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Impact of Heavy Metals and other Edaphic Factors on Oribatid Population at a Forest Floor in an Urban Area

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ABSTRACT

Sampling was conducted for three years at a bird sanctuary located near the metropolitan township of Kolkata. Largest group of soil acarines and microarthropods as well was oribatid mites which was separately studied. Negative effect of lead and zinc on soil oribatid population was significant ($p<0.05$) while the effect of copper appeared to be not significant. Positive roles of organic carbon and soil moisture on abundance or oribatids were also conspicuous at the sampling site while the impact of soil temperature and pH remained statistically insignificant ($p>0.05$).

Keywords Oribatid mites, Edaphic factors, Heavy metals, Soil.

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INTRODUCTION

Oribatid mites (having respiratory pores or stigmata hidden in their joints of legs or in coxal region) are often observed to be the most abundant group among soil dwelling microarthropods (Petersen and Luxton 1982, Lamoncha and Crossley 1998, Moitra et al. 2012b, Sarkar et al. 2016, Moitra et al. 2018). They occur in higher densities in forest soils and among forests, their density was reported to be higher in acid moder forests up to 300,000/m^2, (Weigmann et al. 1989) than in calcareous mull forest 20,000/m^2, (Maraun and Scheu 2000). In general, their density in forest may range from 50,000/m^2 to 500,000/m^2 (Coleman et al. 2004). Most of the oribatid species live in soil (Bernini 1990). Oribatids are mostly fungivorous, however, they may also subsist on leaf litter, plant tissues, organic debris, algae, moss, lichen, nematodes and nematode eggs (Luxton 1979, Ramani and Haq 1991, Haq and Konikkara 1988, Crossley and Coleman 1999, Ramani 2007). Population abundance soil oribatids are generally observed to vary in relation to various physico-chemical factors (Coleman et al. 2004, Chitrapati and Singh 2006, Tripathi et al. 2007, Moitra et al. 2012a, 2012b, Moitra 2013).

The present work was taken up to address the dearth of information on the ecology of soil oribatids in the edaphic environments of a forest grown around a metropolitan township and is exposed to the pollution and other disturbances of its surroundings.

MATERIALS AND METHODS

Sampling was conducted for three years from 2007

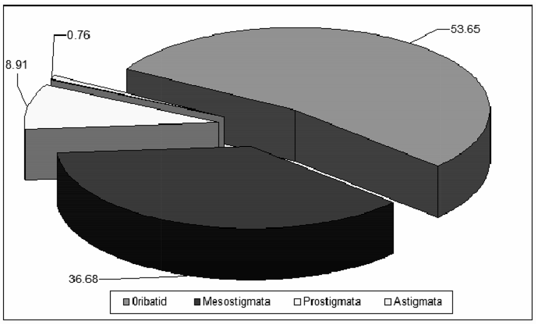

Fig. 1. Relative abundance of mite groups (% on total mite population) at the sampling site.

to 2009 with an interval of thirty days. Stainless steel cores with 5 cm diameter were used and 15 cm depth of soil profile was sampled from 5 sub-plots of $1m^2$ area (Dhillon and Gibson 1962, Lamoncha and Crossley 1998). Tullegren funnel apparatus modified by Macfadyen (1953) was used for extraction, 70% alcohol was used for preservation of extracted microarthropods. Sorting was done with needles and fine camel hair brush. Standard methods were adopted for the estimation of edaphic factors. The sampling site - Chintamani Abhyaranya sanctuary (was located at South Kolkata near Narendrapur Ramkrishna Mission. *Adina* sp. (Rubiaceae), *Dalbergia* sp. (Papilionateae), *Tamarindus* sp. (Leguminosae), *Saracaindica* (Annonaceae), *Terminalia arjuna* (Combretaceae) comprised the major vegetation of the site. Soil was brown in color and loam in texture. Data obtained were logarithmically transformed (base e) as per necessity of the parametric statistical analyses (Gerard and Berthet 1966).

Table 1. Descriptive data on population density of oribatid mites at the sampling site.

