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Population dynamics of earthworms (Oligochaeta) in cultivated soils of central Himalayan tarai region

RENU BISHT, H. PANDEY, D. BHARTI & B.R. KAUSHAL*

Department of Zoology, Kumaun University, Nainital 263 002, India

Abstract: Earthworm population dynamics was studied in a cultivated soil at Shantipuri (29° 55′ N and 79° 40′ E, altitude 233 m) in central Himalayan tarai. A total of 2111 earthworms from 235 samples were collected. Six species of earthworms were found: one Lumbricidae, and five Megascolecidae. Densities ranged from 0 to 19.0 ind. m^{-2} and biomass from 0 to 10.9 g m^{-2}. About 94% of the total earthworms and 94% of the total biomass were found in the 0-10 cm soil layer. Age structure of earthworms indicated that clitellates were more abundant than aclitellates during the wet periods (June-October). The average annual ratio of clitellates to aclitellates was 1:0.8. Earthworm density showed positive correlations between soil moisture and worm biomass.

Resumen: La dinámica poblacional de lombrices de tierra fue estudiada en un suelo cultivado en Shantipuri (29° 55' N y 79° 40' E, altitud 233 m) en el tarai del Himalayan central. En total fueron recolectadas 2111 lombrices de tierra en 235 muestras. Fueron encontradas seis especies de lombrices: una Lumbricidae y cinco Megascolecidae. Las densidades fluctuaron entre 0 y 19.0 ind. m^{-2}, y la biomasa entre 0 y 10.9 g m^{-2}. Cerca de 94% del total de lombrices de tierra y 94% de la biomasa total fueron encontradas en la capa de suelo de 0 -10 cm. La estructura de edades de las lombrices de tierra indicó que las cliteladas fueron más abundantes que las aclitelades durante los periodos húmedos (junio-octubre). El cociente anual promedio de las cliteladas entre las acliteladas fue 1:0.8. La densidad de lombrices terrestres mostró correlaciones positivas entre la humedad del suelo y la biomasa de las lombrices.

Resumo: A dinâmica da população de minhocas foi estudada num solo cultivado em Shantiputi (29º 55' N e 79º 40' E, altitude 233 cm) na região central Himalayan tarai. Um total de 2111 indivíduos de uma amostra de 235 amostras foram colhidos. Seis espécies de minhocas foram encontradas; uma Lumbricidae e cinco Megascolecidae. As densidades variaram entre 0 e os 19,9 indivíduos.m^{-2} e a biomassa de 0 a 10,9 g.m^{-2}. Cerca de 94% do total de minhocas e 94% da biomassa total foram encontradas na camada superior do solo entre os 0 -10 cm. A estrutura de idades das minhocas indicava que os clitelatos eram mais abundantes que os aclitelatos durante os períodos húmidos (Junho – Outubro). O ratio anual médio entre os clitelatos e os aclitelatos era de 1:0,8. A densidade de minhocas mostrou estar positivamente correlacionada com o teor de humidade do solo e a biomassa das minhocas.

Key words: Age structure, cultivated soil, depth distribution, earthworms, Himalayan tarai, population dynamics.

**Corresponding Author*

Introduction

Earthworms are one of the most important groups of soil invertebrates and are known to improve soil fertility by enhancing the physical, chemical and biological characteristics of the soil (Lee 1985). Earthworms can comprise a significant portion of the total biomass (80-96%) of invertebrates in some soils (Didden *et al.* 1994). Most of the studies available on earthworm ecology are from temperate regions (Edwards 1983). Many studies on earthworms are available in tropical soils (Bhandauria & Ramakrishnan 1989; Julka 1988; Kale 1998; Singh 1997). Few studies have been reported from cultivated soils of central Himalaya (Kaushal *et al.* 1999).

This paper is aimed at understanding the influence of soil properties on species composition, population dynamics, depth distribution and age structure of earthworms in cultivated soils in central Himalayan tarai region for developing management strategies for improving soil fertility.

Materials and methods

The earthworms were sampled at Shantipuri near Pantnagar (29°55′ N and 79°40′ E, altitude 233 m). Climatic data from a nearby meterological station (GB Pant Agricultural University, Pantnagar) was used to define the seasons, i.e., summer (March-June), rainy (July-October), and winter (November-February). The climate of the area is subtropical and the average annual temperature and precipitation are 7.2 to 37.8°C and 2270 mm, respectively.

The soil is alluvial and contains 12% sand, 65% silt and 23% clay. Three crops are grown in a year in the study area maize (May-first half of July), paddy (second half of July to October), and wheat and mustard (November to April). The agricultural filed are under manual tillage in the shallow layer of the soil (5 cm depth).

