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MONTHLY VARIATION OF TOTAL EARTHWORM POPULATION IN A SUB-TROPICAL FOREST ECOSYSTEM OF MOKOKCHUNG DISTRICT IN NAGALAND

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ABSTRACT
Amynthas corticis, Amynthas sp.1, Perionyx sp., Drawida sp., Eutyphoeus festivus, Eutyphoeus sp.no.1 and Eutyphoeus marmoreus belonging to three families Megascolecidae, Moniligastridae and Octochaetidae were recorded. However, Amynthas sp.1 was recorded only in the forest ecosystem. The total earthworm density at 0-10 cm in the natural forest ecosystem was maximum in the month of September (88 m^{-2}) and minimum in December (22 m^{-2}). In the fallow ecosystem, the density fluctuation indicated two peak months *i.e.* June (43.98 m^{-2}) and September (64.76 m^{-2}). While, in the plantation ecosystem, it recorded maximum in the month of September (57.43 m^{-2}) and minimum in December (13.43 m^{-2}) at 0-10 cm layer. Among the three sites, reserve forest recorded the highest annual earthworm population density (609.68 Nos. m^{-2}) followed by plantation (386.1 Nos. mÉ²) and fallow (356.56 Nos. m^{-2}) respectively. Moisture content, Soil temperature and Nitrogen content showed high positive significant relationship in the reserve forest (r=0.39, P<0.05; r=0.49.P<0.01; r=0.35, <P0.05), fallow (r=.0.68, P<0.01; r=0.79, P<0.01; r=0.40, P<0.05) and plantation (r=0.39, P<0.05; r=0.51, P<0.01; r=0.37, P<0.05) sites respectively.

INTRODUCTION

Considering the role of earthworm in soil genesis and preservation of soil fertility the great philosopher Aristotle (4th BC) called them "Intestines of earth". Infact, the functional role of earthworms in soil formation, its turnover and organic matter incorporation has also been very well documented by Darwin (1881) in his classical publication "The formation of vegetable mould through the action of worms". Normally earthworms are present in the top 30-40cm layer of soil which is usually moist and have plenty of organic matter. They rarely come out to surface, so they feed mainly on almost decomposed organic matter and soil (Chaudhuri *et al.*, 2008, Blakemore 2010).

Earthworms are scientifically classified as animals belonging to the order Oligochaeta, class Chaetopoda, phylum Annelida ,with about1,800 species of earthworms grouped into five families and distributed all over the world. They have different tolerance to the environmental stress, therefore earthworm species may be diverse within different areas (Edwards 2004). According to their ecological status, earthworms can be classified into epigeic, anecic, and endogeic. Epigeic earthworms live on the ground surface and feed on litters. Anecic earthworms build vertical burrow where one end is opened into the surface. Meanwhile, endogeic earthworms build their burrow in the ground. Climatic status, as well as biotic factors, has been observed to strongly influence the richness and distribution of earthworms (Werner *et al.*, 2005). The number and biomass of earthworms vary significantly among the sites and among the seasons, thus indicating that climate and soil physicochemical characteristics play a major role in earthworm communities (Najar & Khan, 2011). Different physico-chemical factors such as soil texture, soil moisture, food, pH, temperature, soil depth, organic content, carbon, nitrogen, phosphorus, potassium and calcium were reported to be highly responsible for the distribution, abundance, diversity and biomass of the earthworms (Phillipson *et al.*, 1976; Lavelle, 1983; Baker *et al.*, 1993). Furthermore, the fecundity of earthworms is found to be greatly influenced by moisture (Edwards and Lofty, 1972). Soil moisture has a key influence on earthworm abundance and diversity even though other soil properties such as texture, pH and organic matter content may also be important (Edwards and Bohlen, 1996). Blanchart and Julka (1997) have also shown that higher numbers of earthworms are found during wet periods. Whereas some studies on earthworms in India like in Orissa and Garhwal Himalaya has been done by Mishra and Dash (1984) and Joshi *et al.* (2010) respectively, informations on the ecology of earthworms are still fragmentary and insufficient (Ganihar,, 1996; Chaudhuri, and Bhattacharjee, 1999). While certain works on earthworm population distribution pattern is available from other part of north-east India (Halder, 1999; Lalthanzara *et al.*, 2011; Haokip and Singh, 2012; Dey and Chaudhuri, 2013; Jamatia and Chaudhuri, 2017), there is paucity of such information in Nagaland. In view of that, an effort has been made in this paper to present the variation pattern of earthworm population density and the possible impact on soil fertility in Mokokchung District of Nagaland.

