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Earthworm diversity, density and distribution under shifting (Jhum) cultivation in a tropical hilly terrain of Mizoram, North East India

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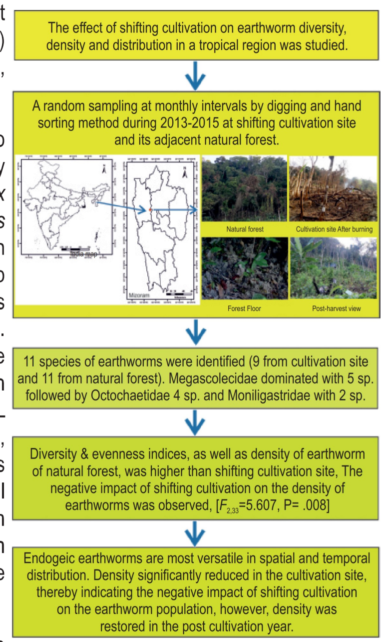
Abstract

Aim : To investigate the earthworm community and its interaction with traditional shifting cultivation to find the effect of traditional shifting cultivation on diversity, density and distribution of earthworms.

Methodology : Earthworm was sampled from five random sites located at least 20 m apart at monthly intervals by digging and hand sorting method during January 2013 to October 2015 in an experimental plot of one acre of natural forest, demarcated into natural forest (control, CTRL) and traditional shifting (slash and burn) cultivation site (Experimental, EXPTL) at Khawrihnim, Mizoram, North-east India.

Results : A total of 11 species of earthworms belonging to five genera under three families were recorded. Family Megascolecidae dominates with five species (*Perionyx excavatus, P. macintoshi, Metaphire houlleti, Amynthas alexandri and A. cortices*) followed by Octochaetidae with four species (*Eutyphoeus gigas, E. assamensis* and two unidentified species) and Moniligastridae with two species (*Drawida nepalensis and* one unidentified *Drawida sp.*). Diversity and evenness indices of earthworm at CTRL were higher as compared to EXPTL site. Earthworm density in CTRL (1353.6 ind.m^{-2}) was significantly higher than EXPTL (857.6 ind.m^{-2}) site [t = 2.039, df = 66, P= .045]. Thus, negative impact of shifting cultivation on earthworms density was observed [$F_{2,33}$= 5.607, P= .008]. Vertical distribution showed significant (P > .05) decrease in earthworm population with an increase in soil depth in both CTRL and EXPTL sites. The endogeic *Drawida* sp. was the most versatile earthworm in temporal distribution.



Interpretation : The study clearly indicates that the land use system in the form of traditional shifting cultivation adversely affects earthworm density and diversity. The destructive effect of shifting cultivation on earthworm is mainly attributed to habitat disturbances, reduced food availability and changes in soil physico – chemical properties. However, the spatial distribution pattern of an earthworm is not significantly affected by shifting cultivation. The temporal distribution followed a general pattern where there is a rapid population increase of earthworm after the onset of the rainy season.

Key words: Diversity, Earthworms, Endogeic, Shifting cultivation

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Introduction

Earthworms are the most prominent group of soil macrofauna in temperate as well as tropical soils. They draw a lot of attention for their beneficial effects particularly relevant in the field of agriculture. Earthworm's feeding behavior, burrowing and casting is vital in nutrient cycling, decomposition and humification of organic matter by fragmentation and incorporation of litter into the soil (Dechaine *et al.,* 2005). Thus, in agricultural ecosystems, the loss in earthworm biodiversity may negatively affect the soil functioning (Ernst and Emmerling, 2009). Majority of human population in Mizoram rely on the traditional farming system- shifting cultivation. Even though burning temporarily increases the availability of soil nutrients by means of rapid mineralization, addition of nutrient-rich ash and changes in soil pH, burning can also lead to long-term nutrient losses due to increased erosion and leaching, in addition to volatile losses during combustion (Sommer *et al.,* 2004).

