricultural practices that eliminate their beneficial contribution and influence soil biodiversity. Eni *et al*. (2014) investigated the seasonal distribution, abundance and diversity of soil arthropods and recorded total of 2486 soil arthropods, classified into four classes, five Orders and Nine genera. These included; chilopoda, diplopoda, arachnida and insecta comprising Hymenoptera, Coleoptera, Collembola, Isoptera and Orthoptera. Zayadi *et al*. (2013) investigated Soil arthropods in several categories of land use; savanna, paddy fields, orchards and forest. They reported 10 orders with 21 families (702 individuals), maximum number of individuals of order Hymenoptera, Coleoptera, Collembola and Araneida were found.

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 provide, 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. Soil ecology research has been productive at the ecosystem level on nutrient cycling,

arthropod regulation of micro and meso-fauna in below-ground food webs, impact of microfauna on soil genesis and structure, rhizosphere dynamics and energy dynamics of soil systems (Peterson and Luxton, 1982; Moore *et al.*, 1988). Abundant and diverse communities of soil macro fauna are considered as an important factor in the sustainability of agroecosystems (Lavelle, 1997).

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. It is being increasingly recognized that soil fauna play a significant role in soil processes affecting nutrient availability and crop performance (Ouedraogo *et al.*, 2006). 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 vital and of fundamental importance to the management and preservation of biological diversity (Bardgett, 2002).

In view of paucity of information regarding abundance, species composition, distribution, diversity in apple ecosystem, the present study was undertaken with an objective to ascertain the population abundance and diversity of some predominant soil arthropods in apple ecosystem of Kashmir.

MATERIALS AND METHODS

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 at an altitude of 2146 m above mean sea level.

Data collection

For soil sampling three fruit belts of the district were selected and the locations were Jamnagar (with orchard locations; J_1, J_2 and J_3) , Gadipora (G_1, G_2 and G_3), Reshinagar (R_1, R_2 and R_3), Vehil (V_1, V_2 and V_3), Nowgam (N_1, N_2 and N_3), Kachidora (K_1, K_2 and K_3), Pinjora (P_1, P_2 and P_3), Trenz (T_1, T_2 and T_3), Shopian (S_1, S_2 and S_3) During the survey 27 soil samples were collected in each month from (J_1, J_2, J_3, G_1, G_2, G_3, R_1, R_2, R_3, V_1, V_2, V_3, N_1, N_2, N_3, K_1, K_2, K_3, P_1, P_2, P_3, T_1, T_2, T_3, S_1, S_2 and S_3) orchard locations, one sample from each orchard. The soil samples were taken from the selected orchards regularly throughout the study period beginning from May 2013 to March 2014. The soil samples were taken under the tree canopy upto a depth of about 45 cm in each selected orchard. 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 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 Price (1973), Mir (1986), Khan and Singh (2007) and many other workers. 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 form sample as followed by Ying-hua *et al.* (2013).

The soil arthropods extracted were observed under stereobinocular microscope, sorted and counted at order level or higher taxonomic levels such as Acarina, Collembola, Symphyla, Chilopoda, Hymenoptera, Orthoptera, Heteroptera, Isopoda and Dermaptera (Price, 1973). The different chemicals used for the purpose included 70% ethyl alchohol, glycerine, Kevin's fluid, 1% glacial acetic acid, lacto phenol (50:50), Hoyer's medium etc.

Data analysis

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

Relative abundance

The relative abundance of the soil arthropod categories at various locations was determined to know about the variation of faunal establishment in apple orchard ecosystem in different months. The abundance of the soil arthropods was determined with the help of following formula:

$$\text{Relative abundance} = \frac{\text{Abundance of particular soil arthropod category}}{\text{Total abundance}} \times 100$$

Shannon-Wiener Diversity index (H)

In order to study the proportion of each category within the local community, diversity of various categories was computed based on Shannon-Wiener formula, also called the Shannon index or Shannon-Wiener index (Humphries *et al.*, 1996).

$$H = -\sum_{i=1}^{s} p_i \log_e p_i$$

H is the Shannon-Wiener biodiversity index; Pi is the proportion of each category in the sample (relative abundance of i_{th} category); $\log_e P_i$ is the natural log of P_i; and S is the number of categories in the community at each location.