MATERIALS AND METHODS

Earthworms were collected from each site consisting of nine locations by digging nine 25 x 25 x 30 cm monoliths at regular monthly interval and hand sorting the worms following Anderson and Ingram (1993) and these were preserved in 4% formalin for further identification. Preserved worms were identified with the help of available keys (arrangement of setae, location and size of clitellum, location of genital openings, shape and number of spermathecae, location of gizzard and prostrate gland (Julka, 1988). Density of earthworms was calculated as the number of individuals present per meter square. Soil temperature was recorded every month at 0-10 cm depth using soil thermometer. Moisture was determined by gravimetric method monthly at 0-10 cm depth and was expressed as a percentage of the weight of the sample after oven drying at 105ºCfor 24 hours. From soil monolith where earthworm was sampled a mixture of soil was collected and brought into laboratory, air dried (bigger lumps crushed) and sieved through 2 mm sieve and stored for subsequent chemical parameters analysis. The analyzed soil chemical parameters include pH (1:2 soil water solution), total nitrogen (N) using Kjheldahl digestion method (Anderson and Ingram, 1993), Phosphorus (Bray and Kurtz, 1945 for acidic soil and Olsen *et al.*, 1954 for alkaline soil), organic carbon (Walkley and black, 1934) and Potassium by flame photometer (130) method using ammonium acetate as an extractant. Graphical representation, Correlation coefficient (r) and one way ANNOVA in relation to earthworm density with various soil chemical properties was analysed using ORIGIN Pro 2016.

Description of study sites

The present study was conducted from November, 2014 to October 2015 in three different sites of acontiguous sub-tropical hill forest ecosystem characterised with gentle to steep slopes *viz*. Reserved forest (site I), Plantation (site II) and fallow area (site III) respectively located in Mingkong area which is about 10 km away from Mokokchung town. These sites lie at 29º 15′–30º 15′ North latitude and 77º 55′– 78º 30′ East longitude and altitude ranges from 1400 to 1600 m above MSL. The site I is a natural mixed reserved forest with common tree species of Atrocarpus chaplasha, Castanopsis tribuloides,, Iteamacro phylla, Elaeocarpus floribundus, Ficus semicordata, Schima wallichii, Kydia calycina, Macarang adenticulata, Firmiana colorata, Mallotus tetracocccus, Trema orientalis, Sapium eugeniifolium. Shrubs like Tephrosia candida, Vernonia volkameriifolia, Pavetta indica, Styrax serrulata , Abroma augusta , Leeamacro phylla, Crotalaria cytisoides are quite common in the study area. The site is protected from various biotic interference since 1950 having an area of (275.32) hectares. The site II *i.e.* plantation area is dominated by Daubanga grandiflora. Grasses like Digitaria sp., Panicum sp., Saccharum arundinaceum intermixed with Musa markkuana is common in this study area with infrequent biotic disturbances. Site III is Jhum fallow land since 2004 with infrequent tree species like Macaranga denticulata, Mallotu stetracoccus, Sapium baccatum, Bischofia javanica , Ficus hirta, Ficus semicordata, Schima wallichii. Shrubs flora is dominated by Mussa endaroxburghii, Rubus indotibetanus, Melastoma malabathricum *etc*. Climbers are quite common and dominated by Dioscore apentaphylla, Smilax perfoliata, Thunbergia grandiflora, Thunbergia coccinea, Paederia scandens etc. Grasses like Saccharum arundinaceum, Themada villosa intermixed with Digitaria sp., and Panicum sp. are quite common in the area.