Mean	Median	TrMean	StDev	SE Mean
2404	2133	2375	1086	181
Minimum	Maximum	Q1	Q3	
815	4604	1434	3255	

RESULTS AND DISCUSSION

Oribatid mites constituted more than half (53.65%) of the mite population and mesostigmatids were also abundant constituting more than 36% of mite population. Prostigmata shared nearly 9% while Astigmata was only 0.74% (Fig. 1). The density exhibited a range from 814.54 individuals /m^2 to 4604.44 individuals /m^2 with a mean of 2403.72 ± 181.02 individuals /m^2 (Table 1) . Monthly abundance reached the peak during the month of September-October and declined to lowest during April-May as observed in the three years span of collection (Fig. 2). Seasonal Variation of abundance was statistically significant (Table 2).

In the current work, seasonal and monthly population abundance of soil oribatids, tended to increase during the monsoon or post-monsoon declined in the summer or pre-monsoon season. This is in agreement

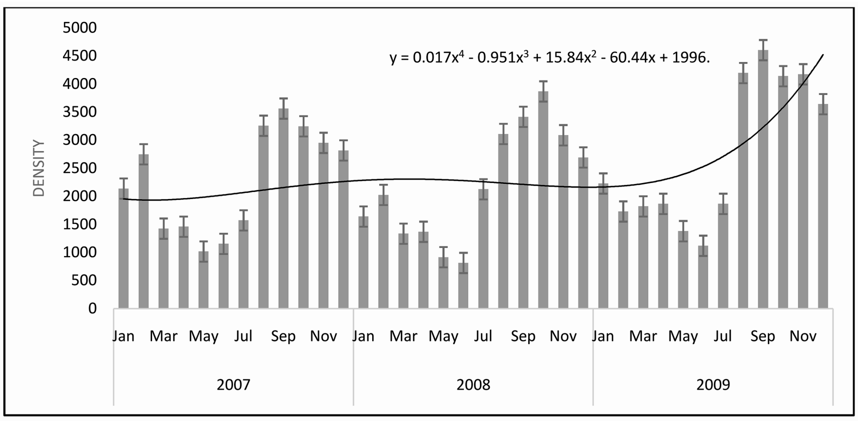

Fig. 2. Fluctuation of population density of oribatid mites at the sampling site.

Table 2. ANOVA for seasonal abundance (mean number of individuals per sample) of soil oribatid mites at Site-IV. DF = Degree of Freedom, SS = Sum of square, MS = Mean square, F = F statistics, StDev = Standard deviation, Cls = Confidence Intervals, W = Winter, S = Summer, M = Monsoon, A =Autumn. [Individual confidence intervals given in dotted line indicate (with 95% confidence) the probable range of occurrence of the mean. The asterix in the middle of the line marks the present mean. The ranges of mean within parentheses not overlapping implies that those means are different].

Analysis of Variance

Source	DF	SS	NS	F	P
Factor	3	5.8965	1.9655	27.76	0.000
Error	32	2.2659	0.0708		
Total	35	8.1624			

Level	N	Mean	St Dev	Individual 95% CIs For Mean Based on Pooled St Dev
				--------------+--------------+-------------------+-----------
W	9	5.1001	0.2275	(- - - - * - - -)
S	9	4.6618	0.2565	(- - - - * - - -)
M	9	5.5494	0.3713	(-------*------)
A	9	5.6940	0.1667	(- - - * - - - -)
				----------------+-------------+-------------------+-------------
Pooled St Dev	=	0.2661		4.80 5.20 5.60

with several observations made in West Bengal and India as well (Hazra and Sanyal 1989, Ghatak and Roy 1991, Hazra 1991, Singh and Yadava 1998, Chitrapati and Singh 2006, Devi and Singh 2006). Oribatids, in the alluvial soil, which was also a feature of the study area, population maxima and minima were observed during July - August and April-May respectively (Sheela and Haq 1991). In laterite soil, a pre-monsoon (May-June) minima and a post-monsoon peak (September-October) were reported by Bhattacharya and Raychoudhuri (1979).

