International Journal of Ecology and Environmental Sciences 45 (2): 179-190, 2019
ISSN: 2320-5199 (Online)

Earthworm Communities under Pasture Ecosystems in Tripura, India

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ABSTRACT

Studies on earthworm community characteristics under pasture ecosystems revealed a total of 11 earthworm species. Among them 4 earthworm species belonged to the family Octochaetidae [*Eutyphoeus assamensis* Stephenson, *Eutyphoeus comillahnus* Michaelsen, *Octochaetona beatrix* (Beddard), *Dichogaster bolaui* (Michaelsen)], 3 species to the family Megascolecidae [*Lampito mauritii* (Kinberg), *Metaphire houlleti* (Perrier), *Kanchuria* sp.], 2 species to the family Moniligastridae (*Drawida assamensis* Gates, *Drawida papillifer papillifer* Stephenson) and 1 earthworm species each to the family Glossoscolecidae [*Pontoscolex corethrurus* (Muller)] and Almidae (*Glyphidrilus* sp.). *L. mauritii* was eudominant on the basis of its relative abundance (34.14%) and shared the same habitat with 2 dominant earthworm species, *D. assamensis* and *P. corethrurus*. Out of 11 earthworm species 7 species were endogeic, 3 species were anecic and 1 species of the epigeic category. *E. comillahnus* showed restricted distribution in Tripura, India and hence considered to be endemic to Tripura. Native earthworm species were found to be dominant (78.82%) in the pasture soils. In the pasture ecosystem earthworms had a mean density of 128.94±4.11 ind. m^{-2} and mean biomass of 63.76±2.22 g m^{-2}. Earthworms in general occurred in the soils of pasture with a mean soil temperature of 27.36°C, pH 5.44, moisture 14.97%, organic matter 1.17 g % and bulk density of 1.05 g cm^{-3}. In pasture Shannon's diversity (Ĥ), Simpson's index of dominance (D), Menhinick species richness index (R) and Species evenness (J') were 1.51, 0.30, 0.37 and 0.55 respectively.

Key Words: Tropical Earthworms; Density; Biomass; Dominance; Diversity Index

INTRODUCTION

Biodiversity and ecosystem services are declining due to increasing anthropogenic activities over the soil. Soil is the habitat of diverse flora and fauna (Lavelle and Spain 2001). Although, below ground species diversity is higher than above ground in most cases, studies on the former have been ignored for lower visibility of below-ground organisms and an absence of 'charismatic' species (Susilo et al. 2004).

Nowadays earthworms are recognized as major biological drivers in the below ground biodiversity (Lemtiri et al. 2014). Aristotle called earthworms as the "Intestine of the Earth". In the late 1800s Charles Darwin brought attention to the major importance of earthworms. They are called as an "ecosystem engineers" due to their feeding, burrowing and casting activities that improve soil aggregation, increase soil pore size and water infiltration rate. Highest soil invertebrate biomass is represented by earthworms (Lavelle et al. 1994, Sinha et al. 2003). Earthworms play a vital role in the decomposition of organic matter, nutrient cycle and increase the availability of plant nutrients for plant growth.

With a minimal 2.4% of the world's area, India accounts for 7.46% of the total faunal species (Forest Survey of India 2005). Along with the Western Ghats and Eastern Himalayas North-eastern hill regions belong to biodiversity hotspot zones. The land use patterns in India are the areas under cultivation (46%) followed by forests (23%), pastures (4%), fallow land (7%), cultivable wasteland (6%) and other uses (14%) (Mukherjee 2009). In India, pastures have originated from the forest ecosystem as a result of deforestation, abandoned agricultural systems and are maintained at various successional stages by grazing, burning, harvesting (Thokchom and Yadava 2016). In North East India only 1% of the total land area is under pasture and grazing (Yadava 1990). Tropical grasslands play a major role in the carbon cycle (Ghosh and Mahanta 2014). Generally pasture ecosystem comprises of herbaceous vegetation and plays a major role in the conservation of diverse native fauna. Earthworms accelerate carbon activation and facilitate carbon sequestration in their burrows by generating an earthworm-mediated "carbon trap" (Zhang et al. 2013). Continuous carbon inputs into earthworm burrows mainly by those of anecic species are strongly dependent on their activity (Don et al. 2008). Thus soil carbon and earthworms are important components in the sustainable agro-ecosystems (Utomo et al. 2010). Information is scanty on earthworm diversity, density and biomass in the pasture (Senapati et al. 1979, Senapati and Dash 1983, Suthar 2012). In fact, earthworms dominate the biomass (>80%) of invertebrates in grasslands and pasture ecosystems of the world (Dash 1978). Their role as an important consumer and decomposer group has been elucidated by Darwin (1881) and Satchell (1967). The energetic relationship of earthworms, a dominant consumer group in tropical pastures, with regard to primary production was highlighted for the first time by Dash and Patra (1977). Earthworms are well known biological indicators of soil health (Edwards and Bohlen 1996). The presence and dispersal of earthworms in the soil are affected by a variety of environmental factors such as soil moisture, temperature, rainfall pattern, surface vegetation litter fall quality or litter inputs, soil organic matter, land use patterns, as well as, human disturbances (Edwards 2004). The surface plant species influences the belowground biological system by improving soil micro-climatic conditions and indirectly by litter quality. Reports are available on the communities of tropical earthworms in different habitats such as, deciduous forest (Mishra and Dash 1984), upland irrigated paddy field (Pani 1987), tropical rain forest (Blanchart and Julka 1997), acacia plantation (Blanchart and Julka 1997), pine forest (Bhadauria et al. 2000), rubber plantation (Chaudhuri et al. 2008), bermuda grass (Suthar 2012), pineapple plantation (Dey and Chaudhuri 2014), bamboo plantation (Chakraborty and Chaudhuri 2017), tea plantation (Jamatia and Chaudhuri 2017). On the basis of above facts aims of our present research paper were to study the community characteristics of earthworms in pastures in Tripura, North East India.

