Rec. zool. Surv. India : **101** (Part 1–2) : 139–160, 2003

EFFECT OF VEHICULAR LEAD POLLUTION ON BIODIVERSITY WITH SPECIAL REFERENCE TO ANTS

ACHINTYA CHATTOPADHYAY AND SOUMYENDRA NATH GHOSH
Zoological Sruvey of India, M-Block, New Alipore, Kolkata-700 053

INTRODUCTION

Soil inhabiting ants along with other soil microarthropods constitute the major biotic components of soil ecosystem. This ant community play a major role for smooth functioning of this ecosystem which in turn controls the behaviour of the soil itself. Social insects, like ants (Hymenoptera : Formicidae), have exhibited a great ecological success due to their better adaptability in the soil in comparison to other microarthropods (Holldobler and Wilson, 1990). However, soil arthropods in genera undergo qualitative and quantitative changes in a polluted environment have been demonstrated earlier (Przbylski 1979, 1981, Chattopadhyay and Hazra 2000). It has also been observed that ants are well tolerant to environmental pollution, heavy metals in particular (Petal, 1981; Stary and Kubiznakova, 1987; Krzysztofiak, 1991, Migula *et al.* 1993). On the other hand it has been observed anthropogenic disturbances in habitat result in the lowering of species diversity and species richness in ants (Mackay *et al.* 1991; Gadagkar *et al.* 1993). Pollutants therefore are expected to cast its effects on the species diversity of the microarthropods, including ants, as has already been observed in other groups of organisms (Biswas *et al.* 1998).

Kolkata, the largest metropolis in India, probably has the largest traffic density, the exhaust of which contain a large amount of lead, which is used as antiknock compound in the fuel. Thus, the road side soils are expected to have a high lead load. Since no account is available on the effect of lead pollution on the species diversity of soil ants, the present study was undertaken to—

(a) find out the quantum of lead deposited in the road side soils of Kolkata with its seasonal variations; (b) establish the seasonal variations in species diversity of ants; (c) establish relationship between the lead load and variations in species diversity of ants, through seasons; (d) study the richness of species, equitability in distribution of species and similarity pattern of species diversity between different localities.

STUDY SITES

Four major arterial roads were selected as study sites, one each at North, South, East and Central Kolkata; henceforth referred to as NC, SC, EC and CC respectively.

Soil at NC, along Tala Park Avenue, was coarse and sandy loam in nature admixed with various city refuses, and had little vegetation except some herbs during monsoon. At SC, adjacent to Southern Avenue, the soil was sandy clay loam with rich vegetation of herbs, shrubs and trees. At EC along Eastern Bypass the soil was loam, enriched with vegetation of mainly herbs and shrubs. At CC along Red Road the soil was clay loam in texture having herbs, mainly grasses as vegetal cover interspaced with old trees. The site experienced frequent water logging during monsoon.

MATERIALS AND METHODS

Soils were collected at monthly intervals for 24 months from three horizontal plots—A, B and C away from the roads respectively. Each plot measured about five metres by two metres.

Ten soil samples were collected, at random, from each plot, following standard procedure (Holldobler & Wilson 1990), from 0–5 cm depth of the soil.

Ants were collected from soil samples by hand picking and through light extraction funnel as recommended (Holldobler and Wilson 1990).

Identification of ant fauna was established along with their numerical strength.

Soil samples were analysed for estimation of lead content (in ppm) following atomic absorption spectrophotometry, conducted by Geological Survey of India, Kolkata.

Index of dominance was calculated as ni x $^{100}/_{N}$ where ni = Number of individuals in ith species and N = Total number of individuals in all the species.

Species diversity index was calculated following Trammer, 1969. Species richness index was found following Margalef, 1951. Evenness or equitability index was established following Pielou, 1975. Modified Sorenson's index of similarity was obtained following Spellerberg, 1991.

The results thus obtained were subjected to various statistical analysis following standard methods including test of significance in the differences of the species diversity indices; correlation between lead concentration and species diversity indices and species richness indices alongwith scattered diagram and trend line for prediction.

RESULTS AND DISCUSSION

A. Concentration of Lead

Concentration of lead (ppm) in the soil was found to vary at different sites and plots. (Table 1). At EC, CC and SC the concentration was found to be maximum at plot A, adjacent to road, and minimum at Plot C farthest from road, whereas at NC the trend was reverse.

On an average each site also exhibited large variations in the concentration of lead in soil (Table 2). At EC the lead concentration (mean) was found to be minimum (121.30 ± 20.14) while

Table 1. Concentration of Lead(ppm) in mean ± SD at different plots of different sites.

SITES/➡ PLOTS	EC			CC			NC			SC		
Months▼	A	B	C	A	B	C	A	B	C	A	B	C
AUG '96	115 ± 17.53	160 ± 10.09	125 ± 7.47	320 ± 9.69	300 ± 7.48	280 ± 11.99	325 ± 18.87	212 ± 6.10	180 ± 6.57	170 ± 12.00	120 ± 14.63	75 ± 6.77
SEP	155 ± 13.85	95 ± 6.19	140 ± 6.00	360 ± 7.00	300 ± 9.13	185 ± 9.87	173 ± 9.13	319 ± 4.65	410 ± 9.11	220 ± 16.22	300 ± 9.64	100 ± 7.31
OCT	150 ± 8.48	100 ± 4.63	70 ± 4.79	340 ± 6.45	400 ± 10.53	260 ± 8.76	227 ± 6.03	373 ± 5.66	395 ± 13.12	180 ± 11.08	200 ± 13.55	80 ± 8.74
NOV	180 ± 8.48	160 ± 4.63	100 ± 4.79	320 ± 6.07	280 ± 10.14	160 ± 5.78	428 ± 8.14	279 ± 5.06	255 ± 6.24	260 ± 11.23	140 ± 6.81	130 ± 7.65
DEC	210 ± 8.48	140 ± 4.63	160 ± 4.79	280 ± 4.94	200 ± 7.76	200 ± 8.81	357 ± 6.62	344 ± 4.71	200 ± 5.60	320 ± 10.13	180 ± 9.68	120 ± 7.97
JAN '97	170 ± 4.79	140 ± 3.77	60 ± 4.79	300 ± 9.15	400 ± 9.57	180 ± 5.12	340 ± 7.08	300 ± 4.96	220 ± 13.56	200 ± 10.32	120 ± 10.47	100 ± 7.00
FEB	100 ± 4.79	90 ± 4.79	130 ± 4.79	360 ± 6.16	450 ± 5.69	300 ± 6.08	290 ± 6.46	368 ± 5.02	310 ± 9.42	160 ± 7.71	140 ± 7.17	100 ± 8.47
MAR	125 ± 4.79	70 ± 4.79	105 ± 4.79	375 ± 6.07	590 ± 7.50	160 ± 5.14	220 ± 6.03	291 ± 5.10	270 ± 4.84	200 ± 10.26	160 ± 8.21	90 ± 7.47
APR	115 ± 4.79	135 ± 4.79	80 ± 4.79	300 ± 7.06	340 ± 6.08	200 ± 6.39	250 ± 5.49	183 ± 5.16	298 ± 6.60	230 ± 9.81	130 ± 8.82	100 ± 10.46
MAY	100 ± 10.3	140 ± 10.3	130 ± 5.12	305 ± 8.11	360 ± 5.90	320 ± 6.40	178 ± 5.49	268 ± 5.14	364 ± 6.71	260 ± 10.57	200 ± 9.37	80 ± 9.12
JUN	125 ± 4.98	150 ± 4.62	140 ± 4.77	240 ± 6.24	200 ± 5.88	185 ± 6.28	290 ± 5.27	287 ± 5.65	372 ± 6.05	200 ± 12.87	100 ± 8.15	120 ± 8.51
JUL	115 ± 14.98	90 ± 7.54	160 ± 4.77	280 ± 6.88	220 ± 6.62	160 ± 5.78	201 ± 5.29	319 ± 7.11	394 ± 9.55	176 ± 10.05	120 ± 9.05	100 ± 8.48
AUG	100 ± 5.53	140 ± 4.77	60 ± 5.38	340 ± 8.67	300 ± 6.72	400 ± 5.95	198 ± 6.05	378 ± 5.88	438 ± 6.66	170 ± 10.46	140 ± 7.83	100 ± 12.29
SEP	125 ± 5.78	135 ± 6.07	190 ± 4.79	400 ± 5.73	255 ± 8.01	120 ± 5.76	348 ± 6.77	471 ± 7.68	284 ± 6.20	145 ± 9.67	110 ± 10.69	85 ± 6.51
OCT	160 ± 5.23	80 ± 9.39	140 ± 7.17	350 ± 6.42	280 ± 5.88	170 ± 6.26	166 ± 6.34	315 ± 5.58	343 ± 6.21	160 ± 5.25	120 ± 9.05	90 ± 8.75
NOV	190 ± 10.24	125 ± 7.03	90 ± 5.42	330 ± 5.90	240 ± 11.83	200 ± 11.32	220 ± 6.05	301 ± 5.29	280 ± 5.62	240 ± 7.00	100 ± 10.24	80 ± 9.41
DEC	205 ± 6.75	90 ± 6.34	115 ± 7.25	260 ± 5.73	220 ± 6.46	155 ± 6.10	260 ± 6.29	140 ± 4.88	355 ± 6.78	330 ± 12.26	140 ± 8.65	120 ± 10.50
JAN '98	60 ± 6.2	65 ± 6.62	180 ± 5.74	250 ± 7.54	230 ± 7.13	160 ± 6.75	285 ± 5.81	305 ± 6.52	455 ± 7.13	170 ± 11.80	140 ± 10.64	100 ± 8.94
FEB	100 ± 6.31	100 ± 6.62	140 ± 7.39	245 ± 5.46	170 ± 8.69	200 ± 7.27	280 ± 6.29	180 ± 7.20	200 ± 5.51	150 ± 7.56	140 ± 7.24	80 ± 7.60
MAR	115 ± 7.56	50 ± 5.12	90 ± 5.08	270 ± 6.75	225 ± 5.64	215 ± 5.95	285 ± 10.19	305 ± 7.40	455 ± 6.56	135 ± 7.68	80 ± 8.85	75 ± 6.98
APR	100 ± 8.60	65 ± 5.91	115 ± 7.22	280 ± 7.61	230 ± 7.27	200 ± 7.20	330 ± 8.92	300 ± 6.18	300 ± 5.20	140 ± 9.35	90 ± 9.18	110 ± 7.33
MAY	125 ± 6.31	80 ± 5.46	144 ± 6.62	260 ± 6.78	200 ± 7.39	140 ± 8.70	360 ± 5.80	260 ± 5.81	240 ± 5.73	200 ± 9.81	130 ± 8.28	100 ± 11.50
JUN	115 ± 6.81	160 ± 6.60	105 ± 6.16	200 ± 7.03	190 ± 7.27	265 ± 6.48	530 ± 6.29	185 ± 5.85	495 ± 10.35	205 ± 12.16	100 ± 11.06	135 ± 7.13
JUL	125 ± 6.06	80 ± 6.56	150 ± 7.21	300 ± 8.01	240 ± 7.72	200 ± 7.27	340 ± 5.12	200 ± 5.00	220 ± 5.20	260 ± 9.55	120 ± 9.16	120 ± 6.35
$\bar{X}$	132.50 ± 36.60	110 ± 34.00	121 ± 34.62	302.71 ± 47.65	284.16 ± 96.40	208.96 ± 63.61	286.71 ± 84.50	286.79 ± 74.16	322.25 ± 89.39	203.37 ± 52.03	138.33 ± 45.06	99.58 ± 17.19