Soil samples were collected from five random locations from 0-10 and 10-20 cm soil depths during April 1998 to March 2000. Soil temperature and soil moisture were measured at 0-10 and 10-20 cm soil layers on each sampling date. Soil moisture was measured gravimetrically by drying the soil at 105°C. Soil pH was determined using the pH meter. Organic C was determined using air dried and sieved soils samples using the wet oxidation method and P by the wet ashing method of Jackson (1958). Soil N was determined by Kjel auto Vs-KTP Nitrogen Analyser based on micro Kjeldahl technique (Misra 1968). Potassium was determined by flame photometry.

Earthworms were sampled from within five plots on each sampling occasion every fortnight using a quadrat (0.5 x 0.5 m) to a depth of 20 cm during April 1998 to March 2000. Earthworms were hand sorted, stored in plastic bags and identified following Julka (1988). Fresh weight of earthworms was recorded after the worms were rinsed with water and dried with blotting paper on the same day when they were collected. The individuals were classified in two developmental stages, aclitellates and clitellates for determining age structure.

Results and discussion

Soil characteristics

Soil pH was slightly alkaline in both soil layers. The maximum soil moisture was 36.6% and 35.3% in the 0-10 cm and 10-20 cm soil layers, respectively during the rainy period. Organic C and C:N ratio decreased with increasing depth. Soil C was significantly higher in the 0-10 cm soil layer ($P<0.05$) than that of 10-20 cm soil layer (Table 1).

Species composition and abundance of earthworms

A total of 2111 earthworms from 235 samples were collected. Six species were identified (Table 2) belonging to two families (*Lumbricidae*, one species; *Megascolecidae*, 5 species) in the study site.

Table 1. Some soil characteristics of the study site (mean ± SE; n = 47).

Soil Characteristics	Soil depth (cm)	
	0-10	10-20
Soil pH	8.0 ± 0.16	7.6 ± 0.11
Soil temperature (°C)	22.8 ± 0.97	20.8 ± 1.0
Soil moisture (%)	16.2 ± 0.87	15.7 ± 0.85
K (%)	0.016 ± 0.0005	0.014 ± 0.0003
P (%)	0.0016± 0.0007	0.001 ± 0.0002
C (%)	1.42 ± 0.096	0.94 ± 0.045
N (%)	0.073 ± 0.0012	0.061 ± 0.0011
C : N ratio	19.5	15.4

Table 2. Number of individuals of different species of earthworm collected in agricultural field soils.

Species	Number	%
Lumbricidae		
Eisenia fetida Savigny	123	5.8
Megascolecidae		
Amynthas alexandri Beddard	81	3.8
Amynthas morrisi Beddard	72	3.4
Eutyphoeus waltoni Mich.	151	7.2
Metaphire posthuma Vaillant	646	30.6
Perionyx excavatus Perr.	80	3.8
Aclitellates	958	45.4
Total	2111	100.0

Percent composition of *Lumbricidae* was 5.8%, *Megascolecidae* 48.2% and aclitellates 45.4% (Table 2).

The abundance and biomass of earthworms fluctuated seasonally (Figs. 1 & 2).

Earthworm density (individuals m^{-2}) was 6.2 to 13.9 in the maize crop; 5.4 to 19.0 in the paddy and pulses crop; 0 to 9.8 in the wheat and mustard inter-cropping (Fig. 1). Biomass of earthworms ranged from 1.8 to 11.0 g m^{-2} in the maize crop; from 3.4 to 16.9 g m^{-2} in wheat and mustard crop (Fig. 2). Earthworms could not be recorded during the winter season as these were not encountered in any of the sampling from 0-20 cm depth.

The seasonal dynamics over an annual cycle showed that the earthworm population and biomass were high in the wet period and low in summer and winter. The present study showed a preference of earthworms to soil sown to paddy rather than to wheat and maize crops. Higher abundance of earthworms under paddy may be related to higher reproduction and survival due to higher moisture in the soil.

Maximum density (19.0 m^{-2}) and biomass (16.9 g fresh weight m^{-2}) recorded in the present study are within the range of other reported values: 6-542 g m^{-2} and 3-193 g fresh weight m^{-2} (Edwards & Lofty 1982), 2.8-2000 m^{-2} and 0.84-238 g m^{-2} (Lee 1985).

