

**Studies of Collembola from Agricultural fields and
Waste Disposal Sites of West Bengal with special
reference to their Microbial Association**

**A. K. HAZRA
B. BHATTACHARYYA**



**RECORDS
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disposal sites of West Bengal with special reference to their
Microbial Association**

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INTRODUCTION

The earliest attempt to study the soil Fauna was made by Diem (1930) in the Alpine Soil. There after a series of workers have published on taxonomy, ecology of collembolan as well as microbial communities in soil of different ecosystems in India and abroad viz McAtee (1907); Brown (1912-13), Imms (1912), Worksman (1916a, b and 17), Thompson (1924), Wilson and Lyon (1926), Dixon (1928), Agrell (1941), Gisin (1943 and '55), Weis-Fogh (1955), Ramakrishna (1955), Sheals (1956,57), Chritiansen *et al.* (1961 and '64), Choudhuri (1961, '62a, b and '63) Dunger (1962), Clark (1965, '67), Choudhuri and Roy (1971, b and 71a, b) Hale (1967), Prabhoo (1967, '71a, b and '76), Rappoport (1967) Gujafati (1968) Sing and Mukherjee (1971 and '73), Hazra *et al.* (1976), Mitra *et al.* (1977), Hazra (1976), Hazra and Choudhuri (1981, '83), Hagvar (1982), Parkinson (1983), Veeresh (1900), Alfred *et al.* (1991), Chakraborty and Bhattacharya (1992) Sage *et al.* (1997), Hazra *et al.* (1999), Mitra *et al.* (1999).

Several Workers have studied the impact of heavy metals on microfauna and viz; microflora, viz; Less (1948), William (1948) Nordgren *et al.* (1983), Bengtsson *et al.* (1985b), Duxbury (1986), Hopkin (1986, '89), Hazra and Choudhuri (1990), Anissimova *et al.* (1993), Roane and Kellogg (1996), Dar (1997) and Chattopadhyay and Hazra (2000). From the above literature it was assumed that the research works on Soil-Biology have tried to assess the impact of different biotic and abiotic factors on the distribution and diversity of soil mesofauna with special reference to Collembola. In addition, impact of polluting agents like heavy metals on the population of soil microbes as well as on Collembola have also been analysed. The review of literature further revealed that in India sub-continent the research work on this fields either lacking or fragmentary. These appartment lacunae prompted the authors to start the present investigation i order to have more or less clear and comprehensive picture on soil bacteria, actinomyoetes, fungi and Collembola in relation to their association with different crops in agriculture as well as with different vegetables grown on waste disposal site. It is in this context the present investigation were undertaken with the following objectives

- i. To estimate the quantitative and qualitative composition of Collembola, fungi-bacteria-actinomycets communities in four different habitats.
- ii. To study the seasonal abundance and population fluctuations of collembolan and soil microorganisms.
- iii. To compare the species composition of Collembola community with that of fungi and bacteria-actinomycets genera in respect of different locality.
- iv. To evolute the Edaphic/Abiotic factor like temperature, moisture and properties such as pH, organic carbon-nitrate and phosphate including the heavy metals like mercury, copper and zinc and their level of concentration in study site.
- v. To assess the significance of soil micro organisms as well as the impact of soil parameters and heavy metals on the population structure of Collembola and also the microflora in different habitats.

MATERIALS AND METHODS

Methods of Sampling

Soil samples were collected at random, at the rate of 3 samples per plot every month during January, 1996. Samples were drawn by using a stainless steel corer (inner cross-sectional diameter 8.5 sq/c.m) from a depth of 5 cm.

Separate sample units were taken from each site for the soil microbes and estimations of soil parameters, heavy metals etc. The soil samples thus collected were kept immediately in sterile polythene packet and stored in 4°C in the laboratory.

Extracation of Collembola

Extracation of soil samples were carried out by 'Expedition Funnel Apparatus' modified by Macfadyen (1953). A 40-watt bulb was used for heat and light source. The extraction period was 72 hours.

Isolation of Soil Microbes (Bacteria, Actinomycetes and Fungi)

Considering the variety of microorganisms harboured in soil, it is apparent that no single method can reveal the total microbial population. The techniques available to study the soil microorganisms, the 'dilution plate method' is most widely used. With wide acceptance and popularity there are many variations of this technique. Jhonson *et al.* (1959) gave a good description of the detail procedure. Though the viable colony count from a plating of diluted soil suspension, however, it must be recognised that a single medium and a prescribed condition of incubation will not support the growth of all the species in any group of these microorganisms.

In the present investigation, sterile de-ionised double distilled water was used to prepare the soil suspension for dilution series. Nature of culture:

Isolation	Medium	Dilution grade	Temperature	Incubation
Bacteria	Luria agar	10 ⁻⁴	37°C	24 hrs.
Actinomycetes	Starch-casein	10 ⁻⁴	28°C	7 days
Fungi	Czapek-Dox	10 ⁻²	30°C	72 hrs.

Composition of the culture medium : LURIA AGAR (1 lit.) : Trypton = 10 g yeast extract =5 g. Sodium Chloride = 5g. and Agar = 15g. dissolved in 1000 ml of distilled water;

pH (at 25°C) = 7.3 + 0.2. STARCH-CASEIN (1 lit.) Soluble starch = 10g. Casein (vitamin free, Difco) = 0.3g, KNO_3 = 2g, NaCl = 2g, K_2HPO_4 = 2g, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ = 0.05g, CaCO_3 = 0.02g, FeSO_4 , & H_2O = 0.01g, & Agar = 20g, Dissolved in 1 liter of distilled water. Cyclohexamide was used at 30 micro-gm / ml. to prevent the fungal growth CZAPEK-DOX (1 lit.) : Sucrose = 30g, Sodium Nitrate = 3g, Magnesium Sulphate = 0.5g, Potassium Chloride = 0.5g, Iron (II) Sulphate = 0.01g, di-potassium Hydrogen Phosphate = 1g, S Agar = 13g, Dissolved in 1000 ml distilled water, pH (at 25°C) = 7.3 + 0.1. Ambystatin was used at 30 micro-gm/100ml. as an antibiotic to prevent bacterial growth. The counts of bacteria, actinomycetes and fungi 100 micro-liter aliquots was used. From each dilution, five replicate plates were prepared on respective agar medium. The mean value of the total viable count (colony forming unit /CFU) from all the respective dilution culture plates were considered. The actinomycetes have been cultured separately but both the counts of bacteria and actinomycetes together have been presented.

Analysis of Soil Factors

Fresh soil sample was dried immediately on a hot air oven at about 105°C in order to stop further bacterial action (some sample was kept separately for the analysis of nitrate and estimation of soil moisture). It was then allowed to cool and stored in a dessicator. The dried soil passed through the 2 mm. sieve, mixed and fractionated before analysis.

Mechanical Analysis : The size of particle in soil is one of the most important physical properties for determination. It is done by following the standard procedure as outlined by the Folk and Ward (1957) and by using Shepard's (1954) nomenclature. At first, the sample was weighed (25 gm.) and soaked in H_2O_2 (30% strength) in a beaker and kept for about 12 hrs. After boiling for some times the sample was allowed to cool and ammonia was added. Sample was washed in distilled water on 230 ASTM mesh, - 230 materials were transferred to 1000 c.c measuring cylinder and distilled water was added to make up the volume. To know the sand- silt-clay percentage this mixture was separately pipetted and weighed. +230 (ASTM) materials were separately collected in a beaker, dried and weighed. If the weight was equal or more than 5% of the bulk, the +230 fraction materials were sieved by mechanical sieving just to know the different coarse fraction percentage.

Pipetting: To know the sand-silt-clay ratio 8 dry beakers (for each sample) were weighed. Before stirring, the sample kept in a cylinder and the temperature of the day was recorded with variation of temperature there would be variation of the time of pipetting 4, 405, 5, 505, 6, 7, 8 and 9 pH fractions were pipetted by 20 c.c pipette from the cylinder and kept in the dry beakers. These were allowed to dry. The weight difference between the last and the first one (empty dry beaker) would give the weight at different pH fraction. This was multiplied by 50 to know the position in total 1000 c.c sample (taken in the cylinder). Based on the formula the sand-silt-clay percentage was derived.

Temperature : Soil- thermometer was used to record the temperature of the soil.

Hydrogen Ion Concentration (pH) : pH of the soil was determined the electronic pH meter, "WTW -pH 320" A soil suspension was prepared in a glass bottle with stopper, where, one part of soil was mixed with 5 parts of deionized double distilled water and shaken in a mechanical shaker for one hour. This ratio has been adapted for all determination by CSIR Division of Soils (Piper, 1942). Before taking the reading of the pH of the soil solution the instrument was standardised each time with a standard Beckman buffer solution to avoid the instrumental error.

Moisture : Moisture of the soil sample was measured by the 'Oven Dry Method' (Dowdeswell, 1959) and expressed in percentage of the weight difference before and after the soil sample was dried at 105°C for four hours.

Organic Carbon : Organic carbon content of the soil was determined by 'Rapid Titration Method' (WALKELY AND BLACK, 1934). %C=3.951/g (1-TS) Organic matter present in the soil (1 gm) is digested with excess 1(N) $K_2Cr_2O_7$ and conc. H_2SO_4 and the residual utilized dichromate is then titrated with 1(N) $Fe(NH_4)_2SO_4$ using diphenyle Amine indicator.

Nitrate : Extraction of soil sample: In a glass bottle 50 gm of natural moist soil, free of coarse stone, was mixed with 100 ml of 0.025 mol/L $CaCl_2$ solution. A spatula tip full of charcoal, activated for soil test, was added and the closed bottle was shaken in a shaker for one hour. The suspension was allowed to settle and filtered through a fluted filter. A drying of the sample before determination is not advisable because of the fast change in nitrogen forms. The analysis therefore carried out very quickly after the sampling.

Measurement : Nitrate content of the soil was determined by using the microprocessor based universally accepted standard single beamed photometer SQ 118, (E. Merck, Germany make) employing tungsten halogen lamp as the light source. Measurement depends upon the reaction of nitrate with Nitrospectral in concentrated (96%) H_2SO_4 to give a deep red nitro-compound. Measurement is done against a blank solution after selection of desired number at 515nm. Analysis value is displayed in mg/l on display board

Phosphate

Extraction of soil sample : 10 gm of soil was mixed with 100ml Ca-lactate Ca-acetate extraction solution in a glass bottle. A spatula tip full of charcoal, activated for soil, was added and closed bottle was shaken in a mechanical shaker for one hour. The suspension was allowed to settle and filtered through filter paper (Whatman No.1)

Measurement : Phosphate contained of the soil was determined by SQ 118 photometer. The solution was acidified with Sulfuric acid, the orthophosphate ion and molybdate ion form molybdophosphoric acid. Ascorbic acid reduces this to phosphomolybdenum blue (PMB), which is determined photometrically at 712 nm wavelength against a blank solution.

Analysis of Heavy Metals :

Copper, Lead & Zinc : Extraction of soil sample : 0.1gm of sample was digested in a teflon beaker with HNO_3 for one hour. It was then allowed to evaporate to a pasty mass on a hot plate. Take up 1(N)HCL, transferred to a 100 ml volumetric flask to make up the volume. Measurement was done by Atomic Absorption Spectrophotometer. Perkin Elmer 5000, present at G.S.I., Chemical Division, Kolkata. Water was aspirated at first, to test any drifting in the absorbance and instrument reading for water is set for zero. The calibration solution for the desired element in order of increasing absorbance was aspirated and then the test solution followed by the blank at respective wavelength. Measuring wavelengths for Cu, Pb & Zn are 324.8 nm., 217.0 nm., 213.9 nm. respectively.

Mercury : Cold vapour atomic (Hg) absorption spectrophotometric method was followed.

Extraction of soil sample : 1 gm of soil was leached with 5 ml H_2SO_4 and 5ml HNO_3 for 10 minutes. It was then kept on hot water bath for one hour. Allowed it to cool down and transferred to a 100 c.c. volumetric flask to make up the volume.

Measurement : Extracted solution was transferred to a 250ml BOD bottle with aspirator for Mercury Analyzer (EC India make) present at G.S.I., Chemical division, Calcutta. 10 % SnCl_2 solution was added and shaken for 2 minutes. Measurement was carried out against the blank and standard solution of 2 ppb HgCl_2 .

OBSERVATIONS

Site Wise Analysis of Collembolan Fauna And Microbial Flora

The present investigation involves extraction / isolation of soil microfauna / flora from the sampling plots in four different habitats (3 plots in each habitats), such as:

Site I : Bethuadhari Reserve Forest (BRF), Nadia District.

Site II : Dhapa (DP), East Kolkata.

Site III : Sugarcane Research Station (SRS), Nadia District.

Site IV : Rice Research Station (RRS), Chinsurah, Hoogly District.

The sites are densely populated and industrialised areas at Gangetic plain of West Bengal (Map 1), a state in the Eastern region of the India Republic, situated between 22°N - 27°N and 86°E - 89°E .

BETHUADHARI RESERVE FOREST (BRF) /SITE I

Location and characteristic of sampling site : It is a man made forest, located at Bethuadahari, by the side of NH- 34, about 120 Km. North of Calcutta, in the district of Nadia, at the eastern part of West- Bengal is being situated in the Gangetic plain (Map 1). Tropic of cancer runs across the middle of the district. Annual rainfall ranges from 77 -84.70 cm. The forest contains major trees like, *Shorea robusta*, *Tectona grandis*, *Ficus religiosa*, *Mangifera indica* and *Azadirachta indica* and under growths like, *Sporobolus diander*, *Dichanthium annulatum*, *Eragrostis brachyphylla*, *Digitaria marginata*, *D. royleana*, *Euphorbia hirta* and *Lantana camara*. The sampling site was covered with litter of the fallen leaves and dried twigs of the above trees and with the excreta of the spotted deer (Photograph 1a-b).

Soil Factors

Soils of the plots were alluvial in nature, blackish brown in colour and sandy silt in texture. Mechanical analysis of soil samples showed maximum percentage of coarse to medium silt 33.6% and more or less equal percentage of fine sand and fine silt (Tab. 1). During May, soil moisture content was 26% in 1996, 25.5% in 1997 and 27% in 1998. The month of August in each sampling year showed maximum moisture content in soil (35.2% in 1996 and 34.8% in 1997). During May other soil factors such as temperature, organic carbon, nitrate and phosphate were 36°C, 1.2%, 1.75 ppm and 5.3 ppm; 33°C, 1.3%, 1.85 ppm and 2.2 ppm; 35°C, 1.22%, 1.75 ppm and 5.5 ppm in 1996, 1997 and 1998 respectively. The mean values of other revealed more or less identical characteristics (Tab. 1a; Fig. 1a).

Heavy Metals

Monthwise mean concentration of heavy metals (Hg, Cu, Pb and Zn) obtained from soil sample have been shown in Tab. 1b, from which it would be evident that, in August the concentration of heavy metals were low (Hg 0.022 ppm, Cu 5.0 ppm, Pb 20 ppm and Zn 20 ppm in 1997). While, in the month of May 1996, the concentration of all these metals were found to be high in this site (Fig. 1b).

Collembolan Fauna

The Collembolan Fauna obtained from this site belonged to 20 species under 16 genera. The genus *Lepidocyrtus magnificus* was the most dominant and it was 40.34% of the total fauna recorded from this site. The species *Homidia* sp. contributed 17.7%, *Yosiia dehradunia* contributed 10.62%, *Isotomurus balteatus* contributed 10.0%, *Sminthurides appendiculatus* contributed 5.16%, *Lepidocyrtus medius* contributed 4.17%, *Cryptopygus thermophilus* contributed 2.23%, *Isotomiella minor* contributed 1.94% and *Cyphoderus javanus* contributed 1.4% (Tab. 1c; Fig. 1c). Populations of other species from this site were numerically low and highly irregular in distribution pattern. Percentage of Collembola obtained was found to be maximum in the month of August in both the years, which coincided with the maximum population of soil fungi as well as maximum concentration of soil factors like moisture, organic carbon and low concentration of heavy metals (Fig. 1a-b, 1d). Partial

increase in population in December - January as obtained in this site might be due to prevalence of winter maxima resulting from increased population of some species of Collembola as evident in (Tab. 1c).

Seasonal Changes

Seasonal changes of each predominant species of collembola obtained from this site revealed that (Fig. 1e), *L. magnificus* had August peak in both the year. While, *Homidia sp* showed maximum peak in January 1996 but in 1997 the peak was shifted to December and second peak was in February. *Y. dehradunia* had its highest population in January 1996, higher population was noticed during July 1997. It is apparently seen that, predominant forms of Collembola obtained from this site exhibited an irregular trend of fluctuation being minimum in May, slightly higher in December/ January/February. In this field, the population peak of other genera / species also varied among the years as well as month of observation due to their irregular occurrence (Tab. 1c).

Microbial Flora

Fungi : The soil fungi obtained from this site belonged to 9 genera.; The genus *penicillium* was the most dominant and 67.52% of the total population recorded from this site. The genus *Aspergillus* contributed 8.59% and *Trichoderma* contributed 3.68% population of other genera recorded were numerically low and irregular in occurrence (Tab. 1 b; Fig. 1f). The maximum percentage representation of total fungi, which obtained in August of both the years, coincided with the maximum concentration of soil factors like moisture, organic carbon and also low concentration of heavy metals (Fig. 1a-b, 1b)

Seasonal Changes

Figure 1g showed the monthwise changes in number of dominant genera of fungi recorded from this site. *Penicillium* had peak in August 1997 and second peak in December 1996. *Aspergillus* had its highest peak in November 1996 and was numerically high during February 1996 while, maximum population density of *Rhizopus* was in January 1996. The abundance of other genera varied among years as well as in months of observation due to their irregular occurrence in this field as evident from the Tab. 1d. In May, absence of some genera and poor occurrence of the dominant forms resulted in minimum population density of total fungi community in this site.

Bacteria - Actinomycetes

The soil bacteria -actinomycetes obtained from this site belonged to 10 genera. The genus *Streptomyces* was the most dominant with 28.08% of the total population recorded from this site, followed by *Bacillus* (22.85%) and *micrococcus* (16.14%). In addition some other genera were also obtained from this study site, but ,they were irregular and numerically very poor (Tab. 1e; Fig. 1h). A maximum of 7.23% and 4.71% population of bacteria -actinomycetes were recorded in the month of December' 1997 and October' 1996 respectively (Fig. 1d). The population was high when the concentration of soil phosphate was fairly high. The

minimum population obtained in the month of May in each year, found to be coincided with that of Collembola and fungi as minimum content of moisture, organic carbon and the high level of heavy metals in soil (Fig. 1a-b, 1d)

Seasonal Changes

The population peak of dominant genera varied during different years as well as in the months of observation (Fig. 1i). The genus *Streptomyces* showed more or less gradual trend inflection throughout the study period with the highest peak in September'1996. The population of *Bacillus* gradually declined from January to July in 1996 while it became very best till February'1997, the population during the months of observation exhibited fluctuations, the highest peak was in January ' 1998. The population density and the trend of fluctuation of the other genera were found to be numerically very low and irregular. In May, absence of some genera and poor occurrence of the dominant forms resulted in minimum population density of total bacteria - actinomycetes communities in this site (Table. 1e).

Table 1 - Mechanical analysis of soil

Sampling site	Coarse sand	Medium sand	Fine sand	coarse to Medium silt	fine silt	Clay
Site I:BRF	4.3684	2.4573	20.4777	33.5962	21.6687	17.4317
Site II: DP	57.9562	3.9447	8.5943	9.0118	1.0002	9.492
Site III:SRS	-	-	29.1842	37.1479	20.4836	13.1843
Site IV: RRS	-	-	1.6866	37.6271	42.2057	18.4806

Table 1a. Values of edaphic factors per month (Jan '96-Jun'98) at site I : BRF

MONTH		Temperatuere(0C)	Moisture (%)	pH	Organic carbon(%)	Nitrate (ppm)	Phosphate (ppm)
	^J	20.00	30.00	6.5	3.00	2.35	8.4
	F	22.00	30.00	6.4	3.10	2.27	7.7
	M	29.00	30.50	6.7	2.80	2.15	7.0
	A	36.00	28.00	7.0	2.66	1.90	5.7
1	M	36.00	26.00	7.0	1.20	1.75	5.3
9	J	32.00	27.00	6.8	2.10	2.00	2.0
9	J	32.00	32.00	6.3	3.63	2.40	2.4
6	A	30.50	35.20	6.1	3.95	2.57	4.5
	S	31.20	33.50	6.5	3.66	2.48	6.6
	O	31.00	31.00	6.6	3.52	2.35	8.1
	N	29.70	30.00	6.4	3.52	2.00	8.6
	D	26.00	29.00	6.3	3.30	2.48	8.6
	J	19.00	28.00	6.4	3.40	2.35	7.9
	F	21.00	27.50	6.4	2.92	2.20	8.3
	M	26.00	29.00	6.4	2.700	2.15	6.3
	A	34.00	28.00	6.5	1.50	1.90	6
1	M	33.00	25.5.0	6.9	1.30	1.83	2.2
9	J	30.00	31.90	6.8	2.76	2.40	2.2
9	J	30.50	33.00	6.2	3.90	2.46	2.3
7	A	32.00	34.80	6.0	4.05	2.50	3.5
	S	30.00	33.20	6.3	3.75	2.30	3.1
	O	28.00	31.00	6.5	3.20	2.30	7.7
	N	25.00	30.00	6.2	2.80	2.35	7.9
	D	23.00	28.50	6.1	3.00	2.48	8.4
	^J	20.00	28.00	6.3	3.23	2.45	8.0
1	F	21.00	27.50	6.5	3.00	2.1.00	7.7
9	M	28.00	27.00	6.6	2.66	2.15	7.0
9	A	37.00	27.00	6.8	2.00	1.9.00	5.9
8	M	35.00	25.00	7.0	1.22	1.75	5.5
	J	33.00	27.00	6.8	2.30	1.95	5.5

Table 1b. Values of edaphic heavy metals per month at site I : BRF

MONTH		Mercury	Copper	Lead	Zinc
	^J	0.045	30	30	65
	F	0.041	35	27	70
	M	0.043	30	30	85
	A	0.055	40	32	120
1	M	0.059	42	30	120
9	J	0.041	45	30	100
9	J	0.030	10	25	80
6	A	0.030	8.0	22	70
	S	0.038	28	27	70
	O	0.041	25	25	65
	N	0.043	30	25	60
	D	0.050	35	25	60
	J	0.040	30	20	80
	F	0.043	35	25	75
	M	0.067	40	30	75
	A	0.600	50	30	90
1	M	0.600	50	30	120
9	J	0.043	30	30	100
9	J	0.029	5.0	25	25
7	A	0.022	5.0	20	20
	S	0.031	30	20	20
	O	0.030	30	20	65
	N	0.040	30	20	70
	D	0.043	35	25	70
	^J	0.057	30	20	70
1	F	0.060	30	20	65
9	M	0.060	35	20	70
9	A	0.045	30	20	80
8	M	0.040	45	25	100
	J	0.045	35	25	90

Table 1c: Abundance (no./ sq.m.) of individual collembolan species obtained per month from site 1: BRF

species	← 1 9 9 6 →											
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Lepidocyrtus magnificus</i>	1497.8 (0.62)	1145.37 (0.47)	352.42 (0.14)	176.21 (0.073)	176.21 (0.073)	440.52 (0.18)	11101.32 (4.62)	27136.56 (11.28)	1585.9 (0.66)	440.52 (0.18)	704.84 (0.29)	1674.01 (0.69)
<i>Homidia sp.</i>	1145.37 (0.47)	264.31 (0.11)	264.31 (0.11)	X	X	352.42 (0.140)	88.1 (0.036)	X	264.31 (0.11)	88.1 (0.036)	X	792.95 (0.33)
<i>Yosiia dehradunia</i>	3171.8 (1.32)	9138.32 (0.80)	2114.53 (0.88)	X	X	616.74 (0.25)	881.05 (0.36)	352.42 (0.14)	1585.9 (0.66)	X	X	440.52 (0.18)
<i>Isotomurus balteatus</i>	881.05 (0.36)	264.31 (0.11)	X	264.31 (0.11)	88.1 (0.036)	X	1850.22 (0.77)	440.52 (0.18)	88.1 (0.036)	88.1 (0.036)	88.1 (0.036)	176.21 (0.073)
<i>Sminthurides appendiculatus</i>	X	X	X	969.16 (0.40)	264.31 (0.11)	88.1 (0.036)	176.21 (0.073)	1057.26 (0.44)	264.31 (0.11)	440.52 (0.18)	792.95 (0.33)	5110.13 (2.12)
<i>L. medius</i>	704.84 (0.29)	88.1 (0.036)	88.1 (0.036)	88.1 (0.036)	X	X	440.52 (0.18)	4669.6 (1.94)	969.16 (0.40)	264.31 (0.11)	88.1 (0.036)	528.63 (0.22)
<i>Cryptopygus thermophilus</i>	88.1 (0.036)	X	X	88.1 (0.036)	176.21 (0.073)	X	352.42 (0.14)	88.1 (0.036)	264.31 (0.11)	440.52 (0.18)	88.1 (0.036)	264.31 (0.11)
<i>Isotomiella minor</i>	X	X	264.31 (0.11)	X	88.1 (0.036)	X	176.21 (0.073)	176.21 (0.073)	176.21 (0.073)	X	528.63 (0.22)	X
<i>Cyphoderus javanus</i>	X	X	176.21 (0.073)	352.42 (0.14)	X	352.42 (0.14)	X	X	X	176.21 (0.073)	88.1 (0.036)	X
<i>L. exploratorius</i>	264.31 (0.11)	X	X	X	X	88.1 (0.036)	X	X	X	88.1 (0.036)	X	88.1 (0.036)

figures in parenthesis showing %

Table 1c

Genera	← 1 9 9 7 →											
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Lepidocyrtus magnificus</i>	3964.75 (1.65)	881.05 (0.36)	1585.9 (0.66)	264.31 (0.11)	1762.11 (3.92)	10308.37 (4.29)	762.11 (0.73)	2114.53 (0.89)	2463.17 (1.1)	3171.8 (1.32)	2463.17 (1.1)	3171.8 (1.32)
<i>Homidia</i> sp	4493.4 (1.87)	6079.3 (2.53)	792.95 (0.33)	X	X	X	440.52 (0.18)	88.1 (0.036)	5374.45 (2.23)	1145.37 (0.47)	704.84 (0.23)	10308.37 (4.29)
<i>Yosiia dehradunia</i>	440.52 (0.18)	616.74 (0.25)	264.31 (0.11)	X	X	X	2819.3 8(1.17)	2463.17 (1.1)	969.16 (0.40)	X	264.31 (0.11)	1233.5 (0.51)
<i>Isotomurus balteatus</i>	352.42 (0.14)	440.52 (0.18)	6167.4 (2.56)	88.1 (0.036)	88.1 (0.036)	528.63 (0.22)	1409.7 (0.58)	1321.6 (0.550)	X	264.31 (0.11)	1674.01 (0.69)	X
<i>Sminthurides appendiculatus</i>	X	X	X	1145.37 (1.47)	176.21 (0.073)	X	X	440.52 (0.18)	X	88.1 (0.036)	528.63 (0.22)	88.1 (0.036)
<i>L medius</i>	2290.75 (0.95)	440.52 (0.18)	616.74 (0.25)	440.52 (0.18)	X	X	792.95 (0.33)	2026.43 (0.84)	176.21 (0.073)	88.1 (0.036)	528.63 (0.22)	616.74 (0.25)
<i>Cryptopygus thermophilus</i>	1057.26 (0.44)	176.21 (0.073)	X	88.1 (0.036)	176.21 (0.073)	88.1 (0.036)	440.52 (0.18)	528.63 (0.22)	X	264.31 (0.11)	352.42 (0.14)	88.1 (0.036)
<i>Isotomiella minor</i>	X	X	X	X	352.42 (0.14)	1850.22 (0.77)	X	X	176.21 (0.073)	88.1 (0.036)	704.84 (0.29)	X
<i>Cyphoderus javanus</i>	X	X	88.1 (0.036)	X	X	X	X	X	176.21	440.52 (0.18)	X	352.42 (0.14)
<i>L exploratorius</i>	440.52 (0.18)	88.1 (0.036)	X	X	X	88.1 (0.036)	X	X	X	X	X	88.1 (0.036)

Table 1c

	1997											
species	J	F	M	A	M	J	J	A	S	O	N	D
<i>L heterolepis</i>	X	X	X	X	X	352.42 (0.14)	X	X	X	X	X	176.21 (0.073)
<i>Folsomides exigus</i>	X	X	X	88.1 (0.036)	176.21 (0.073)	352.42 (0.14)	X	X	X	X	X	X
<i>Xenylla obscura</i>	176.21 (0.073)	176.21 (0.073)	X	X	88.1 (0.036)	X	X	X	X	X	X	X
<i>Sminthurides</i> sp	X	X	X	X	X	176.21 (0.073)	88.1 (0.036)	X	X	X	176.21 (0.073)	X
<i>Sphaeridia</i> sp	X	X	616.74 (0.25)	X	X	X	X	X	X	X	X	X
<i>Bourletiella</i> sp	X	X	X	X	X	X	352.42 (0.14)	X	X	X	X	X
<i>Pararrhopalites</i> sp	88.1 (0.036)	X	176.21 (0.073)	X	X	X	X	X	X	X	X	X
<i>Deuterosminthurus</i> sp	X	X	X	X	X	88.1 (0.036)	88.1 (0.036)	X	X	X	176.21 (0.073)	X
<i>Sinella Montana</i>	X	X	X	X	X	X	X	X	X	X	X	X
<i>Dicyrtomina</i> sp	X	X	X	X	X	88.1 (0.036)	X	X	X	X	X	X

Table 1c

species	← J	1 F	9 M	9 A	8 M	→ J
<i>Lepidocyrtus magnificus</i>	2378.85 (0.99)	2114.53 (0.88)	4052.86 (1.68)	1497.8 (0.62)	792.95 (0.33)	792.95 (0.33)
<i>Homidia sp</i>	1057.26 (0.44)	2466.96 (1.02)	2643.17 (1.1)	1057.26 (0.44)	88.1 (0.036)	2555.06 (0.06)
<i>Yosiia tehradunia</i>	1585.9 (0.66)	2202.64 (0.92)	1145.37 (0.47)	X	X	264.31 (0.11)
<i>Isotomurus balteatus</i>	2731.27 (1.13)	1233.48 (0.51)	X	X	X	X
<i>Sminthurides appendiculatus</i>	X	X	X	264.31 (0.11)	528.63 (0.22)	X
<i>medius</i>	1233.48 (0.51)	440.52 (0.18)	264.31 (0.11)	X	X	176.21 (0.073)
<i>Cryptopygus thermophilus</i>	X	X	X	88.1 (0.036)	176.21 (0.073)	X
<i>Isotomiella minor</i>	X	X	88.1 (0.036)	X	X	X
<i>Cyphoderus javanus</i>	X	X	616.74 (0.25)	176.21 (0.073)	X	528.63 (0.22)
<i>L. exploratorius</i>	X	X	X	264.31 (0.11)	X	X

Table 1c

species	← J	I F	9 M	9 A	8 M	→ J
<i>L. heterolepis</i>	616.74 (0.25)	176.21 (0.073)	X	X	X	X
<i>Folsomides exigus</i>	X	X	X	X	176.21 (0.073)	X
<i>Xenylla obscura</i>	X	X	X	X	X	X
<i>Sminthurides</i> sp	X	X	X	88.1 (0.036)	X	X
<i>Sphaeridia</i> sp	X	X	X	X	X	X
<i>Bourletiella</i> sp	X	X	X	88.1 (0.036)	X	X
<i>Pararrhopalites</i> sp.	88.1 (0.036)	X	X	X	X	X
<i>Deuterosminthurus</i> sp.	X	X	X	X	X	X
<i>Sinella Montana</i>	176.21	X	X	X	X	X
<i>Dicyrtomina</i> sp.	X	X	X	X	88.1 (0.036)	X

Table 1d ; Abundance (no. x 1000/ gm. soil of individual fungal genera obtained per month site I: BRF

Genera	← 1 9 9 6 →											
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Penicillium</i>	17 (1.9)	5 (0.56)	6 (0.67)	4 (0.45)	5 (0.56)	11 (1.23)	32 (3.57)	36 (4.02)	28 (3.12)	12 (1.34)	7 (0.78)	39 (4.35)
<i>Aspergillus</i>	X	12 (1.34)	11 (1.23)	5 (0.56)	2 (0.22)	6 (0.67)	2 (0.22)	2 (0.22)	X	7	14 (1.56)	1 (0.11)
<i>Rhizopus</i>	12 (1.34)	X	3 (0.33)	X	X	X	10 (1.12)	7	X	X	4 (0.45)	X
<i>Trichoderma</i>	2 (0.22)	X	1 (0.11)	X	X	X	X	3	2 (0.22)	X	X	X
<i>Sclerotium</i>	X	X	X	X	X	1 (0.11)	X	2 (0.22)	X	X	X	X
<i>Curvularia</i>	3 (0.33)	2 (0.22)	3 (0.33)	1 (0.11)	X	X	X	X	X	X	X	1 (0.11)
<i>Mucor</i>	X	5 (0.56)	2 (0.22)	1 (0.11)	X	X	3 (0.33)	X	X	3	1 (0.11)	X
<i>Cladosporium</i>	5 (0.56)	2 (0.22)	1 (0.11)	X	X	X	X	X	X	X	X	X
<i>Fusarium</i>	X	2 (0.22)	X	X	X	X	X	14 (1.56)	X	X	X	X

Table 1d

Genera	← 1 9 9 7 →											
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Penicillium</i>	27 (3.01)	24 (2.68)	11 (1.23)	13 (1.45)	5 (0.56)	18 (2.01)	44 (4.91)	52 (5.80)	16 (1.78)	22 (2.45)	29 (3.24)	38 (4.24)
<i>Aspergillus</i>	X	1 (0.11)	2 (0.22)	X	X	1 (0.11)	X	X	3 (0.33)	X	2 (0.22)	1 (0.11)
<i>Rhizopus</i>	6 (0.67)	2 (0.22)	2 (0.22)	X	X	X	X	4 (0.45)	1 (0.11)	X	X	X
<i>Trioderma</i>	X	2 (0.22)	17 (1.90)	X	X	X	X	2 (0.22)	X	X	X	X
<i>Sclerotium</i>	1 (0.11)	X	X	X	X	X	X	11 (1.23)	11 (1.23)	X	X	1 (0.11)
<i>Curvularia</i>	3 (0.33)	3 (0.33)	2 (0.22)	1 (0.11)	X	X	X	X	X	X	X	X
<i>Mucor</i>	1 (0.11)	1 (0.11)	X	X	X	X	4 (0.45)	1 (0.11)	X	X	1 (0.11)	X
<i>Cladosporium</i>	1 (0.11)	2 (0.22)	3 (0.33)	X	5 (0.56)	X	X	X	X	X	X	2 (0.22)
<i>Fusarium</i>	X	X	X	X	X	1 (0.11)	X	X	X	3 (0.33)	X	X

Table 1d

genera	←	1	9	9	8	→
	J	F	M	A	M	J
<i>Penicillium</i>	24 (5.68)	20 (2.23)	18 (2.01)	15 (1.67)	9 (1.00)	18 (2.01)
<i>Aspergillus</i>	1 (0.11)	3 (0.33)	X	X	1 (0.11)	X
<i>Rhizopus</i>	X	X	2 (0.22)	X	X	X
<i>Trichoderma</i>	1 (0.11)	X	3 (0.33)	X	X	X
<i>Sclerotium</i>	X	X	X	X	X	X
<i>Curvularia</i>	3 (0.33)	3 (0.33)	3 (0.33)	X	X	X
<i>Mucor</i>	2 (0.22)	1 (0.11)	X	X	X	X
<i>Cladosporium</i>	X	1 (0.11)	2 (0.22)	X	X	X
<i>Fusarium</i>	2 (0.22)	X	X	X	X	X

Table 1e : Abundance (no.x 100000 /gm.. soil) of individual bacteria-actinomycetes genera obtained per month from site 1: BRF

20

Genera	← 1 9 9 6 →											
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Streptomyces</i>	X	1 (0.06)	29 (1.87)	9 (0.58)	3 (0.19)	14 (0.90)	5 (0.32)	5 (0.32)	49 (3.16)	42 (2.71)	5 (0.32)	26 (1.68)
<i>Bacillus</i>	23 (1.48)	22 (1.42)	24 (1.55)	20 (1.29)	12 (0.77)	10 (0.64)	2 (0.13)	3 (0.19)	2 (0.13)	3 (0.19)	3 (0.19)	1 (0.06)
<i>Micrococcus</i>	16 (1.03)	6 (0.39)	X	X	X	27 (1.74)	12 (0.77)	17 (1.09)	X	15 (0.97)	4 (0.26)	18 (1.16)
<i>Listeria</i>	13 (0.84)	2 (0.13)	4 (0.26)	2 (0.13)	X	X	10 (0.64)	8 (0.52)	5 (0.32)	7 (0.45)	9 (0.58)	X
<i>Cellulomonas</i>	10 (0.64)	X	2 (0.13)	X	X	X	2 (0.13)	10 (0.64)	9 (0.58)	13 (0.84)	7 (0.45)	X
<i>Arthrobacter</i>	6 (0.39)	X	X	X	2 (0.13)	1 (0.06)	7 (0.45)	11 (0.71)	3 (0.19)	X	3 (0.19)	2 (0.13)
<i>Pseudomonas</i>	X	8 (0.52)	X	X	X	X	X	X	X	X	8 (0.52)	X
<i>Promicromonospora</i>	3 (0.19)	X	2 (0.13)	X	X	X	2 (0.13)	X	1 (0.06)	3 (0.19)	X	X
<i>Staphylococcus</i>	2 (0.13)	X	X	X	X	3 (0.19)	X	6 (0.39)	X	X	X	2 (0.13)
<i>Rhizobium</i>	X	X	X	X	X	X	X	X	X	X	2 (0.13)	X

Table 1e

Genera	← 1 9 9 7 →											
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Streptomyces</i>	26 (1.68)	1 (0.06)	39 (2.520)	33 (2.13)	3 (0.19)	17 (1.09)	1 (0.06)	2 (0.13)	10 (0.64)	41 (2.65)	28 (1.81)	17 (1.09)
<i>Bacillus</i>	5 (0.32)	2 (0.13)	25 (1.61)	2 (0.13)	9 (0.58)	1 (0.06)	14 (0.90)	1 (0.06)	2 (0.13)	2 (0.13)	16 (1.03)	2 (0.13)
<i>Micrococcus</i>	12 (0.77)	X	X	X	X	30 (1.94)	X	10 (0.64)	20 (1.29)	X	X	5 (0.32)
<i>Listeria</i>	7 (0.45)	18 (1.16)	20 (1.29)	8 (0.52)	3 (0.13)	X	X	4 (0.26)	4 (0.26)	X	3 (0.19)	23 (1.48)
<i>Cellulomonas</i>	X	2 (0.13)	2 (0.13)	10 (0.64)	4 (0.26)	X	2 (0.13)	10 (0.64)	12 (0.77)	X	5 (0.32)	17 (1.09)
<i>Arthrobacter</i>	X	X	2 (0.13)	1 (0.06)	3 (0.19)	2 (0.13)	17 (1.09)	9 (0.58)	6 (0.39)	1 (0.06)	11 (0.71)	37 (2.39)
<i>Pseudomonas</i>	9 (0.58)	14 (0.90)	X	X	X	X	X	X	X	X	X	X
<i>Promicromonospora</i>	X	5 (0.32)	2 (0.13)	2 (0.13)	X	X	X	X	2 (0.13)	X	X	10 (0.64)
<i>Staphylococcus</i>	X	X	X	X	X	6 (0.39)	X	X	X	X	X	1 (0.06)
<i>Rhizobium</i>	3 (0.19)	1 (0.06)	X	X	X	X	X	X	X	X	X	X

Table 1e

genera	←	1	9	9	8	→
	J	F	M	A	M	J
<i>Streptomyces</i>	7 (0.45)	1 (0.06)	10 (0.64)	2 (0.13)	1 (0.06)	8 (0.52)
<i>Bacillus</i>	35 (2.26)	9 (0.58)	31 (2.00)	30 (1.94)	15 (0.97)	28 (1.81)
<i>Micrococcus</i>	7 (0.45)	10 (0.64)	X	X	X	X
<i>Listeria</i>	X	13 (0.84)	X	X	2 (0.13)	2 (0.13)
<i>Cellulomonas</i>	8 (0.52)	10 (0.64)	7 (0.45)	1 (0.06)	X	X
<i>Arthrobacter</i>	3 (0.19)	2 (0.13)	X	X	2 (0.13)	2 (0.13)
<i>Pseudomonas</i>	2 (0.13)	1 (0.06)	X	X	X	X
<i>Promicromonospora</i>	1 (0.06)	1 (0.06)	2 (0.13)	X	X	X
<i>Staphylococcus</i>	X	3 (0.19)	2 (0.13)	X	X	X
<i>Rhizobium</i>	X	X	X	X	X	X

DHAPA (DP) /SITE II

Location And Characteristic of Sampling Site

The site is a dumping ground of city wastes, located by the side of Eastern Metropolitan By pass, Calcutta (Map 1). The area is demarcated by "Organic fertilizer Pvt. Ltd." as 'Conversion of City Solid Wastes into Organic Fertilizer in Collaboration with Calcutta Municipal Corporation and Eastern Fertilizer Pvt. Ltd.' The main constituents of the dumped materials were household wastes. Industrial effluents and the residues of vegetables. In this sampling site, cultivation of different vegetables (seasonal salad leaves, cauliflower, maize etc.) is practiced mixing the decomposing materials in the soil (Photograph 2a-b) Vallini et al. (1992a, b) claimed that co-composting is the ultimate step for reclaiming digested organic fraction of municipal solid wastes and vegetable residues from garden or market as agriculture fertilizer.

Soil Factors

Soil of this plot was blackish in colour and silty sand to sandy in texture. Mechanical analysis of soil sampled from this site showed maximum percentage of coarse sand 57.96% (Table1).

The soil organic carbon and nitrate content were maximum in the month of March in each sampling year (3.95%, 3.7 ppm in 1996; 3.95%, 3.85 ppm in 1997, and 4.23%, 3.8 ppm in 1998) and in March the soil moisture were 35.9%, 34.9% and 34% in 1996, 1997 and 1998, respectively. The soil pH recorded minimum in March (5.8 in 1996, 5.9 in 1997 and 5.9 in 1998). In the month of May, the soil moisture was minimum (25.4% in 1996, 25.3% in 1997 and 27% in 1998), when the factors like soil temperature, [H and phosphate were minimum (39°C, 6.7, 3.6 ppm in 1996; 35°C, 6.7, 5.7 ppm in 1997 and 39°C, 6.9, 6 ppm in 1998) (Tab. 2a; Fig. 2a).

Heavy Metals

Monthwise mean concentration of heavy metals in soil sample of site II have been shown in Tab. 2b and Fig. 2b. from which it would be evident that, in March 1998 the concentration of heavy metals were low (Hg 0.57 ppm, Co 175 ppm, pb 130 ppm and Zn 495 ppm).

Collembolan Fauna

The Collembolan fauna obtained from site II belonged to species under 15 genera. The genus *Lepidocyrtus cyaneus* was the most dominant with 44.99% of the total fauna recorded from this site. The species *Xenylla obscura*, *Cyphoderus javanus*, *Seira indica*, *Cryptopygus thermophilus*, *Friesea yosii* and *Protsotoma (Clavistoma) fitchioides* represented 25.74%,

19.55%, 2.71%, 2.5%, 1.6% and 1.07% respectively. Population of other species were numerically low and highly irregular in distribution pattern (Tab. 2c; Fig. 2c). Percentage representation of Collembola was maximum during the month of March in each year of observation (Fig. 2d). The population maximum in March found to be coincided with the highest population of soil fungi and bacteria actinomycetes as well as maximum concentration of soil factors like organic carbon, nitrate and also with the minimum concentration of heavy metals like mercury, lead and zinc (Fig 2a-b, 2d).

Seasonal Changes

Figure 2c showed the seasonal changes in number of each predominant species of Collembola obtained from this site. *L. cyaneus* had a single peak in March in a year. While *X. obscura* showed its peak in February. *C. javanus* exhibited highest peak in March with a higher population in February. It is seen apparently that predominant forms of Collembola obtained from this site exhibited maximum population in February March and Minimum in May. The population peak of other genera species varied among years as well as months of observation due to their irregular occurrence in this field (Tab. 2c.).

Microbial Flora

Fungi : The soil fungi obtained from this site belonged to 8 genera. The genus *Penicillium* was the most dominant occupying 64.63% of the total fungal population obtained from this site. The genus *Aspergillus* constituted 13.54% while *Fusarium* constituted 8.19% of total population. Other genera recorded were numerically poor and irregular in occurrence (Tab. 2d. Fig. 2f). The maximum percentage representation of fungi encountered in March every found to be coincided with the highest population of bacteria - actinomycetes as well as maximum concentration of soil factors like organic carbon, nitrate and also minimum concentration of soil pH and heavy metals like mercury, lead and zinc (Fig 2a-b, 2d).