The climate of the area is monsoonal with warm moist summer and cool dry winter. The year is divisible into three season's *viz*. summer, rainy and winter. 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 25.64ºC (January) to 30.8ºC (May) and mean minimum air temperature varied from 5.68ºC (January) to 23.03ºC (July). Minimum monthly rainfall occurred in January (22.5mm) and maximum in July (203mm). The area received an average annual rainfall of 1001.6 mm. Relative humidity was recorded to be maximum in the month of August (83.21%).

RESULTS AND DISCUSSION

Altogether seven earthworm species *viz*. Amynthas corticis, Amynthas sp.1, Perionyx sp., Drawida sp., Eutyphoeus festivus, Eutyphoeus sp.no.1 and Eutyphoeus marmoreus belonging to three families were recorded from the reserve forest(site 1), fallow(site 2)and plantation (site 3) ecosystems in the subtropical hilly forest ecosystem of Mokokchung.Three

Table 1: Correlation and regression analysis between Density of total earthworm and soil parameters (reserved Forest ecosystem)

Variable	Soil layers	r	df	Y	t	p	Variability (%)
Soil temp.	0-10	0.49	35	13.795 + 0.626 X	3.27	<0.01	24.1
	20-Oct	0.19	35	17.726 + 0.529 X	0.82	>0.05	1.9
Soil moisture	0-10	0.39	35	34.572 + 1.305 X	2.44	<0.05	14.9
	20-Oct	0.05	35	29.936 + 0.212 X	0.29	>0.05	0.2
Bulk density	0-10	-0.5	35	1.190 – 0.011 X	-3.39	<0.01	25.2
	20-Oct	0.03	35	1.201 – 0.004 X	-0.19	>0.05	0.1
Soil Ph.	0-10	0.2	35	5.278 + 0.310 X	1.19	>0.05	4
	20-Oct	0.17	35	5.270 + 0.069 X	1.02	>0.05	3
Nitrogen (N)	0-10	0.35	35	320.206 – 4.825 X	-2.15	<0.05	12
	20-Oct	-0.34	35	261.970 – 8.351 X	-2.13	<0.05	11.8
Phosphorus (P)	0-10	0.24	35	18.198 + 0.325 X	1.44	>0.05	5.7
	20-Oct	-0.35	35	16.640 – 0.790 X	-2.16	<0.05	12.1
Potassium (K)	0-10	-0.08	35	132.356 – 1.117 X	-0.45	>0.05	0.6
	20-Oct	-0.08	35	83.020 – 2.054 X	-0.48	>0.05	0.7
Carbon (C)	0-10	0.05	35	2.360 + 0.006 X	0.28	>0.05	0.2
	20-Oct	-0.06	35	1.675 – 0.015 X	-0.35	>0.05	0.3

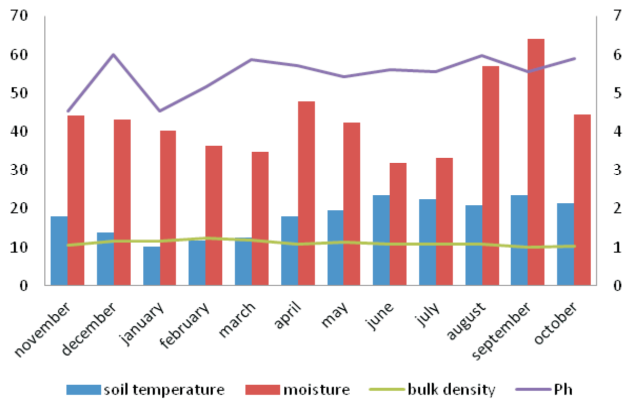

Figure 1: Monthly variation of soil physical properties in reserved forest ecosystem

