Species Diversity and Pattern of Distribution of Collembola (Apterygota: Insecta) in Cultivated and Uncultivated Sites of Orissa, India

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Collembola have a more extensive distribution than the species of any other insect group. This is mainly due to the fact that they are easily dispersed by air, water or in the feet of birds. The most important single factor governing the distribution of collembola is humidity. The species composition of a collembolan population depends largely on the moisture content of the soil and this phenomenon has been amply demonstrated by HALE /1963/, NOSEK /1962/, POOLE /1961, 1962, 1964/ and STEBAEVA /1963/.

In this study an attempt was made to study the species diversity of collembola in a crop field and a grassland site at different soil depths during an 18-month study period and subsequently to quantify the species diversity, to detect the aggregation phenomenon and to determine the degree of similarity between the two sites.

Materials and methods

The sites are situated in Bhubaneswar /85°53'E longitude and 20°21'N latitude/. The uncultivated site was a grassland having Cyperus rotundus, Cynodon dactylon as the dominant species. The pH of the grassland varied from 7.6 to 8.3. The cultivated site was a rice field, with a soil pH ranging from 7.3 to 8.3. The moisture content of the soil during the study period varied between 5.2% and 15.7% in the grassland and between 9.5% and 21.7% in the crop field. The maximum soil temperature recorded during the summer month of May was 36.7 °C in the grassland and 39.6 °C in the crop field, while the maximum atmospheric temperature was 38 °C.

Soil samples /10 cm x 10 cm x 15 cm/ were collected during the 18-month study period from both sites. The Tullgren funnel method was used for the extraction of collembola. To quantify the species diversity, the Shannon Index /ODUM, 1975/ was used in different months of the study period, employing the following formula:

$$H = \Sigma \frac{n_i}{N} \log_e \frac{n_i}{N} = \Sigma p_i \log_e p_i$$

The H designates the Shannon Index; Σ means the sum of, N represents the total number of collembola, n_i as the value for each species, the ratio $\frac{n_i}{N}$ is the probability function, p_i for each of the parts of the whole and $\log_e$ represents the natural logs.

Data analysis of random sampling was carried out to detect aggregation in the collembola population. Two methods were used:

1. Detection of aggregation using the frequency distribution /DASH and CRAGG, 1972/ in which sample unit values were grouped into frequency distribution around their individual means with multiples of standard deviation as the class boundaries and compared with a normal distribution by chi-square analysis;
2. Detection of aggregation using the coefficient of variation /SALT and HOLLICK, 1946/.

Based on the numbers of species available; the degree of similarity between the two study sites were calculated by using the Sorenson's quotient of similarity /BUTCHER et al., 1971/.

$$QS = \frac{2c}{a+b} \cdot 100$$

where QS = Quotient of similarity; a = No. of species in site A; b = No. of species in site B; c = No. of common species.

Results

Altogether five species of collembola were available in the grassland site and six species were collected from the crop field. Cryptopygus thermophilus, Lepidocyrtus caeruliconis and Isotoma sp. were common on both sites. Acrocyrtus cryptocephalus and Hypogastrura sp. were confined to the grassland while the species like Folsomia brevifurca and protaphorura sp. were restricted to the crop field only.

The Shannon diversity indices for different depths of the two sites are given in Table 1. The index values were 86.09 and 85.75 for the grassland and crop fields, respectively. At 0-5 cm soil depth, there was no significant difference between the indices; the values were 81.52 and 83.39 for the grassland and crop field, respectively. However, at 5-10 cm depth, the index was more than 90 in the cropland, while in the grassland the value was 85.7. At 10-15 cm depth in the grassland, the diversity index was 76.39 and this value was the lowest. The recorded indices were never below 70. The maximum index value was 97.52 in the cultivated field during May, 1983. In the

Table 1

Shannon diversity indices for species diversity at different depths of two study sites /Value in percentage/

Site	Value at			Value for the site
	0-5 cm depth	5-10 cm depth	10-15 cm depth	
Grassland	81.52	85.70	76.39	86.09
Crop field	83.39	91.35	84.18	85.75

grassland, the maximum and minimum values were observed in January, 1984 and February, 1983, respectively. In the crop field, the maximum value was found in May, 1983 and minimum in July, 1983 /Table 2/. When all the depths were taken into consideration there was no significant difference between the indices of both sites.

Table 2

Shannon diversity indices for species diversity in two different sites during the 18-month study period /values in percentage/

Year	Month	Value in Grassland	Value in Crop field
1982	September	88.92	80.23
	October	89.77	80.79
	November	92.42	82.50
	December	86.83	80.38
1983	January	79.06	82.53
	February	74.55	91.65
	March	85.93	89.13
	April	92.94	90.10
	May	88.04	97.52
	June	92.55	95.98
	July	78.79	79.57
	August	92.13	88.27
	September	92.81	92.06
	October	93.54	90.78
	November	91.63	85.87
	December	89.66	84.94
1984	January	95.65	85.71
	February	93.69	90.95

Table 3

Additive chi-square values for three depths in the study sites

Site	Value at 0-5 cm depth	Value at 5-10 cm depth	Value at 10-15 cm depth
Grassland	8.171	7.031	5.182
Crop field	5.900	5.708	5.685