Evenness (J)

In order to understand how similar the abundance of different categories is, evenness was calculated to estimate the equitability component of diversity (Pielou, 1969).

$J = H/\log_e S$

Richness (Ma)

In order to assess how the diversity of the population is distributed or organised among the particular category, richness was calculated (Pielou, 1969).

$Ma = S\text{-}1/\log_e N$

Where Pi is the proportion of each category in the sample (relative abundance of i_{th} category), S is the number of categories in the community at each location. N is the total

number of individuals in all the categories.

RESULTS

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, Coleopteran, Heteroptera and Orthoptera. Dermaptera represented a small group present in

Table1: Mean monthly population density of soil arthropods (SE at 95% Confidence limits).

	Mean monthly population (individuals/m^2)					
Category	13-May	13-Jun	13-Jul	Aug. 13	Sep. 13	13-Oct
Acarina	1225.86 (1108.62-1343.10)	1450 (1310.34-1587.93)	1174.14 (1039.66-1310.34)	1627.59 (1413.79-1843.10)	1431.03 (1291.38-1568.97)	1143.1 (984.48-1301.72)
Collembola	1034.48 (927.59-1141.38)	1194.83 (1131.03-1256.90)	996.55 (850.00-1141.38)	1296.55 (1215.52-1377.59)	1124.14 (955.17-1293.10)	951.72 (820.69-1082.76)
Symphyla	70.69 (32.76-106.90)	56.9 (25.86-87.93)	82.76 (50.00-115.52)	75.86 (34.48-118.97)	44.83 (15.52-74.14)	75.86 (43.10-110.34)
Chilopoda	153.45 (87.93-218.97)	205.17 (136.21-272.41)	210.34 (98.28-324.14)	120.69 (53.45-187.93)	141.38 (75.86-205.17)	115.52 (63.79-165.52)
Hymenoptera	229.31 (106.90-351.72)	274.14 (170.69-379.31)	243.1 (74.14-410.34)	274.14 (194.83-353.45)	255.17 (168.97-343.10)	236.21 (144.83-329.31)
Coleoptera	165.52 (132.76-200.00)	198.28 (131.03-265.52)	82.76 (34.48-132.76)	75.86 (31.03-122.41)	75.86 (43.10-110.34)	75.86 (43.10-110.34)
Orthoptera	51.72 (20.69-81.03)	75.86 (39.66-113.79)	32.76 (6.90-56.90)	32.76 (6.90-56.90)	63.79 (27.59-100.00)	63.79 (31.03-96.55)
Heteroptera	44.83 (15.52-74.14)	75.86 (27.59-125.86)	44.83 (15.52-74.14)	63.79 (22.41-105.17)	68.97 (37.93-103.45)	68.97 (37.93-103.45)
Isopoda	56.9 (25.86-87.93)	63.79 (15.52-112.07)	51.72 (15.52-86.21)	56.9 (25.86-87.93)	115.52 (74.14-155.17)	96.55 (53.45-137.93)
Dermaptera	32.76 (6.90-56.90)	75.86 (43.10-110.34)	25.86 (1.72-48.28)	44.83 (15.52-74.14)	44.83 (15.52-74.14)	32.76 (6.90-56.90)
Total	3065.52	3670.69	2944.82	3668.97	3365.52	2860.34

Table1a : Mean monthly population density of soil arthropods (SE at 95% Confidence limits).

