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Seasonal diversity of soil fauna in semi-arid regions of Karnataka

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Abstract
The soil fauna was studied in three major seasons viz., summer, rainy and winter in different systems in semi-arid regions of Karnataka. Different diversity indices were derived to assess the diversity of soil fauna. The results revealed that highest number of soil fauna species were recorded during winter (18) and least was observed in summer season (11). Simpson (1-D) indices was highest under rainy (0.776) and lowest was under summer (0.610). Shannon-Weiner (1.888), Margalef richness (2.771) and Chao-1 (18.25) index was recorded highest in winter followed by rainy season and least in Summer season. The Pielou's evenness index was highest in rainy (0.654), followed by winter season (0.653) while lowest value was recorded under summer (0.607). A total of 22 different taxa/ species of soil fauna were recorded in three seasons. The highest numbers of individuals were recorded in rainy season (722) followed by winter (462) and summer (141). Out of different species identified relative density of Mesostigmata (40%) was highest followed by Cryptostigmata (20.7%) and Onychiuridae (14.00%). Cluster analysis revealed that, soil fauna of winter and rainy season were more similar compared to summer season. Based diversity analysis it can be concluded that, winter season followed by rainy season is the best season to study the soil fauna in semi-arid regions of Karnataka.

Keywords: Shannon-weiner index, soil diversity, collembola, mites

Introduction
Soil is the most important reservoir of biodiversity. Microarthropods living in the litter layer and in the upper strata of the soil are an important component of the ecosystem, because of their role as regulators of key functional processes, such as porosity and water infiltration [1,2], organic matter decomposition and mineralization [3,4], nutrient cycling [5] and soil formation [6].
The intensification of land use and severe anthropogenic interventions, whether for human occupancy or agricultural production, lead to changes in soil quality. It is important to know that the stress created on the organisms is reducing the number of animal and plant communities in a skewed manner where species that are able to bear stress predominate while many rare taxa decrease in abundance or disappear [7]. With continuous cultivation, physical properties and productivity of many soils decline primarily due to decrease in organic matter content and decrease in soil pH [8]. Several studies have shown that soil fauna play a crucial role in regulating soil quality [9,10]. The soil biota comprises organisms of diverse nature and is used as critical indicators to evaluate changes in the environment [9]. In general, changes in group abundance, diversity, and composition reflect undesirable changes in the ecosystem.
An understanding of the importance of these organisms to soil ecology is still poorly understood. Macro-arthropods are found to play a significant role in accelerating plant residue decomposition through their interactions with the micro-flora [11,12]. The species composition and abundance of the soil fauna are influenced by the geographical location, climate, physical and chemical properties of the soil, vegetation, nature and depth of the litter and humus, and a variety of other environmental factors including the seasonal changes. The abundance of micro-arthropods in soil is determined by resource availability, pH, disturbance and climatic factors [13]. The abiotic factors *viz.,* moisture and temperature play most important role in growth and development of soil fauna. In the light of the above, present study aims at understanding the seasonal dynamics of soil fauna in semi-arid climatic conditions.

Materials and Methods
The soil fauna was studied in three major seasons viz., summer, rainy and winter in different land use systems. The study is conducted at the University of Agricultural Sciences,

Bengaluru, Karnataka, India, located at 13º 05' North and Longitude: 77º 34' East and Altitude of 924m.

Soil fauna and litter fauna sampling

The soil samples were collected using the circular core-sampler measuring 12 cm diameter and 10 cm height. The core sampler was placed on the soil surface and with little force, it was pressed and turned in a clockwise direction to a depth of 10 cm. The soil samples thus obtained were immediately transferred to aluminium cans.

