Tropical Ecology **49**(2): 225-234, 2008 ISSN 0564-3295

www.tropecol.com

Earthworm population of rubber plantations (*Hevea brasiliensis*) in Tripura, India

P.S. CHAUDHURI[1*], SABYASACHI NATH[1] & R. PALIWAL[2]

[1]*Department of Zoology, Maharaja Bir Bikram College, Agartala, Tripura 799004*
[2]*Zoological Survey of India, 27 J.L. Nehru Road, Kolkata 700016*

Abstract: Survey of earthworm species in rubber plantations of Tripura (India) with reference to their diversity, biomass, density, frequency and distribution revealed the presence of at least 20 species of earthworms belonging to 10 genera and 5 families: Octochaetidae (*Eutyphoeus gigas, E. gammiei, E. comillahnus, E. assamensis, E. festivas, Eutyphoeus* sp. 1, *Dichogaster bolaui, D. affinis, Lenogaster chittagongensis, Octochaetona beatrix),* Megascolecidae (*Metaphire houlleti, Perionyx* sp.1, *Kanchuria sumerianus, Kanchuria* sp.1, *Kanchuria* sp.2), Moniligastridae *(Drawida nepalensis, Drawida* sp.1, *Drawida* sp.2), Glossoscolecidae *(Pontoscolex corethrurus)* and Ocnerodrilidae *(Gordiodrilus elegans).* Earthworms experienced mean soil temperature 25.9^{0}C, moisture 24.8%, pH 4.85 and organic matter 1.8 %. Mean values for density and biomass were 108.6 m^{-2} and 43.4 g m^{-2}. *Pontoscolex corethrurus* was the dominant species of rubber plantations, representing 61.5% biomass and 72% density of the total earthworm population. *Hevea* agroecosystem is largely dominated by endogeic species of earthworms.

Resumen: La inspección de las especies de lombriz de tierra en las plantaciones de caucho de Tripura (India) en relación con su diversidad, biomasa, densidad, frecuencia y distribución, reveló la presencia de al menos 20 especies de lombrices de tierra pertenecientes a 10 géneros y 5 familias: Octochaetidae (*Eutyphoeus gigas, E. gammiei, E. comillahnus, E. assamensis, E. festivas, Eutyphoeus* sp.1, *Dichogaster bolaui, D. affinis, Lenogaster chittagongensis, Octochaetona beatrix),* Megascolecidae (*Metaphire houlleti, Perionyx* sp.1, *Kanchuria sumerianus, Kanchuria* sp.1, *Kanchuria* sp.2), Moniligastridae *(Drawida nepalensis, Drawida* sp.1, *Drawida* sp.2), Glossoscolecidae *(Pontoscolex corethrurus)* y Ocnerodrilidae *(Gordiodrilus elegans).* Las lombrices de tierra experimentaron una temperatura del suelo promedio de 25.9°C, una humedad del suelo de 24.8%, pH de 4.85 y una materia orgánica de 1.8%. Los valores promedio de densidad y biomasa fueron 108.6 m^{-2} y 43.4 g m^{-2}. *Pontoscolex corethrurus* fue la especie dominante en las plantaciones de caucho, con una representación de 61.5% biomasa y de 72% de la densidad de la población total de lombrices. El agroecosistema de *Hevea* está dominado en gran medida por especies de lombriz de tierra endogéicas.

Resumo: Um levantamento das espécies de minhocas em plantações de borracheiras em Tripura (Índia) com referência à sua diversidade, biomassa, densidade, frequência e distribuição revelou a presença de pelo menos 20 espécies pertencentes a 10 géneros e 5 famílias: Octochaetidae (*Eutyphoeus gigas, E.gammiei, E. comillahnus, E. assamensis, E. festivas, Eutyphoeus* sp.1, *Dichogaster bolaui, D. affinis, Lenogaster chittagongensis, Octochaetona beatrix),* Megascolecidae (*Metaphire houlleti, Perionyx* sp.1, *Kanchuria*

* *Corresponding Author*; e-mail: priya_1956@rediffmail.com

sumerianus, Kanchuria sp.1, *Kanchuria* sp.2), Moniligastridae *(Drawida nepalensis, Drawida* sp.1, *Drawida* sp.2), Glossoscolecidae *(Pontoscolex corethrurus)* and Ocnerodrilidae *(Gordiodrilus elegans*. As minhocas viviam num intervalo de temperatura média do solo de 25,9ºC, uma humidade de 24,8%, pH de 4,85 e matéria orgânica de 1,8%. Os valores médios da densidade e biomassa foram de 108,6 m^{-2} e 43,4 g m^{-2}. A *Pontoscolex corethrurus* foi a espécie dominante nas plantações de borracheiras, representando 61,5% da biomassa e 72% da densidade de todas a população de minhocas. O ecossistema de *Hevea* é largamente dominado por espécies de minhocas endogeicas.