Seasonal Changes

Figures 2g have shown the monthwise numerical changes of the predominant genera of soil fungi recorded from this site. The *Penicillium* had its peak in March in each year of observation. *Aspergillus* had its highest peak in July '1996, second peak in March '1997, The maximum abundance of other genera varied among year as well as in months of observation due to their irregular occurrence in this field (Tab. 2d). In May, absence of some genera and poor occurrence of the dominant resulted in minimum population density of total fungi community.

Bacteria - Actinomycetes

The soil bacteria- actinomycetes obtained from this site belonged to 10 genera. The genus

Bacillus was the most dominant and represented 59.09% of the total population recorded. The genus *Streptomyces* occupied 12.29% and *Micrococcus* occupied 7.73%. In addition some more genera were also recorded from this field but, their occurrences were irregular (Tab. 2e, Fig. 2h). A maximum population of 4.37% was in March' 1996 and 5.84%, 5.81% observed in February and March in 1997 respectively. The high percentage of total bacteria-actinomycetes during March, coincided with the high concentration of soil factors like organic carbon and nitrate, low value of pH and low concentration of heavy metals like Hg, Pb and Zn. The minimum population recorded in the month of May in each year coincided with that of Collembola and fungi as well as minimum content of soil moisture, phosphate and maximum value of soil pH (Fig. 2a-b, 2d).

Seasonal Changes

From figure 2i, it is evident that, population peak of dominant genera varied among years as well as in months of observation. The population of *Bacillus* showed an increasing trend from January' 1996 reaching peak in March, another peak was observed in December, the density was low between these two peaks; in 1997 the highest peak was in February and another in April but in remaining months it remained more or less high with slight fluctuation. The population of *Streptomyces* showed gradual trend in fluctuation with the highest peak in January' 1997. The third dominant genus *Micrococcus* was found to be very irregular, its population peaks were recorded in March, February and April respectively in the three consecutive year of study. The other genera also revealed irregular population peak due to their infrequent occurrence in this field. In May, absence of some genera accompanied with low population of pre dominant genera resulted in the minimum population density of

Table 2a : values of edaphic factors per month (Jan '96- Jun '98) at site II : DP

MONTH		Temperatuere(0C)	Moisture (%)	pH	Organic carbon(%)	Nitrate (ppm)	Phosphate (ppm)
	^J	22.00	27.20	6.20	3.63	3.15	11.20
	F	29.00	34.60	6.00	3.80	3.68	7.80
	M	35.00	35.90	5.80	3.95	3.70	8.20
	A	37.00	30.10	6.10	3.95	3.50	5.50
1	M	39.00	25.40	6.70	3.71	2.65	3.60
9	J	35.00	28.50	6.60	3.70	2.70	14.20
9	J	35.00	33.60	6.40	3.57	2.75	13.50
6	A	31.30	35.90	6.40	3.28	2.70	14.60
	S	34.10	31.30	6.50	3.50	3.00	14.60
	O	36.00	28.20	6.60	3.63	3.00	14.00
	N	24.70	27.00	6.60	3.50	3.12	12.90
	D	29.00	25.10	6.30	3.57	3.25	12.30
	J	21.00	24.10	6.20	3.47	3.38	7.80
	F	31.00	32.60	6.20	3.85	3.50	11.00
	M	39.00	34.90	5.90	3.95	3.85	11.20
	A	35.00	30.10	5.08	3.85	3.00	10.50
1	M	35.00	25.30	6.70	3.20	2.70	5.70
9	J	28.00	28.00	6.70	3.30	2.80	12.40
9	J	34.00	33.00	6.50	3.47	2.85	14.60
7	A	27.00	34.00	6.50	3.60	2.90	14.10
	S	36.50	30.00	6.60	3.95	3.10	14.50
	O	32.00	29.10	6.50	3.63	3.15	12.20
	N	30.00	27.00	6.60	3.95	3.23	11.90
	D	27.00	27.00	6.30	3.60	3.20	10.80
	J	21.00	24.00	6.30	3.80	3.25	7.70
1	F	26.00	30.90	6.10	3.98	3.40	9.70
9	M	34.00	34.00	5.90	4.23	3.80	11.00
9	A	37.00	30.00	6.20	4.00	3.00	9.30
8	M	39.00	27.00	6.70	3.66	2.90	6.00
	J	38.00	29.20	6.90	3.25	2.95	5.10

Table 2b values of edaphic heavy metals per month at site II DP

MONTH		Mercury	Copper	Lead	Zinc
	^J	1.000	200	170	600
	F	0.631	159	140	515
	M	0.620	190	130	515
	A	0.660	200	130	530
1	M	0.950	195	180	530
9	J	1.100	210	200	550
9	J	4.200	200	200	570
6	A	0.950	180	260	580
	S	1.300	190	300	620
	O	1.300	210	280	600
	N	1.200	205	270	610
	D	1.000	200	150	600
	J	0.630	200	150	550
	F	0.660	205	150	530
	M	0.600	180	140	510
	A	1.300	180	170	510
1	M	106.0	200	200	530
9	J	2.000	200	230	570
9	J	1.300	175	260	550
7	A	1.300	175	250	550
	S	2.000	205	320	615
	O	2.000	205	300	620
	N	1.600	20	250	610
	D	1.000	205	230	600
	J	0.930	180	180	615
1	F	0.500	185	150	505
9	M	0.570	175	130	495
9	A	1.000	175	150	515
8	M	1.000	180	150	510
	J	0.850	175	180	550

Table 2c : Abundance (no. / sq. m.) of individual collembolan species obtained per month from site II : DP

Species	← 1 9 9 6 →											
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Lepidocyrtus Cyaneus</i>	1762.11 (0.26)	6519.82 (0.96)	440.52 (0.065)	1585.9 (0.23)	88.1 (0.013)	1057.26 (0.15)	1674.01 (0.25)	176.21 (0.026)	176.21 (0.026)	88.1 (0.013)	440.52 (0.065)	88.1 (0.013)
<i>Xenylla obscura</i>	X	X	X	X	X	X	X	X	X	X	2555.06 (0.37)	528.63 (0.08)
<i>Cyphoderus javanus</i>	1145.37 (0.17)	9339.2 (1.37)	9339.2 (5.47)	37356.82 (0.18)	1233.48 (0.026)	176.21 (0.013)	88.1 (0.052)	352.42 (0.013)	88.1 (0.12)	792.95 (0.27)	1850.22 (0.08)	528.63 (0.039)
<i>Seira indica</i>	X	X	18942.76 (2.71)	X	X	X	X	X	X	X	X	X
<i>Cryptopygus thermophilus</i>	X	X	881.05 (0.13)	X	X	X	X	X	X	X	X	616.74 (0.09)
<i>Friesea yosii</i>	X	X	X (0.052)	X	352.42	X	X	X (0.13)	X	881.05 (0.026)	X	176.21
<i>Proisotoma</i> (Clavistoma) <i>fitchioides</i>	X	X	X	2202.64 (0.32)	264.31 (0.039)	1057.26 (0.15)	88.1 (0.013)	88.1 (0.013)	881.05 (0.13)	X	1497.79 (0.22)	X
<i>I. exploratorius</i>	X	X	X	264.31 (0.039)	X	X	X	X	X	X	88.1 (0.013)	88.1 (0.013)
<i>Ballistrura bengalensis</i>	X	X	X	X	352.42 (0.052)	X	X	X	792.95 (0.12)	X	X	X

Table 2c

Species	← 1 9 9 6 →											
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Sminthurides appendiculatus</i>	X	X	X	X	X	176.21 (0.026)	1057.36 (0.15)	1145.37 (0.017)	X	88.1 (0.013)	X	X
<i>Catx sp.</i>	X	X	X	X	X	X	X	X	X	X	X	X
<i>Isotomurus balteatus</i>	X	X	X	X	X	X	X	X	X	88.1 (0.013)	1145.37 (0.17)	X
<i>I. heterolrpis</i>	X	X	X	176.21 (0.026)	88.1 (0.013)	176.21 (0.026)	88.1 (0.013)	X	X	X	X	X
<i>I. heterolrpis</i>	X	X	X	176.21 (0.026)	88.1 (0.013)	176.21 (0.026)	88.1 (0.013)	X	X	X	X	X
<i>Sphaendia sp</i>	X	X	X	X	X	X	X	264.31 (0.039)	X	X	X	X
<i>Archerontiella sp</i>	X	X	X	X	X	X	X	X	X	X	X	X
<i>Isotomiella minor</i>	X	X	X	X	X	X	X	X	176.21 (0.026)	X	X	X
<i>Willemia sp.</i>	X	X	X	X	176.21 (0.026)	X	X	X	X	X	X	X

Table 2c

Species	← 1 9 9 7 →											
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Lepidocyrtus Cyaneus</i>	88.1 (0.013)	1762.11 (0.26)	137885.5 (20.21)	4581.5 (0.67)	792.95 (0.12)	440.53 (0.065)	88.1 (0.013)	88.1 (0.013)	88.1 (0.013)	88.1 (0.013)	88.1 (0.013)	88.1 (0.013)
<i>Xenylla obscura</i>	4052.86 (0.58)	575.33 (8.43)	1246.7 (1.8)	10660.8 (1.56)	616.74 (0.09)	7400.88 (1.08)	1585.9 (0.23)	1538.76 (0.83)	7577.09 (1.11)	8193.83 (1.2)	5462.55 (0.80)	1145.37 (0.17)
<i>Cyphoderus javanus</i>	176.21 (0.026)	8017.62 (1.18)	264.31 (0.039)	145.37 (0.17)	176.21 (0.026)	88.1 (0.013)	88.1 (0.013)	176.21 (0.026)	3612.33 (0.53)	6519.82 (0.96)	12070.48 (1.77)	6784.14 (0.99)
<i>Seira indica</i>	X	X	X	X	X	X	X	X	X	X	X	X
<i>Cryptopygus thermophilus</i>	176.21 (0.026)	6286.34 (0.77)	264.31 (0.039)	88.1 (0.013)	88.1 (0.013)	528.63 (0.08)	176.21 (0.026)	264.31 (0.039)	2026.43 (0.30)	1850.22 (0.27)	176.21 (0.026)	88.1 (0.013)
<i>Friesea yosii</i>	X	X	1585.9 (0.23)	528.63 (0.08)	88.1 (0.013)	1850.22 (0.07)	176.21 (0.026)	88.1 (0.013)	881.05 (0.13)	88.1 (0.013)	88.1 (0.013)	528.63 (0.80)
<i>Proisotoma(Clavistoma) fitchioides</i>	X	X	X	X	X	X	X	X	X	X	1233.48 (0.18)	X
<i>I. exploratorius</i>	X	528.63 (0.08)	1762.11 (0.26)	704.84 (0.10)	X	X	X	X	X	X	X	88.1 (0.013)
<i>Ballistrura bengalensis</i>	X	X	X	X	X	1674.01 (0.25)	616.74 (0.09)	X	X	X	X	X

Table 2c

Species	←	1	9	9	8	→
	J	F	M	A	M	J
<i>Lepidocyrtus Cyaneus</i>	2026.43 (0.30)	32599.11 (4.78)	104229.1 (15.28)	6255.51 (0.92)	792.95 (0.10)	969.16 (0.14)
<i>Xenylla obscura</i>	2731.27 (0.40)	28634.36 (0.42)	9515.41 (1.40)	6960.35 (1.02)	792.95 (0.12)	1762.11 (0.26)
<i>Cyphoderus javanus</i>	881.05 (0.13)	17180.6 (2.52)	18590.3 (2.72)	4140.96 (0.60)	176.21 (0.026)	88.1 (0.013)
<i>Seira indica</i>	X	X	X	X	X	X
<i>Cryptopygus thermophilus</i>	440.52 (0.065)	1850.22 (0.27)	1762.11 (0.26)	176.21 (0.026)	88.1 (0.013)	176.21 (0.026)
<i>Friesea yosii</i>	X	X	264.31 (0.039)	88.1 (0.013)	176.21 (0.026)	88.1 (0.013)
<i>Proisotoma</i> (Clavistoma) <i>fitchioides</i>	X	X	X	X	X	X
<i>I. exploratorius</i>	88.1 (0.013)	440.52 (0.065)	X	176.21 (0.026)	X	X
<i>Ballistrura bengalensis</i>	X	X	X	X	X	X

Table 2c.

Species	← J	I F	9 M	9 A	8 M	→ J
<i>Sminthurides appendiculatus</i>	X	X	X	X	X	X
<i>Catx</i> sp.	X	X	440.52 (0.065)	X	X	X
<i>Isotomurus balteatus</i>	X	X	X	X	X	X
<i>I. heterolrpis</i>	X	176.21 (0.026)	X	X	X	X
<i>Sphaendia</i> sp	X	X	X	X	X	X
<i>Sphaendia</i> sp	X	X	X	X	X	X
<i>Archerontiella</i> sp	X	X	X	X	88.1 (0.013)	X
<i>Isotomiella</i> minor	X	X	X	X	X	X
<i>Willemia</i> sp.	X	X	X	X	X	X

Table 2d

Genera	←————— 1 9 9 7 —————→											
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Penicillium</i>	23 (1.81)	5 (0.39)	55 (4.33)	46 (3.62)	14 (1.10)	33 (2.6)	14 (1.10)	28 (2.20)	29 (2.28)	22 (1.73)	50 (3.94)	26 (2.05)
<i>Aspergillus</i>	4 (0.31)	2 (0.16)	13 (1.02)	1 (0.08)	5 (0.39)	5 (0.39)	5 (0.39)	3 (0.24)	4 (0.31)	1 (0.08)	10 (0.79)	4 (0.31)
<i>Fusarium</i>	X	51 (4.02)	X	X	1 (0.08)	X	X	X	8 (0.71)	X	X	3 (0.24)
<i>Trichoderma</i>	X	9 (0.71)	8 (0.63)	8 (0.63)	X	X	1 (0.08)	X	X	11 (0.87)	2 (0.16)	X
<i>Cephalosporium</i>	X	X	X	X	14 (1.10)	X	X	X	X	16 (1.26)	X	X
<i>Mucor</i>	X	X	X	1 (0.08)	X	2 (0.16)	X	1 (0.08)	3 (0.24)	2 (0.16)	X	X
<i>Rhizopus</i>	X	X	X	X	X	X	X	X	X	X	X	X
<i>Sclerotium</i>	X	X	X	X	X	X	X	3 (0.24)	1 (0.08)	X	X	X

Table 1d

Genera	←	1	9	9	8	→
	J	F	M	A	M	J
<i>Penicillium</i>	26 (2.05)	55 (4.33)	59 (4.64)	43 (3.38)	16 (1.26)	25 (1.97)
<i>Aspergillus</i>	5 (0.39)	5 (0.39)	9 (0.71)	3 (0.24)	1 (0.08)	4 (31)
<i>Fusarium</i>	X	X	X	1 (0.08)	1 (0.08)	X
<i>Trichoderma</i>	X	X	8 (0.63)	2 (0.16)	X	X
<i>Cephalosporium</i>	X	9 (0.71)	7 (0.55)	X	X	X
<i>Mucor</i>	X	X	X	X	X	X
<i>Rhizopus</i>	X	X	X	X	X	X
<i>Sclerotium</i>	X	X	X	X	X	X

Table 2b : Abundance (no. x 1000 / gm. soil) of individual fungal genera obtained per month form site 11: DP

Genera	← 1 9 9 6 →											
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Bacillus</i>	33 (1.05)	49 (1.56)	71 (2.270)	47 (1.50)	21 (0.67)	36 (1.15)	29 (0.920)	14 (0.45)	10 (0.32)	5 (0.16)	13 (0.41)	72 (2.29)
<i>Streptomyces</i>	18 (0.38)	13 (0.41)	21 (0.67)	16 (0.51)	5 (0.16)	3 (0.09)	12 (0.38)	7 (0.22)	30 (0.96)	32 (1.02)	17 (0.54)	2 (0.06)
<i>Micrococcus</i>	X	X	30 (0.96)	29 (0.92)	5 (0.16)	X	X	15 (0.48)	X	8 (0.25)	X	X
<i>Cytophaga</i>	7 (0.22)	10 (0.32)	10 (0.32)	7 (0.22)	X	3 (0.09)	4 (0.13)	9 (0.29)	X	6 (0.19)	56 (1.79)	7 (0.22)
<i>Arthrobacter</i>	8 (0.25)	2 (0.06)	X	X	X	X	1 (0.03)	11 (0.35)	8 (0.25)	8 (0.25)	11 (0.35)	X
<i>Promicromonospora</i>	X	9 (0.29)	5 (0.16)	3 (0.09)	X	X	X	6 (0.19)	X	13 (0.41)	13 (0.41)	X
<i>Corynebacterium</i>	X	X	X	X	X	X	6 (0.19)	1 (0.03)	13 (0.41)	36 (1.15)	X	X
<i>Pseudomonas</i>	X	X	X	8 (0.25)	X	X	X	X	X	5 (0.16)	5 (0.16)	X
<i>Staphylococcus</i>	X	X	X	3 (0.09)	X	X	X	X	X	4 (0.13)	X	X
<i>E.coli</i>	X	X	X	X	X	X	X	X	X	10 (0.32)	X	X

figures in parenthesis showing %

Table 2e

Genera	←					1	9	9	7	→		
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Bacillus</i>	25 (0.79)	136 (4.34)	71 (2.26)	119 (3.79)	58 (1.85)	43 (1.37)	80 (2.55)	94 (3.0)	125 (3.99)	120 (3.83)	122 (3.89)	85 (2.71)
<i>Streptomyces</i>	50 (1.59)	13 (0.41)	21 (0.67)	6 (0.19)	13 (0.41)	7 (0.22)	3 (0.09)	5 (0.16)	8 (0.25)	1 (0.03)	5 (0.16)	17 (0.54)
<i>Micrococcus</i>	19 (0.60)	25 (0.79)	20 (0.63)	15 (0.47)	X	X	X	10 (0.32)	X	X	X	8 (0.25)
<i>Cytophage</i>	10 (0.32)	4 (0.13)	31 (0.99)	X	4 (0.13)	10 (0.32)	X (0.06)	X	2 (0.19)	X	6	X
<i>Arthrobacter</i>	14 (0.44)	X	23 (0.73)	X	X	41 (1.31)	20 (0.63)	X	7 (0.22)	X	X	14 (0.44)
<i>Promicromonospora</i>	3 (0.09)	X	11 (0.35)	X	X	3 (0.09)	X	X	X	X	2 (0.06)	X
<i>Corynebacterium</i>	4 (0.13)	X	3 (0.09)	X	X	X	X	X	X	X	X	2 (0.06)
<i>Pseudomonas</i>	X	X	2 (0.06)	10 (0.32)	X	X	X	X	X	X	X	10 (0.32)
<i>Staphylococcus</i>	6 (0.19)	5 (0.16)	X	X	X	X	X	X	X	X	X	2 (0.06)
<i>E coli</i>	X	X	X	X	X	7 (0.22)	X	X	X	X	X	X

Table 2e

Genera	←	1	9	9	7	→
	J	F	M	A	M	J
<i>Bacillus</i>	59 (1.88)	73 (2.33)	70 (2.23)	80 (2.55)	38 (1.21)	53 (1.69)
<i>Streptomyces</i>	10 (0.31)	16 (0.51)	15 (0.47)	13 (0.41)	9 (0.29)	3 (0.09)
<i>Micrococcus</i>	X	X	24 (0.77)	31 (0.99)	3 (0.09)	X
<i>Cytophage</i>	X	8 (0.25)	10 (0.32)	11 (0.35)	X	X
<i>Arthrobacter</i>	9 (0.29)	3 (0.09)	15 (0.48)	2 (0.06)	X	X
<i>Promicromonospora</i>	X	X	9 (0.29)	10 (0.32)	X	X
<i>Corynebacterium</i>	X	X	X	X	X	X
<i>Pseudomonas</i>	X	X	5 (0.06)	X	X	X
<i>Staphylococcus</i>	2 (0.06)	X	X	X	X	2 (0.06)
<i>E coli</i>	X	X	X	X	X	3 (0.09)

total bacteria- actinomycetes community (Tab. 2e).

SUGARCANE RESEARCH STATION (SRS) / Site III

Location Ad Characteristic of Sampling Site

The sampling site is situated at the campus of experimental field of Sugarcane Research station, by the side of NH-34 at Bethuadahari of district Nadia (Map 1). The land cultivated with sugarcane is treated as a monoculture crop field in the present investigation which remains in the field throughout the year (April to March). No chemical or organic manure was applied in the field. But the field was disturbed by usual agricultural practices like tilling hand weeding etc. The marginal boundary of the field was covered with Eucalyptus trees and grasses like *Cynodon dactylon*, *Dithanthium annulatum* and *Arundinella* sp. (Photograph 3).

Soil Factors

Soil of this plot was alluvial in nature, dark grey in colour and sandy silt in texture. Mechanical analysis of soil sampled from this site showed maximum percentage of coarse to medium silt 37.15% (Tab. 1). The soil organic carbon, nitrate and phosphate content were maximum in February in each sampling year (1.81%, 1.6 ppm in 1996; 1.63% 1.7 ppm, 7.7 ppm in 1997, and 1.72%, 1.65 ppm, 6.5 ppm in 1998), when the soil pH was minimum (6.7 in 1996, 6.6 in 1997 and 6.6 in 1998), when the soil temperature found to be maximum (38°C 40°C and 39°C in 1996, 1997 and 1998 respectively) (Tab. 3a : Fig. 3a).

Heavy Metals

Monthwise mean concentration of heavy metals obtained from soil sample of site III have been shown in Tab. 3b and Fig. 3b, from which it would be evident that in February the concentration of heavy metals like Hg (0.02 ppm), Pb (18 ppm) and Zn (30 ppm) were low.

Collembolan Fauna

The collembolans obtained from this site belonged to 22 species under 10 genera. The species *Salina indica* was the most dominant from contributing 31.3% of the total fauna recorded from this site. The species *Isotomurus balteatus* represented 25.5%, *Lepidocyrtus heterolpis* represented 22.26%, *Cyphoderus javanus* represented 4.2%, *Sminthurides appendiculatus* represented 3.75%, *Isotomiella minor* represented 3.07%, *Lepidocyrtus cyaneus* represented 2.55%, *Seira indica* represented 1.65% and *Lepidocyrtus exploratorius* represented 1.27% of total population. Other species in this site were numerically low and highly irregular in distribution pattern (Tab. 3c : Fig. 3c). The percentage representation of total Collembola was observed to be maximum during February in each year and coincided with the highest population of soil fungi as well as maximum concentration of soil factors like organic carbon, nitrate and phosphate, minimum value of pH and minimum concentration of heavy metals like mercury, lead and zinc (Fig. 3a-b, 3d). Partial increase in population in August as obtained

in this site might be due to the prevalence of monsoon maxima resulting from increased population of some species of Collembola (Tab. 3c).

Seasonal Changes

The seasonal changes in number of each predominant species of Collembola as observed in this site has been shown in Fig. 3e. The most dominant species *Salina indica* had its peak in August in both the years of observation. *I. balteatus* showed its peak in February in each year. The population density of *L. heterolepis* was maximum in April in 1998 and it remained high during January-February in each year. *C. javanus* and *S. appendiculatus* showed highest population peak during August (1997) and June (1996) respectively. It is seen apparently that, predominant forms of Collembola obtained from this site exhibited minimum in May and Maximum abundance either in February or in August. The population peak of other genera / species varied among years as well as month of observation due to their irregular occurrence in this field (Tab. 3c).

Microbial Flora

Fungi : The soil fungi obtained from this site belonged to 9 genera. The *Pencillium* was the most dominant being representation by 78.86% of the total population recorded from this site. The genus *Aspergillus* and *Fusarium* contributed 9.38% and 5.4 respectively. Population of other genera obtained were numerically low and infrequent in occurrence (Tab. 3d : Fig 3f). The maximum percentage representation of total fungi obtained in February of all three years coincided with the maximum concentration of soil factors like organic carbon, nitrate, phosphate, minimum value of pH and also with minimum concentration of heavy metals like mercury, lead and zinc (Fig. 3a-b, 3d).

Seasonal Changes

Figure 3g showed the monthwise changes in number of predominant genera of soil fungi recorded from this site. *Penicillium* had its highest peak in February and a second peak in August in each year of observation. *Aspergillus* was most abundant in March and June in 1996 and in February 1998. However, the maximum population peak of other genera varied among years as well as in months of observation due to their irregular occurrence in this field (Tab. 3d.) In May ,absence of some genera and poor occurrence of the dominant forms result in minimum population density of total fungi community.

Bacteria-Actinomycetes

The soil bacteria-actinomycetes obtained from this site belonged to 6 genera. *Streptomyces* was the most dominant and its representation was 43.7% of the total population recorded from this site. The genus *Arthrobacter* contributed 34.7% and *Micrococcus* contributed 10.99%. In

addition some more genera were also recorded with poor percentage during this study. (Tab.3e : Fig.3h). A maximum of 8.4% of bacteria-actinomycetes population were recorded in January 1996 and when the maximum population 5.5% was in November 1997 (Fig. 3d). The minimum population obtained in May during each year were found to be coincided with that of Collembola and fungi as well as minimum soil moisture, organic carbon content and with maximum value of soil temperature (Fig.3a, 3d).

Seasonal Changes

Figure 3i exhibited that, highest population peak of dominant genera varied among year as well as in the months of observation. The *Streptomyces* population showed two moderate peaks in 1996 (in March and September), the population density remained more or less high during October' 1996 to March' 1997 and from April' 1997 to rest of the months of observation when the highest peak was exhibited in December' 1997. The maximum population density of *Arthrobacter* was in January' 1996, however it was irregular from June' 1996 to July' 1997 and during August' 1997 to June' 1998 it showed a number of peaks. The population-fluctuation-graph of most of the other genera also revealed the appearances of irregular peak due to their infrequent occurrence in this field. In May, absence of some genera accompanied with numerically lower population of major genera result in minimum population density of total bacteria-actionmycetes communities (Tab.3e).

Table 3a : Values of edaphic factors per month (Jan'96-jun '98) at site III: SRS

MONTH		Temperatuere(0C)	Moisture (%)	pH	Organic carbon(%)	Nitrate (ppm)	Phosphate (ppm)
	^J	21.5	15.5	6.9	1.6	1.3	6.7
	F	22	14.1	6.7	1.81	1.6	6.9
	M	38	14	7	1.35	1.35	5.8
	A	41	10.4	7	1.3	1.3	5.2
1	M	38	10	7.2	0.85	1	3.4
9	J	27.5	12.7	2	1.06	1.2	3.3
9	J	30.5	19.5	6.9	1.2	1.25	3.2
6	A	32	23	6.9	1.8	1.45	3.2
	S	31	22.5	7	1.7	1.4	3.8
	O	29	20.7	7.1	1.7	1.35	4.5
	N	29	20	7.2	1.6	1.2	6.7
	D	20	17.2	7.1	1.7	1.1	6.8
	J	20	17.2	7	1.04	1.28	7.5
	F	21.5	15.5	6.6	1.63	1.7	7.7
	M	35	18.2	6.8	1.08	1.3	6.2
	A	35	20	7	1	1	6.6
1	M	40	11.1	7.4	0.75	0.85	6
9	J	30.5	12	7.2	1.08	0.9	4.2
9	J	31.2	18.9	7	1.59	1.1	4
7	A	33	23.5	6.9	1.55	1.4	3.5
	S	31	22	7	2.55	1.2	4.4
	O	30	20.2	7	1.52	1.2	7.1
	N	29	18	7.1	1.4	1	7.7
	D	22	17.7	7	1.6	1.2	7.4
	^J	21	18.3	6.9	1.55	1.25	6.5
1	F	23	18	6.6	1.72	1.65	6.5
9	M	37	15.5	6.9	1.5	1.3	6.3
9	A	41	13.1	7.2	1.3	1.2	6
8	M	39	9.5	7.3	1.02	1	6.2
	J	32	11.3	7.3	1.02	1.1	3.9

Table 3b : Values of edaphic heavy metals per month at site III: SRS

MONTH		Mercury	Copper	Lead	Zinc
	^J	0.07	25	20	50
	F	0.045	32	20	30
	M	0.05	29	20	40
	A	0.06	25	22	40
1	M	0.066	25	23	35
9	J	0.05	20	22	30
9	J	0.05	15	20	30
6	A	0.05	15	20	30
	S	0.06	17	25	30
	O	0.05	18	22	45
	N	0.06	15	25	50
	D	0.06	20	25	50
	J	0.05	35	22	50
	F	0.03	37	20	35
	M	0.03	30	20	32
	A	0.03	30	20	40
1	M	0.06	25	20	40
9	J	0.06	20	25	35
9	J	0.05	20	25	35
7	A	0.04	13	25	32
	S	0.04	18	20	35
	O	0.03	23	20	40
	N	0.03	27	25	40
	D	0.04	30	25	45
	^J	0.04	30	18	40
1	F	0.02	29	18	30
9	M	0.02	29	20	40
9	A	0.03	30	20	50
8	M	0.03	26	22	50
	J	0.03	25	20	45

Table 3c : Abundance (no./sq.m.) of individual collembolan species obtained per month from site III: SRS

Species	←				M	1	9	9	6	→		
	J	F	M	A		J	J	A	S	O	N	D
<i>Salina indica</i>	176.21 (0.15)	352.42 (0.3)	704.84 (0.60)	969.16 (0.82)	176.21 (0.15)	704.84 (0.60)	2643.8 (2.25)	5374.44 (4.57)	1850.22 (1.57)	264.31 (0.22)	88.1 (0.075)	352.42 (0.3)
<i>Isotomurus batteatus</i>	1762.1 (1.5)	4493.4 (3.82)	1233.48 (1.05)	881.05 (0.75)	X	X	X	176.21 (0.15)	X	88.1 (0.075)	88.1 (0.075)	264.31 (0.22)
<i>Lepidocyrtus helerolepis</i>	1057.3 (0.90)	2290.74 (2.23)	969.16 (0.82)	176.21 (0.15)	X	X	X	352.42 (0.3)	440.52 (0.37)	1145.37 (0.97)	264.31 (0.22)	616.74 (0.52)
<i>Cyphoderus javanus</i>	88.1 (0.075)	264.31 (0.22)	88.1 (0.075)	88.1 (0.075)	X	88.1 (0.075)	176.21 (0.15)	264.31 (0.22)	176.21 (0.15)	X	X	352.42 (0.3)
<i>Sminthurides appendiculatus</i>	X	176.21 (0.15)	88.1	X (0.075)	264.31	1850.22 (0.22)	264.31 (0.22)	X	176.21 (0.15)	X	X	X
<i>Isotomiella minor</i>	176.21 (0.15)	88.1 (0.075)	X (0.075)	X (0.075)	X (0.075)	88.1 (0.82)	88.1 (0.37)	X	X	88.1	969.16	440.52
<i>Lepidocyrtus cyaneus</i>	X	X (0.3)	352.42 176.21	176.21	X	X	X	X	X	X	X	X
<i>Seira indica</i>	X	X	X	X	X	X	X	X	X	X	X	X
<i>Lepidocyrtus exploratorius</i>	X	264.31 (0.22)	X	X	X	X	88.1 (0.075)	X	88.1 (0.075)	176.21 (0.15)	X	X
<i>Entomobrya</i> sp.	X	X	X	X	88.1 (0.075)	X	88.1 (0.075)	X	88.1 (0.075)	88.1 (0.075)	264.31 (0.22)	X
<i>Bourletiella</i> sp.	X	X	X	X	X	440.52 (0.37)	X	X	X	X	X	X
<i>Heteromuricus cerciter</i>	X	88.1 (0.075)	X	X	X	X	X	X	X	X	X	X

figures in parenthesis showing %

Table 3c

Species	←				M	1	9	9	6	→		
	J	F	M	A		J	J	A	S	O	N	D
<i>Dicyrtomina</i> sp	X	X	X	X	X	176.21 (0.15)	X	X	X	X	X	X
<i>Lepidocyrtus suborientalis</i>	X	X	X	X	X	X	X	X	X	X	88.1 (0.075)	88.1 (0.075)
<i>Sphaeridia</i> sp	X	X	X	X	X	X	X	X	X	X	176.21 (0.15)	X
<i>Dicranocentrus</i> sp.	X	X	X	X	X	X	X	X	X	X	X	X
<i>Ballistrura bengalensis</i>	X	X	X	X	X	X	X	X	X	X	X	X
<i>Xenylla obscura</i>	X	X	X	X	X	X	X	X	X	X	X	X
<i>Homodia</i> sp.	X	X	X	X	X	X	X	X	X	X	X	X
<i>Yosiia dehradunia</i>	X	X	88.1 (0.075)	X	X	X	X	X	X	X	X	X
<i>Friesea yosii</i>	X	X	X	X	X	X	88.1 (0.075)	X	X	X	X	X
<i>Dicranocentroides</i> sp.	X	X	X	X	X	X	X	X	X	X	X	X

Table 3c

Species	←					1	9	9	7	→		
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Salina indica</i>	1057.3 (0.9)	528.63 (0.45)	440.52 (0.37)	704.84 (0.6)	88.1 (0.075)	704.84 (0.6)	3259.91 (2.8)	8810.6 (7.5)	1409.7 (1.2)	1057.3 (0.97)	440.52 (0.37)	176.21 (0.15)
<i>Isotomurus batteatus</i>	440.52 (0.37)	6167.4 (5.25)	2907.5 (2.47)	528.63 (0.45)	X	X	X	704.84 (0.6)	88.1 (0.075)	88.1 (0.075)	440.52 (0.37)	704.84 (0.86)
<i>Lepidocyrtus helerolepis</i>	4052.86 (3.45)	3700.44 (3.15)	969.16 (0.82)	X	X	X	792.95 (0.6)	88.1 (0.075)	616.74 (0.52)	88.1 (0.075)	440.52 (0.37)	352.42 (0.30)
<i>Cyphoderus javanus</i>	88.1 (0.075)	528.63 (0.45)	176.21 (0.15)	88.1 (0.075)	(0.075)	176.21 (0.15)	1145.4 (0.97)	176.21 (0.15)	X	X	X	X
<i>Sminthurides appendiculatus</i>	X	440.52 (0.37)	176.21 (0.15)	88.1 (0.075)	264.31 (0.22)	88.1 (0.075)	X	X	88.1 (0.075)	X	X	X
<i>Isotomiella minor</i>	440.52 (0.37)	352.42 (0.30)	X	X	X	176.21 (0.15)	X	X	88.1 (0.075)	X	88.1 (0.075)	176.21 (0.15)
<i>Lepidocyrtus cyaneus</i>	X	352.42	792.95	881.05 (0.30)	88.1 (0.67)	X (0.75)	88.1 (0.075)	X	X (0.075)	X	X	X
<i>Seira indica</i>	X	X	X	X	88.1 (0.075)	1850.22 (1.57)	X	X	X	X	X	X
<i>Lepidocyrtus exploratorius</i>	176.21 (0.15)	X	X	X	X	X	X	X	X	88.1 (0.075)	88.1 (0.075)	88.1 (0.075)3
<i>Entomobrya</i> sp.	X	X	X	X	X	X	X	X	X	88.1 (0.075)	88.1 (0.075)	X
<i>Bourletiella</i> sp.	X	88.1 (0.075)	X	88.1 (0.075)	176.21 (0.15)	X	X	X	X	X	X	X

Table 3c

Species	←				M	1	9	9	7	→		
	J	F	M	A		J	J	A	S	O	N	D
<i>Heteromuricus cerciter</i>	X	X	X	88.1 (0.075)	X	X	X	X	88.1 (0.075)	X	X	X
<i>Dicyrtomina</i> sp	X	X	X	X	X	X	X	352.42 (0.30)	X	X	X	X
<i>Lepidocyrtus suborientalis</i>	176.21 (0.15)	X	X	X	X	X	X	X	X	X	88.1 (0.075)	X
<i>Sphaeridia</i> sp	X	176.21 (0.15)	X	X	X	X	X	X	88.1 (0.075)	X	X	X
<i>Dicranocentrus</i> sp.	X	X	X	352.42 (0.30)	X	X	X	X	X	X	X	X
<i>Ballistrura bengalensis</i>	X	X	X	X	X	X	88.1 (0.075)	X	176.21 (0.15)	X	X	X
<i>Xenylla obscura</i>	X	X	X	X	X	X	X	176.21 (0.15)	X	X	88.1 (0.075)	X
<i>Homodia</i> sp.	X	X	X	176.21 (0.15)	X	X	X	X	X	X	X	X
<i>Yosii dehradunia</i>	88.1 (0.075)	X	X	X	X	X	X	X	X	X	X	X
<i>Friesea yosii</i>	X	X	X	X	X	X	X	X	X	X	X	X
<i>Dicranocentroides</i> sp.	X	X	X	88.1 (0.075)	X	X	X	X	X	X	X	X

Table 3c

Species	← J	1 F	9 M	9 A	6 M	→ J
<i>Salina indica</i>	1497.8 (1.27)	881.05 (0.75)	881.05 (0.75)	264.31 (0.22)	88.1 (0.075)	881.05
<i>Isotomurus batteatus</i>	616.74 (0.52)	5198.24 (4.42)	2114.53 (1.80)	881.05 (0.75)	88.1 (0.075)	X
<i>Lepidocyrtus helerolepis</i>	2555.07 (2.17)	3171.81 (2.70)	1671.01 (1.42)	440.52 (0.37)	X	X
<i>Cyphoderus javanus</i>	88.1 (0.075)	88.1 (0.075)	264.31 (0.22)	X	X	176.21 (0.15)
<i>Sminthurides appendiculatus</i>	X	176.21 (0.15)	X	88.1 (0.075)	88.1 (0.075)	88.1 (0.075)
<i>Isotomiella minor</i>	88.1 (0.075)	264.31 (0.22)	X	X	X	X
<i>Lepidocyrtus cyaneus</i>	X	X	176.21 (0.15)	X	X	88.1 (0.075)
<i>Seira indica</i>	X	X	X	X	X	X
<i>Lepidocyrtus exploratorius</i>	176.21 (0.15)	X	176.21 (0.15)	X	X	88.1 (0.075)
<i>Entomobrya</i> sp.	X	X	X	X	X	X
<i>Bourletiella</i> sp.	X	X	X	X	X	X

Table 3c

Species	← J	1 F	9 M	9 A	6 M	→ J
<i>Heteromurjcus cerciter</i>	X	352.42 (0.30)	X	X	X	X
<i>Dicyrtomina</i> sp	X	X	X	X	X	88.1 (0.075)
<i>Lepidocyrtus suborientalis</i>	X	X	X	X	X	X
<i>Sphaeridia</i> sp	X	X	X	X	X	X
<i>Dicranocentrus</i> sp.	X	X	X	X	X	X
<i>Ballistrura bengalansis</i>	X	X	X	X	X	X
<i>Xenylla obscura</i>	X	X	X	X	X	X
<i>Homodia</i> sp.	X	X	X	X	X	X
<i>Yosia dehradunia</i>	X	X	X	X	X	X
<i>Friesea yosii</i>	X	X	X	X	176.21 (0.15)	X
<i>Dicranocentroides</i> sp.	X	X	X	X	X	X

Table 3d : Abundance (no.x 1000/gm. soil of individual fungal genera obtained per month from site III : SRS

Genera	← 1 9 9 7 →											
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Penicillium</i>	8 (0.72)	49 (4.41)	22 (1.98)	8 (0.72)	7 (0.63)	12 (1.08)	13 (0.17)	40 (3.60)	17 (1.53)	2 (0.18)	2 (0.18)	3 (0.27)
<i>Aspergillus</i>	2 (0.18)	1 (0.09)	13 (1.17)	X	X	13 (1.17)	4 (0.36)	X	X	6 (0.54)	5 (0.45)	1 (0.09)
<i>Fusarium</i>	X	X	2 (0.18)	3 (0.27)	X	X	X	5 (0.45)	X	X	2 (0.18)	X
<i>Trichoderma</i>	2 (0.18)	5 (0.45)	X	X	X	X	3 (0.27)	X	X	X	X	10 (0.90)
<i>Rhizopus</i>	5 (0.45)	X	1 (0.09)	X	X	X	X	2 (0.18)	X	X	4 (0.36)	X
<i>Sclerotium</i>	X	X	X	3 (0.27)	X	X	X	X	X	X	X	X
<i>Cephalosporium</i>	X	X	2 (0.18)	X	X	X	X	X	X	X	X	X
<i>Mucor</i>	X	X	X	X	X	1 (0.09)	X	X	X	X	1 (0.09)	X
<i>Nigrospora</i>	2 (0.18)	X	X	X	X	X	X	X	X	X	X	X

figures in parenthesis showing %

Table 3d

Genera	← 1 9 9 7 →											
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Penicillium</i>	70 (6.30)	100 (9.00)	57 (5.13)	30 (2.70)	10 (0.90)	4 (0.36)	59 (5.4)	49 (4.41)	10 (0.90)	16 (1.44)	16 (1.44)	15 (1.35)
<i>Aspergillus</i>	4 (0.36)	2 (0.18)	X	6 (0.54)	X	1 (0.09)	X	9 (0.81)	7 (0.63)	X	1 (0.09)	1 (0.09)
<i>Fusarium</i>	X	X	X	X	X	X	X	18 (1.62)	22 (1.98)	X	4 (0.36)	X
<i>Trichoderma</i>	X	2 (0.18)	1 (0.09)	X	X	3 (0.27)	X	X	1 (0.09)	X	4 (0.36)	1 (0.09)
<i>Rhizopus</i>	X	X	3 (0.27)	X	X	X	X	10 (0.90)	5 (0.45)	X	X	X
<i>Sclerotium</i>	X	X	X	5 (0.45)	X	1 (0.09)	X	5 (0.45)	X	X	X	X
<i>Cephalosporium</i>	X	X	X	X	X	5 (0.45)	X	X	X	X	4 (0.36)	X
<i>Mucor</i>	X	X	X	X	X	X	1 (0.09)	2 (0.18)	X	X	X	1 (0.09)
<i>Nigrosporum</i>	3 (0.27)	X	X	X	X	X	X	2 (0.18)	X	X	X	X

Table 3d

Genera	←	1	9	9	8	→
	J	F	M	A	M	J
<i>Penicillium</i>	40 (3.60)	80 (7.20)	49 (4.41)	23 (2.07)	8 (0.72)	12 (1.08)
<i>Aspergillus</i>	5 (0.45)	13 (1.17)	3 (0.27)	X	X	2 (0.18)
<i>Fusarium</i>	X	X	X	1 (0.09)	X	X
<i>Trichoderma</i>	10 (0.90)	5 (0.45)	X	X	X	X
<i>Rhizopus</i>	X	2 (0.18)	2 (0.18)	X	X	X
<i>Sclerotium</i>	X	X	1 (0.09)	X	X	X
<i>Cephalosporium</i>	X	X	1 (0.09)	X	X	X
<i>Mucor</i>	X	X	X	X	X	1 (0.09)
<i>Nigrosporum</i>	X	X	X	X	X	X

Table 3e : Abundance (no.x 100000/gm. soil of individual bacteria actinomycetes genera obtained per month from site III SRS

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Genera	←					1	9	9	7	→		
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Streptomyces</i>	1 (0.09)	2 (0.19)	24 (2.27)	1 (0.09)	2 (0.19)	3 (0.28)	9 (0.85)	8 (0.75)	27 (2.56)	18 (1.70)	14 (1.33)	19 (1.80)
<i>Arthrobacter</i>	60 (5.68)	2 (0.19)	7 (0.66)	18 (1.70)	7 (0.66)	X	19 (0.75)	7 (0.66)	10 (0.94)	4 (0.37)	X	X
<i>Micrococcus</i>	24 (2.27)	X	X	12 (1.14)	X	6 (0.57)	X	X	8 (0.75)	X	4 (0.37)	15 (1.42)
<i>Bacillus</i>	4 (0.37)	17 (1.61)	15 (1.42)	15 (1.42)	X	7 (0.66)	X	X	1 (0.19)	X	3 (0.28)	7 (0.66)
<i>Xanthomonas</i>	X	X	X	16 (1.52)	X	X	X	X	X	X	X	X
<i>Pseudomonas</i>	X	X	X	X	X	X	X	X	X	X	X	X

Table 3e

Genera	←	1	9	9	8	→
	J	F	M	A	M	J
<i>Streptomyces</i>	19 (1.08)	23 (2.18)	30 (2.80)	10 (0.94)	10 (0.94)	3 (0.24)
<i>Arthrobacter</i>	33 (3.130)	42 (3.98)	3 (0.28)	13 (1.23)	2 (0.19)	19 (1.08)
<i>Micrococcus</i>	10 (0.94)	2 (0.19)	X	X	X	X
<i>Bacillus</i>	3 (0.28)	X	X	1 (0.09)	X	X
<i>Xanthomonas</i>	X	X	X	X	X	X
<i>Pseudomonas</i>	X	X	X	4 (0.37)	X	X

RICE RESEARCH STATION (RRS)/Site IV:

Location and Characteristics of Sampling Site

The site under study was in the experimental crop fields of Rice Research Station, Chinsura, in the district Hoogly, river Ganges runs along its eastern border (Map 1). Geographically it is situated within the range of 87.30° to 88.30° longitudes east and about 45 Km. West of Calcutta. The experimental field, (Photograph 4), was cultivated with IR 36 variety of paddy during June through November and followed during remaining months of the year. All the agricultural practices like ploughing, hand weeding, periodic inundation (July-September) etc. were carried out in the plots. No pesticide or weedicide was used. Paddy was harvested in early December. The area outside the plot contained seasonal grasses, herbs and shrubs like *Cynodon dactylon*, *Commelina* sp., *Arundinella* sp., *Lantana* sp., *Echinochloa* sp., *Monochoria vaginallis* and *Sphenoclea zeylanica*.