*All values are significant /$p < 0.05$/

For the detection of aggregation phenomenon in Collembola, two methods were employed, namely the frequency distribution method /DASH and CRAGG, 1972/ and coefficient of variation /CV/ method /SALT and HOLLICK, 1946/. The chi-square values for the three depths in two study sites are given in Table 3. In all the cases, the calculated values were always less than the tabulated values, indicating that the distribution pattern was not significantly different from the normal. Thus aggregation could not be detected in this population by using the frequency distribution method. To confirm this, the

Table 4

Coefficient of variation values in the grassland and crop field during the 18-month study period

Month	Value at 0-5 cm depth	Value at 5-10 cm depth	Value at 10-15 cm depth	Value in total	Value at 0-5 cm depth	Value at 5-10 cm depth	Value at 10-15 cm depth	Value in total
	Grassland				Crop field			
1982								
September	0.0724	0.1990	0.2964	0.0769	0.0838	0.1075	0.3892	0.0370
October	0.1105	0.2130	0.4205	0.1091	0.1264	0.2406	0.4441	0.0270
November	0.1950	0.3464	0.5052	0.1056	0.0887	0.1630	0.2617	0.0635
December	0.0625	0.3722	0.9083	0.0346	0.1852	0.1101	0.4625	0.1045
1983								
January	0.0822	0.1064	0.3500	0.0210	0.1373	0.1784	0.1781	0.0487
February	0.1759	0.2529	0.6380	0.0902	0.0959	0.1160	0.2350	0.0476
March	0.0990	0.1816	0.2184	0.0762	0.1183	0.2586	0.4062	0.0666
April	0.0833	0.0964	0.4700	0.0349	0.1340	0.8593	0.4384	0.2428
May	0.3136	0.3423	0.3857	0.1416	0.2440	0.2593	0.4611	0.1580
June	0.2388	0.2828	0.3406	0.2460	0.3234	0.2593	0.4611	0.1000
July	0.1417	0.2257	0.3333	0.1016	0.0915	0.1500	0.1571	0.0463
August	0.1898	0.1575	0.4000	0.1544	0.1764	0.1727	0.3406	0.1277
September	0.1535	0.2307	0.6595	0.1070	0.2451	0.5090	0.6441	0.3216
October	0.0748	0.1575	0.3838	0.1093	0.1365	0.3137	0.6526	0.0727
November	0.1788	0.3095	0.6357	0.0393	0.0881	0.1436	0.4285	0.0929
December	0.0778	0.2500	0.6916	0.0361	0.1308	0.2169	0.4625	0.0619
1984								
January	0.1443	0.1781	0.2964	0.0564	0.2123	0.2473	0.4464	0.0788
February	0.1013	0.1000	0.3934	0.0831	0.1566	0.1560	0.5428	0.0863

CV method was applied and the results of this analysis are enlisted in Table 4 showing the values at all soil depths in both sites monthly during the 18-month study period. The values were always less than one. So, the aggregated form of population could not be detected in this way either.

It was observed that the QS value between both sites was 54.54. The number of Collembolan species recorded in the grassland site was 5, and that in the crop field was 6. The number of common species was 3 in both sites.

Table 5
Values of Quotient of similarity between the three soil depths in the grassland and crop field site

Soil depth	No. of collembola species	No. of 5-10 cm	Common species 10-15 cm	QS 5-10 cm	Values with 10-15 cm
			Grassland site		
0-5 cm	4	3	1	75.0	33.3
5-10 cm	4	-	2	-	66.6
10-15 cm	2	2	-	66.6	-
			Crop field site		
0-5 cm	4	4	1	80.0	28.57
5-10 cm	6	-	3	-	66.66
10-15 cm	3	3	-	-	-

Table 5 gives the QS values of three soil depths of the grassland and crop field, respectively. In both sites the QS values between the 0-5 cm and 10-15 cm soil depths were very low. The QS values between the 0-5 cm and 5-10 cm depth were 75 and 80 in the grassland and crop fields, respectively.

Conclusions

The species composition in a mixed population in different places depends largely upon the moisture content of the soil. HAZRA and CHOUDHURI /1983/ recorded 14 genera of collembola from cultivated and uncultivated sites of West Bengal. MITRA et al. /1983/, - while doing some preliminary observations on the effect of the rotation of crops and fertilizers on collembola in the soils of West Bengal - have described 9 species from the paddy fields. SINGH and MUKHERJII /1971/ recorded 9 species of collembola from uncultivated fields of Varanasi. PAI and PRABHOO /1981/ collected 5 species of collembola from the post-harvest decay of paddy tillers in Kerala. In the present investigation, 6 species were recorded from the crop field and 5 species from the grassland, which can be well compared with the observations of the above workers from Indian soils.

The Shannon Index is an index of diversity in which the higher the value, the greater the diversity and the less the community is dominated with one or few kinds /ODUM, 1975/. TAKEDA /1981/, while evaluating the community structure of collembola in Thailand, concluded that the species richness was significantly higher in the forest than in the crop plots. However in this investigation, the species diversity indices showed high values in both sites. The values also showed a more or less uniform pattern even at various soil depths. There was no significant change during the different months either. It can be concluded that the higher values of the Shannon Index in this investigation clearly indicate species richness in both sites.