Table 2. Concentration of Lead (ppm) in mean ± SD at different sites (Average).

Site ▶ Month ▼	EC	CC	SC	NC
AUG '96	133.33 ± 22.96	300.00 ± 19.09	121.66 ± 40.50	239.00 ± 63.36
SEP	130.00 ± 27.18	281.67 ± 73.13	206.67 ± 83.02	300.67 ± 97.94
OCT	106.67 ± 33.58	333.33 ± 58.01	153.33 ± 53.69	331.67 ± 75.09
NOV	146.67 ± 34.56	253.33 ± 68.41	176.67 ± 59.71	320.67 ± 76.81
DEC	170.00 ± 30.10	226.67 ± 38.42	206.67 ± 84.31	300.33 ± 71.37
JAN '97	123.33 ± 46.82	293.33 ± 90.31	140.00 ± 44.21	286.67 ± 50.74
FEB	106.67 ± 17.66	370.00 ± 61.93	133.33 ± 26.13	322.67 ± 33.85
MAR	100.00 ± 23.33	375.00 ± 175.66	150.00 ± 46.29	260.33 ± 30.26
APR	110.00 ± 23.23	280.00 ± 59.24	153.33 ± 56.42	243.67 ± 47.51
MAY	123.33 ± 19.19	328.33 ± 24.21	180.00 ± 75.46	270.00 ± 76.17
JUN	138.33 ± 11.34	208.33 ± 24.01	140.00 ± 44.36	316.33 ± 39.79
JUL	121.67 ± 29.56	220.00 ± 49.41	132.00 ± 33.46	304.67 ± 79.80
AUG	100.00 ± 33.08	346.67 ± 41.72	136.67 ± 30.49	338.00 ± 102.17
SEP	150.00 ± 29.11	258.33 ± 114.52	113.33 ± 26.25	367.67 ± 77.90
OCT	126.67 ± 34.80	266.67 ± 74.34	123.33 ± 29.74	274.67 ± 77.92
NOV	135.00 ± 42.16	256.67 ± 55.29	140.00 ± 71.74	267.00 ± 34.79
DEC	136.67 ± 49.85	211.67 ± 43.70	196.67 ± 95.22	251.00 ± 88.18
JAN '98	101.67 ± 55.79	213.33 ± 39.24	136.67 ± 30.54	348.33 ± 76.14
FEB	113.33 ± 20.04	205.00 ± 31.66	123.33 ± 31.80	220.00 ± 43.67
MAR	85.00 ± 27.44	236.67 ± 24.69	96.67 ± 28.30	348.33 ± 76.31
APR	93.33 ± 22.19	236.67 ± 33.81	113.33 ± 22.30	310.00 ± 15.76
MAY	115.00 ± 26.22	200.00 ± 49.58	143.33 ± 43.06	286.67 ± 52.81
JUN	126.67 ± 24.80	218.33 ± 33.96	146.67 ± 44.86	403.33 ± 155.24
JUL	118.33 ± 29.71	246.67 ± 41.81	166.67 ± 66.53	253.33 ± 62.03
$\bar{X}$	121.30 ± 20.14	265.28 ± 32.35	147.10 ± 28.42	298.57 ± 43.79

at NC it was maximum (298.57 ± 43.79). SC had a mean concentration of 147.10 ± 28.42 ppm which was slightly higher than EC while at CC mean lead concentration was found to be little less than NC.

Lead concentration was therefore in an increasing order at EC, SC, CC and NC. Though lead load in the soil was related to the intensity of vehicular movement, vegetation also probably played a role in controlling the soil lead concentration (Bhalsberg-Phalsson, 1989; Migula and Binkowska, 1993). At EC the vehicular movement was more intense in comparison to NC, but rich vegetation at EC might have resulted in uptaking large lead load from the soil and a poor vegetation at NC might have resulted into maximum soil lead concentration.

The seasonal variations of lead concentration did not follow any particular trend and were found to be highly irregular.

B. Faunal composition and dominance

Altogether 28 species of ants were recorded during this study of which 20, 17, 13 and 17 species were found to occur at EC, CC, NC and SC respectively (Table 3). *Solenopsis geminata* was the most dominant species and widely distributed in all the sites. The abundance of various species varied from site to site, which is reflected in their indices of dominance. (Table 3). It therefore appeared that a rich vegetation and a lowest mean concentration of lead (121.30 ppm) at EC had probably influenced the diversity of species in a positive manner, whereas highest mean lead concentration (298.57 ppm) and scanty floral presence might have had a negative effect on the variation of species at NC. From the index of dominance it is also clear that at NC beside *S. geminata* (30.39) three other species *Pheidole roberti* (18.74), *Tetramorium walshi* (12.76) and *Meranoplus bicolor* (11.34) played dominant role in building up the soil ant community, whereas at EC, CC and SC only one or two species played a major role. This may be attributed to less interspecific competition and better adaptability to the environment.

C. Species richness index

From Table 4 it is evident that species richness indices were quite variable at all the sites and no definite pattern in seasonal variations could be observed. The maximum value was found to be 3.33 and lowest being zero.

However, from the mean values it is clear that species richness index was maximum at plot C of EC, CC and SC whereas the order is opposite at NC. A comparison of mean lead concentration (Table 2) with that of species richness index revealed that they had an inverse relationship, which suggests that concentration of lead might have had a negative effect on the species richness of ants.

On an average it is observed (Table 5) that species richness ranged from 0 to 4.35 at EC, 0.45 to 3.57 at CC, 1.05 to 2.97 at NC and 0.58 to 3.33 at SC in different months; however the fluctuations did not have any definite pattern.

It is also found that at EC the species richness was maximum (5.65) followed by CC (4.94), SC (4.91) and minimum at NC (3.74). *Solenopsis geminata* was observed to be the only species

Table 3. Distribution of ant species at different sites under study. ['+' Present; figures indicate the index of Dominance].