Earthworm diversity is mainly influenced by soil nutrients and rainfall patterns (Fragoso and Lavelle, 1995). Therefore, changes in soil properties may eliminate certain earthworm population and induce the establishment of new ones (Smetak *et al.,* 2007). More than 4400 distinct species of earthworms have been identified so far (Sinha, 2009). Comprehensive information on the diversity and composition of earthworms with reference to different land use systems and modification of natural habitat is available from the previous reports (Decaëns and Jiménez, 2002; Dlamini and Haynes, 2004; Haynes *et al.,* 2003; Smith *et al.,* 2008; Tondoh *et al.,* 2011). India is one of the richest areas for tropical earthworms with the presence of 590 species of earthworms (Julka *et al.,* 2009). Despite the fact that considerable amount of research has been carried out on earthworm ecology, only sporadic reports on earthworm diversity and population structure with respect to different land use systems are available from the country, including that of Blanchart and Julka (1997) from Karnataka.

Knowledge on earthworm community structure in relation to different land use systems in North-east India has been enriched by the contributions of Chaudhuri and Nath (2011), Dey and Chaudhuri (2014), Jamatia and Chaudhuri (2017). In the context of Mizoram, Ramanujam *et al.* (2004) reported 11 species of earthworm belonging to 4 families from Mizoram. Research in this field is relevant because total inventory is far from completion with discovery of new species, *Eutyphoeus mizoramensis* by Julka *et al.* (2005) from this locality. Although extensive literature is available on the ecology of earthworms in both temperate and tropical regions, only scanty reports are available on the earthworm population with reference to shifting cultivation systems. Mishra and Ramakrishnan (1988) studied earthworm population dynamics in different jhum fallows developed after slash and burn agriculture in north-eastern India. Bhadauria and Ramakrishnan (1989) studied earthworm population dynamics and contribute to nutrient cycling during cropping and fallow phases of shifting agriculture (Jhum) in North-east India. Darlong and Alfred (1991) studied the effect of shifting cultivation (jhum) on soil fauna with particular reference to earthworms in North-east India. The significant role of earthworms, the farmers' friend, also known as ecosystem engineers, in maintaining soil fertility and soil physical nature is universally well known. Mean while, the traditional shifting cultivation system of Mizoram is supposed to have an adverse negative impact on this useful soil invertebrate. However, no literature is available in this aspect from Mizoram. Therefore, the present investigation was carried out with the objective to provide a baseline data on how a traditional shifting cultivation system affect the diversity, density and distribution of earthworms.

Materials and Methods

Study area : Mizoram, a part of Indo-Myanmar Biodiversity Hotspot, covers an area of 21,081 sq km in North-east India. It lies between 21º56'N and 24º31 'N latitude, 92º16 'E and 93º26'E longitude. The forest is mainly tropical semi-evergreen rainforest. The soil of Mizoram is slightly acidic; normally soil pH ranges from 4.5 to 7. The average temperature varies between 11°C and 21°C in winter and raises up to 20°C and 33°C during summers. It receives an annual rainfall of about 2500 mm. On the basis of variations in the elements of climate, *i.e.,* changes in air temperature, amount of rainfall attributes as well as wind direction, four seasons have been recognized in Mizoram: Pre-Monsoon/Spring (March to May), Monsoon/Summer (June to September), Post-Monsoon/Autumn (October and November) and Winter (December to February). Comparative study of earthworm population was conducted at an experimental plot of one acre of natural forest at the Khawrihnim village (23° 36'58" N and 92° 38'04" E, 950 m above sea level), Mamit district, Mizoram. The plot was divided into control (CTRL, the natural forest) and experimental (EXPTL) sites. The land and vegetation were left undisturbed for the last 30 years. The landscape is steep with a slope percentage ranging from 55% to 80%.

