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Community structure of earthworms under rubber plantations and mixed forests in Tripura, India

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Abstract

Studies on community structures of earthworms of rubber (*Hevea brasiliensis*) plantations and their adjacent mixed forests in West Tripura (India) revealed that both the studied sites harvoured 10 earthworm species. Nine species (*Pontoscolex corethrurus, Kanchuria* sp 1, *Metaphire houlleti*, *Drawida papillifer papillifer*, *Drawida assamensis*, *Gordiodrilus elegans*, *Eutyphoeus assamensis*, *Eutyphoeus comillahnus* and *Eutyphoeus gigas*) were common to both. While *Octochaetona beatrix* was found only in the rubber plantations, *Dichogaster affinis* was restricted to the mixed forest only. Earthworms were found mostly within 15 cm depth of soils having mean temperature of 27ºC, moisture of 23% , pH of 4.57, organic matter of 1.34% and water holding capacity of 36% . Mean earthworm density in rubber plantations (115 ind. m^{-2}) was significantly higher ($p = 0.003$, $t = 3.83$) than that in the mixed forests (69 ind. m^{-2}) due to dominance of *Pontoscolex corethrurus*, an exotic species. Numbers of dominant species were two (*P. corethrurus* and *D. assamensis*) in the rubber plantations and five (*P. corethrurus D. assamensis*, *D. papillifer papillifer*, *M. houlleti* and *Kanchuria* sp 1) in the mixed forests. Compared to the mixed forests, significantly low ($p<0.05$) Shannon diversity index ($\bar{H}$) and species evenness and high index of dominance in the rubber plantation were evaluated.

Key words

Earthworm community, Rubber plantation, Mixed forest, Dominance, Shannon-diversity index

Introduction

Raising forest plantation is the most widely adopted method to recover the fragile ecology of forest due to denudation and shifting cultivation in the north-east India. Plantations are being established also as buffer zones for biodiversity conservation (Tien *et al.*, 2000; Sarlo, 2006). Rubber tree, *Hevea brasiliensis*, endemic to the Amazon rain forests, was planted in Tripura by the forest department as a part of tribal rehabilitation program. Historically most of the rubber plantations in Tripura were derived either from afforestation of 'waste land' or fallows after repeated slash-and-burn agriculture. Rubber is an important cash crop in the economy of Tripura where it is cultivated in more than 40,000 ha area over hill slopes, hillocks and plains. Being a deciduous plant with very fast rate of growth, it shows maximum litter fall during February and March with annual litter addition to plantation floor amounting to 7 tonnes $^{-1}$ (Jacob, 2000). Flow of rubber latex starts at 7 yr age of plantation, becomes the maximum at 20 yr and typically ceases at 35 yr (Zhang *et al.*, 2007). Rubber plantations often face anthropogenic interferences such as latex harvesting, collection of leaf litter for using as fuel by local tribal people, intermittent weeding etc. According to Zhang *et al.* (2007), rubber plantation decreases soil organic carbon which is linked to latex harvesting. Rubber leaf litter while reported to be less palatable to the Indian epigeic earthworm *Perionyx excavatus*, has been utilized as a good vermiculture substrate for the South African species, *Eudrilus eugeniae* (Chaudhuri *et al.*, 2003). Since earthworms constitute the highest macrofauna biomass in tropical soils (Fragoso and Lavelle, 1992), they play an important role in maintaining soil fertility, ecosystem function and production. Thus earthworms can be utilized as an effective tool in assessing the degree of anthropogenic influences such as afforestation and silvicultural practices.