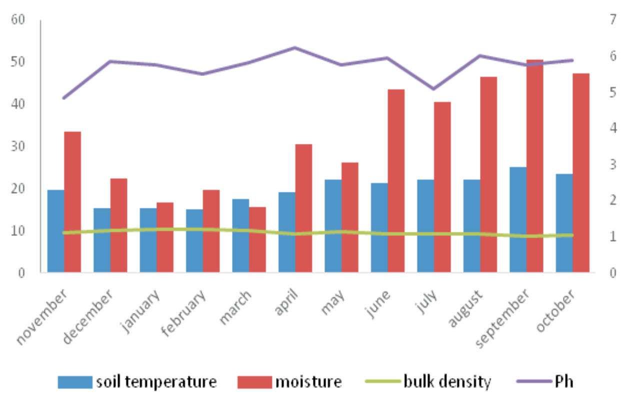

Figure 2: Monthly variation of soil physical properties in Fallow ecosystem

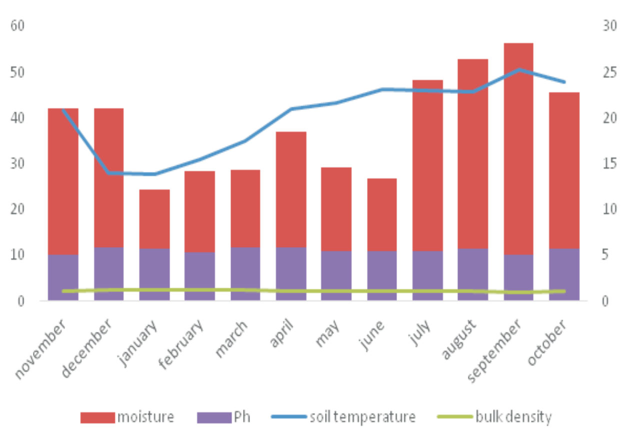

Figure 3: Monthly variation of soil physical properties in Plantation ecosystem

species belonged to Megascolecidae family (Amynthas corticis, Amynthas sp.1 and Perionyx sp.), one species Drawida sp. belonged to Moniligastridae family and three species Eutyphoeus festivus, Eutyphoeus sp.no.1 and Eutyphoeus marmoreus belonged to Octochaetidae family. Excepting Amynthas sp.1 which was recorded only in the reserved forest ecosystem, all the remaining six species were common in the three sites. Some Perionyx sp. like Perionyx sansibaricus (Michaelsen), Perionyx excavatus (Michaelsen) and Drawida sp. like Drawida calebi (Gates) and Drawida willsi (Michaelsen) have also been reported by Sinha *et al.* (2013).

It was observed that the variation of earthworm density and diversity in all the three study sites were found to be affected by several microclimatic or abiotic factors of the soil ecosystem. Similarly, Kumari and Sinha (2012) emphasized that anthropogenic interference have a detrimental impact on earthworm biomass and density and further reported 16% higher population density in grassland habitat compare to cropland where land management has been done for long period of time. Among the abiotic factors the soil physico-chemical factors such as soil moisture content, soil temperature, bulk density and nutrient content *viz.*total nitrogen and phosphorus have been found to play an important role in the variation of population structure and species diversity of earthworms of the study sites.

In the present investigation, the maximum soil moisture content were found during monsoon season and gradually decreased during pre-monsoon and winter season (Figure 1, 2 &3). The population density also showed similar trend with highest population density during monsoon season (Fig. 7) wherein moisture was also highest. Monthly variation in the total number of earthworms showed similar pattern in the maximum and minimum points as indicated in Figure 7. The total earthworm population at 0-10 cm in the natural forest ecosystem showed maximum count in the month of September (88 m^{-2}) and minimum in the month of December (22 m^{-2}).However at 10-20 cm layer, the maximum count was in the month of may (19.55 m^{-2}) with nil records in four months *i.e.* January, July, August and September. Overall, two peaks were observed *i.e.* one in September (88 m^{-2}) and the other in May (72.1 m^{-2}). Population size of earthworms varies to a great extent in different habitats and different geographical regions.