Traditional shifting cultivation in Mizoram involves slashing of vegetation in the month of December or early January, followed by burning of dried felled vegetation in early March or sometime in April. Sowing of seeds in the month of April/May is followed by the first weeding carried out in the month of June. The cropping system is of mixed type, where all kinds of crops were grown with rice as the main crop. Weeding using a hand hoe is usually carried out three times a year, whereby weeds were pulled-out along with roots and upper fertile soil was roughly semi-tilled with a hand hoe. Traditional shifting cultivation was conducted at the EXPTL site in the year 2014. The study duration in the EXPTL site was divided into three phases, viz. Pre-cultivation phase (2013), Cultivation phase (2014) and Post-cultivation phase (2015).

Earthworm sampling : Earthworm samples were collected from five random sites each within the natural forest (CTRL) and shifting cultivation sites (EXPTL), located at least 20 m apart at monthly intervals from January 2013 to October 2015. At each sample point, blocks of soil (25 cm x 25 cm x 30 cm) was dug out, transferred to laboratory and earthworms were then collected by hand sorting method. They were fixed in 5% formalin for 24 hr and preserved in 70% alcohol for further studies. Strata-wise information for vertical distribution at three different depths, viz. 0-10 cm, 10-20 cm and 20-30 cm were also recorded and seasonal variation was determined from monthly data. Density was determined as number of individuals per square meter. The taxonomic study was carried out at the Research and Instrumentation Centre, Pachhunga University College by thorough morphological and anatomical examinations using Optika Stereomicroscope (SZN-4) and available monographs (Gates, 1972 and Julka 1988, 2008). Protocol of Hendrix and Bohlen (2002) was followed for determining the ecological categories of earthworms of studied sites.

Data analyses : Data were used to determine Fisher's alpha diversity index, Shannon's diversity index, Simpson's index of dominance, Menhinick's species richness index and Pielou's evenness index, following Heip *et al,* (2003) and density of earthworm (ind. m^{-2}) using Microsoft Office Excel. T-test and ANOVA were performed using the Statistical Software package SPSS 20.

Results and Discussion

Earthworm species, ecological categories and their occurrence in CTRL and EXPTL sites are given in Table 1. A total of 11 earthworm species belonging to three families and five genera were identified from two study sites. Out of these 11 earthworm species, five species (*Perionyx excavatus, P. macintoshi, Metaphire houlleti, Amynthas alexandri* and *A. cortices*) belonged to family Megascolecidae, four species (*Eutyphoeus gigas, E. assamensis* and two unidentified species of genus *Eutyphoeus*) belonged to family Octochaetidae and two species (*Drawida nepalensis* and one unidentified *Drawida* sp.) belonged to family Moniligastridae. The most common species recorded were *P. excavatus, M. houlleti, Drawida* sp. and *Eutyphoeus* sp.1. All 11 species were found in CTRL whereas only nine species were recorded at EXPTL site. Although earthworm study is not new to Mizoram, this is the first detailed record of earthworm species from shifting cultivation site in the state of Mizoram. Natural forest (CTRL) had a significantly higher ($P > .05$) index of diversity and evenness, but a lower index of species richness and dominance than cultivation site, EXPTL (Table 2). Species richness index of CTRL was low as compared to EXPTL site because out of 423 earthworms collected from CTRL site, only 11 different species were identified; whereas, in the EXPTL site, only 268 earthworms were collected of which 9 different species were present. The family-wise dominant hierarchy can be represented as–Megascolecidae> Octochaetidae> Moniligastridae.

The total earthworm density along with soil profile (0–30 cm) during the course of study was 1353.6 ind.m^{-2} in CTRL and 857.6 ind.m^{-2} in EXPTL site. T-test showed significant variation [$t = 2.039$, $df = 66$, $P = .045$] in the mean density between CTRL and EXPTL sites. The average earthworm density in control (CTRL) site during pre-cultivation, cultivation and post-cultivation phases were 37.6 ind.m^{-2}, 41 ind.m^{-2} and 41.04 ind.m^{-2} whereas average density was 38.93 ind.m^{-2}, 5.07 ind.m^{-2} and 32.96 ind.m^{-2}, respectively for pre-cultivation, cultivation and post-cultivation phases in EXPTL site. A one-way ANOVA was conducted to determine if shifting cultivation affected mean density of earthworms for pre-cultivation, cultivation and post-cultivation phases in both CTRL and EXPTL sites. As predicted, there was no significant [$F_{2, 33} = .075$, $P = .928$] change in earthworm density of CTRL site because this site remained undisturbed. On the other hand, there was a significant effect of shifting cultivation on earthworm density in EXPTL site at $P < .05$ level for three cultivation phases [$F_{2, 33} = 5.607$, $P = .008$]. A Tukey post hoc test revealed significant difference between pre-cultivation and cultivation phases (33.87±10.72 ind.m^{-2}, $P = .010$) as well as between cultivation and post-cultivation phases (27.89±11.24 ind.m^{-2}, $P=.048$). However, there were no significant differences in earthworm density between pre-cultivation and post-cultivation phases (5.97±11.24 ind.m^{-2}, $P =.857$).