Key words: Biomass, earthworm, *Hevea brasiliensis*, rubber plantation, species diversity.

Introduction

In Tripura, rubber (*Hevea brasiliensis*) plantation was introduced in 1963 by the forest department to check soil degradation due to slash and burn agriculture practiced by the local tribal people, and also as a part of their rehabilitation programme. Tripura, with a sub-tropical climate, has 33,000 ha of land under rubber cultivation (Bahuguna 2006). *Hevea brasiliensis* is an exotic and deciduous plant showing maximum litter fall during February-March, with annual litter addition to plantation floor amounting to 7 t ha^{-1} (Jacob 2000). The litter is not generally removed but persists on the plantation floor through a large part of the year and shows very slow rate of decomposition due to high lignin content. Some phenolic compounds are known to be present in the rubber plant material (Stern 1967). In the humid tropics, *Hevea* plantations are often considered a sustainable system which, in some cases, might even upgrade the level of soil fertility (Gilot *et al.* 1995). According to Tian *et al.* (2000), tree plantation may influence earthworm abundance by altering the physico-chemical properties of soils *viz.* temperature, moisture regime, pH, soil organic content, litter inputs, etc.

Earthworms account for the highest biomass among tropical soil macrofauna (Fragoso & Lavelle 1992). The role of earthworms in the process of decomposition, building and maintenance of soil structure has been well documented for soils of temperate region (Edwards & Bohlen 1996; Lee 1985). In tropics, studies on diversity, ecology and role of earthworms have been carried out in savanna (Lavelle 1974), pasture (Dash & Patra 1977), rain forests (Fragoso & Lavelle 1992) and agricultural lands (Sathianarayanan & Khan 2006). However, there is paucity of information on earthworm communities in subtropical forests (Fragoso *et al.* 1999; González *et al.* 2007). Although north-east India constitutes a huge biodiversity reservoir, there is possibly no record on the occurrence of earthworm fauna in its deciduous/semi-deciduous forests.

In the present paper an attempt has been made to know the species composition, abundance, biomass of earthworms and their distribution in relation to some physico-chemical parameters of soil in rubber plantations of Tripura, a north-eastern state of India.

Materials and methods

Study area

Survey was conducted during 2006-2007(July - November) in ten subdivisions (Sonamura, Bishalgarh, Sadar and Khowai subdivisions belonging to West District; Udaipur and Belonia - South District; Kailasahar and Dharmanagar - North District; Kamalpur and Longtarai valley - Dhalai District) out of seventeen subdivisions of Tripura (22°51′-24°32′N and 90°10′-92°21′E) having an area of 10,491 sq. km. Tripura is almost encircled by Bangladesh except in the north-east, where it meets its neighbouring states, Assam and Mizoram. The year is divisible into summer (April-June), monsoon (July-October), winter (November-February) and a short spring (March) with an

average annual rainfall of about 2000 mm. Soils of Tripura, in general, are acidic indicating that these have developed from non-calcareous parent material under conditions of high rainfall.

Study sites

Study sites selected for earthworm survey comprised mature rubber plantations (beyond 10 years). Only one rubber plantation with ca.1 ha area was selected in each subdivision. Distance between the study sites varied from 20 - 40 km. Rubber plantations are usually on undulating landscapes with uplands (locally called 'tilla') mostly derived from afforestation of either 'waste land' or fallows after repeated slash and burn cultivation. Soil of rubber plantation, in general, is well drained, acidic (pH 4.1-5.3) with sandy loam or sandy clay loam texture. Mature plantations possess good canopy cover and horizontal distribution of roots in the top soil. Plantation floor generally remains covered with *Hevea* leaf litter.

Sampling for earthworm population

Sampling was done every Saturday of a month during monsoon and post monsoon periods. For each study site, five widely separated 10 x 10 m plots were randomly selected for sampling. Composite sample comprising of five sub-samples was taken from each plot. Sampling points were located at the corner and center of sampling plot and separated by a distance of 10 m. Earthworms were collected by conventional digging (25 x 25 x 30 cm) and hand sorting method. Worms were counted, weighed (with gut content) in an electronic balance and some were preserved in 4% formalin. Preserved specimens were sent to the Zoological Survey of India, Solan (Himachal Pradesh) for identification. For conservation of biodiversity, minimum number of worms (10-15) was preserved and others were released back to the soil. Results were expressed in terms of biomass (fresh weight, g m^{-2}) and density (individuals m^{-2}). Relative density and frequency of earthworms were determined following Dash (1993).

Intact casts of different earthworm species were collected during September-October and the amount of casts (dry weight, g m^{-2}) was determined.

Soil analysis

Soil temperature (soil thermometer), moisture (gravimetric wet weight method) and pH (1 : 2.5 dilution method) were recorded at each sample plot from a depth of 0-15 cm soil. Oxidizable organic matter was estimated following Walkley & Black (1934).