Extraction of soil fauna

The fauna was extracted from the soil samples using Rothamsted Modified Macfadyen High Gradient Funnel apparatus. Soil samples (400 g) were placed carefully in the canisters. The electric bulbs (25 w) served as the source of light and heat. The apparatus was run for 48 hours. The invertebrates passing through 2 × 2 mm sieve of the sample holder were collected in vials containing 70% ethyl alcohol fixed to the lower end of the funnel. These vials were periodically checked to keep the alcohol at required levels and appropriately labelled. A stereo binocular microscope (35 × magnifications) was used for sorting the extracted soil invertebrates. They were separated into different taxonomic groups. The number in each group was recorded. The recorded numbers were used to derive the diversity index of the soil invertebrates.

Soil fauna diversity indices

Shannon diversity index (H')

Shannon diversity index [14] is a measure of heterogeneity which takes into account the evenness of abundance of species. Shannon index was calculated by using the formula

$$H = \sum_{i=1}^{n} Pi \ln Pi$$

Where 'Pi' is the proportion of individuals of i^{th} species relative to the total number of species; 'n' is the total number of species.

Simpson index

This Simpson index [15] popularly used to know the evenness in distribution or degree of concentration and calculated by using the formula

$$\lambda = \sum_{i=1}^{n} Pi^2$$

Where, 'Pi' is the proportion of individuals of i^{th} species relative to the total number of species on the farm; 'n' is the total number of species.

Dominance

Dominance = 1-Simpson index. Ranges from 0 (all taxa are equally present) to 1 (one taxon dominates the community completely) [16].

$$D = \sum (ni/n)^2$$

where *ni* is number of individuals of taxon *i*.

Margalef's richness index (d)

This index is weighted towards species richness and is the measure of the total number of species for a given number of individuals [16].

$$d = (S-1) / \ln(n)$$

Where d = Species richness, S is number of taxa and n is the total number of individuals.

Pielou's evenness index (J')

This index indicates how evenly the individuals are distributed among the different species [16].

J' = H'/ln S,

Where ln S = H' max

H' max (the maximum value of Shannon diversity) is what H' would be if all the species in the community had an equal number of individuals; S is the number of species.

Chao-1, bias corrected

An estimate of total species richness [16].

$$\text{Chao-1} = S + F1(F1 - 1) / (2 (F2 + 1)),$$

where $F1$ is the number of singleton species and $F2$ the number of doubleton species.

Statistical Analysis

The diversity indices was calculated using PAST software [16]. The cluster analysis was carried out using XLSTAT 2020.1.1 software.

Results and discussion

Soil fauna diversity

The soil fauna diversity during different season (summer, winter and rainy) were analyzed and compared (Table 1 and Fig. 1 & 2). The results revealed that highest number of soil fauna species were recorded during winter (18) and least was observed in summer season (11). The highest number of individuals were recorded in rainy season (722) and lowest in summer (141). The species dominance was highest in summer (0.390) and least under rainy season (0.224). Simpson (1-D) was highest under rainy (0.776) and lowest was under summer (0.610). Shannon-Weiner index was recorded highest in winter (1.888), followed by rainy season (1.853) (Figure 2). The least Shannon-Weiner index was recorded in summer (1.455). Margalef species richness index was highest in winter (2.771), followed by rainy (2.431) and least was observed under summer season (2.021). The Pielou's evenness index was highest in rainy (0.654), followed by winter season (0.653) while lowest value was recorded under summer (0.607). The Chao-1 index was highest in winter (18.25) followed by rainy (17) and lowest was recorded under summer (11.5).