MATERIALS AND METHODS

Study Area and Sites

The study was conducted from November 2015 to October 2017 in Ujan Abhoynagar and Nandannagar of West Tripura district (23º 16' - 24º14' N and 91º 09' - 91º 47' E) and Sutarmura and Kolam Chowra of Sepahijala district (23º 36' - 23º 50' N and 91º 15' - 91º 19' E) of Tripura, India. A minimum of three replicate plots was considered for the survey in West Tripura (two plots in Nandannagar, one in Abhoynagar) and Sepahijala district (two plots in Sutarmura, one in Kolam Chowra). Each of the studied sites was 20 to 50 km apart from each other. Tripura, a north eastern state of India with an area of 10,491 km^2 is surrounded by Assam and Mizoram to the east and Bangladesh to the north, south and west. The seasons of Tripura are separable into summer (March-May), monsoon (June-September), autumn (October), winter (November-February) with an average annual rainfall of about 2000 mm and mean temperature of 25ºC. The soils in the study areas are acidic in general (Dey and Chaudhuri 2014).

Pasture ecosystem is a heterogeneous system of herbaceous vegetation where earthworms play the role of main decomposers. The studied sites were totally devoid of tree canopy, more often subjected to cattle grazing and found to be dominated by herbaceous species from family Poaceae such as- *Isachne globosa*, *Axonopus compressus*, *Eleusine indica*, *Cynodon dactylon*, *Panicum repens*. Besides these have a good number of other plant species such as *Desmodium triflorum* (Fabaceae), *Mimosa pudica* (Fabaceae), *Leucas aspera* (Lamiaceae), *Clerodendrum infortunatum* (Lamiaceae), *Cyperus rotundus* (Cyperaceae), *Scoparia dulcis* (Plantaginaceae), *Blumea lacera* (Asteraceae) etc. are also present in pasture.

Collection of Earthworms

Earthworms were collected during November 2015 – October 2017 for two consecutive years by TSBF soil monolith (25 cm × 25 cm × 30 cm) digging and hand sorting method (Anderson and Ingram 1993). Sampling points (quadrats) were separated by a distance of 5-10 m in each of the studied plots. After collection, earthworms were counted, rinsed in water, wiped with tissue paper and weighted alive on electronic balance in the field. Some of the adult worms were preserved in 10% formalin and identified in the laboratory based on the taxonomic keys (Gates 1972, Julka 1988). Earthworm biomass and density were expressed in fresh weight, g m^{-2} and ind. m^{-2} respectively. A total of 221 quadrats (n=221) were considered for earthworm population studies. Relative abundance, frequency (Dash and Dash 2009), diversity (Shannon and Wiener 1963), dominance (Simpson 1949), species evenness (Dash and Dash 2009) and species richness (Menhinick 1964) were calculated. Dominance of species was ascertained on the basis of relative abundance (RA) using Engelmann's scale (Nath 2012) as follows: eudominant species (RA 31.7% – 100%), dominant species (RA 10.1% – 31.6%), subdominant species (RA 3.2% – 10.0%), recedent species (RA 1.1% – 3.1%) and subrecedent species (RA < 1.0%). Based on relative abundance, rank abundance curve for earthworm species was made to know the relative importance of the species in pasture ecosystem. Ecological categories of earthworms were considered based on Edwards and Bohlen (1996). Casts of different earthworm species were also collected during April-October 2017 and the amount of earthworm casts produced was determined on a dry weight basis (g m^{-2}).

Analysis of Soil

To determine the soil physicochemical parameters collection of soil sample was done at 0-15 cm depth with a metal shovel. Composite soil samples [made from 4 subsamples of 221 quadrats (n=221)] were prepared for physico-chemical analysis. Using digital soil thermometer soil temperature was determined at the 15 cm depth and soil moisture was determined by a gravimetric wet weight method. Soil bulk density was determined following Okalebo et al. (1993). Collected soil samples were air dried, ground with mortar and pestle and sieved (2 mm). Soil pH (1:2.5 dilution method) and organic matter (Walkley and Black 1934) were determined. Simple regression coefficient was employed to determine the relationship of earthworm density and biomass with temperature, moisture, pH, organic matter (Zar 1999).

RESULTS

Site Characteristics

Mean values of physico-chemical and ecological variables such as temperature, moisture, pH, organic matter, bulk density, amount of cast production, diversity indices etc. are provided in Table 1.