Soil Factors

Soil of this plot was alluvial in nature, brownish in colour and clayey silt to silty in texture. Mechanical analysis of soil sampled from this site showed maximum percentage of fine silt the amount being 42.21% (Tab. 1). In the month of August, when it was totally inundated, the soil moisture showed maximum value (45.2% in 1996, 44.5% in 1997) (Tab. 4a.). Other factors like organic carbon, nitrate and phosphate were low (1.4%, 0.70 ppm, 2.2 ppm in 1996 and 0.95%, 0.75 ppm in 1997). Amount of organic carbon, nitrate and phosphate in soil were found to be maximum in November (2.75%, 1.48 ppm, 6.8 ppm in 1996; 2.85%, 1.55 ppm, 6.9 ppm in 1997) (Tab. 4a, Fig. 2a).

Heavy Metals

In November, the concentration of heavy metals (Hg 0.02 ppm, Pb 20 ppm and Zn 65 ppm) in this field were found to be low (Tab. 4b, Fig. 4b).

Collembolan Fauna

The collembolan fauna obtained from this site belonged to 12 species under 8 genera. The genus *Lepidocyrtus suborientalis* was the most dominant form with 40.37% of the total fauna. The species *Isotomurus balteatus* contributed 28.07%, followed by *Isotomiella minor* (7.68%), *Cryptopygus thermophilus* (4.61%), *Sminthurides cf aquaticus* (3.89%), *Lepidocyrtus exploatorius* (3.48%) and *Lepidocyrtus heterolepis* (3.07%). In addition some more genera/species were recorded from this sites, they were found to be irregular in distribution pattern and numerically low (Tab. 4c Fig. 4c). Maximum percentage of collembolan population was obtained in November of both the years coincided with the highest soil fungal population as

well as maximum concentration of soil factors like organic carbon, nitrate, phosphate and low concentration of heavy metals like mercury, lead and zinc (Fig. 4a-b,4d).

Seasonal Changes

The monthwise changes in abundance of individual predominant species of Collembola recorded from this site have been shown in figure 4c. Maximum population density of the most dominant species *L. suborientalis* was January 1996 and it showed second peak in December' 1997. *I. balteatus* exhibited its peak in November of both the years. *Lsotomiella minor* had two prominent peaks, one in June 1997 and another in December' 1997. The highest population density of *C. thermophilus* was in June' 1997 and another peak was in December' 1996. On the other hand *Sminthurides aquaticus* experienced summer maximum with its highest peak in May' 1997 and another in June' 1998. It is apparent from the present study that, the predominant forms of Collembola encountered in this site exhibited maximum population between November to January. The scanty population in August might be due to the disappearance of most of the Collembolan species from the water logged field (Tab 4c). The maximum population of other species varied in sampling years as well as during months which is probably due to their very irregular occurrence in this field.

Microbial Flora

Fungi The soil fungi obtained from this site belonged to 8 genera. The genus *Penicillium* was the most dominant form representing 8.4.4% of the total population followed by *Fusarium* and *Rhizopus* contributing 6.27% and 4.45% of the total population respectively. Other genera recorded in this site were numerically low and infrequent in occurrence, (Tab. 4d : Fig. 4f). The maximum percentage representation of total fungi was observed during November during both the years when the soil factors like organic carbon, nitrate and phosphate had their maximum concentration and the heavy metals like mercury, lead and zinc were in low level (Fig. 4a-b,4d). Lowest population density of fungi also recorded in August like that of Collembola in this field (Fig. 4d).

Seasonal Changes

Figure 4g showed the monthwise changes in number of predominant genera of soil fungi recorded from this site. The most dominant fungi *Penicillium* had highest peak in November in each year of observation. *Fusarium* showed its peak population in June' 1997 while the population density of *Rhizopus* was maximum in April' 1996. The peak population of other genera varied in sampling years as well as in months of observation due to their irregular occurrence in this field (Tab. 4d). In May, absence of some genera and poor occurrence of the dominant forms resulted in minimum population density of total fungi community.

Bacteria- Actinomyetes

The soil bacteria- actinomycetes obtained from this site belonged to 6 genera. The genus *Streptomyces* was recorded as the most dominant from with 55.83% of the total population. The genus *Nocardia* recorded with 22.88% and *Arthrobacter* with 11.44%. In addition some other genera such as *Bacillus* (5.15%), *Micrococcus* (3.32%) and *Pseudomonas* (0.91%) were also recorded from this site, but they were irregular in their distribution (Tab 4e Fig. 4h). A maximum of 7.32% population of bacteria - actinomycetes were recorded on December' 1996 and it shifted in November' 1997 (3.66%) (Fig. 4d). In each year of study, minimum population was recorded in May when the soil moisture was found to be minimum and soil temperature was maximum (Fig. 4a. 4d).

Seasonal Changes

The population peak of dominant genera as observed varied in each year as well as from one month to another month (Fig. 4i). the most predominant genus *Streptomyces* exhibited a trend of fluctuation from January' 1996 to December' 1997 when it reached the highest peak but, become numerically thin during remaining months of observation. The dominant genus *Nocardia* showed highest peak in March in 1997, while it was in February in 1996 and 1998. The genus *Arthrobacter* exhibited a single peak in June' 1997. The other genera were very irregular in occurrence in this field (Tab. 4e). In May, absence of some genera and numerically poor population of dominant genera might have resulted in minimum population density of bacteria-actionomycetes communities.

Table 4a : Values of edaphic factors per month(Jan' 96- Jun' 98) at site IV : RRS

MONTH	Temperatuere(OC)	Moisture (%)	pH	Organic carbon(%)	Nitrate (ppm)	Phosphate (ppm)
^J	19.00	37.00	7.0	2.70	1.42	6.7
F	24.00	36.60	6.8	2.00	1.40	6.0
M	30.00	34.40	7.0	2.00	1.41	4.9
A	33.00	34.00	7.0	2.75	1.20	3.5
1 M	35.00	30.00	7.2	1.40	1.20	2.9
9 J	32.000	81.20	7.0	1.60	1.00	2.7
9 J	31.00	35.80	7.0	1.70	0.85	2.2
6 A	30.00	45.20	7.2	1.40	0.70	2.2
S	30.00	42.60	7.0	1.40	1.10	2.7
O	30.00	40.30	6.7	2.00	1.35	3.2
N	29.00	38.00	6.7	2.75	1.48	6.8
D	18.00	37.20	6.9	2.66	1.44	6.7
J	20.00	38.00	6.7	2.05	1.39	6.2
F	25.00	36.70	6.6	2.00	1.30	6.0
M	28.00	38.10	6.9	2.30	1.28	6.0
A	32.00	35.00	6.9	1.80	1.34	5.2
1 M	33.50	31.00	7.3	1.60	1.10	3.2
9 J	33.00	33.90	7.3	1.60	1.10	3.0
9 J	32.00	42.50	7.2	1.20	0.82	3.1
7 A	32.00	44.50	7.3	0.95	0.75	2.5
S	30.00	41.20	7.0	1.40	0.90	2.4
O	31.00	39.00	7.0	1.80	1.10	3.9
N	29.00	38.70	6.6	2.85	1.55	6.9
D	20.00	38.30	6.7	2.60	1.40	6.9
^J	20.00	36.50	7.0	1.95	1.45	5.8
1 F	24.00	35.20	7.0	1.90	1.35	5.9
9 M	29.00	35.20	7.2	2.10	1.35	5.8
9 A	34.00	32.40	7.0	2.00	1.30	3.9
8 M	35.00	32.00	7.3	1.80	1.20	3.7
J	31.00	35.20	7.4	1.70	0.97	3.3

Table 4b Values of edaphic heavy metals per month at site IV : RRS

MONTH		Mercury	Copper	Lead	Zinc
	^J	0.030	55	27	75
	F	0.030	60	30	80
	M	0.030	50	30	80
	A.	0.350	55	32	80
1	M	0.040	55	35	75
9	J	0.060	55	30	80
9	J	0.050	50	30	70
6	A	0.040	50	30	70
	S	0.040	50	27	80
	O	0.025	55	27	80
	N	0.025	55	25	70
	D	0.030	60	25	70
	J	0.020	60	25	75
	F	0.020	55	27	70
	M	0.030	55	25	70
	A	0.050	60	25	80
1	M	0.050	60	35	80
9	J	0.060	60	30	80
9	J	0.070	57	30	75
7	A	0.070	55	30	70
	S	0.040	60	32	65
	O	0.040	55	25	65
	N	0.020	60	20	65
	D	0.025	60	20	70
	^J	0.040	60	35	70
1	F	0.030	55	35	70
9	M	0.035	60	30	80
9	A	0.035	60	32	70
8	M	0.040	65	35	75
	J	0.050	60	30	75

Table 4c Abundance (no/sq.m.) of individual collembolanspecies obtained per month from site IV :RRS

Species	←————— 1 9 9 6 —————→											
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Lpidocyrtus</i>	3436.12 (3.99)	2290.75 (2.66)	2114.54 (2.46)	1585.9 (1.84)	881.05 (1.02)	88.1 (0.10)	176.21 (0.20)	88.1 (0.10)	616.74 (0.72)	616.74 (0.72)	1938.32 (2.25)	881.05 (1.02)
<i>Isotomurus</i>	1497.8 (1.74)	264.31 (0.31)	X	X	88.1 (0.10)	88.1 (0.10)	X	X	88.1 (0.10)	1145.4 (1.33)	4405.3 (5.12)	2995.6 (3.50)
<i>Isotomiella mnor</i>	X	X	176.21 (0.20)	X	88.1 (0.10)	1145.4 (1.33)	264.31 (0.31)	X	X	88.1 (0.10)	881.05 (1.02)	1145.4 (1.33)
<i>Cryptopygus thermophilus</i>	176.21 (0.20)	88.1 (0.10)	X	88.1 (0.10)	88.1 (0.10)	88.1 (0.10)	176.21 (0.20)	X	X	88.1 (0.10)	176.21 (0.20)	616.74 (0.72)
<i>Sminthurides cf. aquaticus</i>	X	X	X	88.1 (0.10)	88.1 (0.10)	176.21 (0.20)	88.1 (0.10)	88.1 (0.10)	88.1 (0.10)	X	X	X
<i>L. exploratorius</i>	X	X	X	X	X	X	X	X	X	X	88.1 (0.10)	352.42 (0.41)
<i>L. heterolpis</i>	X	264.31 (0.31)	88.1 (0.10)	X	X	X	X	X	X	X	X	X
<i>Xenylla obscura</i>	X	X	X	X	X	X	X	X	X	88.1 (0.10)	440.52 (5.12)	88.1 (0.10)
<i>Lepidocyrtus sp.</i>	176.21 (0.20)	X	X	X	X	X	X	X	X	X	X	176.21 (0.20)
<i>Sminthurides parvulus</i>	X	X	X	X	X	264.31 (0.31)	88.1 (0.10)	X	X	X	X	X
<i>Cyphoderus javanus</i>	X	X	X	X	X	X	176.21 (0.20)	X	88.1 (0.10)	X	440.52 (0.51)	88.1 (0.10)
<i>Entomobrya sp.</i>	X	X	X	X	X	X	X	X	X	88.1 (0.10)	X	88.1 (0.10)

*figures in parenthesis showing %

Table 4c

Species	←	I	9	9	8	→
	J	F	M	A	M	J
<i>Lpidocyrtus</i>	1409.69 (1.64)	1762.11 (2.05)	1762.11 (2.05)	969.16 (1.13)	1057.27 (1.23)	264.31 (0.31)
<i>Isotomurus</i>	1762.11 (2.05)	352.42 (0.41)	X	88.1 (0.10)	176.21 (0.20)	88.1 (0.10)
<i>Isotomiella mnor</i>	X	X	X	88.1 (0.10)	176.21 (0.20)	88.1 (0.10)
<i>Cryptopygus thermophilus</i>	264.31 (0.31)	X	X	X	88.1 (0.10)	264.31 (0.31)
<i>Sminthurides cf. aquaticus</i>	X	X	X	176.21 (0.20)	X	440.52 (0.51)
<i>L. exploratorius</i>	264.31 (0.31)	X	X	X	X	X
<i>L. heterolpis</i>	528.63 (0.61)	176.21 (0.20)	X	88.1 (0.10)	X	X
<i>Xenylla obscura</i>	X	X	X	X	X	X
<i>Lepidocyrtus sp.</i>	264.31 (0.31)	X	X	176.21 (0.20)	X	X
<i>Sminthurides parvulus</i>	X	X	X	X	88.1 (0.10)	704.84 (0.82)
<i>Cyphoderus javanus</i>	X	X	X	X	X	X
<i>Entomobrya sp.</i>	X	X	X	X	X	X

Table 4d : Abundance (no.x 1000/gm. soil of individual fungal genera obtained per month from site IV : RRS

Genera	←					1	9	9	7	→		
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Penicillium</i>	25 (3.48)	26 (3.62)	17 (2.37)	8 (1.11)	11 (1.53)	14 (1.95)	2 (0.28)	1 (0.14)	14 (1.95)	14 (1.95)	37 (5.15)	28 (3.90)
<i>Fusarium</i>	3 (0.42)	X (0.14)	1 (0.69)	5	X	X	X	X (0.28)	2	X (0.14)	1	X
<i>Rhizopus</i>	X	2 (0.28)	X (0.97)	7 (0.28)	2	X (0.56)	4	X	X	X	X	X
<i>Aspergillus</i>	X	X	X	2 (0.28)	2 (0.28)	X	X	X	X	1 (0.14)	X	X
<i>Sclerotium</i>	X	1 (0.14)	X	X	X	X	X	X	X (0.28)	2	X	X
<i>Mucor</i>	X	2 (0.28)	X	X	X	X	1 (0.14)	X	X	X	X	X
<i>Curvularia</i>	X	X	X	X	X	X	3 (0.42)	X	X	X	X	X
<i>Cephalosporium</i>	X	X	X	X	X	X	X	X	X	1 (0.14)	X	X

*figures in parenthesis showing %

Table 4d

Genera	←					1	9	9	7	→		
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Penicillium</i>	35 (4.87)	24 (3.34)	32 (4.45)	25 (3.48)	5 (0.69)	6 (0.84)	13 (1.81)	5 (0.69)	14 (1.95)	16 (2.23)	61 (8.49)	48 (6.68)
<i>Fusarium</i>	1 (0.14)	X	X	5 (0.69)	10 (0.40)	14 (1.95)	X	X	X	X	X (0.14)	1
<i>Rhizopus</i>	3 (0.42)	1 (0.14)	X	X	X	1 (0.14)	X	X	X	X	5 (90.69)	1 (0.14)
<i>Aspergillus</i>	X	X	2 (0.14)	1 (0.14)	X	X	X	X	X	1 (0.14)	X	X
<i>Sclerotium</i>	X	X	2 (0.28)	X	X	X	X	X	X	X	2 (0.28)	X
<i>Mucor</i>	X	X	X	X	X	X	X	X	9 (1.25)	X	X	X
<i>Curvularia</i>	X	X	X	X	X	X	X	X	X	2 (0.28)	X	X
<i>Cephalosporium</i> X	X	1 (0.14)	X	X	X	X	X	X	X	X	X	

Table 4d

Genera	←	1	9	9	8	→
	J	F	M	A	M	J
<i>Penicillium</i>	25 (3.48)	26 (3.62)	25 (3.48)	19 (1.39)	10 (1.40)	10 (1.40)
<i>Fusarium</i>	X	X	2 (0.28)	X	X	X
<i>Rhizopus</i>	1 (0.14)	2 (0.28)	3 (0.42)	X	X	X
<i>Aspergillus</i>	X	1 (0.14)	2 (0.28)	X	X	X
<i>Sclerotium</i>	1 (0.14)	X	X	X	X	X
<i>Mucor</i>	2 (0.28)	X	X	X	X	X
<i>Curvularia</i>	X	X	1 (0.14)	X	X	X
<i>Cephalosporium</i>	X	X	X	X	X	X

Table 4e : Abundance (no.x 100000/gm. soil of individual bacteria actinomycetes genera obtained per month from site IV RRS

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Genera	← J F M A				1 M	9 J	9 J	6 A	→ S O N D			
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Streptomyces</i>	10 (1.14)	10 (1.14)	15 (1.72)	2 (0.23)	4 (0.46)	10 (1.14)	8 (0.91)	2 (0.23)	9 (1.03)	10 (1.14)	24 (2.74)	15 (1.72)
<i>Nocardia</i>	5 (0.57)	12 (1.37)	7 (0.80)	4 (0.46)	1 (0.11)	1 (0.11)	1 (0.11)	2 (0.23)	7 (0.80)	9 (1.03)	5 (0.57)	10 (1.14)
<i>Arthrobacter</i>	10 (1.14)	10 (1.14)	2 (0.23)	X	X	4 (0.46)	5 (0.57)	X	X	X	X	X
<i>Bacillus</i>	1 (0.46)	X	X	4 (0.11)	1 (0.57)	5 (0.69)	6 (0.57)	5 (1.14)	10 (0.34)	3 (0.11)	X	X
<i>Micrococcus</i>	X	X	X	3 (0.34)	X	5 (0.57)	X	3 (0.34)	X	X	1 (0.11)	X
<i>Pseudomonas</i>	X	X	X	X	X	2 (0.23)	X	X	X	X	2 (0.23)	2 (0.23)

figures in parenthesis showing %

Table 4e

Genera	← J F M A				1 M	9 J	9 J	7 A	→ S O N D			
	J	F	M	A	M	J	J	A	S	O	N	D
<i>Streptomyces</i>	34 (3.90)	6 (0.69)	30 (3.43)	15 (1.72)	5 (0.57)	9 (1.03)	10 (1.14)	32 (3.66)	39 (4.46)	18 (2.06)	18 (2.06)	58 (6.64)
<i>Nocardia</i>	2 (0.23)	10 (1.14)	22 (2.52)	2 (0.23)	6 (0.69)	7 (0.80)	10 (1.14)	2 (0.23)	10 (1.14)	5 (0.57)	5 (0.57)	X
<i>Arthrobacter</i>	X	X	6 (0.69)	31 (3.55)	4 (0.46)	4 (0.46)	X	X	3 (0.34)	X	X	2 (0.23)
<i>Bacillus</i>	X	X	X	X	X	X	X	X	2 (0.23)	X	2 (0.23)	2 (0.23)
<i>Micrococcus</i>	X	4 (0.46)	X	X	X	X	X	X	X	X	8 (0.91)	2 (0.23)
<i>Pseudomonas</i>	4 (0.46)	X	X	X	X	X	1 (0.11)	X	X	X	X	X

Table 4e

Genera	← J	I F	9 M	9 A	7 M	→ J
<i>Streptomyces</i>	30 (3.43)	22 (2.52)	13 (1.49)	10 (1.14)	8 (0.91)	12 (1.37)
<i>Nocardia</i>	12 (1.37)	18 (2.06)	7 (0.80)	5 (0.57)	4 (0.46)	9 (1.03)
<i>Arthrobacter</i>	X	2 (0.23)	10 (1.14)	7 (0.80)	X	X
<i>Bacillus</i>	3	X (0.34)	1 (0.11)	X	X	X
<i>Micrococcus</i>	X	X	3 (0.34)	X	X	X
<i>Pseudomonas</i>	X	1 (0.11)	X	X	X	X

Statistical analysis of data

The statistical analysis of the complex soil faunal communities has been conducted to show the relationship between the soil factors and soil microorganisms. The application of LINEAR CORRELATION, ANOVA, STEP WISE REGRESSION and TWO WAY ASSOCIATION were undertaken in the present study involving the data of soil factors, heavy metal content and floral and faunal population densities of soil separately for each site. All the analysis has been carried out by using BMDP Statistical Software.

Linear correlation

The correlation coefficient ('r' value) of each variable (i.e. total population of Collembola, fungi and bacteria-actinomycetes, six edaphic factors and four heavy metals on each other in individual site were shown (16 a-d.). The correlation revealed identical relationship between the biotic variables in all sites, of which the relationships between Collembola and fungi were strongly significant. But the bacteria-actinomycetes showed respective significant correlation only in waste disposal site (site II) (Tab. 16b). The correlation coefficient data mentioned in the above tables broadly indicated that the edaphic factors like moisture, organic carbon, nitrate and phosphate with all the three biotic variables showed strong positive correlation in almost all sites except in paddy field (site IV), where the moisture content of soil was negatively correlated with total number of Collembola and fungi (Tab. 16d). The 'r' values in respect of other variables like temperature and pH with the biotic variables were found to be negatively significant in almost all cases except in case of site II (Tab. 16b), where temperature found to be positively correlated with the population densities of Collembola and fungi. The heavy metals like mercury, lead and zinc showed negative correlation with the total Collembola as well as fungi / bacteria-actinomycetes populations. However, the relationships between copper and faunal / floral population varied from one sampling site to other.

Table. 16a-d : Correlations between different variables in the four sampling sites:**Table a** : Site I / BRF :

	Cxx	Fxx	Bxx	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10
Cxx	1.00												
Fxx	0.87*	1.00											
Bxx	0.28	0.32	1.00										
S01	-0.26	-0.39**	-0.49	1.00									
S02	0.66*	0.77*	0.27	-0.12	1.00								
S03	-0.66*	-0.79*	-0.29	0.45**	-0.50*	1.00							
S04	0.61*	0.79*	0.36**	-0.39**	0.83*	-0.61	1.00						
S05	0.39**	0.34	0.15	-0.52*	0.54*	0.18	0.29	1.00					
S06	-0.26	-0.01	0.39**	-0.58*	-0.22	-0.06	0.11	0.70	1.00				
S07	-0.26	-0.35	-0.16	0.23	-0.41**	0.07	-0.53	-0.01	-0.20	1.00			
S08	-0.71*	-0.79*	-0.05	0.07	-0.79*	0.57	-0.80*	0.58*	0.19	0.48	1.00		
S09	-0.40**	-0.41**	-0.02	0.29	-0.29	0.25	-0.43**	0.04	-0.22	0.34	0.45**	1.00	
S10	-0.46*	-0.70*	-0.25	0.32	-0.64*	0.63*	-0.77*	0.23	-0.09	0.36	0.66*	0.59	1.00

Table b : Site II / DP :

	Cxx	Fxx	Bxx	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10
Cxx	1.00												
Fxx	1.86*	1.00											
Bxx	1.59*	1.70*	1.00										
S01	0.15	0.04	-0.01	1.00									
S02	0.37**	0.35	0.34	0.40**	1.00								
S03	-0.55*	-0.52*	-0.32	-0.0	-0.39**	1.00							
S04	0.60*	0.70*	0.52*	0.15	0.33	-0.41*	1.00						
S05	0.76*	0.66*	0.45*	-0.00	0.01	-0.58*	0.44*	1.00					
S06	0.01	0.18	0.18	-0.15	0.33	0.08	-0.08	-0.42*	1.00				
S07	-0.33	-0.16	-0.21	-0.12	0.09	0.26	-0.27	-0.49*	0.38*	1.00			
S08	-0.28	-0.05	0.00	-0.18	-0.49*	0.31	-0.09	-0.17	0.17	0.29	1.00		
S09	-0.41**	-0.29	-0.07	-0.03	-0.06	0.46*	-0.41*	0.64*	0.64*	0.46*	0.29	1.00	
S10	-0.49**	-0.28	-0.16	-0.39**	-0.39*	0.38**	-0.37**	-0.56*	0.49*	0.38**	0.49*	0.74*	1.00

explanations *=significant at 1% **=significant at 5% Cxx= total collembolan population Fxx = total fungal population, Bxx=total bacteria actinomycetes population, S01=temperature SO2=moisture SO3=pH, SO4=organic carbon, SO5=nitrate, SO6-phosphate, SO7=Hg, SO8=Cu, SO9=Pb, S10=Zn.

Table b : Site III / SRS :

	Cxx	Fxx	Bxx	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10
Cxx	1.00												
Fxx	0.93*	1.00											
Bxx	0.11	0.13	1.00										
S01	-0.39**	-0.33	-0.45**	1.00									
S02	0.31	0.34	0.10	-0.32	1.00								
S03	-0.66*	-0.61*	-0.03	0.17	-0.08	1.00							
S04	0.40**	0.30	0.29	-0.51*	0.59*	-0.07	1.00						
S05	0.69*	0.71*	0.29	-0.44**	-0.10	-0.59*	0.19	1.00					
S06	0.10	0.19	0.46*	-0.37**	-0.07	-0.13	0.15	0.52*	1.00				
S07	-0.36**	-0.51*	-0.00	-0.02	-0.10	0.18	-0.07	-0.46*	-0.36*	1.00			
S08	0.22	0.34	0.32	-0.16	-0.42**	-0.36**	-0.18	0.71*	0.71*	-0.46*	1.00		
S09	-0.23	-0.27	-0.17	-0.04	0.11	0.35	0.07	-0.47*	-0.15	0.41**	0.42**	1.00	
S10	-0.47*	-0.39*	0.19	-0.04	-0.25	0.39*	-0.11	-0.12	0.49*	0.08	0.21	0.13	1.00

Table b : Site III / RRS :

	Cxx	Fxx	Bxx	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10
Cxx	1.00												
Fxx	0.79*	1.00											
Bxx	0.31	0.56*	1.00										
S01	-0.54*	-0.50*		-0.50*	1.00								
S02	-0.09	-0.17	0.17	-0.07	1.00								
S03	-0.59*	-0.69*		-0.42**	0.51*	-0.01	-1.00						
S04	0.84*	0.79*	0.33	-0.59*	-0.29	-0.65*	1.00						
S05	0.71*	0.64*	0.14	-0.54*	-0.44**	-0.57*	0.75*	1.00					
S06	0.74*	0.84*	0.49*	-0.73*	-0.21	-0.63*	0.86*	0.76*	1.00				
S07	-0.22	-0.17	-0.26	0.29	-0.08	0.18	-0.23	-0.00	-0.27	1.00			
S08	0.26	0.33	0.23	-0.10	-0.35	0.06	0.22	0.07	0.29	-0.09	1.00		
S09	-0.62*	-0.64*	-0.42**	0.38**	-0.27	0.66*	-0.59*	-0.35	-0.51*	0.23	0.04	1.00	
S10	-0.43**	-0.28	-0.30	0.26	-0.25	0.29	-0.29	-0.13	-0.23	0.29	-0.03	0.25	1.00

explanatations *=significant at 1% **=significant at 5% Cxx= total collembolan population Fxx = total fungal population, Bxx=total bacteria actinomycetes population, S01=temperature SO2=moisture SO3=pH, SO4=organic carbon, SO5=nitrate, SO6-phosphate, SO7=Hg, SO8=Cu, SO9=Pb, S10=Zn.

Analysis of Variance

An univariate analysis of variance with the month as a factor have been carried out to find out whether any significant seasonal fluctuation exist or not in the population of individual species /genera of Collembola, fungi and bacteria-actinomycetes in their respective habitat. The results of analysis are represented in the table 17-20 a-c. From the table 17a, pertaining to individual collembolan species population it is evident that population fluctuations of four species namely, *Leptodocyrtus magnificus*, *I. medius*, *Bourettella* sp and *Deuterosminthurus* sp were significant in the forest floor (site I). In fungal community significant seasonal pattern were shown by *Penicillium* and *Curvularia* (Table 17b) Except the *Streptomyces*, other bacterial genera found to be reasonably constant in their monthwise abundance in the forest floor site (Table 17c). In the waste disposal site Dhapa (site II), significant seasonal pattern were exhibited only by the most predominant *Collembola Leptodocyrtus* cyaneus and third dominant bacterial strain *Micrococcus* (18a-c). Table 19a revealed that, population density of most of the dominant collembolans in the sugarcane field (site III) varied significantly from one month to other, these were, *Salma idica*, *I. balteatus*, *I. heteroleps*, *C. javanus* and *Entomobrya* sp Among the fungi and bacteria-actinomycetes forms, only one dominant genus in each community (*penicillium* and *Arthrobacter* respective) found to be fluctuated significantly from one month to other (Table 19b-c). In the rice field population fluctuations of six collembolan species namely, *I. subborrentalis*, *I. balteatus*, *I. minor*, *Leptodocyrtus* sp, *C. javanus* and *X. obscura* were significant (Table 20a). In fungal community significant seasonal fluctuations were shown *Penicillium* and *Sclerotium* (Table 20b). It is of interest to note that, seasonal pattern of the population of the predominant form in Collembolan and fungal (except in site II) communities in the respective habitats showed glaring differences, however, it was reasonably constant in case of bacteria-actinomycetes community.

Table 17a : ANOVA for individual collembolan species with respect to site I : BRF

DEPENDENT VARIATE	SOURCE	SUM OF SQUARE	DF	MEAN SQUARES	FEST	*TAIL PROB
<i>L. magnificus</i>	MEAN	50668.88889	I	50668.88889	44.10	0.00
	MONTH	86116.30000	II	7828.75455	6.81	0.00
<i>Homidia sp.</i>	MEAN	7801.25000	I	7801.25000	11.87	0.00
	MONTH	8616.20000	II	783.29091	1.19	0.36
<i>Y. dehraduma</i>	MEAN	2776.93889	I	2776.93889	31.93	0.00
	MONTH	1961.16667	II	178.28788	2.05	0.09
<i>I. balteatus</i>	MEAN	1680.55556	I	1680.55556	7.57	0.01
	MONTH	1773.70000	II	161.24545	0.73	0.70
<i>S. appendiculatus</i>	MEAN	819.20000	I	819.20000	8.51	0.01
	MONTH	1642.96667	II	149.36061	1.55	0.20
<i>I. medius</i>	MEAN	602.05000	I	1602.05000	39.64	0.00
	MONTH	2648.66667	II	240.78788	5.96	0.00
<i>C. thermophilus</i>	MEAN	138.68889	I	138.68889	21.16	0.00
	MONTH	70.96667	II	6.45152	0.98	0.498
<i>Isotomiella minor</i>	MEAN	92.45000	I	92.45000	5.30	0.03
	MONTH	177.53333	II	16.13939	0.93	0.54
<i>Cyphoderus javanus</i>	MEAN	49.08889	I	49.08889	14.18	0.00
	MONTH	60.33333	II	5.4848	51.58	0.9
<i>I. exploratorius</i>	MEAN	7.60556	I	7.60556	6.68	0.02
	MONTH	8.86667	II	1.71515	1.51	0.21
<i>I. heterolemis</i>	MEAN	5.33889	I	5.33889	2.04	0.17
	MONTH	16.33333	II	1.48485	0.57	0.83
<i>X. obseura</i>	MEAN	3.75556	I	3.75556	2.74	0.12
	MONTH	18.70000	II	1.70000	1.24	0.33
<i>Sphaeridia sp.</i>	MEAN	5.68889	I	5.68889	2.02	0.17
	MONTH	28.70000	II	2.60909	0.93	0.54
<i>F. exigus</i>	MEAN	4.35556	I	4.35556	6.03	0.02
	MONTH	10.36667	II	0.94242	1.03	0.30
<i>Sminthurides sp.</i>	MEAN	7.20000	I	7.20000	10.51	0.00
	MONTH	13.03333	II	1.18485	1.73	0.15
<i>Dourletiella sp.</i>	MEAN	4.67222	I	4.67222	11.73	0.00
	MONTH	23.80000	II	2.16364	5.43	0.00
<i>Pararrhopcolites sp.</i>	MEAN	3.75556	I	3.75556	3.17	0.09
	MONTH	17.33333	II	1.57576	1.33	0.29
<i>Deuterosminthurus sp.</i>	MEAN	2.93889	I	2.93889	16.71	0.00
	MONTH	8.70000	II	0.79091	4.50	0.00
<i>Sinella montana</i>	MEAN	0.80000	I	0.80000	1.08	0.31
	MONTH	5.46667	II	0.49697	0.67	0.75
<i>Dicyrtomina sp.</i>	MEAN	0.08889	I	0.88894	1.20	0.29
	MONTH	0.53333	II	0.04848	0.65	0.76

* <0.05 significant

Table 17b : ANOVA for individual fungal genera with respect to site I : BRF

DEPENDENT VARIATE	SOURCE	SUM OF SQUARE	DF	MEAN SQUARES	FEST	*TAIL PROB
<i>Penicillium</i>	MEAN	13606.80556	I	13606.80556	244.31	0.00
	MONTH	3665.66667	II	333.24242	5.98	0.00
<i>Aspergilles</i>	MEAN	192.20000	I	192.20000	12.25	0.00
	MONTH	135.03333	II	12.27576	0.78	0.65
Rhizopus	MEAN	96.80000	I	96.80000	12.60	0.00
	MONTH	151.03333	II	13.73030	1.79	0.13
<i>Trichoderma</i>	MEAN	29.60556	I	29.60556	3.35	0.08
	MONTH	129.53333	II	11.77576	1.33	0.28
<i>Sclerotium</i>	MEAN	34.67222	I	34.67222	6.07	0.02
	MONTH	121.86667	II	11.07879	1.94	0.10
<i>Curbularia</i>	MEAN	18.05000	I	18.05000	129.96	0.00
	MONTH	45.36667	II	4.12424	29.69	0.00
<i>Mucor</i>	MEAN	23.47222	I	23.47222	19.65	0.00
	MONTH	29.96667	II	2.72424	2.28	0.06
<i>Cladosporium</i>	MEAN	13.88889	I	13.88889	7.08	0.02
	MONTH	23.46667	II	2.13333	1.09	0.42
<i>Fusarium</i>	MEAN	20.67222	I	20.67222	3.43	0.08
	MONTH	89.3667	II	8.12424	1.35	0.28

Table 17c : ANOVA for individual bacteria- actinomycetes genera with respect to site I : BRF

DEPENDENT VARIATE	SOURCE	SUM OF SQUARE	DF	MEAN SQUARES	FEST	*TAIL PROB
<i>Streptomyces</i>	MEAN	6734.45000	I	6734.45000	49.52	0.00
	MONTH	3951.66667	II	359.24242	2.64	0.03
<i>Bacillus</i>	MEAN	3200.45000	I	3200.45000	34.94	0.00
	MONTH	1823.96667	II	165.81515	1.81	0.13
<i>Micrococcus</i>	MEAN	1496.45000	I	1496.45000	23.65	0.00
	MONTH	1142.13333	II	103.83030	1.64	0.17
<i>Listeria</i>	MEAN	911.25000	I	911.25000	19.34	0.00
	MONTH	333.30000	II	30.30000	0.64	0.77
<i>Cellulomonas</i>	MEAN	772.93889	I	772.93889	31.95	0.00
	MONTH	289.86667	II	26.35152	1.09	0.42
<i>Arthrobacter</i>	MEAN	772.93889	I	772.93889	19.14	0.00
	MONTH	852.53333	II	77.50303	1.92	0.11
<i>Pseudomonas</i>	MEAN	47.02222	I	47.02222	5.25	0.03
	MONTH	189.86667	II	17.26061	1.93	0.10
<i>Promicromonospora</i>	MEAN	45.00000	I	45.00000	10.34	0.00
	MONTH	48.46667	II	4.40606	1.01	0.47
<i>Staphylococcus</i>	MEAN	19.33889	I	19.33889	7.28	0.01
	MONTH	34.33333	II	3.12121	1.17	0.37
<i>Rhizobium</i>	MEAN	1.08889	I	1.08889	2.26	0.15
	MONTH	4.13333	II	0.37576	0.78	0.66

Table 18a : ANOVA for individual collembolan species with respect to site II : DP

DEPENDENT VARIATE	SOURCE	SUM OF SQUARE	DF	MEAN SQUARES	FEST	*TAIL PROB
<i>L. cyaneus</i>	MEAN	272533.42222	I	272533.42222	3.52	0.08
	MONTH	201365.80000	II	200124.16364	2.58	0.04
<i>X. obscura</i>	MEAN	105366.80556	I	105366.80556	7.67	0.01
	MONTH	240398.36667	II	21854.39697	1.59	0.18
<i>C. javamis</i>	MEAN	64373.42222	I	64373.42222	10.63	0.00
	MONTH	131748.80000	II	11977.16364	1.98	0.10
<i>Seira indica</i>	MEAN	980.00000	I	980.00000	0.60	0.45
	MONTH	13230.00000	II	1202.72727	0.74	0.69
<i>Cthermophilus</i>	MEAN	1100.13889	I	1100.13889	7.78	0.01
	MONTH	1857.86667	II	170.53333	1.21	0.35
<i>F.yosu</i>	MEAN	252.05000	I	252.05000	7.64	0.01
	MONTH	216.50000	II	19.68182	0.60	0.81
<i>P. (Clavisotoma) fitchioides</i>	MEAN	242.67222	I	22.67222	7.61	0.01
	MONTH	561.20000	II	51.01818	1.60	0.18
<i>L. exploratorius</i>	MEAN	54.45000	I	54.45000	3.17	0.09
	MONTH	1565.03333	II	14.18485	0.83	0.62
<i>B. bengalensis</i>	MEAN	49.0889	I	49.08889	2.79	0.11
	MONTH	139.96667	II	12.72424	0.72	0.70
<i>S. appendiculatus</i>	MEAN	37.35556	I	37.35556	4.21	0.05
	MONTH	132.20000	II	12.01818	1.35	0.27
<i>Calx sp.</i>	MEAN	10.75556	I	10.75556	0.92	0.35
	MONTH	88.53333	II	8.04848	0.69	0.73
<i>I. balteatus</i>	MEAN	9.80000	I	9.80000	2.08	0.17
	MONTH	78.46667	II	7.13333	1.51	0.21
<i>L. heterolepis</i>	MEAN	3.75556	I	3.75556	7.51	0.01
	MONTH	4.20000	II	0.38182	0.76	0.67
<i>Sphaeridia sp.</i>	MEAN	1.25000	I	1.25000	2.87	0.11
	MONTH	4.96667	II	0.45152	1.04	0.46
<i>Archerontiella sp.</i>	MEAN	0.45000	I	0.45000	2.11	0.16
	MONTH	1.63333	II	0.14848	0.70	0.73
<i>Isotomiella minor</i>	MEAN	0.35556	I	0.35556	2.40	0.14
	MONTH	2.03333	II	0.18485	1.25	0.33

* < 0.05 significant

Table 18b : ANOVA for individual fungal genera with respect to site II : DP

DEPENDENT VARIATE	SOURCE	SUM OF SQUARE	DF	MEAN SQUARES	FEST	*TAIL PROB
<i>Penicillium</i>	MEAN	20608.20000	I	20608.20000	115.92	0.00
	MONTH	3258.96667	II	296.26970	1.67	0.16
<i>Aspergillus</i>	MEAN	998.75556	I	998.75556	71.62	0.00
	MONTH	158.86667	II	14.44242	1.04	0.46
<i>Fusarium</i>	MEAN	322.67222	I	322.67222	2.94	0.10
	MONTH	730.96667	II	66.45152	0.60	0.80
<i>Trichoderma</i>	MEAN	228.93889	I	228.93998	10.65	0.00
	MONTH	445.03333	II	40.45758	1.88	0.11
<i>Cephalosporium</i>	MEAN	62.42222	I	62.42222	3.64	0.07
	MONTH	190.00000	II	17.27273	1.01	0.48
<i>Mucor</i>	MEAN	26.45000	I	26.45000	17.97	0.00
	MONTH	23.36667	II	2.12424	1.44	0.24
<i>Rhizopus</i>	MEAN	4.05000	I	4.05000	2.44	0.15
	MONTH	29.80000	II	2.70909	1.50	0.21
<i>Sclerotium</i>	MEAN	0.80000	I	0.80000	2.88	0.11
	MONTH	4.46667	II	0.40606	1.46	0.23

Table 18c : ANOVA for individual bacteria - actinomycetes genera with respect to site II : DP

DEPENDENT VARIATE	SOURCE	SUM OF SQUARE	DF	MEAN SQUARES	FEST	*TAIL PROB
<i>Bacillus</i>	MEAN	111054.67222	I	111054.67222	62.76	0.00
	MONTH	8203.13333	II	745.73939	0.42	0.93
<i>Streptomyces</i>	MEAN	4590.45000	I	4590.45000	39.52	0.00
	MONTH	1039.33333	II	94.48485	0.81	0.63
<i>Micrococcus</i>	MEAN	1631.25000	I	1531.25000	29.04	0.00
	MONTH	2474.70000	II	224.97273	4.27	0.00
<i>Cytophaga</i>	MEAN	1502.22222	I	1502.22222	14.75	0.00
	MONTH	1768.50000	II	160.77273	1.58	0.19
<i>Arthrobacter</i>	MEAN	1248.20000	I	1248.20000	12.12	0.00
	MONTH	662.03333	II	60.18485	0.58	0.82
<i>Promicromonospora</i>	MEAN	240.35556	I	240.35556	14.41	0.00
	MONTH	260.36667	II	23.66970	1.42	0.25
<i>Corynebacterium</i>	MEAN	196.35556	I	196.35556	4.59	0.05
	MONTH	620.50000	II	56.40909	1.32	0.29
<i>Pseudomonas</i>	MEAN	67.22222	I	67.22222	8.42	0.01
	MONTH	131.83333	II	11.98485	1.50	0.21
<i>Staphylococcus</i>	MEAN	13.88889	I	13.88889	4.87	0.04
	MONTH	26.53333	II	2.41212	0.85	0.60
<i>E. coli</i>	MEAN	18.05000	I	18.05000	4.04	0.06
	MONTH	64.16667	II	5.83333	1.30	0.30

* < 0.05 significant

Table 19a : ANOVA for individual collembolan species with respect to site III : S

DEPENDENT VARIATE	SOURCE	SUM OF SQUARE	DF	MEAN SQUARES	FEST	*TAIL PROB
<i>Salina indica</i>	MEAN	7068.80000	I	7.68.80000	123.29	0.00
	MONTH	11235.86667	II	1.21.44242	1.82	0.00
<i>I. balteatus</i>	MEAN	2800.55556	I	2800.55556	92.38	0.00
	MONTH	9325.00000	II	847.727	27.96	0.00
<i>I. heterolepis</i>	MEAN	2361.68889	I	2361.68889	48.25	0.00
	MONTH	4071.70000	II	370.15455	7.56	0.00
<i>C.javamus</i>	MEAN	108.88889	I	108.88889	25.79	0.00
	MONTH	109.46667	II	9.95152	2.36	0.05
<i>S. appendiculatus</i>	MEAN	62.42222	I	62.42222	3.97	0.06
	MONTH	149.66667	II	13.60606	0.87	0.59
<i>Isotomiella minor</i>	MEAN	60.08889	I	60.08889	15.16	0.00
	MONTH	87.63333	II	7.96667	2.01	0.09
<i>L. cyaneus</i>	MEAN	26.45000	I	26.45000	5.50	0.03
	MONTH	98.96667	II	8.99697	1.87	0.11
<i>Seira indica</i>	MEAN	10.75556	I	10.75556	0.66	0.43
	MONTH	131.20000	II	11.992727	0.72	0.70
<i>L. exploratorius</i>	MEAN	9.33889	I	9.33889	11.59	0.00
	MONTH	6.83337	II	0.62424	0.77	0.66
<i>Entomobrya</i> sp.	MEAN	3.75556	I	3.75556	18.44	0.00
	MONTH	8.6333	II	0.78485	3.85	0.01
<i>Bourletiella</i> sp.	MEAN	1.80000	I	1.80000	1.57	0.23
	MONTH	7.63333	II	0.69394	0.60	0.80
<i>H. cercifer</i>	MEAN	1.25000	I	1.25000	2.29	0.15
	MONTH	7.53333	II	0.68485	1.25	0.32
<i>Dicyrtomina</i> sp.	MEAN	1.80000	I	1.80000	3.24	0.09
	MONTH	9.36667	II	0.85152	1.53	0.20
<i>L. suborientalis</i>	MEAN	0.93889	I	0.93889	5.34	0.03
	MONTH	3.00000	II	0.27273	1.55	0.20
<i>Sphaeridia</i> sp.	MEAN	0.93889	I	0.93889	3.27	0.09
	MONTH	3.00000	II	0.27273	0.95	0.52
<i>Dicranocentrus</i> sp.	MEAN	0.35556	I	0.35556	0.60	0.45
	MONTH	4.80000	II	0.43636	0.74	0.69
<i>B. bengalensis</i>	MEAN	0.45000	I	0.45000	3.24	0.09
	MONTH	2.20000	II	0.20000	1.44	0.24
<i>X. obscura</i>	MEAN	0.45000	I	0.45000	3.24	0.09
	MONTH	2.20000	II	0.20000	1.44	0.24
<i>Homidia</i> sp.	MEAN	0.08889	I	0.08889	0.60	0.45
	MONTH	1.20000	II	0.10909	0.74	0.69
<i>Y.dehradunia</i>	MEAN	0.08889	I	0.08889	1.20	0.29
	MONTH	0.53333	II	0.4848	0.65	0.76