Results

A total of 20 species belonging to 10 genera and 5 families of the class Oligochaeta were collected from 10 out of 17 subdivisions (under 4 districts) of Tripura. Among them, 10 species belong to the family Octochaetidae [*Eutyphoeus gigas* Stephenson, *Eutyphoeus gammiei* (Beddard), *Eutyphoeus comillahnus* Michaelsen, *Eutyphoeus assamensis* Stephenson, *Eutyphoeus festivus* Gates, *Eutyphoeus* sp.1, *Dichogaster bolaui* Stephenson, *Dichogaster affinis* Michaelsen, *Lenogaster chittagongensis* Stephenson, *Octochaetona beatrix* Gates], 5 species [*Metaphire houlleti* (Perrier), *Perionyx* sp.1, *Kanchuria sumerianus* Julka, *Kanchuria* sp.1, *Kanchuria* sp. 2] to Megascolecidae, 3 species [*Drawida nepalensis* Michaelsen, *Drawida* sp. 1, *Drawida* sp.2] to Moniligastridae and 1 species each to Glossoscolecidae [*Pontoscolex corethrurus* (Muller)] and Ocnerodrilidae (*Gordiodrilus elegans* Beddard). In live condition, *E. gammiei* is the largest (length 300 mm-400 mm, diameter 7 mm-10 mm) and *D. bolaui* is the smallest (length 19 mm-23 mm, diameter 1 mm-2 mm) of the earthworms of Tripura. Among the earthworm species recorded, 11 were found in the earthworm communities in the rubber plantation of Sadar, followed by 10 species at Kailasahar, 9 species each at Kamalpur, Dharmanagar, Bishalgarh and Udaipur, 8 species, 5 species, 4 species and 3 species at Belonia, Khowai, Longtharai Valley and Sonamura subdivision, respectively. Interestingly, *Pontoscolex corethrurus, Drawida* sp. and *Kanchuria* sp. are of common occurrence in the rubber plantations of Tripura while different species of *Eutyphoeus, Octochaetona beatrix* and *Perionyx* sp. showed restricted distribution.

Ecological categories, habitat, feeding and morphological characteristics of some earthworm species of rubber plantation are given in Table 1.

Table 1. Ecological categories, habitat, feeding and morphological characteristics of some earthworm species of rubber plantation.

Family and Earthworm species	Ecological category	Habitat	Food	Size	Colour/ Pigmentation
Octochaetidae					
D. bolaui	Epigeic/ Epiendogeic	Surface soil	Soil with high organic content	19-23 x 1-2mm	Light
D. affinis	Epigeic	Surface soil/ Leaf litter	Soil with high organic content	27-60 x 1-3mm	Light body with reddish clitellum
E. comillahnus	Endogeic	0-15 cm soil	Soil	65-250 x 3-5 mm	Light
E. festivius	Endogeic	0-15 cm soil	Soil	146 x 6 mm	Light
E. gammiei	Endoanecic	0-30 cm soil, live in vertical burrow	Soil with high organic content	300-400 x 7-10 mm	Olive brown pigmentation dorsally
E.gigas	Endoanecic	0-30 cm soil, live in burrow	Soil	175-290 x 7-11 mm	Deep brown pigmentation dorsally
O. beatrix	Endogeic	0-15 cm soil	Soil	80-100 x 3-5 mm	Non pigmented
Moniligastridae					
D. nepalensis	Endogeic	0-15 cm soil	Soil with little organic matter	70-130 x 4-5 mm	Light
Drawida sp1	Epianecic	0-10 cm soil	Soil and leaf litter	60-120 x 3-5 mm	Bluish
M. houlleti	Epianecic	Surface soil and litter	Leaf litter and soil	92-200 x 4-7 mm	Slate colour dorsally
Perionyx sp	Epigeic/ Epianecic	Litter soil interface	Leaf litter and soil	120-206 x 3-6 mm	Bluish purple dorsally
K. sumerianus	Endogeic	0-15 cm soil	Soil	77-162 x 2-3 mm	Non pigmented
Glossoscolecidae					
P. corethrurus	Endogeic	0-15 cm soil	Soil with litter organic matter	60-120 x 4-6 mm	Light

Distribution of earthworm species in the rubber plantations with reference to the ecological parameters, namely temperature, moisture, pH and soil organic matter is given in Table 2. In the rubber plantation, earthworms experienced mean soil temperature 25.9°C, moisture 24.8%, pH 4.85 and organic matter 1.8 %. Among all the species, *P. corethrurus* showed wide range of tolerance to edaphic factors (soil temperature 22°C-28°C, moisture 8.7% -51.0%, pH 4.1-6.8, organic matter 0.67-8.46%. Wide ranges of ecological tolerance were also exhibited by *Drawida* sp.1 and *Kanchuria* sp.1 (Table 2). Interestingly, *Metaphire houlleti, Dichogaster affinis, Dichogaster bolaui* and *Pontoscolex corethrurus* were found in the decomposed substrates with pH ≤ 6.8 and organic matter content > 8 %.

