

**Original Research**

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# Earthworm community structure and population dynamics at Minkong forest of Mokokchung, Nagaland, India

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**Abstract**

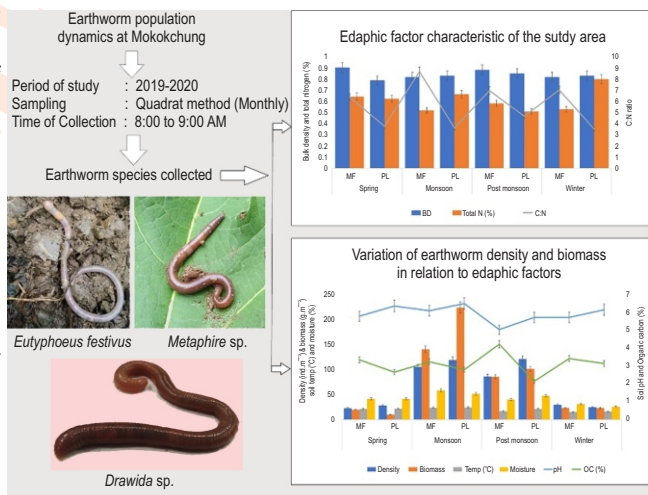
**Aim:** The present study was undertaken to assess the seasonal variations of density, biomass and community characteristics of earthworms in two different types of forest at Minkong area, Mokokchung.

**Methodology:** The survey was conducted during the period from January 2019-February 2020 in two areas viz., mixed forest and plantation. Standard methods were followed to determine the ecological categories of earthworms, density and biomass, relative abundance and species richness as well as for determination of different soil parameters viz., pH, moisture, bulk density, organic carbon, total and available nitrogen, available phosphorus and potassium.

**Results:** 12 number earthworm species viz., *Amyntas corticis* (Kinberg), *Amyntus gracilis* (Kinberg), *Drawida assamensis* (Gates), *Drawida hodgarti* (Stephenson), *Drawida nepalensis* (Michaelson), *Drawida sp.*, *Eutyphoeus assamensis* (Stephenson), *Eutyphoeus festivus* (Gates) *Metaphire houlleti* (Perrier), *Perionyx excavatus* (Perrier), *Perionyx simlaensis* (Michaelson) and *Pontoscolex corethurus* (Müller) were recorded. Dominant earthworm species in both the areas were *D. nepalensis*, *P. excavatus*, *Drawida sp.* and *E. festivus*. The Shannon diversity, Simpson diversity and Pielou's species evenness were 2.17, 0.87 and 0.87 in mixed forest and 2.05, 0.86, 0.86 in plantation. The earthworm density and biomass were greater in plantation (276.74 ind m<sup>-2</sup> and 338.47g m<sup>-2</sup>) compared to mixed forest (230.52 ind m<sup>-2</sup> and 254.55 g m<sup>-2</sup>).

**Interpretation:** As earthworm community characteristics differ depending on the type of forest, therefore, earthworm's diversity and its indices can be used as an ecological indicator of anthropogenic disturbances and can help designing conservation programs for reclaiming the depleted areas.

**Key words:** Biomass, Earthworm diversity, Minkong, Relative abundance, Subtropical ecosystem



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## Introduction

Earthworms constitute about 80% of the total soil invertebrate's biomass in temperate, tropical and sub-tropical ecosystem; and are known to play an important role in sustaining ground biodiversity (Fragoso and Lavelle, 1992). Earthworm's role in litter degradation, nutrient cycling and improvement of physico-chemical properties of soil such as structure, density, porosity and moisture has also been extensively studied (Carey *et al.*, 2009; Zhi-Wei *et al.*, 2019; Tamartash and Ehsani, 2021). Earthworms are sensitive to habitat change and in recent times, mass destruction of forest for intense agriculture management and other anthropogenic activities has detrimentally affected the earthworm diversity (Singh *et al.*, 2020). Even under similar climatic condition, earthworm community structure and distribution pattern depend on land use system, plant species composition and availability of organic matter (Gonzalez *et al.*, 1999; Bhaudaria *et al.*, 2000; Chaudhuri and Nath, 2011).