* < 0.05 Significant

Table 19a

DEPENDENT VARIATE	SOURCE	SUM OF SQUARE	DF	MEAN SQUARES	FEST	*TAIL PROB
<i>F.yosii</i>	MEAN	0.13889	I	0.13889	2.14	0.16
	MONTH	0.70000	II	0.06364	0.98	0.50
<i>Dicranocentroides</i> sp.	MEAN	0.02222	I	0.02222	0.60	0.45
	MONTH	0.30000	II	0.02727	0.74	0.69

Table 19b : ANOVA for individual fungal genera with respect to site III : SRS

DEPENDENT VARIATE	SOURCE	SUM OF SQUARE	DF	MEAN SQUARES	FEST	*TAIL PROB
<i>Penicillium</i>	MEAN	20140.08889	I	20140.08889	64.66	0.00
	MONTH	13677.30000	II	1243.39091	3.99	0.00
<i>Aspergillus</i>	MEAN	299.02222	I	299.02222	13.53	0.00
	MONTH	92.63333	II	8.42121	0.38	0.95
<i>Fusarium</i>	MEAN	151.25000	I	151.25000	8.11	0.01
	MONTH	422.86667	II	38.44242	2.06	0.08
<i>Trichoderma</i>	MEAN	70.93889	I	70.93889	10.45	0.00
	MONTH	99.20000	II	9.01818	1.33	0.29
<i>Rhizopus</i>	MEAN	44.00556	I	44.00556	10.73	0.00
	MONTH	75.63333	II	6.87576	1.68	0.16
<i>Sclerotium</i>	MEAN	6.80556	I	6.80556	4.62	0.05
	MONTH	27.00000	II	2.45455	1.67	0.16
<i>Mucor</i>	MEAN	2.00556	I	2.00556	8.66	0.01
	MONTH	3.20000	II	0.29091	1.26	0.32

Table 19c : ANOVA for individual bacteria - actinomycetes genera with respect to site III : SRS

DEPENDENT VARIATE	SOURCE	SUM OF SQUARE	DF	MEAN SQUARES	FEST	*TAIL PROB
<i>Streptomyces</i>	MEAN	7220.00000	I	7220.00000	86.29	0.00
	MONTH	2068.96667	II	188.08788	2.25	0.06
<i>Arthrobacter</i>	MEAN	3708.27222	I	3708.27222	32.14	0.00
	MONTH	3597.96667	II	327.08788	2.83	0.02
<i>Micrococcus</i>	MEAN	480.20000	I	480.20000	12.74	0.00
	MONTH	663.13333	II	60.28485	1.60	0.18
<i>Bacillus</i>	MEAN	204.80000	I	204.80000	7.31	0.01
	MONTH	155.13333	II	14.10303	0.50	0.88
<i>Xanthomonas</i>	MEAN	8.02222	I	8.02222	0.82	0.38
	MONTH	76.30000	II	6.93636	0.71	0.72
<i>Pseudomonas</i>	MEAN	1.08889	I	1.08889	1.18	0.29
	MONTH	6.70000	II	0.60909	0.66	0.76

* < 0.05 significant

Table 20a : ANOVA for individual collembolan species with respect to site IV : RRS

DEPENDENT VARIATE	SOURCE	SUM OF SQUARE	DF	MEAN SQUARES	FEST	*TAIL PROB
<i>L. suborientalis</i>	MEAN	4651.250000	I	4615.250000	109.94	0.00
	MONTH	2351.96667	II	213.81515	5.05	0.00
<i>I. balteatus</i>	MEAN	3042.22222	I	3042.22222	386.54	0.00
	MONTH	5807.80000	II	527.98182	67.08	0.00
<i>Isotomiella minor</i>	MEAN	222.22222	I	222.22222	39.74	0.00
	MONTH	372.83333	II	33.89394	6.06	0.00
<i>C. thermiphilus</i>	MEAN	66.00556	I	66.00556	18.71	0.00
	MONTH	74.00000	II	6.72727	1.91	0.11
<i>Sminthurides of aquaticus</i>	MEAN	42.05000	I	42.05000	10.34	0.00
	MONTH	74.70000	II	6.79091	1.67	0.16
<i>L. exploratorius</i>	MEAN	50.13889	I	50.13889	10.90	0.00
	MONTH	68.63333	II	6.23939	1.36	0.27
<i>L. heterolepis</i>	MEAN	22.75556	I	22.75556	5.69	0.03
	MONTH	54.00000	II	4.90909	1.23	0.34
<i>Lepidocyrtus sp.</i>	MEAN	13.33889	I	13.33889	8.84	0.01
	MONTH	44.70000	II	4.06364	2.69	0.03
<i>Sminthurides parvulus</i>	MEAN	11.75556	I	11.75556	8.94	0.01
	MONTH	25.00000	II	2.27273	1.73	0.15
<i>Cyphoderus javanus</i>	MEAN	14.45000	I	14.45000	74.31	0.00
	MONTH	39.86667	II	3.62424	18.64	0.00
<i>X. obscura</i>	MEAN	30.42222	I	30.42222	12.54	0.00
	MONTH	84.50000	II	7.68182	3.71	0.01
<i>Entomobrya sp.</i>	MEAN	0.20000	I	0.20000	3.60	0.00
	MONTH	0.86667	II	0.07879	1.42	0.25

* < 0.05 significant

Table 20b : ANOVA for individual fungal genera with respect to site IV : RRS

DEPENDENT VARIATE	SOURCE	SUM OF SQUARE	DF	MEAN SQUARES	FEST	*TAIL PROB
<i>Penicillium</i>	MEAN	11600.13889	I	11600.13889	221.70	0.00
	MONTH	4407.63333	II	400.69394	7.66	0.00
<i>Fusarium</i>	MEAN	49.08889	I	49.08889	3.95	0.06
	MONTH	75.83333	II	6.89394	0.55	0.84
<i>Rhizopus</i>	MEAN	30.42222	I	30.42222	8.01	0.01
	MONTH	215.3333	II	1.95758	0.52	0.87
<i>Aspergillus</i>	MEAN	3.75556	I	3.75556	8.45	0.01
	MONTH	7.20000	II	0.65455	1.47	0.22
<i>Sclerotium</i>	MEAN	2.22222	I	2.22222	10.0	0.01
	MONTH	7.86667	II	0.71515	3.22	0.01
<i>Mucor</i>	MEAN	1.61556	I	1.61556	3.69	0.07
	MONTH	3.53333	II	0.32121	0.74	0.69
<i>Curvularia</i>	MEAN	1.60556	I	1.60556	4.03	0.06
	MONTH	5.63333	II	0.51212	1.29	0.31
<i>Cephalosporium</i>	MEAN	0.13889	I	0.13889	2.14	0.16
	MONTH	0.70000	II	0.06364	0.98	0.59

Table 20c : ANOVA for individual bacteria - actinomycetes genera with respect to site IV : RRS

DEPENDENT VARIATE	SOURCE	SUM OF SQUARE	DF	MEAN SQUARES	FEST	*TAIL PROB
<i>Streptomyces</i>	MEAN	80.00000	I	80.00000	13.80	0.00
	MONTH	63.16667	II	5.74242	0.99	0.49
<i>Nocardia</i>	MEAN	1206.42222	I	1206.42222	55.35	0.00
	MONTH	340.33333	II	30.93939	1.42	0.25
<i>Arthrobacter</i>	MEAN	245.00000	I	245.00000	6.09	0.02
	MONTH	383.00000	II	34.81818	0.87	0.59
<i>Bacillus</i>	MEAN	80.00000	I	80.00000	13.80	0.00
	MONTH	63.16667	II	5.74242	0.99	0.49
<i>Micrococcus</i>	MEAN	28.80000	I	28.80000	7.37	0.01
	MONTH	38.63333	II	3.51212	0.90	0.56
<i>Pseudomonas</i>	MEAN	4.67222	I	4.67222	4.55	0.05
	MONTH	6.70000	II	0.60909	0.59	0.87

* < 0.05 significant

Step Regression Analysis

To determine the effects of fungi, bacteria and soil factors on the collembolan community usually the linear regression technique is followed. But, in that case, the factors are assumed to be independent, which is rather inapplicable. Therefore, Stepwise Linear Regression analysis was carried out, with the inclusion of a new factor already considered at every stage. However, there is no *a priori* theory about which factor or factors (biotic/abiotic) are most important. The steps were not been repeated until all the factors were included in the model. In this study, the predominant species of Collembola in a given site were considered as dependable variables and the observations of analysis were continued till the factors considered the improvement value upto 1% level. The results of tests are showed in the tables 21a-d.

Table 21a showed that effects of the following six factors namely, Fusarium, copper, phosphate, *Penicillium*, *Rhizopus* and *Micrococcus* were most important on the population density of the most dominant species *Lepidocyrtus magnificus* in site I. The abundance of second predominant species *Promicromonospora*, lead, *Rhizopus*, *Streptomyces*, *Listeria*, *Cellulomonas*, *Sclerotium* and temperature. Thirteen factors namely, moisture, *Rhizobium*, *Fusarium*, *Trichoderma*, mercury *Cladosporium*, *Promicromonospora*, *Cellulomonas*, lead, *Curvularia*, *Arthrobacter*, nitrate and zinc found to have important impact on the population of third dominant species *Yosiia dehradunia* at site I. It is of interest to note in the table 21a that, population densities of other two dominant collembolan species, *Isotomurus balteatus* and *Sminthurides appendiculatus* were governed by same factors (14 nos.) in same order of importance. In site II, the occurrence of different predominant collembolan species found to be regulated by single most important factor (like, only the fungi *Trichoderma* have most impact on the population of fourth dominant species *Seira indica*) as well as by maximum of seven factors (Table 21b.). The effects of following seven factors namely, *Penicillium*, *Cephalosporium*, zinc, *Arthrobacter*, *Aspergillus*, *Fusarium* and copper were important on the population density of the most dominant species *L. cyaneus* in site II. While the abundance of third dominant species *Cyphoderus javanus* was governed by the following seven factors, namely, *Trichoderma*, *Cephalosporium*, pH, copper, phosphate and zinc. Table 21b showed that the occurrence of second and fifth dominant species *Xenylla obscura* and *Cryptopygus thermophilus* were influenced only by two (*Fusarium* and *Bacillus*) and three (*Fusarium*, *Penicillium* and *Promicromonospora*) biotic factors respectively.

Table 21c revealed that in site III, the effects of following six factors namely, *Rhizopus*, phosphate, *Penicillium*, nitrate, *Sclerotium* and organic carbon were most important on the abundance of the most dominant species *Salina indica*. The population density of second predominant collembolan species *Isotomurus balteatus* found to be regulated by eleven important factors namely, nitrate, organic carbon, temperature, pH, moisture, *Rhizopus*, *Nigrosporim*, copper, *Pseudomonas* and *fusarium*. Five factors (Nitrate, *Nigrosporium*, *Sclerotium*, moisture and *Rhizopus*) found to have impact on occurrence of third dominant species *L. exploratorius* in site III. Table 21b showed that the abundance of fourth dominant species *Cyphoderus javanus* was influenced by the following seven factors namely, *Rhizopus*, pH, *Mucor*, *Trichoderma*, *Sclerotium*, *Arthrobacter*

and copper. While population of *Sminturides appendiculatus*, the fifth dominant collembolan form in site III was governed by twelve factors, namely, *Aspergillus*, moisture, zinc, *Arthrobacter*, temperature organic carbon, *Micrococcus*, *Trichoderrma*, *PseudomoasFusarium*, copper and *Cephalosporium*.

In site IV, the population density of different predominant collembolan species found to be influenced by single most important factor (like, only the fungi *Fusarium* found to have most impact on the population of fourth dominant *Collembola Cryptopygus thermophilus*) as well as by maximum of eight factors as it is evident in table 21d. The effects of eight factors namely, organic carbon, moisture, *Arthrobacter*, *Nocardia*, *Sclerotium*, copper, *Fusarium* and zinc were most important on the population of second dominant species *Isotomurus balteatus* at site IV. The abundance of most predominant species *L. suborientalis* of this site was governed by six factors, namely, phosphate, nitrate, *Pseudomonas*, *Arthrobacter*, copper and *Sclerotium*. Only three factors (organic carbon, *Nocardia* and *Pseudomonas*) found to be important in occurrence of the third dominant *Collembola*, *Isotomiella minor* in site IV. While population density of *Sminthurides of aqaticus*, the fifth dominant collembolan species in this site was influenced by seven factors, namely, pH, nitrate, moisture, *Aspergillus*, *Streptomyces*, *fusarium* and *Micrococcus*. Thus the above tables broadly indicated that abundance of same collembolan species in different sites were influenced by different sets of factors which are subject to change i.e. the type and number of variables found to be important for the population density of collembolan forms varied for different species in a given site as well as for a same species in different sites Table 21a, 21c and 21d revealed that population of *Istomurus balteatus* in site I, III and IV was governed by fourteen, eleven and eight different factors respectively, on the other hand occurrence of *Sminthurides appendiculatus* in site I and III was governed by fourteen and twelve different factors respectively (Table 21a, 21c), while seven important factors found to be different in influencing the occurrence of *C. javanus* in site II and III (Table 21b, 21c), however, only one two factor / factors showed their impact on the population density of *Cryptopygus thermophilus* in site II and IV (Table 21b, 21d).

Table 21a : Summary table of STEP REGRESSION ANALYSIS of site 1/BRF:

Variable used = C04,C05,C06,C11,C13, F01 to F07,F09,F09,B01 to B04,B07 to B10,B12,B15,S01 to S10

Independent variables = F01 to F07, F09, B01, to BO4, B07, to B10, B12, B15, S01 to S10

Dependent variable = C04 (= *Lepidocyrtus magnificus*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	F03	0.7998	0.6397	0.6397	0.6268	49.71	1.28
2	S08	0.9249	0.8555	0.2158	0.8448	79.93	2.27
3	S06	0.9395	0.8826	0.0271	0.8691	65.18	3.26
4	F01	0.9549	0.9118	0.0291	0.8976	64.57	4.25
5	F05	0.9680	0.9371	0.0253	0.9240	71.51	5.24
6	B04	0.9755	0.9516	0.0145	0.9390	75.38	6.23

Dependent variable = C06 (= *Homidia sp.*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	B09	0.7629	0.5821	0.5821	0.5671	39.0	1.28
2	S09	0.8388	0.7033	0.1212	0.6813	32.0	2.27
3	B15	0.868	0.7534	0.0501	0.7249	26.47	3.26
4	F05	0.8893	0.7908	0.0374	0.7573	23.63	4.25
5	B02	0.9042	0.8176	0.0268	0.7796	21.52	5.24
6	F06	0.9212	0.8487	0.0311	0.8097	21.50	6.23
7	B08	0.9322	0.8689	0.02302	0.8272	20.84	7.22
8	F07	0.9455	0.8939	0.0249	0.8535	22.11	8.21
9	S01	0.9551	0.9123	0.0184	0.8728	23.12	9.20

Table 21a

Dependent variable = C11 (= *Y. dehradunia*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	MULTIPLE RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	S03	0.6539	0.4276	0.4276	0.4072	20.92	1.28
2	B15	0.6996	0.4895	0.0619	0.4517	12.94	2.27
3	F03	0.7500	0.5625	0.0730	0.5120	11.14	3.26
4	F04	0.7899	0.6239	0.0614	0.5637	10.37	4.25
5	S07	0.8979	0.6923	0.0684	0.6283	10.80	5.24
6	F10	0.8979	0.8061	0.1138	0.7556	15.94	6.23
7	B09	0.9119	0.8316	0.0254	0.7780	15.52	7.22
8	B08	0.9220	0.8501	0.0185	0.7930	14.88	8.21
9	S09	0.9326	0.8698	0.0197	0.8112	14.84	9.20
10	F09	0.9403	0.8841	0.0143	0.8231	14.49	10.19
11	B03	0.9568	0.9155	0.0314	0.8638	17.72	11.18
12	S05	0.9626	0.9259	0.0105	0.8737	17.71	12.17
13	S10	0.9682	0.9374	0.0115	0.8866	18.44	13.16

Dependent variable = C05 (= *Isotomurus balteatus*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	MULTIPLE RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	B01	0.2695	0.0726	0.0726	0.6390	52.34	1.28
2	S06	0.3683	0.1356	0.0630	0.6991	34.68	2.27
3	B07	0.5163	0.2666	0.1309	0.7362	27.97	3.26
4	B10	0.5710	0.3260	0.0595	0.7368	21.29	4.25
5	B08	0.6252	0.3909	0.0649	0.7498	18.38	5.24
6	B02	0.6634	0.4461	0.0492	0.7684	17.03	6.23
7	F04	0.7134	0.5089	0.0688	0.7844	16.08	7.22
8	S07	0.7392	0.5463	0.0375	0.7917	14.78	8.21
9	S04	0.7725	0.5968	0.0504	0.8113	14.85	9.20
10	B04	0.7982	0.8371	0.0403	0.8464	16.98	10.19
11	S01	0.8333	0.6944	0.0573	0.8688	18.46	11.18
12	F01	0.8807	0.7756	0.0813	0.8966	21.96	12.17
13	S08	0.9274	0.8600	0.0844	0.9170	25.64	13.16
14	F06	0.9417	0.8868	0.0268	0.9244	26.32	14.15

Table 21aDependent variable = C13 (= *Sminthurides appendiculatus*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	B01	0.2695	0.0726	0.0726	0.0395	2.19	1.28
2	S06	0.3683	0.1356	0.0630	0.0716	2.12	2.27
3	B07	0.5163	0.2666	0.1309	0.1819	3.15	3.26
4	B10	0.5710	0.3260	0.0595	0.2182	3.02	4.25
5	B08	0.6252	0.3909	0.0649	0.2640	3.08	5.24
6	B02	0.6634	0.4401	0.0492	0.2941	3.01	6.23
7	F04	0.7134	0.5089	0.0688	0.3526	3.26	7.22
8	S07	0.7392	0.5463	0.0375	0.3735	3.16	8.21
9	S04	0.7725	0.5968	0.0504	0.4153	3.29	9.20
10	B04	0.7982	0.6371	0.0403	0.4461	3.34	10.19
11	S01	0.8333	0.6944	0.0573	0.5076	3.72	11.18
12	F01	0.8807	0.7756	0.0813	0.6172	4.90	12.17
13	S08	0.9274	0.8600	0.0844	0.7463	7.50	13.16
14	F06	0.9417	0.8868	0.0268	0.7812	8.40	14.15

explanation F01=*Penicillium*, F02=*Aspergillus*, F03=*Fusarium*, F04= *Trichoderma*, F05 = *Rhizopus*, F06=*Mucor*, F07= *Sclerotium*, F08=*Ccephalosporium*, F09=*Curvularia*, F10=*Cladosporium*, B01=*Bacillus*, B02=*Streptomyces*, B03=*Arthrobacter*, B04=*Micrococcus*, B07=*Listeria*, B08 =*Cellulomina*s, B09=*Promicromonospora*, B10= *Pseudomonas*, B11=*Corynebacterium*, B12= *Staphylococcus*, B15 = *Rhizobium*, S01 = temperature, S02 = moisture, S03 = pH, S04 = organic carbon, S05 = nitrate, S06 = phosphate, S07 = mercury, S08 = lead, S09 = copper, S10 = zinc

Table 21d Summary table of Step Regression Analysis of Site II / DP

Variable used = C01, C02, C03, C10, C12, F01 to F08, B01 to B05, B09 to B13, S01 to S10

Independent variables = F01 to F08, B01, to B05, B09, to B13, S01 to S10

Dependent variable = C01 (= *Lepidocyrtus cyaneus*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	MULTIPLE RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	F01	0.6071	0.3686	0.3686	0.3460	16.34	1.28
2	F08	0.6884	0.4739	0.1054	0.4349	12.16	2.27
3	S10	0.7748	0.6003	0.1263	0.5541	13.01	3.26
4	B03	0.8232	0.6777	0.0775	0.6262	13.14	4.25
5	F02	0.8589	0.7376	0.0599	0.6830	13.50	5.24
6	F03	0.8769	0.7689	0.0313	0.7087	12.76	6.23
7	S08	0.8977	0.8059	0.0369	0.7441	13.04	7.22

Dependent variable = C02 (= *Xenylla obscura*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	MULTIPLE RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	F03	0.7748	0.6003	0.6223	0.5860	42.04	1.28
2	F01	0.8629	0.7446	0.1444	0.7257	39.37	2.27
3	B09	0.8989	0.8080	0.0634	0.7858	36.47	3.26

Table 21dDependent variable = C03 (= *Cyphoderus javanus*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	F04	0.7657	0.5863	0.5863	0.5715	39.68	1.28
2	F08	0.8137	0.6622	0.0758	0.6371	26.46	2.27
3	F01	0.8486	0.7201	0.0579	0.6878	22.29	3.26
4	S03	0.8583	0.7366	0.0165	0.6945	17.48	4.25
5	S08	0.8677	0.7528	0.0162	0.7013	14.62	5.24
6	S06	0.8739	0.7638	0.0109	0.70121	12.339	6.23
7	S10	0.8865	0.7859	0.0221	0.7178	11.54	7.22

Dependent variable = C10 (= *Cryptopygus thermophilus*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	F03	0.7945	0.6313	0.6313	0.6181	74.93	1.28
2	B01	0.8719	0.7601	0.1289	0.7424	42.78	2.27

Dependent variable = C12 (= *Seira indica*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	F04	0.7382	0.5449	0.5449	0.5287	33.53	1.28

explanation F01=*Penicillium*, F02=*Aspergillus*, F03=*Fusarium*, F04= *Trichoderma*, F05 = *Rhizopus*, F06=*Mucor*, F07= *Sclerotium*, F08=*Ccephalosporium*, B01=*Bacillus*, B02=*Streptomyces*, B03=*Arthrobacter*, B04=*Micrococcus*, B05=*Cytophage*, B09=*Promicromonospora*, B10= *Pseudomonas*, B11=*Corynebacterium*, B12= *Staphylococcus*, B13 = *E.coli*

Table 21c : Summary table of Step Regression Analysis of Site III / SRS

Variable used = C03, C05, C07, C09, C13, F01 to F08, B01 to B04, B10 to B12, B13, S01 to S10

Independent variables = F01 to F08, F11, to B01, B04, to B10, B12, B13, B14, S01 to S10

Dependent variable= C03 (= *Cyphoderus javanus*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	MULTIPLE RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	F05	0.6158	0.3792	0.3792	0.3571	17.11	1.28
2	S03	0.6989	0.4885	0.1093	0.4506	12.89	2.27
3	F06	0.7512	0.5622	0.0758	0.5141	11.23	3.26
4	F04	0.7814	0.6106	0.0462	0.5483	9.80	4.25
5	F07	0.8156	0.6651	0.0546	0.5945	9.53	5.24
6	B03	0.8461	0.7158	0.0507	0.6417	9.66	6.23
7	B10	0.8658	0.7496	0.0337	0.6699	9.47	7.22

Dependent variable = C05 (= *Isotomurus balteatus*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	MULTIPLE RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	S05	0.8676	0.7527	0.07527	0.7439	85.23	1.28
2	S04	0.8865	0.7859	0.0332	0.7700	49.55	2.27
3	S01	0.9015	0.8127	0.0268	0.7991	37.61	3.26
4	S03	0.9121	0.832	0.0192	0.8051	30.95	4.25
5	S02	0.9226	0.8512	0.0193	0.8203	27.47	5.24
6	F05	0.9335	0.8715	0.0202	0.8380	26.00	6.23
7	F11	0.9507	0.9039	0.0324	0.8733	29.56	7.22
8	S08	0.9571	0.9160	0.0121	0.8840	28.63	8.21
9	S10	0.9625	0.9264	0.0104	0.8933	27.98	9.20
10	B10	0.9678	0.9367	0.0103	0.9034	28.12	10.19
11	F03	0.9733	0.9474	0.0106	0.9152	29.45	11.18

Dependent variable = C07 (= *Saline indica*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	MULTIPLE RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	F05	0.5947	0.3536	0.3536	0.3306	15.32	1.28
2	S06	0.7304	0.5335	0.1799	0.4990	15.44	2.27
3	F01	0.8044	0.6471	0.1135	0.6063	15.89	3.26
4	S05	0.8840	0.7815	0.1345	0.7466	22.36	4.25
5	F07	0.9008	0.8115	0.0299	0.7722	20.66	5.24
6	S04	0.9219	0.8499	0.0384	0.2208	21.71	6.23

Table 21cDependent variable = C09 (= *Lepidocyrtus heterolepis*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	CHANGE RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	S05	0.906	0.8209	0.8209	0.8145	128.0	1.28
2	F11	0.9321	0.8688	0.0479	0.8591	89.43	2.27
3	F07	0.9511	0.9045	0.0356	0.8934	82.03	3.26
4	S02	0.9647	0.9307	0.0262	0.9196	83.92	4.25
5	F05	0.9695	0.94	0.0093	0.9275	75.22	5.24

Dependent variable = C13 (= *Sminthurides appendiculatus*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	CHANGE RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	F02	0.4060	0.1648	5.53	0.1350	5.53	1.28
2	S02	0.5302	0.2811	4.37	0.2278	5.28	2.27
3	S10	0.6496	0.422	6.34	0.3553	6.33	3.26
4	B03	0.6857	0.4702	2.27	0.3854	5.55	4.25
5	S01	0.7263	0.5275	2.91	0.4291	5.36	5.24
6	S04	0.7639	0.5836	3.1	0.4750	5.37	6.23
7	B04	0.7971	0.6354	3.12	0.5193	5.48	7.22
8	F04	0.841	0.7073	5.16	0.5958	6.34	8.21
9	B10	0.8802	0.7747	5.99	0.6733	7.64	9.20
10	F03	0.9091	0.8265	5.66	0.7351	9.05	10.19
11	S08	0.9339	0.8722	6.45	0.7941	11.17	11.18
12	F08	0.9543	0.9108	7.34	0.8478	14.46	12.17
13	S03	0.9612	0.924	2.78	0.8622	14.95	13.16

explanation : F01=*Penicillium*, F02=*Aspergillus*, F03=*Fusarium*, F04= *Trichoderma*, F05 = *Rhizopus*, F06=*Mucor*, F07= *Sclerotium*, F08=*Ccephalosporium*, F11=*Nigrosporium*, B01=*Bacillus*, B02=*Streptomyces*, B03=*Arthrobacter*, B04=*Micrococcus*, B10= *Pseudomonas*, B12= *Staphylococcus*, B14 = *Xanthomonas*

S01 = temperature, S02 = moisture, S03 = pH, S04 = organic carbon, S05 = nitrate, S06 = phosphate, S07 = mercury, S08 = lead, S09 = copper, S10 = zinc

Table 21d : Summary table of Step Regression Analysis of Site IV / RRS

Variable used= C05, C08, C10, C15, C18, F01 to F09, B01 to B04, B06, B10, S01 to S10

Independent variables = F01 to F09, B01 to B04, to B04, B06, B10, S01 to S10

Dependent variable = C05 (= *Isotomurus baleatus*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	MULTIPLE RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	S06	0.7976	0.6361	0.6361	0.6231	48.95	128
2	S05	0.8396	0.7050	0.0689	0.6831	32.36	227
3	B08	0.8768	0.7687	0.0637	0.7420	28.81	326
4	B06	0.8933	0.7979	0.0292	0.7656	24.68	425
5	S08	0.8991	0.8083	0.0104	0.7684	20.25	524
6	F06	0.905	0.8190	0.0106	0.7718	17.34	623

Dependent variable = C08 (= *Lepidocyrtus suborientalis*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	MULTIPLE RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	S04	0.7581	0.5747	0.5747	0.5559	37.83	128
2	S02	0.8046	0.6474	0.0727	0.6213	24.79	227
3	B06	0.8296	0.6882	0.0408	0.6255	19.12	326
4	B12	0.8522	0.7262	0.0381	0.6824	16.58	425
5	F06	0.8869	0.7866	0.0604	0.7421	17.69	524
6	S08	0.9033	0.8159	0.0294	0.7679	16.99	623
7	F04	0.9139	0.8352	0.0193	0.7828	15.93	722
8	S10	0.9200	0.8463	0.0111	0.7878	14.46	821

Dependent variable = C10 (= *Cryptopygus thermophilus*)

STEP NO	VARIABLE ENTERED	MULTIPLE R	MULTIPLE RSQ	CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
1	F04	0.4854	0.2356	0.2356	0.2083	8.68	128

Table 21d

Dependent variable = C15 (= *Isotomiella minor*)

STEP NO	VARIABLE ENTERED	MULTIPLE		CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
		R	RSQ				
1	S04	0.4973	0.2473	0.2473	0.2204	9.2	1.28
2	B12	0.6074	0.3690	0.1217	0.3222	7.89	2.27
3	B08	0.6726	0.4524	0.0834	0.3892	7.16	3.26

Dependent variable = C21 (= *Sminthurides of aquaticus*)

STEP NO	VARIABLE ENTERED	MULTIPLE		CHANGE IN RSQ	ADJUST RSQ	F RATIO	DF
		R	RSQ				
1	S03	0.5658	0.3201	0.3201	0.2959	13.19	1.28
2	S05	0.6257	0.3915	0.0714	0.3464	8.69	2.27
3	S02	0.6899	0.476	0.0845	0.4156	7.87	3.26
4	F02	0.7253	0.5261	0.0501	0.4503	7.94	4.25
5	B15	0.7415	0.5498	0.0237	0.456	5.84	5.24
6	F04	0.7542	0.5688	0.019	0.4563	5.06	6.23
7	B09	0.7644	0.5843	0.0155	0.4521	4.42	7.22

explanation F01=*Penicillum*, F02=*Aspergillus*, F03=*Fusarium*, F04=*Trichoderma*, F05=*Rhizopus*, F06=*Mucor*, F07= *Sclerotium*, F08=*Ccephalosporium*, F09=*Curvularia*, B01=*Bacillus*, B02=*Streptomyces*, B03=*Arthrobacter*, B04=*Micrococcus*, B06= *Nocardia*
S01 = temperature, S02 = moisture, S03 = pH, S04 = organic carbon, S05 = nitrate, S06 = phosphate, S07 = mercury, S08 = lead, S09 = copper, S10 = zinc

TWO WAY ASSOCIATION

Study of association between pairs of Collembolan species, pairs of fungal genera, pairs of bacteria / actinomycetes genera pairs of collembolan and fungal forms, pairs of collembolan and bacteria / actinomycetes forms pairs of fungal and bacteria / actinomycetes forms have counted by means of Two Way Frequency tables in each site separately. The association between the Collembola, fungi and bacteria / actinomycetes with different edaphic factor and heavy metals were also analysed statistically. It is to be mentioned that, the predominant and site specific genera / species of collembola, fungi and bacteria / actinomycetes of given site were considered. The significant result of these tests were shown in the table 22a-d. Table 22a revealed that the two pairs of Collembola were found to have significant association in between second dominant species *Homidia sp.* and a site specific species *Folsomides exigus*, fifth dominant species *Sminthurides appendiculatus* and another site-specific species *Deuterosminthurus sp.* In site I, also two pairs of Collembola and fungi showed significant association between the most predominant forms of both the communities of Collembola (*L. magnificus*) and fungi (*Penicillium*) between the two site specific species (*Pararrhopalites sp.*) and (*Cladosporium*). Association between the third dominant fungi *Rhizopus* and site specific bacteria *Rhizobium* was significant. Another site specific Collembola *L. medius* showed significant association with the edaphic factor pH and organic carbon. *Micrococcus*, the third dominant bacterial strain in site I, showed significant association with the soil phosphate. It is seen in the table 22a that two collembolans *Yosia Dehradunia* (3rd dominant form), *Sinella montana* (site - specific forms) and the fungi *Cladosporium* exhibited significant association with three different heavy metals namely Zn, Pb and Cu respectively. In the site II, two pairs of Collembola were found to have significant association in Collembolan community, in between second (*X. obscura*) and fifth (*Cryptopygus thermophilus*) dominant species, in between two site - specific species (*Archerontiella sp.*) and (*Calx sp.*) (Table 22b). In site II, The most predominant form of Collembola (*L. cyaneus*) showed significant association with the most predominant forms of fungi (*Penicillium*) and, first second dominant forms of bacteria / actinomycetes (*Bacillus* and *Streptomyces*). The site - specific of Collembola *P. (Clavisotoma) fitchioides* and second dominant fungi (*Aspergillus*) exhibited significant association. In bacteria-actinomycetes community two site-specific bacterial strains (*E. coli*, *Corynebacterium*) in this site showed significant association with each other. Table 22b revealed significant association of *C. javanus* and *P. (Clavisotoma) fitchioides* with Cu, of *L. cyaneus* and *penicillium* with Zn, and, between *Micrococcus* and Hg. It is evident in the table 22c, that, the significant results of association were showed by the collembolan species *L. heterolepis* with moisture and organic carbon. In site III, the site-specific bacteria *Xanthomonas* exhibited significant association with the site - specific fungi *Nigrosporium* and third dominant fungal genus *Fusarium*. However, no significant association was found in-between two collembolan forms or between Collembola and fungi or bacteria / actinomycetes. In site IV, significant result of association of two biotic factors were found between two site - specific collembolans *Sminthurides* of aquaticus and *Sminthurides parvulus*, between third dominant bacteria *Arthrobacter* and another site - specific *Collembola Epidocyrtus sp.* and second dominant fungi *Fusarium* (Table 18d). *Sminthurides aquaticus* also showed significant

association with soil factors like, pH, organic carbon and Cu. The most dominant Collembola *L.suborientalis* in site IV exhibited significant association with temperature and Hg. The association of *Isotomurus balteatus* (2nd dominant Collembola) and *Nocardia* (site - specific actinomycetes) with soil phosphate were significant. It is seen in table 22d, the most predominant fungi *Pencillium* showed significant association with different soil factors like, moisture, pH organic carbon, phosphate and Hg. Thus, measure of association broadly indicates more significant in the complex biotic communities in soil (*viz* between pairs of different genera / species of Collembola / fungi bacteria- actinomycetes) at waste disposasl site and, between pairs of biotic and varriables (*viz* different edaphic factos and heavy metals) at paddy field.

Table 22a Analysis of Two-Way Frequency tables Site I / BRF

Frequency Table i	<i>Penicillium</i>		<i>L. magnificus</i>		LAST	TOTAL
	0	8.75	18	31.5		
0	0	0	0	0	0	0
10.5	0	5	2	0	0	7
18	0	2	5	2	1	10
28.25	0	0	2	3	1	6
LAST	0	0	0	2	5	7
TOTAL	0	7	9	7	7	30

Measure of Association : PROB = 0.0017

Frequency Table ii	<i>PH</i>		<i>L. medius</i>		LAST	TOTAL
	0	2	5	8.75		
6.47	0	1	1	1	4	7
6.65	0	0	4	2	2	8
7	4	6	1	2	0	13
LAST	2	0	0	0	0	2
TOTAL	6	7	6	5	6	30

Measure of Association : PROB = 0.0035

Frequency Table iii	Organic carbon		<i>L. medius</i>		LAST	TOTAL
	0	2	5	8.75		
6.47	0	1	1	1	4	7
2.57	5	1	1	0	0	7
3	1	2	3	4	0	10
2.52	0	3	1	1	2	7
LAST	0	1	1	0	4	6
TOTAL	6	7	6	5	6	30

Measure of Association PROB = 0.0025

Frequency Table iv	<i>Folsomides exigus</i>		<i>Homidia sp.</i>		LAST	TOTAL
	0	3	9	29		
0	0	6	5	6	5	22
1	5	0	0	0	0	5
2	1	1	0	0	0	2
LAST	1	0	0	0	0	1
TOTAL	7	7	5	6	5	30

Measure of Association : PROB = 0.0042

Table 22a

Frequency Table v	Zinc	<i>Yosiia dehradunia</i>				
		0	5	12	23.5	LAST
65	3	1	1	0	4	9
70	0	2	0	5	0	7
90	2	3	2	0	1	8
LAST	5	0	1	0	0	6
TOTAL	10	6	4	5	5	30

Measure of Association PROB = 0.0005

Frequency Table vi	<i>Deuterosminthurus</i>	<i>S. appendiculatus</i>				TOTAL
		0	2	5	10	
0	11	5	4	1	4	25
1	2	0	0	0	0	2
2	0	0	1	2	0	3
LAST	0	0	0	0	0	0
TOTAL	13	5	5	3	4	30

Measure of Association PROB = 0.0003

Frequency Table vii	<i>Cladosporium</i>	<i>Pararrhopalites</i>				TOTAL
		0	1	1.5	5	
0	18	1	0	0	1	20
1	2	1	0	0	0	3
2	4	0	0	0	0	4
3.5	0	0	0	1	0	1
LAST	2	0	0	0	0	2
TOTAL	26	2	0	1	1	30

Measure of Association PROB = 0.0006

Frequency Table viii	Lead	<i>Sinella montana</i>			TOTAL
		0	2	3	
20	8	1	0	0	9
25	10	0	0	0	10
30	10	0	0	0	10
LAST	0	0	0	1	1
TOTAL	28	1	0	1	30

Measure of Association PROB = 0.0

Table 22a

Frequency Table ix	<i>Rhizobium</i>	<i>Rhizopus</i>				
	0	2	4	7	LAST	TOTAL
0	19	3	2	1	2	27
1	0	1	0	0	0	1
2	0	0	1	0	0	1
3	0	0	0	1	0	1
LAST	0	0	0	0	0	0
TOTAL	19	4	3	2	2	30

Measure of Association : PROB = 0.0025

Frequency Table x	Copper	<i>Cladosporium</i>				
	0	1	2	3.5	LAST	TOTAL
30	13	3	0	0	1	17
36.25	2	0	4	0	0	6
LAST	5	0	0	1	1	7
TOTAL	20	3	4	1	2	30

Measure of Association : PROB = 0.0024

Frequency Table xi	Phosphate	<i>Micrococcus</i>					
	0	7	20	18	LAST	TOTAL	
	4.25	2	0	2	0	3	7
	6.45	7	0	0	1	0	8
	7.92	5	1	2	0	0	8
	LAST	1	3	0	3	0	7
	TOTAL	15	4	4	4	3	30

Measure of Association : PROB = 0.0014

Table 22b : Analysis of Two-Way Frequency tables : Site II / DP

Frequency Table i	<i>Penicillium</i>	<i>L. Cyaneus</i>					
		0	1	6.5	20.75	LAST	TOTAL
	0	0	0	0	0	0	0
	16	0	2	1	5	0	8
	25	0	4	2	2	0	8
	34.25	0	3	2	1	1	7
	LAST	0	1	0	0	6	7
	TOTAL	0	10	5	8	7	30

Measure of Association : PROB = 0.0022

Frequency Table ii	<i>Bacillus</i>	<i>L. cyaneus</i>					
		0	1	6.5	20.75	LAST	TOTAL
	0	0	0	0	0	0	0
	32	0	3	3	1	0	7
	55.5	0	0	1	6	1	8
	18.25	0	2	1	0	5	8
	LAST	0	5	0	1	1	7
	TOTAL	0	10	5	8	7	30

Measure of Association : PROB = 0.001

Frequency Table iii

	<i>Streptomyces</i>	<i>L. cyaneus</i>				
	0	1	6.5	20.75	LAST	TOTAL
0	0	0	0	0	0	0
5	0	6	0	2	0	8
12	0	1	2	3	2	8
16.25	0	0	0	3	4	7
LAST	0	3	3	0	1	7
TOTAL	0	10	5	8	7	30

Measure of Association : PROB = 0.0092

Frequency Table iv	Zinc	<i>L. cyaneus</i>					
		0	1	6.5	20.75	.LAST	TOTAL
	515	0	0	1	1	6	8
	550	0	4	0	5	0	9
	600	0	3	2	2	0	7
	LAST	0	3	2	0	1	6
	TOTAL	0	10	5	8	7	30

Measure of Association : PROB = 0.0031

Table 22b

Frequency Table v	<i>Archerontiella sp.</i>		<i>Calx Sp.</i>			
	0	5	11	12.75	LAST	TOTAL
0	26	1	0	0	0	27
1	2	0	0	0	0	2
2	0	0	0	0	1	1
LAST	0	0	0	0	0	0
TOTAL	28	1	0	0	1	30

Measure of Association : PROB = 0

Frequency Table vi	Copper		<i>Cyphoderus javamis</i>			
	0	2	9.5°	74.75	LAST	TOTAL
180	0	5	1	3	1	10
157.5	0	1	1	0	3	5
205	0	3	3	4	2	12
LAST	0	1	0	1	1	3
TOTAL	0	10	5	8	7	30

Measure of Association : PROB = 0.0045

Frequency Table vii	<i>Xenylla obscura</i>		<i>Cryptopygus thermophilus</i>			
	0	2	3	17.5	LAST	TOTAL
0	9	0	0	1	0	10
18.5	0	4	0	1	0	5
63	1	3	0	1	0	5
104.25	0	1	1	1	2	5
LAST	0	1	1	0	3	5
TOTAL	10	9	2	4	5	30

Measure of Association : PROB = 0.0008

Frequency Table viii	<i>Aspergillus</i>		<i>P.(Clavisotoma) Fitchioides</i>			
	0	1.5	11	16.25	LAST	TOTAL
0	0	0	0	0	0	0
2.75	6	1	0	0	0	7
5	11	0	0	0	0	11
9	4	0	2	1	0	7
LAST	1	1	0	1	2	5
TOTAL	22	2	2	2	2	30

Measure of Association : PROB = 0.0099

Table 22b

Frequency Table ix	Copper	<i>P.(Clavisotoma) Fitchioides</i>				
	0	1.5	11	16.25	LAST	TOTAL
18.	9	1	0	0	0	10
197.5	3	0	2	0	0	5
205	9	1	0	0	2	12
LAST	1	0	0	2	0	3
TOTAL	22	2	2	2	2	30

Measure of Association : PROB = 0.001

Frequency Table x	zinc	<i>Penicillium</i>				TOTAL
	0	16	25	34.25	LAST	
515	0	1	1	0	6	8
550	0	5	3	1	0	9
600	0	2	2	3	0	7
LAST	0	0	2	3	1	6
TOTAL	0	8	8	7	7	30

Measure of Association : PROB = 0.0038

Frequency Table xi	Mercury	<i>Micrococcus</i>			LAST	TOTAL
	0	8	17	26		
0.66	2	0	0	4	2	8
1	4	3	1	0	1	9
1.3	4	1	2	0	0	7
LAST	6	0	0	0	0	6
TOTAL	16	4	3	4	3	30

Measure of Association : PROB = 0.0097

Frequency Table xii	<i>Corynebacterium</i>	<i>E. coli</i>			LAST	TOTAL
	0	3	7	10		
0	21	1	1	0	0	23
2	2	0	0	0	0	2
4	2	0	0	0	0	20
13	2	0	0	0	0	2
LAST	0	0	0	1	0	1
TOTAL	27	1	1	1	0	30

Measure of Association : PROB = 0.0023

Table 22c : Analysis of Two- Way Frequency tables : Site III / SRS

Frequency Table i	Moisture	<i>Lepidocyrtus heterolepis</i>				
	0	4	7.5	20.75	LAST	TOTAL
13	6	1	0	00	7	
17.45	0	0	2	33	8	
20	2	2	1	22	9	
LAST	0	3	2	10	6	
TOTAL	8	6	5	65	30	

Measure of Association : PROB = 0.0073

Frequency Table ii	organic carbon	<i>Lepidocyrtus heterolepis</i>				
	0	4	7.5	20.75	LAST	TOTAL
1.07	6	0	0	0	1	7
1.51	2	1	2	3	0	8
1.61	0	4	1	2	1	8
LAST	0	1	2	1	3	7
TOTAL	8	6	5	6	5	30

Measure of Association : PROB = 0.0058

Frequency Table iii	<i>Xanthomonas</i>	<i>Fusarium</i>				TOTAL
	0	2	3.5	14.75	LAST	
0	21	3	0	2	2	28
3	1	0	0	0	0	1
9.5	0	0	0	0	0	0
12	0	0	0	0	0	0
LAST	0	0	1	0	0	1
TOTAL	22	3	1	2	2	30

Measure of Association : PROB = 0.0002

Frequency Table iv

	<i>Xanthomonas</i>	<i>Nigrosporium</i>				
		0	2	3	LAST	TOTAL
0	26	2	0	0	0	28
3	0	0	1	0	0	1
9.5	0	0	0	0	0	0
12	0	0	0	0	0	0
LAST	1	0	0	0	0	1
TOTAL	27	2	1	0	0	30

Measure of Association : PROB = 0

Table 22d : Analysis of Two- Way Frequency tables : Site IV / RRS

Frequency Table i Temperature

Lepidocyrtus suborientalis

	0	4.25	14	21.5	LAST	TOTAL
24.75	0	0	1	3	3	7
30	0	2	2	2	4	10
32	1	5	0	1	0	7
LAST	1	0	4	1	0	6
TOTAL	2	7	7	7	7	30

Measure of Association : PROB = 0.0098

Frequency Table ii

Phosphate

Lepidocyrtus suborientalis

	0	4.25	14	21.5	LAST	TOTAL
2.97	0	5	2	0	0	7
3.9	2	1	4	2	0	9
6	0	1	0	4	3	8
LAST	0	0	1	1	4	6
TOTAL	2	7	7	7	7	30

Measure of Association : PROB = 0.0048

Frequency Table iii

Mercury

Lepidocyrtus suborientalis

	0	4.25	14	21.5	LAST	TOTAL
0.03	0	0	2	3	7	12
0.04	0	2	4	3	0	9
0.05	0	3	1	0	0	4
LAST	2	2	0	1	0	5
TOTAL	2	7	7	7	7	30

Measure of Association : PROB = 0.001

Frequency Table iv

*Arthrobacter**Lepidocyrtus sp.*

	0	2	3	LAST	TOTAL
0	13	1	2	0	16
2.75	2	0	1	0	3
4.5	4	0	0	0	4
10	4	2	0	0	6
LAST	0	0	0	1	1
TOTAL	23	3	3	1	30

Measure of Association : PROB = 0.0002

Table 22d

Frequency Table v	Phosphate	<i>Isotomurus balteatus</i>				
		0	1	5	17	LAST
	2.97	3	3	1	0	0
	3.9	2	2	2	3	0
	6	2	1	4	0	1
	LAST	0	0	0	2	4
	TOTAL	7	6	7	5	5
						30

Measure of Association : PROB = 0.0086

Frequency Table vi		<i>Sminthurides parvulus</i> <i>Sminthurides of aquaticus</i>				
		0	1	3	LAST	TOTAL
	0	14	8	0	0	22
	1.25	0	1	1	0	2
	2.5	1	0	1	0	2
	3	0	0	1	2	3
	LAST	0	0	0	1	1
	TOTAL	15	9	3	3	30

Measure of Association : PROB = 0.0002

Frequency Table vii	pH	<i>Sminthurides of aquaticus</i>				
		0	1	3	LAST	TOTAL
	6.87	7	0	0	0	7
	7	7	5	1	1	14
	7.2	1	3	0	0	4
	LAST	0	1	2	2	5
	TOTAL	15	9	3	3	30

Measure of Association : PROB = 0.0061

Frequency Table viii	Organic carbon	<i>Sminthurides of aquaticus</i>				
		0	1	3	LAST	TOTAL
	1.6	0	4	3	2	9
	1.85	1	4	0	1	6
	2.06	8	0	0	0	8
	LAST	6	1	0	0	7
	TOTAL	15	9	3	3	30

Measure of Association : PROB = 0.0009

Table 22d

Frequency Table ix

	Mercury	<i>Sminthurides of aquaticus</i>				TOTAL
		0	1	3	LAST	
0.03		11	1	0	0	12
0.04		4	4	0	1	9
0.05		0	2	0	2	4
LAST		0	2	3	0	5
TOTAL		15	9	3	3	30

Measure of Association : PROB = 0.0001

Frequency Table x

	Moisture	<i>Penicillium</i>				TOTAL
		0	10	16.5	26	
34.3		0	4	2	1	7
36.65		0	2	0	6	8
40		0	0	1	2	9
LAST		0	2	4	0	6
TOTAL		0	8	7	9	30

Measure of Association : PROB = 0.0001

Frequency Table xi

	pH	<i>Penicillium</i>				TOTAL
		0	10	16.5	26	
6.87		0	0	1	2	7
7		0	2	4	6	14
7.2		0	1	2	1	4
LAST		0	5	0	0	5
TOTAL		0	8	7	9	30

Measure of Association : PROB = 0.0033

Frequency Table xii

	Organic carbon	<i>Penicillium</i>				TOTAL
		0	10	16.5	26	
1.6		0	4	5	0	9
1.85		0	4	1	1	6
2.06		0	0	1	6	8
LAST		0	0	0	2	7
TOTAL		0	8	7	9	30

Measure of Association : PROB = 0

Table 22d

Frequency Table xiii	Phosphate	<i>Penicillium</i>				
	0	10	16.5	26	LAST	TOTAL
2.97	0	3	4	0	0	7
3.9	0	5	3	1	0	9
6	0	0	0	7	1	8
LAST	0	0	0	1	5	6
TOTAL	0	8	7	9	6	30

Measure of Association : PROB = 0

Frequency Table xvi	Mercury	<i>Penicillium</i>				
	0	10	16.5	26	LAST	TOTAL
0.03	0	0	1	5	6	12
0.04	0	2	4	3	0	9
0.05	0	3	0	1	0	4
LAST	0	3	2	0	0	5
TOTAL	0	8	7	9	6	30

Measure of Association : PROB = 0.0038

Frequency Table xv	<i>Arthrobacter</i>	<i>Fusarium</i>			LAST	TOTAL
	0	1	2	5		
0	12	2	1	1	0	16
2.75	1	2	0	0	0	3
4.5	2	0	0	0	2	4
10	4	0	1	1	0	6
LAST	0	0	0	1	0	1
TOTAL	19	4	2	3	2	30

Measure of Association : PROB = 0.0071

Frequency Table xvi	Phosphate	<i>Nocardia</i>			LAST	TOTAL
	0	3	6	10		
2.97	0	5	0	2	0	7
3.9	0	0	5	4	0	9
6	0	1	0	3	4	8
LAST	1	1	3	1	0	6
TOTAL	1	7	8	10	4	30

Measure of Association : PROB = 0.0008

DISCUSSION

The present studies were based on the sample survey of 12 plots from 4 contrast ecological habits of West Bengal over a period of 30 months (January'96-June'98). In the plots sampled three had polluted environment, three were from a sugarcane field, three from a rice field which remained irrigated condition during monsoon and remaining three were from the forest floor which served as a control for comparative study for other plots. All the sites were in Gangetic plains exposed to tropical climate with humidity and temperature, these two factors were comparatively low during winter months. The general nature of soil was more or less identical.

