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Population dynamics of earthworms in relation to soil physico-chemical parameters in agroforestry systems of Mizoram, India

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Abstract

Earthworm population dynamics was studied in two agroforestry systems in the tropical hilly terrain of Mizoram, north-east India, over a period of 24 months, from July 2002 to June 2004. Two sites of agroforestry situated at Sakawrtuichhun (SKT) and Pachhunga University College (PUC) campus, Aizawl, having pineapple as the main crop, were selected for detail studies on population dynamics. Five of the total twelve species of earthworm reported from the state were recorded in the study sites. The density of earthworm ranged from 6 to 243 ind.m^{-2} and biomass from 3.2 - 677.64 g.m^{-2} in SKT. Comparatively the density and biomass in PUC, which is at relatively higher altitude were lower with a range of 0 to 176 ind.m^{-2} and biomass from 0 - 391.36 g.m^{-2} respectively. Population dynamics of earthworm was significantly correlated with rainfall and physical characters of the soil. Earthworm biomass was significantly affected by rainfall and moisture content of the soil. The influence of chemical factors was relatively less.

Key words

Biomass, Earthworm, Population dynamics, Rainfall, Soil, Agroforestry systems

Introduction

Earthworms are known to constitute more than 80% of the soil invertebrate biomass in subtropical and tropical, as well as in temperate zones (Kale, 1997; Nainawat and Nagendra, 2001). Earthworms have the ability to improve soil physical structure, contribute to the breakdown of organic matter and release plant nutrients (Edwards and Bohlen, 1996). Type of vegetation is the major biotic factor which determines the distribution and diversity of earthworms of Mizoram (Ramanujam *et al.,* 2000). Different agro-based land use systems, a potential option for transformation of degraded lands into productive agricultural system, may affect the abundance and diversity of soil and litter fauna which in turn may restore the soil fertility and productivity.

Extensive literature is available on earthworm ecology in temperate regions (Edwards and Bohlen, 1996; Reynolds, 1995). However, relatively less work is done in the tropical regions (Kale, 1997; Tripathi and Bhardwaj, 2004). Only scanty reports are available on earthworm population from north-east India (Chaudhuri and Bhattacharjee, 1999; Halder, 1999, Chaudhuri *et al.,* 2008). Ramanujam *et al.* (2004) have reported 12 species of earthworms from Mizoram including one new species *Eutyphoeus mizoramensis* (Julka *et al.,* 2005). No comprehensive work has been carried out on their population dynamics in the tropical hilly agroforestry systems of Mizoram till date. Keeping the above facts in view, the present study aimed at understanding the relationship between rainfall and physico-chemical properties of soil on the population dynamics of earthworms in agroforestry systems of Mizoram.

Materials and Methods

Study dite: Mizoram, located in north-eastern India, lies between 21°56'N and 24°331'N latitude and 92°16'E and 93°26'E longitude. The state has international borders with Bangladesh in the west and Myanmar in the east and south. The hilly state has steep gorges with north-south trending mountains, covered with tropical and subtropical forest with an annual rainfall of 250 cm.

Two agroforestry based experimental plots were laid down. Experimental site-I was set up near Sakawrtuichhun (SKT) village, 20 km north-west of Aizawl, at an elevation of 650 msl situated at

92°40'E and 23°45'N and the slope varies from 40 to 65%. The soil is brown to dark brown in color with clay to clay loam in texture. The land is left fallow for four years and grasses like *Imperata cylindrica* and *Erianthus longisetosus* occupied the area before taking up for agroforestry plantation. Experimental site-II was situated within Pachhunga University College (PUC) campus, Aizawl situated at 92°44'E and 23°43'N, at an elevation of 825 msl and the slope varies from 50 to 67%. The soil is brown in color and sandy – clay loam. It was previously dominated by a grass, *Imperata cylindrica*, and few trees like *Schima wallichii, Albizia* sp. and *Sapium baccatum.* The adjacent site is covered by semi-dense forest. In both study sites, plants introduced were a hedge, *Leucaena leucocephala* (Hawaiian Giant), a horticultural plant - pine apple and a tree species – *Citrus reticulata*. Weeding was carried out manually when required using a hand hoe.