Earthworm feeding behaviour and burrowing activities plays an essential role in changing the soil nutrient conversion, organic carbon stabilisation, and bulk density of soil (Blouin *et al.*, 2013). Earthworms are also known for enhanced decomposition by facilitating microorganism such as fungi and bacteria and increasing nutrient availability to plants (Blouin *et al.*, 2013; Castro *et al.*, 2019). Due to its stabilizing effect on the soil ecosystem, considerable attention is given to studies on population dynamics, diversity, distribution and community structures of earthworm (Cardinael *et al.*, 2019; Mcinga *et al.*, 2021; Cameron *et al.*, 2021, Cremonesi *et al.*, 2021). While a few reports are available on different aspects of earthworm studies from different climatic zone of North Eastern India like Tripura (Chakraborty *et al.*, 2020), Assam (Tiwari *et al.*, 2020), Manipur (Singh *et al.*, 2020) and Mizoram (Lalthanzara and Zodinpuii, 2021), information on earthworm in Nagaland is very scanty (Thyug and Kakati, 2018). Hence, the present study was undertaken to understand the seasonal variation of earthworm population dynamics and community characteristics in two different forest types (plantation and mixed forest) in Mokokchung, Nagaland.

## Materials and Methods

**Study sites:** The present study was carried out from January, 2019 till February, 2020 at Minkong forest, Nagaland during spring, monsoon, post monsoon and winter season of the year. The two study sites viz., mixed forest and plantation lying at an altitude of 1325 m above sea level are characterised by gentle to steep slopes. The most common tree species mixed forest are *Atrocarpus chaplasha* Roxb., *Ficus semicordata* Buch. ex J.E. Smith, *Schima wallichii* (DC.) Korth., *Trema orientalis* (L.) Bl. etc., while, plantation area is a mono plantation of *Daubanga grandiflora* (Roxb. ex DC.) Walp. The ground surface of the plantation area is cleared about 3 times a year, while mixed forest remains fairly undisturbed. The climate is monsoonal with warm moist summer and cool dry winter, and receives an average annual rainfall of 1001.6 mm. Minimum monthly rainfall occurs in

January (22.5mm) and maximum in July (203mm). The month of March and October are the transitional months between winter and summer, and rainy and winter season, respectively. The mean maximum air temperature varied from 25.64°C (January) to 30.8°C (May) and the mean minimum air temperature varied from 5.68°C (January) to 23.03°C (July). The maximum relative humidity (83.21%) was recorded in the month of August.

**Sampling of earthworm and soil analysis:** Each site was divided into 3 equal plots according to the elevation. A grid of 9 sub-plots (5m×5m) size each were randomly demarcated from three plots (3 in each plot). Earthworm samplings were done by digging 27 (25×25×30 cm<sup>3</sup>) soil monoliths randomly selected from each site (3 from each 9 different sub plots). A total of 54 quadrates were sampled from both study area. Earthworm samples were collected at monthly intervals from 8:00 to 9:00 a.m., after which they were washed, dried (with the help of blotting paper) and weighed immediately for biomass estimation. Specimen's maturity was determined based on the presence/absence of clitellum. Ecological categories of earthworms were studied following Hendrix and Bohlen (2002). Earthworms were separated into different age categories based on the clitellum development viz., juveniles (weight ≤ 20 mg), young (>20 mg but without distinct clitellum) and adults (distinct clitellum). Earthworm density and biomass were expressed in terms of population density (individual m<sup>-2</sup>) and of biomass (fresh weight g m<sup>-2</sup>).

Earthworm communities were analyzed using the data on relative abundance, index of dominance (Engelmann, 1973), Species richness index (Menhinick, 1964), index of general diversity (Shannon and Weiner, 1963), and Simpson diversity (Simpson, 1949). From each experiment sites, composite soil samples to a depth of 15 cm were collected at monthly intervals and the average soil temperature was recorded *in situ*. Soil moisture and pH was determined in fresh soil samples. Soil bulk density was determined by bottle weighing method (Pawar *et al.*, 2009). Soil samples were air dried, ground and passed through a 1 mm mesh size sieve and used for subsequent chemical analysis viz., organic carbon (Walkley and Black, 1934), total and available nitrogen by mircoKjeldahl method (Kjeldahl, 1883) using kel plus nitrogen estimation system, available phosphorus (Bray and Kurtz, 1945) and available potassium was estimated by ammonium acetate method (Hanway and Heidel, 1952).

