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Study on earthworm population of Srinagar (J&K), India with reference to soil physiochemical characteristics

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Abstract
The study reports the diversity and seasonal population dynamics of earthworms at Srinagar based on the data collected from four sites. A total of five earthworm species- *Aporrectodea caliginosa trapezoides*, *Aporrectodea rosea rosea*, *Eisenia fetida*, *Octolasion cyaneum* and *Drawida japonica* were recorded. Out of the five species, *A. c. trapezoides* was present at maximum sites whereas D. *japonica* and *O. cyaneum* exhibited restricted distribution. Diversity indices- Margalef species richness and Shannon-Wiener diversity index exhibited maximuim value of 0.31 and 1.05 at site-III respectively. pH and EC exhibited significant variation within the sites (F_3= *40.28; 46.94* $P < 0.05$), temperature among the seasons (F_3=*137.91*, $P < 0.05$) whereas moisture and organic carbon among the seasons (F_3= 7.10; 3.88, $P < 0.05$) and within the sites (F_3= *30.55; 57.09*, $P < 0.05$). pH, organic carbon, organic nitrogen along with moisture favors the diversity of earthworms whereas the temperature affects the overall population dynamics.

Keywords: diversity, earthworms, population, soil, Srinagar

Introduction
Earthworms are among the key organisms in soil ecology [1]. As ecosystem engineers their activity affects not only many important soil processes such as soil aeration, decomposition or nutrient availability, but they also promote soil biodiversity, soil fertility and soil health [2-4]. They play a major role in ecosystem functioning [5] and contribute to wide range of essential ecosystem services [6]. They are important macrofauna of the rhizosphere [7] and part of the decomposer foodweb, consume large amounts of plant remains and soil [8]. In different pedoecosystems they enhance the turnover of organic residues [9-10], increase the microbial activity and therefore contribute to an enhanced mineralisation and nutrient availability in soil [11-14]. Their contributions to improve drainage and transformation of minerals and plant nutrients to available and accessible forms make the soil favorable for crop yield [4, 15-18]. The objective of the study is to evaluate the soil factors affecting earthworm population dynamics.

Materials and Methods
Study Area
Kashmir Valley of the State of Jammu and Kashmir, India is situated between 33°15' and 34°30' N latitude and 74° and 75° 13' E longitude. It lies in a temperate zone, characterized by wet and cold winter and relatively dry and moderately hot summer.

Study Sites
Earthworms were collected from four sites (table 1) each characterized by different vegetation, slopes and elevation ranging between 1490 and 1680 m above sea level (masl).

Table 1: Description of sites

Name of site	Coordinates	Elevation
Chinar trees	34°12.763′N 074°21.115′E	1490
Paddy cultivation	34°16.573′N 074°52.972′E	1680
Populus plantation	34°03.259′N 074°47.483′E	1525
Vegetable garden	34°47.265′N 074°47.779′E	1500

Earthworm and Soil Sampling
Sampling for earthworms and soil was done every month at each site. Earthworms were collected by digging soil monolith (25 x 25 x 30 cm) and handsorting [1,3]. Worms were counted, weighed, preserved in 4 % formalin and sent to Zoological Survey of India (ZSI) for identification.

Soil Analysis
Composite soil samples were analyzed by following methods-soil temperature by soil thermometer and soil moisture by gravimetric method [19] pH, electrical conductivity (EC) and organic nitrogen (ON) by micro Kjeldal method [20] and organic carbon (OC) by Walkley and Black (1934) [21].

Diversity Measurements
The Margalef species richness DMg (D=S-1/ln N, where, S is number of species and N is number of individuals), Shannon and Wiener diversity index H′ (H′= -Σpi ln pi, where, pi the proportional abundance of the *i*th species = ni/N) and Pielou's evenness E (E= H′/ ln S, where, H′ is Shannon and Weiner diversity index and S is number of species) were calculated for each site [22].

Statistical analysis

With the objective of evaluating significant variation within and among the sites for all soil parameters, data sets were analyzed using two-way analysis of variance (ANOVA) at 0.05 % level of significance. Pearson correlation coefficient (r) was employed to examine the relationship between number of earthworm species with soil physicochemical parameters [1, 3, 23].