Earthworm sampling: Earthworms were collected in the morning hours from five random samples of 25×25×30 cm, at least 5 m apart at monthly (July 2002 to June 2004) intervals as per Tropical Soil Biology and Fertility Programme (Anderson and Ingram, 1993). The worms were segregated into age-wise and species-wise by hand sorting and wet sieving method. Density of earthworms was calculated as the number of individuals present per meter square. Biomass was determined on fresh weight basis (Dash and Patra, 1977). Monthly rainfall in the study areas was recorded throughout the study period.

Soil analysis: The soil samples were collected from three different strata (0-10, 10-20 and 20-30 cm depths) by digging 30 cm depth at the time of earthworm sampling (July 2002 to June 2004). The soils of different strata were thoroughly mixed, air-dried, ground and passed through sieves of fine mesh (0.2 mm) size (Ghosh *et al.,* 1983) and kept in plastic bag for further chemical analysis. Soil temperature was measured by using soil thermometer. The soil moisture content was calculated following Anderson and Ingram (1993). The samples were analyzed for organic carbon (Colorimetric method; Anderson and Ingram, 1993), pH (soil to water ratio of 1:2.5, Anderson and Ingram, 1993), available phosphorus (Brays method; Bray and Kurtz, 1945), available potassium (Flame photometer method; Stanford and English, 1949) and total nitrogen (Kjeldahl method; Jackson, 1962).

Statistical analysis: The co-efficient of correlation (*r*) was employed to find the relationship among earthworm density and biomass with rainfall and soil characteristics and the data were calculated using the statistical package SPSS version 7.5.

Results and Discussion

In general, it was observed that the seasonal variation of density followed a bimodal pattern both at SKT and PUC sites. Bimodal pattern in density have been reported in cultivated soils of Central Himalayas tarai region (Bisht *et al.,* 2003). Five species of