The vertical distribution of different species are presented in Table 1. The surface layer (0-10cm) harbors 54% of the total population, 41% were found in the subsurface layer (10-20 cm) whereas only 5% of earthworms were collected from deeper layer (20-30 cm) of soil. All three types of ecological categories viz. epigeic, endogeic and anecic species were recorded from both the study sites. Endogeic species occurred at both the study sites. However, *Drawida* sp. was most versatile species in terms of spatial distribution as well as temporal distribution as it was found at all three different soil strata. A one-way analysis of variance was conducted to evaluate any significant decrease in earthworm density with increase in soil depth. The independent variable soil depth included three groups: 0-10cm (21.46±2.89), 10-20 cm (16.37±2.03) and 20-30 cm (1.97±0.70) in CTRL site and 0-10 cm (13.27±2.83), 10-20 cm (10.73±2.35) and 20-30 cm (1.22±0.65) in EXPTL site. Results indicated that there was a significant difference in the mean of density in different soil profile layers, $F_{2, 99} = 23.689$, $P < .001$ in CTRL and $F_{2, 99} = 8.663$, $P < .001$ in EXPTL site.

The study sites were rich in earthworms during rainy season between April and October and scanty during winters months (Fig. 1). It was, however, observed that *Drawida* sp. tolerates winter and was found almost throughout the year at a depth of 10-20 cm. Records of earthworm species, except for *Drawida* sp. during winter months was negligible. During rainy season, *Metaphire houlleti* out-numbered all other earthworm species, followed by *Perionyx excavatus*. Study of earthworm density in relation to four climatic seasons indicated that population density was higher during wetter season (*i.e.* monsoon and post-monsoon) as compared to dry seasons (pre-monsoon and winter) (Fig. 1).

The average earthworm density during pre-monsoon was 30.93 ind.m^{-2} CTRL whereas it was only 11.37 ind.m^{-2} in EXPTL sites. During monsoon season, the average density in CTRL was

Table1: Earthworm community composition, ecological category and occurrence

Family, genus and species	Ecological category	Occurrence		Vertical distribution
		CTRL	EXPTL	
Megascolecidae				
Perionyx excavatus Perrier	Epigeic	+	+	0-10 cm
Perionyx macintoshi Stephenson	Epigeic	+	+	0-10 cm
Metaphire houlleti Perrier	Anecic	+	+	0-20 cm
Amynthas alexandri Beddard	Anecic	+	+	0-20 cm
Amynthas cortices Kinberg	Endogeic	+	+	5-20 cm
Moniligastridae				
Drawida nepalensis Michaelsen	Endogeic	+	+	10-20 cm
Drawida sp.	Anecic	+	+	0-30 cm
Octochaetidae				
Eutyphoeus gigas Stephenson	Endogeic	+	+	10-30 cm
Eutyphoeus assamensis Stephenson	Endogeic	+	+	5-20 cm
Eutyphoeus sp.1	Endogeic	+	-	0-20 cm
Eutyphoeus sp. 2	Anecic	+	-	10-30 cm

+ = present, - = absent

slightly higher (54.4 ind.m^{-2}) as compared to EXPTL site (41.33 ind.m^{-2}). The average density of earthworms in CTRL site during post-monsoon season was also higher (65.92 ind.m^{-2}) than EXPTL site (40.96 ind.m^{-2}). Similarly, the average density of earthworms during winter was also higher in CTRL (11.6 ind.m^{-2}) as compared to EXPTL site (6.8 ind.m^{-2}).