Table 1: Soil fauna diversity in different seasons

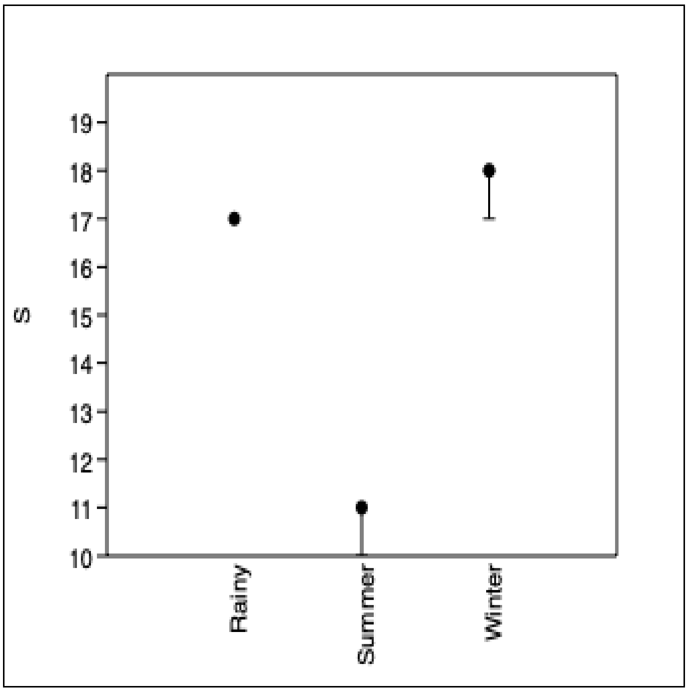
Diversity indices	Rainy	Summer	Winter
Taxa_S	17	11	18
Individuals	722	141	462
Dominance_D	0.224	0.390	0.231
Simpson_1-D	0.776	0.610	0.769
Shannon_H	1.853	1.455	1.888
Margalef	2.431	2.021	2.771
Pielou's evenness (J)	0.654	0.607	0.653
Chao-1	17	11.5	18.25

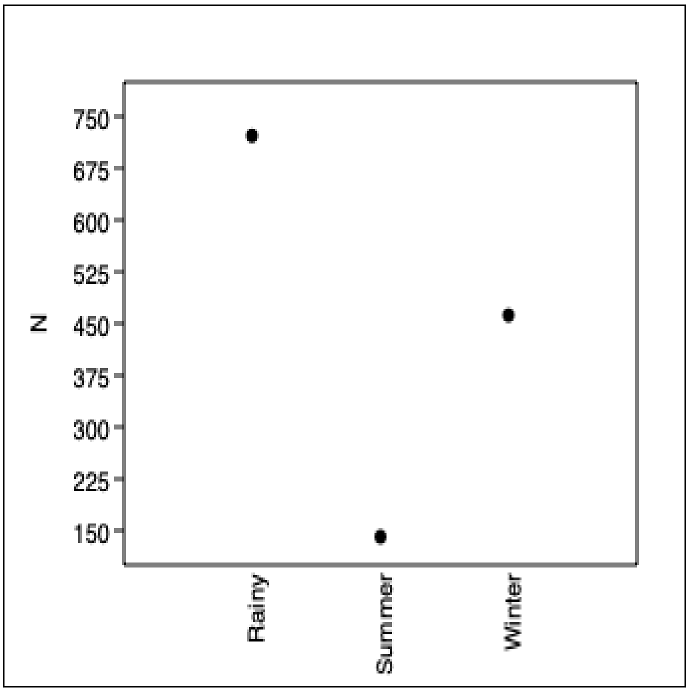
Soil biota play an essential role in soil functions as they are involved in processes such as the decomposition of organic matter, the formation of humus and the nutrient cycling of many elements (nitrogen, sulphur, carbon). Moreover, edaphic fauna affect the porosity and aeration as well as the infiltration and distribution of organic matter within soil horizons. The ecosystem services provided by soil fauna are one of the most significant contributions for the conservation of edaphic biodiversity [7]. Decomposition of organic matter by soil organisms is crucial for the functioning of an ecosystem because of its substantial role in plant growth and primary productivity [17].

In different seasons soil fauna was studied under different land use system to identify the best season to study the soil fauna. The dominance value ranges from 0 to 1, where 0 means all taxa are equally present and 1 means one taxon dominates the community completely). In the present study it is observed that, highest value was recorded in summer, suggesting that only few species are dominating the ecosystem while in rainy season the dominance value was less, inferring equal distribution of taxas. The Simpson 1-D is an index which measures the evenness of a community was highest under rainy season followed by winter stating that, more even distribution of species in these seasons compared to summer.The equity or uniformity indices show the distribution pattern of individuals among the species, denoting less or greater uniformity in the composition of the parcels. The Pielou's evenness value of this index varies from 0 to 1, and when it reaches the value 1, it means that all species are equally abundant [18, 19]. The highest evenness index was recorded in rainy season followed by winter and summer.