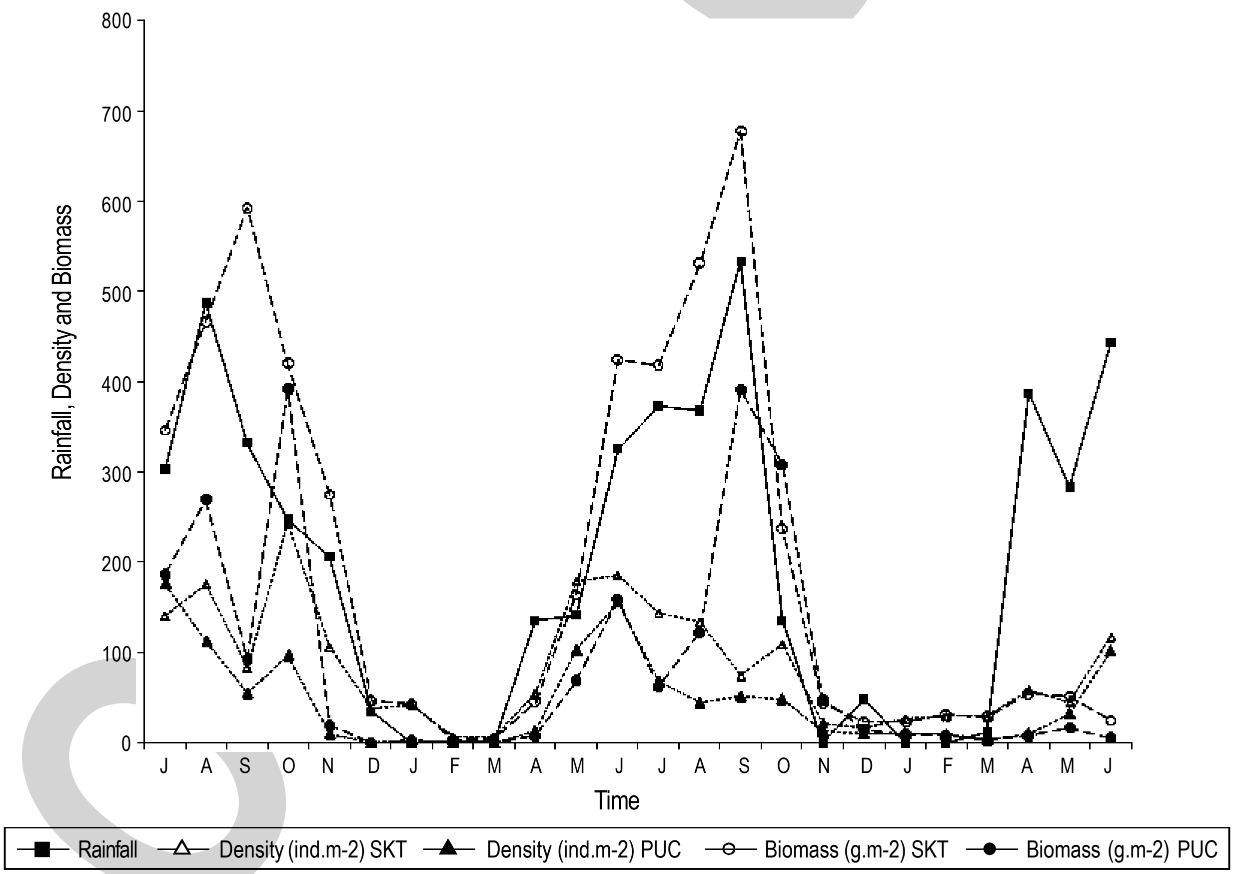

Fig. 1: Monthly (July 2002 - June 2004) variation in earthworm density and biomass with rainfall in (SKT) and (PUC)

Table - 1: Correlation coefficients (r) of earthworm density (ind.m^{-2}) and biomass (g.m^{-2}) with rainfall and soil physico-chemical variables

Soil parameters	Density (ind.m^{-2})		Biomass (g.m^{-2})	
	SKT	PUC	SKT	PUC
Rainfall	0.646**	0.735**	0.485**	0.375**
Soil temperature	0.482**	0.62**	0.091	0.111
Soil moisture	0.630**	0.562**	0.531**	0.508**
Soil pH	0.359	0.432*	0.309	0.242
Soil organic carbon	0.437*	0.211	0.192	0.281
Soil nitrogen	-0.022	-0.487**	0.074	0.122
Soil phosphorus	0.481**	0.284	0.335	0.017
Soil potassium	0.287	-0.192	0.362*	0.296
C/N ratio	0.262	0.538*	0.095	0.085

Level of significance *p<0.05 **p<0.01, SKT = Sakawrtuichhun, PUC = Pachhunga University College

earthworms were recorded from the two agroforestry sites. *Perionyx excavatus* Perrier*, Metaphire houletti* Perrier*, Eutyphoeus mizoramensis* Julka *et al*. and *Drawida* sp. were common to both sites, while *Perionyx macintoshi* Stephenson was restricted to PUC site. In the present investigation, besides plantations, many physical characteristics of soil were similar in the two study sites. Therefore, this may be the reasons for presence of similar species of earthworm in both study sites. The occurrence of *P. macintoshi* at PUC may be due to migration from nearby forest area.

The earthworm population dynamics with rainfall is presented in Fig. 1. The co-efficient of correlation (*r*) of worm density and biomass with rainfall and soil characteristics are presented in Table 1. The peak density of earthworms in SKT was in the month of October 2002 (243 ind.m^{-2}), whereas in PUC it was observed in July 2002 (176 ind.m^{-2}). The peak population density coincided with the high rainfall period. A positive correlation (p<0.01) between the rainfall and earthworm abundance was observed in both study sites. Similar observation was reported by other workers (Bhadauria *et al.,* 1997; Karmegam and Daniel, 2007; Joshi and Aga, 2009). The peak biomass of earthworm was observed in September 2003 (677.64 g.m^{-2}) in SKT and October 2002 (391.36 g.m^{-2}) in PUC. There are reports that the earthworm biomass was high in the rainy and early winter season, and low in summer (Kaushal and Bisht, 1994; Bisht *et al.,* 2003; Joshi and Aga, 2009).

Density and biomass in SKT were relatively higher compared to PUC. This may be attributed to soil type and differences in their nutrient contents. Earthworm community structure in an agro-ecosystem was reported to be determined by the soil type (Decaëns *et al.,* 2004), quantity and quality of organic matter added to the soil

Table - 2: Month-wise (July 2002 to June 2004) variations in density and biomass of earthworm population with soil physical factors