One-way analysis of variance was conducted to compare the effect of seasonal changes on earthworm density for four seasonal changes-spring, summer, rainy, autumn and winter seasons. The results indicated that seasonal changes had a statistically significant [$F_{3,\ 66}$ = 9.380, P <.001] effect on soil macrofauna density as a whole for four seasonal changes: spring (22.04±4.74), summer (49.07±6.04), autumn (49.60±11.73) and winter (12.09±4.08). Prior to present study, 11 species of earthworm have been reported from Mizoram State (Ramanujam *et al.,* 2004). Three unidentified species of earthworm collected in this study *Drawida* sp., *Eutyphoeus* sp. 1 and *Eutyphoeus* sp. 2 are newly recorded. Some of the species like *P. excavatus, M. houlleti, A. alexandri, E. gigas* and *D. nepalensis* recorded in the present study have been reported from the neighbouring states of North-east region (Mishra and Ramakrishnan, 1988; Chaudhuri and Bhattacharjee, 1999; Halder, 1999; Dey and Chaudhuri, 2014; Jamatia and Chaudhuri, 2017). This may be due to similar climatic condition as well as edaphic characteristics with its adjacent geographical areas.

Two unidentified species of *Eutyphoeus* recorded in CTRL site were not found at EXPTL site. This could be attributed to lack of adaptability in a disturbed environment as a consequence of conversion of natural forest into agricultural fields. Conversion of natural forests to shifting agriculture and plantation results in loss of some earthworm species richness (Dash and Saxena, 2012). Meanwhile, all other nine species were recorded from both CTRL and EXPTL sites, indicating their adaptability irrespective of varying soil conditions and plants associated with cultivation site. In line with this result, Fragoso *et al.,* (1999) also reported that the structural components in earthworm communities vary depending on the type of agroecosystem.

Higher diversity of earthworms in CTRL compared to EXPTL site may be attributed to its undisturbed nature of forest litter and soil, which is more suitable for the survival of earthworm community, particularly for two *Eutyphoeus* species found only at CTRL site. Lower species richness of CTRL site compared to EXPTL site indicated that diversity of CTRL site was not high despite abundance of earthworms. However, reports of 11 species of earthworms from this study corroborate with the findings of Fragoso *et al.* (1999), who suggested that the species number in a given earthworm community ranges from 3-17 in tropical and temperate ecosystems. Temperature and moisture has a significant influence on earthworm diversity. (Edwards and Bohlen, 1996; Blakemore, 2006). These observed variations in earthworm diversity appear to be associated with management practices such as destruction of habitats due to cutting down of trees, use of fire, modification of soil physico-chemical properties

Table 2 : Earthworm diversity indices in CTRL and EXPTL sites

Indices	CTRL	EXPTL	T-value	P value
Fisher's alpha diversity index	2.06	1.80	14.353	.044
Shannon's diversity index	2.23	2.07	41.381	.015
Simpson's index of dominance	0.10	0.14	52.457	.012
Pielou's evenness index	0.93	0.88	37.521	.017
Menhinick's species richness index	0.53	0.55	72.307	.009

Table 3 : Layer-wise variation in earthworm density (ind.m^{-2}) during three cultivation phases