Density of earthworms ranged from 10 ind. m^{-2} to 262 ind. m^{-2} (mean 108.6 ± 9.2) and biomass from 9 g m^{-2} to 100 g m^{-2} (mean 43.4 ± 3.17). *Pontoscolex corethrurus* was the dominant species of rubber plantations, representing 61.5% biomass and 72% density of total earthworm species population. *Drawida* sp. *Kanchuria* sp.1, *Metaphire houlleti*, *Eutyphoeus comillahnus* contributed 15.4%, 12%, 3.6% and 1.9% to total worm biomass, respectively. *Pontoscolex* sp. was commonly associated with *Drawida* sp.1 and *Drawida* sp.2 in 30% and 43% samples, respectively. Density, biomass, relative density, and frequency of ten earthworm species of rubber plantations are given in Table 3. *Pontoscolex* sp. topped the list followed by *Drawida* sp. and *Kanchuria* sp.1. Our observations on density and

Table 2. Occurrence of earthworm species of rubber plantations in different ecological conditions. (Mean ± S.E.).

Family and Earthworm species	Soil temperature (^{0}C)	Soil moisture (%)	Soil pH	Soil organic matter (%)
A) Octochaetidae				
Eutyphoeus gigas	26.75 ± 0.48	22.63 ± 0.85	4.58 ± 0.11	1.22 ± 0.09
Eutyphoeus gammiei	25.3 ± 0.10	25.99 ± 2.07	4.77 ± 0.05	2.05 ± 0.51
Eutyphoeus comillahnus	26.08 ± 0.33	24.20 ± 1.33	4.75 ± 0.06	1.55 ± 0.15
Eutyphoeus assamensis	25.95 ± 0.65	24.32 ± 3.2	4.92 ± 0.11	1.25 ± 0.11
Eutyphoeus festivus	25.32 ± 0.08	25.90 ± 2.23	4.83 ± 0.05	1.80 ± 0.26
Eutyphoeus sp.1	25.4 ± 0.20	23.84 ± 0.60	5.14 ± 0.05	1.44 ± 0.03
Dichogaster bolaui	25.67 ± 0.48	28.86 ± 11.26	5.38 ± 0.74	3.68 ± 2.39
Dichogaster affinis	25.2 ± 0.20	32.70 ± 18.34	5.70 ± 1.17	4.84 ± 3.63
Lenogaster chittagongensis	N.D.	N.D.	N.D.	N.D.
Octochaetona beatrix	27.0	22.90	4.22	1.47
(B) Moniligastridae				
Drawida nepalensis	25.45 ± 0.05	27.40 ± 3.48	4.88 ± 0.07	1.59 ± 0.06
Drawida sp 1	25.77 ± 0.29	22.27 ± 0.78	4.65 ± 0.05	1.26 ± 0.04
Drawida sp 2	25.85 ± 0.17	23.63 ± 0.54	4.82 ± 0.03	1.40 ± 0.05
(C) Megascolecidae				
Metaphire houlleti	25.9 ± 0.25	23.47 ± 0.90	4.80 ± 0.09	1.55 ± 0.26
Perionyx sp	27.5 ± 0.50	23.14 ± 0.78	4.88 ± 0.05	1.24 ± 0.005
Kanchuria sumerianus	26.6 ± 0.41	22.36 ± 0.96	4.84 ± 0.03	1.23 ± 0.04
Kanchuria sp. 1	26.0 ± 0.22	23.97 ± 0.77	4.75 ± 0.05	1.46 ± 0.07
Kanchuria sp. 2	25.3 ± 0.10	27.59 ± 2.04	4.96 ± 0.14	2.12 ± 0.26
(D) Glossoscolecidae				
Pontoscolex corethrurus	25.85 ± 0.19	22.97 ± 0.74	4.68 ± 0.06	1.40 ± 0.12
(E) Ocnerodrillidae				
Gordiodrilus elegans	26.05 ± 0.21	23.50 ± 0.81	4.73 ± 0.07	1.29 ± 0.05
Mean ± S.E.	25.94 ± 0.14	24.82 ± 0.62	4.85 ± 0.07	1.79 ± 0.21

N.D. → Not determined

biomass of earthworms in the rubber plantations are compared with other studies in Table 4.