Depth distribution and age structure

Depth distribution of earthworms in the three crops and of the three crops when combined together showed that worms appeared mainly in the 0-10 cm soil layer (Table 3). 83.7% of earthworms and 80.9% of biomass in maize crop, 100% of earthworms and 100% of biomass in paddy and pulses crop, and 95.5% of earthworms and 92.6% of biomass in wheat and mustard crop were collected at the 0-10 cm soil layer. A mean of 94% of earthworms and 93.7% of biomass were collected at 0-10 cm soil layer when three crops were considered together.

Only two age classes have been considered, aclitellates and clitellates. The yearly ratio of cli-

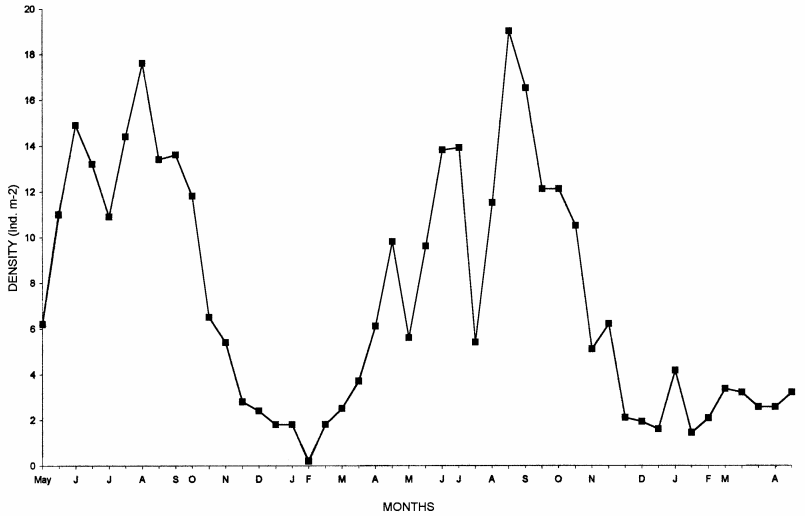

Fig. 1. Variations in the population density (ind m^{-2}) of earthworms during April 1998 to March 2000.

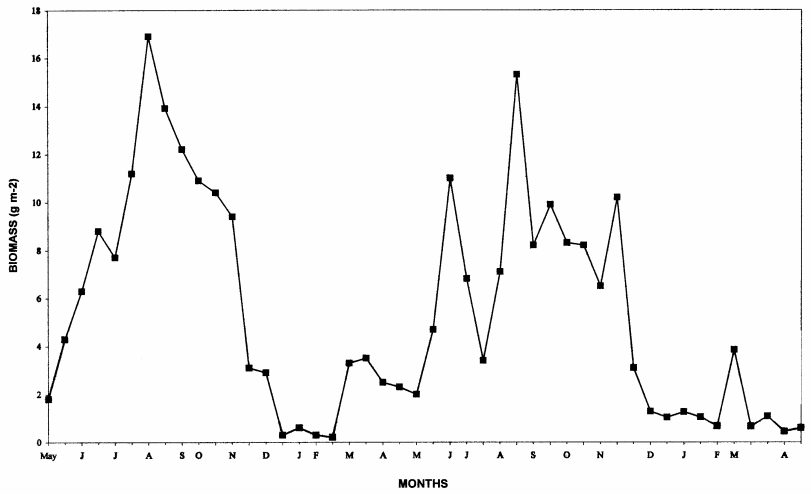

Fig. 2. Variations in the biomass (g m^{-2}) of earthworms during April 1998 to March 2000.

tellates to aclitellates was 1:0.8 (Table 4).

The habitat preference of earthworms was clear in the three crops in the studied site in the present investigation. The earthworm species are mineral-soil living since 83.7-100% of the specimens were recorded at 0-10 soil layer was also higher (80.9-100%) than in the 10-20 cm soil layer.

The habitat preference of lumbricid species was studied in various localities in Europe and several groupings of these species have proposed but Bouche's (1972) system of classifying earthworms into three categories: epigees - litter dwellers, endogees-horizontal burrowers and anecique - deep burrowers is most widely used.

Table 3. Average number of earthworms and their biomass at 0-10 cm and 10-20 cm soil depths as influenced by crop sepcies during 1998-2000. Values in parentheses are percentage.

Year	0-10 cm soil layer		10-20 cm soil layer	
	Density (no. m^{-2})	Biomass (g fresh weight m^{-2})	Density (no. m^{-2})	Biomass (g fresh weight m^{-2})
Maize crop				
1998	210	15.1	75	6.1
1999	251	22.2	17	2.3
Mean	(83.7)	(80.9)	(16.3)	(19.1)
Paddy and pulses crop				
1998	552	83.2	–	–
1999	556	60.4	–	–
Mean	(100.0)	(100.0)	–	–
Wheat and mustard crop				
1998 – 99	204	26.3	17	3.9
1999 – 2000	226	31.1	3	0.6
Mean	(95.5)	(92.6)	(4.5)	(7.4)
Annual				
1998 – 99	966	124.6	92	10.0
1999 – 2000	1033	113.7	20	6.2
Mean	(94.0)	(93.7)	(6.0)	(6.3)

Table 4. Age structure of earthworms in the study site. Values in parentheses are percent.