Shannon diversity is the most common diversity index used in ecological studies. Shannon values generally vary between 1.3 and 3.5, and may exceed 4.0, and reach around 4.5 in tropical forest environments [20]. The Shannon diversity index was highest in winter and is least in summer. The Margalef index measures species richness. The greater the number of species, greater is the value of the index [18, 19, 21]. The species richness was found highest in winter and least in summer. The Chao 1 is an estimate of total species richness. It is also a qualitative measure of alpha diversity which, beside species richness, takes into account the ratio of singletons (n = 1) to doubletons (n = 2) giving more weight to rare species. This index also states that winter season had highest species richness whereas summer had the least species richness.

The species richness index such as Shannon, Margalef and Chao-1 was highest under winter season while lowest in summer. The lowest dominance and highest evenness index was recorded during rainy season stating equal distribution of species compared to other season. Bartz *et al.* 2014 [22] also found that there were changes in total abundance, richness of groups and in the distribution of the relative frequency of groups of fauna among the land use system during the two seasons sampled (Summer and winter). Similar results were also found by several authors who have studied the influence of soil management on the abundance of soil fauna in the state of Santa Catarina [23, 24]. Moço *et al.* (2005) [25] and Santos *et al.* (2008) [26] observed higher soil fauna abundance in the winter compared with the summer season, attributing this to the fact that during the summer of that year there was a drought when there were months without rain.





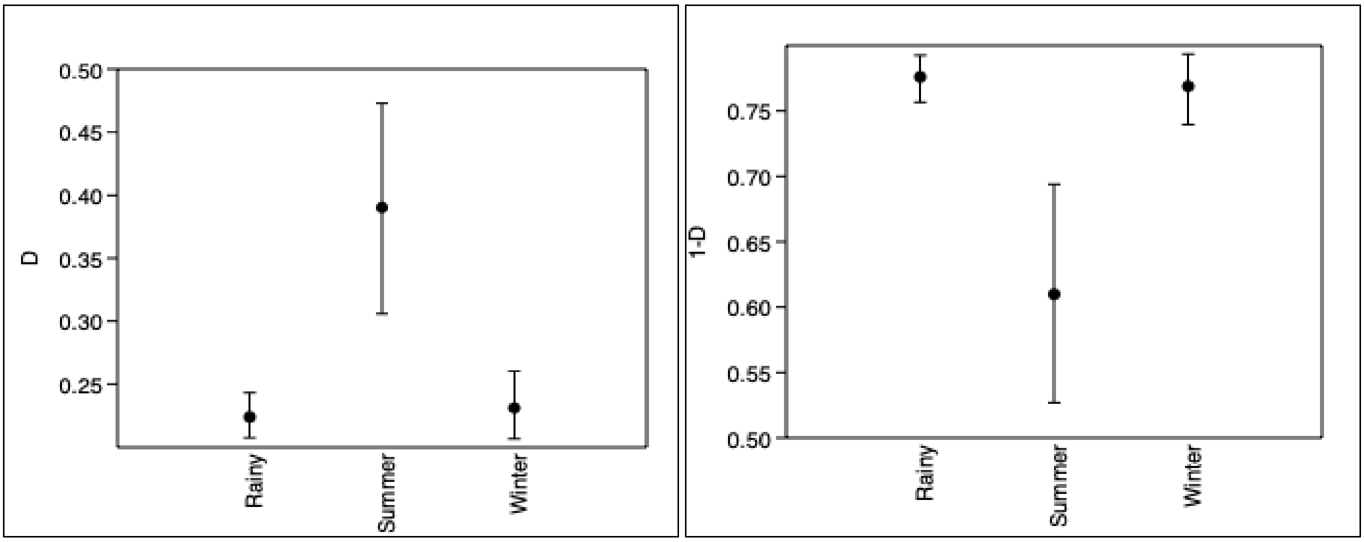


Fig 1: Number of taxa (S), total individuals (N), Dominance (D) and Simpson (1-D) of soil fauna in different seasons