Soil temperature and pH did not exhibit significant correlation with the abundance. Positive correlation was observed for organic carbon and soil moisture while lead and zinc exhibited strong negative correlation ($p<0.01$). No significant correlation was observed for copper (Table 3). The slopes of regression lines were negative for temperature, lead and zinc and positive for others. The adjusted R^2 showed a range from 0 (pH and copper) to 39.2% (organic carbon) (Figs. 3-9). In multiple regression analysis, ANOVA revealed that the model estimated by the regression procedure is significant ($p<0.01$).Probability values (of t-tests) for the estimated coefficients of the factors however indicated relatively low individual

Table 3. Correlation analysis between the abundance of oribatid mites (individuals/ month) and the physico-chemical parameters at Site-IV. OR = Number of oribatid mite, T = Soil temperature, M = Soil moisture, OC = Organic carbon, pH = Soil pH, Pb = Lead, Zn = Zinc, Cu = Copper, * = Significant correlation.

	OR	T	M	OC	pH	Pb	Zn
T	-0.319						
0.058							
M	**0.502***	-0.174					
	0.002	0.310					
OC	**0.640***	-0.246	**0.603***				
	0.000	0.149	0.000				
pH	0.108	0.107	0.264	0.172			
	0.530	0.535	0.120	0.317			
Pb	**-0.418***	0.180	**-0.452***	**-0.343***	-0.299		
	0.011	0.292	0.006	0.041	0.076		
Zn	**-0.383***	**0.395***	-0.069	**-0.404***	0.080	0.253	
	0.021	0.017	0.689	0.014	0.642	0.137	
Cu	0.115	-0.140	**-0.403***	-0.173	-0.277	0.299	0.115
	0.503	0.416	0.015	0.313	0.103	0.077	0.504

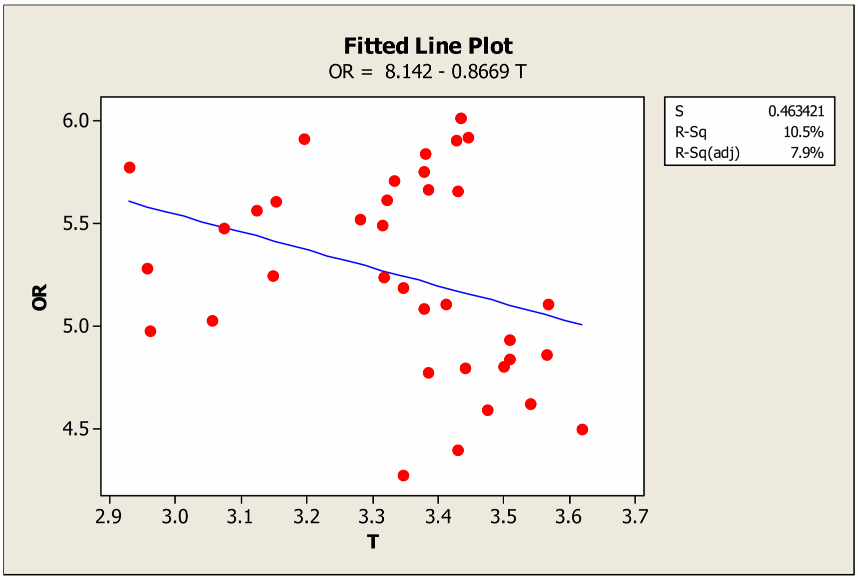

Fig. 3. Regression line for the population abundance of oribatid mites and the soil temperature Site-IV. (S = Standard distance of data values from regression line. R-Sq = Coefficient of determination. R-Sq (adj) = Coefficient of determination adjusted for the number of observations. OR = Oribatid mite. T = Soil temperature).

impact on the magnitude of variance of population abundance of oribatids. Only copper exhibited significant impact on the fluctuation. They collectively however might explain up to 61% variance of the