The surface soil of the plots in general contained good vegetational cover. Earlier observation by Mitra et. al.(1977) and Hazra and Choudhuri (1990) showed that, surface soil vegetations exert an indirect influence on the collembolan population through its effect on the porosity of soil, humus formation and soil moisture. The nature of vegetation in most of the sampling sites considered here were different. There might be some amount of interaction between plant and collembolan association, but so far there is no evidence on the association of a particular collembola in various forest type in Poland, including both deciduous and coniferous trees, Szeptycki (1967) observed that, the fauna was astonishingly alike, through the sites in question differed in soil, inclination, exposition and microclimate etc. He opined that, the main factor regulating the collembolan fauna in these forests was the presence of coniferous trees, which provided litter with special chemical features. According to Wallwork (1970), the collembolan fauna of certain locality was determined by a complex factor of both ecological and historical. Therefore, in this view, the degree of similarity in species composition between two sites could be used as an index of overall ecological similarity. According to him, the influence of vegetation type is indirect, being exerted perhaps through its effect on soil type, microfloral composition or soil moisture. Hagvar (1982) found that, in coniferous forest floor the species number of Collembola increased with increasing soil fertility but the diversity of species was maximum in medium rich soil. He measured the fertility-scale in accordance to vegetation types, and noticed that, in case of more extreme environmental condition e.g. the soil moisture, the vegetation would better indicate collembolan fauna. Recently, Hazra and Sanyal (1996) found that, in mangrove forest of an island of river Hooghly, in West Bengal, the diversity of collembolan species was increased in artificially raised mangrove site and also noticed that the number of collembolan fauna increased with high concentration of moisture and nitrate.

The collembolan fauna obtained here belonged to 28 genera of the families Hypogastruidae, Isotomidae, Entomobyidae and Sminthuridae (Tab 5. plate 1-8) [in the present study the classification of Collembola is followed after Salmon, 1964, Mitra, 1967, Christiansen and Bellinger, 1980]. As mentioned earlier, some forms differed in their abundance from one site to other and from season to season. Moreover, the number of genera occurring in the different sampling sites also varied, maximum being extracted from the sugarcane field (22 species under 19 genera) and minimum from the rice field (12 species under 8 genera). of

the 28 genera the predominant were *Lepidocyrtus* (7 species), *Xenylla* (1 species), *Cyphoderus* (1 species), *Isotomurus* (1 species) mentioned in order of dominance. The genus *Sminthurides* comprises of four species but holds ninth position in order of dominance (Tab. 5, Fig. 5). The genus *Lepidocyrtus* spp. was represented by 7 species (Tab. 5), e.g. *Lepidocyrtus cyaneus* (27.5%), *L. magnificus* (8.61%), *L. suborientalis* (3.08%), *L. heterolepis* (2.78%), *L. medius* (1.61%), *L. exploratorius* (0.84%) and *Lepidocyrtus* sp. (0.71%); (Fig. 6). The genus was widely distributed in all sampling plots, comprising of 44.61% of total population of Collembola and being numerically dominant over other forms. The wide distribution range and numerical dominance suggested the capability of this genus to exist in varying ecological conditions. The species *Lepidocyrtus cyaneus* was the most dominant taxon under this genus and occupied first position in order of dominance in respect of total number of Collembola (Tab. 6, Fig. 6). The population maximum of this species was in the month of March (Tab. 7). The total population of this genus was also maximum in March.

The second predominant genus *Xenylla* was represented by only one species *obscura* and comprising 15.9% of total collembolan population being found in all the sites (Tab 6; Fig. 5). The individuals of the species were obtained maximum from the sample of site II (15.58%) (Fig. 6). This genus exhibited its population peak in the month of February (Tab. 7).

Table 5 : Taxonomic status of the collembolan species from the study sites.

ORDER : COLLEMBOLA

SUB ORDER : ARTHROPLEONA Börner, 1901

FAMILY HYPOGASTRIDAE Börner, 1913

Subfamily Neanurinae Börner, 1901

Frisea yosii Prabhoo, 1971

Subfamily Hypogastrinae Börner, 1901

Xenylla obscura Imms 1912

Archerontiella sp.

Willemia sp.

Family ISOTOMIDAE Börner, 1913

Subfamily Anurophorinae Börner, 1901

Cryptogus thermophilus (Axelson, 1900)

Folsomide exigus Folsom, 1932

Subfamily Proisotominae Stach, 1947

Proisotoma (Clavisotoma) fitchioides Denis, 1947

Ballistrura bengalensis Yosil, 1966

Subfamily Isotominae Schaeffer, 1896

Isotomurus basteatus (Reuter, 1976)

Isotomiella minor (Schaeffer, 1898)

Family ENTOMOBRYIDAE Tomosvary, 1882

Subfamily Entomobryinae Schaeffer, 1896

Lepidocyrtus cyaneus Tullberg, 1956

- Leppidocyrtus magnificus* Carpenté, 1924
Lepidocyrtus Suborientalis Denis, 1948
Lepidocyrtus heterolepis Yosii, 1959
Lepidocyrtus medis Schaeffer, 1898
Lepidocyrtus exploatorius Carpenter, 1924
Lepidocyrtus sp.
Homodia sp.
Seira indica (Ritter, 1911)
Cals sp.
Entomobrya sp.
Sinella montana Imms, 1912
Heteromuricus cecifer Imms, 1912
Dicranocentrus sp.
 Subfamily: Cyphoderinae Börner, 1913
Cyphoderus javanus Börner, 1906
 Subfamily Paronellinae Börner, 1913
Salina indica (Imms, 1916)
Yosiia dehradunia Mitra, 1967
Dicranocentroides sp.
 Sub order : SYMPHYPLEONA Börner, 1901
 Family Sminthuridae Lbb, 1862
 Subfamily Sminthurinae Börner, 1906
Sminthurides appendiculatus Imms, 1912
Sminthurides of aquaticus (Bourlet, 1842)
Sminthurides sp.
 Subfamily : Sminthurinae Börner, 1906
Bourletiella sp.
Deuterosminthurus sp.
 Subfamily Katinanninae Christiaansen, 1980
Pararrhopalites sp.
 Subfamily Dicyrtominae Börner, 1906
Dicyrtomina sp.

Table 6 : Relative abundance of collembolan species in different sampling sites (%)

species	site I : BRF	site II : DP	site III : SRS	site IV : RRS
<i>Lepidocyrtus cyaneus</i>	-	27.25	0.26	-
<i>Xenylla obscura</i>	0.1	15.58	0.02	0.2
<i>Cyphoderus javanus</i>	0.31	11.84	0.44	0.13
<i>Lepidocyrtus magnificus</i>	8.61	-	-	-
<i>Isotomurus balteatus</i>	1.82	0.11	2.66	2.14
<i>Homodia</i> sp.	3.78	-	0.015	-
<i>Salina indica</i>	-	-	3.27	-
<i>Lepidocyrtus suborientalis</i>	-	-	0.04	3.08
<i>Lepidocyrtus heterolepis</i>	0.12	0.09	2.32	0.23
<i>Cryptopygus thermophilus</i>	0.48	1.51	-	0.35
<i>Yosiia dehrdunia</i>	2.27	-	0.015	-
<i>Seira indica</i>	-	1.64	0.17	-
<i>Sminthurides appendiculatus</i>	1.1	0.22	0.39	-
<i>Lepidocyrtus medius</i>	1.61	-	-	-
<i>Isotomiella minor</i>	0.41	0.02	0.32	0.59
<i>Lepidocyrtus exploratorius</i>	0.13	0.37	0.13	0.26
<i>Friesea yosii</i>	-	0.07	0.015	-
<i>Lepidocyrtus</i> sp.	-	-	-	0.017
<i>Proisotoma (clavisotoma) fitchioides</i>	-	0.65	-	-
<i>Ballistrura bengalensis</i>	-	0.28	0.22	-
<i>Sminthurides of aquaticus</i>	-	-	-	0.29
<i>Sphaeridia</i> sp.	0.1	0.07	0.04	-
<i>Calx</i> sp.	-	0.17	-	-
<i>Sminthurides parvulus</i>	-	-	-	0.16
<i>Bourletiella</i> sp.	0.09	-	0.07	-
<i>Folsomides exigus</i>	0.1	-	-	-
<i>Sminthurides</i> sp.	0.1	-	-	-
<i>Entomobrya</i> sp.	-	-	0.07	0.015
<i>Pararrhopalites</i> sp.	0.08	-	-	-
<i>Dicyrtomina</i> sp.	0.015	-	0.054	-
<i>Deuterosminthurus</i> sp.	0.06	-	-	-
<i>Sinella montana</i>	0.05	-	-	-
<i>Hetermuricus cercifer</i>	-	-	0.05	-
<i>Dicranocentrus</i> sp.	-	-	0.03	-
<i>Archerontiella</i> sp.	-	0.03	-	-
<i>Willemia</i> sp.	-	0.02	-	-
<i>Dcranocentroides</i> sp.	-	0.005	-	-

Table 7 : Abundance of collembolan species obtained per month from all sampling sites : (expressed in % of total population)

Species	J	F	M	A	M	J	J	A	S	O	N	D
<i>Lepidocyrtus cyaneus</i>	0.113	1.22	7.22	0.4	0.05	0.07	0.08	0.01	0.01	0.005	0.025	0.005
<i>Xenylla obscura</i>	0.203	2.57	0.64	0.52	0.043	0.226	0.07	0.26	0.345	0.4	0.39	0.08
<i>Cyphoderus javanus</i>	0.07	1.04	1.71	0.213	0.18	0.05	0.045	0.074	0.23	0.4	0.59	0.35
<i>Lepidocyrtus magnificus</i>	0.23	0.12	0.18	0.08	0.04	0.09	0.91	0.66	0.14	0.11	0.14	0.21
<i>Isotomurus balteatus</i>	0.323	0.556	0.37	0.086	0.03	0.043	0.145	0.117	0.02	0.12	0.55	0.33
<i>Homodia</i> sp.	0.196	0.26	0.11	0.036	0.003	0.02	0.025	0.004	0.25	0.055	0.03	0.49
<i>Salina indica</i>	0.08	0.053	0.06	0.056	0.01	0.066	0.26	0.63	0.145	0.6	0.025	0.025
<i>Lepidocyrtus suborientalis</i>	0.196	0.18	0.16	0.12	0.07	0.01	0.005	0.003	0.04	0.105	0.19	0.155
<i>Lepidocyrtus heterolepis</i>	0.28	0.29	0.08	0.05	0.003	0.017	0.035	0.02	0.05	0.055	0.03	0.065
<i>Cryptopygus thermophilus</i>	0.07	0.22	0.086	0.018	0.03	0.6	0.5	0.04	0.1	0.125	0.045	0.08
<i>Yosiia dehrdunia</i>	0.153	0.14	0.043	-	-	0.026	0.0165	0.13	0.115	-	0.01	0.065
<i>Seira indica</i>	-	-	0.55	-	0.003	0.05	-	-	-	-	-	-
<i>Sminthurides appendiculatus</i>	-	0.023	0.006	0.076	0.046	0.02	0.07	0.117	0.02	0.025	0.06	0.23
<i>Lepidocyrtus medius</i>	0.12	0.03	0.03	0.015	-	0.003	0.05	0.29	0.05	0.01	0.25	0.03
<i>Isotomiella minor</i>	0.023	0.02	0.013	0.005	0.02	0.11	0.02	0.005	0.03	0.02	0.175	0.115
<i>Lepidocyrtus exploratorius</i>	0.047	0.04	0.003	0.04	-	0.01	0.04	-	0.005	0.035	0.04	0.04
<i>Friesea yosii</i>		-	0.053	0.016	0.023	0.056	0.01	0.004	0.04	0.045	0.004	0.035
<i>Lepidocyrtus</i> sp.	0.023	-	-	0.023	-	-	-	-	-	-	-	0.02
<i>Proisotoma (clavisotoma) fitchioides</i>	-	-	-	0.06	0.006	0.03	0.004	0.004	0.04	-	0.12	-

Table 7

Species	J	F	M	A	M	J	J	A	S	O	N	D
<i>Ballistrura bengalensis</i>	-	-	-	-	0.01	0.5	0.03	-	0.045	-	-	-
<i>Sminthurides of aquaticus</i>	-	-	0.003	0.003	0.03	0.03	0.005	0.01	0.025	-	-	-
<i>Sphaeridia</i> sp.	0.003	0.003	0.016	-	-	0.003	-	0.035	0.003	-	0.003	-
<i>Calx</i> sp.	-	-	0.01	-	-	0.043	-	-	-	-	-	-
<i>Sminthurides parvulus</i>	-	-	-	0.003	0.006	0.025	0.004	0.007	0.01	-	-	-
<i>Bourletiella</i> sp.	-	-	0.006	0.003	-	-	0.025	-	-	-	-	-
<i>Folsomides exigus</i>	-	-	-	0.005	0.013	0.01	-	0.004	-	-	0.004	-
<i>Sminthurides</i> sp.	-	-	-	0.003	-	0.003	0.01	-	-	0.015	0.01	-
<i>Entomobrya</i> sp.	-	-	-	-	0.003	-	0.004	-	0.004	0.01	0.015	0.004
<i>Pararrhopalites</i> sp.	0.003	-	0.003	-	-	-	-	-	-	-	-	0.03
<i>Dicyrtomina</i> sp.	-	-	-	-	0.003	0.006	-	0.015	-	-	-	-
<i>Deuterosminthurus</i> sp.	-	-	-	-	-	0.003	0.004	-	-	0.005	0.015	-
<i>Sinella montana</i>	0.003	-	-	0.01	-	-	-	-	-	-	-	-
<i>Hetermuricus cercifer</i>	-	0.013	-	0.003	-	-	-	-	0.004	-	-	-
<i>Dicranocentrus</i> sp.	-	-	-	0.003	-	-	-	-	-	-	-	-
<i>Archerontiella</i> sp.	-	-	-	-	0.003	0.003	-	0.004	-	-	-	-
<i>Willemia</i> sp.	-	-	-	-	0.003	-	-	-	-	-	-	-
<i>Dcranocentroides</i> sp.	-	-	-	0.01	-	-	-	-	-	-	-	-
TOTAL	2.136	6.778	11.352	1.857	0.578	2.123	2.3675	3.443	1.721	2.14	2.496	2.349

The third numerical dominant genus *Cyphoderus* was represented by single species *javanus*. The species was extracted from all the sampling sites and comprised 12.73% of total collembolan population being maximum in March (Tab. 6,7, Fig. 5). In two habitats namely site III and IV it showed its maxima in November and August respectively, while its occurrence was very irregular in site I (Tab. 1c, 3c, 4c). The maximum number of species was obtained from Dhapa dumping area (site II) (11.84%) where its population peak was in March (Fig. 2e, 6).

Another dominant genus *Isotomurus* was represented by the species *balteatus*. It was extracted from all the sites and comprised 6.73% of total collembolan population and occupied fourth position in order of dominance (Tab. 6, Fig. 5). The sugarcane research station (site III) maintained maximum number (2.66%) of this species (Fig. 6). The population maxima of this genus in all the sites together was in the month of February (Tab. 7), but the population maxima were recorded in March, February and November respectively in the site I, III and IV (Fig. 1e, 3e, 4e).

The fifth important genus *Homidia* sp. was extracted from two sites only (site I and III). The species comprised 3.79% of the total collembolan population (Tab. 6; Fig. 5). The maximum population was exhibited in the month of December (0.49%, considered all sites) (Tab. 7), but when it was considered sitewise the population maxima was recorded in the month of April in site III (Tab. 3c).

The other important collembolan genera obtained were *Salina*, *Cryptopygus*, *Yosiia*, *Sminthurides*, *Seira* constituting 3.27%, 2.34%, 2.28%, 2.27%, 1.81% of total population of *Collembola* respectively (Fig. 5).

The genus *Salina* was found only in the sugarcane site and was represented by single species *indica* (Tab. 6, Fig. 6). Its population was maximum in the month of August (0.63%) (Tab. 7).

The *Cryptopygus* occurred in the sampling sites of forest floor, waste disposal site and in rice field (Tab. 6; Fig. 6). Its population reached the peak in June (Tab. 7).

The genus *Yosiia* occurred in the two sampling sites, namely reserve forest floor (site I) and sugarcane research station (site III) and was represented by a single species *Y. dehradunia*. Numerically the genus was dominant in forest floor site (2.27%) (Tab. 6, Fig. 6). It showed maximum population in the month of January (0.153%) and minimum in the month November. The species was not encountered in the month of April, May and October (Tab. 7).

The member of the genus *Sminthurides* was represented by four species namely *S. appendiculatus*, *Sminthurides cf aquaticus*, *Sminthurides sp.* and *Sminthurides parvulus* (Tab. 5). The genus was widely distributed and being extracted from all the sampling sites (Tab. 6, Fig. 6). Its population was maximum in the month of December (0.23%) (Tab. 7).

The genus *Seira*, represented by single species *indica*, was obtained only from two sites viz. Dhapa waste disposal site and sugarcane research station. The population was maximum

in the month of March (0.55%) and the population of the genus was predominant (1.64%) at Dhapa site (Tab. 6,7, Fig. 6).

The members of the genus *Isotomiella* (1.34%) was represented by single species *minor* and observed in all the sites. It was numerically maximum in rice research station (0.59%) (Tab. 6; Fig. 5, 6). The individuals of the genus showed highest peak in November (0.175%) and another in June (0.11%) (Tab. 7).

The other collembolan forms belonging to genera *Friesea* (0.72%), *Proisotoma* (0.65%), *Ballistrura* (0.33%), *Sphaeridea* (0.19%), *Calx* (0.17%), *Bourletiella* (0.16%), *Folsomides* (0.10%), *Entomobrya* (0.08%), *Pararrhopalites* (0.08%), *Dicyrtomina* (0.07%), *Deuterosminthurus* (0.06%), *Sinella* (0.05%), *Heteromuricus* (0.05%), *Dicranocentrus* (0.03%), *Archerontiella* (0.03%), *Willemia* (0.02%) and *Dicranocentroides* (0.005%) occurred individually very poor in number in relation to total collembolan community and were more or less localised forms being restricted to only one or two sites (Tab. 6, Fig. 5, 6).

The above mentioned variations in the faunal makeup might be due to the differences in the ecological conditions. Some genera were wide spread occurring regularly in different sampling sites, they could tolerate wide variety of habitats and were aptly called “ubiquists” or “ecological generalised groups”, on the other hand some forms were localised i.e. restricted to ecological specialised group.

The six genera of Collembola (*Lepidocyrtus*, *Xenylla*, *Cyphoderus*, *Isotomurus*, *Sminthurides* and *Isotomiella*) seemed to have wider tolerance for various habitats in the present study (Tab. 8), therefore, they were “ubiquists” Addison (1980) remarked that, such faunal groups have the capacity to utilize different food sources and microhabitat for survival. While eighteen forms of Collembola were found to be restricted to any single site of four contrasting habitats (namely *Lepidocyrtus magnificus* L. medius, *Lepidocyrtus* sp., *Salina indica*, *Proisotoma (Clavisotoma) fitchioides*, *Sminthurides cf aquaticus*, *Sminthurides* sp., *Sminthurides parvulus*, *Calx* sp., *Folsomides exigus*, *Pararrhopalities* sp., *Deuterosminthurus* sp., *Sinella montana*, *Heteromuricus cercifer*, *Dicranocentrus* sp., *Archerontiella* sp., *Willemia* sp., *Dicranocentroides* sp.) and as such they were “Stenocious” (Tab. 8). Hagvar (1982) while working in a coniferous forest of Norway found fourteen species of Collembola in seven vegetation types. In West Bengal (India) Hazra and Choudhury (1990) while working on the distribution pattern of soil arthropod particularly Collembola and Acari of fourteen kinds of ecosystems, found two “ubiquists” collembolan genera (*Lepidocyrtus* and *Cyphoderus*) and twenty three “stenocious” species, in another observation Hazra and Sanyal (1996) recorded four “ubiquists” collembolan species and eleven “stenocious” species from a deciduous reserve forest floor as well as from two mangrove planted areas (one natural and another artificially raised) in a silt deposited island in the river Hooghly. Reserve forest floor site contained maximum number of “stenocious” species (7) (Tab. 8). Similar observations were made by Hazra and Choudhuri (1990) (7 species) and Hazra and Sanyal (1996) (8 species).

Among these faunal genera, *Lepidocyrtus* showed largest “ubiquists” beside occurring in all the sampling sites, their abundance were rather high in all the sites except sugarcane field. In a study of Collembola from twenty different habitats in south Sweden, Bodvarson (1961) found that the “ubiquists” dominated the picture in most of the habitat. In this investigation, collembolan community within a particular habitat was characterised by a high level of dominance, like, *Lepidocyrtus magnificus* in BRF, *L. cyaneus* in DP, *L. suborientalis* in RRS and *Salina indica* in SRS comprising 40.34%, 44.99%, 40.37% and 31.3% respectively (Fig. 1 - 4c). Similar observation were made by Takeda (1987) Kopeszki and Meyer (1994) from extensive studies on collembolan fauna in different forest soil while they found, most dominant species comprised 22.50% of total population in a habitat.

The distribution pattern of various species of Collembola and their numerical importance in total collembolan fauna could be expressed in terms of relative density. The results thus obtained are presented in the table 6 and figure 6.

Table 8 'Ubiquitous' & 'Stenocious' species of Collembola in the study sites

'Stenocious' species (restricted to)				'Ubiquitous' species
site I : BRF	site II : DP	site III : SRS	site IV : RRS	(present in all sites)
<i>Lepidocyrtus magnificus</i>	<i>Proisotoma (Clavisotoma) fitchiodes</i>	<i>Salina indica</i>	<i>Lepidocyrtus sp.</i>	<i>Xenylla obscura</i>
<i>Lepidocyrtus medius</i>	<i>Archerontiella sp.</i>	<i>Heteromuricus cercifer</i>	<i>Sminthurides cf. aquaticus</i>	<i>Cyphoderus javanus</i>
<i>Flsomides exigus</i>	<i>Willemia sp.</i>	<i>Dicranocentrus sp.</i>	<i>Sminthurides parvulus</i>	<i>Isotomurus balteatus</i>
<i>Sminthurides sp.</i>	<i>Dicranocentroides sp.</i>			<i>Lepidocyrtus heterolepis</i>
<i>Pararrhopalites sp.</i>				<i>Isotomiella minor</i>
<i>Deuterosminthurus sp. exploratorius</i>				<i>Lepidocyrtus</i>
<i>Sinella montana</i>				

The total Population of collembolan fauna obtained from all the sampling sites in the present study showed numerically variation with the change of season (Fig 1 - 4d). It was minimum in May in all sites except the paddy field, however a remarkable variation was observed in their population maxima. A low summer population of Collembola agreed with the general experience of this group as reported froms different types of field of West Bengal by numerous workers. Moreover, a general patttern of fluctuation with maxima in monsoon and minimum in May, as found in the control plots of forest floor site in the present study agreed with the observation of Hazra Choudhuri (1990) and Hazra and Sanyal (1996). In Ireland, Curry (1971) found that the maximum and minimum population were confined to a particular month or season of the years of observation in a particular study site agreed with the findings of most of the other workers in different parts of the world. The population maxima in March in waste disposal site with minimum population in May was similar to the observation of Mukherji and Singh (1970) at Varanasi rose garden Gangetic plane of India. Bisht and Chattora (1986) recorded highest collembolan population in March in Garwal Himalayn forest. While, in paddy field the Higest population density was in November and lowest August which confirmed the observations made by Pai and Prabhoo (1987), Panda (1987), Guru (1987) *et al.* (1988) and Sengupta and Sanyal (1991) in different paddy filds of India. According to them, water logged condition in the field during monsoon due to heavy rainfall exerted the adverse effect of the soil fauna. Most of the predominant collembolan forms obtained from different study sites exhibited poor population in may contrast to the general high abundance / peak in monsoon (July - August) as observed by earlier workers, single high peck was found in any month during November to March [*L. cyaneus*, *Cyphoderus javanus* and *saira indica* in March, *exploratorius* and *Yosiia dehradunia* in January, *Homidia sp* and *Sminthhurides appendiculatus* in December, *Isotomiella minor* and *P. (Clavisotoma) fitchioides* in November] (Tab. 7). In present study, only three predominant species (*L. magnificus*, *L. medius* and *Salina indica*) attained maxima in August and two (*Cryptopygus Thermophilus* and *Friesea yosii*) in June (Tab. 7) Individuals of other species like *Ballistrura bengalensis*, *Sphaeridia sp.*, *Calx sp.*, *Sminthurides parvulus*, *Bourlettella sp.*, *Sminthurides sp.*, *Entomobrya sp.*, *Pararrhopalites sp.*, *Dicyrtomina sp.*, *Deuterosmintohurus sp.*, *Sinella montana*, *Heteromuricus cercifer*, *Dicranocentrus sp.*, *Archerontiella sp.*, *Willemia sp.*, *Dicranocentroides sp.* were numerically low in May and showed a very irregular trend of fluctuation, being altogether absent in many of the sampling months (Tab 7). Thus, most of the predominant collembolan forms encountered here found to exhibit a single peak in a year. According to Straalen (1997) within collembolan community some species have sharp peak in respective months where others tend to fluctuate gradually throughtout the year. The pattern of seasonal variations appeared to be different in different forms, which perhaps indicated the existence of different breeding periods Existence of single peak suggested the probability of single generation per year (Bellinger, 1954 and Hale, 1966), opined, the species, which showed two annual peaks, had two generations in a year. According to him the occurrence of peak populations in various Collembola was related to their life cycles, peak populations of different species were caused by the prevalence of large number of juveniles in the samples, and peaks could be correlated with the period of egg-laying in the field in species where data on times of egg-laying were available.

On the other hand picture of population fluctuation of same species have shown differences in abundance or peak from one site to another site which might be the effect of soil type, microbial, population, environmental and edaphic parameters and heavy metal content of a particular site. In the year 1954, Bellinger suggested that the habitat preference of soil animal be determined by soil microflora with many edaphic factors. According to Torne (1961 and '67a, b) certain microflora present as gut symbionts in Collembola might have an important role in the digestion of plant material consumed by the host. Satchell (1974) and Parkinson (1983) reviewed the interactive roles of the litter microflora and fauna in decomposition processes and they reiterated the view that soil invertebrate biomass acted "as a reservoir of plant nutrients" and served as a brake of nutrient leaching from decomposing litter. Tadros and Varney (1983) stated Collembola and mites constitute 75 to 80 % of soil arthropods and they feed on soil bacteria and fungi. According to Bengtsson et al. (1983) different species of Collembola channel their feeding effect into different kinds of food, e.g. detritus, bacteria, algae and different species of fungi depending on habitat preference and competitive ability. Mermut (1985) and Visser (1985) studied the role of invertebrates in determining the composition of soil microbial communities and their role in other soil properties. In 1990, Veeresh recognised the soil fauna as an important link between microorganisms and humification, he observed that, by chewing the organic matter they increase the surface area which in turn, increase the rate of microbial decomposition and mineralization, as the food it passes through their gut and makes the organic matter into small fragments. These implied considerable consumption of microbial tissue (the primary decomposer organisms, by invertebrates.). In the year 1980, Vannier distinguished soil with high metabolic activity from low metabolic activity using a process of recolonization by soil fauna (Collembola and Acari) into desiccated soil samples and found qualitative and quantitative variations of bacteria and fungi.

The study of association of collembolans with the soil microorganisms specially with the feeding preference of Collembola for fungal hyphae and spore has previously recorded by several earlier workers, viz. Waksman (1932 and '52), Bellinger (1954), Knight (1961), Torne (1961, '67a, b), Gujarati (1968), Bodvarsson (1970), McMillan and Healey (1971), Anderson and Healey (1972), Dash and Cragg (1972), Christen (1974, '75), Choudhuri and Bannerjee (1975), Singh (1969), McMillan (1975), Visser and Whittaker (1977), Addison and Parkinson (1978), Hanlon and Anderson (1979), Parkinson *et al.* (1979), Behra and Dash (1981), Tadros and Verney (1983), Hazra (1984), Hazra and Choudhuri (1990), Klironomos *et al.* (1992) and Pal *et al.* (1992) but the study of relationship within Collembola and soilbacterial community are fragmentary, specially, in field condition and constructive study has not been done so far specially in India on the aspect.

In the year 1968, Macfadyen worked on the animal habitat of soil bacteria and argued the indirect effect of small arthropods in litter and soil. According to Chiba *et al.* (1975) much of the decomposition depends on the initial breakdown of the litter by bacteria Ahrenus (1977) reported that, the decomposition of organic matter was closely related to the number of bacteria and soil respiration.

In this study, the underground microbial community encountered, belonged to 11 fungal

genera, 13 bacterial genera and 2 actinomycetes genera (Tab 9, 12). As stated earlier, the abundance of these forms were varied from one site to other and from season to season (Fig. 1- 4d). The density of most of the dominant taxa in microbial floral generally took remarkable changes throughout the year in which one or two outstanding maxima and minima occurred.

Of the 11 fungal genera the predominant forms were *Penicillium*, *Aspergillus* and *Fusarium* mentioned in order of dominance (Fig. 7).

The most prevalent form *Penicillium* comprising 71.71% of the total fungi flora obtained during this study and it was isolated from all the samples collected for this study (Tab. 9; Fig. 7). Interestingly the highest population peaks of this genus in each site coincided with that of the total fungal population (thus, in the month of August, March, February and November respectively in site I, II, III, IV) (Fig. 1-4d, 1-4g). However, the total population of this genus considering all sampling sites showed its highest peak in February (3.77%) (Tab. 10).

The second dominant genus was *Aspergillus*, built up 9.01% of the total population (Fig. 7). Interestingly, the genus holds the second predominant position in three of four sampling sites (Fig. 1-4f). Its occurrence was most pronounced in Dhapa waste disposal area (4.31% of total population) (Tab. 9, Fig. 8) and present in all the samples of this site unlike other three sites, where it exhibited infrequent occurrence. The maximum population of this genus was observed in the month of November (0.55%) (Tab. 10).

The genus *Fusarium* occupied third dominant position, constituting 5.7% of the total fungal flora (Fig. 7). This form was isolated from all the study sites. The population of this genus was predominant in Dhapa (2.6% of total population) (Tab. 7, Fig. 8). The *Fusarium* exhibited highest population density in August (0.64%) (Tab. 10), but when it was considered sitewise, it failed to show any regular population peak in a particular month being very irregular in occurrence.

The other important fungi isolated were *Trichoderma*, *Rhizopus*, *Mucor*, *Sclerotium* and *Cephalosporium* constituted 4.31%, 3.2%, 1.7%, 1.38%, and 1.35% respectively of total fungal population buildup, among these forms, *Trichoderma* and *Cephalosporium* did not occur in site IV and site I respectively, of which, *Cephalosporium* showed very infrequent occurrence and was absent in several months during observation period (Tab. 10, Fig 7, 8).

In the fungi community encountered in this study, six genera namely *Penicillium*, *Aspergillus*, *Fusarium*, *Rhizopus*, *Mucor* and *Sclerotium* were “ubiquists” indicating their capability to withstand a varying ecological condition in comparison to other five genera encountered, of which *Cladosporium* (0.6%) and *Nigrosporium* (0.17%) occupied individually very minor position in relation to total fungi community and were termed as “stenocious” being restricted as localised forms in single sampling site (Tab. 11, Fig. 8) Hazra and Choudhuri (1990) also found the *Penicillium* and *Aspergillus* having capability to tolerate eleven different habitats of West Bengal.

Table 9 : Relative abundance of fungal genera in different sampling sites (%)

Genera	site I BRF	site II DP	site III SRS	site IV RRS
<i>Penicillium</i>	15.15	20.56	2.083	15.17
<i>Aspergillus</i>	1.93	4.31	2.48	0.3
<i>Fusarium</i>	0.55	2.6	1.43	1.13
<i>Trichoberma</i>	0.83	2.3	1.18	-
<i>Rhizopus</i>	1.32	0.22	0.84	0.8
<i>Mucor</i>	0.65	0.68	0.18	0.18
<i>Sclerotium</i>	0.7	0.1	0.37	0.2
<i>Cephalosporium</i>	-	1	0.3	0.05
<i>Curvularia</i>	0.7	-	-	0.15
<i>Cladosporium</i>	-0.6	-	-	-
<i>Nigrosporium</i>	-	-	0.17	-

Table 10 : Abundance of fungal genera per month obtained from all sampling Sites: (Expressed in % of total fungal population)

genera	J	F	M	A	M	J	J	A	S	O	N	D
<i>Penicillim</i>	2.94	3.77	3.22	2.1	0.89	1.49	2.38	2.66	1.9	1.56	2.94	2.75
<i>Aspergillus</i>	0.19	0.41	0.47	0.23	0.14	0.31	0.32	0.2	0.25	0.31	0.55	0.21
<i>Fusarium</i>	0.05	0.44	0.15	0.24	0.09	0.12	-	0.64	0.42	0.12	0.09	0.06
<i>Trichoberma</i>	0.12	0.27	0.51	0.06	-	0.12	0.07	0.07	0.06	0.14	0.07	0.14
<i>Rhizopus</i>	0.23	0.07	0.13	0.06	0.02	0.01	0.27	0.29	0.07	-	0.16	0.02
<i>Mucor</i>	0.04	0.075	0.02	0.07	0.03	0.05	0.14	0.07	0.06	0.14	0.02	-
<i>Sclerotium</i>	0.02	0.01	0.02	0.07	0.02	0.02	0.04	0.25	-	-	0.05	0.01
<i>Cephalosporium</i>	-	-	0.14	0.01	-	0.04	-	-	-	0.24	0.05	0.12
<i>Curvularia</i>	0.07	0.06	0.07	0.02	-	-	0.04	-	-	0.02	-	0.01
<i>Cladosporium</i>	0.05	0.04	0.05	-	0.04	-	-	-	-	-	-	0.02
<i>Nigrosporium</i>	0.04	-	-	-	-	-	-	-	-	-	-	-
TOTAL	3.75	5.145	4.78	2.86	1.23	2.16	3.26	4.18	2.76	2.53	3.93	3.34

It is evident from the figure 9, that in total bacteria-actinomycetes community the bacterial genus *Bacillus* outnumbered all the other forms considering all the sites together and comprising 35.34% of total population followed by *Streptomyces*, *Arthrobacter* and *Mucor*.

Maximum isolates of the genus *Bacillus* obtained from waste disposal site (site II) (28% of total population), it is to be noted that, only in this site the genus found to be dominated over the other forms (Tab. 12, Fig. 1-4f, 10). In site I and II, *Bacillus* appeared in all samples collected during this study but its occurrence was irregular in both the agricultural fields (Tab. 1-4e). Highest peak of total population occurred in April considering all sites together (0.78%) (Tab. 13).

The second dominant form in bacteria-actinomycetes community was the actinomycetes genus *Streptomyces*, which comprised 26.76% of total population (Fig. 9). Jensen (1930), Kononova (1966), Kuster (1967 and '68), Kutzner (1968) and Huntjens (1972) identified actinomycetes as a major group of soil microorganisms and mentioned their active participation in turnover of soil organic matter. In the Present study, another genus of actinomycetes *Nocardia* (3.02%) was obtained from the paddy field (site IV) only, and stood sixth position in total bacteria-actinomycetes population (Fig. 9, 10). The members of the genus *Streptomyces* (constituted 98.94% of actinomycetes population) found to be dominated over the bacterial genera in all the sampling sites except waste disposal area (site II) (Fig. 1-4h). Similarly, prevalence of *Streptomyces* among the soil actinomycetes was well documented by several authors (Davies and Williams, 1970; Selin, 1971; Alexander, 1977; Reed Rodrigues and Drozdowicz, 1978) but, isolation of members of genus *Nocardia* have also been reported. Orchard et al. (1977) isolated *Nocardia* only from 15 out of 42 cerrado soil examined while it was not found in the isolates obtained by Reed Rodrigues and Drozdowicz (1978) from the same soil. The total actinomycetes population constituted 39.79% of total bacteria-actinomycetes population in this observation. This agreed with the findings of several workers, according to whom, soil actinomycetes made up 10-50% of total bacteria-actinomycetes population (Alexander, 1977). However, Reed Rodrigues and Drozdowicz (1978) found 77-98% of total number of bacteria-actinomycetes while they worked on cerrado soil of Brazil. The population maxima of *Streptomyces* was observed in October while *Nocardia* exhibited peak in February (Tab. 13).

The third major form *Arthrobacter* comprised 12.04% of total bacteria-actinomycetes population (Fig.9). Maximum number obtained from site III (5.54%), followed by site II (2.98%), site I (2.01%) and site IV (1.15%) (Tab. 12; Fig. 10). It was encountered as second and third predominant form in the two agricultural fields (site III and site IV respectively) (Fig. 3-4h). The members of this genus showed highest population in January in site III and in April in site IV (Tab. 3-4e) but, considering all site together population peak was observed in January (Tab. 13).

In the present study two cocci forms were obtained in the bacterial community (*Micrococcus* and *Staphylococcus*). The *Micrococcus* occurred in all sites being an important member in microbial community and occupied fourth dominant position in total

bacteria-actinomycetes form is site I, II and III (Fig. 1-3h). The *Staphylococcus*, however, did not occur in the agricultural fields of site III and IV. Abundance of these forms were noticed in waste disposal area (site II) (3.66% and 0.38% respectively) and forest floor area (site I) (3.16% and 0.38% respectively) (Tab. 12; Fig. 10). The *Micrococcus* population density was maximum in April (0.47%) considering all sites together, however, the *Staphylococcus* was not regular in occurrence (Tab. 13).

In this investigation, members of only two bacterial strains (*Pseudomonas* and *E. coli*) were found to be gram-negative, of which *E. coli* (0.3%) was obtained only from waste disposal site (site II). The genus *Pseudomonas* was abundant in site II (0.67%) and site I (0.64%) followed by site IV (0.18%) and site III (0.11%) (Tab. 12; Fig. 10). Thus they together constituted 1.9% of total population. This agreed with the finding of Hattori and Hattori (1976), who reported that, the number of gram negative bacteria to total bacterial count was usually smaller than 10% in outer part of soil profile while frequently exceeding 30% in the inner profile.