Table 1. Showing physico-chemical and ecological parameters in pasture (n=221)

Parameters	Pasture (Mean ± SE)
Soil temperature (°C)	27.36 ± 0.08
Soil moisture (%)	14.97 ± 0.19
Soil pH	5.44 ± 0.01
Organic matter (g %)	1.17 ± 0.02
Bulk density (g cm^{-3})	1.05 ± 0.01
Overall earthworm biomass (g m^{-2})	63.76 ± 2.22
Native species biomass (g m^{-2})	51.33 ± 2.34
Exotic species biomass (g m^{-2})	12.43 ± 1.62
Overall earthworm density (ind. m^{-2})	128.94 ± 4.11
Native species density (ind. m^{-2})	101.72 ± 4.25
Exotic species density (ind. m^{-2})	27.22 ± 3.14
Production of casts (g m^{-2})	28.19 ± 6.98
Total number of species	11
Shannon diversity index (Ĥ)	1.51 ± 0.19
Simpson index of dominance (D)	0.30 ± 0.06
Species evenness (J')	0.55 ± 0.05
Menhinick species richness index (R)	0.37 ± 0.05

Community Composition

A total of 11 different species of earthworms from 9 genera belonging to five families such as Octochaetidae with four earthworm species [*Eutyphoeus assamensis* Stephenson, *Eutyphoeus comillahnus* Michaelsen, *Octochaetona beatrix* (Beddard), *Dichogaster bolaui* (Michaelsen)]. Megascolecidae with 3 species [*Lampito mauritii* (Kinberg), *Metaphire houlleti* (Perrier), *Kanchuria* sp.], Moniligastridae with 2 species [*Drawida assamensis* Gates, *Drawida papillifer papillifer* Stephenson] and Glossoscolecidae [*Pontoscolex corethrurus* (Muller)] and Almidae (*Glyphidrilus* sp.) with 1 species each. On the basis of length and diameter *E. assamensis* was the largest (137-350 mm × 4-6 mm) and *D. bolaui* was the smallest species (21-28 mm × 1-2 mm) in pasture soils (Table 2). In pasture ecosystem a maximum of 9 earthworm species in both Nandannagar (West Tripura) and Sutarmura (Sepahijala) and a minimum of 6 earthworm species were recorded from Ujan Abhoynagar (West Tripura).

L. mauritii expressed itself as eudominant over other earthworms and occurred more frequently in the pasture ecosystem on the basis of its relative abundance (RA, 34.14%) and frequency (48.87%) and also shared habitat resources with two more dominant earthworm species, *D. assamensis* (RA 15.77%, Frequency 36.65%)

Table 2. Species-wise population characteristics of the earthworms found in the soils of pasture (n=221)

Earthworm families and species	Ecological Category	Size (mm) (L x D)	Biomass (g m^{-2}) Mean ± SE	Density (ind. m^{-2}) Mean ± SE	Relative abundance (%)	Frequency (%)
Megascolecidae						
Lampito mauritii (Kinberg)	Anecic	70-181 × 3-4	21.18 ± 1.91	44.31 ± 4.07	34.14	48.87
Metaphire houlleti (Perrier)	Anecic	61-175 × 3-4	8.10 ± 1.52	11.66 ± 1.97	9.07	23.53
Kanchuria sp.	Endogeic	160-360 × 3-5	5.70 ± 1.00	7.75 ± 1.34	6.03	22.17
Octochaetidae						
Eutyphoeus assamensis Stephenson	Endogeic	137-350 × 4-6	7.45 ± 1.39	6.23 ± 1.36	4.85	14.93
Eutyphoeus comillahnus Michaelsen	Endogeic	71-180 × 3-4	5.97 ± 1.08	7.09 ± 1.24	5.52	19.00
Octochaetona beatrix (Beddard)	Endogeic	55-120 × 2-3	1.62 ± 0.42	4.05 ± 1.02	3.15	10.41
Dichogaster bolaui (Michaelsen)	Epigeic	21-28 × 1-2	0.05 ± 0.03	0.51 ± 0.29	0.40	1.36
Moniligastridae						
Drawida assamensis Gates	Endogeic	66-140 × 2-3	6.36 ± 0.81	20.27 ± 2.41	15.77	36.65
Drawida papillifer papillifer Stephenson	Anecic	41-120 × 1-2	3.01 ± 0.45	11.87 ± 1.76	9.24	28.51
Glossoscolecidae						
Pontoscolex corethrurus (Muller)	Endogeic	48-110 × 1-3	4.28 ± 0.76	15.06 ± 2.64	11.72	27.15
Almidae						
Glyphidrilus sp.	Endogeic	100-110 × 2-3	0.04 ± 0.03	0.14 ± 0.10	0.11	0.45
TOTAL			63.76 ± 2.22	128.94 ± 4.11		

and *P. corethrurus* (RA 11.72%, Frequency 27.15%). According to the rank abundance curve *L. mauritii*, *D. assamensis*, *P. corethrurus* occupied the first, second and third position respectively (Figure 1). Whereas *Glyphidrilus* sp. was poorly observed during the present study (RA 0.11%, Frequency 0.45%) (Table 2).

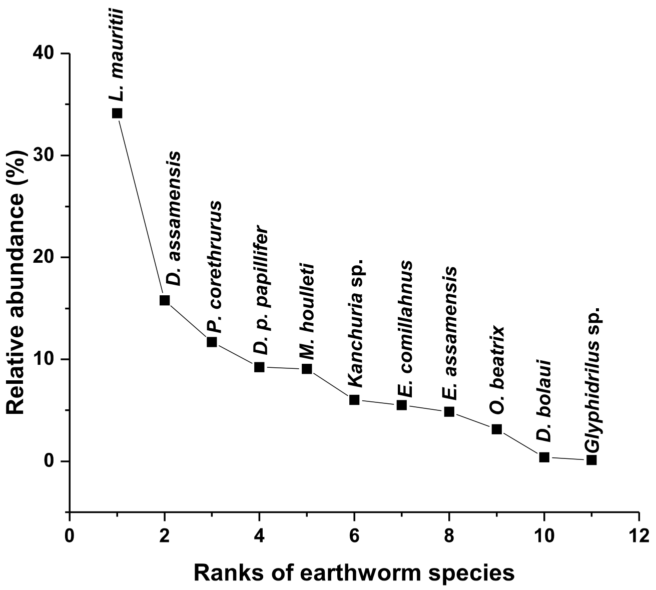

Figure 1. Rank abundance curve showing relative abundance of earthworm species in the soils of pasture