**Statistical analyses:** The mean differences of earthworm density, biomass and other soil parameters was tested using independent sample t-test. One-way ANOVA (P<0.05) followed by Post hoc tukey test was performed to determine significant difference in seasonal variations of earthworm density and biomass. All data were analysed using SPSS (Version 22).

## Results and Discussion

A total of 389 and 467 individuals of earthworm were sampled from mixed forest and plantation area, respectively. Twelve number of earthworm species viz., *Amyntas corticis*

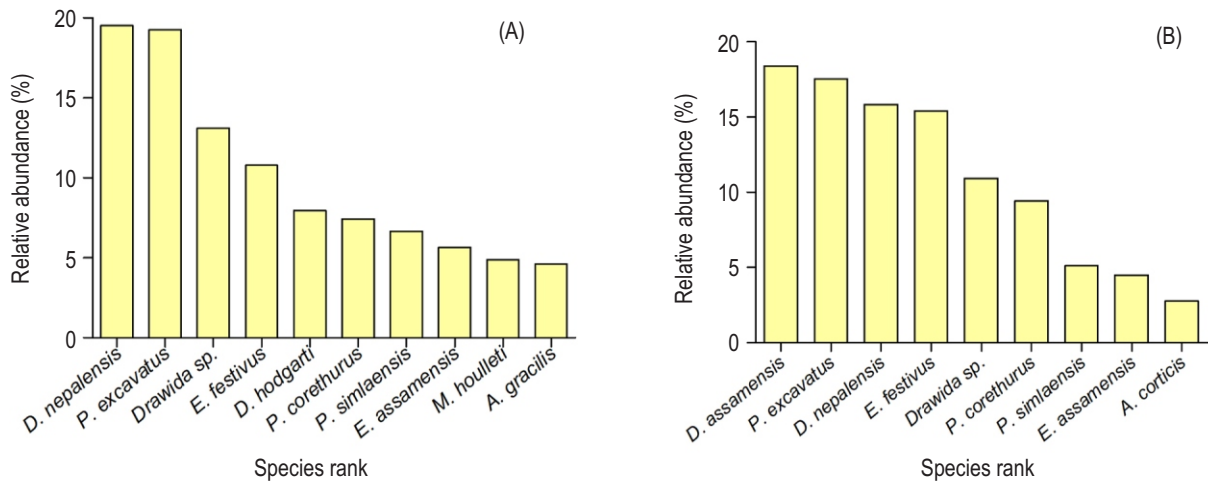


Fig. 1: Relative abundance of earthworm species in two study sites: (A) mixed forest and (B) plantation.

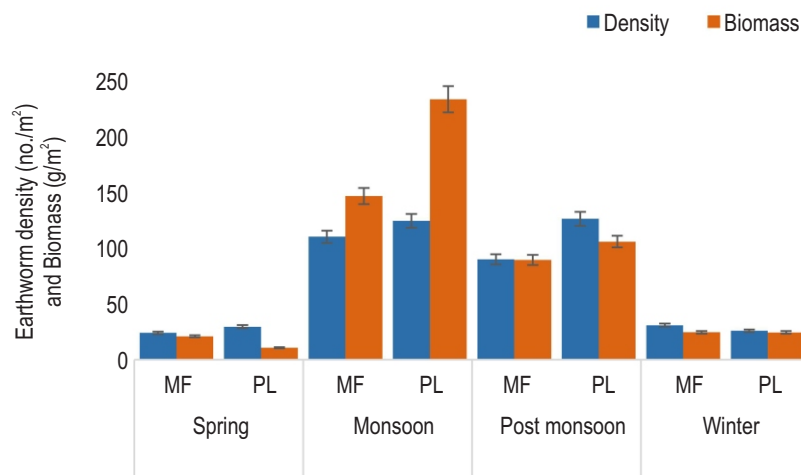


Fig. 2: Variations of earthworm density and biomass during four major seasons in two study sites (MF- mixed forest; PL- plantation).