In the fallow ecosystem, total earthworm population fluctuation indicated two peak months *i.e.* June (43.98 m^{-2}) and September (64.76 m^{-2}).But at 0-10 cm soil depth September (63.54 m^{-2}) and October (42.74 m^{-2}) were the two peak months. At 10-20 cm soil depth, November, May and June recorded identical count of 2.44 m^{-2} while there was no recordings in the months of January, February, march, April, July and August. Further, the months of September, October and December recorded a similarity of 1.22 m-2 total earthworm count at 10-20 cm soil layer.

In the plantation ecosystem, total earthworm population recorded maximum in the month of August with 57.43 m^{-2} and the minimum was in December with 13.43 m^{-2} at 0-10 cm layer. At 10-20 cm, maximum record was in May (11 m^{-2}) with nil count in the months of November, January, February, April, July, August and September. Overall two peak months were observed in the month of August (57.54 m^{-2}) and September (57.43 m^{-2}) respectively. Annually, reserve forest recorded the highest earthworm population density (609.68 Nos. m^{-2}) which was followed by plantation (386.1 Nos. m^{-2}) and fallow (356.56 Nos. m^{-2}) respectively.

The importance of soil moisture content in relation to population of earthworm in India were reported by Dash and Senapati (1980), and by others Julka (1986a and b), Bhadauria

Table 2 : Correlation and regression analysis between Density of total earthworm and soil parameters (Fallow ecosystem)

4	Soil layers	r	df	Y	t	p	Variability (%)
Soil temp.	0-10	0.79	35	15.818 + 0.990 X	7.51	<0.01	62.4
	20-Oct	0.18	35	19.478 + 1.813 X	1.06	>0.05	3.2
Soil moisture	0-10	0.68	35	19.478 + 3.287 X	5.48	<0.01	46.9
	20-Oct	0.03	35	26.535 + 0.664 X	0.15	>0.05	0.1
Bulk density	0-10	-0.47	35	1.179 – 0.015 X	-3.1	<0.01	22.1
	20-Oct	-0.13	35	1.164 – 0.054 X	-0.73	>0.05	1.6
Soil Ph.	0-10	0.13	35	5.269 – 0.020 X	0.74	>0.05	1.6
	20-Oct	0.06	35	5.464 + 0.097 X	0.37	>0.05	0.4
Nitrogen (N)	0-10	0.4	35	252.157 – 4.979 X	-2.51	<0.05	15.6
	20-Oct	-0.07	35	215.967 – 5.876 X	-0.38	>0.05	0.4
Phosphorus (P)	0-10	0.38	35	14.817 + 1.023 X	2.42	<0.05	14.7
	20-Oct	-0.07	35	15.325 – 0.964 X	0.39	>0.05	0.4
Potassium (K)	0-10	-0.02	35	153.455 – 0.328 X	-0.11	>0.05	0
	20-Oct	0.07	35	94.339 + 4.544 X	0.43	>0.05	0.5
Carbon (C)	0-10	0.06	35	2.111 + 0.011 X	0.37	>0.05	0.4
	20-Oct	-0.13	35	1.720 – 0.133 X	-0.77	>0.05	1.7

Table 3: Correlation and regression analysis between Density of total earthworm and soil parameters (Plantation ecosystem)