Earthworm casts were most abundant during September to November (i.e. post monsoon period). Average mass (air dried) of casts in the plantation floor was 251 g m^{-2}. Earthworm species of rubber plantation defecate different forms of casts: columnar, spheroid, pyramidal and composite irregular aggregates. Columnar casts of medium size (height 35-70 mm, diameter 15-35 mm) with regular arrangement of spherical/sub-spherical aggregates are found in *Metaphire houlleti*. Surface casts of *Eutyphoeus* are generally columnar with tubular convolutions or spherical aggregated units. Thick tubular convolutions are found in the large casts of *Eutyphoeus gammiei* (140-160 x 40-50 mm), *E assamensis* (30-50 x 15-30 mm). In *Eutyphoeus* sp.1, casts are paste-like and pyramidal in appearance. Casts are large globoid mounds in *Kanchuria* sp.1 (diameter 30-45 mm). Composite irregular paste like slurries (height 10-15 mm) are released by *P. corethrurus* and *Drawida* sp. Except for a few species (*P. corethrurus, Eutyphoeus* sp.1), in most of the earthworm species a single cast is formed by more than one days activities of an individual.

Table 3. Earthworm population structure (n=40) in rubber plantations of Tripura.

Earthworm species	Biomass (g m^{-2})	Density (no m^{-2})	Relative density (%)	Frequency (%)
Pontoscolex corethrurus	26.72	78.00	71.80	77.50
Drawida sp	6.70	17.20	15.83	75.00
Kanchuria sp. 1	5.28	5.04	4.64	47.50
Metaphire houlleti	1.55	1.60	1.47	30.00
Kanchuria summerianus	0.18	0.24	0.22	5.00
Eutyphoeus gigas	0.84	0.24	0.22	7.50
Eutyphoeus comillahnus	0.82	1.36	1.25	25.00
Eutyphoeus assamensis	0.95	0.48	0.44	10.00
Octochaetona batrix	0.09	0.16	0.18	5.00
Gordiodrilus elegans	0.24	4.24	3.76	40.00
Total	43.37	108.56		

Table 4. Density and biomass of earthworms in different habitats under tropical/subtropical climatic conditions.

Habitat	Density (no. m^{-2})	Biomass (g m^{-2})	Site	Extraction method	References
Deciduous Rubber Plantation (Subtropical)	108.56	43.37	Tripura (India)	Digging and hand sorting	Present study
Deciduous forest	24-131	7.0-28.5	Orissa (India)	Digging and hand sorting	Mishra & Dash (1984)
Grazed upland Pasture	75-272	12-70	Orissa (India)	Hand sorting and wet sieving	Senapati & Dash (1981)
Reserve forest	72.64	9.77	Tamilnadu (India)	Digging and hand sorting	Ismail *et al.* (1990)
Plain grassland	322	58.74	Karnataka (India)	Hand sorting	Krishnamoorthy (1985)
Forest	160.5	27.92	Western Ghat (India)	Hand sorting	Blanchart & Julka (1997)
Acacia plantation	200	9.67	Western Ghat (India)	Hand sorting	Blanchart & Julka (1997)
Mixed forest	149	4.1	Central Himalaya (India)	Hand sorting	Bhadauria *et al.* (2000)
Pine forest (6 year old)	65	1-40	Central Himalaya (India)	Hand sorting	Bhadauria *et al.* (2000)
Tropical rain forest	80-121	34.2-42.4	Mexico	Hand sorting	Fragoso & Lavelle (1987)
Tropical Savana	230	49	Ivory Coast	Hand sorting and wet sieving	Lavelle (1974)
Tropical rain forest	64-166	3.3-22.7	Malaysia	Hand sorting	Leaky & Proctor (1987)
Rubber plantation (20 yrs)	150.4	59.5	Cote d' Ivoire	Hand sorting	Gillot *et al.* (1995)

Discussion

This study revealed the presence of 20 species of earthworms distributed in 5 families in rubber plantations in Tripura. This adds 10 species to the earlier list of earthworms from Tripura (Chaudhuri & Bhatttacharjee 2005). Eight species of earthworms in the rubber plantations of Tripura, namely *Pontoscolex corethrurus*, *Eutyphoeus gammiei*, *E comillahnus*, *E. gigas*,

Dichogaster bolaui, *Lenogaster chittagongensis*, *Drawida nepalensis* and *Gordiodrilus elegans* were reported from the neighbouring Bangladesh (Reynolds *et al.* 1995). At least six earthworm species of rubber plantation, namely *E. gammiei*, *E. gigas*, *E. assamensis, E. festivus, D. bolaui, D. nepalensis,* etc. were found also in other north-eastern states like Assam, Mizoram, Meghalaya and Arunachal Pradesh (Gates 1972; Julka 1988).