Year / Month	Temperature (°C)		Moisture (%)		Density (ind. m^{-2})		Biomass (g. m^{-2})	
	SKT	PUC	SKT	PUC	SKT	PUC	SKT	PUC
2002								
January	20.80±0.53	26.06±0.25	25.46±0.59	25.00±0	141	176	346.08	186.72
April	23.90±0.15	24.80±0.21	27.04±0.55	23.10±1.87	176	112	466.56	268.80
September	24.70±0.19	25.50±0.46	23.30±0.65	23.55±0.40	83	54.4	592.80	92.32
October	24.60±0.21	22.56±0.19	27.45±0.69	28.32±0.88	243	96	419.84	391.36
November	22.10±0.07	22.24±0.16	26.07±1.33	27.05±0.38	106	9.6	274.88	19.20
December	21.10±0.49	19.90±0.18	19.68±1.33	27.05±0.38	38	0	46.08	0
2003								
January	17.80±0.94	18.46±0.37	19.27±0.59	21.29±1.71	42	3	42.08	1.92
February	19.40±0.15	19.16±0.34	13.88±1.48	12.29±2.37	6	0	3.20	0
March	20.78±0.55	20.44±0.95	13.42±0.89	14.07±0.45	6	0	4.96	0
April	22.10±0.21	23.86±0.17	10.77±0.41	20.44±0.92	54	13	45.28	7.68
May	23.14±0.11	25.38±0.13	22.25±1.19	26.14±1.77	179	102	163.84	68.08
June	22.99±0.10	22.28±0.10	16.70±1.11	25.14±0.35	186	156	424.00	158.88
July	22.96±0.13	23.76±0.17	26.73±2.01	28.24±1.35	144	67	417.92	61.60
August	23.12±0.22	23.78±0.12	28.62±0.42	27.86±0.60	134	44	530.56	121.76
September	23.08±0.13	23.78±0.10	27.09±0.87	28.32±0.70	74	51	677.64	390.92
October	23.47±0.07	23.46±0.05	26.35±3.70	26.14±1.05	109	48	236.80	308.16
November	22.16±0.08	19.84±0.36	19.65±0.91	20.03±0.77	22	13	43.52	47.04
December	22.90±0.14	20.01±0.10	21.13±0.67	22.95±0.12	16	10	22.56	14.72
2004								
January	23.08±0.02	22.15±0.06	22.71±0.79	21.74±0.68	26	10	22.00	8.64
February	18.10±0.24	22.14±0.25	19.46±0.39	19.78±0.90	29	9	30.72	7.68
March	22.02±0.26	23.7±0.08	18.26±0.57	15.15±1.12	29	3	28.32	2.88
April	24.14±0.09	23.48±0.05	24.97±0.49	23.61±0.55	58	10	54.08	7.68
May	28.93±0.02	27.53±0.08	20.04±0.64	21.02±0.69	45	32	51.04	16.48
June	28.74±0.63	28.81±0.57	24.27±0.64	24.53±0.73	117	101	24.57	5.06

Values are mean±SE of 5 samples, SKT = Sakawrtuichhun, PUC = Pachhunga University College

Table - 3: Month-wise(July 2002 to June 2004) variations in density earthworm population with soil pH, organic carbon and nitrogen content

