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Effect of Physico-chemical Parameters on Earthworm Abundance: A Quantitative Approach

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Abstract: Data on the abundance of earthworms, collected from a three year study (1997-1999) at ten sites in Dindigul District, Tamil Nadu, South India were correlated with soil physico-chemical parameters such as pH, electrical conductivity (EC), nitrogen (N), organic carbon (OC), soil temperature (ST), soil moisture (SM), humidity (HU) and rainfall (RF). The contribution of each selected parameter to variation in abundance of each earthworm species was determined using multiple correlation. The analysis showed that the contribution of soil nitrogen to the abundance of *Dichogaster saliens, Drawida paradoxa, Lampito kumiliensis* and *Pontoscolex corethrurus* ranged from 34 to 48% and in the case of *Dichogaster bolaui, Drawida chlorina, D.pellucida pallida* and *Octochaetona thurstoni,* the contribution ranged from 62 to 87%. A total of about 80% of the variance of earthworm abundance on the observed parameters is explicable. This is an attempt made to measure quantitatively the influence of various physico-chemical parameters on earthworm population at species level.

Keywords: Correlation analysis, earthworm population, soil moisture, soil temperature, soil nitrogen, soil organic carbon.

INTRODUCTION

Earthworms are fundamental to the dynamics of an ecosystem. Both physical and organic factors of soils have been known to influence the abundance and distribution of earthworms[1]. The establishment of earthworm population in an ecosystem not only depends on the above factors but also on their reproductive potential and the ability to disperse(2). In India, studies on the ecology of earthworms are fragmentary and insufficient[3,4,5,6,7,8,9,10,11]. Only very few reports are available on earthworms in the Sirumalai Hills and in the adjacent plains of Dindigul District, Tamil Nadu, South India[12,13,14]. These studies mainly focused on the influence of various physico-chemical parameters on the population dynamics and biomass of earthworms, but the multiple correlation studies and the contribution of each soil parameter on earthworm abundance have not been done. Therefore an attempt has been made in the present study to quantify statistically the effect of selected physico-chemical parameters on the population density of earthworms.

MATERIALS AND METHODS

Survey and Collection of Earthworms: The survey was carried out during 1997-1999 and was restricted to a few sites in Gandhigram Rural Institute (GRI), Gandhigram, and the Sirumalai Hills (Table 1). The Sirumalai Hills (Eastern Ghats) is situated in Dindigul District of Tamil Nadu, South India, and the hill range lies between 10° 00' and 10°30' N latitude and 77°33' and 98°15' E longitude. The adjacent plains, including GRI, are covered by different types of habitats. The habitats selected for the study in the Sirumalai Hills are located eastward from a small village named Sirumalaiputhur. The samplings of earthworms were done at regular monthly intervals from a total of eight quadrats of 25 cm x 25 cm x 30 cm per sampling site per sampling occasion and the soil core was dug out and the worms were hand-sorted[15]. The worms were preserved in 5-10 percent formalin solution[16] and sent for identification to the Indian Oligochaetologist Dr.J.M.Julka, Solan, Himachal Pradesh.

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Table 1: Habitats explored for the study of earthworm population

Sl. No.	Sampling region	Site description
I.	Plains (GRI)	1. Irrigated crop land
		2. Rainfed crop land
		3. Shaded fallow land with tree plantation
		4. Fallow land without trees
		5. Garden
		6. Orchard
II.	Hills (Sirumalai)	7. Foothills (Alt. <450 m.)
		8. Grass land (Alt. 1,000 m.)
		9. Semi evergreen forest (Alt. 1,100 m.)
		10. Sacred grove land (Alt. 1,300 m.)

Analysis of Physico-chemical Parameters: On each sampling occasion, the soil from each quadrat was collected in polythene bags, numbered and taken to the laboratory for the analysis of moisture content, pH, electrical conductivity (EC), organic carbon and total nitrogen. Soil pH and EC were measured using 1:5 soil water (distilled) suspension in Systronic pH meter and conductivity bridge respectively. Organic carbon was estimated by Walkey and Black method[17] and the total nitrogen content was analysed by microkjeldhal method[18]. The moisture content was found out by keeping fresh soil samples in an oven at 105°C until getting constant weight.

The data on rainfall, humidity and monthly average atmospheric temperatures were obtained from the Meteorology Center, GRI, Gandhigram and the District Sericulture Center, Sirumalaiputhur, for the plains and the hilly regions respectively. The soil temperature (10 cm below the soil) was found out using soil thermometer on all the sampling occasions.