	Mean monthly population (individuals/m^2)				
Category	Nov. 13	Dec.13	Jan.14	Feb.14	Mar. 14
Acarina	1124.14 (1001.72-1244.83)	600 (474.14-727.59)	141.38 (96.55-184.48)	101.72 (60.34-143.10)	344.83 (87.93-408.62)
Collembola	824.14 (672.41-975.86)	262.07 (170.69-353.45)	94.83 (58.62-132.76)	96.55 (62.07-129.31)	250 (143.10-584.48)
Symphyla	82.76 (44.83- 120.69)	37.93 (10.34-65.52)	56.9 (25.86-87.93)	32.76 (6.9-56.90)	56.9 (1.72-113.79)
Chilopoda	89.66 (48.28- 120.69)	0	0	0	0
Hymenoptera	153.45 (105.17-201.72)	70.69 (32.76-106.90)	0	0	141.38 (93.10-251.72)
Coleoptera	68.97 (37.93-103.45)	0	0	0	0
Orthoptera	63.79 (31.03-96.55)	0	0	0	0
Heteroptera	63.79 (31.03-96.55)	0	0	0	0
Isopoda	75.86 (43.10-110.34)	0	0	0	108.62 (36.21-155.17)
Total	2546.56	970.69	293.11	231.03	901.73

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

Category	Acarina	Collembola	Symphyla	Chilopoda	Hymenoptera	Coleoptera	Orthoptera	Heteroptera	Isopoda	Dermaptera	Total
Mean	942.16	738.71	61.29	94.2	170.69	67.56	34.95	39.19	56.9	23.35	2229
RA	42.27	33.14	2.75	4.23	7.66	3.03	1.57	1.76	2.55	1.05	

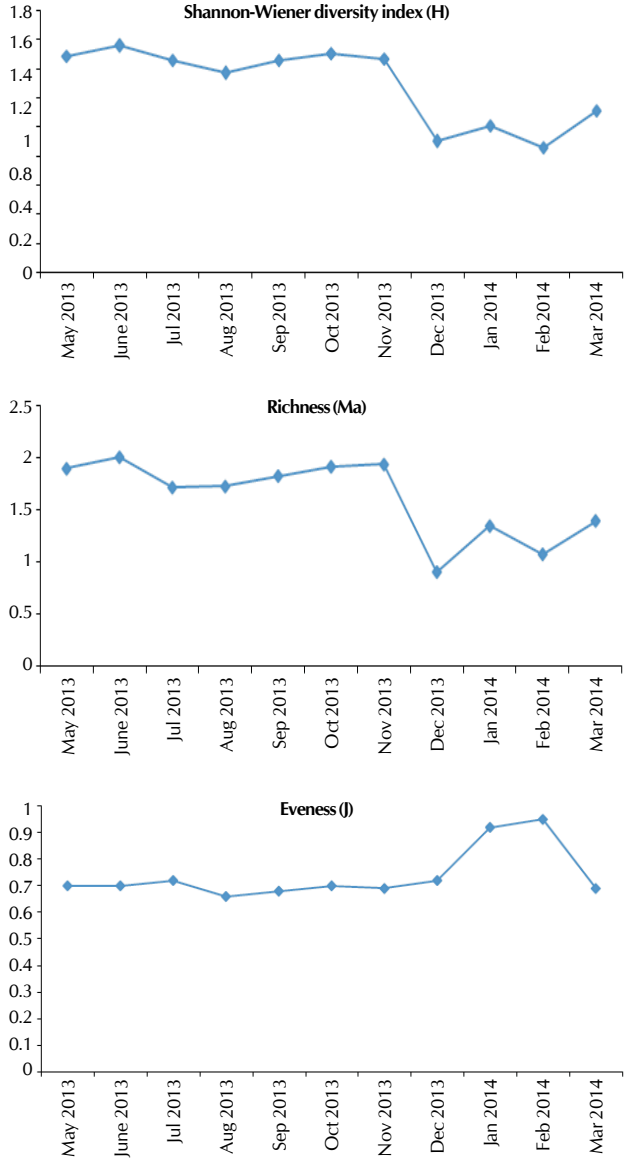

Figure1: Temporal fluctuation pattern of arthropod Diversity (H), richness (Ma) and Eveness (J) during study period.

soil. Class Chilopoda represented by the order Geophilomorpha includes centipedes which posses dorsoventrally flattened body, first pair of trunk appendages modified into poision 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.

Mean monthly population density of soil arthropods

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 (Table 1and1a) population of soil arthropods per m^2 showed that the highest population of total soil arthropods (3670.69/m^2) was recorded in June and the lowest (231.03/m^2) in February. The populations of individual groups exhibited the peak population of Acarina (1627.59/m^2) in August and lowest (101.72/m^2) in February closely followed by Collembola which recorded maximum population (1296.55/m^2) in August and minimum (94.83/m^2) in January. Moreover, symphyla were the other group among micro arthropods which mainly constituted population besides Acarina and Collembola. The highest population of Symphyla (82.76/m^2) was recorded in July and November while minimum (32.76/m^2) in February.