Soils of pasture ecosystem have all the three ecological categories of earthworms. Out of 11 species of earthworms seven species belonged to the endogeic (*Kanchuria* sp., *E. assamensis*, *E. comillahnus*, *D. assamensis*, *P. corethrurus*, *O. beatrix*, *Glyphidrilus* sp.), 3 species to the anecic (*L. mauritii*, *M. houlleti*, *D. papillifer papillifer*) and 1 species to the epigeic (*D. bolaui*) category (Table 2). On the basis of relative abundance anecic earthworms were the major components of the earthworm population in pasture soils and occupied 52.45% of total earthworm population. Whereas, endogeic and epigeic occupied only 47.15% and 0.40% of the total earthworm population respectively (Figure 2).

Earthworms ingest soils with organic matter and minerals, breakdown as well as decompose organic matter and at last excrete these as casts in various forms and sizes. Of the 11 species of earthworms 7 species formed surface casts, others probably produced subsurface casts (Figure 3). Composite irregularly-shaped casts were produced by *P. corethrurus*. Small tower-like casts with a regular arrangement of spherical/sub-spherical aggregates were produced by *M. houlleti*. Thick tubular convolutions were observed in the casts of *E. assamensis*. Fragile aggregates with or without convolutions were produced by *E. comillahnus*. Casts were large globoid mounds in case of *Kanchuria* sp. and

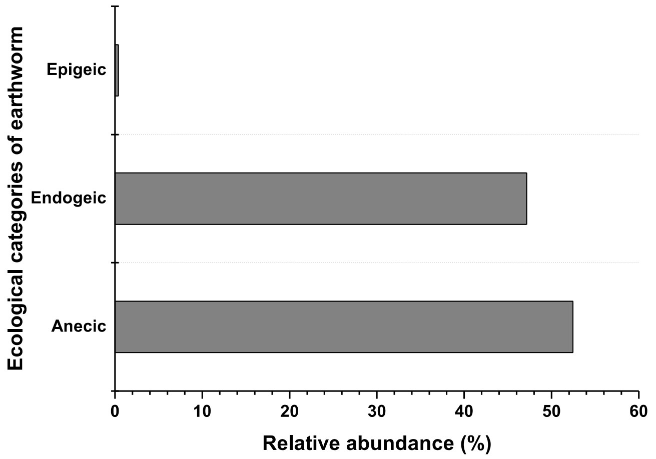

Figure 2. Ecological category-wise occurrence (%) of earthworms found in pasture

small heaps made of mostly spheroidal or oval pellets deposited by *L. mauritii*. On the other hand *Glyphidrilus* sp. deposited casts in the form of heaps made of small composite tubular convolutions. The average mass (air-dried) of casts produced by 7 species of earthworms in the pasture ecosystem was 28.19±6.98 g m^{-2}.

Native and Exotic Earthworms

In pasture soils native species (*L. mauritii*, *Kanchuria* sp., *O. beatrix*, *E. comillahnus*, *E. assamensis*, *D. assamensis*, *D. papillifer papillifer* and *Glyphidrilus* sp.) contributed 78.82% of the total earthworm population. On the other hand exotic earthworms (*M. houlleti*, *P. corethrurus* and *D. bolaui*) represented only 21.18% of the total earthworm population (Figure 4).