Statistical Analysis: Correlation analyses were carried out using the software Microcal Origin (version 3.5). The goodness of the fit was discussed using correlation coefficient (R), coefficient of multiple determination (R^2) and standard deviation (sd). In a multiparameter equation each parameter indicates a specified effect on the observed property. This effect and its significance may be quantified by estimating the percentage contribution of the parameter to the observed property.

Many experiments in elementary science are concerned with the effect on a dependent variable Y of changes in an independent variable X, i.e., there is a cause and effect relationship of X to Y. In this event we plot the graph of Y against X and if the overall pattern of the points seem to agree with the linear relationship Equation 1:

$$Y = mX + c \qquad (1)$$

where 'm' is the slope of the line and 'c' is the intercept on the Y axis. On the other hand, if the scatter seems out of all proportion to the likely experimental error, then it is supposed that there is some complicating factor, possibly another independent variable which is influencing Y. Thus, the multiple linear regression of a dependent variable Y with a series of explanatory variables X_1, X_2, X_3, etc. in Equation 2 raises the question of significance in an acute form:

$$Y = m_1 X_1 + m_2 X_2 + m_3 X_3 + \ldots\ldots\ldots\ldots + c \qquad (2)$$

Attempts have been made to correlate the abundance of earthworm population (EWP) with various physico-chemical parameters in order to quantify and rationalize their effects on the existence of earthworms. The various physico-chemical parameters of the soil used as explanatory variables for better understanding are pH, electrical conductivity (EC), nitrogen content (N), organic carbon (OC), soil moisture (SM), soil temperature (ST), humidity (HU) and rainfall (RF). In the present study these physico-chemical parameters have been divided into two groups, namely, the chemical parameters such as pH, electrical conductivity, organic carbon and nitrogen and the climatic parameters such as soil moisture, soil temperature, humidity and rainfall.

Table 2: Occurrence of earthworm species as a function of different habitats.

Earthworm (FAMILY/*Species*)	Study site									
	1	2	3	4	5	6	7	8	9	10
MEGASCOLECIDAE										
Lampito kumiliensis (Kinb.).	-	-	-	-	-	-	-	+	+	+
Lampito mauritii (Kinb.).	+	+	+	+	+	+	+	-	-	-
Megascolex insignis Mich.	+	-	-	-	+	-	-	-	-	-
OCTOCHAETIDAE										
Dichogaster bolaui (Mich.).	-	-	-	-	-	-	-	-	+	-
Dichogaster saliens (Bedd.).	-	-	-	-	-	-	-	+	-	+
Octochaetona thurstoni Mich.	-	+	+	-	+	-	-	-	-	-
MONILIGASTRIDAE										
Drawida chlorina (Bourne).	+	+	+	+	+	+	+	-	-	-
Drawida paradoxa Rao.	+	-	-	-	-	-	-	-	-	-
Drawida pellucida var. *pallida* Mich.	+	+	+	+	+	+	+	-	-	-
GLOSSOSCOLECIDAE										
Pontoscolex corethrurus (Muller)	-	-	-	-	-	-	-	+	+	+

\+ Present; - Absent

The correlation of population values of all the earthworm species studied, with individual chemical parameters, in the form of Equation 1, is not satisfactory (correlation coefficient is less than about 0.4). Such a poor correlation indicates that no single chemical parameter would sufficiently explain the existence of earthworm population. So the population data were subjected to multiple regression analysis in the form of Equation 2. The correlation results were obtained for all the species at different locations.

Parallel to the correlation of EWP with a single chemical parameter, the correlation of EWP with a single climatic parameter is also not quite satisfactory. Hence, the EWP data were analysed using multiple regression equation in the form of Equation 2. The percentage contribution of a parameter to the total effect was calculated as described in the literature[19].

RESULTS AND DISCUSSIONS

A total of ten earthworm species belonging to four families, namely, Megascolecidae (three species), Octochaetidae (three species), Moniligastridae (three species) and Glossoscolecidae (one species) were studied from different locations as indicated in Table 2. The results discussed below are based on the available data with additional data collected during the subsequent years[12,13,14].

The multiple correlation results were obtained for all the species at different locations from which the contribution of each variance to the earthworm abundance was established. Since the results are similar, only a representative data for the species *Drawida chlorina* at Site 7 is given in Equations 3-6.