Species	EC	CC	NC	SC
Solenopsis geminata	+ 42.71	+ 41.65	+ 30.39	+ 40.95
Camponotus compressus	+ 3.13	+ 1.85	+ 1.29	+ 0.72
Technomyrmex albipes	+ 6.56	+ 3.35	+ 4.81	+ 5.72
Amblyopone rothneyi	+ 0.04			
Syscia sp.	+ 0.09			
Pheidole roberti	+ 14.35	+ 18.49	+ 18.74	+ 9.82
Meranoplus bicolor	+ 2.07	+ 15.89	+ 11.34	+ 4.05
Tapinoma melanocephalum	+ 5.90	+ 1.96	+ 3.76	+ 2.99
Cardiocondyla nuda	+ 1.19	+ 0.06	+ 0.31	+ 0.72
Crematogaster rothneyi	+ 0.97	+ 0.64		+ 2.27
Paratrechina longicornis	+ 8.81	+ 5.26	+ 5.80	+ 5.60
Anochetus graeffei	+ 0.09		+ 0.31	
Dorylus orientalis	+ 2.06			
Pachycondyla rufipes	+ 0.06			
Plagiolepis jerdoni	+ 4.76	+ 3.12	+ 3.70	+ 6.66
Tetramorium walshi	+ 2.82	+ 1.68	+ 12.76	+ 2.61
Diacamma vagans	+ 0.09			
Messor barbarus	+ 1.01			
Polyrhachis tubericeps	+ 1.06			
Carebara lignata	+ 1.67	+ 3.24	+ 1.36	+ 1.33
Hypoponera truncata		+ 0.35		
Monomorium floricola		+ 1.79	+ 5.43	+ 14.82
Tetraponera allaborans		+ 0.06		+ 0.78
Oligomyrmex asinus		+ 0.06		
Lophomyrmex quadrispinosus		+ 0.58		
Pheidologeton diversus				+ 0.28
Tetraponera rufonigra				+ 0.17
Recurvidris recurvispinosa				+ 0.50

Table 4. Species Richness Index of Formicidae (Hymenoptera) at different plots.

Site/Plot ▶	East Calcutta			Central Calcutta			North Calcutta			South Calcutta		
Month ▼	A	B	C	A	B	C	A	B	C	A	B	C
Aug-96	0	2.22	3.33	1.28	1.26	1.33	0	0.62	0.81	0.66	0	0
Sep	1.44	1.11	0	0.90	0	0	0.59	0	0	0	0	3.33
Oct	1.54	1.05	0.69	0	0	0.9	0	0.83	0	1.4	0.93	0
Nov	0.64	1.19	2.22	0.67	1.00	0.85	0	0	0	0	0	0
Dec	1.15	0	0	0	0	0	0	0	0	0	0	1.05
Jan-97	0	0	0	0	0	0	1.30	0.85	0.57	0	0	0
Feb	2.30	1.12	1.19	0	0.96	0	1.88	0	0	0	0	0
Mar	0.60	0	0.62	0	0	1.11	0	1.87	0	1.21	0.71	0.78
Apr	0.67	0.87	0.72	0	0.93	0.87	0.9	1.30	0.80	0	0.69	0.96
May	0	0	2.08	1.47	0.76	0	0	1.44	0	1.91	1.11	0.62
Jun	0	0.61	0.63	0.72	1.18	1.68	0.62	0	1.54	0	0.66	1.10
Jul	0.75	0.93	0	0	0	0	0	0	0	1.42	0	1.74
Aug	0.63	0	1.10	0.65	0	0	2.01	0	0	0.65	0	0.8
Sep	0	1.26	0.87	0.85	0.90	0	1.60	0	0	0	2.06	1.43
Oct	2	0	1.86	0.56	0	0.59	0.68	0	0	0.71	0	0.90
Nov	0	0	0	0	0	2.85	0	1.60	0.70	0	1.08	0.77
Dec	1.85	0	0.93	0.77	0	0.83	0	1.23	0.56	0	0.67	0
Jan-98	0.56	0.54	0	0	2.10	1.12	0	0.72	0	1.19	1.76	0
Feb	0	0	0	1.00	0	0	1.27	0	0.65	0.73	1.11	0
Mar	0	0.71	0	0	0	0	0	1.11	0	0.7	0	0
Apr	1.25	1.43	1.85	0	0	0	1.54	0	0.69	1.54	0	1.16
May	1.20	0	0	1.91	2.27	1.96	0	0.68	0.78	1.26	0.68	2.20
Jun	0.57	0	0.63	2.08	0.61	0	0	0	0.77	0	1.03	3.33
Jul	1.35	0.74	0	0	0.65	0.70	1.51	0.69	0.81	1.88	1.47	1.11
$\bar{X}$	0.77	0.57	0.78	0.54	0.53	0.62	0.58	0.54	0.36	0.64	0.58	0.89

occurring in Jan '97, at EC, which has resulted in reducing the index to zero. It is therefore clear that richness of species in a given environment is dynamic in character, having fluctuation with given time and space and which is dependent on various ecological factors. So far as the present study is concerned the presence of excess amount of lead in the soil might have exerted an effect on the richness of species. It is evident from Figures 1 and 2 that species richness had negative relationship with lead at CC, NC and SC and the relationship was faintly positive at EC. However none of these relationships is found to be significant.

Table 5. Species Richness Index in the community of Formicidae (Hymenoptera) at different seasons and at different sites (average).

Months ➢ / Sites ▼	Aug-96	Sep	Oct	Nov	Dec	Jan-97	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan-98	Feb	Mar	Apr	May	Jun	Jul	TOTAL
East Calcutta	4.35	1.76	1.70	2.03	2.27	0	2.58	1.98	2.17	1.13	0.92	1.66	2.46	2.17	3.39	0.49	2.27	1.83	0.99	1.58	2.65	0.93	1.83	2.16	5.65
Central Calcutta	2.11	2.09	2.16	2.86	1.11	0.45	1.32	1.38	1.95	2.31	2.38	0.66	1.91	1.85	1.93	2.60	2.91	2.20	1.87	1.13	1.89	3.57	2.76	2.19	4.94
North Calcutta	1.66	1.16	2.10	1.12	1.05	2.97	2.66	2.26	1.65	1.82	2.05	1.17	1.76	1.82	1.64	2.12	1.48	1.42	2.04	1.99	2.22	2.21	1.82	2.75	3.74
South Calcutta	1.14	3.33	3.04	1.05	0.61	0.47	1.01	3.07	2.00	2.86	1.90	2.87	1.66	2.69	1.86	1.50	0.58	3.09	0.99	1.53	2.67	2.55	2.33	3.24	4.91

Table 6. Seasonal variation in Evenness Index in the community of Formicidae (Hymenoptera) at different sites (cumulative).

Months ➢ / Sites ▼	Aug-96	Sep	Oct	Nov	Dec	Jan-97	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan-98	Feb	Mar	Apr	May	Jun	Jul	$\bar{X}$
East Calcutta	0.96	0.47	0.94	0.78	0.37	0	0.61	0.94	0.66	0.38	0.67	0.83	0.58	0.41	0.75	0.69	0.70	0.89	0.66	0.82	0.93	0.28	0.88	0.98	0.67
Central Calcutta	0.65	0.96	0.93	0.92	0.83	0.93	0.95	0.69	0.81	0.88	0.85	0.42	0.73	0.61	0.76	0.56	0.85	0.71	0.83	0.55	1.00	0.87	0.70	0.95	0.79
North Calcutta	0.77	0.78	0.81	0.88	0.92	0.89	0.98	0.78	0.89	0.70	0.66	0.78	0.96	0.90	0.94	0.88	0.62	0.71	0.91	0.86	0.87	0.96	0.97	0.98	0.85
South Calcutta	0.48	0.95	0.91	0.99	0.45	0.49	0.51	0.96	0.70	0.75	0.78	0.90	0.85	0.82	0.78	0.81	0.64	0.71	0.20	0.81	0.70	0.67	0.41	0.92	0.72