Population dynamics, diversity and distribution of earthworms in natural ecosystems of the tropics have received considerable attention in recent years (Fragoso and Lavelle, 1992; Blanchart and Julka, 1997; Zou and Gonzalez, 1997; Bhadauria *et* *al.*, 2000; Sinha *et al.*, 2003; Chaudhuri and Bhattacharjee, 2005; Julka and Paliwal, 2005; Gonzalez *et al.*, 2007; Dash and Dash, 2008). Recently Chaudhuri *et al.* (2008, 2009a) reported the occurrence of 27 species of earthworms in the rubber plantations, where *Pontoscolex corethrurus*, an exotic species became dominant contributing 66.5% biomass and 76% density of the total earthworm communities. Morphometric and seasonal variations in cast productions by 12 different species of earthworms in the rubber plantations have been studied by Chaudhuri *et al.* (2009b). Indeed, studies on anthropogenic influences on earthworm communities due to afforestation in tropics are scarce (Fragoso *et al.*, 1999; Nath and Chaudhuri, 2010). Thus the main objective of our investigation was to study the structures of earthworm communities inhabiting two adjacent but different types of habitats – rubber plantations with anthropogenic practices and natural mixed forests with least disturbances. Such study is necessary to evaluate the impact of afforestation on the earthworm communities of Tripura.

Materials and Methods

Study area: Study area comprised of Anandanagar, Sepahijala and Boxonagar, 30 km apart from each other in West of Tripura state (latitude 22º56'–24º32'N and longitude 91º10'–92º21'E), in North-East India. The subtropical climate of the area experiences a mean annual temperature of 25ºC and annual rainfall of 2000 mm. Soils of study area, in general, are acidic.

In each of the three areas, studied sites were mature (15-25 yrs old) rubber plantations (RP) and mixed forests (MF) that were in close proximity (less than 1 km). The RP possess well developed canopy covers and horizontal distribution of roots in the topsoil. The plantation floor remained covered with *Hevea* leaf litter. At least fifty plant species were distributed scatteredly in the mixed forests.

Sample collection and data analysis: Sampling was done during the monsoon period of 2007. From 1 ha area of each study site 10 widely separated square plots (100 m^2) were randomly selected for earthworm sampling. Earthworms were extracted by hand sorting, after digging a cubic pit of size 25×25×25 cm. Ten composite samples each comprising of 5 sub-samples, were taken from 10 sampling plots of each studied site. Thus a total of 30 composite samples (150 sub-samples) each for RP and MF were taken from the three studied areas.

Earthworms were counted, washed, wiped dry on a filter paper and their fresh weights were determined following phenotypic separation under magnifying glass. Only 10–15 earthworms of each species were preserved in 5% formalin for later identification.

Results were expressed in terms of biomass (fresh weight g m^{-2}) and population density (individual m^{-2}). Using the data available, frequency, relative abundance, dominance (Engelmann, 1973), index of dominance (Simpson, 1949), species richness index (Menhinick, 1964), index of general diversity (Shannon and Weiner, 1963), species evenness and index of similarity (Dash and Dash, 2009) of earthworm communities were analysed and ecological categories of earthworms were studied following Hendrix and Bohlen (2002).

Soil samples were collected at 0–15 cm depth from the location of maximum earthworm occurrence with a metal shovel and composite soil samples were prepared for physico-chemical analysis. Soil samples were air dried, ground with mortar and pastle and sieved with 1 and 2 mm sieves. Sieved soil samples were analysed for their moisture (gravimetric wet weight method), pH (1: 2.5 dilution method) and soil organic matter content (Walkley and Black, 1934) and texture (feel method). Soil temperatures were recorded in situ at each sample plot at a depth of 15 cm.

Variations in earthworm biomass, density, diversity, species richness index, index of dominance and species evenness of RP and MF were tested using Student's t-test.