Aggregation in Collembola has been recorded by various workers from various soils /GLASGOW, 1939; MACFADYEN, 1952, 1957; HUGHES, 1962; POOLE, 1961; JOOSSE, 1970 and VERHOEF and SLEM, 1983/. However, USHER /1969/ found the distribution of collembola within a block of samples to be of 3-types: uniform, random and aggregated. In the present investigation, aggregation of collembola could not be detected in all the soil profiles in both sites.

Communities of collembola in different soils of the same locality are more similar than that of different locality /BUTCHER et al., 1971/. In this study the 54.54 QS values between two sites was only due to difference in the habitat conditions. In both study sites; the uppermost soil layers /0-5 cm/ showed lesser QS values with the bottom layer /10-15 cm/ which can only be explained with the help of vertical distribution of each and every species.

The species diversity and distribution in collembola are governed by various edaphic as well as biological factors, such as: soil moisture, soil temperature, micro-climate, fungi, mites, cropping, cultivation practices, organic matter, biotic disturbances, soil type and feeding habits of the species. A holistic approach is essential for having a proper understanding on Collembola distribution.

References

BUTCHER, J.W., SNIDER, R. and SNIDER, R.J., 1971. Bioecology of edaphic collembola and Acarina. Ann. Rev. Entomol. 16. 249-288.

DASH, M.C. and CRAGG, J.B., 1972. Selection of micro-fungi by Enchytriedae /Oliyochaeta/ and other members of soil fauna. Pedobiologia. 12. 282-286.

GLASGOW, J.P., 1939. A population study of subterranean soil collembola. J. Anim. Ecol. 8. 323-353.

HALE, W.G., 1963. The Collembola of eroding blanket dog. In: Soil organisms /Eds. DOCKSON, J. and VAN DER DRIFT, J./. 406-413. North Holland Publ. Co., Amsterdam.

HAZRA, A.K. and CHOUDHURI, D.K., 1983. A study of Collembola communities in cultivated and uncultivated sites of West Bengal in relation to three major soil factors. Rev. Ecol. Biol. Sol. 20. /3/ 385-401.

HUGHES, R.E., 1962. The study of aggregated populations. In: Progress in Soil Zoology /Ed.: MURPHY, P.W./, 51-55.

JOOSSE, E.N.G., 1970. The formation and biological significance of aggregations in the distribution of Collembola. Neth. J. Zool. 20. 299-314.

MACFADYEN, A., 1952. The small arthropods of a Molinia fen at Cothill. J. Anim. Ecol. 21. 87-117.

MACFADYEN, A., 1957. Animal Ecology, 'Aims and Methods', Pitman, London.

MITRA, S.K. et al., 1983. Changes in the population structure of collembola and acarina in a grassland and rain water drainage at Calcutta. In: New Trends in Soil Biology. /Eds: LEBRUN, Ph. et al./ 664-667.

NOSEK, J., 1962. Zur Kenntnis der Apterygoten der Klenikarpathischan Wald und Dauergrun land boden. Pedobiologia. 2. 108-131.

ODUM, E.P., 1975. Ecology. Amerind Publ. Co. Ltd., New Delhi, 232-233.

PAI, C.G.A. and PRABHOO, N.R., 1981. General soil fauna. Preliminary observation on the microarthropod fauna of paddy fields and adjoining

uncultivated soils of South Kerala. In: Progress in Soil Biology and Ecology in India, UAS Tech. Ser. No. 37. 27-32.
POOLE, T.B., 1961. An ecological study of Collembola in a coniferous forest soil. Pedobiologia. 1. 113-137.
POOLE, T.B., 1962. The effect of environmental factors on the pattern of distribution of soil Collembola in a coniferous woodland. Pedobiologia. 2. 169-182.
POOLE, T.B., 1964. A study of distribution of soil Collembola in three small areas in a coniferous woodland. Pedobiologia. 4. 35-42.
SALT, G. and HOLLICK, F.S.J., 1946. Studies of wireworm population, spatial distribution. J. Expt. Biol. 23. 1-46.
SINGH, J. and MUKHERJI, S.P., 1971. Qualitative composition of soil arthropods in some fields at Varanasi, India. Oriental Insects. 5. 487-494.
STEBAEVA, S.K., 1963. Oekologische verteilung der Collembolan in Waldern und steppen Sud. Tuvas. Pedobiologia. 3. 75-85.
TAKEDA, H., 1981. Effects of shifting cultivation on the soil mesofauna with special references to Collembolan populations in the North-East Thailand. Mem. Coll. of Agric. Kyoto Univ. No. 118. 45-60.
USHER, M.B., 1969. Some properties of the aggregations of soil arthropods: Collembola. J. Anim. Ecol. 38. 606-622.
VERHOEF, H.A. and VAN SLEM, A.J., 1983. Distribution and population dynamics of collembola in relation to soil moisture. Holarctic Ecology. 6. 387-394.