- $EWP = - 6.540\ pH - 13.291\ EC + 51.807$ (3)
  $N = 36, R = 0.277, R^2 = 0.077, sd = 3.17$
- $EWP = 2.760\ OC + 68.091\ N - 35.818$ (4)
  $N = 36, R = 0.907, R^2 = 0.823, sd = 1.381$
- $EWP = 2.724\ OC + 66.286\ N - 1.962\ pH - 21.645$ (5)
  $N = 36, R = 0.910, R^2 - 0.829, sd = 1.39$
- $EWP = 2.712\ OC + 69.223\ N - 1.986\ pH - 5.257\ EC - 24.397$ (6)
  $N = 36, R = 0.911, R^2 = 0.830, sd = 1.40$

For all the species studied at different locations, there exists a satisfactory correlation between the population values and the chemical parameters. From the magnitude of the coefficients of the various terms the percentage contributions of the chemical parameters to the observed population values were calculated and the results are given in Table 3. For all the species investigated, the sign of the coefficients of pH and EC are negative and this observation indicates that the EWP indirectly depends on these two parameters, i.e., with increase in pH or EC the EWP decreases. The positive sign of the coefficients of N and OC indicates that the EWP directly depends upon these two parameters. Values in

Table 3: Contribution of various chemical parameters to earthworm abundance.

Species Name	Equation used[A]	Chemical Parameters (Percentage contribution)[B]			
		pH	EC	OC	N
1. *Dichogaster bolaui*	(3)	13.69	86.45	-	-
	(4)	-	-	2.81	95.01
	(5)	0.27	-	5.05	94.68
	(6)	0.71	21.29	3.67	74.33
2. *Dichogaster saliens*	(3)	12.97	87.04	-	-
	(4)	-	-	7.03	92.42
	(5)	20.56	-	12.73	67.28
	(6)	7.70	53.18	4.77	34.36
3. *Drawida chlorina*	(3)	31.89	68.11	-	-
	(4)	-	-	4.22	95.78
	(5)	12.61	-	3.95	83.44
	(6)	8.97	25.88	2.60	62.55
4. *Drawida paradoxa*	(3)	14.10	85.90	-	-
	(4)	-	-	16.47	83.53
	(5)	26.08	-	17.98	55.95
	(6)	7.29	53.00	0.61	39.11
5. *Drawida pellucida pallida*	(3)	26.67	70.33	-	-
	(4)	-	-	5.01	95.00
	(5)	9.14	-	5.24	85.61
	(6)	5.40	19.90	2.32	72.37
6. *Lampito kumiliensis*	(3)	11.05	88.95	-	-
	(4)	-	-	5.95	95.05
	(5)	18.76	-	12.38	63.02
	(6)	7.45	45.87	2.24	41.80
7. *Lampito mauritii*	(3)	35.40	64.60	-	-
	(4)	-	-	4.52	95.48
	(5)	9.97	-	4.70	85.32
	(6)	7.68	29.12	3.49	59.71
8. *Megascolex insignis*	(3)	22.23	77.78	-	-
	(4)	-	-	5.54	94.46
	(5)	4.62	-	5.16	90.22
	(6)	5.87	37.34	1.69	55.12
9. *Octochaetona thurstoni*	(3)	27.06	73.07	-	-

Table 3: Continued

	(4)	-	-	4.27	95.74
	(5)	5.53	-	3.91	90.56
	(6)	5.23	4.01	3.76	87.01
10. *Pontoscolex corethrurus*	(3)	12.34	87.66	-	-
	(4)	-	-	4.34	95.66
	(5)	13.16	-	7.80	79.04
	(6)	5.19	43.36	3.25	48.20

A=As given in results; B=Average values at different locations; EC=electrical conductivity; OC=organic carbon; N = nitrogen; Sign of co-efficients of OC and N are positive and that of pH and EC are negative.

Table 3 indicate that the contribution of nitrogen content of the soil to EWP is predominant. Furthermore, these results indicate that the contribution of EC to EWP is also appreciable.

Most 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[2,20,21]. The increase in the organic carbon content of soils was associated with increase in biomass and population of earthworms and there exists a strong positive correlation between earthworm population density and soil organic matter content[10,22,23,24]. Nitrogen rich diets help in rapid growth of earthworms and more cocoon production than those with less nitrogen[25]. In the present study also the percentage contribution of nitrogen to EWP was high and earlier reports on the qualitative dependence of EWP on soil nitrogen content support the same[9,10,13].

With reference to the climatic factors, here again, a representative data for the species *Drawida chlorina* at Site 7 is given in Equations 7-10.