Results and Discussion

Community composition: A total of 1082 and 647 earthworms were collected from the soils of RP and MF respectively. Eleven species belonging to 5 families were identified from the studied sites. Of these, 9 species (*Pontoscolex corethrurus* (Muller), *Kanchuria* sp 1, *Metaphire houlleti* (Perrier), *Drawida papillifer papillifer* Gates, *Drawida assamensis* Stephenson, *Gordiodrilus elegans* Beddard, *Eutyphoeus assamensis* Stephenson, *Eutyphoeus comillahnus* Michaelsen and *Eutyphoeus gigas* Stephenson) were present in both RP and MF (Table 1). *Octochaetona beatrix* (Beddard) and *Dichogaster affinis* (Michaelsen) were restricted only to the RP and MF respectively. So both types of study sites harboured 10 species (Fig. 1) and the quotient of similarity between them was 90%. The occurrence of 10 species of earthworms in each of the two types of study sites (RP and MF) in Tripura is well within the reported range of 1 to 15 species (Fragoso and Lavelle, 1992). *P. corethrurus*, *G. elegans* and *D. affinis* are exotic to the Indian subcontinent.

Significantly higher ($p<0.01$) mean earthworm densities in RP (115 ind m^{-2}) than in MF (69 ind m^{-2}) was contributed mainly by exotic species, *P. corethrurus* (76% of the total earthworm densities) (Table 1 and 2). *D. papillifer papillifer*, a native species exhibited higher ($p<0.05$) density in the MF than in the RP. Interestingly mean earthworm biomasses did not differ significantly ($p>0.05$) between RP (46 g m^{-2}) and MF (45 g m^{-2})

Among different earthworm species, biomass of only *P. corethrurus* was significantly higher ($p<0.05$) in the RP than in the MF (Table 1). In terms of biomass *P. corethrurus* contributed 66.5% and 12% of the earthworm communities in the RP and the MF respectively. All other species showed higher biomass values (significant in *M. houlleti* and *D. papillifer papillifer*) in MF than in RP (Table 1).

The biomass values of earthworms in RP and MF are comparable to or higher than that in savana, rain forest, acacia plantation and mixed forests of tropical areas, but their densities are