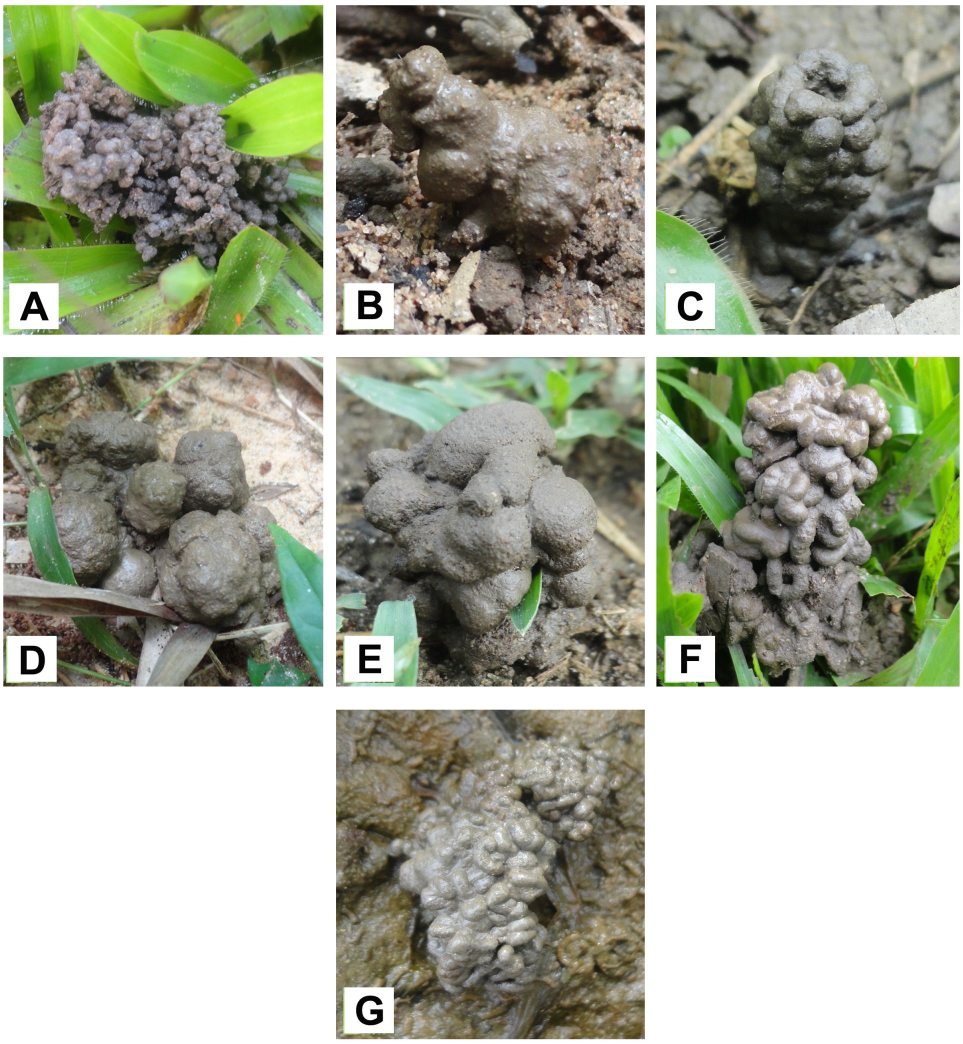

Figure 3. Different forms of casts produced by (A) *Lampito mauritii* (B) *Pontoscolex corethrurus* (C) *Metaphire houlleti* (D) *Kanchuria* sp. (E) *Eutyphoeus comillahnus* (F) *Eutyphoeus assamensis* (G) *Glyphidrilus* sp. in the soils of pasture ecosystems

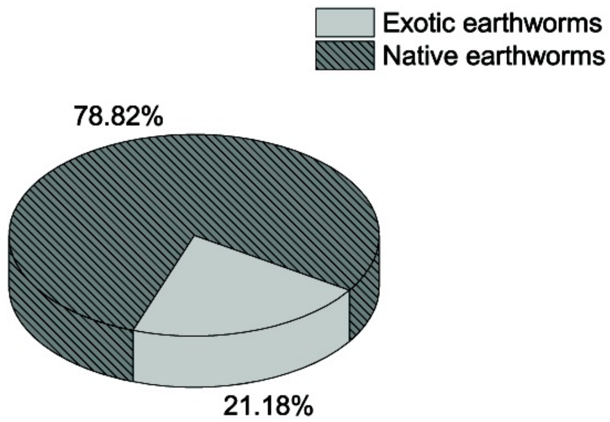

Figure 4. Occurrence of native and exotic earthworms in pasture

Density and Biomass of Earthworms

Earthworms in general had a mean density of 128.94 ± 4.11 ind. m^{-2}, mean biomass of 63.76 ± 2.22 g m^{-2} in the pasture ecosystem (Table 1). Species wise biomass, density, relative abundance and frequency of earthworm species under pasture ecosystem are given in Table 2.

L. mauritii had the highest density (44.31 ± 4.07 ind. m^{-2}) and biomass (21.18 ± 1.19 g m^{-2}) among the earthworm species in the soils under pastures (Table 2). Density and biomass of exotic and native earthworm species are also presented in Table 1.

Biodiversity Indices under Pasture Ecosystem

Shannon diversity index in the pasture ecosystem was 1.51. On the other hand dominance index, evenness and species richness were 0.30, 0.55 and 0.37 respectively (Table 1).

Earthworm and Soil Physico-chemical Characteristics

Earthworms in the pasture ecosystem experienced mean soil temperature (°C) of 27.36 ± 0.08, pH 5.44 ± 0.01, moisture (%) 14.97 ± 0.19, organic matter (%) 1.17 ± 0.02 and bulk density 1.05 g cm^{-3} (Table 1). Native earthworms, *L. mauritii*, *D. assamensis*, *D. papillifer papillifer* and exotic *P. corethrurus* exhibited a wide range of tolerance to the soil physicochemical parameters. On the other hand, *D. bolaui*, *O. beatrix*, *E.*

Table 3. Mean ± SE and range (in parentheses) values of edaphic parameters associated with the occurrence of earthworm species in the pasture