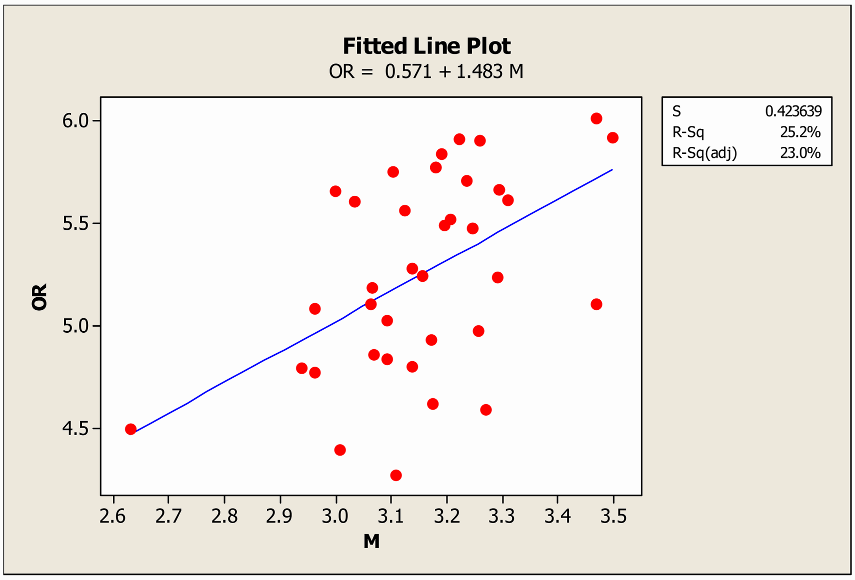

Fig. 4. Regression line for the population abundance of oribatid mites and the soil moisture at Site-IV. (S = Standard distance of data values from regression line. R-Sq = Coefficient of determination. R-Sq (adj) = Coefficient of determination adjusted for the number of observations. OR = Oribatid mite. M = Soil moisture.

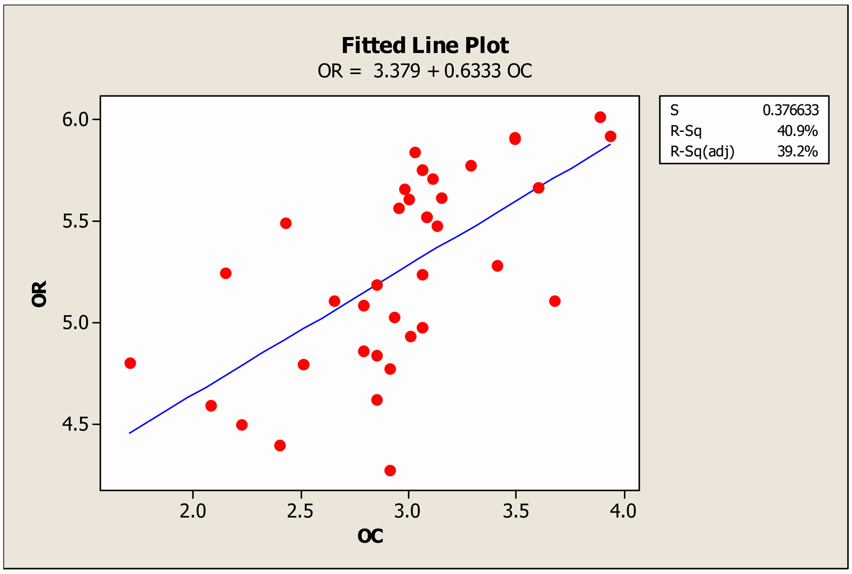

Fig. 5. Regression line for the population abundance of oribatid mites and the Organic carbon at Site-IV. (S = Standard distance of data values from regression line. R-Sq = Coefficient of determination. R-Sq (adj) = Coefficient of determination adjusted for the number of observations. OR =Oribatid mite. OC = Organic carbon).

abundance of oribatids as the R^2 value indicated. The R^2 value, adjusted for the number of predictors was 51.2%. ANOVA indicated that the regression model was statistically significant (Table 4).