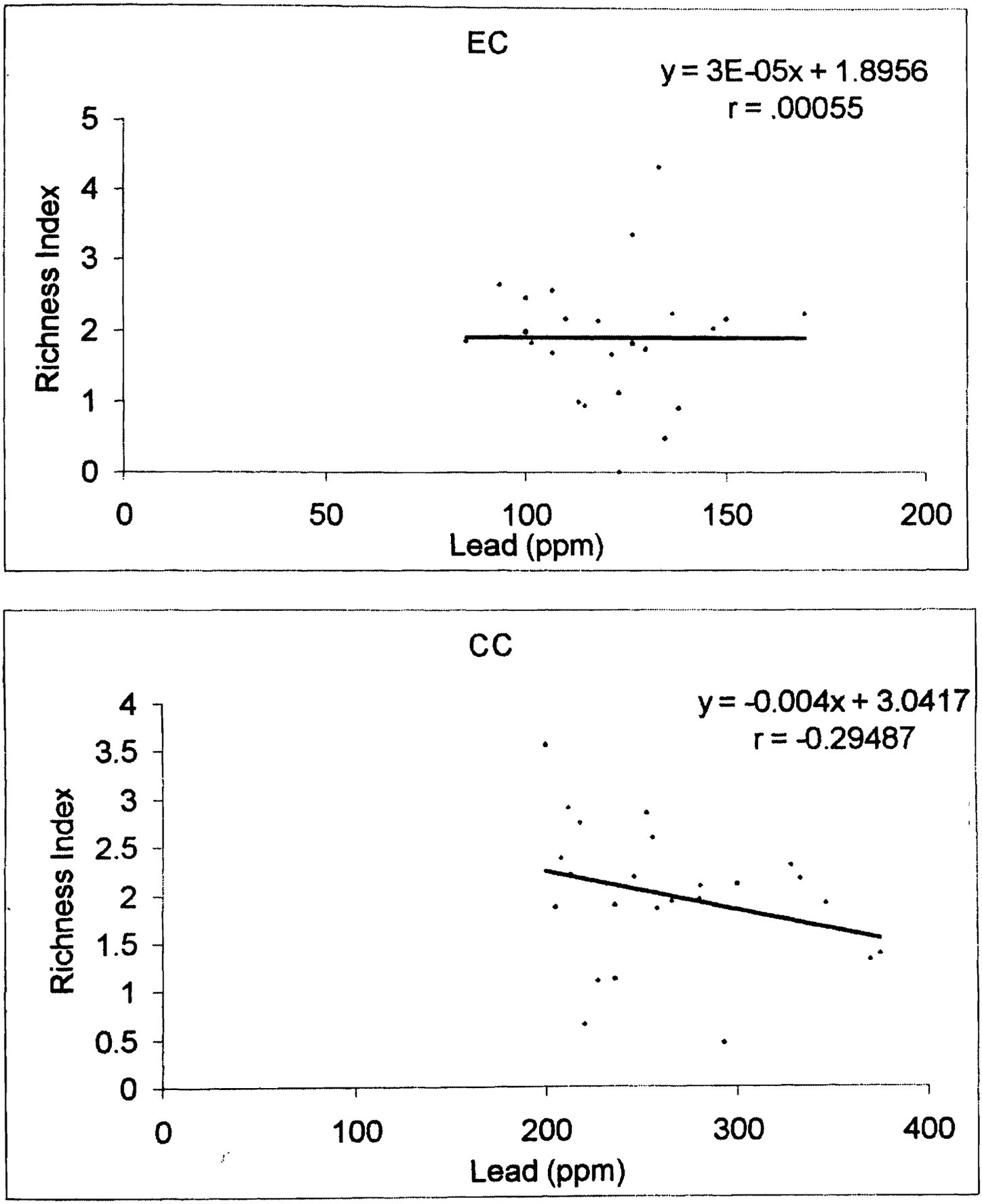

Fig. 1. Showing correlation coefficient (r), regression equation and trend line of species richness index on Lead (ppm) at EC and CC.

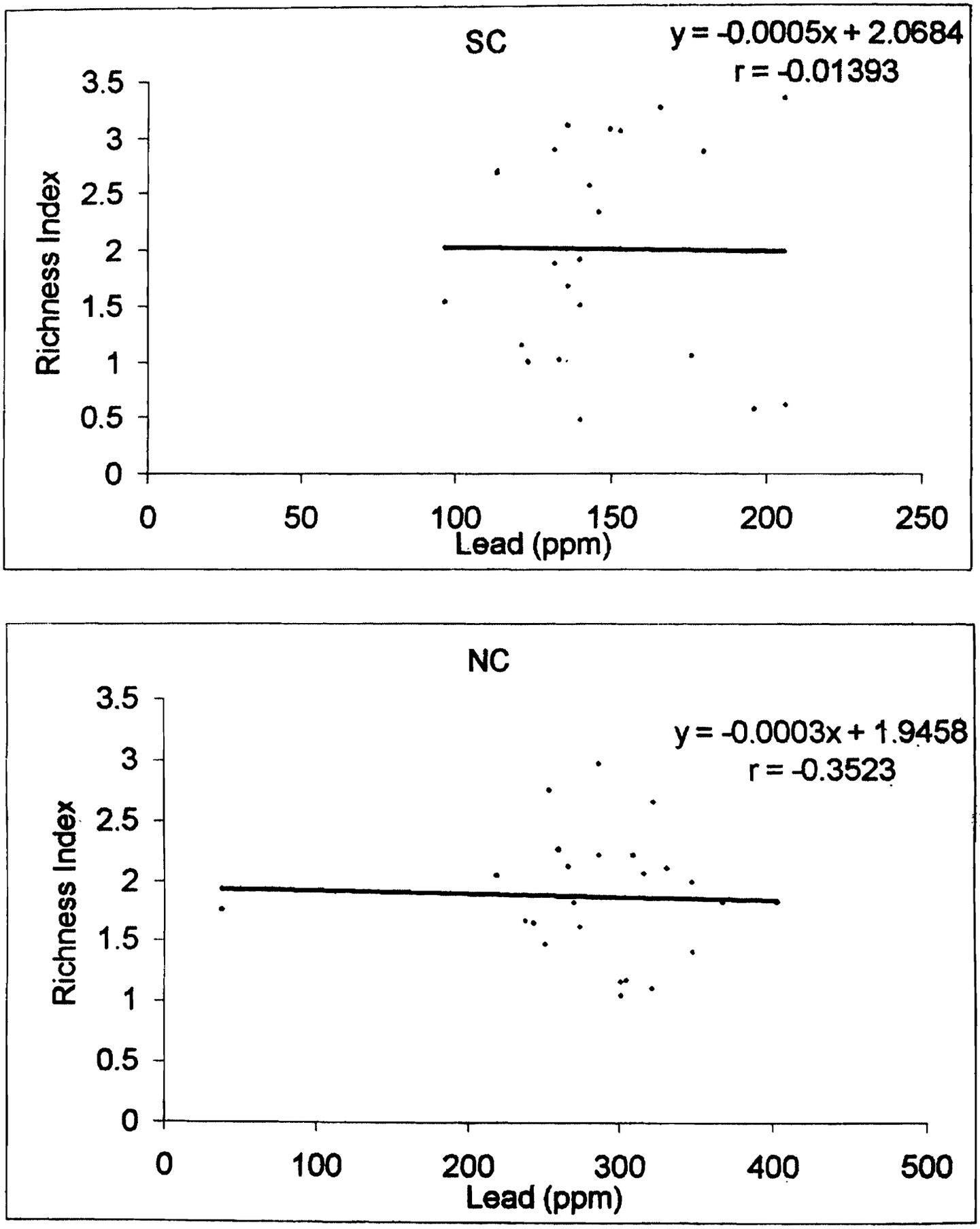

Fig. 2. Showing correlation coefficient (r), regression equation and trend line of species richness index on Lead (ppm) at NC and SC.

D. Index of Evenness

From Table 6 it is observed that evenness in the distribution of species varied greatly from site to site and also in different seasons. The maximum evenness was observed to be 0.98 and minimum of 0.28 at EC while these at CC, NC and SC were 1.00 and 0.42; 0.98 and 0.62; and 0.99 and 0.20 respectively. Higher evenness values on October and July at all the sites suggested that monsoon and post monsoon seasons as best suited for even distribution of species. However, in other months no definite pattern in the evenness could be observed.

It is thus clear that at NC the range of evenness was much better in comparison to other sites with a mean value of 0.85; which suggests that at NC species holding capacity reached a near stability, so far as ant community was concerned, in comparison to other sites. Whereas at EC the range of evenness was maximum, resulting in a lowest mean value of 0.67 suggesting the availability of a better scope of distribution of species.

This factor in all probability was also related to the floral component of the ecosystem. At NC the vegetation was comparatively poor along with a large lead load; the species available, got adapted to such an adverse situation with a better distribution throughout the year. Whereas at EC less lead load and better availability of vegetation and their large fluctuations had its effect on the evenness of species distribution.

E. Index of similarity

As far as abundance of different species was concerned it is found (Table 7) that maximum similarity (79%) existed in between NC and CC while the minimum (64%) was in between NC and EC. Both NC and CC had large concentration of lead, the vegetal composition also did not vary largly, hence these two sites exhibited maximum similarity in the abundance of different species. Whereas EC had lowest lead load and a rich vegetation in comparison to NC which probably resulted into a poor index of similarity.

F. Species diversity index

Plot wise seasonal variations and species diversity indices at each site are given in Table 8. At all the plots in some months monospecific population was found, reducing the diversity to zero, whereas in some months the diversity index was found to be below two decimal levels. Beside this, the index values ranged from 0.16 to 1.44. The maximum values at EC, CC, NC and SC in the plots A, B and C were found to be 1.32, 0.99, 1.05; 1.00, 1.25, 1.44; 1.33, 1.02, 0.95 and 1.25, 1.04, 1.39 respectively. Only at CC the diversity values were found to be maximum in the month of May in all the plots. In all other sites the diversity index did not exhibit any particular pattern of seasonal fluctuation. From Table 2 it is evident that concentration of lead was minimum in May '98, which might be responsible for an increase in diversity at that time at CC.