The table 12 and figures 9, 10 revealed that, the bacterial genera *Cytophaga* (3.25%), *Listeria* (2.51%), *Cellulomonas* (2.16%), *Corynebacterium* (0.98%), *E. coli* (0.3%), *Xanthomonas* (0.29%), *Rhizobium* (0.09%) and the actinomycetes *Nocardia* (3.02%) were recorded from only one study site and may be called as 'stenocious' form. On country, the distribution pattern of other five genera (namely *Bacillus*, *Streptomyces*, *Arthrobacter*, *Micrococcus* and *Pseudomonas*) suggested their capability to withstand varying ecological conditions and thus they may be termed as "ubiquitous" species (Tab. 14). community (Fig. 9). It is mentioned that the genus was found as third predominant.

Table 11 : Relative abundance of bacteria - actinomycetes genera in different sampling sites (%)

Genera	site I : BRF	site II : DP	site III : SRS	site IV : RRS
<i>Bacillus</i>	5.36	28	1.3	0.68
<i>Streptomyces</i>	6.58	5.82	6.97	7.38
<i>Arthrobactor</i>	2.01	2.98	5.54	1.51
<i>Micrococcus</i>	3.16	3.66	1.75	0.44
<i>Cytophaga</i>	-	3.25	-	-
<i>Nocardia</i>	-	-	-	3.02
<i>Listeria</i>	2.51	-	-	-
<i>Cellulomonas</i>	2.16	-	-	-
<i>Promicromonospora</i>	0.54	0.31	-	-
<i>Pseudomonas</i>	0.64	0.67	0.11	0.18
<i>Corynebacterium</i>	-	0.98	-	-
<i>Staphylocollus</i>	0.38	0.38	-	-
<i>E. coli</i>	-	0.3	-	-
<i>Xanthomonas</i>	-	-	0.29	-
<i>Rhizobium</i>	0.09	-	-	-

Table 12 : Abundance of individual bacteria - actinomycetes genera per month obtained from all sampling sites
(expressed in % of total bacteria - actinomycetes population)

Genera	J	F	M	A	M	J	J	A	S	O	N	D
<i>Bacillus</i>	0.96	1.57	1.56	1.60	0.87	0.92	0.99	0.91	1.15	1.04	1.21	1.30
<i>Streptomyces</i>	1.10	0.67	1.39	0.66	0.36	0.56	0.42	0.48	1.40	1.46	1.03	1.50
<i>Arthrobacter</i>	0.87	0.35	0.34	0.46	0.10	0.46	0.52	0.37	0.39	0.14	0.28	0.43
<i>Micrococcus</i>	0.44	0.24	0.39	0.47	0.04	0.24	0.09	0.42	0.33	0.17	0.28	0.36
<i>Cytophaga</i>	0.09	0.11	0.26	0.06	0.02	0.07	0.03	0.07	0.02	0.05	0.47	0.05
<i>Nocardia</i>	0.10	0.2	0.18	0.06	0.06	0.09	0.08	0.03	0.13	0.11	0.08	0.08
<i>Listeria</i>	0.10	0.17	0.12	0.05	0.02	0.01	0.07	0.09	0.07	0.05	0.09	0.17
<i>Cellulomonas</i>	0.09	0.06	0.05	0.05	0.02	-	0.03	0.15	0.16	0.09	0.09	0.13
<i>Promicromonospora</i>	0.03	0.07	0.16	0.07	-	0.01	0.01	0.04	0.01	0.12	0.11	0.70
<i>Pseudomonas</i>	0.05	0.14	0.04	0.11	-	0.01	0.01	-	-	0.04	0.11	0.09
<i>Corynebacterium</i>	0.02	-	0.02	-	-	-	0.05	0.01	0.10	0.27	-	0.02
<i>Staphylococcus</i>	0.04	0.04	0.01	0.03	-	0.05	-	0.05	-	0.03	-	0.04
<i>E. coli</i>	-	-	-	-	-	0.01	0.05	-	-	0.07	-	-
<i>Xanthomonas</i>	0.02	-	-	0.08	-	-	-	-	-	-	-	-
<i>Rhizobium</i>	0.02	0.01	-	-	-	-	-	-	-	-	0.02	-
TOTAL	3.93	3.63	4.52	3.70	1.40	2.53	2.35	2.62	3.76	3.54	3.77	4.24

Total population densities of bacteria-actinomycetes obtained from all the sites showed numerical variations with changes of season. It was minimum in the population of fungi was also showed minimum in the month of May (Tab. 10), which supported the finding of Behra and Dash (1981) in Orissa, and Hazra and Choudhuri (1990), Pal *et al.* (1992) in West Bengal (India); except in paddy field where minimum was in the month of August. A considerable reduction in number of major bacterial forms were observed during summer month, when the rate of mortality of delicate and susceptible bacterial forms were also increased. This might be due to the low moisture content in soil during this period. Kauri (1982) observed the high temperature resulted in deficiency of moisture which reflects on the low number of bacteria during summer in the beach forest soil and the predation of microfauna has a greater importance for diminishing the bacterial population. The decline of bacterial and fungal population might be associated with the reduction of population of collembolan fauna in this study. As mentioned earlier the soil microflora specially fungal hyphae and spores were the major food for Collembola according to the findings of Dash and Cragg (1972), Mitchell and Parkinson (1976), Visser and Whittaker (1977) who examined the gut contents and faeces of various soil fauna and made food preference studies for these organisms. Hazra and Choudhuri (1990) and Pal *et al.* (1992) met the similar observations with fungi and Collembola in West Bengal, Testerink (1981) found starvation period in collembolan population during dry periods. While, Bengtsson *et al.* (1985b) stated starvation period may coincide with the period of reduced fungal growth; the relation between starvation and absence of food still needs to be assessed. Torne (1967a, b) observed that, in certain species of Collembola, including Onychiurids, has the ability to utilise certain food sources, is directly related to the presence of certain bacteria, because, the bacterial enzyme make available or otherwise unavailable nutritional food.

It is interesting to note that the fungal population showed an almost parallel pattern of fluctuation with that of Collembola. This coincided with the observations of Knight (1961), Dash and Cragg (1972), Choudhuri and Banerjee (1975), Mitchell and Parkinson (1976), Visser and Whittaker (1977), Tadros and Verney (1983), Hazra and Choudhuri (1990), Pal *et al.* (1992), Choudhuri and Bannerjee (1975) and Hazra (1984). This suggested a direct dependence of collembolan population on fungi. The maximum population peak of Collembola and fungi were found in month of August (monsoon) in forest floor site, it agreed with the observations of Hazra and Choudhuri (1990) and Pal *et al.* (1992); according to them, the significant increase in the moisture content of soil leading to an luxuriant growth of macro and microflora during monsoon. In the paddy field, the peak population of Collembola and fungi were shifted in November and showed lowest in August, this unusual situation was prevailed in this field which might be due to waterlogged during monsoon. A winter peak (November - December) was also reported by Waksman (1932 and '52), Gujarati (1968), Choudhuri and Banerjee (1975), Behra and Dash (1981) and Hazra and Choudhuri (1990). In the present investigation, the bacterial population was also found to be directly proportionate to collembolan and fungal population. However, inconsistent trend of population fluctuation was noticed in bacteria-actinomycetes community might be due to irregular occurrence in the sampling fields; the highest peak of total population as well as that of individual strains

occurred in different months in different year in the habitats under study in contrast to that of Collembola or fungi (Fig. 1-4d, 1-4i). Number of soil bacteria and their fluctuations by plate count method was studied by earlier workers mainly in different forest soil, like, Feher (1933) in Europe, Gray *et al.* (1974) in England and Kilbertus *et al.* (1979) in France. Holm and Jensen (1972) also observed inconsistent fluctuation pattern in bacterial population in beech forest soil of Denmark. The maximum population was observed in any month between November to March in all habitats.

In this study the population densities of collembolan fauna extracted from waste disposal site was maximum (60%), followed by the forest site (21%), sugarcane crop field (11%) and paddy field (8%) (Fig. 11). The bacteria-actinomycetes population was found in the same graded sequence in the four sampling sites and maximum population of fungi also obtained in waste disposal site and minimum in paddy field. Addison and Parkinson (1978), Hanlon and Anderson (1979) and Parkinson *et al.* (1979) reported the effects of grazing by collembolan population on fungal growth or colonization on leaf litter which also depends upon the density of collembolan population.

Comparatively poor populations in the agriculture fields (as seen in this study in sugarcane and rice field) were also reported in case of Collembola by Hammer (1949), Sheals (1956), Edwards and Lofty (1973), Ghilarov (1973) and Hazra and Choudhuri (1983, 1990).

According to Ghilarov (1973) for the preparation of field for cultivation, tilting is an usual practice which results in disappearance of litter and other plant debris from the upper layer of soil, as a result, all the animals living in the litter layer found no suitable place after cultivation and obviously disappeared. Further, in his opinion, the decrease in density of soil forms after cultivation indicated a dropping of biological activity in the soil resulting in a marked decrease in humus content. In present investigation also, the agriculture fields showed significantly low content of organic carbon and supported lower fauna. Effects of tillage practices on soil fauna are though not clear (Loring *et al.* 1981 and Moore *et al.* 1984); workers like Edwards and Lofty (1969, 1975), Hammer (1949) and Sheals (1956) found the deleterious effects of tillage which reduce density and diversity of edaphic and hemiedaphic Collembola. In general, no tillage provides a more favourable environment for soil litter biota; crop residues are left on the soil surface reducing the moisture loss and providing relatively continuous substrate for decomposers; organic matter input is more gradual as in nutrient release; faunal interactions are probably more pronounced and more significant in regulating decomposition rates under no-tillage condition. Thus the fact was similar for the abundance in population density at the waste disposal site of Dhapa where cultivation of different vegetables are practiced in different seasons and vegetable residues used to be remained in the ground. Bormann *et al.* (1974) and Waide and Swank (1976) considered ploughing to be a major perturbation even in forest floor with well defined soil structure. Mitra (1993) studied the effects of cultivation through crop rotation by method of ploughing with continuous application of fertilizer, herbicides and pesticides on soil fauna, chiefly Collembola and Acarina at Jute Agricultural Research institute, Barrackpore, West Bengal; he observed that crop rotation and other agronomic practices over years significantly reduced Collembola population

and diversity of species with consequent reduction of C/N ratio of soil, microbial activities and crop yield. Further the high abundance of collembolan fauna in Dhapa and reserve forest sites in comparison to monoculture crop fields of sugarcane and rice, agreed with the findings of Stebaeva (1963) and Addison (1980), who suggested that, the abundance of *Collembola* might increase in a site with different plant species.

The number of isolates of microbial flora obtained from both agriculture fields were under eight fungal genera and six bacteria - actinomycetes genera; while forest floor and waste disposal site harboured nine fungal genera and ten bacteria - actinomycetes genera. On the other hand, the sugarcane research field supported maximum numbers of collembolan forms (19 genera, 22 species). The present finding in SRS site where, the monoculture crop sugarcane remained in the field through out the year agreed with the observation of Haarlov (1960). He opined that the favourite habitats for microarthropods were characterised by stable humid condition with plant material available throughout the year. While, rice cultivated field where crop remained in field for certain months found to have minimum numbers of collembolan forms (8 genera, 12 species), similar observation were made by Pai and Prabhoo (1981) (5 sp.), Mitra *et al.* (1983) (9 sp.), Panda (1987) (6 sp.), Guru *et al.* (1988) (6 sp.) and Sengupta and Sanyal (1991) (7 sp.) in different paddy fields of India. The increase in number of genera in microflora in the waste disposal site and forest floor in comparison to the agriculture fields might be due to the presence of high concentration of inorganic and organic nutrients and accumulation of higher amount of vegetable residues / litter in the soils. These agreed with the findings of Tadros (1980), Mitchell and Horner (1980) and Hazra and Choudhuri (1990). However, the toxicity of pollutants exerted much adverse effect on collembolan community compare to fungi or bacteria - actinomycetes communities as it was evident in the table 6, 9, 12, as number of floral genera specially fungal forms did differ much in the contrasting habitats, but reduced number of collembolan genera encountered in waste disposal site. Reduction in number of collembolan forms (15 genera, 17 species) in the waste disposal site (DP) was perhaps due to the potential toxic effects of some of the pollutants / heavy metals on some. *Collembola*, similar results were also obtained by Mitchell *et. al* (1980), Chattopadhyay and Hazra (1983), Hazra and Choudhuri (1990). As it been mentioned earlier, different vegetables are cultivated in different times in different year in DP rotationally, it might have an impact in reduction of collembolan genera. Edward and Loftly (1969) suggested that crop rotated decreases species diversity even to a greater extent than monoculture eliminating those species which are associated with other plants. Besides, the specific plant cover not only affects the quantitative and qualitative composition of *Collembola* but also dominance of individual species, which changed with the crop rotations (Aleinikova and Utrobina, 1975). Here in DP site, predominance of the species *L. cyaneus*, *Proisotoma (Clavisotoma) fitchioides* and *Seira indica* during cultivation of maize while that of the species *Xenylla obscura* during cultivation of other vegetables were noticed. Mitra (1993) also studied the specificity of occurrence of some collembolan species according to particular crop-type. Another interesting observation was made in this study that, species composition in floral and faunal community were similar in different contrasting habitats. In collembolan community, maximum number of same species (12 species) found in BRF / SRS site, DP/

SRS site, BRF / DP site have 9 common species, while RRS site shared 7 number of collembolan species with each of other three sites.

Moreover, DP / SRS site also reported to have maximum number of similar fungal genera, while BRF and RRS site each shared 7 number of similar forms of fungi with other three sites. Considering the similarity of species composition in bacteria - actinomycetes community, it is found that, maximum 7 species were common to BRF / DP site, while SRS and RRS site both shared 5 species with other three sites (Tab 6, 9, 12, Fig. 6, 8, 10). According to Wallwork (1970), the collembolan fauna of certain locality was determined by a complex of both ecological and historical factors. Therefore, similarity in species composition might indicate and overall ecological similarity of two sites. In his opinion, influence of vegetation type is indirect, being exerted perhaps through its effect on soil type, microfloral composition or soil moisture. In this investigation, the closeness of the sampling site BRF and SRS (two Km. apart from each other) (Map 1), might play a vital role in the species composition and value of pH did not differ much. On the other hand, occurrence of some species in two crop fields namely, sugarcane (SRS) and rice (RRS) might be due to the more or less similar value of pH and nitrate content in soil of the agricultural fields (Fig. 12). In a study on distribution of *Collembola* in various forest type in Poland, including both deciduous and coniferous trees, Szeptycki (1967) noticed that, the fauna was astonishingly alike, though the sites in question differed in soil, inclination, exposition and microclimate etc. Similarly, in the present observation, few numbers of collembolan species that occurred in comparatively polluted soil environment of waste disposal site also found in least polluted soil of forest floor and agricultural fields. There might be a moderate agreement between plant and collembolan community and the intensity of vegetation might directly or indirectly influence the population density, but whether the vegetation exerted any effect on the species composition could not be ascertained.

According to Knight (1961) and Torne (1961 and '67a, b), as *Collembola* showed strong feeding preference for fungal hyphae and spores, it might be suggested that, distribution of these animals would partly be conditioned by the distribution of fungi species. The presence of fungal hyphae, spores and humus particles in the gut content of *Collembola* has been reported by numerous workers. In 1984, Bignel reported arthropod gut as an environment for microorganisms. The studies of Knight and Angel (1967), Bodvarsson (1970), McMillan and Healey (1971) indicated that the gut content of a single collembolan species taken from several habitats may show greater diversity than the gut content of several species taken from the same habitat; this suggests that collembolans are indiscriminate feeders. Several reports showed that, *Collembola* may discriminate between fungal species (McMillan, 1976; Visser and Whittaker, 1977; Newell, 1984; Gilmore and Raffensperger, 1970; McBrayer and Richel, 1971). Mitchell and Parkinson (1976), Dash and Cragg (1972) and Visser and Whittaker (1977) reported the preference of *Collembola*, Acari and other insect larvae on the species of the fungi like *Penicillium* and *Paecilomyces*. Torne (1961 and '67a, b) suggested that, certain microflora present as gut symbionts in *Collembola* might have an important role in the digestion of plant material consumed by the host; however, there was no direct

evidence from the field observation that, the distribution of collembolan population was limited by this relationship. In his opinion, the direct competition between Collembola and fungi might have a limiting effect on the distribution specially when these two groups were found to compete for the available moisture in the habitat. Christen (1974, '75) did an extensive work on the association of Collembola and fungi. He isolated thirty species of fungi from the four species of soil and dung inhabiting Collembola. In his view, some fungi were probably externally associated, others were ingested and digested, or ingested and passed in a viable state. In 1979, Parkinson *et al.* did an extensive field study of the leaf litter biota of and aspen poplar forest at the time of snow melt and confirm the selective fungal feeding by field collected specimens of *Onychiurus subtenuis*. They studied the effects of selective feeding on the colonization of the leaf litter by two common species of litter fungi and found that, relatively low rate of selective grazing by the Collembola have potentially important effect on the competitive colonization ability of individual fungal species Bengtsson and Rundgren (1983) found some fungal species were grazed more than others, while it was unknown whether, the relative abundance of fungal species was same in the soil as in the gut of Collembola in a mixed environment. But, they assumed that, the preferred fungal species are more actively searched for than the less preferred species in a multispecies environment. Lastly, they established that, grazing could not be rejected as a hypothesis for increased fungal activity. In a microcosm experiment, Klironomos *et al.* (1992) investigated the ability of Collembola (*Folsomia candida*) to survive and reproduce on the fungi.

As to the role of edaphic factors on the distribution and population pattern of different groups of soil inhabiting microfauna and flora, it might be assumed that the factors analysed in this study exerted both significant and insignificant effects either singly or in a cumulative way, depending on the nature of the site. This could be substantiated if an analysis was made as to the extent of important factors by taking into consideration the mean values of soil factors during maximum and minimum population peaks in different sampling sites (Tab. 15). The data in this table showed that in all sampling sites the population was maximum when the factors like moisture, organic carbon, nitrate, phosphate and microflora population also were maximum or significantly high and other conditions were optimum.

Temperature and soil moisture appear to be the main driving variables for seasonal fluctuation of microarthropod population specially in temperate climate with dry summer period (Straalen, 1985, Stamou *et al.*, 1993, Diekkertiger and Roske, 1995). As in the summer months soil temperature was significantly high, the minimum population resulted in summer was also greatly attributed to both the lesser water content and to the physical instability of the humus layer in this type of climate in West Bengal. Of the edaphic factors studied, temperature showed wide variation with the change of season, ranging between 18°C to 41°C (Fig. 12). However, it is evident from table 16a-d that, only at DP the Collembola and fungi population showed positive correlation with temperature, which confirmed the study of Mitra *et al.* (1977) and Bhattacharya and RoyChoudhuri (1979). In another observation Takeda (1978) found both positive and negative correlation between temperature and different species of springtails Pal *et al.* (1992) observed negative correlation of soil temperature with

Collembola and a weak negative correlation with fungi in West Bengal. The negative and significant correlation between temperature and population in other studied sites might be due to the fact as observed by Guru *et al.* (1988) in other fields of India, that, the rise of temperature was expected to cause greater evaporation from the soil making it dry which may be responsible for decrease in breeding activity and thus increase mortality rate of Collembola. The bacterial population always showed negative correlation with temperature during the observation period. Kauri (1982) suggested that, the high temperature results in deficiency in moisture that reflects in low number of bacteria in summer. Hazra and Choudhuri (1983) commented that direct influence of temperature on the distribution pattern of Collembola was difficult to evaluate because collembolans are known to withstand a wide range of temperature, as low as -50°C (Paclt, 1956 and Pryor, 1962) and as high as 55°C (Willson, 1960 and Dunger, 1964); they concluded that, temperature alone did not show significant correlation. According to Christiansen (1964) relationship between population and temperature optima was not clear. Agrel (1941), Bellinger (1954), Davis (1963) and Takeda (1976) reported high mortality rate of some forms of arthropods in temperature range between 34°C - 40°C . Ashraf (1971) from his laboratory experiment reported that both high and low temperature were injurious, the favourable temperature for different species ranged between 10°C - 30°C , when he considered 30°C as the optimum temperature for some species of Collembola. Thus it might be noted in this connection that, the direct influence of temperature on the distribution pattern of soil arthropods was difficult to evaluate.

The actual influence of temperature on the soil organisms could be evaluated in conjunction with the effect of moisture. During this investigation, the moisture content recorded minimum in summer when the samples yielded low population. In the year 1930, Scheubert also suggested that being interlinked with each other temperature and moisture might exert their effects on the population conjointly, similar result was recorded by Webb (1970), Hazra and Choudhuri (1990).

Table 14 : values of soil factors, levels of heavy metals and abundance of fungi / bacteria - actinomycetes population in the months when maximum and minimum population of Collembola obtained from respective sites.

Sampling sites	Temperature (°C)	Moisture (%)	pH	Organic Carbon (%)	Nitrate (pp)	Phosphate (ppm)	Mercury (ppm)
BRF	3.25	35	6.05	4	2.53	4	0.026
	34.67	25.5	0.97	1.24	1.78	4.33	0.23
DP	36	34.93	5.87	4.04	3.78	10.13	0.59
	37.67	25.9	6.77	3.52	2.68	5.1	1.18
SRS	22.17	15.87	6.63	1.72	1.65	7.03	0.028
	39	10.2	7.3	0.87	0.95	5.2	0.052
RRS	29	38.35	6.65	2.8	1.51	6.85	0.022
	31	44.85	7.25	1.17	0.725	2.35	0.055

Table 14

Sampling sites	Copper (ppm)	Lead (ppm)	Zinc (ppm)	Fungi Population (%)	Bacteria-Actinomycetes Population (%)	Maximum&Minimum Collembolan Population Month (%)
BRF	6.5	23.5	45	7.53	3.095	August 10.79
	45.67	26.67	113.33	1.006	1.24	May 0.57
DP	181.67	133.33	506.67	5.88	4.97	March 16.9
	191.67	176.67	523.33	1.39	1.65	May 0.26
SRS	32.67	19.33	31.67	7.77	3.95	February 8.64
	25.33	21.67	41.67	0.75	0.82	May 0.47
RRS	57.5	22.5	67.5	7.52	3.71	November 10.24
	52.5	30	72.5	0.415	2.63	August 0.35

In the present study the moisture content was recorded to be maximum (45.2%) in waterlogged RRS site and minimum (10.0%) in SRS site and thus a wide range of variation was observed in different fields in different season (Fig. 12). It was found to be positively correlated with the populations of soil microflora and collembolan fauna in all sites with the exception of the paddy field RRS, where the moisture showed negative correlation with the population of Collembola and fungi and it was marked interestingly that in RRS site the bacteria showed positive correlation (Tab 16a-d). The value of correlation of Collembola with moisture was significant in BRF and DP site, and that of fungi only in BRF site. Mukherjee and Singh (1970), Choudhuri and Roy (1972), Hazra and Choudhuri (1983, '90) and Guru *et al.* (1988) found positive but not significant correlation between the soil organisms and moisture.

Laudelout *et al.* (1978) found small but significant correlation between soil moisture and bacteria-fungi population at Hainaut. However, negative correlation between Collembola, fungi and soil moisture in paddy field (RRS), might be due to the waterlogged condition during monsoon. The inundation effecting adversely the population of soil organisms and shifted the usual monsoon population peak (the general experience of this group specially in West Bengal) to some other month (November) at paddy field. Similar result was obtained by Hazra and Choudhuri (1990) while studying the population of Collembola, acarina and fungi in three different sites which remained frequently submerged due to heavy monsoon rainfall; and also by Pai and Prabhoo (1981) and Sengupta and Sanyal (1991) in the different paddy fields of India. Choudhuri and Roy (1972) and Singh and Pillai (1975) affirmed that soil humidity exerts the most important influence on soil microarthropods specially on Collembola.

Highly significant positive correlation with Collembola and its monsoon population peak in forest floor (BRF) agreed the observations of Agrell (1941), Poole (1961), Knight (1961), Christiansen *et al.* (1961), Davis (1963), Gupta and Mukherjee (1976), Mitra *et al.* (1977), Hazra and Choudhuri (1981, '83). The similar result in case of fungi was very much supported by the observations of Dixon (1928), Waksman (1932, '52), Cobbs (1932), Ghosh and Dutta (1960), Mishra (1964), Gujarati (1968), Choudhuri and Banerjee (1975), Parkinson (1983), Behra and Mukherjee (1984) and Hazra (1984) and Hazra and Choudhuri (1990). However, Macfadyen (1952), Huther (1961) and Murcuzzi (1962) found no association with moisture and population. In sugarcane field (SRS), the population peak was obtained in February when, the temperature and moisture were comparatively low. Choudhuri (1963) opined that the variable capacity of collembolan forms to withstand the condition of desiccation or drought occasionally prevailing in nature, which might be considered as one of the factors contributing to the population fluctuation. In the monsoon months when the moisture content is recorded to be maximum, also the soil temperature remains higher being more or less near to summer temperature in the climate of Gangetic West Bengal, having high precipitation rate and temperature. In the present study, this could be supported by the occurrence of the peak population of soil organisms in waste disposal site in March, when the temperature and moisture were moderately high. Moreover, the vegetable residues were found to be the main constituents of the waste dumped in this site which underwent decomposition and might

increase the water-content in soil. Haarlov considered either moisture or organic matters as an important ecological factor in the life of Collembola in Danish soil. However Choudhuri and Roy (1967) and Nijima (1971) reported significant influence of organic matter and soil moisture on the population of Collembola. According to Singh and Pillai (1975), the ecological parameters like soil temperature, moisture, organic matter and CaCO_3 content of soil have either individual or a combined influence on the composition of soil fauna. In some instances wetness or dryness as such influence the soil fauna indirectly rather than directly, since these factors largely determine the type and density of vegetation which in turn contribute towards the augmentation of soil organic matter. The later not only served as a source of food but influence the amount of living space available for the soil animals. From the information available Hazra (1978 a, b) and Hazra and Choudhuri (1990) suggested that organic matter and water content of soil together exerted direct or indirect influence on the microbial floral and faunal population by (i) maintaining soil reaction, (ii) controlling humification and (iii) stimulating the growth of micro- and macro-flora.

The content of organic carbon varied between 0.75% and 4.23% (Fig. 12) and exhibited strong positive correlations with the population densities of soil fauna and flora (Tab. 16a-d). The increased population of fungi and collembolan fauna with the increased content of organic matter as confirmed the views by Haarlov (1960), Christiansen *et al.* (1961), Christiansen (1964), Davis (1963), Curry (1969), Choudhuri and Roy (1972), Hazra (1978a, b), Hazra and Choudhuri (1983) in case of Collembola; and in case of soil fungi Mishra (1964), Gujarati (1968), Dickinson and Pugh (1974), Satchell (1974), Cromach *et al.* (1975), Parkinson (1983) and Tadros and Verney (1983) and Hazra (1984). Moreover, the concentration of large population of flora and fauna in the litter and humus layer suggested their affinity to organic matter. The high temperature and low moisture in soil seemed to influence the amount of organic carbon as it was evident from the present study that during summer, soil contain less amount of organic carbon which might be due to low moisture level and ready oxidation occurring in organic matter.

Another important driving variable affecting the population fluctuation of soil biota was the soil pH. It was measured minimum 5.8 at DP and maximum 7.4 at SRS and RRS. The graphical presentation of seasonal changes of pH exhibiting very little fluctuation (Fig. 1-4a). However, its average value in four different sites did not vary much and was more or less neutral (Fig. 12). Hazra and Choudhuri (1983) stated more or less neutral pH was favourable to soil organisms. The statistical analysis showed strong negative correlation with the population of all the groups studied and are highly significant with collembolan and fungal population (Tab. 16a-d). This was in agreement with the finding of Agrell (1941), Bellinger (1954), Choudhuri *et al.* (1978) and Pal *et al.* (1992). Hazra *et al.* (1976) and Hazra and Choudhuri (1990) have reported that, soil pH may exert indirect influence on the growth and activities of soil micro and macro flora and also the vegetation and other physiochemical properties of soil. However, Kauri (1982) studied a simple relation between pH and number of soil bacteria, which even does not always exist. While Dhillon and Gibson (1962) suggested that, soil pH has very little or no direct effect on the floral or faunal makeup. Baath (1989)

commented that, different processes in soil are pH dependent; therefore, it will be difficult to differentiate or to assess the effects due to pH changes or other parameters like toxicity of heavy metals under field condition. In a more concentration of DP site was maximum 3.13 ppm, and in other sites 2.2 ppm at BRF, 1.23 ppm at SRS and 1.2 ppm at RRS (Fig. 12). A strong positive significant correlation between the nitrate and Collembola has also been observed by Kuhnelt (1950), Choudhuri and Roy (1972), Hazra and Choudhuri (1990) and Pasi *et al.* (1992). The analysis of correlation coefficient revealed positive and significant correlation in most cases with the populations of all the three groups studied here (Tab. 16a-d). The nitrate, being the most essential macronutrients for the plants probably exerts its influence on collembolan population through vegetation.

It is an accomplished fact that the phosphates in soil are available both in organic and inorganic form and exerts significant influence on the growth of vegetation and organic compounds of phosphate usually form a constituent part of humus complex of soil. In the present investigation, the phosphate content of the soil measured maximum 14.6 ppm at DP and minimum at BRF, 2 ppm. The mean value of phosphate was high in DP (10.59 ppm.) in comparison to other sites, 6.01 ppm. at BRF, 5.57 ppm. at SRS and 4.47 ppm. at RRS (Fig. 12). The analysis of correlation coefficient showed positive with the population of soil organisms considered. Choudhuri and Roy (1972) observed either positive (strong or weak) or negative correlation between collembolan population and phosphate contents (Tab. 16a-d). However, Hazra (1976) found either weak or negative correlation with collembolan population. Thus the above study suggested that, the relation between soil phosphate and Collembola were not regular or consistent, perhaps due to the fact that all the phosphate in soil were not available to the living system. The term 'available' referred to that phosphate which readily stimulated the growth of plants; the availability of which again would depend on the pH and the concentration of decaying organic matter. Finally it might be assumed that, phosphate as a single factor did not exert any significant influence on the population but in combination with other factors might contribute to the population of soil biota.

In the heterogeneous atmosphere of soil, the heavy metals, as nondegradable substances are accumulated in the upper layer of soil mainly in the organic part of the soil profile where the biological activities are maximum and thus the decomposer organisms inhabiting the litter layer suffer more from metal exposure. In natural polluted soil, never a single metal is found to be responsible for toxicity of soil habitat, it polluted mainly from the cumulative effect of two to almost all the possible metals.

Among the heavy metal content in soil cadmium, copper and lead are the most thoroughly investigated metals, fewer data are available for mercury, zinc, nickel and chromium. Among the soil animals, most data concern earthworms, followed by slugs and springtails. In this investigation, a simple comparative approach was made to demonstrate the impact of heavy metals like Hg, Cu, Pb and Zn on the collembolan population characteristics i.e. species composition, species richness, abundance and distribution in different habitats in association with soil bacteria - actinomycetes and fungi by correlation study. But, one point in particular is that, it is very difficult to evaluate the impact of single metal on the soil microfauna / flora

The concentration levels of heavy metals in the soil considered in the present investigation showed wide range of variation from 0.2 ppm to 1.6 ppm mercury, 5 ppm to 200 ppm copper, 20 ppm to 320 ppm lead, and 20 ppm to 620 ppm zinc (Fig. 12). The correlations of Hg, Pb and Zn with total populations of soil bacteria - actinomycetes, fungi and Collembola were found to be negative in all sites and significant in most cases of Collembola and few cases of fungi, these agreed with the findings of Hazra and Choudhuri (1990) (except in SRS site where the bacterial population exhibited a positive correlation with Pb) (Tab. 16a-d). However, it is evident that, the result ('r' value) was quite different in case of Cu (Tab 16a-d). All the organisms (Collembola/ fungi/ bacteria) studied showed positive correlation with Cu in SRS and RRS site, and with bacteria in waste disposal site (DP), though the levels were low in these sites in comparison to DP site (Fig. 12). Thus no definite conclusion could be drawn as to whether the microflora and fauna collected from the site which contained a higher level of various heavy metals, where tolerant populations. Straalen (1993) found that the springtails are very insensitive to copper, while other soil invertebrates like earthworms and snails are very sensitive but for lead no such conclusion could be made. In another observation Bengtsson and Tranvik (1989) noticed that, earthworm and enchytraeid densities were reduced in soil with Cu measured less than 100 mg./ Kg. and when the other metals were at negligible concentration, however, the number of Collembola remained same even at concentration twice as high. This finding seemed to be similar to that of Yamamoto *et al.* (1985), added Cu to paddy field soil but did not observe any differences in number of fungi growing in control and amended soil. Nordgren *et al.* (1983) found no effect on CFU of fungi in area with more than 10000 ppm Cu / gm of soil and approximately at the same level of Zn. In another observation Nordgren *et al.* (1985) reported only minor effects on fungal species diversity, which was evident at Cu levels over 10000 ppm. Bengtsson and Rundgren (1988) suggested that Cu is quite firmly bond in soil matrix and thus remain unavailable to some extent. Therefore, further studies should be made on the toxicity of heavy metals on the microflora and fauna collected from this polluted area.

In all the studies sites, populations were found to be maximum when the concentration levels of metals (specially Hg, Pb and Zn) were significantly low and minimum in summer months when the levels of metals were high (Tab. 15), when all the surrounding industries which generate these pollutants remain very active during summer in comparison to other months of the year. Moreover, due to low rainfall for more than three months, the deposited solid wastes remain over the soil surface and during monsoon it perhaps percolate through the soil pores.

It is interesting to note that, the highest concentration levels of all the metals were recorded in the waste disposal site DP that supported the maximum population densities of soil microflora and fauna. The DP site is situated by the site of Eastern Metropolitan Bypass at Calcutta and main source of metals in the soil may be the garbage material dumped by Calcutta Municipal Corporation. CMC gather all sorts of wastes, for e.g., the households refuse as well as the industrial discharges together dumped in the same place, moreover, residues of different seasonal vegetables cultivated here, might have contributed a lot to the

organic matter in field study, moreover, the effect of interaction between species is very critical in the field resources found in this sampling site, It has already been established by numerous workers like, Muskett and Jones (1980), Tranvik and Eijsackers (1989) and Williams *et al.* (1977) that the Collembola as a group remains invulnerable with respect to the pollution. Strojan (1978) observed that Collembola were least affected arthropod group near a smelter and suggested that, abundance of this group might be due to an increase in some metal-tolerant species. On the other hand, Posthuma and Straalen (1993) argued, adaptation in one species may affect other species indirectly, since it may change exposure of species at other trophic levels, which need not be adapted. Moreover, according to Joosse and Bukar (1979) collembolans are less affected by pollution due to their various detoxifying mechanisms, such as periodic moulting. In this study the high concentration of nitrate showed direct correlation with maximum population of Collembola at DP site, this might be due to the fact as stated by Bengtsson and Tranvik (1989) that, with nitrogen rich food source the costs of increased moulting frequency which resulted in slow growth seemed to be compensated, and a high growth rate maintained even in a polluted environment. Out of four sampling sites, the DP site also recorded highest organic carbon content in soil, which might be an important factor in reducing the toxicity of metals, this result coincided with the finding of Baath (1989) Bengtsson and Rundgren (1988) further opined that, since the soil environment is very heterogeneous, metal concentration might vary greatly between microhabitats that are different with respect to soil texture and organic matter Babich and Stotzky (1978,'85) and Straalen (1993) emphasised that the properties of soil substrate such as, organic matter content, pH may greatly influence the chemical speciation of metals in soil, hence the bioavailability of metals and their toxicity. But they considered it to be difficult to evaluate the influence of any such particular parameter in a field study, as in natural condition these factors interact together and exert cumulative effect.

On the other hand, the waste disposal site DP witnessed a decline in collembolan species diversity as compared to forest floor (BRF) and sugarcane agricultural field (SRS), which agree with the views of Bengtsson and Rundgren (1988), Bengtsson and Tranvik (1989) who concluded that, the common effect of metal contamination in all the invertebrates is a decrease in species diversity. According to them, the total abundance is not clearly affected, as decrease in some species is compensated for by an increase in number of individuals of more tolerant species. A reduction in number of animal species has been observed by many previous workers like Strojan (1978), Bengtsson and Rundgren (1988), Bengtsson *et al.* (1988a), Tyler *et al.* (1989), Hagvar and Abrahamsen (1990), which indicates that many species fail to adapt to local concentration (Posthuma and Van Straalen, 1993). Bengtsson and Rundgren (1988) studied that low diversity in collembolan community in polluted soil was associated with the predominance of one species, which may be one of various metal tolerant species of Collembola. Similarly, in the present observation, collembolan population was dominated by *Lepidocyrtus cyaneus* constituting 45% of the total population obtained from this sampling site (DP). Table 6 and figure 7 elicited the differences in occurrence of some collembolan forms specially, *Xenylla obscura*, *Cyphoderus javamis*, *Seira indica*, *Cryptopygus thermophilus* and *proisotoma (Clavisotoma) fitchioides*, which were found to

be more pronounced in this polluted site. The occurrence of some terrestrial invertebrate species having capability to tolerate edaphic heavy physical adaptation or genetic changes varied from case to case, rather a shift in species composition with metal tolerant species is a more common phenomena in highly polluted soil, resulting the high abundance of metal tolerant fungi. In present study, some fungal namely *Penicillium*, *Aspergillus*, *Fusarium*, *Trichoderma* were found to be more abundant in DP site in comparison to other sites. Similar abundance of *Penicillium* in polluted soil has also been reported by Carter (1978). Yamamoto *et al.* (1981) found a simplified flora dominated by *Penicillium* spp in soil polluted by Cu mine drainage. On the other hand, many authors like, Jordan and Lechevalier (1975), Williams *et al.* (1977), Nordgren *et al.* (1985) found a decrease in population of commonly isolated genus of *Penicillium* in metal polluted soil Metal (Zn) tolerant *Aspergillus niger* strain was reported by Elorza (1969). But, Pugh *et al.* (1975) found a metal sensitive species of *Trichoderma*. Jensen (1977) examined the effect of Pb on the composition of bacteria and fungi on dilution plates and found no great changes in case of bacterial flora, while, in case of fungi, he noticed the occurrence of the dominant species *Fusarium*. Carter (1978) and Arnebrant *et al.* (1987) noticed that large variations in metal tolerance exist within single fungal genus.

The species composition in bacterial population encountered from DP site was dominated by gram-positive taxa *Bacillus* (28% of total population obtained from all sites) and among the other forms *Micrococcus* (3.66%), *Cytophaga* (3.25%), *Promicromonospora* (1.32%), *Corynebacterium* (0.98%), *Pseudomonas* (0.67%) and *E. coli* (0.3%) were abundant (Tab. 8, Fig. 11). Mahler *et al.* (1986) found many gram-positive spore formers resistant to Hg and Cd. However, in contrast to this finding Doelman and Haanstra (1979c), Baath (1989) and Tyler *et al.* (1989) reported gram-positive taxa to be more sensitive to heavy metals than gram-negative, Duxbury and Bicknell (1983) isolated the metal tolerant bacterial population from natural and metal polluted soils and found the rod shaped Gram-negative bacteria in maximum numbers. According to Fouly (1976) found some species of enterobacteriaceae appear to be susceptible to Pb, but, at the same concentration *Bacillus* was resistant. In a study on the effect of Pb on the soil bacteria Doelman and Haanstra (1979c) found proportionately more gram-negative rods than coryneform bacteria, such as *Arthrobacter*. According to them, gram-negative rods are predominantly found in moist containing interior of soil aggregates, thus these strains may be more protected against the adverse action of heavy metals, similarly the drought resistance coryneform bacteria in outer layer of soil aggregates may be suppressed. Here the gram-negative forms (*Pseudomonas* and *E. coli*) contributed maximum of 0.97% of the isolates in total population while, *Arthrobacter* population isolated in the DP site was only 2.98% (Tab. 8). Roane and Kellogg (1996) isolated Pb tolerant bacterial genera like, *Pseudomonas*, *Bacillus*, *Corynebacterium* and enterobacter species. Here the genus *Corynebacterium* was found to isolated only from DP site. Tornabene and Edwards (1972) isolated a Pb resistant strain of *Micrococcus*. The actinomycetes represented by *Streptomyces* obtained minimum from DP (Tab. 8, Fig. 11) while, Kandaswamy *et al.* (1981) found no growth of actinomycetes in the effluent added soil from chemical industries. Lastly, it is to be mentioned that, Barkay *et al.* (1985) did not observed any

difference in species composition and diversity of bacterial community in control and sludge amended soil. Doelman and Haanstra (1979c), Yamamoto *et al.* (1985), Arnebrant *et al.* (1987), Tyler *et al.* (1989) and Baath (1989) suggested that a more sensitive approach to detect heavy metal effect on microorganisms might be to estimate the number of tolerant instead of total number of organisms.

It may be difficult or sometimes impossible to define a 'critical' concentration or degree of pollution at which noxious effects of heavy metals on organisms or ecosystems do appear (Tyler *et al.* 1989). According to Bengtsson *et al.* (1983), high concentration of metals seem to be necessary for significant reduction of population density. In a review Bengtsson and Tranvik (1989) comprehended the field study of many workers on the effects of metal on forest soil invertebrates and suggested, 100-200 mg Pb, < 100 mg Cu, < 500 (?) mg Zn and 10-50 mg Cd / Kg soil or litter as maximum allowable metal concentration that will cause no adverse effects. It is to be mentioned that, in this investigation, the present level of metal toxicity at DP site was not enough to show the adverse effect on soil biota (Dr. Hopkin, S.P, Div. of Zoology, School of Animal and Microbial Sciences, Univ of Reading, PO Box 228, Reading RG6 6AJ, England, 1998, personal communication). Moreover, there is a strong evidence for the occurrence of adaptation in natural population of the springtails *Isotoma notabilis*, *Onychiurus armatus*, *Orchesella sincta* (Collembola); population divergence indicates acclimatization or adaptation in many other terrestrial invertebrates (Posthuma and Straalen, 1993).

The results of this investigation mostly corroborated those of other workers, while in certain aspects they showed striking differences from those reported earlier. This might be due to the prevalence of local environmental factors which were likely to exert profound influences in the pattern of population structure (Wallwork, 1970). It might be inferred that the factorial components evaluated here in conjunction with the other components not considered in this study collectively contributed to the population fluctuation and the distribution pattern of soil arthropod fauna and microflora in the different contrasting habitats of tropical climate of Eastern India.

Taking into account the overall quantitative and qualitative changes undergone by the communities of soil arthropod Collembola and soil microbe fungi / bacteria / actinomycetes, precise information could be obtained. The qualitative variations of a single species or category did not permit to draw definite conclusions, although these could be provided by the comparative study of species having different sensibilities. In this context the question of studying the whole community as an indicator of the above mentioned pollution became indispensable.

Lastly, it would be worth mentioning that the attempt to unravel the interactions between edaphic factors and fungal / bacteria-actinomycetes / collembolan population would be abortive unless the behaviour of individual species in relation to each factor and pollutant were studied separately under controlled laboratory condition (Choudhuri and Roy, 1972, Garay *et al.*, 1980, Wong and Kwan, 1980), further, simultaneous experiments also to be performed in the field to indicate the complex interactions between metals on the fate of individual population.

SUMMARY

Present studies contain results of an ecological study involving the impact of different soil factors and some heavy metal pollutants on subterranean collembolan population and their association with the soil microbes (Fungi and bacteria actinomycetes population) from four different polluted, agricultural and forest habitats of West Bengal.

Soil factors like temperature, moisture, pH, organic carbon, nitrate and phosphate and heavy metals such as mercury, copper, lead and zinc were taken into consideration. Fungi and bacteria - actinomycetes population and their interactions with these parameters and soil fauna were also studied. All these were found to vary sampling site wise and seasonally.

A total of 1,080 soil samples were drawn from various plots at monthly intervals over a period of thirty months (January 1996 to June 1998). Of 12 plots sampled, three had polluted soil environment, three were from a sugarcane field where the crop remained through out the year, three from a rice field which remained in irrigated condition during monsoon and remaining three were from the forest floor which served as a control for comparative study for other plots.

Population density of total Collembola, fungi and bacteria-actinomycetes in order of abundance were 60.50%, 31.8% and 47.38% respectively at waste disposal site, 21.34%, 22.43% and 23.43% respectively at the forest floor site, the sugarcane crop field showed their respective abundance 10.43%, 27.8% and 15.96% and the paddy field were with 7.63%, 17.98%, and 13.22% respectively.