Earthworm species	Temperature (°C)	pH	Moisture (%)	Organic matter (%)	Bulk density (g cm^{-3})
Lampito mauritii	27.67 ± 0.13	5.48 ± 0.02	14.79 ± 0.26	1.13 ± 0.04	1.05 ± 0.01
	(24.9-30.3)	(5.05-6.1)	(9.75-20.04)	(0.46-1.86)	(0.94-1.25)
Metaphire houlleti	27.64 ± 0.13	5.46 ± 0.03	17.10 ± 0.38	1.31 ± 0.06	1.01 ± 0.01 `
	(26-29.3)	(5.11-5.78)	(12.1-22.07)	(0.43-2.38)	(0.94-1.13)
Kanchuria sp.	26.69 ± 0.14	5.36 ± 0.03	13.53 ± 0.38	1.02 ± 0.05	1.08 ± 0.01
	(24.9-28.8)	(5.05-5.89)	(8.13-19.58)	(0.46-1.96)	(0.93-1.15)
Dichogaster bolaui	26.1 ± 0.42	5.34 ± 0.11	13.09 ± 0.83	0.94 ± 0.14	1.10 ± 0.03
	(25.5-26.9)	(5.16-5.55)	(11.89-14.68)	(0.75-1.22)	(1.05-1.15)
Octochaetona beatrix	27.06 ± 0.18	5.38 ± 0.03	16.29 ± 0.65	1.46 ± 0.06	1.04 ± 0.01
	(25.5-28.2)	(5.12-5.75)	(10.69-22.07)	(0.99-2.02)	(0.95-1.22)
Eutyphoeus comillahnus	26.79 ± 0.16	5.35 ± 0.03	12.92 ± 0.36	0.97 ± 0.05	1.11 ± 0.01
	(25.5-28.6)	(5.04-5.85)	(8.58-16.74)	(0.43-1.55)	(1.01-1.22)
Eutyphoeus assamensis	27.45 ± 0.15	5.33 ± 0.02	15.05 ± 0.38	1.34 ± 0.08	1.03 ± 0.01
	(25.7-29.8)	(5.16-5.65)	(12.06-18.58)	(0.48-2.02)	(0.93-1.15)
Drawida assamensis	26.97 ± 0.12	5.38 ± 0.02	14.90 ± 0.32	1.21 ± 0.05	1.05 ± 0.01
	(24.9-29.2)	(5.04-5.8)	(8.58-20.49)	(0.43-2.02)	(0.93-1.22)
Drawida papillifer papillifer	27.44 ± 0.17	5.49 ± 0.03	15.22 ± 0.32	1.23 ± 0.05	1.02 ± 0.01
	(25.3-29.5)	(5.05-5.89)	(10.59-19.83)	(0.6-1.86)	(0.94-1.14)
Pontoscolex corethrurus	26.70 ± 0.12	5.41 ± 0.03	15.04 ± 0.32	1.14 ± 0.05	1.06 ± 0.01
	(25.3-28.3)	(5.04-5.91)	(9.79-21.86)	(0.43-1.86)	(0.95-1.25)
Glyphidrilus sp.	27.2	5.63	22.35	1.16	1.25

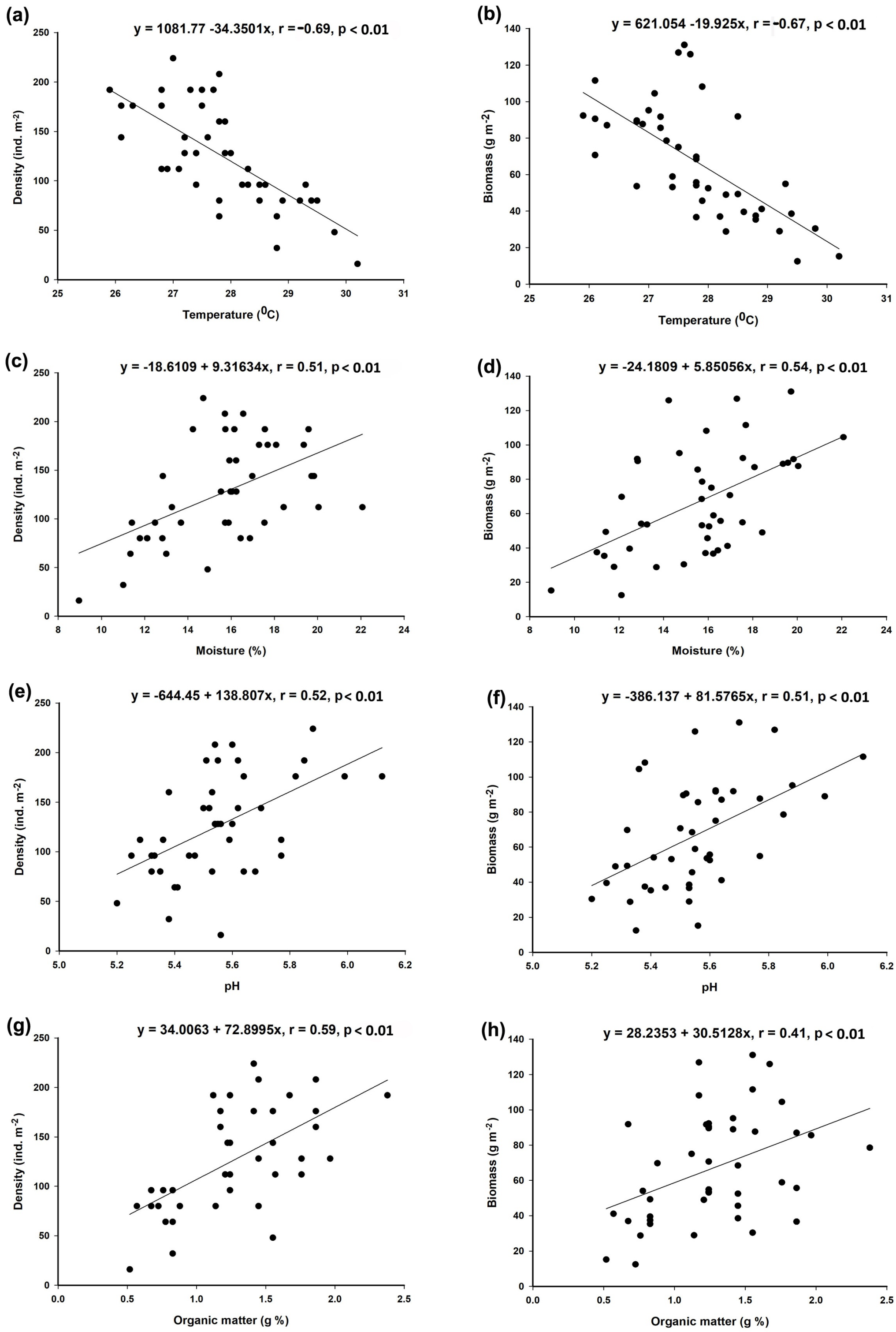

Figure 5. Overall relationship between (a) earthworm population density and soil temperature, (b) earthworm biomass and soil temperature, (c) earthworm population density and soil moisture, (d) earthworm biomass and soil moisture (e) earthworm density and pH, (f) earthworm biomass and pH, (g) earthworm population density and soil organic matter content, (h) earthworm biomass and soil organic matter content

comillahnus and *Glyphidrilus* sp. had a narrow level of tolerance (Table 3). In general, temperature and moisture in the soils of pastures had a significant negative and positive correlation ($P < 0.01$) respectively with overall population density and biomass of earthworms (Figure 5a-d). Earthworms exhibit a good positive correlation ($p < 0.01$) with pH and organic matter (Figure 5e-h).