Table 7. Index of similarity in the population of Formicidae (Hymenoptera) in between different sites.

SITES	N.C.	E.C.	S.C.
C.C.	0.79	0.67	0.75
N.C.		0.64	0.70
E.C.			0.71

Table 8. Seasonal variation in the species diversity indices of Formicidae (Hymenoptera) at different plots.

Site/Plot ▶	East Calcutta			Central Calcutta			North Calcutta			South Calcutta		
Month ▼	A	B	C	A	B	C	A	B	C	A	B	C
Aug-96	0	0.9	1.05	0.46	0.66	0.72	0	0.62	0.47	0.23	0	0
Sep	0.7	0.39	0	0.62	0	0	0.64	0	0	0	0	0.7
Oct	0.95	0.69	0.57	0	0	0.67	0	0.41	0	0.88	0.64	0
Nov	0.69	0.82	0.99	0.68	0.67	0.58	0	0	0	0	0	0
Dec	0.36	0	0	0	0	0	0	0	0	0	0	0.68
Jan-97	0	0	0	0	0	0.6	0.87	0.69	0.66	0	0	0
Feb	1.32	0.55	0.68	0	0.68	0	1.33	0	0	0	0	0
Mar	0.69	0	0.47	0	0	0.57	0	1.02	0	0.99	0.69	0.68
Apr	0.65	0.66	0.66	0	0.6	0.68	0.99	0.64	0.64	0.47	0.47	0.66
May	0	0	0.64	1	0.63	0	0	0.68	0	0.36	0.66	0.58
Jun	0	0.26	0.28	0.16	0.53	0.72	0.2	0	0.95	0	0.14	0.86
Jul	0.49	0.45	0.64	0	0	0	0	0	0	0.87	0	0.8
Aug	0.2	0	0.68	0.22	0	0	1.24	0	0	0.36	0	0.23
Sep	0	0.7	0.52	0.24	0.43	0	0.67	0	0	0	1.04	0.97
Oct	0.8	0	0.89	0.48	0	0.32	0.58	0	0	0.28	0	0.62
Nov	0	0	0	0	0	1.32	0	0.87	0.68	0	0.57	0.68
Dec	0.72	0	0.28	0.2	0	1.09	0	0.85	0.45	0	0.14	0
Jan-98	0.68	0.67	0	0	0.95	1.09	0	0.28	0	0.6	0.8	0
Feb	0	0	0	0.33	0	0	0.86	0	0.69	0.2	0.7	0
Mar	0	0.17	0	0	0	0	0	0.57	0	0.26	0	0
Apr	1.09	0.83	1.05	0	0	0	0.85	0	0.62	0.75	0	0.72
May	0.63	0	0	0.47	1.25	1.44	0	0.64	0.66	0.62	0.68	1.39
Jun	0.55	0	0.68	0.87	0.68	0	0	0	0.65	0	0.82	1.05
Jul	1.09	0.69	0	0	0.64	0.68	0.93	0.69	0.47	1.25	1.06	0.68
$\bar{X}$	0.48	0.33	0.42	0.24	0.32	0.44	0.38	0.33	0.29	0.34	0.35	0.47

Table 9. Species diversity indices of Formicidae (Hymenoptera) in different months at different sites (Average).

Months ➤ / Sites ▼	Aug-96	Sep	Oct	Nov	Dec	Jan-97	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan-98	Feb	Mar	Apr	May	Jun	Jul	Total
East Calcutta	1.72	0.76	1.30	1.25	0.59	0	1.10	1.52	1.07	0.42	0.74	1.16	1.04	0.73	1.47	0.62	1.13	1.58	0.73	1.14	1.66	0.31	1.41	1.58	2.04
Central Calcutta	1.04	1.34	1.29	1.64	0.57	0.64	1.04	0.76	1.11	1.41	1.52	0.29	1.01	0.85	1.22	1.07	1.52	1.27	1.15	0.60	1.11	1.81	1.37	1.53	1.86
North Calcutta	1.24	0.86	1.13	0.97	1.01	1.74	1.75	1.26	1.24	0.97	1.06	1.09	1.34	1.26	1.31	1.41	0.86	0.98	1.46	1.20	1.40	1.55	1.34	1.76	2.06
South Calcutta	0.53	1.05	1.63	0.68	0.31	0.34	0.56	1.87	1.12	1.34	1.26	1.61	1.08	1.46	1.09	1.12	0.70	1.39	0.22	1.12	1.13	1.20	0.74	1.79	2.01

On an average two different patterns of species diversity were obtained. At EC and NC, plots A, B and C had a more or less decending pattern of species diversity, the values being 0.48, 0.33, 0.42 and 0.38, 0.33, 0.29 respectively; while the pattern was reverse at CC and SC (0.24, 0.32, 0.44 and 0.34, 0.35, 0.47).

The decending order of lead load in soil (Table 1) in plots A, B and C at all the sites might have spelt a negative effect on species diversity at CC and SC. At NC where the lead pollution gradually increased from plots A to C might have also exerted a negative effect on the species diversity. However, at EC, though the lead load was much lower in comparison to other sites, it was found to have a positive effect on the species diversity.

At each site on an average it was found that (Table 9) species diversity was maximum in the months of July, August and November, i.e., during monsoon and post monsoon period at EC, CC and NC. However, a summer maxima was observed in March at SC. Thus the normal well established trend of proliferation of soil arthropods during monsoon were still maintained at EC, CC and NC, whereas at SC the best suited environment was probably utilized best. It was also found that, on total, the species diversity was maximum at NC (2.06) followed by EC, SC and CC.

The differences in the species diversity indices at different sites were subjected to 't' tests (Table 10), which showed that the differences in the species diversity indices between NC and EC as well as between NC and SC were quite significant and statistically no difference existed in the species diversity between EC and SC; CC and SC; CC and EC.

Table 10. Comparative 't' values of species diversity indices of Formicidae (Hymenoptera) in between different sites.

SITES	N.C.	E.C.	S.C.
C.C.	1.44	0.75	0.58
N.C.		*2.00	*1.80
E.C.			0.15

*Significant at 5% level.

The results thus obtained when subjected to correlation and regression, it was observed in most of the plots of all the sites that the species diversity indices had negative relationships with concentration of lead. (Figs. 3–6). While these negative relationships were significat at plots CC (C), and NC (B,C); in other plots such relationships were not significant. Only plots EC (B) and SC (C) exhibited positive relationships of species diversity index with lead though those were much below the level of significance.