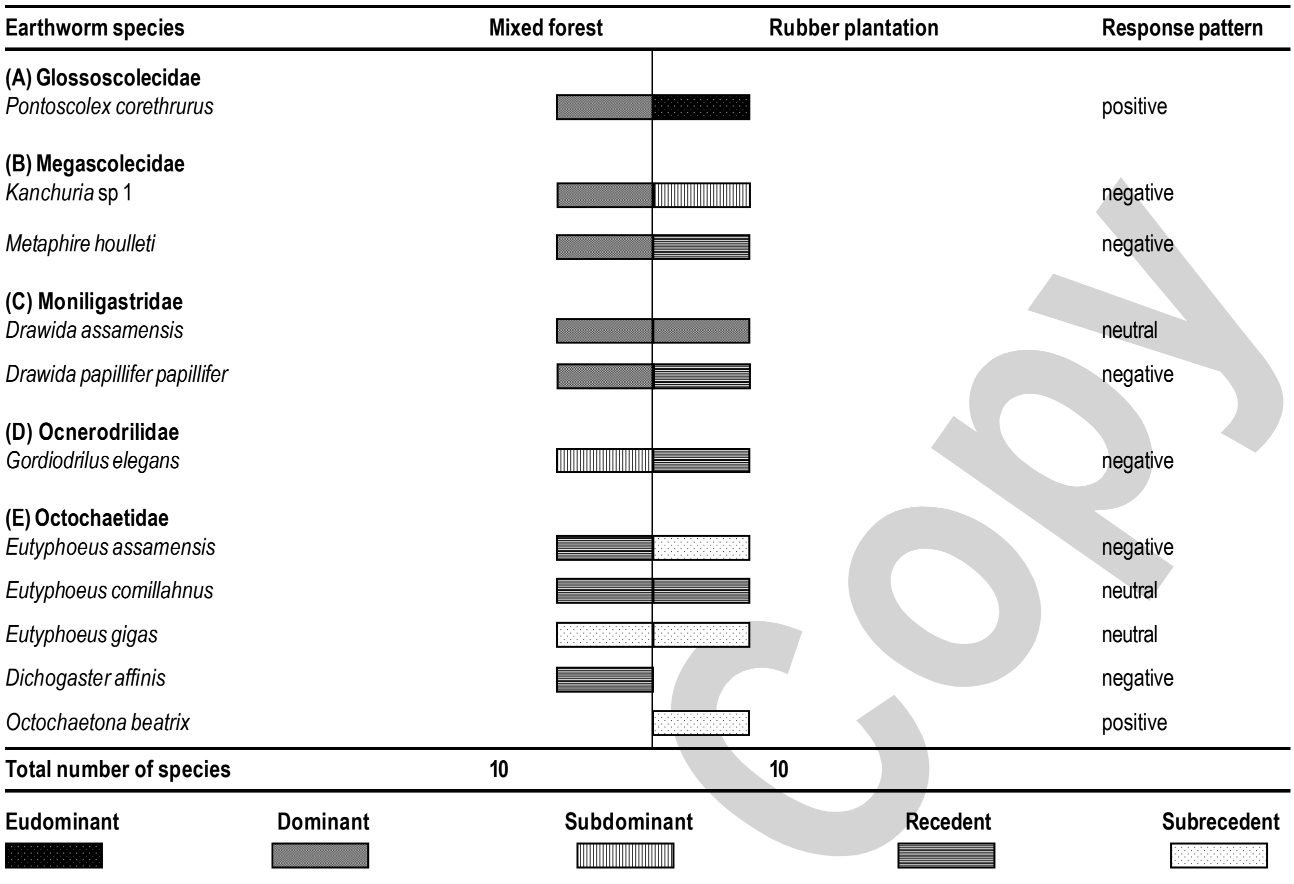

Fig. 1: Earthworm population and their response pattern

generally less than those habitats (Bhadauria *et al.*, 2000; Blanchart and Julka, 1997; Fragoso and Lavelle, 1987, 1992). Low densities of earthworm species in the studied sites are probably related to the acidic nature of the soil in Tripura because earthworms, in general, are neutrophilic in nature (Edwards and Bohlen, 1996).

Of the 11 species found in the study sites, 7 species (*P. corethrurus, Kanchuria* sp 1, *D. assamensis*, *E. assamensis*, *E. comillahnus*, *O. beatrix* and *G. elegans*) were endogeic, 2 species (*M. houlleti* and *D. papillifer papillifer*) epianecic and 1 species each from epigeic (*D. affinis*) and endoanecic *(E. gigas*) categories. The MF ecosystem had more diverse functional groups of earthworms than the RP (Table 3) due to varied ecological niches in the former. Based on the population densities and biomasses endogeics were the dominant functional group in both RP and MF. In Mexico, having similar climatic conditions to India, endogeics dominated in both natural and disturbed ecosystems (Fragoso *et al.*, 1999). Epigeic worms were absent in the RP. Density and biomass of epianecics were significantly higher ($p<0.05$) in the MF compared to the RP, but those of endogeics were significantly higher ($p<0.05$) in the RP than in the MF (Table 3). Less palatability of *Hevea* leaf litter due to rich content of lignin and polyphenols (Chaudhuri *et al.*, 2003) may be an important factor for the absence of the epigeic and significant decrease of epianecic species in the RP compared to the MF.

Community organization: Highest species frequency of earthworms was attained by a native species, *Kanchuria* sp 1 (90%) in the MF and an exotic species, *P. corethrurus* (77%) in the RP. Species frequency higher than 70% were shown by 5 species *viz. Kanchuria* sp 1, *D. assamensis*, *D. papillifer papillifer*, *M. houlleti* and *P. corethrurus* in mixed forests (Table 1). The endemic species *viz. Kanchuria* sp 1, *M. houlleti*, *D. assamensis*, *D. papillifer papillifer*, *E. comillahnus* had relatively higher relative abundances in the MF than in the RP (Table 1). In contrast, the exotic species, *P. corethrurus* showed the highest relative abundance in the RP. Exotic species occur and often dominate in disturbed sites (Hendrix and Bohlen, 2002; James and Hendrix, 2004; Grosso *et al.*, 2006). RP often faces anthropogenic interferences such as forest cleaning, taping and weeding. So occurrence of *P. corethrurus* as a eudominant species of RP is not surprising. Being the commonest earthworm of Brazil, *P. corethrurus* is the most widely distributed earthworm species of the world (Gates, 1972). As the origin of the rubber plant, *H. brasiliensis* is also Brazil, dispersal of *P. corethrurus* (indigenous to North-Eastern and South America) through exotic crops like *H. brasiliensis* to different parts of the world is quite possible (Chaudhuri *et al.*, 2008). There are also reports on the occurrence of *P. corethrurus* in rubber plantations of Malaysia, Burma and South India (Gates, 1972; Julka and Paliwal, 2005). According to James and Hendrix (2004), reforestation