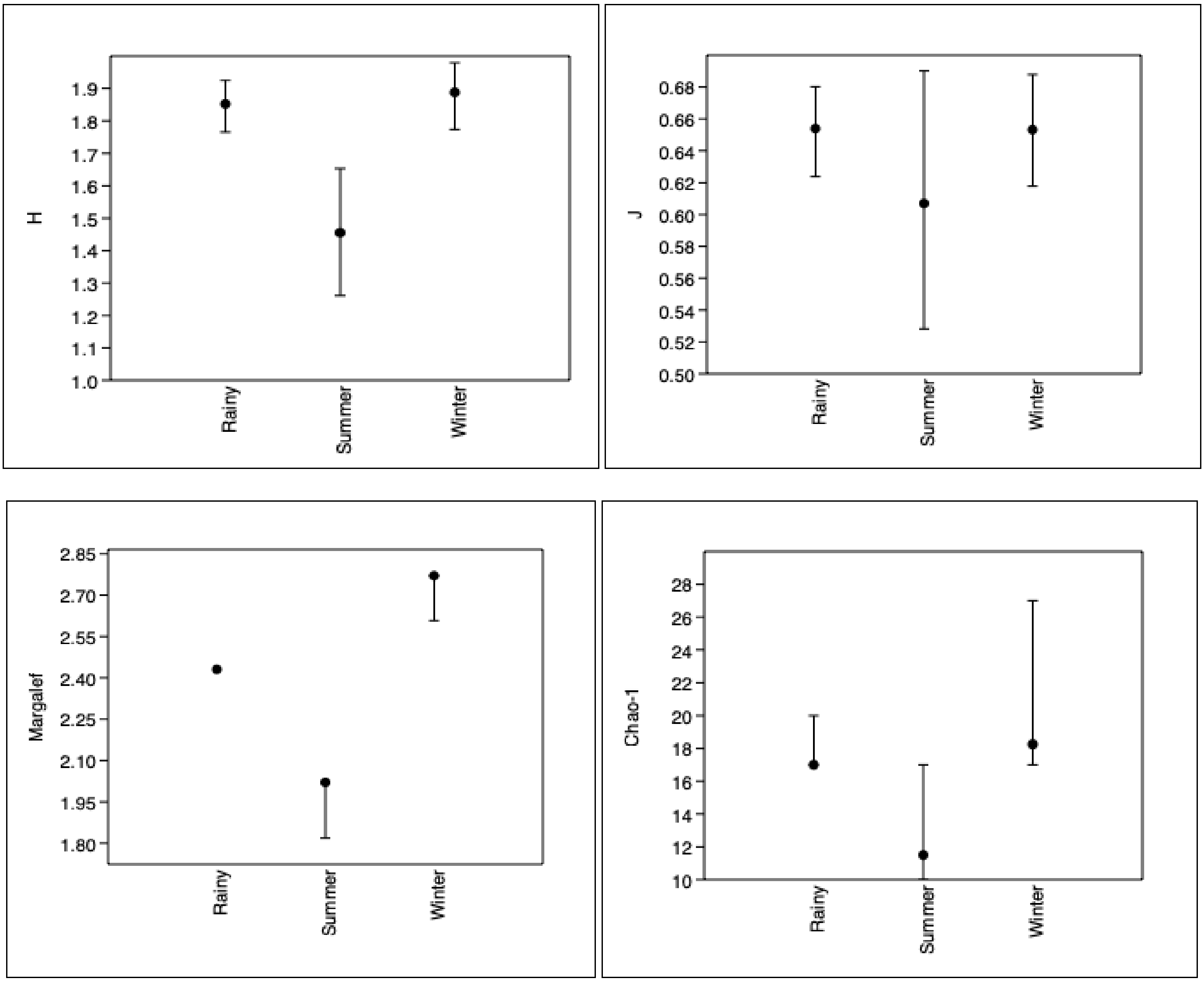


Fig 2: Shannon diversity (H), Evenness (J), Margalef and Chao-1index of soil fauna in different seasons