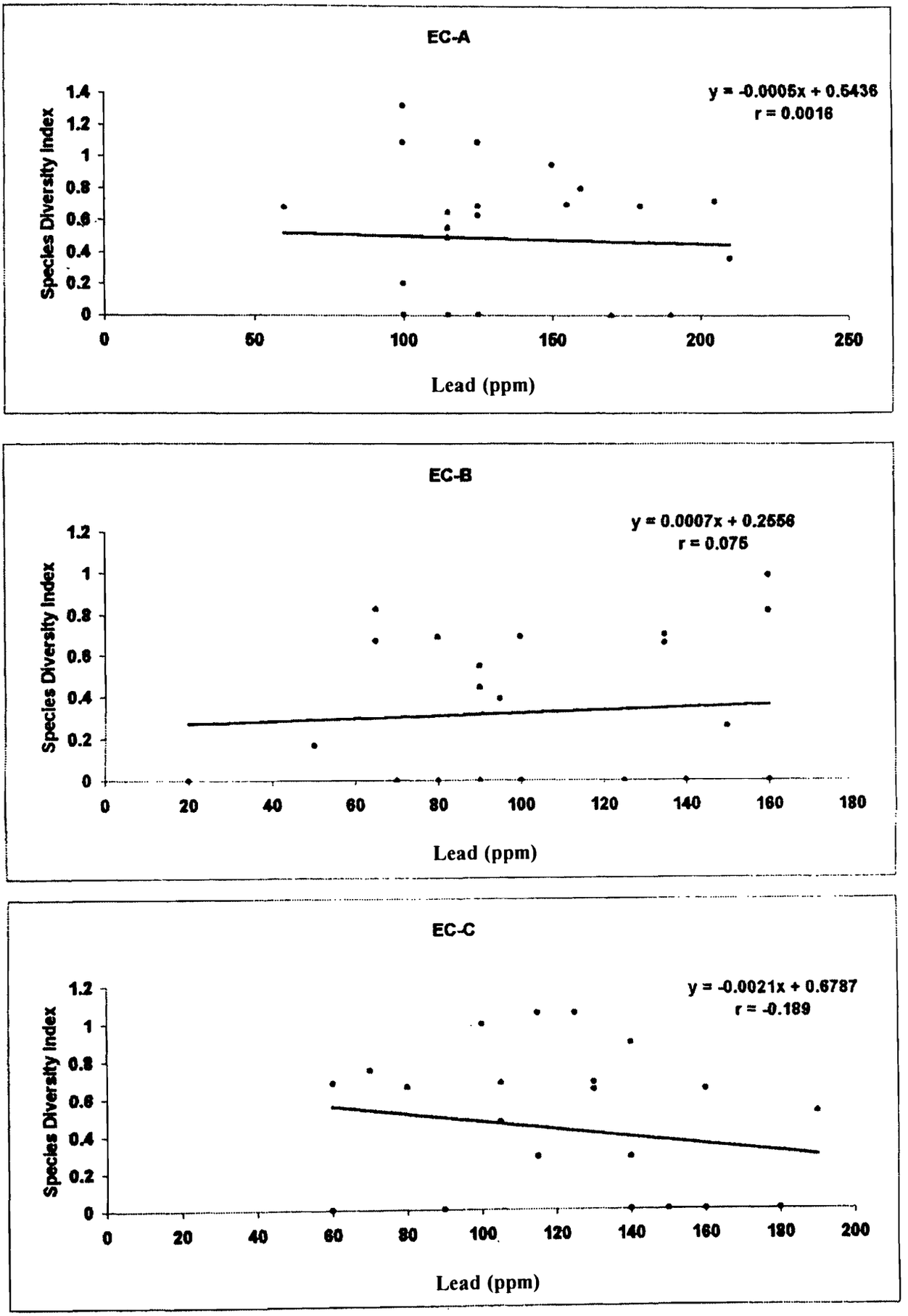

Fig. 3. Showing correlation coefficient (r), regression equation and trend line of species diversity index on Lead (ppm) at different plots of EC.

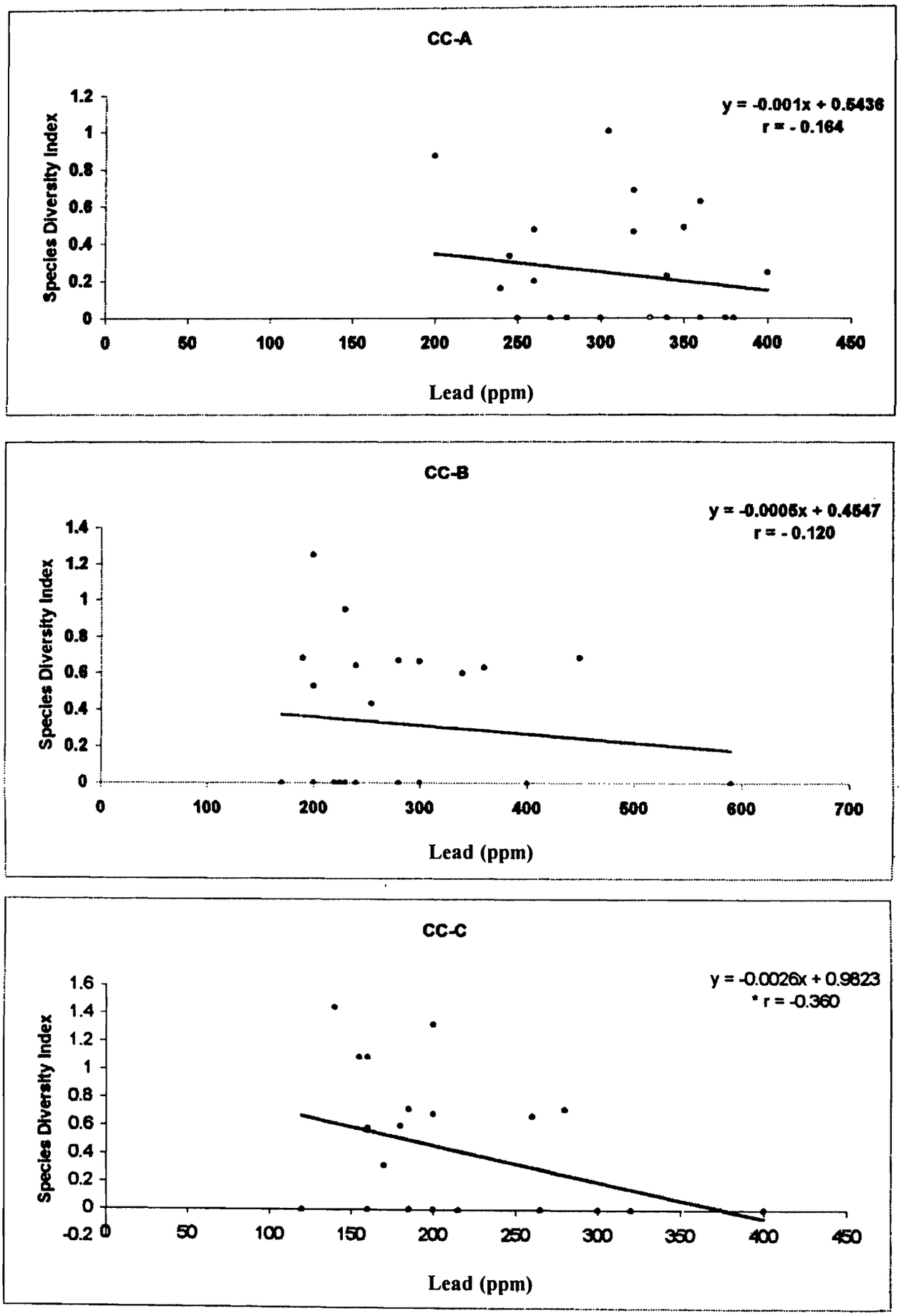

Fig. 4. Showing correlation coefficient (r), regression equation and trend line of species diversity index on Lead (ppm) at different plots of CC (*P < 0.10).

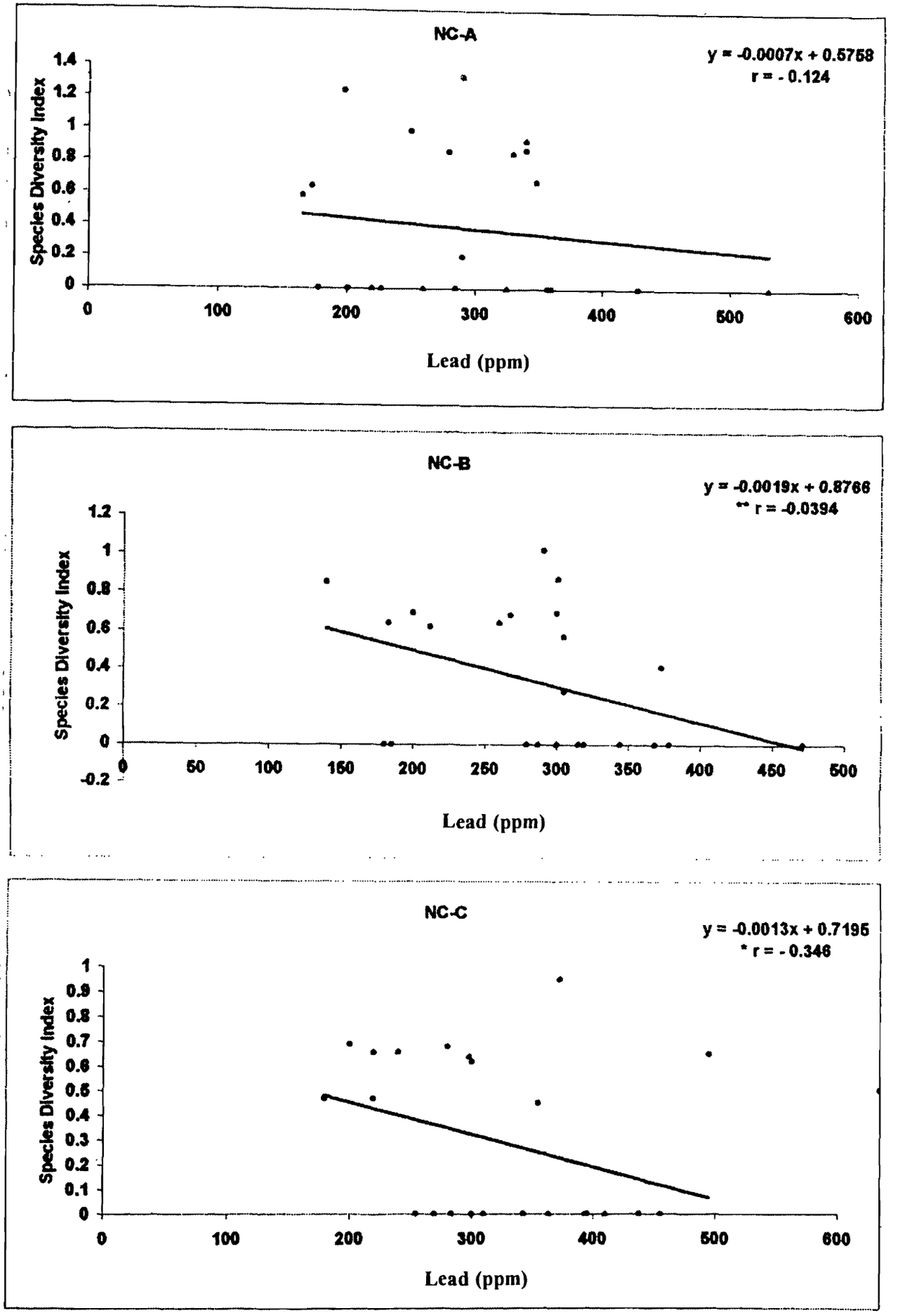

Fig. 5. Showing correlation coefficient (r), regression equation and trend line of species diversity index of Lead (ppm) at various plots of NC (*P < 0.10, **P < 0.05).