The population of individual macro arthropod groups exhibited the highest population of Hymenoptera (274.14/m^2) in June and August, while the lowest (70.69/m^2) in December. Similarly, the maximum population of Chilopoda (210.34/m^2) was observed in July while minimum (89.66/m^2) in November. Coleoptera showed the highest population of (198.28/m^2) and lowest (67.71/m^2) in the month of June and November, respectively.

The other groups, Orthoptera, Heteroptera, Isopoda and Dermaptera were very low in abundance. In case of Orthoptera the highest population (75.86/m^2) was recorded in June and lowest population (32.76/m^2) in July and August. Similarly, the highest population of Heteroptera (75.86/m^2) was recorded in June and lowest (44.83/m^2) in May and July. Furthermore, maximum Isopod population (115.52/m^2) was observed in September while the minimum (51.72/m^2) in July. Dermaptera, one of the rare groups showed the highest population (75.86/m^2) in June and least (25.86/m^2) in July.

Relative abundance

The mean monthly relative abundance expressed as percentage abundance of different soil arthropod categories (Table 2) in the present study revealed that Acarina constituted about (42.27%) of the total fauna per soil sample, while Collembola constituted about (33.14%) of total fauna per soil sample. Therefore, it was clear that Acarina and Collembola constituted the major portion (75%) of fauna found in the soil. The other groups viz. hymenoptera and Chilopoda were 7.66 and 4.23 per cent, respectively. Coleoptera represented (3.03%) of fauna per soil sample. The remaining categories Orthoptera, Heteroptera, Isopoda, Symphyla and Dermaptera constituted less than 3 per cent per soil sample

Diversity of soil arthropods

The various indices of diversity of soil arthropod (fig.1) viz. Shannon-Wiener diversity index (H), Evenness index (J), and Richness index (Ma) in apple orchard ecosystem revealed that the maximum Shannon–Wiener diversity index (1.56) in June 2013 while the lowest Shannon–Wiener diversity index (0.86) in February 2014. The highest (0.95) Evenness was observed in February 2014 while lowest (0.66) in August 2013. The highest (2.01) richness was observed in June 2013 and the lowest (1.08) in February 2014.

DISCUSSION

The widely accepted assertion that the soil is our basic source had evoked thought of 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.

Faunistic composition

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 workers like Edwards and Heath (1963) and Hoyer and Ryke (1968) who reported Acarina as the most dominant group, when they collected Acari, Collembola, pseudoscorpians and Araneida from Holland and New Zealand soils. Gonclaves and Pereira (2012) reported hymenoptera as the most representative group followed by Coleoptera in the Olive grove ecosystem while centipedes and earwig were low in number. Lal *et al*. (2011) reported similar population dynamics of Collembola and Acari in croplands in indo-gangetic plains of North Bihar. The above findings also receive support from Singh and Mukharji (1971), Price (1973), Mir (1986), Gupta and Mukharji (1978), Eni *et al*. (2014) who recorded that, out of the total soil arthropods under study, Acarina and Collembola dominated in faunistic composition studied in different ecosystems.

Relative abundance

The mean monthly relative abundance expressed as percentage abundance of different soil arthropod categories in the present study revealed that Acarina constituted about (42.27%) of the total fauna per soil sample, while Collembola constituted about (33.14%) of total fauna per soil sample. Therefore, it was clear that Acarina and Collembola constituted the major portion (75%) of fauna found in the soil. The other groups *viz*. hymenoptera and Chilopoda were 7.66 and 4.23 per cent, respectively. The remaining categories Orthoptera, Heteroptera, Isopoda, Symphyla and Dermaptera constituted less than 3 per cent per soil sample. The reason for showing high relative contributions to the total soil fauna by Acarina and Collembola may be attributed to their predominance in the soil. Differences in abundance of individuals of soil arthropods are caused by the vegetation diversity, environmental conditions and abundance of litter in these areas (Zayadi *et al*., 2013).