Results and discussion

A total of five earthworm species (table 2)- *Aporrectodea caliginosa trapezoides*, *Aporrectodea rosea rosea*, *Eisenia fetida*, *Octolasion cyaneum* and *Drawida japonica* were recorded at four sampling sites with varying physiochemical characteristics (Fig.1). In terms of distribution, *Aporrectodea caliginosa trapezoides* was present at three sites, *A. r. rosea* and *E. fetida* at two sites each, whereas *D. japonica* and *O. cyaneum* at one site. Out of 5 species, *A. c. trapezoides* was present at the maximum number of sites and exhibit a wide range of tolerance to edaphic factors. *O. cyaneum* was restricted to only one site each. Sims and Gerard (1999) [24] report that *O. cyaneum* prefers moist habitats in Great Britain. Najar and Khan (2011b) [25] also reported the species from the site with more moisture content. Najar and Khan (Najar and Khan 2011c) [26] also reported *E. fetida* from site rich in organic matter. The presence of species in a particular habitat and its absence from other habitats shows the species-specific distribution of earthworms in different pedoecosystems.

Earthworm density ranged from 24/m^2 at Site-III during winter to 85.6/m^2 at Site-IV during spring with a biomass of 13.13 g/m^2 to 34.22 g/m^2 respectively (Fig.2). Maximum earthworm density was recorded during spring and may be related to the optimum moisture and temperature conditions. Callaham and Hendrix (1997) [27] also reported higher earthworm density during spring. Low earthworm density was reported during winter and is which is attributed to low temperature during winter as low temperature delays hatching of cocoons [1, 3]. Timmerman et al. (2006) [28] also reported low earthworm abundance during winter due to the low temperature. Diversity indices are given figure 3. Margalef species richness was 0.31 at site-III, Shannon-Wiener diversity index 1.05 at site-III whereas Pielou's evenness was 0.97 at site-II. Significant positive correlation was observed between the number of earthworm species and organic nitrogen (P < 0.01), moisture (P < 0.01) and organic carbon (P P < 0.05). Shannon-Wiener diversity index and Margalef species richness are higher at site-III and could be related to higher carbon, moisture and nitrogen content of soil compared to other sites. Similarly finding was also reported by Tripathi and Bhardwaj (2004) [29] as favorable edaphic characteristics increase the species diversity [1]. Najar and Khan (2011a; 2014) [3, 1] also reported positive correlation of earthworm diversity with soil moisture, organic carbon and nitrogen. Soil moisture, pH, temperature, organic nitrogen, electrical conductivity and organic carbon play Important role in the distribution of earthworms [1, 4, 30]. pH exhibited non-significant variation among the seasons (F_3= *0.84, P < 0.05*) whereas vary significantly (F3= 40.28, P < 0.05) within the sites. pH ranged from 7.01 at site-II (spring) to 8.20 at site-III during winter. Chaudhuri and Bhattacharjee (1999) [31] reported earthworms are mostly distributed in a pH range of slightly acid to moderate alkaline, thus pH value recorded in the present study are within the range for the distribution of earthworms. EC showed non-significant variation (*F3= 2.50, P < 0.05*) among seasons, whereas significant variation (F_3= *46.94, P < 0.05*) within the sites. EC varied from 0.06 at site-II to 0.48 at site-IV during summer and is the indicator of different salts concentration in the soil, thus plays vital role in earthworm metabolism. Moisture ranged from 16.22 at site-II (summer) to 39.52 at site-IV (winter), with significant variation among the seasons (F_3= *7.10, P < 0.05*) and within the sites (F_3= *3.88, P < 0.05*). Population density was lower during summer at all the sites. One of the reasons might be low moisture content of soil, as fecundity of earthworms is greatly influenced by low soil moisture content. Schmidt and Curry (2001) [32] reported low population density with low soil moisture content. Further Najar and Khan (2011a, 2014) [3, 1] also confirmed the absence of earthworm in pedoecosystems with low moisture content. Temperature recorded was 4.31 at site-II (winter) to 17.05 at site-III during summer. Temperature varied significantly among the seasons (F_3= *137.91, P < 0.05*) whereas non-significant within the sites (F_3= *1.49, P < 0.05*). Low earthworm density was recorded during the winter. The low temperature could be attributed to lower density during winter and corroborates the findings of Najar and Khan (2011a, b 2014; Najar et al. 2020) [3, 1, 4]. Organic nitrogen showed non-significant variation among the season (F_3= *1.74, P < 0.05*) and within the sites (F_3= *2.2, P < 0.05*), with range from 1.03 at site-III (winter) to 2.98 at site-III (autumn). The low nitrogen content of soil is often considered as critical factor, since it limits the distribution of earthworms in many temperate ecosystems [33] however in the present study the nitrogen was present in moderate range and plays important role in population dynamics of earthworms [1]. Organic carbon varied significantly among the seasons (F_3= *30.55, P < 0.05*) and within the sites (F_3= *57.09, P < 0.05*) with a mean value from 18.20 at site-IV during summer to 33.87 at site-III (autumn). Soil organic carbon play important role in the distribution of earthworms as it determines the nature of food which and plays important role in distribution [34, 13].