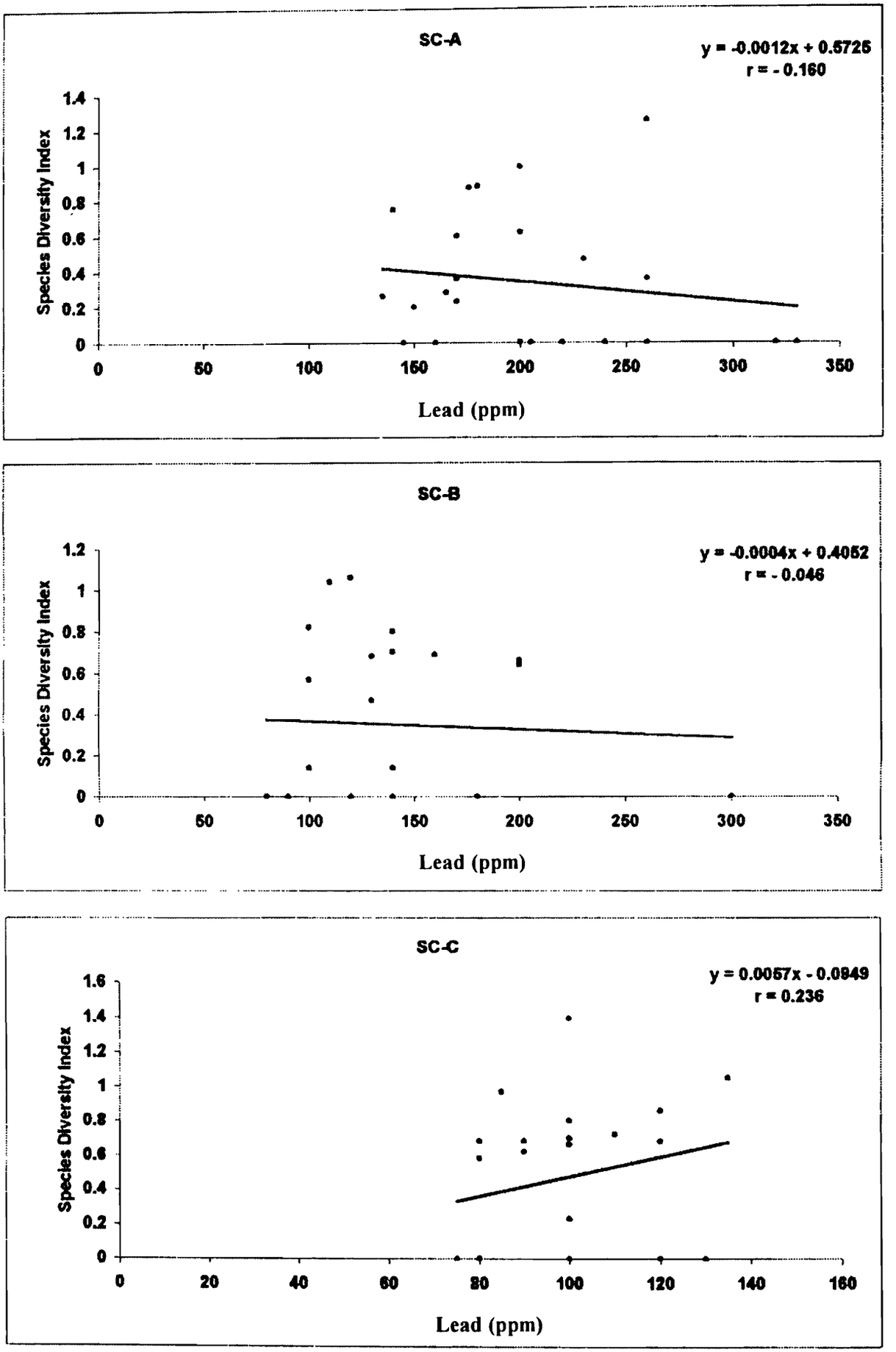

Fig. 6. Showing correlation coefficient (r), regression equation and trend line of species diversity index of Lead (ppm) at different plots of SC.

On cumulative basis the relationships of species diversity index with lead at EC, CC and NC were found to be negative (Figs. 7–8); of which the relationships were significant at EC and NC; while at CC the relationship did not show any significance. At SC however the relationship was positive but not significant.

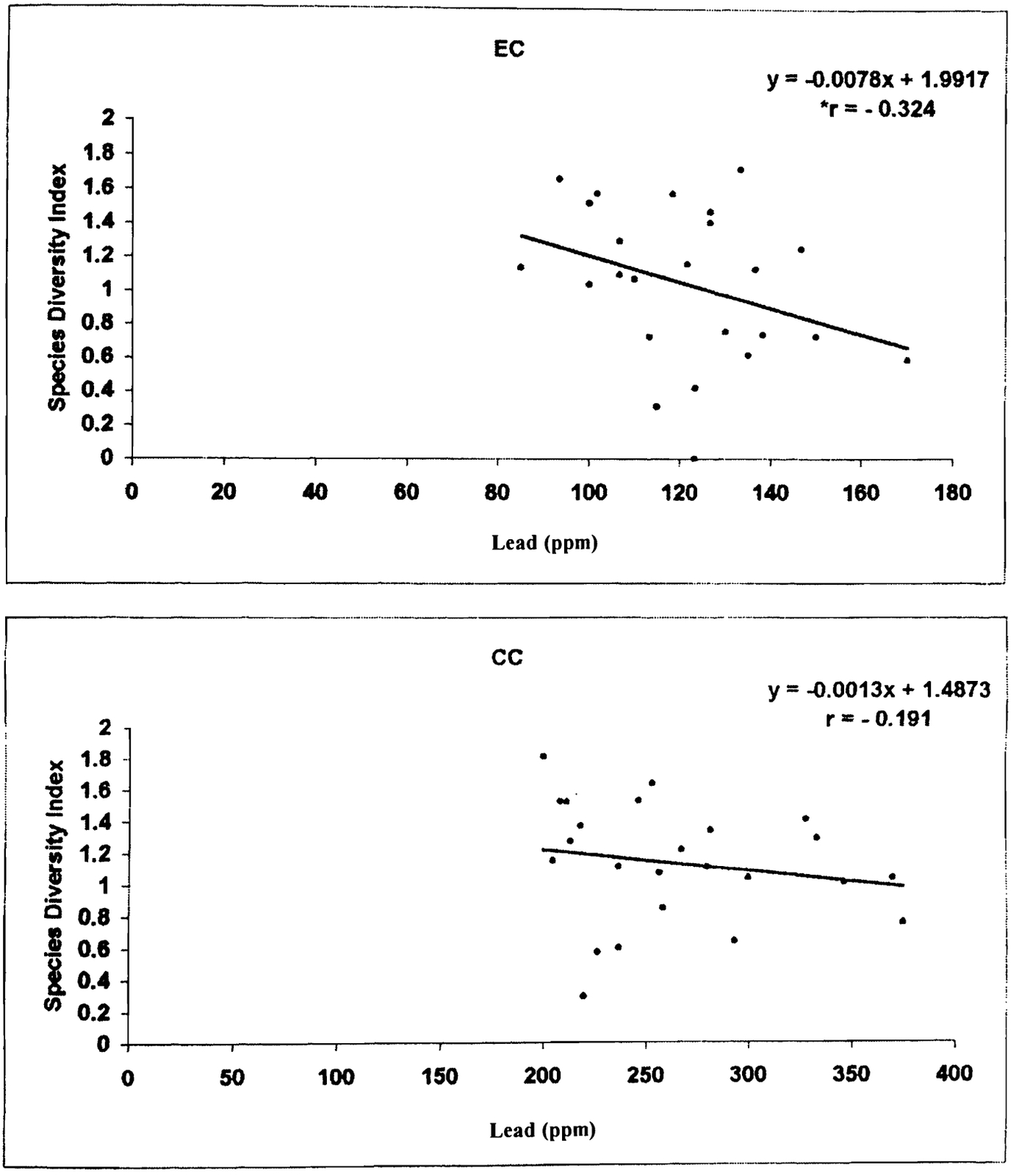

Fig. 7. Showing correlation coefficient (r), regression equation and trend line of species diversity index on Lead (ppm) at sites EC and CC (average) (*P < 0.10).