Soil strata	0-10 cm		10-20 cm		20-30 cm	
Jhum phase/Site	**CTRL**	**EXPTL**	**CTRL**	**EXPTL**	**CTRL**	**EXPTL**
Pre-cultivation phase (2013)	281.6	259.2	198.4	182.4	3.2	16
Cultivation phase (2014)	201.6	70.4	128	44.8	0	0
Post-cultivation phase(2015)	249.6	134.4	252.8	150.4	0	0
Total density (ind.m^{-2})	732.8	464	579.2	377.6	3.2	16

as a consequence of weeding in the EXPTL site. These results are in agreement with Bhadauria and Ramakrishnan (1991), who stated that large scale destruction of natural forests severely affects earthworms diversity. Edwards and Bohlen (1996) also reported that diversity of earthworm community at a given locality is largely influenced by land use pattern and disturbance. Burning of felled trees in EXPTL site during cultivation phase eliminates litter from topsoil which may serve as nourishment for epigeic species thus affecting species diversity. This is consistent with previous findings that ascertained correlation between earthworm diversity and soil litter quality (Sinha *et al.,* 2003). The most diverse family of this study, was Megascolecidae, which is in agreement with the findings of Julka *et al.* (2009) who reported that the most diverse families in terms of recorded earthworm species are Megascolecidae, followed by Octochaetidae and Moniligastridae in the Indian region. Significant reduction in earthworm density at EXPTL site as compared to CTRL site clearly indicated that slashing and burning of forest in preparation for cultivation and subsequent disturbance of soil by means of weeding at EXPTL site has led to loss of nutrient and surface litter, further resulting in drastic reduction in density of earthworms as soil no longer can provide sufficient nutrients and moisture to support earthworm population. This is in accordance with Jordan *et al.* (2000), who observed that earthworm density decrease in forests where organic matter has been removed and attributed the population decline to decreased nutrient availability. Influence of soil conditions on earthworm population has also been described by Chaudhuri and Mitra (1983). Earthworms are organisms with highly contagious spatial distribution (Rossi and Lavelle, 1998). The two studied ecosystems (forest and shifting cultivation site) had majority of earthworms in the surface layer (0-10cm) followed by a subsurface layer (10-20cm) and deepest layer (20-30cm). The possible explanation of earthworms more abundant in the upper two layers (0-10cm and 10-20cm) lies in

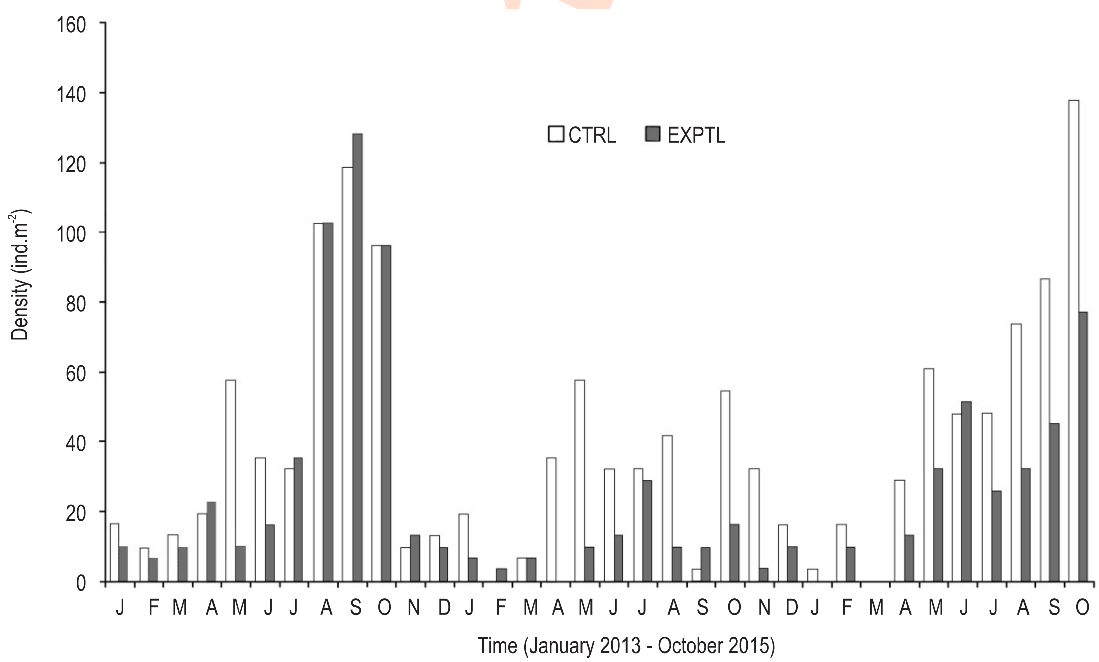

Fig. 1 : Monthly variation in earthworm density (ind.m^{-2}) during January 2013 to October 2015.