Variable	Soil layers	r	df	Y	t	p	Variability (%)
Soil temp.	0-10	0.51	35	17.106 + 0.627 X	3.41	<0.01	25.5
	20-Oct	-0.03	35	20.161 – 0.146 X	-0.15	>0.05	0.1
Soil moisture	0-10	0.39	35	31.150 + 1.473 X	2.5	<0.05	15.5
	20-Oct	-0.17	35	31.233 – 2.156 X	-0.98	>0.05	2.7
Bulk density	0-10	-0.3	35	1.165 – 0.008 X	-2.31	<0.05	14.7
	20-Oct	0.1	35	1.209 + 0.010 X	0.59	>0.05	1
Soil Ph.	0-10	0.16	35	5.441 + 0.024 X	0.92	>0.05	2.4
	20-Oct	0.19	35	5.279 + 0.111 X	1.11	>0.05	3.5
Nitrogen (N)	0-10	0.37	35	294.953 – 12.614 X	-2.31	<0.05	13.6
	20-Oct	-0.03	35	215.360 – 2.612 X	-0.17	>0.05	0.1
Phosphorus (P)	0-10	0.31	35	14.849 + 1.278 X	2.15	<0.05	12.8
	20-Oct	-0.17	35	14.210 – 1.394 X	-1.02	>0.05	3
Potassium (K)	0-10	-0.35	35	139.157 – 9.662 X	-2.15	<0.05	11.9
	20-Oct	0.44	35	66.956 + 42.237 X	2.83	<0.01	19.1
Carbon (C)	0-10	0.14	35	2.170 + 0.035 X	0.83	>0.05	2
	20-Oct	0.39	35	1.693 + 0.341 X	2.47	<0.05	15.2

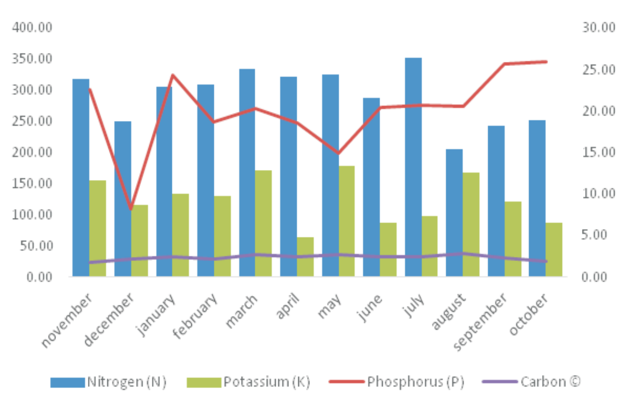

Figure 4: Monthly variation of soil nutrients in Reserve forest ecosystem

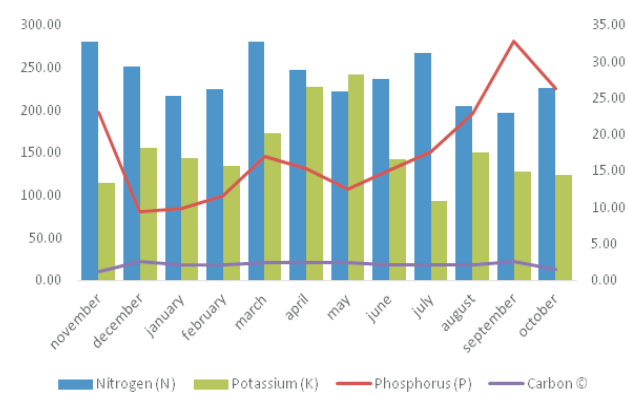

Figure 5:Monthly variation of soil nutrients in Fallow ecosystem

and Ramakrishnan, (1989 and1991). Blanchart and Julka, (1997) have also recorded higher number of earthworm during wet periods. The present investigation also correspond to these reports. Conforming to Fragoso *et al*. (1993) and Fragoso and Rojas (1994), Sinha *et al*. (2013) also reported from the study of biodiversity of earthworm in Uttarakhand that native species are dominant in natural ecosystem whereas in disturbed habitat such as agro-ecosystem and artificially managed landscape peregrine species dominate over native population of earthworms. Similarly, even in the present investigation the reserve forest showed maximum presence of earthworms. Among the different edaphic factors studied soil moisture content was found to play the most important role in the fluctuation patterns of the earthworm population. In the present