Sengupta and Sanyal (1991), Sanyal et al. (1999),

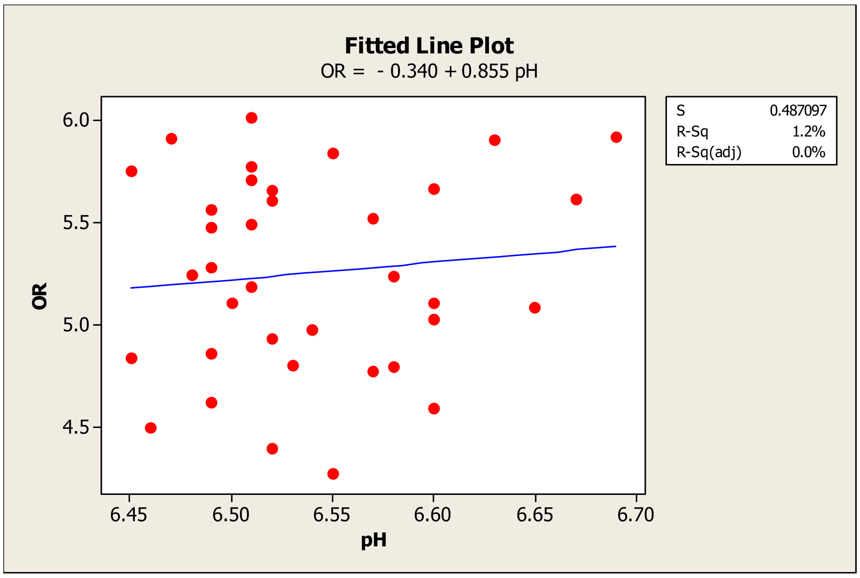

Fig. 6. Regression line for the population abundance of oribatid mites and the Soil pH at Site-IV. (S = Standard distance of data values from regression line. R-Sq = Coefficient of determination. R-Sq (adj) = Coefficient of determination adjusted for the number of observations. OR = Oribatid mite. pH = Soil pH).

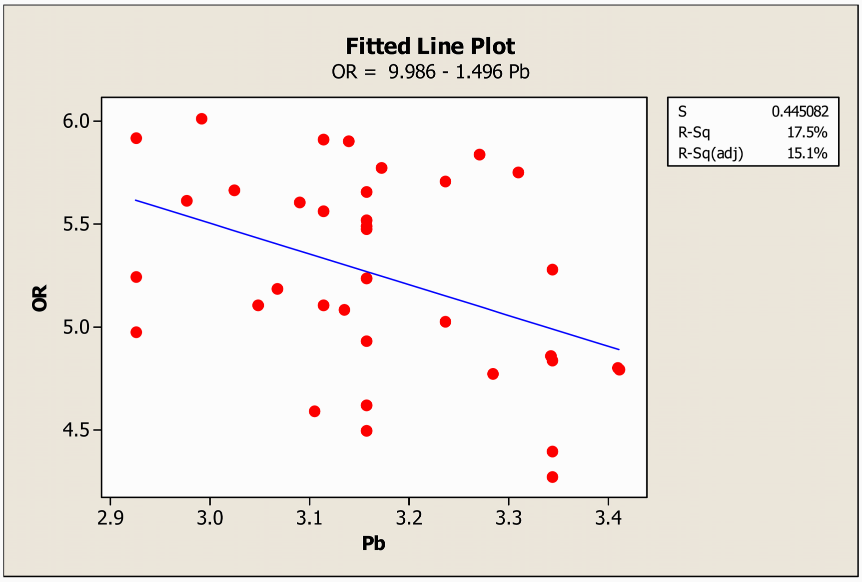

Fig. 7. Regression line for the population abundance of oribatid mites and the lead concentration at Site-IV. (S = Standard distance of data values from regression line. R-Sq = Coefficient of determination. R-Sq (adj) = Coefficient of determination adjusted for the number of observations. OR = Oribatid mite. pb = Lead).