Year / Month	pH		Organic carbon(%)		Nitrogen (%)		Density (ind. m^{-2})	
	SKT	PUC	SKT	PUC	SKT	PUC	SKT	PUC
2002								
January	5.40±0.09	5.34±0.11	3.43±0.02	2.83±0.01	0.23±0	0.18±0	141	176
April	5.39±0.10	5.29±0.08	3.21±0.16	2.53±0.12	0.16±0	0.15±0	176	112
September	5.34±0.10	5.58±0.06	1.94±0.03	1.96±0.05	0.20±0	0.30±0.03	83	54.4
October	5.16±0.08	5.11±0.05	2.83±0.10	2.34±0.16	0.69±0.07	0.56±0.02	243	96
November	5.01±0.02	4.92±0.03	2.48±0.17	2.29±0.12	0.55±0.02	0.53±0.02	106	9.6
December	5.03±0.08	4.78±0.02	2.32±0.04	2.05±0.20	0.41±0.05	0.39±005	38	0
2003								
January	4.79±0.03	4.82±0.04	2.43±0.15	1.78±0.12	0.40±0.06	0.37±0	42	3
February	4.78±0.04	4.49±0.04	1.86±0.07	1.88±0.05	0.45±0.01	0.48±0	6	0
March	4.83±0.07	4.76±0.03	2.02±0.09	2.15±0.21	0.52±0.01	0.42±0.05	6	0
April	4.75±0.04	4.68±0.04	2.93±0.28	1.88±0.11	0.42±0.05	0.32±0.08	54	13
May	4.81±0.06	4.77±0.05	2.53±0.09	2.15±0.16	0.48±0	0.44±0	179	102
June	5.31±0.12	4.96±0.12	2.32±0.16	1.97±0.11	0.49±0.02	0.37±0.05	186	156
July	5.27±0.08	5.42±0.09	1.61±0.13	1.48±0.12	0.51±0	0.52±0	144	67
August	5.04±0.11	4.92±0.05	2.33±0.02	1.77±0.07	0.52±0.01	0.40±0.03	134	44
September	5.23±0.09	5.10±0.07	1.40±0.05	1.34±0.06	0.50±0	0.47±0.01	74	51
October	5.32±0.07	5.02±0.02	2.72±0.09	2.94±0.08	0.45±0	0.50±0	109	48
November	5.31±0.05	4.91±0.13	1.03±0.05	1.55±0.10	0.53±0	0.50±0	22	13
December	4.92±0.03	4.96±0.02	2.06±0.02	2.04±0.02	0.53±0	0.53±0.01	16	10
2004								
January	5.06±0.02	4.92±0.02	2.38±0.05	1.98±0.10	0.52±0.01	0.50±0.01	26	10
February	5.24±0.04	5.14±0.01	2.04±0.07	2.65±0.13	0.49±0	0.48±0	29	9
March	5.30±0.06	5.52±0.02	1.88±0.02	2.03±0.07	0.47±0	0.53±0	29	3
April	4.99±0.04	5.09±0.01	1.32±0.07	1.49±0.2	0.53±0	0.50±0.01	58	10
May	5.32±0.01	5.15±0.03	1.93±0.03	1.81±0.04	0.54±0	0.50±0	45	32
June	5.30±0.02	5.16±0.02	1.42±0.07	1.60±0.06	0.52±0.03	0.22±0.01	117	101

Values are mean±SE of 5 samples, SKT = Sakawrtuichhun, PUC = Pachhunga University College

(Lavelle *et al*., 1994). The differential response of density and biomass in SKT in the second year of study may be due to the higher density of smaller sized worms like *Drawida* sp. The type of species and density of earthworms determines the biomass. The biomass was greatly reduced in the second year of study in both the study sites. This sudden fall of biomass may be due to depletion in availability of food supply. Similar observations have been made by Bisht *et al.* (2003). It might also be due to lesser surface cover as a result of weeding and leaching. A sudden increase in biomass was observed in the month of June 2003 when the monsoon set in which may be attributed to the increased availability of food materials and higher moisture content of the soil following rains. Growth rates might have been enhanced by the higher food intake. It has been suggested that earthworms with more food availability gain weight faster than those with little or no supplementary food (Muldowney *et al*., 2003). Eriksen-Hamel and Whalen (2006) pointed out that increased soil moisture, temperature and microbial activity result in significant increased in growth rate of earthworms.

There was a seasonal variation in earthworm population in both study sites and peak density was observed during the monsoon season (May-Sep.) when both moisture content and temperature of soil were in relatively high range (Table 2). The average minimum and maximum soil temperature of SKT varied from 17.8°C±0.94 (Jan.'03) to 28.93°C±0.02 (May '04) with earthworm density 42 and 45 ind.m^{-2}, respectively. Likewise, PUC also showed soil temperature in the range of 18.46°C±0.36 (Jan.'03) to 28.81°C±0.57 (Jun.'04) with density 3 and 101 ind.m^{-2}, respectively. Soil temperature showed a significant correlation ($p<0.01$) with density. Temperature largely affects activity of earthworms in temperate regions. Tropical species can withstand higher temperatures. In tropical regions the temperature fluctuations are minimal when compared to temperate regions (Kale and Karmegam, 2010). According to earlier works (Bhadauria *et al.,* 1997,2000; Valle *et al.,* 1997) the total density and biomass of earthworm population were higher during the relatively higher temperature period. Similar pattern of population dynamics was observed in the present study. Curry (1998) opined that on a global scale, temperature is the climatic variable of greatest significance, because it determines metabolic rates and the diversity of food resources, but on a more local scale, moisture restriction often determines patterns of distribution and activity. The result of the present study reveals that *Drawida* sp. tolerates the winter months. This may be an adaptation to the low range of temperature in higher altitudes.