the fact that upper layers are characterized by adequate living space, favourable temperature, and moisture conditions, aeration rates and rich accumulation of organic debris. Distribution of earthworms within soil profile is determined by both abiotic and biotic factors (Lavelle and Martin, 1992). The versatility of *Drawida* sp. observed in this study corroborates Lalthanzara and Ramanujam (2014) who investigated the vertical distribution of earthworms in agroforestry systems.

Out of three soil profile layers, as in elsewhere density of earthworms was found to be highest in 0-10 cm layer of soil profile layer of both study sites (Table 3). The amount of litter accumulated under the shrubs has also been found to be a factor influencing the density of earthworms in deeper soil layer (Peterson *et al.,* 2001). Earthworms in the study area showed a decrease in density with increase in depth, irrespective of forest (CTRL) or cultivation (EXPTL) soil under consideration. A similar observation was recorded by Lathanzara and Ramanujam (2014). This observed low abundance of anecic earthworm species may be attributed to compaction of soil in deeper layer. A similar observation was recorded by Pižl (1992) and Söchtig and Larink (1992), who stated that the activity of earthworms was significantly higher in non-compact soil than in compact soil columns. The mean lower abundance and biomass under compact soil may result from factors such as reduced pore volume, oxygen deficiency and temporary water logging of the soil (Bostrom, 1986).

This observation is also in conformity with Doblas-Miranda *et al.* (2009) who observed that soil macrofauna density showed a significant difference among litter and soil layers with a progressive decrease in the mean number of species from litter to deepest level. Decreased earthworm density with increasing depth corrborates the findings of Bisht *et al.* (2003) and Irannejad and Rahmani (2009) who observed highest diversity and density in the top (0-10cm) layer. However, in contrast to this finding, Kooch *et al.* (2008) reported highest density and biomass of earthworms in the deepest layer (20-30 cm) and lowest in the middle layer (10-20 cm) of Hornbeam forest, Iran. Seasonal fluctuation in earthworm distribution was observed in this study. This may be an adaptation to low range of temperature at higher altitudes (Lalthanzara *et al.,* 2011). Distribution of earthworms has been frequently uneven and the numbers show discrepancy relative to type of soil (Curry and Baker, 1998) and ecological factors, mainly temperature and moisture (Ismail and Kaleemurrahman, 1981). The occurrence of *M. houlleti* in greater number during rainy season could be attributed to abundance of litter and suitable environmental factors like temperature and moisture content during this season, which further enhanced the breeding capability and resulted in higher number of individuals.

The results of this study clearly indicate that earthworms were more abundant during summer and rainy seasons, despite the type of forest under consideration (*i.e.,* CTRL and EXPTL) as compared to autumn and winter seasons when soil is comparatively low in moisture content. Soil moisture is essential for earthworms (Edwards and Bohlen, 1996). However, the moisture required for different species of earthworms from various regions can be highly diverse (Auerswald *et al.,* 1996). Blanchart and Julka (1997) also reported a higher number of earthworms during wet periods.

Significant variations in earthworm density with respect to various seasons indicated that seasonal change is an important factor that determines the density of earthworm. Generally, favourable soil temperature and food availability during summer and rainy season is an ideal condition for breeding and growth of earthworms. In line with these observations, the highest population of earthworms during rainy season and their low number in dry season has been noted as a general trend by many workers (Hattar *et al.,* 1998; Najar and Khan, 2011; Lalthanzara and Ramanujam, 2014). This study clearly indicates that traditional shifting (Jhum) cultivation has adverse effects on earthworm population density and diversity. The negative impact of shifting cultivation was attributed mainly to habitat destruction, decline in the availability of food and changes in the physical and chemical properties of soil.

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