Roy et al. (2004) earlier reported negative effect of edaphic temperature on population abundance of oribatid mites while statistically significant positive correlation between the abundance and the soil moisture as observed in the present work was in conformity to a few studies attempted by the workers like Choudhuri

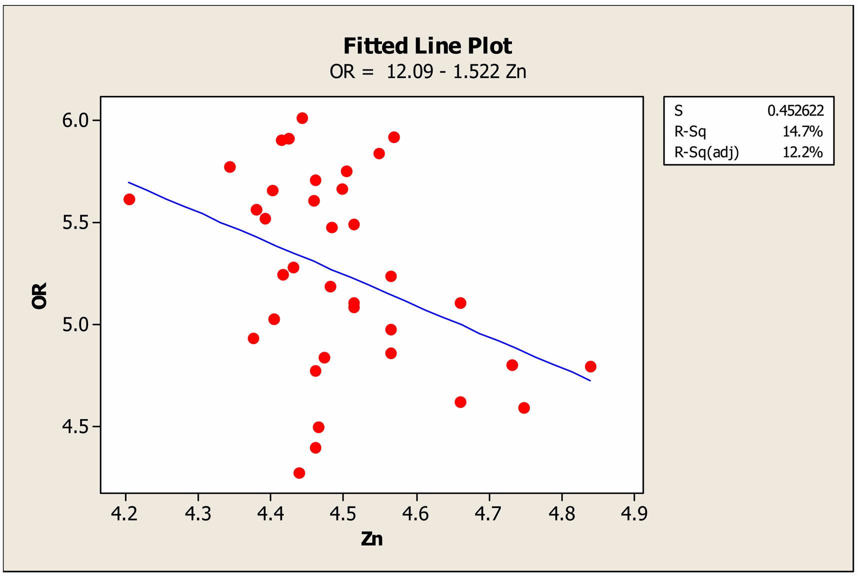

Fig. 8. Regression line for the population abundance of oribatid mites and the lead concentration at Site-IV. (S = Standard distance of data values from regression line. R-Sq = Coefficient of determination. R-Sq (adj) = Coefficient of determination adjusted for the number of observations. OR = Oribatid mite, pb = Lead).

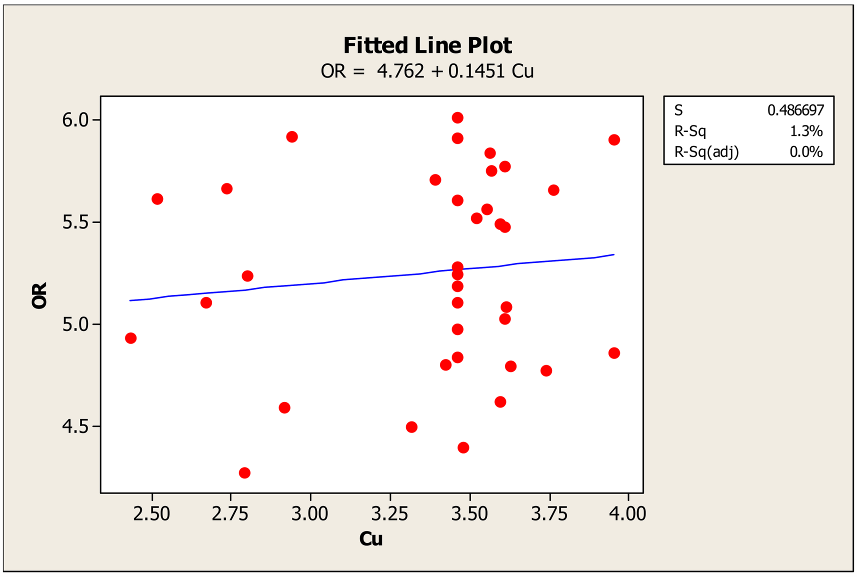

Fig. 9. Regression line for the population abundance of oribatid mites and the copper concentration at Site- IV. (S = Standard distance of data values from regression line. R-Sq = Coefficient of determination. R-Sq (adj) = Coefficient of determination adjusted for the number of observations. OR = Oribatid mite. Cu = Copper).

and Pande (1979), Bhattacharya and Raychoudhuri (1979), Joy and Bhattacharya (1981), Sanyal (1982). Sheela and Haq (1991), Sanyal (1996), Sanyal et al. (1999). Singh and Yadava (1998), Chitrapati and Singh (2006) observed positive impact of moisture in Manipur. The same was reported by Tripathi et

Table 4. The result of multiple regression analysis taking the monthly abundance of soil oribatid mites as response and the selected edaphic factors as the predictors at Site-IV. OR = Number of oribatid mites/month, T= Soil temperature, M = Soil moisture, OC = Organic carbon, pH = Soil pH, Pb = Lead, Zn = Zinc, Cu= Copper, S = Standard distance of data values from regression line. R-Sq = Coefficient of determination, R-Sq (adj) = Coefficient of determination adjusted for the degree of freedom, P = p value of the tests, DF = Degree of freedom, SS =Sum of square, MS = Mean square, F = F statistics.