In Tripura, out of 20 species of earthworms in rubber plantations, a maximum of 11 species and a minimum of 3 species were recorded in the earthworm communities at Sadar and Sonamura subdivisions, respectively. The number of species in a given earthworm community, which is the simplest measure of species diversity, ranged from 1 to 15 species, and most earthworm communities including those of tropical rain forest had around 3 to 6 species (Edwards & Bohlen 1996; Fragoso & Lavelle 1992). Thus, the earthworm species diversity in the rubber plantations in Tripura is well within the reported range. Difference between the earthworm communities at different localities (subdivisions of Tripura) indicates that environmental heterogeneity is important in promoting earthworm diversity (beta diversity) in the rubber plantations of Tripura, as it has been shown by Fragoso & Lavelle (1987) in the forests of Mexico. In spite of the fact that rubber plantation is monoculture, its earthworm species diversity is not remarkably less than that in the mixed forests of Tripura (unpublished data). This is due to the fact that mostly unutilized fallow lands were converted to rubber plantations in order to check soil degradation in Tripura. So here original earthworm communities were retained. Besides these, good canopy cover of mature *Hevea* plantations with deciduous litter fall, varieties of weeds, herbs and shrubs at the plantation floor under subtropical conditions of Tripura provide physical habitat and trophic resource for good earthworm activity. Earlier, Chakraborti & Bhattacharjee (1993) reported that aforestation created favourable micro environmental conditions in the rubber plantation as compared to the wasteland.

Earthworm communities of rubber plantations in Tripura are composed of 15 endemic and 5 exotic species. Exotic species include *Pontoscolex corethrurus, Metaphire houlleti, Dichogaster bolaui, D. affinis* and *Gordiodrilus elegans*. It is known that exotic species occur and often dominate in disturbed sites (Hendrix & Bohlen 2002). Rubber plantation often faces anthropogenic interferences due to forest clearing, tapping process, weeding etc. So occurrence of exotic species like *P. corethrurus*, *M. houlleti* etc. in rubber plantation is not surprising. Being the commonest earthworm species of Brazil, *P. corethrurus* is the most widely distributed earthworm of the world (Gates 1972). Place of origin of the rubber plant, *Hevea brasiliencis* is also Brazil. So dispersal of *Pontoscolex* sp. (indigenous to north-eastern South America) through exotic crops like *Hevea* plants into different parts of the world is quite possible. There are reports on the occurrence of *P. corethrurus* in the rubber plantations of Burma and Malay Peninsula (Gates 1972). Occurrence of greater number of native species in the soil of rubber plantations of Tripura indicates that in the north-east India native species are more resistant to disturbance. This is in contrast to tropical countries like Peru, Brazil and Mexico where native species of earthworms have been replaced largely by the exotics (Fragoso *et al.* 1999). Although native species richness is high in the rubber plantations in the north-eastern part of India, the exotic *P. corethrurus* recorded very high values of biomass, density, relative density, and frequency compared to the native species. *Pontoscolex* sp. represented 61.5% biomass and 72% density of total earthworm population. Thus, *Pontoscolex* sp. could be considered a dominant species in rubber plantations. Interestingly, Bhattacharjee & Chakraborti (1995) reported 2 dominants out of 37 species of oribatid mites in the rubber plantations of Tripura, and considered relative harshness of the rubber plantation due to human interference to be responsible for the occurrence of least number of dominant species. Dramatic increase in biomass, and relative density of *Pontoscolex* sp. might be linked to individual tree species effect (*Hevea brasiliensis)* that favoured *P. corethrurus* over other species (Sarlo 2006). The biomass values of earthworms in our study is comparable to or higher than that in savanna, rain forest, acacia plantation and mixed forest of tropical areas, but density of earthworms in the rubber plantation is less than those habitats (Bhadauria *et al.* 2000; Blanchart & Julka 1997; Fragoso & Lavelle 1987). The high worm biomass (> 40 g fresh wt. m^{-2}) in rubber plantation was

mainly due to *Pontoscolex* sp. According to Gilot *et al.* (1995), soil communities including those of earthworms become abundant, with a biomass comparable to that in the original forest and high microbial activity when anthropogenic disturbances are minimized with increase in the age of rubber plantation. Low density of earthworms in the rubber plantation is probably related to the acidic nature of soil in Tripura because earthworms, in general, are neutrophilic in nature (Lee 1985). According to Shakir & Dindal (1997), population density of earthworms is positively correlated with pH and negatively correlated with species diversity. High frequency inspite of low density and biomass of *Drawida* and *Kanchuria* sp.1 (Table 3) indicates that they are less aggregated and more uniformly distributed in the plantation floor. Presence of some species of rare occurrence *viz*. *Kanchuria* sp., *Eutyphoeus gigas*, *E comillahnus*, *E. festivas*, *Octochaetona beatrix*, *Gordiodrilus elegans* with low density is indicative of rich biodiversity of earthworms in the rubber plantations of Tripura. Thus, being a very small state (only 10,491 sq. km area) and harbouring at least 20 species of earthworms in *Hevea* plantation, Tripura may be considered a place of high regional biodiversity in the north-east range of India.