Table - 1: Earthworm population characteristics and dominance from rubber plantations (RP) and mixed forests (MF) in Tripura

Earthworm species		Population density (ind. m^{-2}) (± SE)	Biomass (g. m^{-2}) (± SE)	Frequency (%)	Relative abundance (%)	Dominance
P. corethrurus	RP -	88.32^{a}±18.65	30.54^{a}±6.30	76.67	76.53	Eudominant
	MF -	19.30^{b}±2.95	5.46^{b}±0.75	73.33	27.98	Dominant
Kanchuria sp 1	RP -	5.39^{a}±3.10	6.29^{a}±2.22	56.67	5.45	Subdominant
	MF -	11.12^{a}±1.57	10.77^{a}±2.32	90.00	15.61	Dominant
M. houlleti	RP -	1.86^{a}±0.70	2.03^{a}±0.73	36.67	1.76	Recedent
	MF -	14.13^{b}±1.82	8.64^{a}±2.95	80.00	12.52	Dominant
D. p. papillifer	RP -	1.16^{a}±0.49	2.56^{a}±0.26	36.67	2.22	Recedent
	MF -	3.78^{b}±2.13	8.75^{b}±0.86	83.33	12.67	Dominant
D. assamensis	RP -	3.41^{a}±8.53	11.95^{a}±2.05	53.33	10.35	Dominant
	MF -	4.66^{a}±5.23	11.95^{a}±1.69	86.67	17.31	Dominant
G. elegans	RP -	0.11^{a}±0.81	1.60^{a}±0.06	23.33	1.39	Recedent
	MF -	0.28^{a}±5.44	5.76^{a}±0.25	23.33	8.35	Subdominant
D. affinis	RP -	0.00	0.00	0.00	0.00	-
	MF -	0.05±0.81	0.96±0.04	16.67	1.39	Recedent
E. assamensis	RP -	1.27^{a}±0.64	0.64^{a}±1.27	10.00	0.55	Subdominant
	MF -	1.91^{a}±0.75	0.75^{a}±1.91	10.00	1.08	Recedent
E. comillahnus	RP -	0.92^{a}±0.28	1.49^{a}±0.37	26.67	1.29	Recedent
	MF -	1.45^{a}±0.32	1.60^{a}±0.39	36.67	2.32	Recedent
E. gigas	RP -	1.12^{a}±0.18	0.32^{a}±0.60	10.00	0.28	Subrecedent
	MF -	2.40^{a}±0.28	0.53^{a}±1.21	13.33	0.77	Subrecedent
O. beatrix	RP -	0.13±0.10	0.21±0.06	6.67	0.10	Subrecedent
	MF -	0.00	0.00	0.00	0.00	-

Same letter (a, b) correspond to no significant difference ($p>0.05$)

Table - 2: A comparison between rubber plantations (RP) and mixed forests (MF) in Tripura with reference to their edaphic and earthworm community characteristics