Relative density of soil fauna in different season

A total of 22 different taxa/ species of soil fauna were recorded in three seasons. (Table 2 and Fig. 3). The highest numbers of individuals were recorded in rainy season (722) followed by winter (462) and summer (141). The highest number of individuals in rainy season indicates the importance of moisture in growth and development of soil fauna. Out of different species identified relative density of Mesostigmata (40%) was highest followed by Cryptostigmata (20.7%) and Onychiuridae (14.00%). Mesostigmata and Cryptostigmata are acari, whereas Onychiuridae is a collembolan

Table 2: Composition of the soil fauna in different seasons.

Soil fauna	Rainy	Summer	Winter	Total	Relative density
Ants	57	11	38	106	8.0
Centipeds	8	0	3	11	0.8
Cockroach	2	1	0	3	0.2
Coleoptera	5	0	10	15	1.1
Cryptostigmata	151	15	108	274	20.7
Diplura	2	0	0	2	0.2
Diptera	11	5	4	20	1.5
Entomobryidae	14	1	8	23	1.7
Hymenoptera	0	2	0	2	0.2
Lepidoptera	0	0	2	2	0.2
Mesostigmata	263	85	182	530	40.0
Onychiuridae	142	0	44	186	14.0
Other mites	11	4	9	24	1.8
Poduridae	12	0	25	37	2.8
Pseudoscorpion	2	0	0	2	0.2
Psocid	24	11	15	50	3.8
Siminthuridae	0	0	1	1	0.1
Spider	5	3	3	11	0.8
Staphylinidae	0	0	1	1	0.1
Symphyla	8	0	5	13	1.0
Termites	0	0	2	2	0.2
Thrips	5	3	2	10	0.8
Total	722	141	462	1325	

Soil fauna have a great influence in functioning of the decomposer flora as a result of their feeding activities [27]. They are the primary agents for the release of nutrients immobilized in the litter biomass [28]. The arthropod fauna of the soil and overlying layer of organic debris normally includes variety of mites, collembolans, pseudoscorpions, centipedes, millipedes, isopods, proturans, diplurans, symphylans, hymenopterans, coleopterans, and larval forms of many other orders. In most soil and litter worldwide, Acarina (mites: Mesostigmata, Cryptostigmata) and Collembola (Onychiuridae, Poduridae, Siminthuridae, Entomobryidae) are the most diverse and abundant arthropods [29]. Vargas *et al.* (2007) [30] studied the micro-arthropods population in tropical dry forest ecosystem and found that numerically dominant groups were Prostigmata, Cryptostigmata, Collembola and Mesostigmata, which constituted 92.6% of the total abundance.

The reason for the Acari dominance 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 [31, 32] who reported Acarina as the most dominant group, when they collected Acari, Collembola, pseudoscorpians and Araneida from Holland and New Zealand soils.