The density of earthworm increased along with parameters such as rainfall (Fig. 1) and soil moisture content (Table 2) in both study sites. Soil moisture content (%) was found to be highest in

Table - 4: Month-wise (July 2002 to June 2004) variations in density of earthworm population with C/N ratio, soil phosphorus and potassium content

Year / Month	C/N ratio		Phosphorus (kg ha^{-1})		Potassium (kg ha^{-1})		Density (ind. m^{-2})	
	SKT	PUC	SKT	PUC	SKT	PUC	SKT	PUC
2002								
January	14.83±0.72	15.72±1.09	63.61±2.19	37.63±3.03	131.04±1.28	73.72±2.96	141	176
April	19.22±0.72	16.87±0.95	86.01±10.73	26.88±5.10	114.24±2.98	67.20±2.22	176	112
September	9.48±0.60	6.14±0.83	51.96±11.23	34.04±7.02	134.40±2.54	57.12±3.32	83	54.4
October	4.29±0.54	4.17±0.33	16.07±3.82	12.97±2.93	181.44±4.60	90.72±3.35	243	96
November	4.71±0.47	4.32±0.34	30.91±3.70	37.18±3.03	161.00±2.11	102.48±1.05	106	9.6
December	6.72±0.45	5.94±0.30	23.74±2.51	23.74±4.44	112.56±1.05	97.08±1.05	38	0
2003								
January	7.30±0.88	4.87±0.43	22.40±2.12	21.5±3.75	112.50±1.03	100.79±2.11	42	3
February	4.11±0.23	3.93±0.19	13.88±1.76	9.83±1.64	179.20±15.23	106.40±5.00	6	0
March	4.00±0.29	5.11±0.22	44.08±3.70	26.81±5.69	184.80±7.37	135.68±16.10	6	0
April	6.05±0.27	5.87±0.37	43.90±8.41	26.42±11.09	225.36±22.92	167.45±11.04	54	13
May	5.27±0.17	4.88±0.38	37.17±5.99	19.70±2.68	276.64±33.50	140.00±11.04	179	102
June	4.73±0.21	5.05±0.29	26.87±1.63	13.44±3.0	141.94±8.54	85.49±6.42	186	156
July	3.16±0.28	2.85±0.26	47.78±1.64	16.67±2.41	173.07±15.16	85.74±5.14	144	67
August	4.50±0.19	4.42±0.28	17.36±1.50	35.83±2.50	138.06±9.86	70.30±2.36	134	44
September	2.85±0.15	2.85±0.08	14.93±2.27	13.44±1.82	162.14±17.44	131.93±17.82	74	51
October	6.04±0.14	5.88±0.14	19.9±1.93	15.18±1.85	133.94±11.19	152.69±5.27	109	48
November	3.08±0.10	3.10±0.16	10.45±1.97	7.21±2.52	91.46±8.31	70.94±2.37	22	13
December	3.98±0.05	3.98±0.18	8.71±1.31	10.69±2.32	42.68±3.39	61.34±3.77	16	10
2004								
January	4.58±0.10	3.97±0.28	15.18±1.85	4.48±1.12	128.17±19.53	25.14±1.27	26	10
February	4.17±0.15	5.52±0.21	11.44±1.99	14.68±0.99	145.00±12.38	79.63±4.50	29	9
March	4.48±0.07	3.83±0.12	9.70±1.49	8.96±1.82	105.65±7.53	83.00±5.46	29	3
April	2.54±0.16	3.23±0.32	15.43±1.31	21.14±3.07	92.71±4.50	66.07±3.35	58	10
May	3.57±0.09	3.62±0.12	16.41±1.52	20.81±1.18	111.75±5.66	61.84±4.16	45	32
June	3.27±0.11	7.61±0.11	16.92±1.67	10.7±1.57	44.05±2.44	65.95±2.90	117	101

Values are mean±SE of 5 samples

August 2003 (28.62±0.42) at SKT having earthworm density of 137 (ind.m^{-2}) and it was 28.32±0.70 in October 2002 at PUC with density 96 (ind.m^{-2}). Minimum soil moisture at SKT was recorded in April 2003 (10.77±0.41) with density 51 (ind.m^{-2}) and in PUC minimum moisture was recorded in February 2003 (12.29±2.37) when earthworms were not found. The density of earthworm in the present study is positively correlated ($p<0.01$) with the moisture content of the soil. Similar observations were made by many researchers (Aroujo and Hernandez, 1999; Baker, 1998; Tian *et al.,* 2000; Whalen *et al*., 1998). The fluctuation in the densities of different earthworm species seen along with changed in moisture content of soil in different months may be adaptation to the local conditions. Earthworm population density at a specific site is the result of the interaction of a number of factors of which moisture is of greater importance (Valle *et al*., 1997). The presence of earthworms of Mizoram which were found in the range of 10-28% of soil moisture seems to be better adapted for higher moisture content which may be attributed to higher rainfall in the region.