DISCUSSION

According to Fragoso and Lavelle (1992), Edwards and Bohlen (1996) in most earthworm communities such as in tropical rain forests number of earthworm species range from 4 to 14. The occurrence of a minimum of 6 and maximum of 9 earthworm species (among a total of 11 species) are well within the reported range. In contrast to our present study, Dash and Patra (1977), Senapati and Dash (1981) reported the occurrence of 2 and 5 species of earthworms from a lowland pasture of Southern Orissa and upland pasture of Western Orissa respectively. Moreover, Senapati et al. (1979) reported a total of 9 species of earthworms in pasture soils from Orissa. Seven earthworm species have been recorded in grasslands of Western Uttar Pradesh by Singh and Prakash (2012). Out of a total of 11 species most of the earthworm species such as *P. corethrurus*, *Kanchuria* sp., *E. comillahnus*, *D. assamensis*, *D. papillifer papillifer*, *M. houlleti*, *L. mauritii* etc. have also been reported from soils of other habitats in Tripura such as in rubber (Chaudhuri et al. 2008), pineapple (Dey and Chaudhuri 2014), bamboo (Chakraborty and Chaudhuri 2017) and tea (Jamatia and Chaudhuri 2017). *Kanchuria* sp. and *E. comillahnus* are new reports from Tripura. Earthworm species from pasture ecosystem in the present study such as, *M. houlleti, Drawida* sp., *Eutyphoeus* sp., have also been reported from agroforestry system of Mizoram (Lalthanzara et al. 2011), *L. mauritii, P. corethrurus, Drawida* sp. *Glyphidrilus* sp. from agroforestry, nursery stalk, cow dung, grassland and subtropical forests etc. of Assam (Rajkhowa et al. 2014), *Eutyphoeus* sp., *P. corethrurus*, *Drawida* sp., *Kanchuria* sp., *D. bolaui* and *M. houlleti* from sub-tropical forest ecosystems of Manipur (Haokip and Singh 2017). In fact, the presence of different weeds, herbs with heavy rainfall in Tripura provided a conducive habitat for a diverse earthworm community under pasture ecosystem. Difference between the earthworm communities at different localities indicates the importance of environmental heterogeneity (β-diversity) for earthworm diversity in the pastures.

L. mauritii is the eudominant species with respect to its density, relative abundance and frequency in pasture ecosystems. Sahu and Sahu (2007) reported *L. mauritii* as dominant species in the grasslands of Jyoti Vihar, Orissa. The dominance of *L. mauritii* in the pasture ecosystem is probably due to its greater polytrophic adaptation and greater tolerance to changing microhabitats (Kale and Krishnamoorthy 1978). Earthworms such as *L. mauritii* not only feed on dead organic matter but also on the pedofauna such as the nematodes (Dash et al. 1980). Abundance of soil nematodes in pasture soils is a probable factor for the dominance of *L. mauritii* in the studied habitat (Lavelle and Spain 2001). Moreover grasses with their roots in pasture provide an ideal food base for earthworms and *L. mauritii* usually preferred decomposing grasses compared to other leaf litters (Kale and Karmegam 2010). The higher density of anecic earthworms in pasture soils was due to the occurrence of anecic *L. mauritii* in a greater number, which constituted 34.14% of the earthworms relative density. Earlier Jimenez et al. (1998) also reported occurrence of 87.9% anecic earthworm species in the pasture soils of Carimagua. Interestingly, *L. mauritii* had a shared dominance with *D. assamensis* and *P. corethrurus*. A similar type of shared dominance among *P. corethrurus*, *Kanchuria* sp., *M. houlleti*, *D. assamensis* and *D. papillifer papillifer* in mixed forest plantation was reported by Chaudhuri and Nath (2011). Sharing of the same habitat is quite common among earthworm species (Edwards and Bohlen 1996). The lesser abundance of *Glyphidrilus* sp. was due to its presence in a single quadrat during earthworm sampling in the pasture soils of Ujan Abhoynagar area, which had a neighbouring small wetland from which the species had probably migrated. According to Chanabun et al. (2013) *Glyphidrilus* sp. is a semi-aquatic earthworm generally inhabiting wetlands, paddy etc.

Out of 11 earthworm species, 3 species such as *M. houlleti*, *P. corethrurus* and *D. bolaui* were exotic and the rests native to India. The existence of exotic species in the pasture soils was due to moderate cattle grazing. Coexistence of native species along with exotic earthworms indicates that native earthworms are more resistant to disturbance and can coexist with the exotic earthworms in North east India (Jamatia and Chaudhuri 2017).