The structure of earthworm communities is determined by a suite of ecological factors: temperature, available organic matter, moisture, pH, etc. Native earthworms such as different species of *Eutyphoeus* showed narrow edaphic and climatic tolerances, and hence, are stenoecius. Although *Eutyphoeus* is the largest genus in terms of number of species, it showed restricted distribution in rubber plantation in different subdivisions of Tripura due to narrow range of ecological tolerances. *Eutyphoeus* has endemic species in Burma, eastern Himalaya and north-east ranges (Julka 1988). Exotic peregrine worms like *Pontoscolex corethrurus*, *Metaphire houlleti*, *Dichogaster bolaui*, *Dichogaster affinis* and endemic peregrine species like *Drawida* sp.1 and *Kanchuria* sp.1 are adapted to a wide range of environmental conditions, and are euryoecius. Besides environmental plasticity, parthenogenetic mode of reproduction, anthropogenic influence, efficient assimilation of low-quality soil organic matter and outstanding abilities to colonize due to their demographic profile could explain the wider distribution of peregrine and absence of native species in other regions (Fragoso *et al.* 1999).

According to Sinha *et al.* (2003), functional guild diversity of earthworm is lower in agroecosystems with homogeneous ecological niches, compared to forest ecosystems with varied ecological niches. *Hevea* agroecosystem is largely dominated by endogeic earthworm species as indicated by their total biomass value (> 85% of earthworms communities). Epigeic species form minor component of earthworm communities in rubber plantation. Fragoso *et al.* (1999) also advocated that earthworm communities of tropical agroecosystem are composed mostly of endogeic species of earthworms. Texture, nutrient status and moisture condition of soil probably determine functional categories of earthworms. Although plantation floor receives a good input of leaf litter, absence of anecic and rare occurrence of epigeic earthworm species are due probably to lower palatability of *Hevea* leaf litter (Chaudhuri *et al.* 2003). Concentration of earthworms in the top soil is due to horizontal distribution of *Hevea* roots and slowly decomposing *Hevea* litters on the plantation floor that reflect better aerobic feeding-cum-breeding zone.

Acknowledgements

The authors express their sincere thanks to anonymous referees for their valuable comments on the paper and Dr. Prabir Chakraborty, Reader, Department of Zoology, M.B.B. College, for constant cooperation and encouragement during the investigation. Financial assistance from the Department of Science & Technology, New Delhi, (scheme No. SR/SO/AS-25/2005 dt. 03.11.06) in the form of fellowship to the second author is gratefully acknowledged.

References

Bahuguna, V.K. 2006. Action plan for expansion of rubber in Tripura. pp. 11-40. *In*: V.K. Bahuguna (ed.) *Natural Rubber in Tripura: Base Line Data and Future Planning*. Tripura Rubber Mission, Govt. of Tripura , Agartala.

Bhadauria, T., P.S. Ramakrishnan & K.N. Srivastava. 2000. Diversity and distribution of endemic and exotic earthworms in natural and regenerating ecosystems in the central Himalayas, India. *Soil Biology & Biochemistry* **32**: 2045-2054.

Blanchart, E. & J.M. Julka. 1997. Influence of forest disturbance on earthworm (Oligochaeta) communities in the western ghats (South India). *Soil Biology & Biochemistry* **29**: 303-306.

Bhattacharjee, T. & P. Chakraborty. 1995. Community structure of soil Oribatida of a young rubber plantation and an adjacent wasteland in Tripura (India). pp. 65-77. *In*: P.C. Mishra, N.Bahera, B.K. Senapati & B.C. Guru (eds.) *Advances in Ecology and Environmental Science*. Ashish Publishing House, New Delhi.

Chakraborty, P. & T. Bhattacharjee. 1993. Spatial microdistribution pattern of Oribatida (Acari) of a rubber plantation and an adjacent wasteland in Tripura (India). *Proceedings of Zoological Society, Calcutta* **46**: 119-123.

Chaudhuri, P.S. & G. Bhattacharjee. 2005. Earthworms of Tripura (India). *Ecology Environment & Conservation* **11**: 295-301.

Chaudhuri, P.S., T.K. Pal, G. Bhattacharjee & S. K. Dey. 2003. Rubber leaf litters (*Hevea brasiliensis* var. RRM 600) as vermiculture substrate for epigeic earthworm, *Perionyx excavatus*, *Eudrilus eugeniae* and *Eisenia fetida*. *Pedobiologia* **47**: 796-800.

Dash, M.C. 1993 *Fundamentals of Ecology*. Tata McGraw Hill Publishing Company Ltd, New Delhi.

Dash, M.C. & V.C. Patra. 1977. Density, biomass and energy budget of a tropical earthworm population from a grassland site in Orissa, India. *Revue d˝ Ecologie et Biolgie du Sols* **14:** 461-471.

Edwards, C.A. & P.J. Bohlen. 1996. *Biology and Ecology of Earthworms*. Chapman and Hall, London.

Fragoso, C. & P. Lavelle. 1987. The earthworm community of a tropical rain forest. pp. 281-295. *In*: A.M. Bonvicini - Pagliani & P. Omodeo (eds.) *On Earthworms*. Mucchi Editore, Modena, Italy.