The regression equation is
OR = 4.06 - 0.012 T + 1.03 M + 0.332 OC + 0.23 pH - 0.723 Pb - 0.872 Zn + 0.512 Cu

Predictor	Coef	SE Coef	T	P
Constant	4.056	7.268	0.56	0.581
T	-0.0125	0.3661	-0.03	0.973
M	1.0310	0.5286	1.95	0.061
OC	0.3318	0.1678	1.98	0.058
pH	0.227	1.030	0.22	0.827
Pb	-0.7232	0.5069	-1.43	0.165
Zn	-0.8720	0.6004	-1.45	0.157
Cu	0.5118	0.1768	2.89	0.007
S = 0.3372	R - Sq = 61.0%		R - Sq (adj) = 51.2%	

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	7	4.9790	0.7113	6.26	0.000
Residual Error	28	3.1834	0.1137		
Total	35	8.1624			

al.(2007) at Thar Desert, Rajasthan.

Organic carbon exhibited significant positive correlation with the population abundance of oribatid mites. This observation does not deviate from those of previous works conducted in West Bengal and from other places as well (Choudhuri and Pande 1979, 1981,1982, Bhattacharya and Raychoudhuri 1979, Joy and Bhattacharya 1981, Sanyal 1982, Sanyal et al. 1999, Roy et al. 2004, Ghosh and Roy 2004, Chitrapati and Singh 2006, Tripathi et al. 2007, Moitra et al. 2012a).

pH exhibited varying effects in previous instances some of which were not statistically significant as observed in the current work (Choudhuri and Pande 1979, 1981, 1982, Bhattacharya and Raychaudhuri 1979, Sanyal et al. 1999, Ghosh and Roy 2004, Tripathi et al. 2007, Moitra et al. 2012a). Though many species of oribatid mites may reach high density at low pH, a few acidophilic species have been reported to exhibit better reproduction in pH near neutral range (Hågver and Abrahamsen 1980, 1990, Maraun and Scheu 2000, Huhta and Räty 2005).

Significant negative impact of lead and zinc on soil microarthropod population including oribatids, as been observed in the current work, was reported workers like Chattopadhyay and Hazra (2000) , Gergocs and Hufnagel (2009), Moitra (2017). Greater accumulation of zinc followed by lead was reported by El-Sharabasy and Ibrahim (2010). Gergocs and Hufnagel (2009) observed that lead was the most effective heavy metal havinf negative effect on cryptostigmatids. Copper did not render statistically significant effect on the abundance of oribatids in the current study which substantiate the observations of Holmstrup et al. (2007), Eeva and Penttinen (2009) who reported relatively greater tolerance of oribatids to copper concentration. Detrimental role of copper in relation to the abundance of soil acarines however was reported from West Bengal by Hazra and Choudhuri (1990), Chattopadhyay and Hazra (2000). van Straalen et al. (2001), Köhler et al. (2005) however opined that the oribatid mites are relatively tolerant to the heavy metal accumulation while Caruso et al. (2009) observed that lead, zinc and copper may render any direct effect on the distribution of oribatids.

In the current work,detrimental effect of lead and zinc on soil oribatid population was conspicuous while the effect of copper appeared not significant. Positive roles of organic carbon and soil moisture on abundance or oribatids were also comprehensible at the sampling site while the impact of soil temperature and pH remained insignificant. The outcome of the study however, is a manifestation of a complex interrelation of several biotic and abiotic factors influencing the edaphic dynamics many of which might have been left out of the scope of the present work and it therefore, appears to necessary to conduct extensive study involving other factors for better understanding of the ecology of edaphic habitats of the site and ensure its protection.

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