The collembolan fauna encountered, belonged to 28 genera of the families Hypogastridae, Isotomidae, Entomobryidae and Sminthuridae. Moreover, the number of genera occurring in the different sampling sites also varied, maximum species diversity was obtained from the sugarcane cultivated field (22 species under 19 genera) and minimum diversity of species was recorded in the paddy field (12 species under 8 genera). Species composition of Collembola of four different habitats differed considerably, only 7 species of Collembola out of total 37 species were found to occur in all the habitats (*Lepidocyrtus heterolepis*, *L. exploratorius*, *Xenylla obscura*, *Cyphoderus javanus*, *Isotomurus balteatus*, *Sminthurides appendiculatus* and *Isotomiella minor*) while the species viz. *L. magnificus*, *L. medius*, *Folsomides exigus*, *Sminthurides* sp., *Pararrhopalites* sp., *Deuterosminthurus* sp., *Sinella montana* were confined only to reserve forest floor site, *Proisotoma (Clavisotoma) fitchioides*, *Archerontiella* sp., *Willemia* sp. were occurred in waste disposal site, *Salina indica*, *Heteromuricus cercifer*, *Dicranocentroides* sp. *Dicranocentrus* sp. were found only at sugarcane field and *Lepidocyrtus* sp., *Sminthurides aquaticus*, *Sminthurides parvulus* were restricted to paddy field.

Fungal population studied belonged to 11 genera and the bacterial community comprised of 13 bacterial genera and 2 actinomycetes genera. Six genera of fungi (*Penicillium*, *Aspergillus*, *Fusarium*, *Rhizopus*, *Mucor*, *Sclerotium*), 4 genera of bacteria (*Bacillus*,

Arthrobacter, *Micrococcus*, *Pseudomonas*) and the actinomycetes strain *Streptomyces* were found in all the four habitats studied. On the other hand, 2 genera of fungi (*Cladosporium*, *Nigrosporium*), 7 bacterial genera (*Cytophaga*, *Nocardia*, *Listeria*, *Cellulomonas*, *Corynebacterium*, *E. coli*, *Xanthomonas*, *Rhizobium*) and one genus of actinomycetes (*Nocardia*) were found to be confined to a particular site.

Numerically the genus *Lepidocyrtus* occupied topmost position among all the collembolans and was widely distributed, *Xenylla* and *Cyphoderus* respectively occupied second and third position, and the other genera like *Isotomurus*, *Homidia*, *Salina*, *Cryptopygus*, *Yossia*, *Sminthurides*, *Seira*, *Isotomiella* mentioned in order of dominance. Populations of most of the other genera were numerically low and irregular in distribution pattern.

In order of dominance the *Penicillium* and the *Bacillus* occupied topmost position among the fungal and bacteria - actinomycetes communities respectively.

Population density of both the microfauna and flora varied considerably from month to month, season to season in different habitats. The population peak was also varied from one site to other, usually minimum in summer month; with an exception in case of paddy field, where the lowest population was in the monsoon month of August due to the waterlogged condition of the field. The peak population of Collembola and fungi found to be coincided in all sites in respective months, like, during monsoon (in the month of August) in the forest site, when in other three sites *i.e.* in waste disposal site, sugarcane field and rice field the respective peaks were in March, February and November. However, the bacterial population peak varied from one year to another year of observation, which was found to be coincided with the collembolan / fungal population in waste disposal site only.

The fluctuation of populations of both Collembola and fungi showed a regular trend in some major species, but majority of collembolans and microbial genera specially in bacterial community exhibited irregular trend.

When the correlation was examined in respect to the population of collembolan fauna and fungal flora showed a significant positive relationship. The relationship between the populations of Collembola, fungi with that of bacteria-actinomycetes were positively correlated in all the cases but it was significant only in case of waste disposal site. The paddy field showed positive correlation at significant level between fungi and bacteria-actinomycetes population.

Of the soil factors *viz.* moisture, organic carbon, nitrate and phosphate also showed positive significant correlation with Collembola, fungi and bacteria-actinomycetes population. But in paddy field, moisture exhibited negative correlation with fungi and Collembola. In respect to soil temperature and pH, nature of correlation were negative in all cases, but in case of waste disposal site, soil temperature found to be positively correlated with collembolan and fungal population.

The heavy metals like mercury, lead and zinc exhibited negative correlation with the total population of Collembola as well as fungi / bacteria-actinomycetes populations (except bacteria

- actinomycetes population, which showed positive correlation with zinc in SRS). However, the relationships between copper and faunal / floral population varied from one sampling site to other (Collembola and fungi population showed positive correlation with copper in SRS and RRS, bacteria-actinomycetes population showed positive correlation with copper in all sites except BRF).

As the population of Collembola, fungi and bacteria are interrelated or interdependent, which also depend upon the soil factors, as there is no *a priori* theory about the governing variables, the Stepwise Linear Regression analysis revealed that, these are subjected to change, *i.e.* the type and number of variables found to be important for the population density of collembolan forms varied for different species in a given site as well as for a same species in different sites.

The measure of association broadly indicates more significant values in the complex biotic communities in soil (*viz.* between pairs of different genera / species of Collembola / fungi / bacteria-actinomycetes) at waste disposal site and , between pairs of biotic and abiotic variables (*viz.* different edaphic factors and heavy metals) at paddy field.

From the present investigation it might be inferred that the effect of mechanical disturbances due to agricultural practices the field leads to poor soil environment and dumping of municipal wastes (household refuses / industrial discharges) on soil surface which cause soil environment polluted and results to the reduction of the soil microfauna / flora quantitatively or qualitatively. Thus, the reduction of these active biological agents the process of soil formation would become slow with the ultimate effects on soil health in general.

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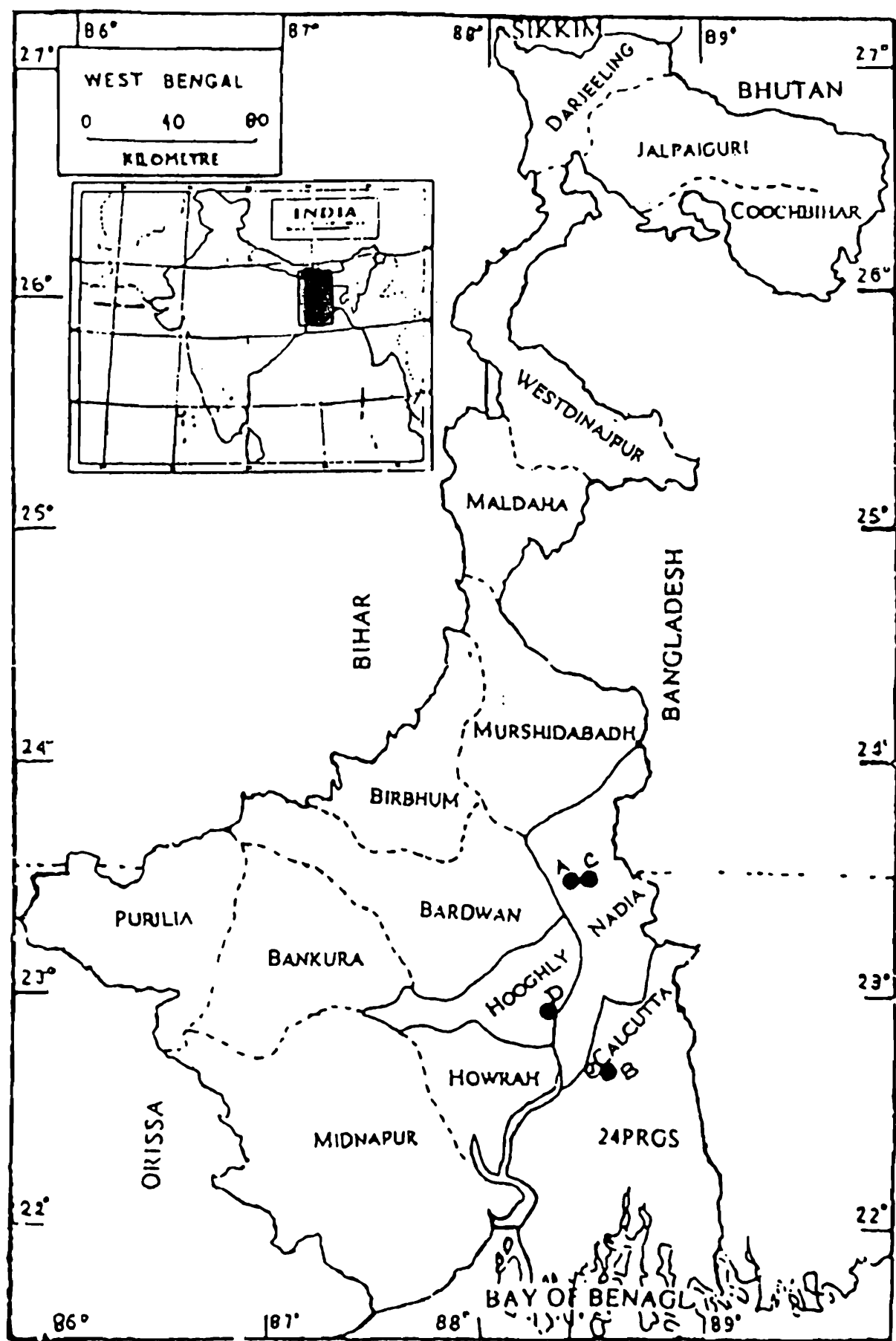
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Map 1. Location of sampling sites (*) : A = Bethuadahari Reserve Forest, B = Dhapa, C = Sugarcane Research Station, D = Rice Research Station.

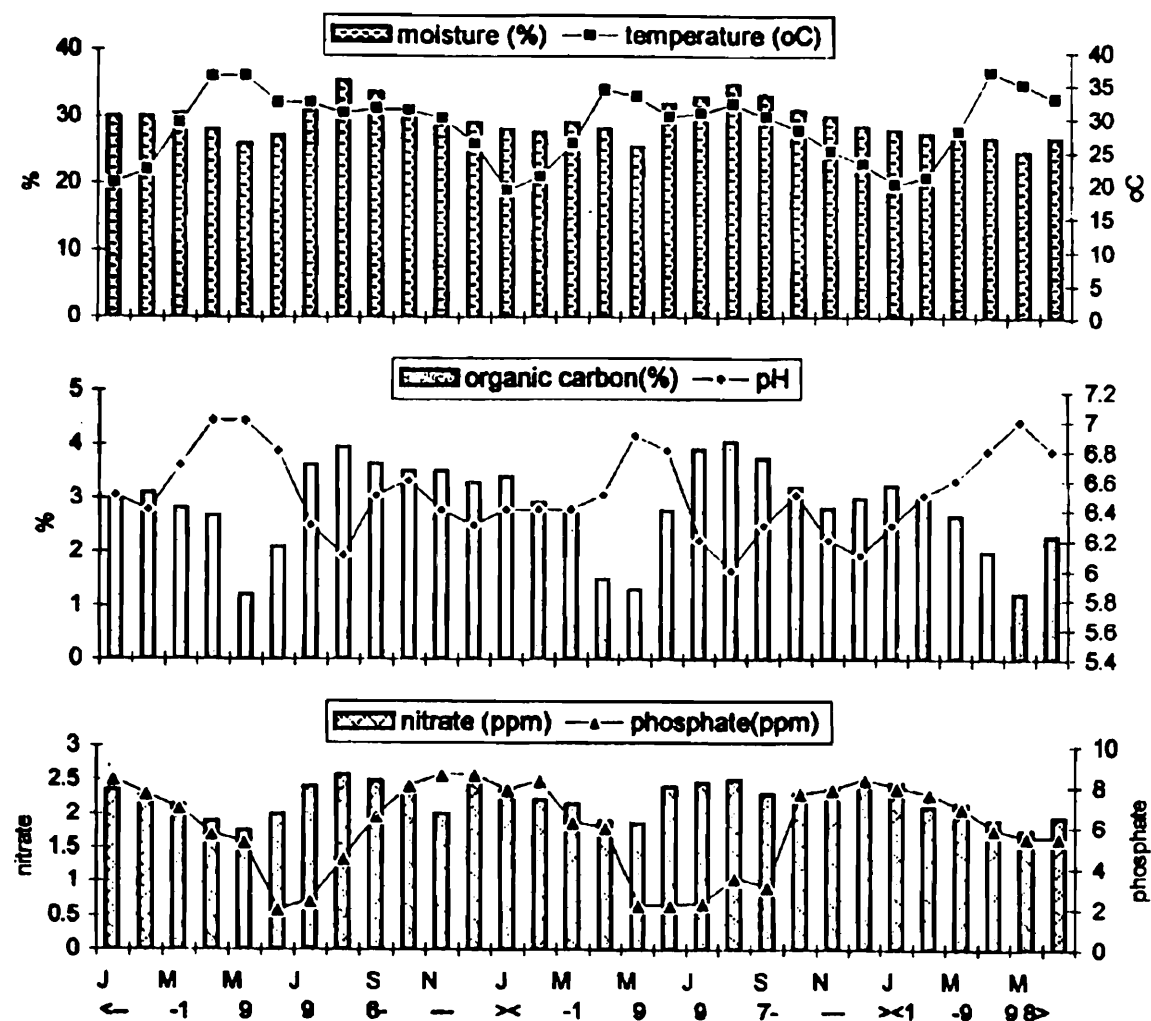


Fig. 1a : Monthly changes of edaphic factors at site I : BRF.

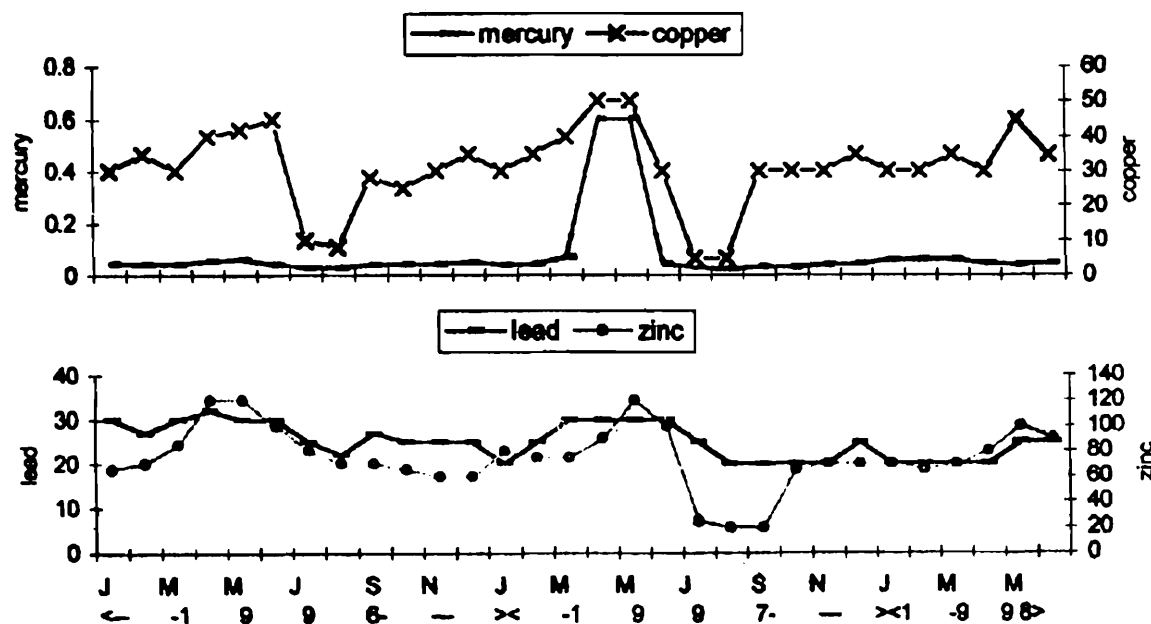


Fig. 1b : Monthly changes of heavy metal levels in soil at site I : BRF

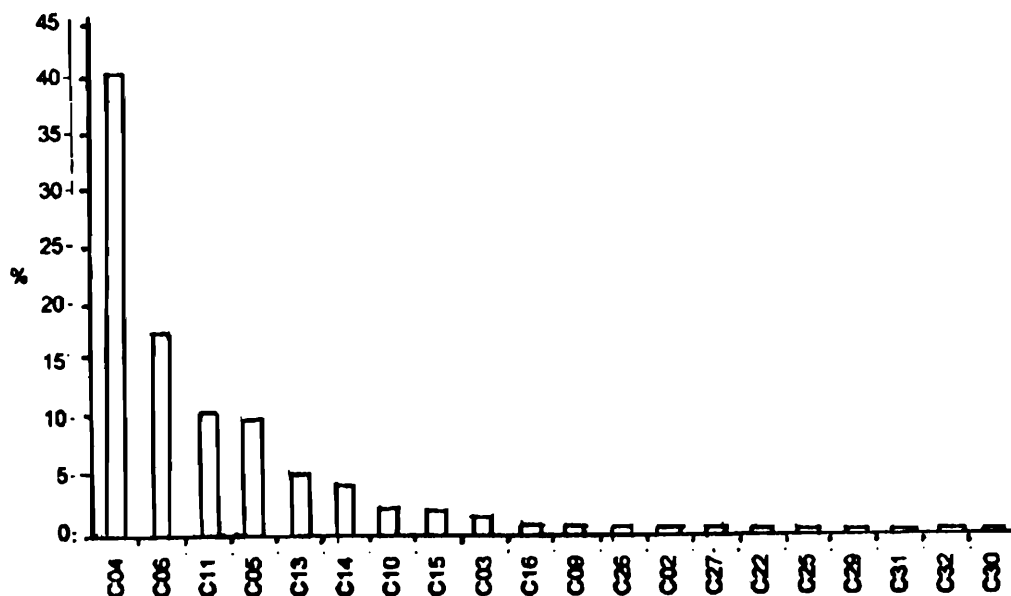


Fig. 1c : Composition of collembolan community in site I : BRF

C04. *Lepidocyrtus magnificus*; C06. *Homidia* sp.; C11. *Yosiia dehradunia*; C05. *Isotomurus balteatus*; C13. *Sminthurides appendiculatus*; C14. *Lepidocyrtus medius*; C10. *Cryptopygus thermophilus*; C15. *Isotomiella minor*; C03. *Cyphoderus javanus*; C16. *Lepidocyrtus exploratorius*; C09. *Lepidocyrtus heterolepis*; C26. *Folsomides exigus*; C02. *Xenylla obscura*; C27. *Sminthurides* sp.; C22. *Sphaeridia* sp.; C25. *Bourietia* sp.; C29. *Pararrhopalites* sp.; C31. *Deuterosminthurus* sp.; C32. *Sinella montana*; C30. *Dicyrtomina* sp.

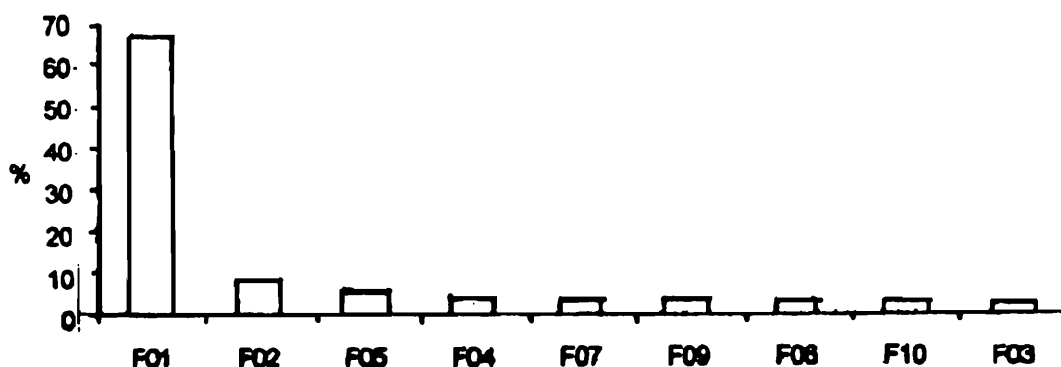


Fig. 1f : Composition of fungal community in site I : BRF

F01. *Penicillium*; F02. *Aspergillus*; F05. *Rhizopus*; F04. *Trichoderma*; F07. *Sclerotium*; F09. *Curvularia*; F06. *Mucor*; F10. *Cladosporium*; F03. *Fusarium*.

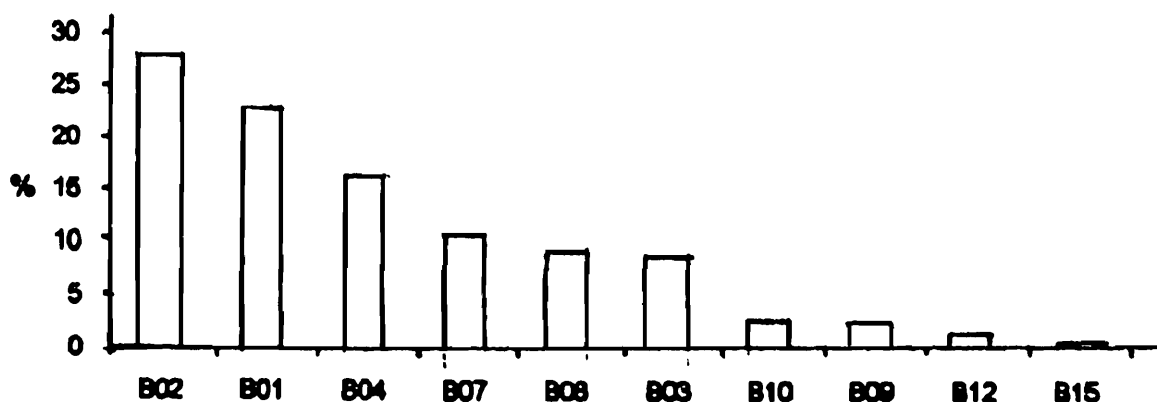


Fig. 1h : Composition of bacteria-actinomycetes community in site I : BRF

B02. *Streptomyces*; B01. *Bacillus*; B04. *Micrococcus*; B07. *Listeria*; B08. *Cellulomonas*; B03. *Arthrobacter*; B10. *Pseudomonas*; B09. *Promioromonas*; B12. *Staphylococcus*; B15. *Rhizobium*.

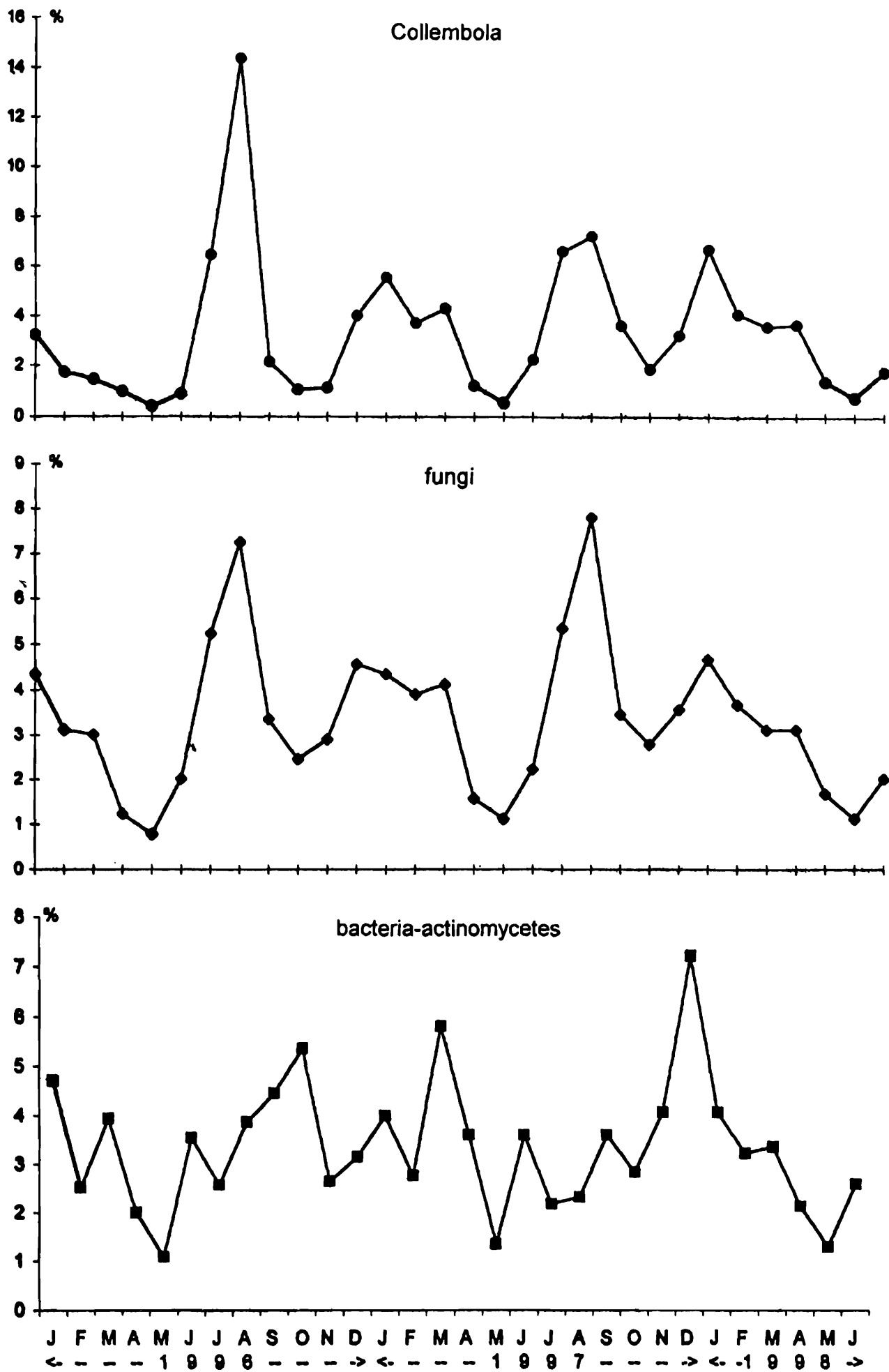


Fig. 1d : Monthly fluctuations of Collembola, fungi & Bactena-actinomycetes population in site I : BRF

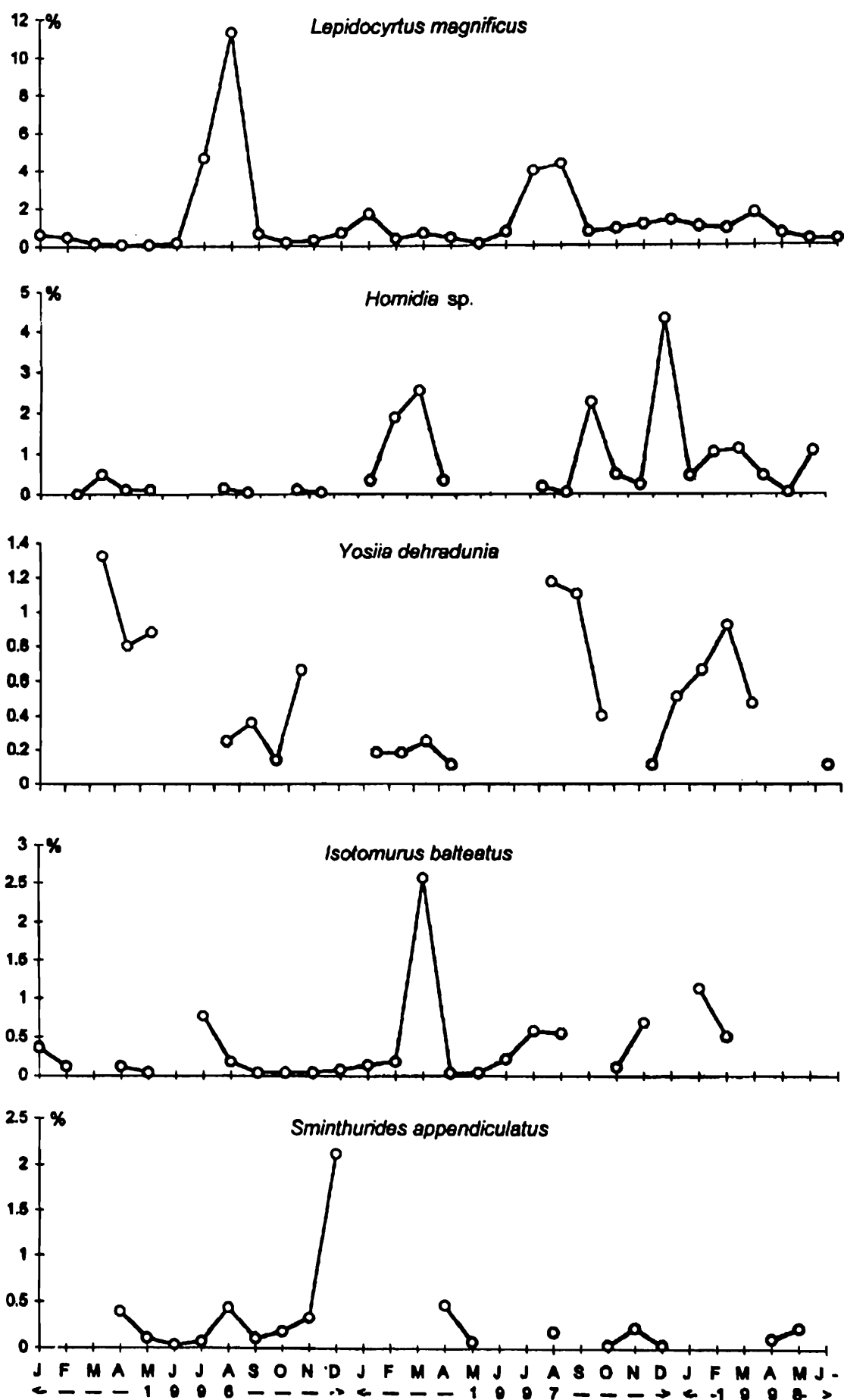


Fig. 1e : Monthly fluctuations of dominant species of Collembola in site I : BRF

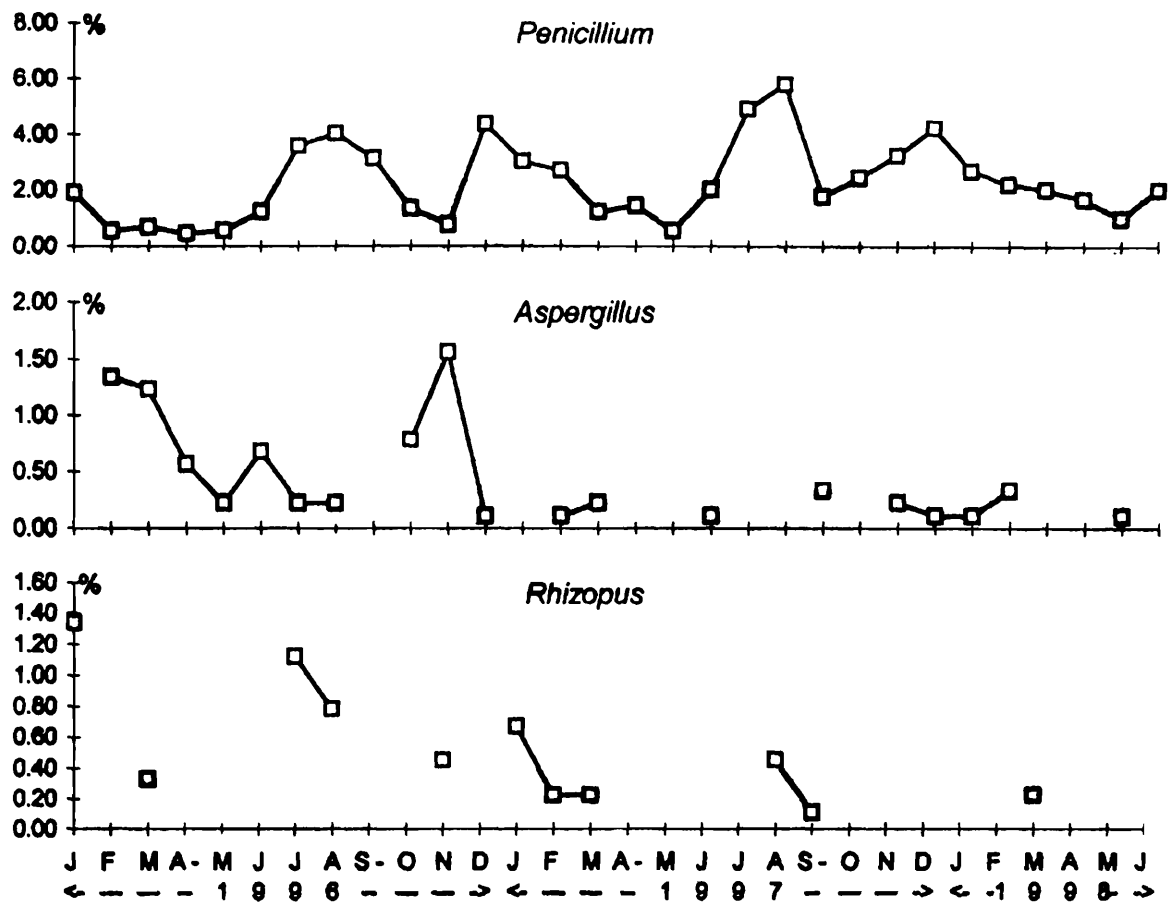


Fig. 1g : Monthly fluctuations of dominant fungal genera in site I BRF

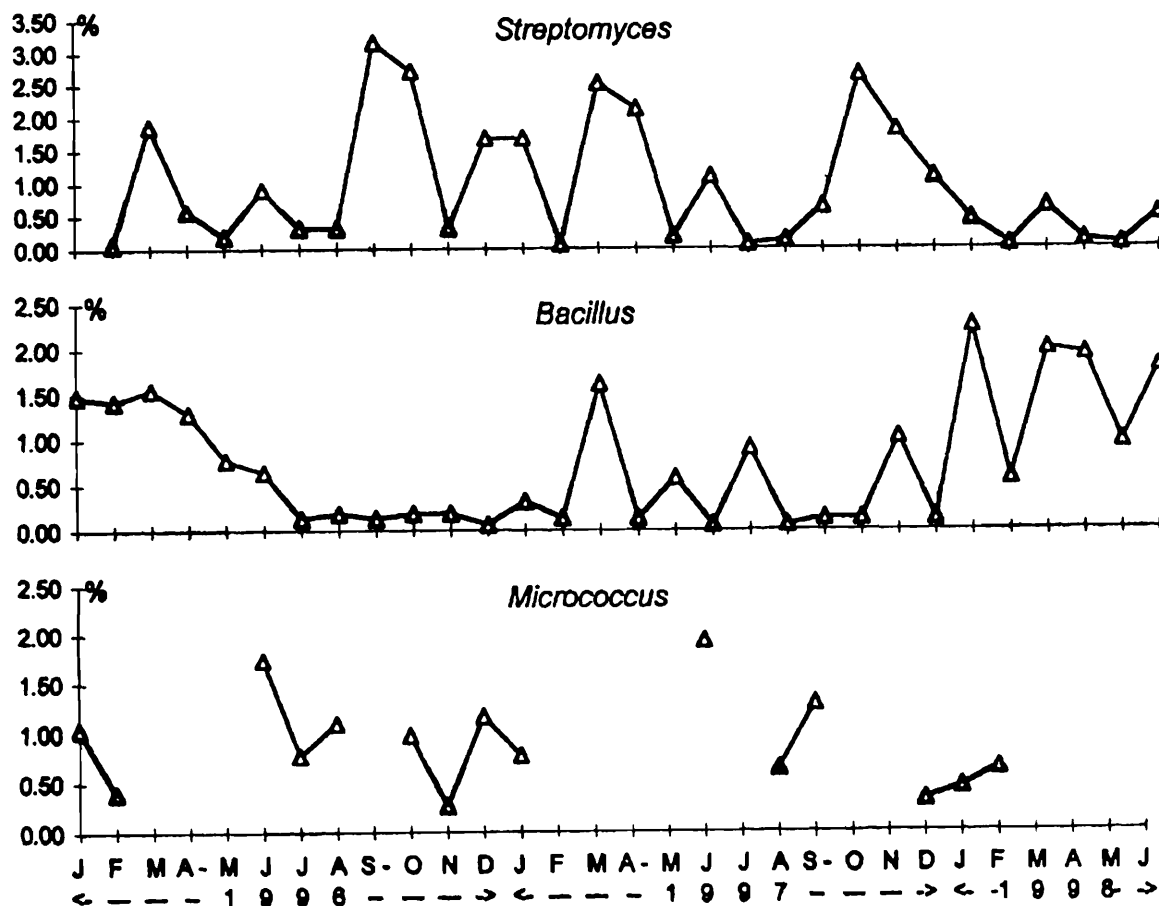


Fig. 1i : Monthly fluctuations of dominant Bacteria-actinomycetes genera in site I BRF

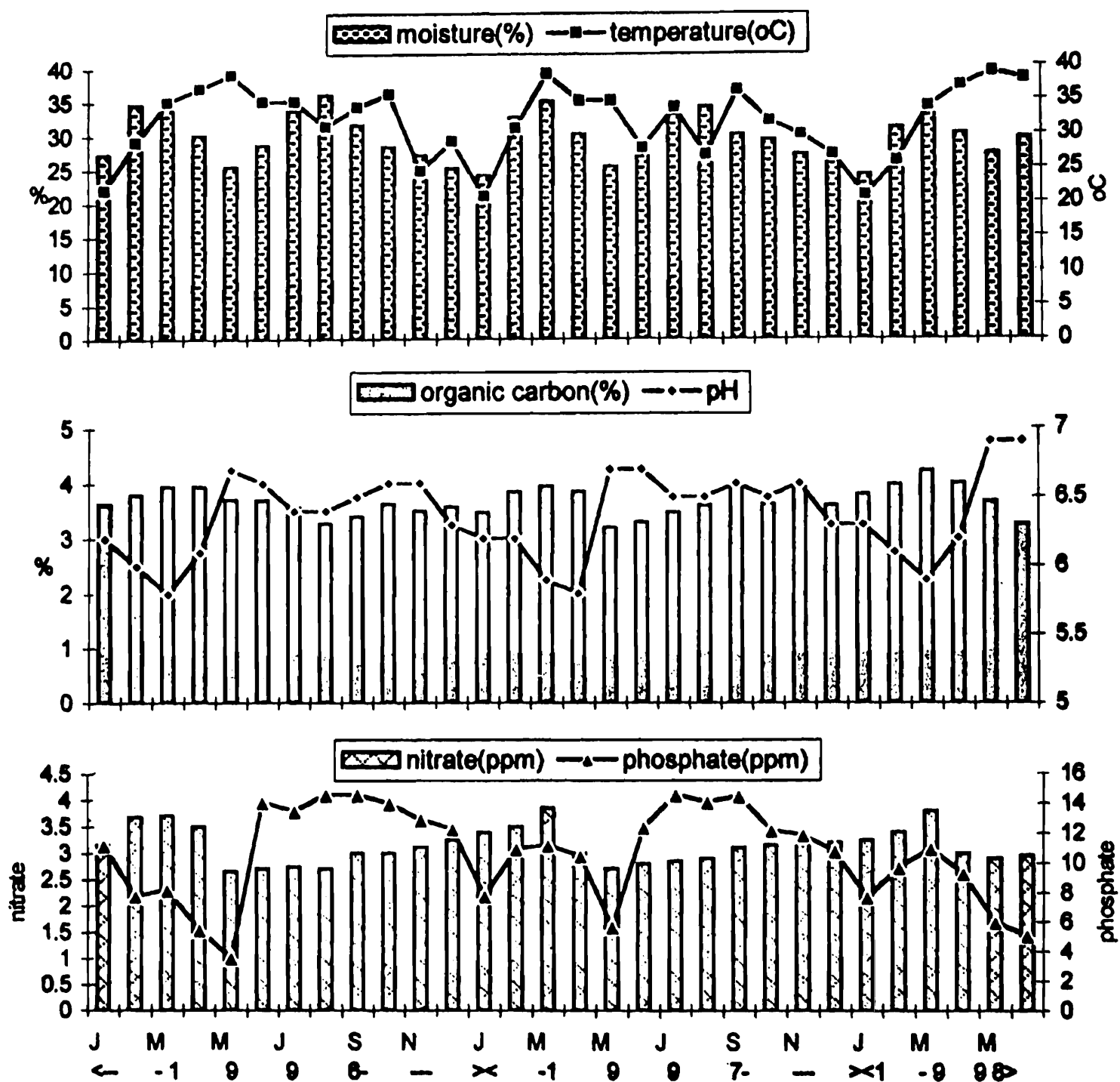


Fig. 2a : Monthly changes of edaphic factors at site II : DP

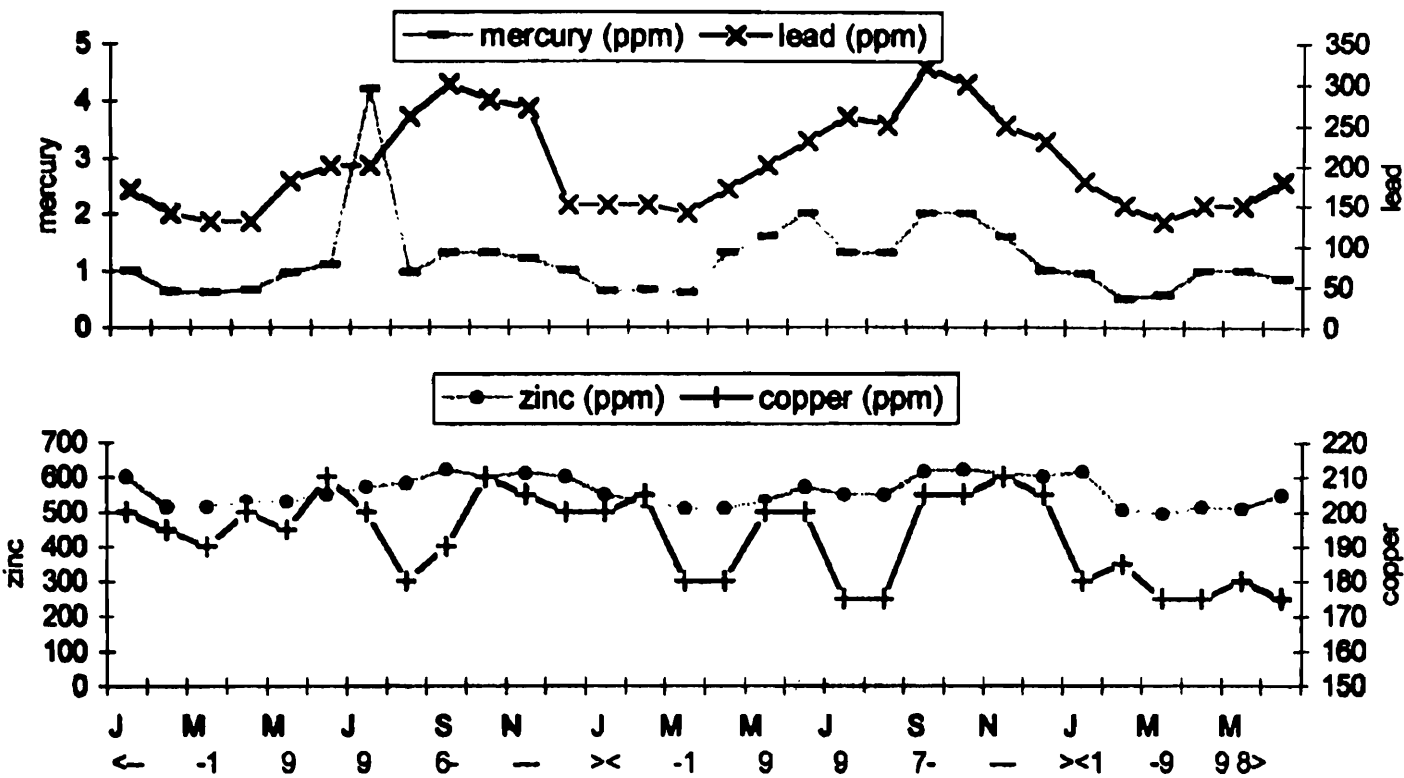


Fig. 2b : Monthly changes of heavy metal levels in soil at site II : DP

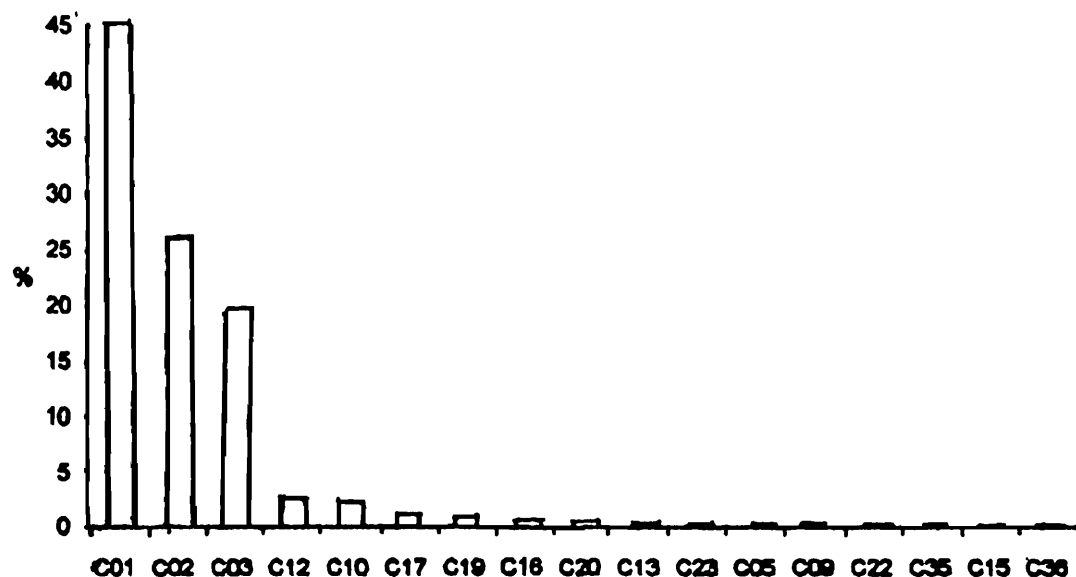


Fig. 2c : Composition of collembolan community in site II : DP

C01. *Lepidocyrtus cyaneus*; C02. *Xenylla obscura*; C03. *Cyphoderus javanus*; C12. *Seira indica*; C10. *Cryptopygus thermophilus*; C17. *Friesea yosii*; C19. *Proisotoma (c) fitchioides*; C16. *Lepidocyrtus exploratorius*; C20. *Ballistrura bengalensis*; C13. *Sminthurides appendiculatus*; C23. *Calx* sp.; C05. *Isotomurus balteatus*; C09. *Lepidocyrtus heterolepis*; C22. *Sphaeridia* sp.; C35. *Archerontiella* sp.; C15. *Isotomiella minor*; C36. *Willemia* sp.