Year	Densities (individuals m^{-2})		Clitellate: Aclitellate ratio
	Clitellates	Aclitellates	
Maize crop			
1998	128	157	1: 1.23
1999	91	177	1: 1.95
Total	219	334	1: 1.59
Paddy and pulses			
1998	361	191	1: 0.53
1999	319	238	1: 0.75
Total	680	429	1: 0.64
Wheat and mustard			
1998 – 99	122	99	1: 0.81
1999 – 2000	154	74	1: 0.48
Total	276	173	1: 0.65
Annual			
1998 – 99	611 (57.8)	447 (42.2)	1: 0.73
1999 – 2000	564 (53.6)	489 (46.4)	1: 0.87
Mean	1175 (55.7)	936 (44.3)	1: 0.80

Most researchers have found earthworms almost exclusively in the top 50 cm of agricultural soil, and most species have been found in the top 20 cm (Clapperton *et al.* 1997; Valle *et al.* 1997). The data obtained in the present work fit this pattern for the earthworm population as a whole. Difference in the vertical distribution of the C:N ratio at 0-10 cm and 10-20 cm, and the organic matter content seems to be the most important factor in earthworm distribution.

As a rule, in annual cycles of the ratios of aclitellates to clitellates the number of adults is below 50% of the total count for any species. This was the case in the maize crop but clitellates were higher in number in the paddy and pulses, and wheat and mustard crops. In the case of aclitellates, the winter drop in numbers was rapid and abrupt. In the wet periods, the number of aclitellates and clitellates increased rapidly. Juveniles generally predominate in the population of epigeic and anecic earthworm species, e.g. *Lumbricus terretris* (Daniel 1992). In endogeic species the data are contradictory. In *Aporrectodea caliginosa*, mature individuals have been found to account for 8% (van Rhee 1965), 2.5% (Reinecke & Ljungstrom 1969), 8.7% (Nowak 1975) and 20.8% to 37% of the population (Rozen 1988). In *Aporrectodea rosea*, the percentages of mature individuals have been reported to be 9.5% (Reinecke & Ljungstrom 1969), 21% to 42% (Nowak 1975) and 21.7% to 29.4% (Rozen 1988).

The regression (r) between earthworm density and biomass was calculated with soil pH, soil moisture, soil C, N and P using a simple correlation coefficient (SAS 1987).

Correlation coefficients for monthly values of soil parameters and earthworms are summarized in Table 5. Significant correlations were obtained between earthworm density and pH ($r = 0.744$; $P<0.01$), earthworm density and temperature ($r = 0.62$; $P<0.01$), earthworm density and moisture ($r = 0.584$; $P<0.05$), earthworm biomass and soil moisture ($r = 0.446$; $P<0.01$); earthworm biomass and soil temperature ($r = 0.383$; $P<0.01$), and earthworm biomass and soil C ($r = 0.566$; $P<0.01$).

Table 5. Correlation coefficients (r) of worm density (ind m^{-2}) and biomass (g m^{-2}) with soil characteristics in the cultivated soil (all crops taken together) at Shantipuri (0-20 cm soil layer) during 1998-2000 ($n = 14$).

Parameters	Worm biomass	Soil pH	Soil moisture	Soil temperature	Soil C	Soil N	Soil K	Soil P
Worm density	0.837	0.744	0.584**	0.62**	0.388*	–0.241	0.147	0.144
Worm biomass		0.722	0.446**	0.383**	0.566**	–0.113	0.169	0.155
Soil pH			0.634**	0.345*	0.519**	0.025	0.215	0.072
Soil moisture				0.479**	0.239	–0.122	0.358*	–0.133
Soil temperature					0.077	–0.287	0.225	0.122
Soil C						0.241	0.062	0.195
Soil N							0.035	–0.209
Soil K								0.114

Levels of significance: *P<0.05 **P<0.01

A variety of environmental factors such as soil texture, soil moisture, food, pH, temperature, soil depth, organic content have been suggested as determinants of the distribution and abundance of worms (Lavelle 1983). Significant correlations observed between earthworm density and biomass with soil properties mainly soil moisture, soil C, soil temperature and soil pH influence the abundance of earthworms in the managed soils of central Himalayan tarai also.

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