Fragoso, C. & P. Lavelle. 1992. Earthworm communities of tropical rain forest. *Soil Biology and Biochemistry* **24**: 1397-1408.

Fragoso, C., P. Lavelle, E. Blanchart, B.K. Senapati, J.J. Jimenez, M.A. Martinez, T. Decaens & J. Tondoh. 1999. Earthworm communities of tropical agro ecosystems : origin, structure and influence of management practices. pp. 27-55. *In*: P. Lavelle, L. Brussaard & P. Hendrix (ed.) *Earthworm Management in Tropical Agroecosystems*. CAB International, Wallingford, UK.

Gates, G.E. 1972. Burmese earthworms. An introduction to the systematics and biology of megadrile oligochaetes with special reference to southeast asia. *Transactions of American Philosophical Society, New Series* **62**: 1-326.

Gilot, C., P. Lavelle, E. Blanchart, J. Keli, P. Kouassi & G. Guillaume. 1995. Biological activity of soil under rubber plantations in Cote d'Ivoire. *Acta Zoologica Fennica* **196**: 186-189.

González, G., E. Garcia, V. Cruz, S. Boges, M. Zalamea & M.M. Rivera. 2007. Earthworm communities along an elevation gradient in northeastern Puerto Rico. *European Journal of Soil Biology* **43**: 24-32.

Hendrix, P.F. & P.J. Bohlen. 2002. Exotic earthworm invasions in north America : ecological and policy implications. *Bioscience* **52**: 1-11.

Ismail, S.A., C. Ramakrishna & M.M. Anzar. 1990. Density and diversity in relation to the distribution of earthworms in Madras. *Proceedings of Indian Academy of Science (Animal Science)* **99**: 73-78.

Jacob, J. 2000. Rubber tree, man and environment. pp. 599-610. *In*: P.J. George & C.K. Jacob (eds.) *Natural Rubber: Agro Management and Crop Processing*. Rubber Board, Kottayam, India.

Julka, J.M. 1988. *The Fauna of India and the Adjacent Countries : Megadrile Oligochaeta (Earthworms)*. Zoological Survey of India, Kolkata.

Krishnamoorthy, R.V. 1985. Competition and coexistence in a tropical earthworm community in a farm garden near Bangalore. *Journal of Soil Biology & Ecology* **5**: 33-47.

Lavelle, P. 1974. Les vers de terre dela savanne de Lamto, in analyse d'un Ecosysteme Tropical Humide: La Savanne de lamto (Cote d' Ivoire). *Bull. De Liaison des chercheurs de Lamto* **5**:133-136.

Lee, K.E. 1985. *Earthworms: their Ecology and Relationships with Soil and Land Use*. Academic Press, Sydney.

Leaky, R.J.G. & J. Proctor. 1987. Invertebrates in the litter and soil at a range of altitudes on Gunug Silam. *Journal of Tropical Ecology* **3**: 119-129.

Mishra, P.C. & M.C. Dash. 1984. Population dynamics and respiratory metabolism of earthworm population in a sub tropical dry woodland of western Orissa . India. *Tropical Ecology* **25**: 103-116.

Reynolds, J.W, J.M. Julka & M.N. Khan. 1995. Additional earthworm records from Bangladesh (Oligochaeta: Glossoscolecidae, Megascolecidae, Moniligastridae, Ocnerodrilidae and Octochaetidae). *Megadrilogica* **6**: 51-62.

Sarlo, M. 2006. Individual tree species effects on earthworm biomass in a tropical plantation in panama. *Caribbean Journal of Science* **42**: 419-427.

Sathianarayanan, A. & A.K. Khan. 2006. Diversity, distribution and abundance of earthworms in Pondicherry region. *Tropical Ecology* **47**: 139-144.

Senapati, B.K. & M.C. Dash. 1981. Effect of grazing on the elements of production in the vegetation of Oligochaeta component of a tropical pasture land. *Review of Ecology & Biological Science* **18**: 187-205.

Shakir, S.H. & D.L. Dindal. 1997. Density and biomass of earthworms in forest and herbaceous microecosystems in central New York, North America . *Soil Biology and Biochemistry* **29**: 275-285.

Sinha, B., T. Bhadauria, P.S. Ramakrishnan, K.G. Saxena & R.K. Maikhuri. 2003. Impact of landscape modification on earthworm diversity and abundance in the Hariyali sacred landscape, Garhwal Himalaya. *Pedobiologia* **47**: 357-370.

Stern, H.J. 1967. *Rubber : Natural & Synthetic*. Maclaren and Sons Ltd. London.

Tian, G., J.A. Olimah, G.O. Adeoye & B.T. Kang. 2000. Regeneration of earthworm population in a degraded soil by natural and planted fallows under humid tropical conditions. *Soil Science Society of America Journal* **64**: 222-228.

Walkley, A. & I.A. Black. 1934.Determination of organic carbon in soil. *Soil Science* **37**: 29-38.