In pastures, the roots of grasses form a layer which provides protection against drought, erosion, which supports earthworm abundance (Martinez et al. 2006). The density values of earthworms in pastures of Tripura are comparable to that of grasslands of Orissa with 64-800 ind. m^{-2} (Dash and Patra 1977), grazed upland pasture with 75-272 ind. m^{-2} (Senapati and Dash 1981), rubber plantation with 108.56 ind. m^{-2} (Chaudhuri et al. 2008), pineapple plantation with 158.66 ind. m^{-2} (Dey and Chaudhuri 2014), bamboo plantation with 108.02 ind. m^{-2} (Chakraborty and Chaudhuri 2017), much lesser than plain grassland with 322 ind. m^{-2} (Krishnamoorthy 1985), tea plantation with 212.75 ind. m^{-2} (Jamatia and Chaudhuri 2017) and much higher than that of pine forest with 65 ind. m^{-2} (Bhadauria et al. 2000).

Species diversity of earthworms in tropical rain forests ranges from 1.7 to 6.5 (Fragoso and Lavelle 1992). Shannon diversity index with a value of 1.51 in pasture soils is little less than that of tropical rain forests. However, diversity index of earthworms in the pasture is much higher than those of monoculture plantations such as in rubber 0.86 (Chaudhuri and Nath 2011), pineapple 0.67 (Dey and Chaudhuri 2014), bamboo 1.00 (Chakraborty and Chaudhuri 2017) and tea 0.72 (Jamatia and Chaudhuri 2017). According to Decaens et al. (2004), Tripathi and Panwar (2012) pastures in tropical and subtropical areas experience moderate disturbance and the roots of grasses retained higher content of organic matter which results in higher earthworm diversity. Dominance index observed during the study is less due to sharing of dominance by *L. mauritii, D. assamensis* and *P. corethrurus* in the studied sites. Senapati and Dash (1981) also reported lower dominance of earthworm species in an upland grazed pasture. Lower species richness value in our present study supports Baker et al. (1992) and Blanchart and Julka (1997), who also reported low species richness in pastures. Absence of canopy, direct exposure to sunlight and low relative abundance of earthworm species (except *L. mauritii*) were the probable reasons for low species richness in pasture soils.

A variety of environmental factors such as soil moisture, pH, temperature, organic matter determine the distribution and abundance of earthworms (Lavelle 1983). Exotic species *P. corethrurus* and native *L. mauritii*, *D. assamensis*, *D. papillifer papillifer* are adapted to a wide range of ecological tolerance and can be recognized as euryoecius species. In contrast, *D. bolaui*, *O. beatrix*, *E. comillahnus* and *Glyphidrilus* sp. are considered as stenoecius due to their narrow tolerance level to soil ecological parameters. Significant correlations observed between earthworm density and biomass with soil properties indicates that temperature, pH, soil moisture and organic matter control the distribution of earthworms in the soil (Edwards and Bohlen 1996). Temperature and moisture are inversely related and high soil temperature and dry soils are much more limiting to earthworm distribution than low temperature and water logged soils (Nordstrom and Rundgren 1974). Earthworms body contains 75-90% of water and in adverse soil moisture conditions they move to a suitable area with optimum moisture to maintain their hydrostatic pressure (Edwards and Bohlen 1996). Moisture in the soils of pastures had a significant positive correlation ($p<0.01$) with the overall population density and biomass of earthworms. Fecundity of animals is largely influenced by difference in temperature (Edwards and Bohlen 1996). Soil temperature in pastures had a significant negative correlation ($p<0.01$) with density and biomass. Tropical earthworm species can withstand higher temperatures than in the temperate conditions (Ismail and Murthy 1985). Earthworms in pastures are exposed to the sunlight throughout the day as pasture ecosystem is totally devoid of tree canopy which limits their distribution. The negative correlation between earthworm population and temperature were also recorded by Dey and Chaudhuri (2014), Chakraborty and Chaudhuri (2017), Jamatia and Chaudhuri (2017) in pineapple, bamboo and tea plantations respectively in Tripura. Earthworms in general are neutrophilic in nature (Lee 1985). Accordingly earthworm population had a significant positive correlation ($p < 0.01$) with pH in the acidic soils of pasture. Senapati et al. (1979) reported a positive correlation between earthworm biomass and soil pH in the pastures of Sambalpur, Orissa. Interestingly, Nath and Chaudhuri (2010) observed a significant negative correlation between *P. corethrurus* and soil pH in the acidic soils of rubber plantations in Tripura. In fact, soil pH is related to factors like clay content, cation exchange capacity which also influences earthworm population, so it is difficult to establish a direct cause and relationship between soil pH and earthworm population (Edwards and Bohlen 1996). Earthworms exhibited a positive correlation with organic matter because organic matter constitutes the source of food for earthworms and soils with low organic matter do not support earthworm population (Edwards and Bohlen 1996). This supports several earlier studies like those of Senapati et al. (1979), Bhadauria and Ramakrishnan (1991), Ganihar (1996) and Joshi et al. (2010).

CONCLUSION

Pastures are lands with heterogeneous system of grasses. In our present study out of 11 earthworm species phytogeophagous *L. mauritii* dominate (eudominant) the soils of pasture on the basis of their relative abundance and shared the land resources with 2 more dominant earthworms, *D. assamensis* and *P. corethrurus*, rests were less abundant. Presence of good number of native species along with a few exotics indicates their ability to coexist with exotics in North east India. Pasture was characterized by low dominance and even distribution of earthworm species and represents diversity value of 1.51.

ACKNOWLEDGEMENTS

We express our sincere thanks to Dr. R. Paliwal, Zoological Survey of India, Solan, for identification of some earthworm species. The first author did the field survey, collected the data and performed statistical analysis after compilation of data. The second author supervised the research work and helped prepare the manuscript.

CONFLICT OF INTEREST: We declare no conflict of interest of any type for this work.

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Received 27 February 2019
Accepted 8 May 2019