These observations are in conformity with the findings of wood (1967), who observed 87-91 per cent Acarina and Collembola; Desmond and Alex (2013) observed relative abundance of 43.31 per cent Acarina, 21.25 per cent Collembola, 1.93 per cent Isopods. Curry (1969) also reported 47.8 per cent Acarina and 41.4 per cent of Collembola in an old grass land site; Price (1973) recorded 58.3 percent of Acarina, 33 per cent of Collembola and 3.5 percent of Symphyla and Chilopoda while, Blesic and Mitrovski (2003) recorded 1.59 per cent Hymenopterans and 0.02 per cent Isopods. Besides agrees with the findings of Brahmam *et al*. (2010) who recorded Collembola 43.34% followed by Hymenoptera 15.95%, Araneida 13.92%, Coleoptera 10.37%, Orthoptera 9.97% in bt-cotton fields of Warangal, Andhra Pradesh.

Population density

The population of soil arthropods per m^2 of soil showed that the highest population (3670.69/m^2) of total soil arthropods was recorded in June 2013 and the lowest (231.03/m^2) in February 2014. The populations of individual groups exhibited the highest population of Acarina (1627.59/m^2) in August 2013 and the lowest (101.72/m^2) in February 2014. This was followed by Collembola which recorded highest population (1296.55/m^2) in August 2013 and the lowest (94.83/m^2) in January 2014.

Symphyla were the other group, which represented micro arthropods besides Acarina and Collembola in population. The highest population of Symphyla (82.76/m^2) was recorded in July and November 2013 and lowest (32.76/m^2) was recorded in February 2014.

The results corroborate with the observations of Shah (2006) who recorded maximum population density of Acarina in September followed in August (2337.2/m^2) followed by Collembola (1731.0/m^2) in August and lowest population density of Acarina (230.8.2/m^2) in February and Collembola (201.9/m^2) in February. The reasons for variations in population record can be possibly because of indiscriminate use of pesticides and disturbance of humans in apple ecosystem year after year. The observations are also in agreement with the findings of Mir (1986), Raina *et al*. (1979) who recorded similar population estimates.

The population density of other arthropod categories exhibited the highest population of Hymenoptera (274.14/m^2) in June and August 2013, while the lowest (70.69/m^2) in December 2013. Similarly, the highest population of Chilopoda (210.34/m^2) was noted in July 2013 and the lowest (89.66/m^2) in November 2013. Coleoptera showed the highest population of (198.28/m^2) and lowest (67.71/m^2) in the month of June and November 2013, respectively. In case of Orthoptera the highest population (75.86/m^2) was recorded in June 2013 and lowest population (32.76/m^2) in July 2013 and August 2013. Likewise, the highest population of Heteroptera (75.86/m^2) was recorded in June 2013 and lowest (44.83/m^2) in May and July 2013. Isopod population was recorded (115.52/m^2) highest in September 2013 and the lowest (51.72/m^2) in July 2013. Dermaptera, one of the rare groups showed the highest population (75.86/m^2) in June 2013 and lowest (25.86/m^2) in July 2013. These findings are in accordance with the results of Shah (2006). The result of this work is similar to Adeduntan (2009) who reported that insects are generally more found in the months where there are favourable environmental conditions and other factors like light, litter falls and food. Lal *et al*. (2011) recorded similar population distributions of Collembola and Acari in different months in croplands of indo-gangetic plains of North Bihar.

Diversity of soil arthropods

The various indices of diversity of soil arthropod *viz*. Shannon-wiener diversity index (H), Evenness index (J), and Richness

index (Ma) in three fruit belts in apple orchard ecosystem revealed that the maximum Shannon–Wiener diversity index 1.56 in June 2013 while the lowest Shannon–Wiener diversity index 0.86 in February 2014. The highest (0.95) Evenness was observed in February 2014 while lowest (0.66) was recorded in August 2013. The highest (2.01) richness was observed in June 2013 and the lowest (1.08) in February 2014. These results are in conformity with the findings of Stone *et al*. (2009).

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