(Kinberg), *Amyntus gracilis* (Kinberg), *Drawida assamensis* (Gates), *Drawida hodgarti* (Stephenson), *Drawida nepalensis* (Michaelsen), *Drawida sp.*, *Eutyphoeus assamensis* (Stephenson), *Eutyphoeus festivus* (Gates) *Metaphire houlleti* (Perrier), *Perionyx excavatus* (Perrier), *Perionyx simlaensis* (Michaelsen) and *Pontoscolex corethurus* (Müller) were recorded from two study sites. Out of 12 species, 5 species (*A. corticis*, *A. gracilis*, *M. houlleti*, *P. excavatus* and *P. simlaensis*) belong to family Megascolecidae, 4 species (*Drawida sp.*, *D. assamensis*, *D. hodgarti*, *D. nepalensis*) from Moniligastridae, 2 species (*E. assamensis*, *E. festivus*) from Octochaetidae and 1 species (*P. corethurus*) from Glossoscolecidae (Table 1).

Relative abundance pattern of earthworm species in the mixed forest was in the following order: *D. nepalensis* > *P.*

*excavatus* > *Drawida sp.* > *E. festivus* > *D. hodgarti* > *P. corethurus* > *P. simlaensis* > *E. assamensis* > *M. houlleti* > *A. gracilis* however, at plantation site it was in the order: *D. assamensis* > *P. excavatus* > *D. nepalensis* > *E. festivus* > *Drawida sp.* > *P. corethurus* > *P. simlaensis* > *E. assamensis* > *A. corticis*. The similarity index was 73% between the two study sites, which could be due to similar physico-chemical properties of the soil. The soil pH ranged from 4.75-5.55 in mixed forest and 5.4-6.13 in plantation area, respectively (Table 2). In the study sites, the maximum temperature and moisture were recorded during monsoon season, followed by spring, post monsoon and winter season. Moisture is an important factor for earthworm distribution, the higher population density and dominance of certain endogeic earthworm species viz., *D. assamensis* and *D. nepalensis* in the plantation area may be due to retention of sufficient amount of

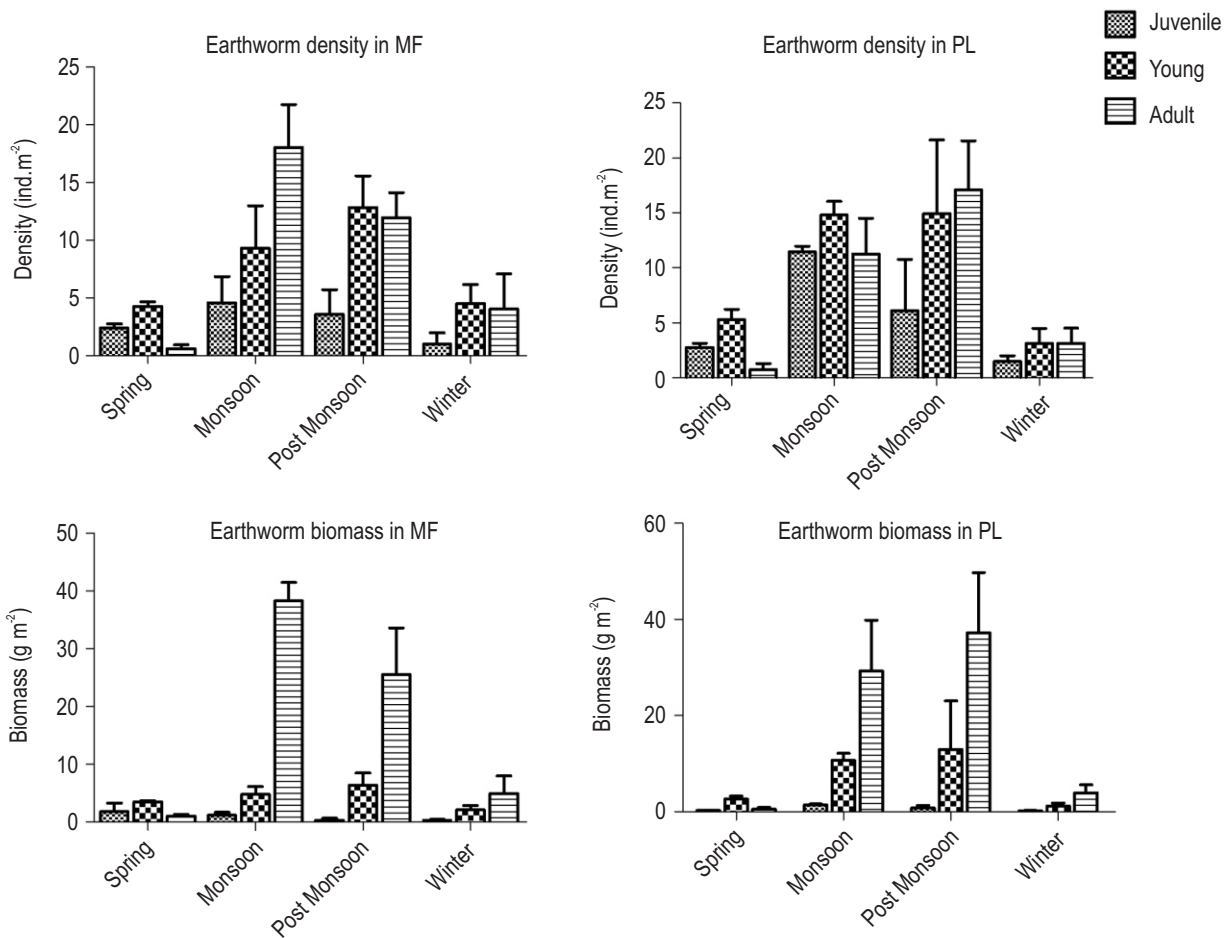
Table 1: Earthworm population characteristics and dominance in two different types of forest at Minkong area, Mokokchung