Ecological parameters	Rubber plantation (Mean ± SE)	Mixed forest (Mean ± SE)
Soil texture	Sandy clay loam	Sandy clay loam
Temperature (ºC)	27.07±0.06	27.02±0.08
Moisture(%)	23.84±0.71	22.83±0.73
pH	4.51±0.07	4.62±0.06
Organic matter (g%)	1.36±0.09	1.40±0.04
Water holding capacity (%)	36.69±0.94	36.97±0.54
Earthworm density (ind. m^{-2})	115.41±10.83	69.01±4.97*
Earthworm biomass (g m^{-2})	45.91±3.69	45.24±3.48
Species richness index (d)	0.45±0.06	0.57±0.03
Shannon diversity index ($\bar{H}$)	0.86±0.22	1.76±0.04*
Index of dominance (c)	0.62±0.12	0.20±0.01*
Species evenness (E)	0.41±0.10	0.83±0.01*
P/O ratio**	5.28±0.98	0.42±0.12*

* Significant at $p<0.05$, ** P/O = Density of *Pontoscolex corethrurus*/ Density of other earthworm species

programme using root-ball planting stock provides important means of dispersal of exotic species.

Monoculture RP had significantly higher ($p<0.05$) index of dominance (0.62) than MF (0.20) (Table 2). On the basis of Engelmann's scale of dominance, the RP was characterized by the presence of 1 eudominant, 1 dominant, 1 subdominant, 4 recedent and 3 subrecedent species of earthworms. The MF, on the other hand, had 5 dominant, 1 subdominant, 3 recedent and 1 subrecedent species of earthworms (Table 1). In both the RP and the MF, *D. assamensis* was found to be a dominant species, *E. comillahnus* a recedent species and *E. gigas* a subrecedent species. Among the 5 dominant species in the MF, only *P. corethrurus* responded positively and became the eudominant species in the RP, while *Kanchuria* sp 1, *M. houlleti* and *D. papillifer papillifer* responded negatively and *D. assamensis* was neutral in response. Such variations in response pattern could be attributed to the effects of human activities on soil biota of the RP (Nath and Chaudhuri, 2010).

Although both RP and adjacent MF in Tripura supported same number of earthworm species, the Shannon-diversity index ($\bar{H}$) was significantly lower and index of dominance was significantly higher in the RP than in the MF (Table 2). According to Shakir and Dindal (1997), population density is negatively correlated with species diversity. Thus the highest population density for more dominant species (*P. corethrurus* in RP) was correlated with lower biodiversity in the RP. Blanchart and Julka (1997) also reported high earthworm species diversity in natural evergreen forest and low diversity in *Acacia* plantation of Western ghat (South India). Cesarz *et al.* (2007) reported a positive correlation between earthworm diversity and tree species diversity indicating the

Table - 3: Density and biomass values of different ecological categories of earthworms in rubber plantations (RP) and in mixed forests (MF) in Tripura

Ecological categories		Population density (ind. m^{-2})	Biomass (g. m^{-2})
Epigeic	RP -	$0.00^a \pm 0.00$	$0.00^a \pm 0.00$
	MF -	$0.96^a \pm 0.80$	$0.05^a \pm 0.04$
Endogeic	RP -	$110.50^a \pm 12.11$	$41.77^a \pm 2.80$
	MF -	$50.13^b \pm 8.08$	$24.88^b \pm 3.83$
Epianecic	RP -	$4.59^a \pm 1.05$	$3.02^a \pm 0.93$
	MF -	$17.81^b \pm 3.25$	$18.03^b \pm 3.38$
Endoanecic	RP -	$0.32^a \pm 0.18$	$1.12^a \pm 0.60$
	MF -	$0.53^a \pm 0.28$	$2.40^a \pm 1.21$

Values are mean ± SE, Same letter (a, b) correspond to no significant difference (p>0.05)

importance of diverse food qualities for the decomposer fauna in the MF. According to Fragoso and Levelle (1992), species diversity of earthworms in tropical rain forests ranges from 1.7 to 6.5. Thus species diversity of earthworms in the MF of Tripura (1.76) lie within this reported range, however, that of the RP (0.86) is far less than that of tropical rain forests.

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