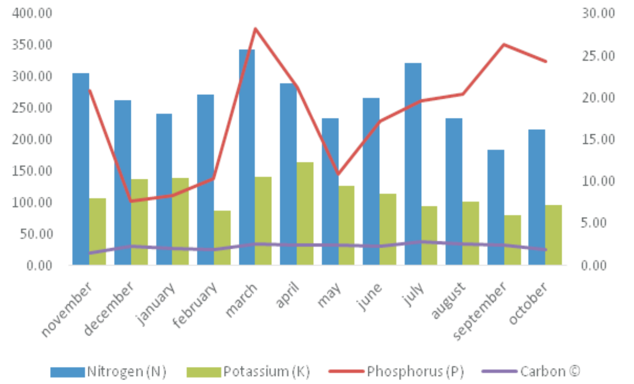

Figure 6: Monthly variation of soil nutrients in Plantation ecosystem

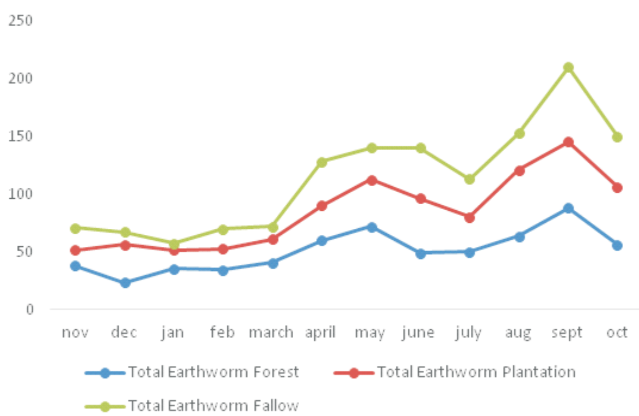

Figure 7. Monthly fluctuation of total earthworm in different sites.

investigation moisture content also showed high positive significant relationship with the population density of total earthworms in the reserve forest (r=0.39, P<0.05), fallow (r=.0.68, P<0.01) and plantation(r=0.39, P<0.05) at 0-10 cm soil layer (Table 1, 2 and3) indicating the importance of moisture for growth and survival of earthworm population. Rainfall together with relative humidity during rainy season leads to the increased in earthworm's population. Low rainfall and moisture content in winter season almost certainly decreased the population of earthworm which was clearly revealed from the result of the present investigation. Earthworm's population density is the result of the interaction of a number of factors of which moisture is of greater importance (Valle et al 1997). Dash and Patra (1977) reported that the other important factor affecting population density is temperature, and the temperature tolerance of earthworms depends to a great extent on soil moisture. The total earthworm density also showed high positive significant relationship with soil temperature in reserve forest (r=0.49.P<0.01), fallow (r=0.79, P<0.01) and plantation (r=0.51, P<0.01) at 0-10 cm soil layer complementing with previous records.

The soil organic C, N, P and K showed similar fluctuation pattern in all the study sites. High gain of soil organic carbon, N, P, and K may be due to higher decomposition rate of litter and availability of all superior micro-climatic conditions which might have enhanced the decomposition process during rainy period. The higher population density of earthworms in reserved forest as compared to fallow and plantation ecosystem may also be attributed to the consistent sustenance of organic C, N, P and K content in the reserved forest which had a direct influence on the availability of food sources of earthworms. Nitrogen content showed positive significant relationship with total earthworm density in the reserve forest(r=0.35, <P0.05), fallow (r=0.40, P<0.05) and plantation (r=0.37, P<0.05) ecosystems. The nitrogen or % organic carbon in soils greatly influences the distribution of earthworms and soils with low nitrogen content do not support earthworm population (Kale and Krishnamurthy, 1981).This was line with the present result. With phosphorus it showed an insignificant relationship at 0-10 and a negative significant relationship (r=-0.35, P<0.05) at10-20 cm soil layer in the reserve forest. However in the plantation (r=0.31, P<0.05) and fallow (r=0.38, P<0.05) ecosystems, phosphorus showed a positive significant relationship at 0-10 cm layer. At 10-20 cm soil layer in the plantation ecosystem, a very high positive significant relationship (r=0.44, P<0.01) was observed with total earthworm density even though no significant relationship could be observed at 0-10 and 10-20 cm soil layer in the fallow and plantation ecosystems.

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