Species name	Mixed forest							Plantation						
	Density (ind.m <sup>-2</sup> ) (± SE)	RA (%)	Dominance	Ecological category	Evenness	Shannon Diversity (H')	Simpson Diversity (D)	Density (ind.m <sup>-2</sup> ) (± SE)	RA (%)	Dominance	Ecological category	Evenness	Shannon Diversity (H')	Simpson Diversity (D)
<i>Pontoscolex corethurus</i>	17.18±0.54	7.45	Sub Dominant	Endogeic				26.07±0.92	9.42	Sub Dominant	Endogeic			
<i>Amyntas corticis</i>	-	-	-	-	-	-	-	7.70±0.34	2.78	Recedent	Epianecic			
<i>Amyntas gracilis</i>	10.66±0.49	4.62	Sub Dominant	Epianecic			-	-	-	-	-			
<i>Metaphire houlleti</i>	11.25±0.63	4.88	Sub Dominant	Epianecic			-	-	-	-	-			
<i>Perionyx excavatus</i>	44.44±1.78	19.28	Dominant	Epigeic	0.87	2.17	0.87	48.59±1.37	17.55	Dominant	Epigeic	0.86	2.05	0.86
<i>Perionyx simlaensis</i>	15.40±0.74	6.68	Sub Dominant	Epigeic				14.22±1.04	5.13	Sub Dominant	Epigeic			
<i>Drawida hodgarti</i>	18.37±0.65	7.96	Sub Dominant	Endogeic				-	-	-	-			
<i>Drawida nepalensis</i>	45.03±1.13	19.53	Dominant	Endogeic				43.85±1.26	15.84	Dominant	Endogeic			
<i>Drawida assamensis</i>	-	-	-	-	-	-	-	50.96±0.98	18.41	Dominant	Endogeic			
<i>Drawida sp.</i>	30.22±1.43	13.11	Dominant	Endogeic				30.22±0.87	10.92	Dominant	Endogeic			
<i>Eutyphoeus festivus</i>	24.88±1.09	10.79	Dominant	Endogeic				42.66±0.88	4.49	Sub Dominant	Endogeic			
<i>Eutyphoeus assamensis</i>	13.03±0.54	5.69	Sub Dominant	Endogeic				12.44±0.51	15.41	Dominant	Endogeic			

Table 2: Soil physico-chemical characteristics from two different types of forest at Minkong area, Mokokchung