Table 2: Distribution of earthworms at different sites

Species	Site-I	Site-II	Site-III	Site-IV
A.c.trapezoides	-	+	+	+
A.r.rosea	+	+	-	-
D.japonica	-	-	+	-
E.fetida	-	-	+	+
O.cyaneum	+	-	-	-

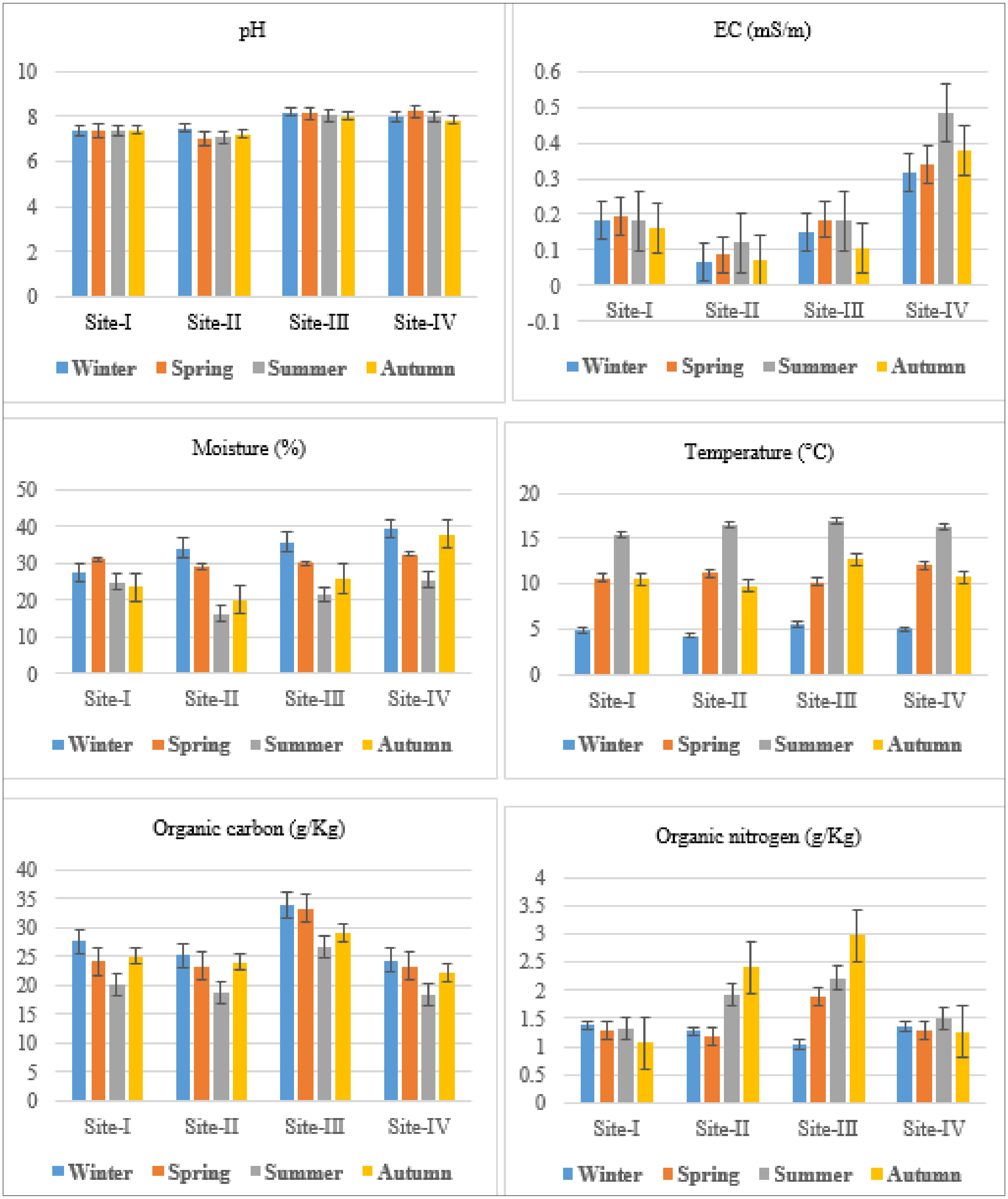

Fig 1: Soil physiochemical characteristics at different sites during different seasons.