- $EWP = 0.222\ HU + 0.012\ RF - 15.166$ (7)
  $N = 36,\ R = 0.754,\ R^2 = 0.568,\ sd = 2.17$
- $EWP = 0.269\ SM + 0.083\ HU - 6.454$ (8)
  $N = 36,\ R = 0.892,\ R^2 = 0.796,\ sd = 1.49$
- $EWP = 0.374\ SM + 0.079\ HU + 0.011\ RF - 6.424$ (9)
  $N = 36,\ R = 0.912,\ R^2 = 0.832,\ sd = 1.37$
- $EWP = 0.351\ SM + 0.046\ HU + 0.010\ RF - 0.194\ ST + 2.137$ (10)
  $N = 36,\ R = 0.921,\ R^2 = 0.848,\ sd = 1.32$

For all the species studied at different locations there exists a satisfactory correlation between the EWP and climatic parameters. From the magnitude of the coefficients of various terms and percentage contributions of the climatic parameters to the observed EWP values were calculated and the results are given in Table 4. For all the earthworm species, in the present study, the sign of the coefficients of the soil temperature (ST) term is negative and it indicates that the EWP decreases with increase in the soil temperature. The positive sign of the coefficients of SM, HU and RF indicates that the population increases with increase in these parameters. It was found that the contribution of soil moisture to EWP is predominant (Table 4). The temperature and the moisture are usually inversely related and high surface temperature and dry soils are much more the limiting factors to earthworms than low temperature and water logged soils(26). The ST plays an important role in the maintenance of EWP in an ecosystem and previous works also indicate the negative correlation of ST to EWP(10, 27, 28). Water constitutes 75-90% of the body weight of earthworms(29), so the prevention of water loss is a major factor in earthworm survival. Earthworms apparently lack a mechanism to maintain constant internal water content and hence their water content is influenced greatly by the soil moisture which directly depends on the water potential of the soil[30]. The moisture requirements for different species of earthworms from various regions can be quite different[24,31,32,33]. The dependence of EWP on soil moisture in the present study was maximum when compared with their dependence on other climatic parameters. This is so because some of the physiological activities of earthworms such as cutaneous respiration and excretion of nitrogenous ammonia and urea need a moist environment which is

Table 4: Contribution of various climatic parameters to earthworm abundance.

Species Name	Equation used[A]	Climatic Parameters (Percentage contribution)[B]			
		ST	SM	HU	RF
1. *Dichogaster bolaui*	(7)	-	-	96.08	3.92
	(8)	-	83.45	16.55	-
	(9)	-	85.06	14.40	0.54
	(10)	61.31	24.51	13.87	0.31
2. *Dichogaster saliens*	(7)	-	-	96.80	3.72
	(8)	-	76.67	15.10	-
	(9)	-	52.58	39.95	7.48
	(10)	27.89	61.61	9.31	0.80
3. *Drawida chlorina*	(7)	-	-	95.26	7.74
	(8)	-	74.51	25.49	-
	(9)	-	77.20	21.62	2.18
	(10)	18.49	63.90	16.46	1.15
4. *Drawida paradoxa*	(7)	-	-	92.52	7.48
	(8)	-	85.19	14.81	-
	(9)	-	85.18	14.80	0.02
	(10)	1.59	83.52	14.88	0.02
5. *Drawida pellucida pallida*	(7)	-	-	93.59	6.41
	(8)	-	83.47	17.90	-
	(9)	-	82.54	16.81	0.66
	(10)	18.25	67.23	13.95	0.57
6. *Lampito kumiliensis*	(7)	-	-	97.24	2.76
	(8)	-	69.53	30.47	-
	(9)	-	76.88	21.81	1.17
	(10)	41.01	43.57	14.48	0.94
7. *Lampito mauritii*	(7)	-	-	96.72	3.28
	(8)	-	73.85	26.15	-
	(9)	-	80.61	18.22	2.02
	(10)	20.15	64.60	14.07	1.64
8. *Megascolex insignis*	(7)	-	-	96.24	3.77
	(8)	-	81.29	18.72	-
	(9)	-	85.90	12.10	2.00
	(10)	8.27	79.74	10.08	1.87
9. *Octochaetona thurstoni*	(7)	-	-	96.44	3.56
	(8)	-	71.05	30.28	-

Table 4: Continued

	(9)	-	72.71	25.78	1.51
	(10)	11.00	66.58	20.99	1.43
10. *Pontoscolex corethrurus*	(7)	-	-	96.43	3.49
	(8)	-	80.75	19.25	-
	(9)	-	81.17	17.81	1.08
	(10)	44.25	43.55	11.25	0.95

A=As given in results; B=Average values at different locations; SM=soil moisture; ST=soil temperature; HU=humidity; RF=rain fall; Sign of co-efficients of SM, HU and RF are positive and that of ST are negative.

essential for the maintenance of their life process[11]. However, all the previous works were concerned only with the qualitative effect of these parameters on earthworm population.

The overall dependence of EWP on physico-chemical parameters in a multiple regression equation is given by R^2 x 100. The results of the systematic correlation analysis indicate that only about 80% of the population dependence can be explained with these physico-chemical parameters and it is presumed that, the remaining may depend on other environmental factors. To conclude, correlation analysis technique may be used to quantify and rationalize the effects of physico-chemical parameters on earthworm abundance.

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