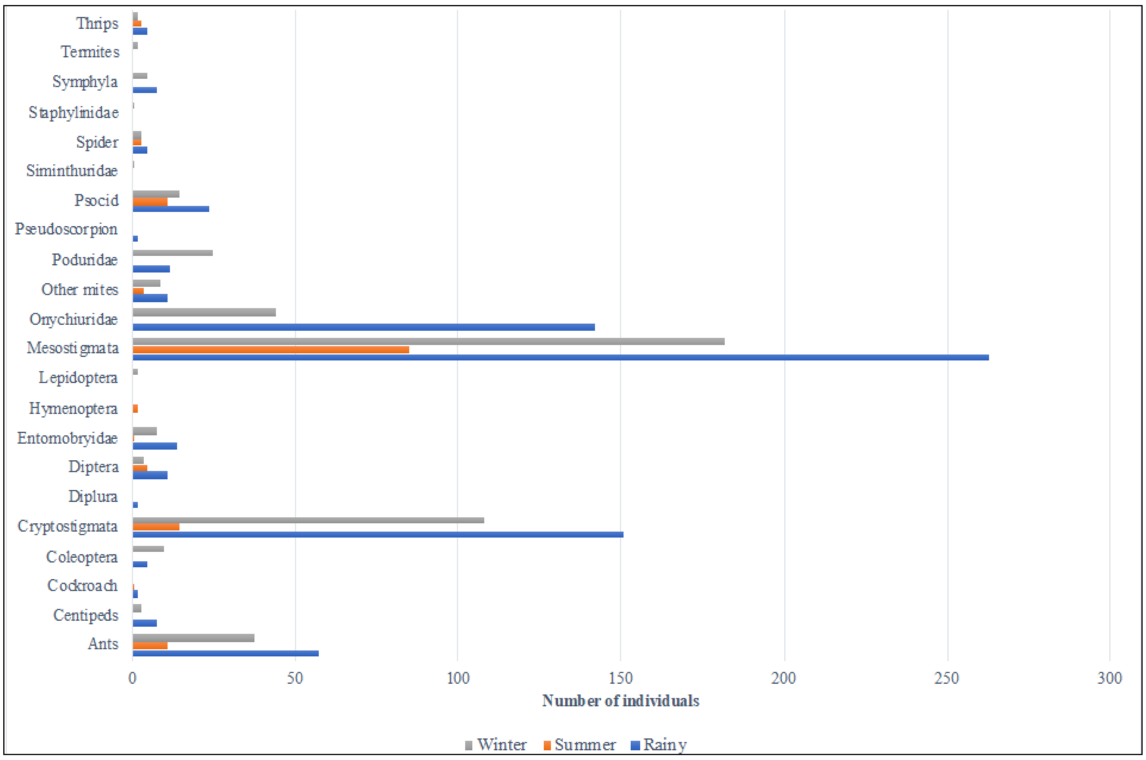


Fig 3: Composition of soil fauna in different season.

Among the arthropods, oribatid mites and collembolans have a great potential as bioindicators of environmental conditions [33, 34], especially land use intensification [35]. The mites and collembolans constitute 72 to 97 per cent of the total arthropod fauna of Indian soil [36,37,38]. Acarina include predators, parasites, parasitoids, fungal feeders, root feeders dead plant feeders, algal feeders, bacterial feeders, omnivores, and scavengers. Acarina have diverse functions in the ecosystem, as evidenced by the range of the feeding guilds to which they belong to and the way they can catalyze primary decomposition and nutrients cycling in soil [39] and activate fungi and bacteria [12]. Acarines are essential for efficient decomposition and nutrient cycling [11].

Collembola are active in decomposition, nutrient cycling, soil formation and can affect fungal composition and activity. They are similar in size as that of oribatid mites, but their role in ecosystem processes in different, as they are primarily fungivores and detrivores [40, 41], and as a result collembolan species can respond more rapidly than oribatid mites to ecosystem disturbance [42, 43]. Generally maximum population density of Collembola is observed in the upper soil layer, where the maximum decomposition activity takes place [44] .

Other soil fauna includes diplurans, ants, soil-dwelling beetles and grubs, spiders, subterranean termites, centipedes, symphylans, earthworms etc. These invertebrates build holorganic structures (their faecal pellets) that serve as incubators for microbial activities; some time after deposition, they re-ingest these pellets to assimilate metabolites that have been released by the microflora [40, 45].