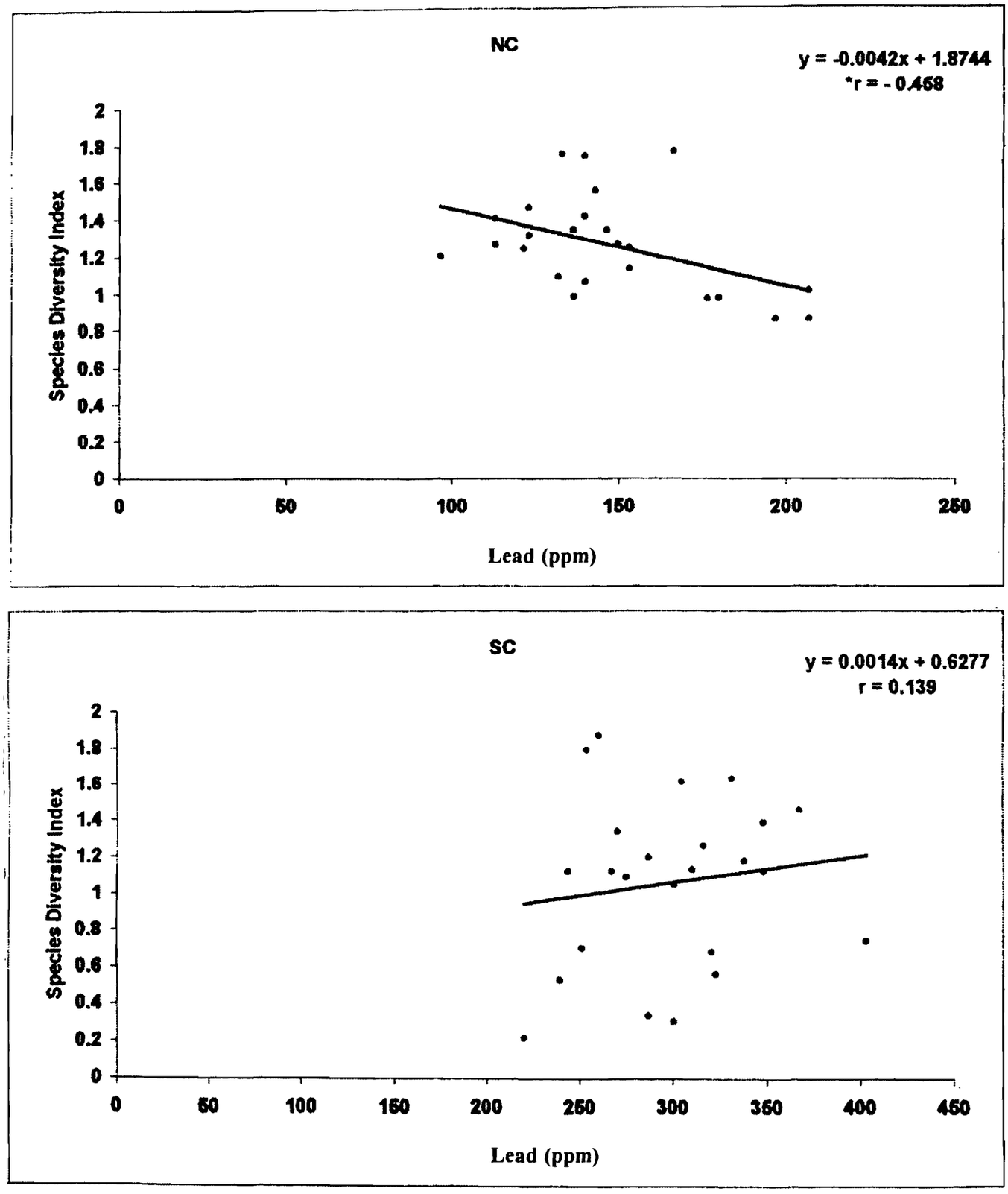

Fig. 8. Showing correlation coefficient (r), regression equation and trend line of species diversity index on Lead (ppm) at sites NC and SC (average) (*P < 0.05).

It thus appeared that species diversity of ants in the road side soil was extremely variable from site to site and which was largely dependent on the physico-chemical parameters of the soil. Lead played a significant role by demonstrating a negative effect on species diversity. However, vegetation being capable of absorbing lead from the soil seemed to control soil lead concentration and thereby

influencing the species diversity. The species having maximum tolerance level augmented its population in a positive manner and occupied highest position according to the index of dominance. Large variations existed in the abundance of species at different sites and highest similarity was established in between the sites having similarity in their vegetal components and physico-chemical nature of the soil. Large variations occurred in the richness of species but no significant relationship could be established for such variations on account of lead.

ACKNOWLEDGEMENT

The authors are grateful to the Director, Zoological Survey of India for providing necessary permission to carry out this project and to take keen interest for making of the final manuscript.

REFERENCES

Bahlsberg-Phalsson, A. 1989. Toxicity of heavy metals (Zn, Cu, Cd, Pb) to vascular plants. *Water, Air, Soil Pollut.*, **47** : 287-319.

Biswas, B. K.; Chakraborty, D; Konar, S. K. 1998. Impact of Environmental Pollution on species diversity of macrobenthic fauna in the river Damodar. *Environment & Ecology,* **16**(4) : 919-923.

Chattopadhyay, A. and Hazra, A. K. 2000. Effects of heavy metal contaminated sewage effluents on the soil Arthropods in and around Calcutta. *Rec. zool. Surv. India.,* Occ. Paper No. **185**.

Gadagkar, R.; Nair, P.; Chandrashekara, K and Bhat, D. M. 1993. Ant species richness and diversity in some selected localities in Western Ghats, India. *Hexapoda,* **5**(2) : 79-94.

Holldobler, B. and Wilson, E. O. 1990. *The Ants.* Harvard University Press, Cambridge, MA, 732 pp.

Krzysztofiak, L. 1991. The effect of habitat pollution with Heavy Metals on ant populations and ant-hill soil. *Ekol. Pol.,* **39**(2) : 181-202.

Margalef, R. 1951. Diversidad deespecies en las comunidades naturals. *Puplnes, Inst. Biol. Apl.,* Bercelona, **6** : 59-72.

Migula, P. and Binkowska, K. 1993. Feeding strategies of grasshoppers (*Chorthippus* sp.) on heavy metal contaminated plants. *The science of the Total Environment,* Supplement 1993, Elsevier Science Publishers B. V., Amsterdam.

Migula, P.; Nuorteva, P. and S-L; Glowacka, E. and Oja, A. 1993. Physiological disturbances in ants (*Formica aquilonia*) from excess of cadmium and mercury in Finish Forest. *The science of the Total Environment* Supplement 1993, Elsevier Science Publishers B. V., Amsterdam, 1305-1313.

Petal, Joanna. 1981. Intraspecific competition as a way of adaptation to food resources in an ant population. *Ekol. Pol.,* **29**(3) : 421-430.

Pielou, E. C. 1975. *Ecological diversity.* John Wiley & Sons, New York.

Przybylski, Z. 1979. The effect of automobile exhaust gases on the arthropods of cultivated plants, meadows and orchards. *Environ. Pollut.,* **19** : 157-161.

Przybylski, Z. 1981. Wplyw skazonego srodowiska gazami spalinowymi pojazdow mechanicznych na zasiedlenie przez stawouogi plantacji pszenicy ozimej polozonych przy drodze o intensywnym ruchu samochodowym [The effect of habitat pollution with exhaust gases of mechanical vehicles on arthropod colonization of winter wheat plantations situated along the roadside of an intense-traffic artery]. In : *Entomologia a gospodarka narodowa [Entomology and national economy]* (Eds. Sierpinski, Z., Sandner, H.; Kania, C. and Mikolajczyk, W.). Panstwowe Wydawnictwo Naukowe 263-267.

Spellerberg, I. F. 1991. *Monitoring ecological change.* Cambridge Univ. Press, Cambridge, 334 pp.

Stary, P. and Kubizñáková, J. 1987. Content and transfer of heavy metal air pollutants in population of *Formica* spp. wood ants (Hym. : Formicidae). *J. Appl. Entomol.,* **104** (1-5) 1-10.

Trammer, E. J. 1969. Birds species diversity : Component of Shanon's formula. *Ecology,* **50** : 925-936.