Habitat	Seasons	Temp (°C)	Moisture (%)	Bulk density	pH	OC (%)	Av. N (kg ha <sup>-1</sup> )	Total Nitrogen%	P (mg kg <sup>-1</sup> )	K (mg kg <sup>-1</sup> )
Mixed forest	Spring	20.06±0.90	39.32±12.8	0.87±0.015	5.46±0.3	1.65±0.42	154.7±65.48	0.62±0.12	19.6±4.78	151±7
	Monsoon	22.63±1.7	50.09±5.59	0.79±0.06	5.75±0.32	2.02±2.2	146.34±68.4	0.50±0.25	21.8±8.53	163±3.6
	Post monsoon	16.02±0.26	36.65±3.77	0.85±0.06	4.75±0.07	0.69±0.007	188.1±28.3	0.56±0.14	8.68±0.18	162.66±13.5
	Winter	14.42±2.55	28.23±2.54	0.79±0.04	5.4±0.26	0.15±0.04	190.6±39.02	0.51±0.06	28.3±8.1	149.33±7.57
	P value	0.012*	0.0033*	NS	0.013*	NS	NS	0.0002***	NS	NS
Plantation	spring	20.73±0.98	41.78±5.38	0.76±0.03	6±0.34	2.51±0.55	156.4±32.65	0.6±0.15	68.72±8.37	149±4.35
	Monsoon	22.98±1.8	51.48±3.07	0.8±0.07	6.13±0.85	2.64±0.55	148.7±18.01	0.64±0.06	37.57±6.67	144.33±11.5
	Post monsoon	20.35±2.68	40.37±8.71	0.82±0.02	5.4±0.42	2.02±1.37	156.3±23.77	0.49±0.05	27.09±0.54	147.66±7.37
	Winter	15.39±1.44	29.7±6.64	0.8±0.1	5.8±0.26	2.96±1.60	189.3±25.12	0.77±0.14	32.84±6.59	140.33±22.47
	P value	0.014*	0.002**	0.036*	NS	NS	NS	0.019*	NS	NS

\*\* indicates statistically high significant difference, \* indicates statistically significant difference



**Fig. 3:** Density and biomass of earthworm age category (juvenile, young and adult) in mixed forest and plantation. The figure indicates that density and biomass peak during monsoon and post monsoons seasons. MF- mixed forest, PL- plantation.

moisture at lower soil depth (10-20cm) to uphold the maximum earthworm density (Sarlo, 2006). Because the two study sites fall under same climatic conditions, soil moisture and temperature ( $P>0.05$ ) did not differ significantly. Also, no significant differences were noted with bulk density, available phosphorus, available potassium and total nitrogen ( $P>0.05$ ) between the two sites. Available phosphorus varied significantly ( $P>0.05$ ) among the seasons in both the study area, while available potassium did not differ significantly ( $P>0.05$ ) among the seasons and remained fairly constant. However, organic carbon in mixed forest (3.61%) was significantly higher than plantation area (2.62%).

Earthworm distribution and density are known to be affected by soil organic carbon (Jänsch *et al.*, 2013). In the present study, organic carbon was significantly ( $P<0.05$ ) higher in mixed forest as compared to plantation, thereby showing a higher abundance of earthworm (Fig.1). Bartz *et al.* (2013) and Jänsch *et al.* (2013) also observed a significant relationship between soil organ carbon and earthworm abundance. The leaf litter decomposition was found to build up the organic matter leading to

higher density of earthworms. The maximum density of earthworms was contributed by *D. nepalensis* ( $45.03 \text{ ind.m}^{-2}$ ) and *D. assamensis* ( $50.96 \text{ ind m}^{-2}$ ) in mixed forest and plantation area, respectively. Earthworm biomass was higher in plantation ( $338.47 \text{ g.m}^{-2}$ ) compared to mixed forest ( $254.55 \text{ g m}^{-2}$ ). However, no significant mean difference ( $P>0.05$ ) was observed. Seasonally, earthworm density varied from  $21.67 \text{ ind.m}^{-2}$  (spring) to  $99.69 \text{ ind.m}^{-2}$  (monsoon) in mixed forest site, while in plantation area it ranged from  $23.32 \text{ ind.m}^{-2}$  (winter) to  $114.25 \text{ ind.m}^{-2}$  (post-monsoon). In both the study sites maximum biomass was recorded during monsoon season ( $132.69 \text{ g.m}^{-2}$  and  $211.19 \text{ g.m}^{-2}$ ) followed by post monsoon and winter with the least during spring season. However, in plantation site, while biomass had shown similar pattern, the density of earthworm was recorded slightly higher during spring than winter season (Fig. 2).