The seasonal variation in chemical parameters with earthworm density is presented in Table 3 and 4. Highest soil pH was observed in the month of July 2002 (5.40±0.09) in SKT; while in PUC, it was observed in September 2002 (5.58±0.06). Lowest pH in SKT and PUC (4.75±0.04 and 4.49±0.04 respectively) was observed in February 2003. A significant correlation ($p<0.05$) was observed between soil pH and earthworm density only in PUC. Edwards and Bohlen (1996) cited soil pH as a limiting factor on earthworm distribution. Most of the earthworms are neutrophilic, preferring a pH of 6.0-7.0 and the species diversity is drastically reduced at pH>7.0 except for tolerant species, which may be due to the fact that soil with pH considerably higher than 7.0 are mostly semiarid or arid and are unfavourable for earthworms (Sathianarayanan and Khan, 2006). The organic carbon content of soil (%) ranges from 1.32±0.07 (Apr.'04) to 3.43±0.02 (Jul.'02) at SKT and in PUC it ranges from 1.34±0.06 (Sept.'03) to 2.83±0.01 (Jul.'02). There was a significant correlation ($p<0.05$) between earthworm density and soil organic carbon in SKT. A positive correlation between earthworm density and the percentage of soil organic carbon have been reported by many workers (Brown *et al.,* 2003; Liu *et al.,* 2004; Scullion and Malik, 2000; Shuster *et al*., 2002; Tian *et al.,* 2000).

Soil nitrogen (%) was highest in the month of October 2002 (0.69±0.07 and 0.56±0.02) and lowest in August 2002 (*i.e.* 16±0 and 15±0) in both study sites. It was found that nitrogen has a significant negative correlation with earthworm density in SKT. This result suggests that the nitrogen alone may not be so important in governing the earthworm population; rather C/N ratio and other physico-chemical parameters are more influential. Edwards and Bohlen (1996) reported that application of nitrogen fertilizers caused adverse effects on earthworm populations. The C/N ratio recorded in SKT ranges from 2.54±0.16 (Apr.'04) to 19.22±0.72 (Aug.'02) and in PUC it ranges between 2.85±0.26 (Sep.'03) to 15.72±1.09 (Jul.'02). C/N ratio showed significant correlation ($p<0.05$) with earthworm density in PUC. Similarly, studies have shown that high earthworm density is associated with high C/N ratio (Kale, 1998; Sathianarayanan and Khan, 2006). In the present study, *Drawida* sp. showed a high tolerance to variation of C/N ratio and *M. houletti* was associated with lower C/N ratio.

The available phosphorus value of soil (kg ha^{-1}) recorded were from 8.71±1.31 (Dec.'03) to 86.01±10.73 (Aug.'02) at SKT and in PUC it ranged between 4.48±1.12 (Jan.'04) to 37.63±3.03 (Jul.'02). Phosphorus showed a significant correlation ($p<0.01$) with earthworm density in SKT. The studies on fallows made by Tian *et al.* (2000) and Suárez *et al.* (2003) suggest that earthworms significantly increased the amount of readily exchangeable phosphorus in the soil.

Available potassium of soil (kg ha^{-1}) ranged between 42.68±3.39 (Jan.'04) and 276.64±33.5 (May '03) in SKT while in PUC it was from 25.14±1.27 (Jan.'04) to 167.45±11.04 (Apr.'03). Among soil chemical parameters, only available potassium showed a significant correlation ($p<0.05$) with earthworm biomass in SKT (Table 1). Reddy and Pasha (1993) observed a coincidence of the peak level of available potassium and high earthworm density. Thus the dynamics of nutrients like phosphorus and potassium are influenced by the density and biomass of earthworm in agroforestry systems.

It may be suggested from the present study that the synergistic effect of soil physical parameters in plantations of both agroforestry sites had relatively more influence on abundance and population dynamics of earthworms as compared to that of the chemical components.

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