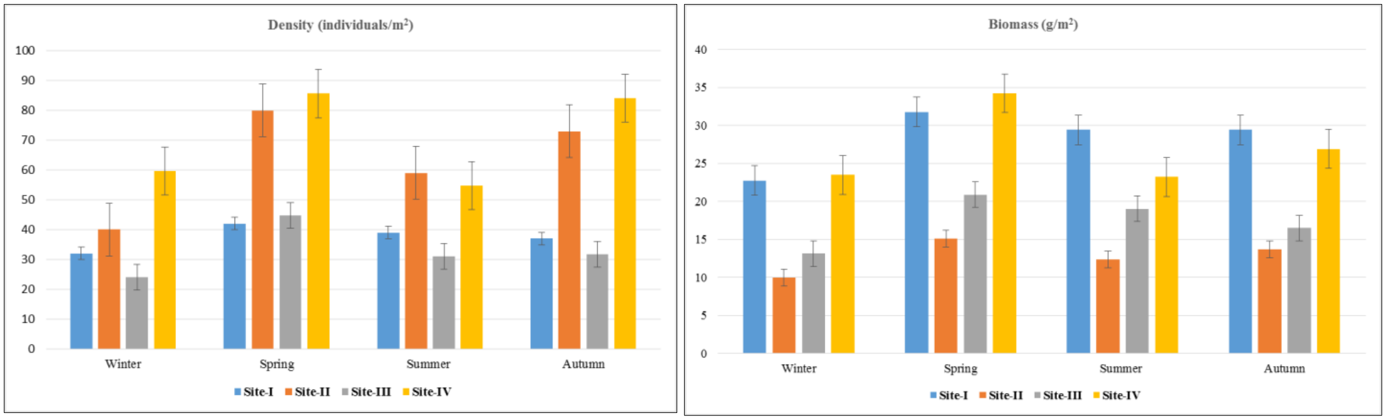

Fig 2: Density and biomass of earthworms at different sites during different seasons.

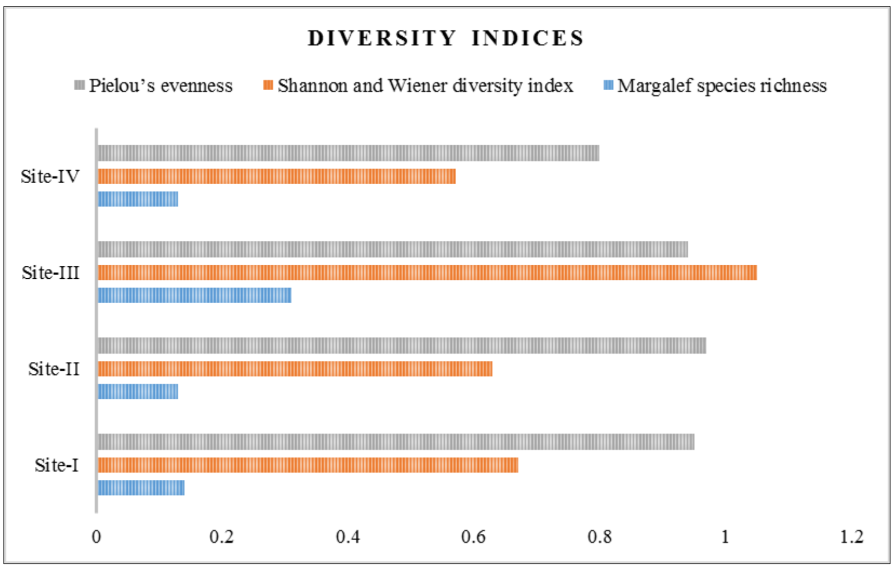

Fig 3: Diversity indices at different sites.

Conclusion

The earthworm species recorded in the study were endogeic (*A. r. rosea*, *O. cyaneum*, *D. japonica* and *A. c. trapezoides*) and epigeic (*E. Fetida*). Among endogeic *A. c. trapezoids* showed a wide range of distribution due to its tolerance to wide range of edaphic factors whereas *O. cyaneum* exhibited restricted distribution as the species prefers specific edaphic factors (low temperature and moderate moisture). Earthworm density and biomass varied among the seasons, thus seasonal variation is major factor affecting the distribution of earthworms as it affects the soil physiochemical characteristics which in turn determines their population dynamics. Sites with optimum soil moisture, organic carbon and nitrogen favors the earthworm population and variety resulting in higher earthworm diversity.

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