The earthworm density and biomass exhibited a significant positive correlation with soil temperature and moisture both study sites. The increased density and biomass of earthworm in the monsoon season might be due to fast litter

decomposition, easy availability of food and shelter that protects them from other predators (Potapov *et al.*, 2021). With the arrival of monsoon, adult population increased significantly at both the study sites. It was observed that clitellate and non-clitellate density increased alternatively. While young population density in mixed forest remained fairly constant with significant increase ( $P < 0.05$ ) along the monsoon season ( $49.75 \text{ ind.m}^{-2}$ ), in plantation area all age category (juvenile, young and adult) showed significant variation with highest density recorded during monsoon (juvenile =  $34.36 \text{ ind.m}^{-2}$ , young =  $44.43 \text{ ind.m}^{-2}$  and adult =  $33.77 \text{ ind.m}^{-2}$ ) (Fig. 3). No significant differences were observed in biomass and density among different age category (juvenile, young and adult) during winter and spring seasons. With increasing moisture and temperature, density of juvenile, young and adult showed an increasing pattern. Generally, monsoon season with optimum temperature acts as a cue for neurosecretion favouring cocoon production and higher breeding rate of earthworm (Bhattacharjee and Chaudhuri, 2002).

In mixed forest, regional seasons, earthworm age category and interaction of two independent factor have significant effect on earthworm density and biomass (Table 2). In plantation area, regional seasons showed significant effect on density and biomass. However, age category and interaction of independent factors (seasons and age category) showed no effect on earthworm density and biomass. Most of the recorded species are endemic to Indian region, except *P. corethurus* which are mostly found in human inhabited area (Grosso *et al.*, 2006). Even though the land use system is different, both the study sites exhibited high percentage of species similarity as the sites are not being spatially apart from each other. As the endogeic earthworms are least affected by disturbance (Mariotte *et al.*, 2016), comparatively higher abundance of this group was exhibited in plantation area (Singh *et al.*, 2020). Coexistence of both exotic (*P. corethurus*) and native species (such as *D. nepalensis* and *P. excavatus*) in two distinct habitats indicates the unique characteristics of biodiversity hotspot zone (Dey and Chaudhuri, 2016). Higher rainfall along with favorable relative humidity might result in higher population density and biomass of earthworm during monsoon season in comparison to winter and spring season rainfall (Joshi and Aga, 2009). Chaudhuri *et al.* (2009) also observed that earthworm remained active for about 6 months (May to October) and is predominantly found during monsoon season in subtropical forest in North-eastern states of India. The pre-monsoon showers during spring coupled with good retention of moisture in the area resulted in increase of earthworm population density which continued up to the monsoon season.

High percentage of soil moisture and organic carbon had influenced the dominance and abundance of *P. excavatus* in mixed forest and plantation sites. Similar findings have been reported from different forest ecosystems in Mizoram (Lalthanzara and Ramanujam, 2014). Good canopy cover in mixed forest provides suitable range of moisture and temperature for the sustenance of earthworms, as tree diversity and earthworm diversity are found to have a positive relation (Cesarz

*et al.*, 2007). The high diversity in mixed forest is attributed to less anthropogenic activities and greater habitat heterogeneity whereas the lesser number of earthworm species in plantation area could be due to homogeneity of ecological niche and less canopy cover (Dey and Chaudhuri, 2014). Earthworm population density negatively correlates with species diversity (Shakir and Dindal, 1997). In plantation area higher density with more dominant species was associated with lower species diversity. It was observed that, earthworm density and biomass begin to increase with the arrival of spring until the post-monsoon season. As shown by a dramatic increase in the number of juveniles, young, and adult populations; earthworm populations are heavily reliant on soil moisture, temperature, and organic carbon. Low earthworm density and biomass was seen during dry season, which coincided with a drop in soil moisture and a drop in temperature. The difference in earthworm distribution between the two study locations also suggests that habitat variability creates a larger niche for the lower macro invertebrate.

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### Add-on Information

**Authors' contribution:** L. Jing: Experimentation, writing, review, data analysis; L. Mozhui: Data analysis, writing, review, editing; L.N. Kakati: Conceptualization, supervision, writing, review, editing; L. Thyug: Writing, review, editing.

**Research content:** The research content of manuscript is original and has not been published elsewhere.

**Ethical approval:** Not applicable.

**Conflict of interest:** The authors declare that there is no competing interest.

**Data from other sources:** Not applicable.

**Consent to publish:** All authors agree to publish the paper in *Journal of Environmental Biology*.

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