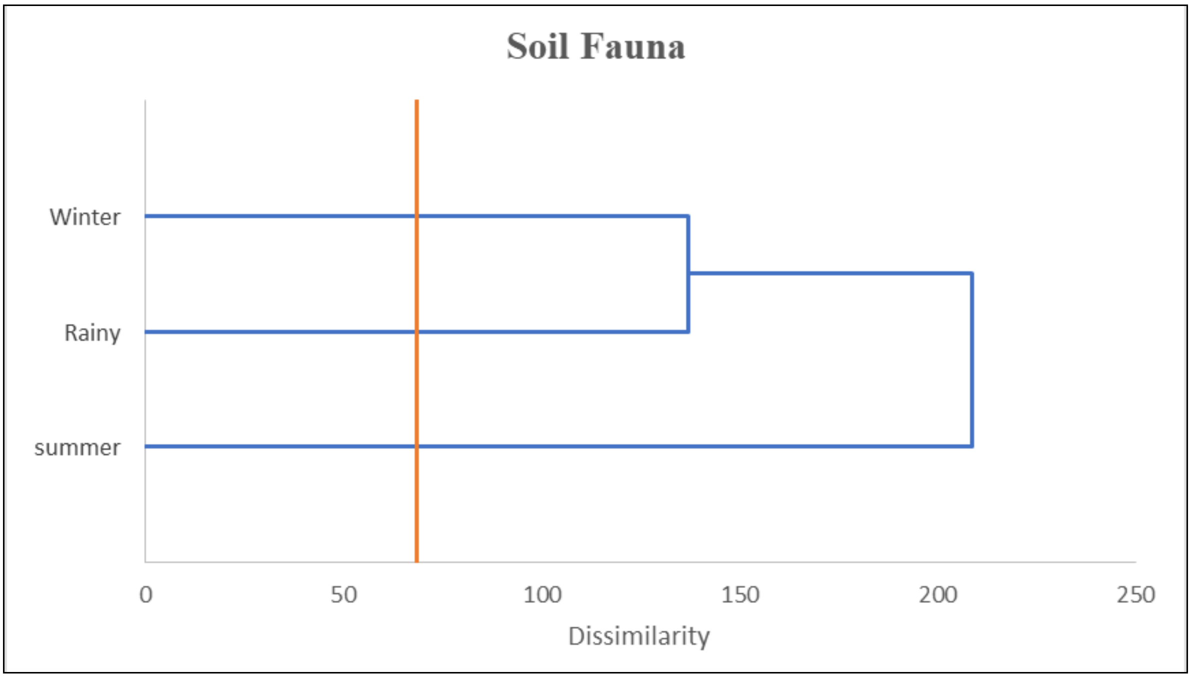


Fig 4: Cluster analysis of soil fauna in different seasons

Cluster analysis

The cluster analysis was carried out to understand the nature of similarity or dissimilarity among the different seasons in soil fauna. It can be seen that there are three clusters distinctly formed (Fig. 4). The winter and rainy season clusters were placed closer compared to summer, inferring that there is similarity of soil fauna in winter and rainy season. Whereas, the cluster of soil fauna in summer was placed separately stating that lesser species diversity compared to winter and rainy. The similarity of species in winter and rainy also states that availability of moisture and ambient temperature is must for optimum growth soil fauna. Climatic seasons tend to translate into seasonal activity patterns in living organisms including arthropods which became active only at certain times of the year [46]. Soil temperature and moisture influence micro arthropod reproduction and development rates [47].

Conclusion

A total of 22 different taxa/ species of soil fauna were recorded in three seasons. The highest numbers of individuals were recorded in rainy season. Seasons had direct influence on the diversity, richness, abundance, evenness of soil arthropods. The species richness index such as Shannon, Margalef and Chao-1 was highest under winter season while lowest in summer. The lowest dominance and highest evenness index was recorded in rainy season stating equal distribution of species compared to other season. It can be concluded that, in order to study the soil fauna diversity in semi-arid regions, the best season would be winter followed by rainy seasons.

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