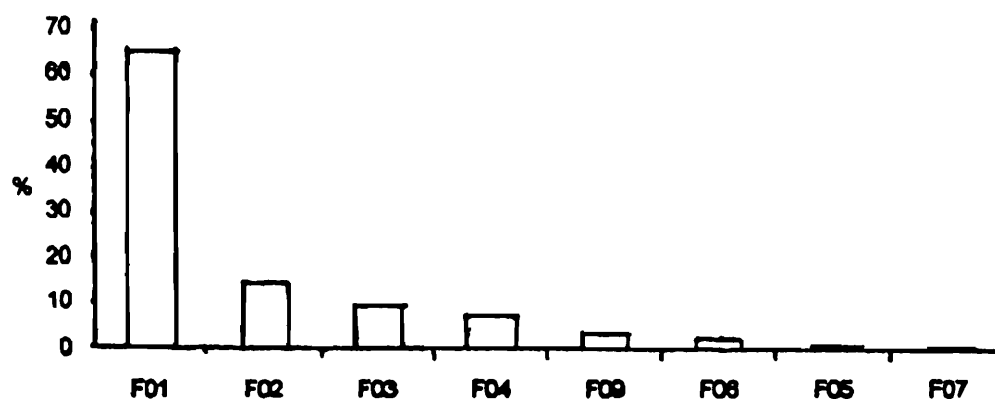


Fig. 2f : Composition of fungal community in site II : DP

F01. *Penicillium*; F02. *Aspergillus*; F03. *Fusarium*; F04. *Trichoderma*; F09. *Curvularia*; F06. *Mucor*; F05. *Rhizopus*; F07. *Sclerotium*.

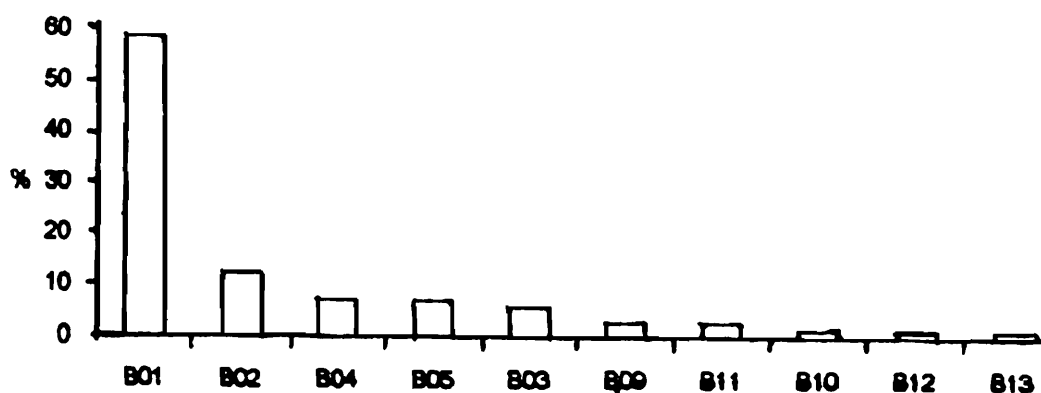


Fig. 2h : Composition of Bacteria-actinomycetes community in site II : DP

B01. *Bacillus*; B02. *Streptomyces*; B04. *Micrococcus*; B05. *Cytophaga*; B03. *Arthrobacter*; B09. *Promicromonospora*; B11. *Corynebacterium*; B10. *Pseudomonas*; B12. *Staphylococcus*; B13. *E. coli*.

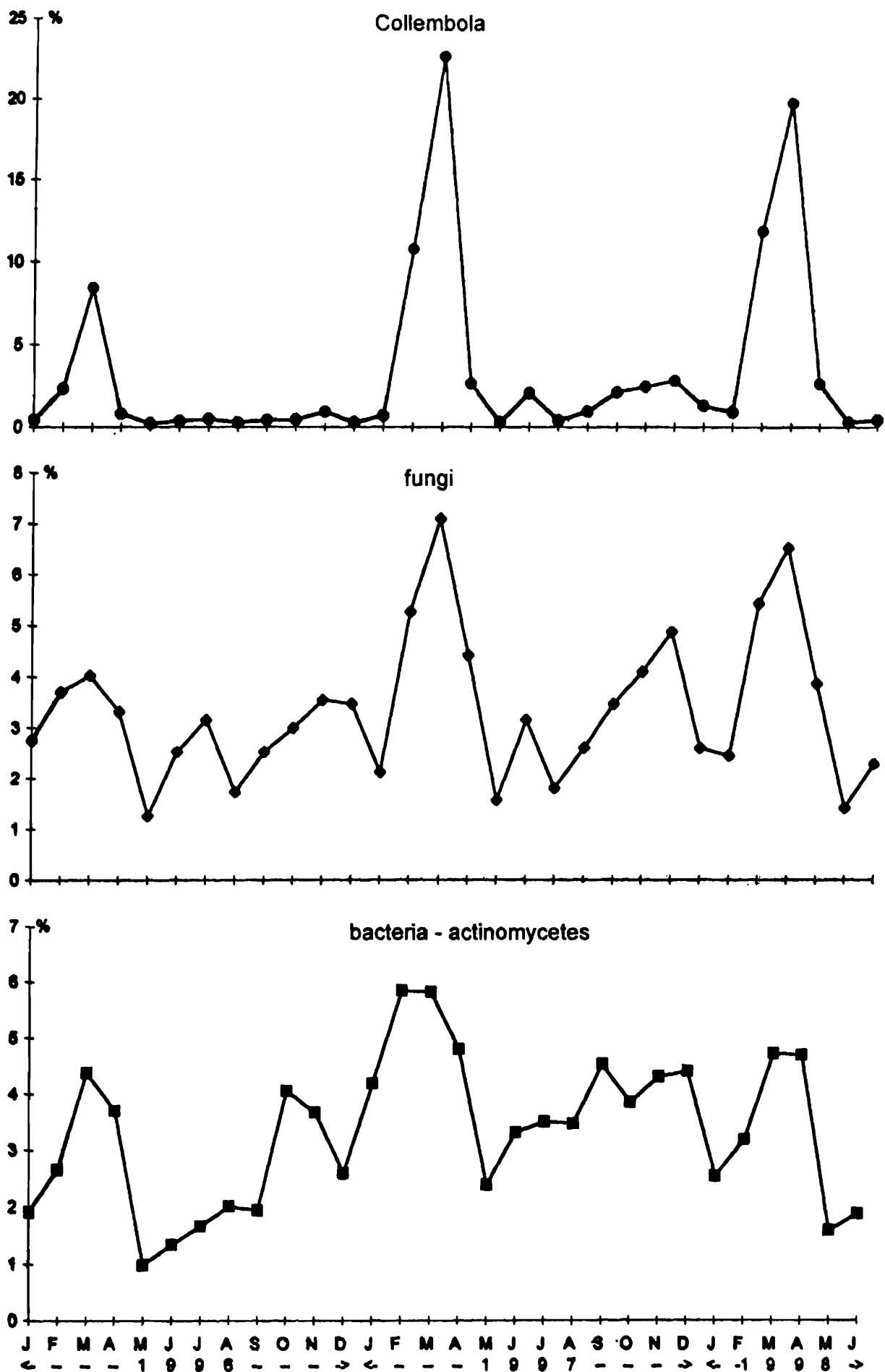


Fig. 2d : Monthly fluctuation of Collembola, Fungi & Bacteria-actinomycetes population in site II : DP

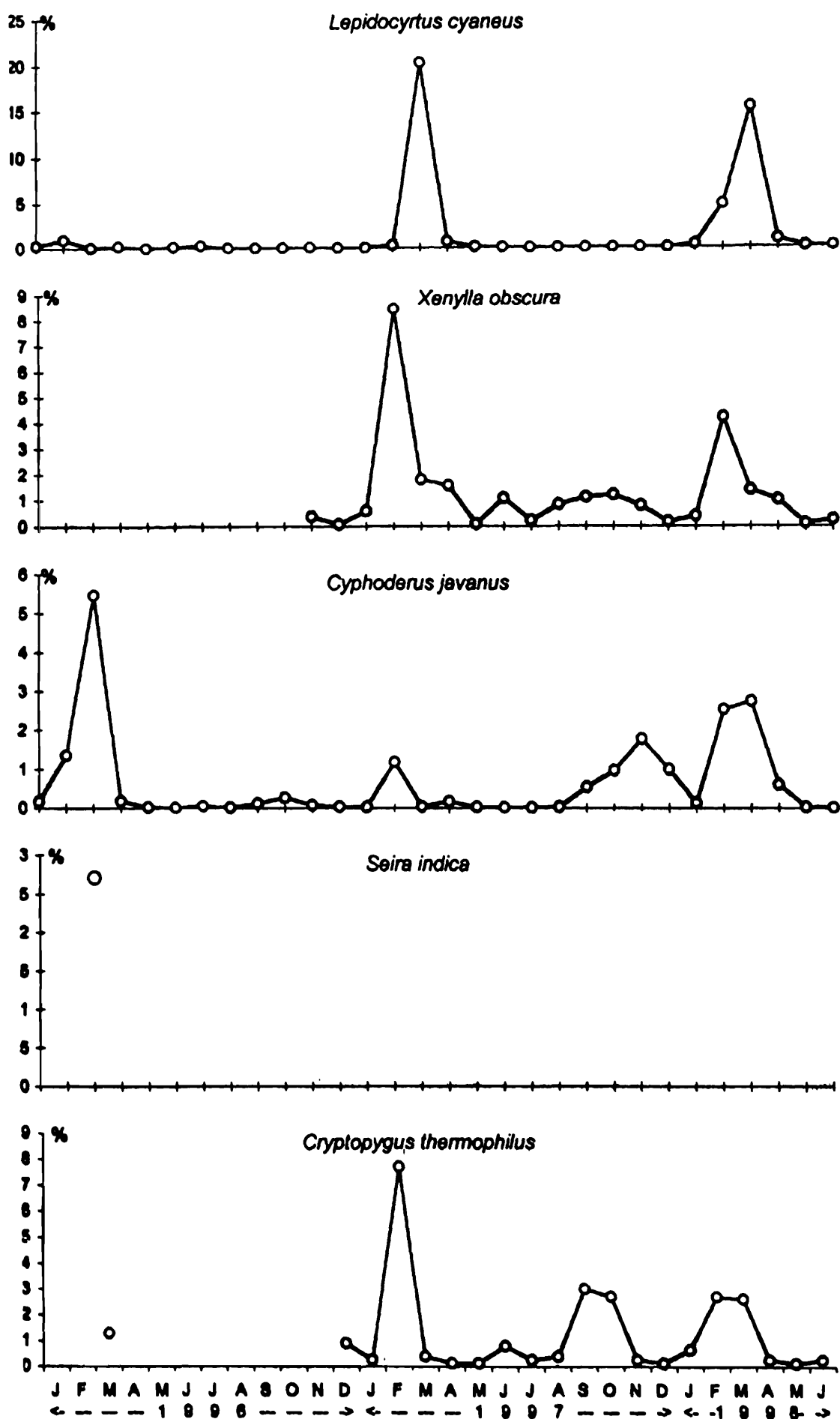


Fig. 2e : Monthly fluctuations of dominant species of Collembola in site II : DP

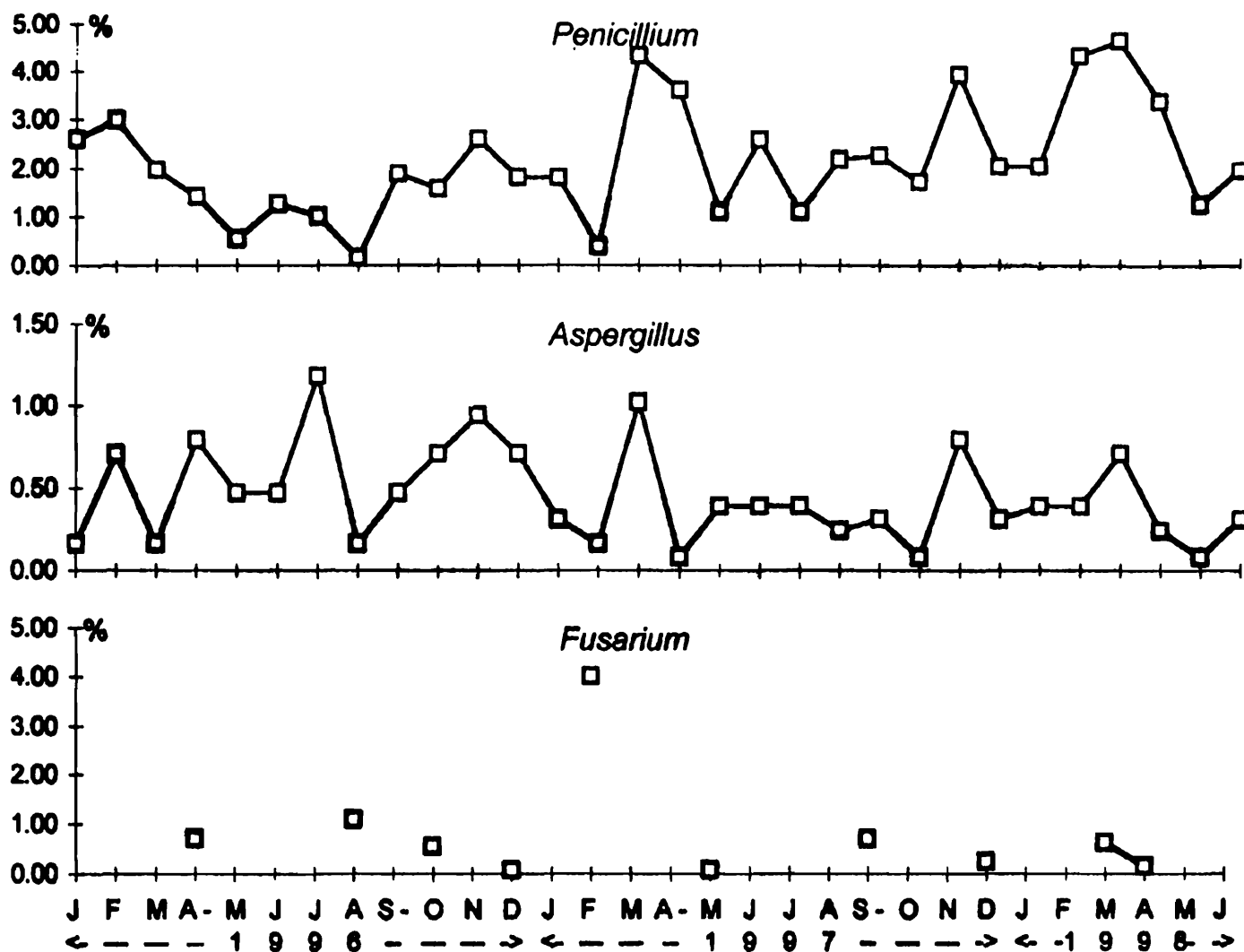


Fig. 2g : Monthly fluctuations of dominant fungal genera in site II : DP

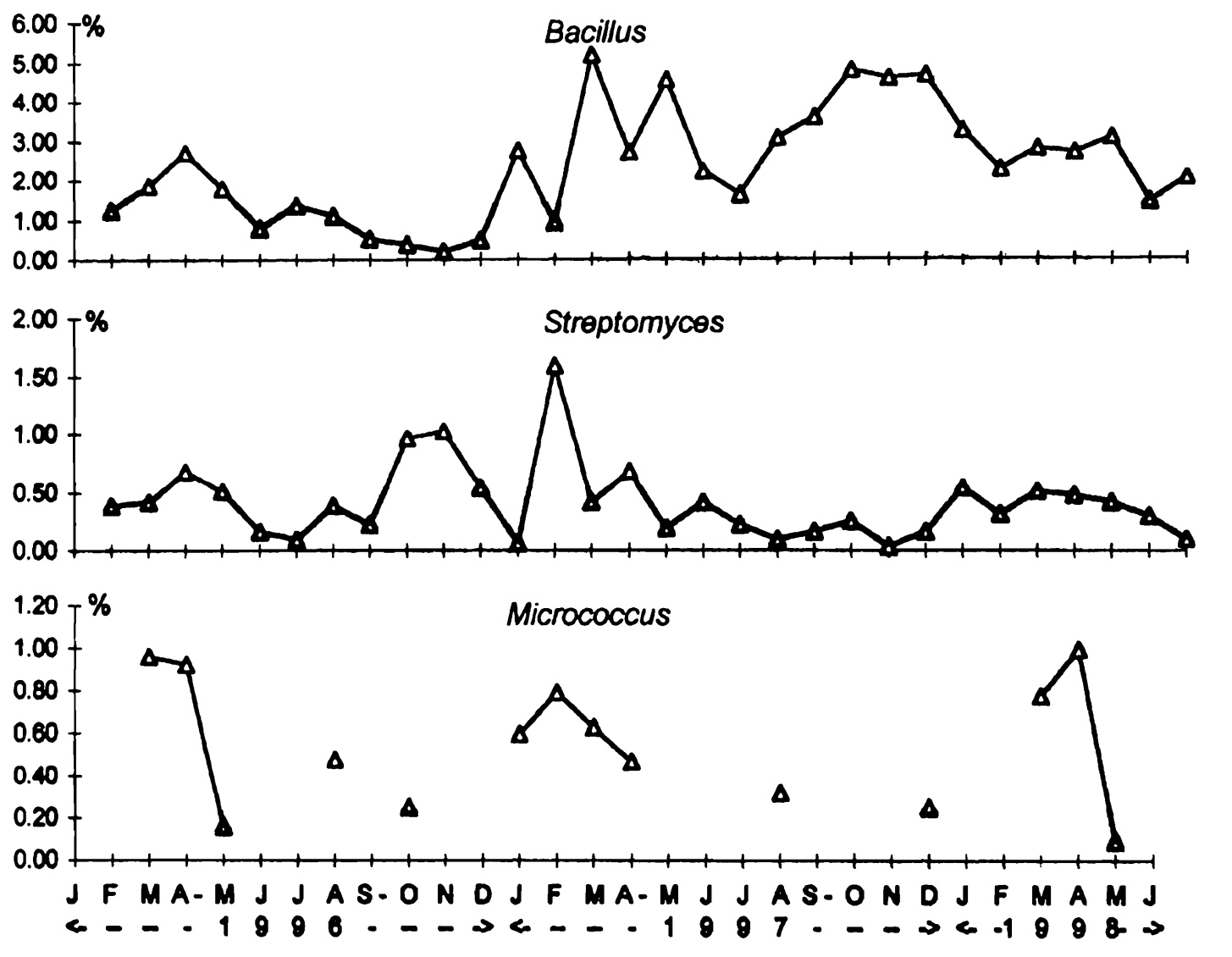


Fig. 2i : Monthly fluctuations of dominant Bacteria-actinomycetes genera in site II : DP

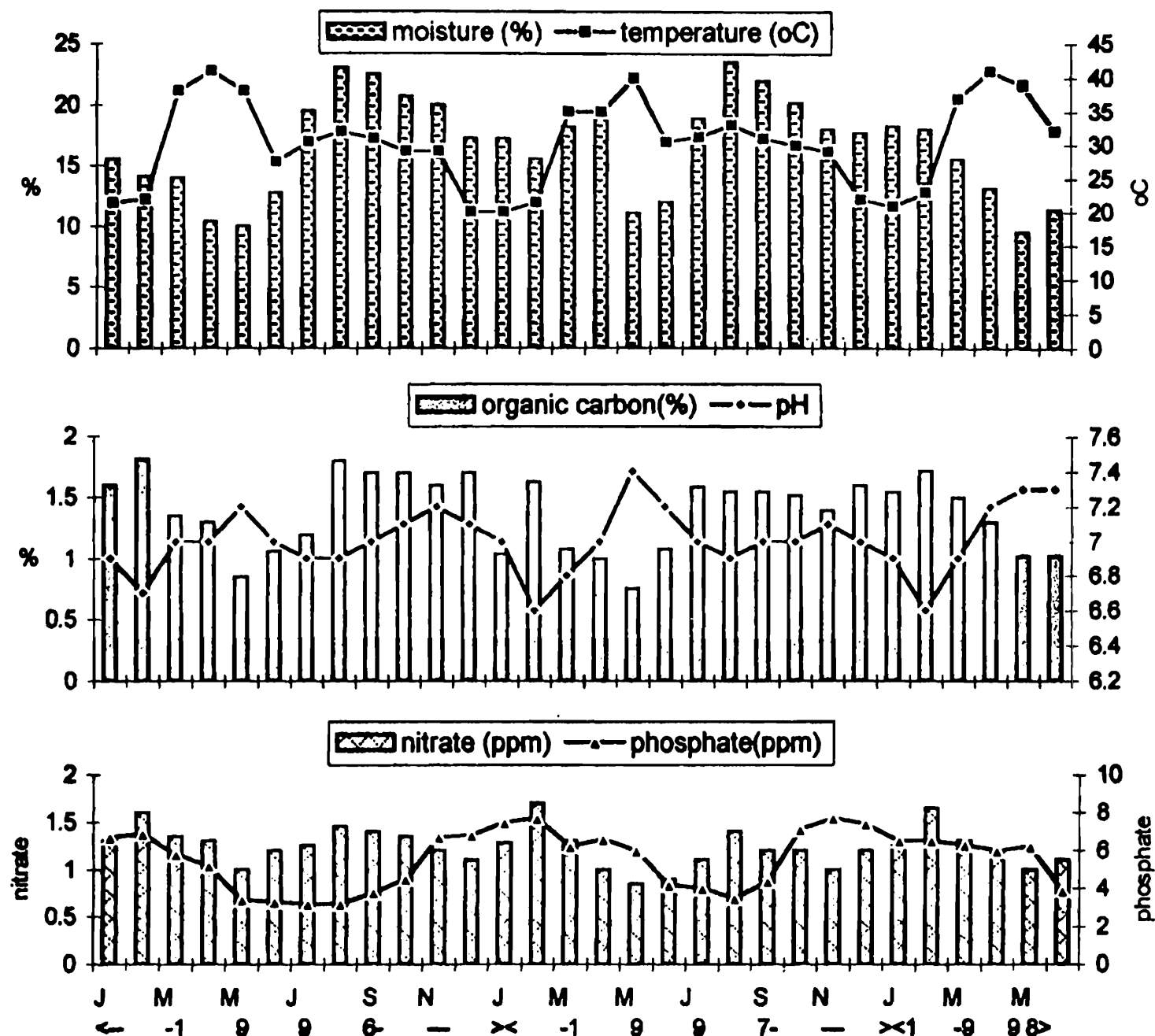


Fig. 3a : Monthly Changes of edaphic factors at site III SRS

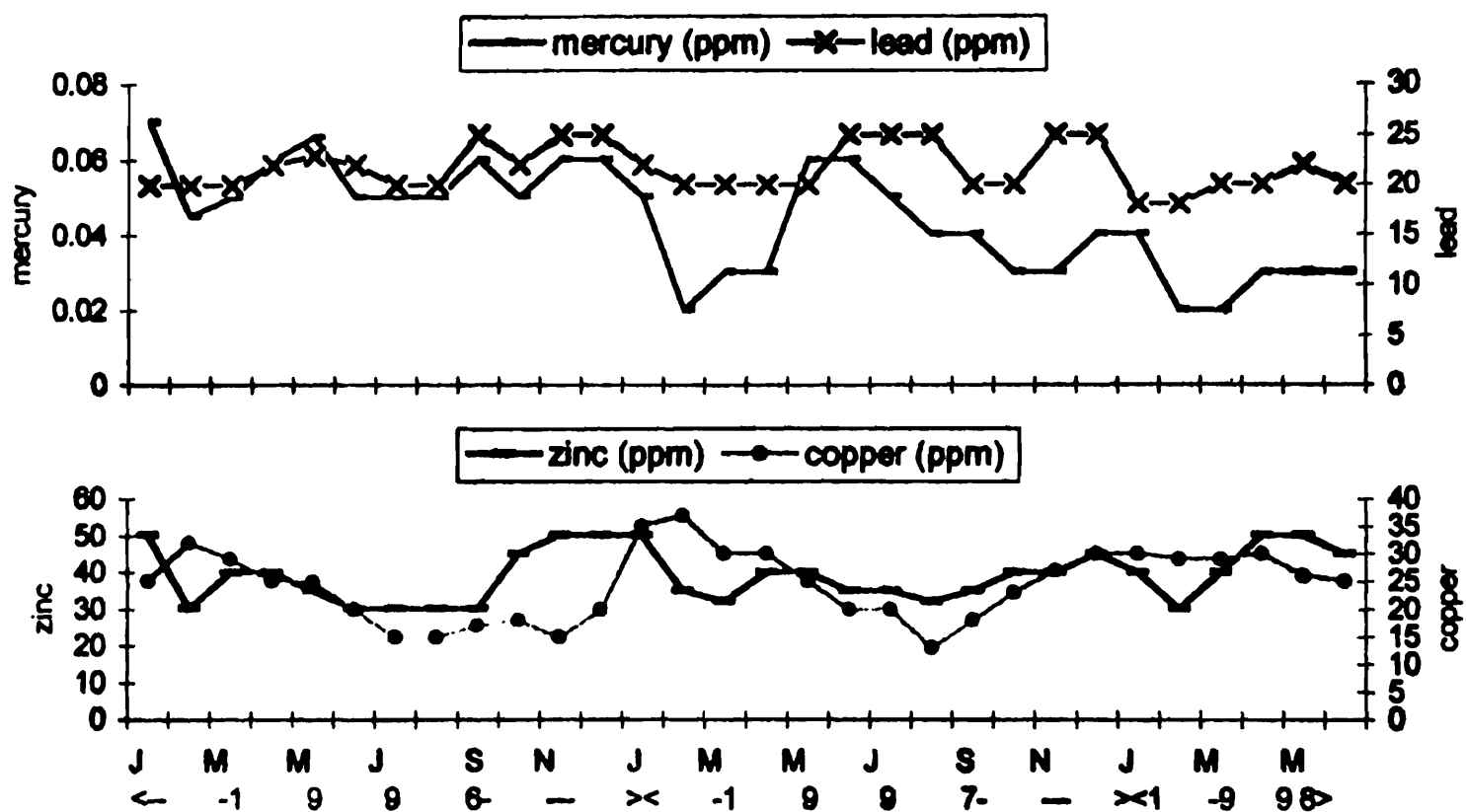


Fig. 3b : Monthly Changes of heavy metal levels in soil at site III : SRS

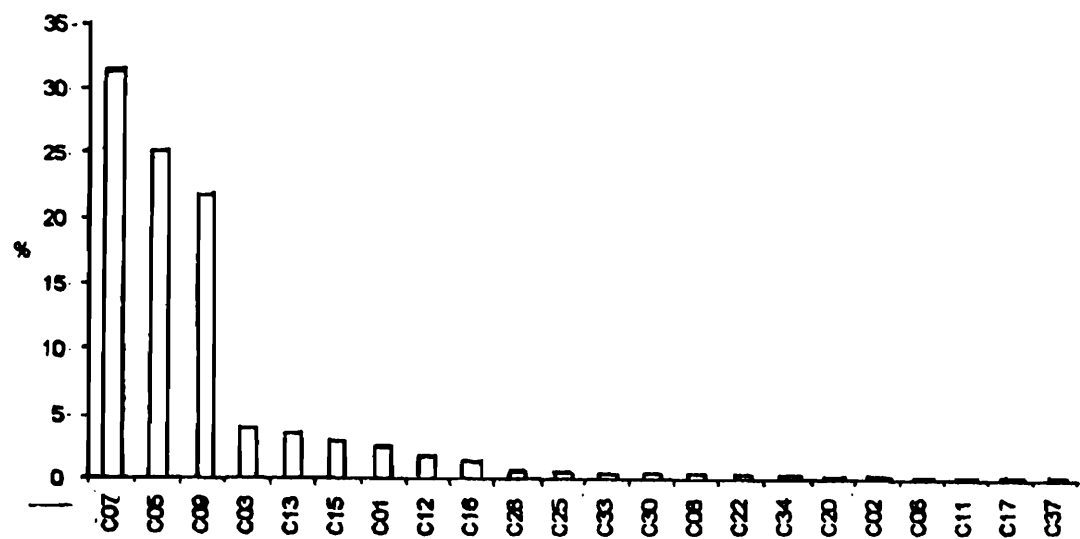


Fig. 3c : Composition of collembolan community in site III : SRS
C07. *Salina indica*; C05. *Isotomurus balteatus*; C09. *Lepidocyrtus heteolepis*; C03. *Cphoderus javanus*; C13. *Sminthurides appendiculatus*; C01. *Lepdocyrtus cyaneus*; C12. *Seira indica*; C16. *Lepidocyrtus exploratorius*; C28. *Entomobrya* sp.; C25. *Bourietiella* sp.; C33. *Heteromuricus cercifer*; C30. *Dicyrtomina* sp.; C08. *Lepidocyrtus suborientalis*; C20. *Ballistrura bengalensis*; C02. *Xynella obscura*; C06. *Homidia* sp.; C11. *Yosia dehradunia*; C17. *Friesea yosii*; C37. *Dicranocentroides* sp.

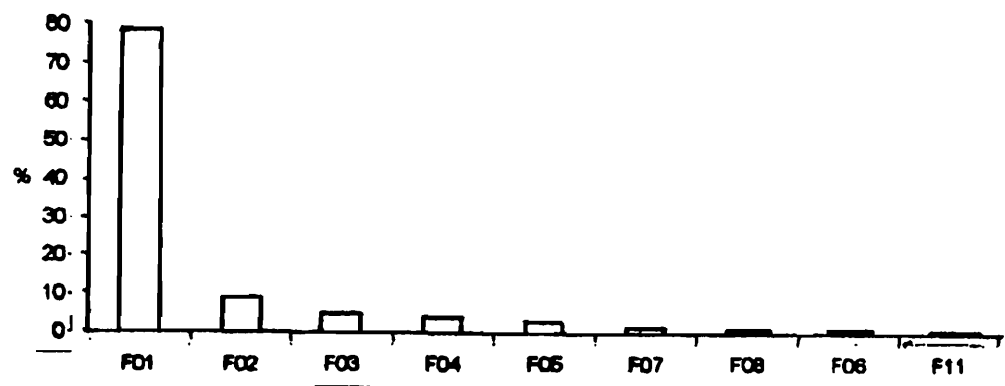


Fig. 3 f : Composition of fungal community in site III : SRS
F01. *Penicillium*; F02. *Aspergillus*; F03. *Fusarium*; F04. *Trichoderma*; F05. *Rhizopus*; F06. *Mucor*; F07. *Sclerotium*; F08. *Cephalosporium*; F09. *Curuvlaria*; F10. *Cladosporium*; F11. *Nigrosporium*.

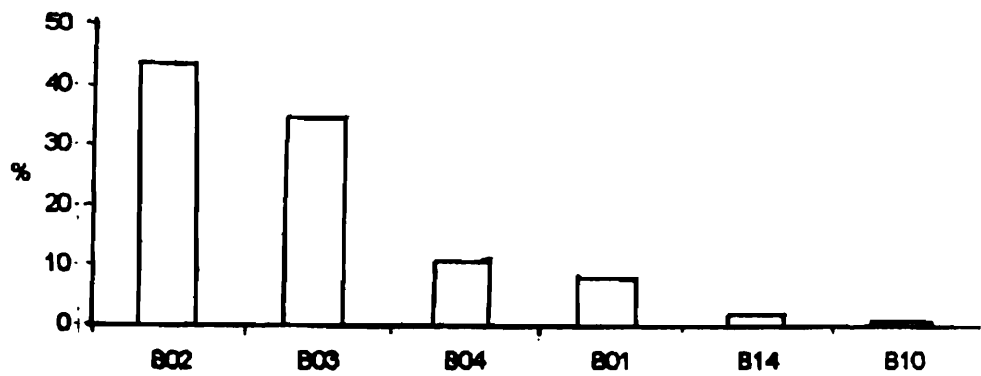


Fig. 3h : Composition of bacteria-actinomycetes community in site III : SRS
B02. *Streptomyces*; B03. *Arthrobactor*; B04. *Micrococcus*; B01 *Bacillus*; B14. *Xanthomonas*; B10. *Pseudomonas*.

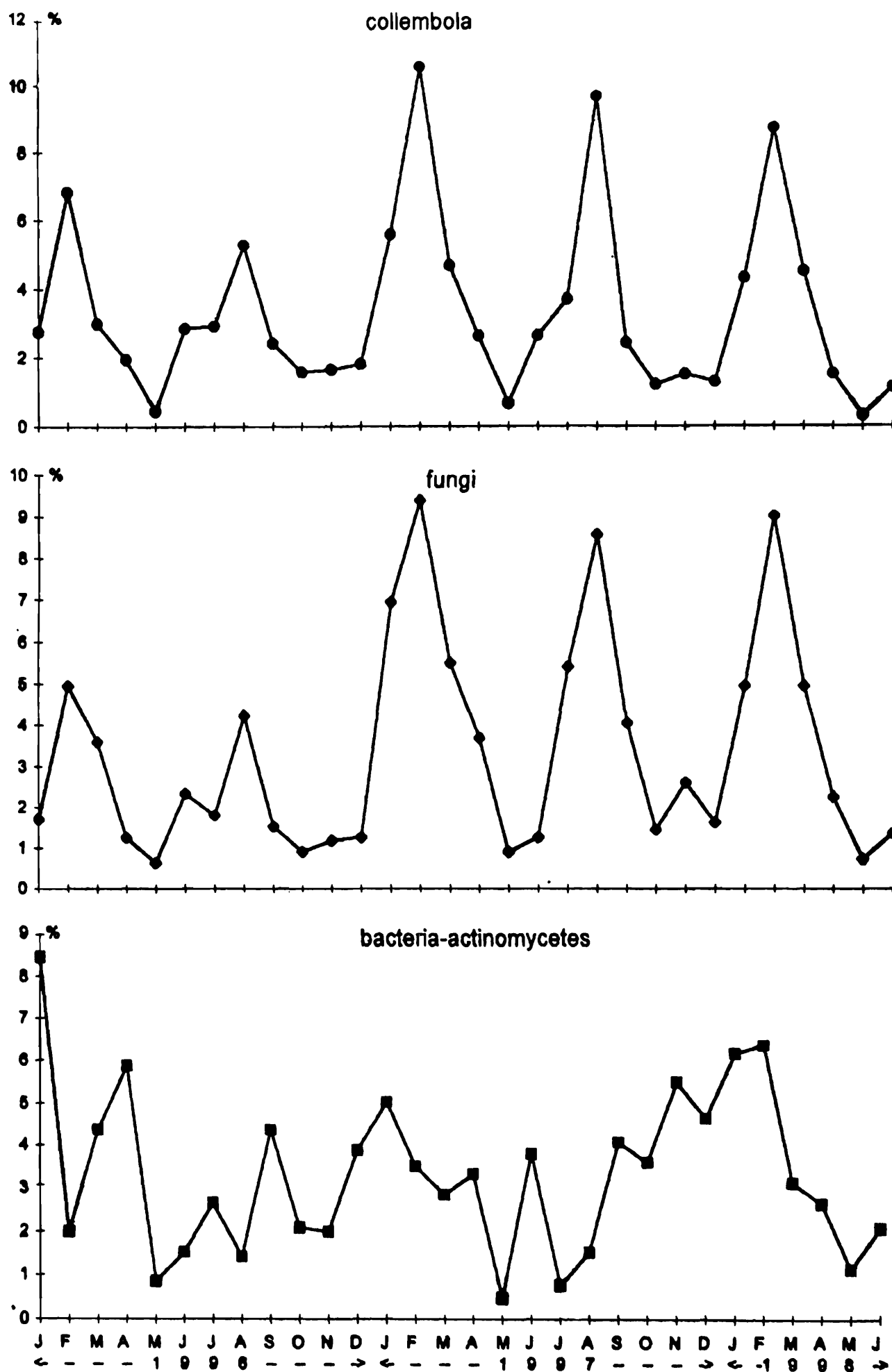


Fig. 3d : Monthly fluctuation of Collembola, Fungi and Bacteria-actinomycetes population in site III : SRS

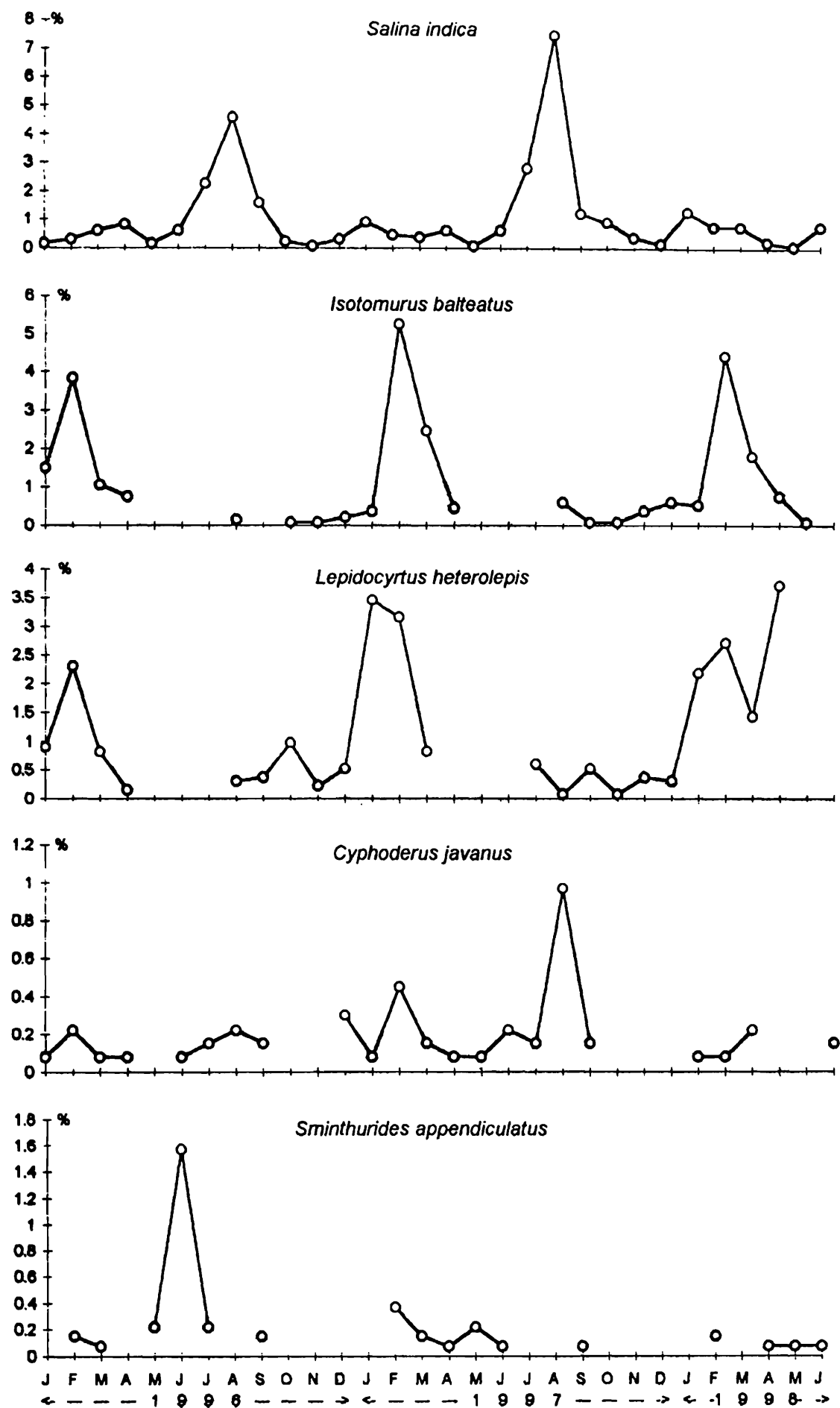


Fig. 3e : Monthly fluctuations of dominant species of Collembola in site III : SRS

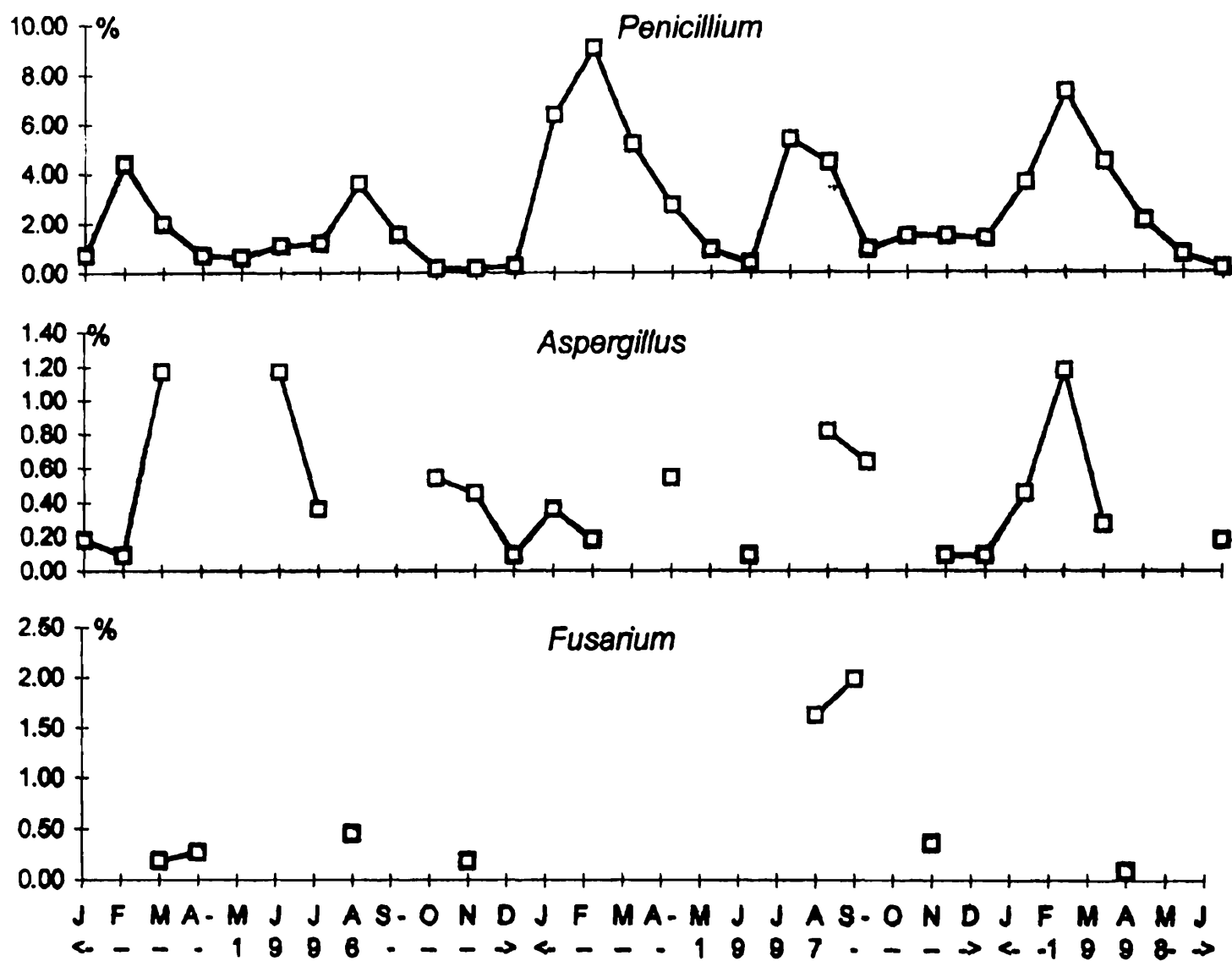


Fig. 3g : Monthly fluctuations of dominant fungal genera in site III : SRS

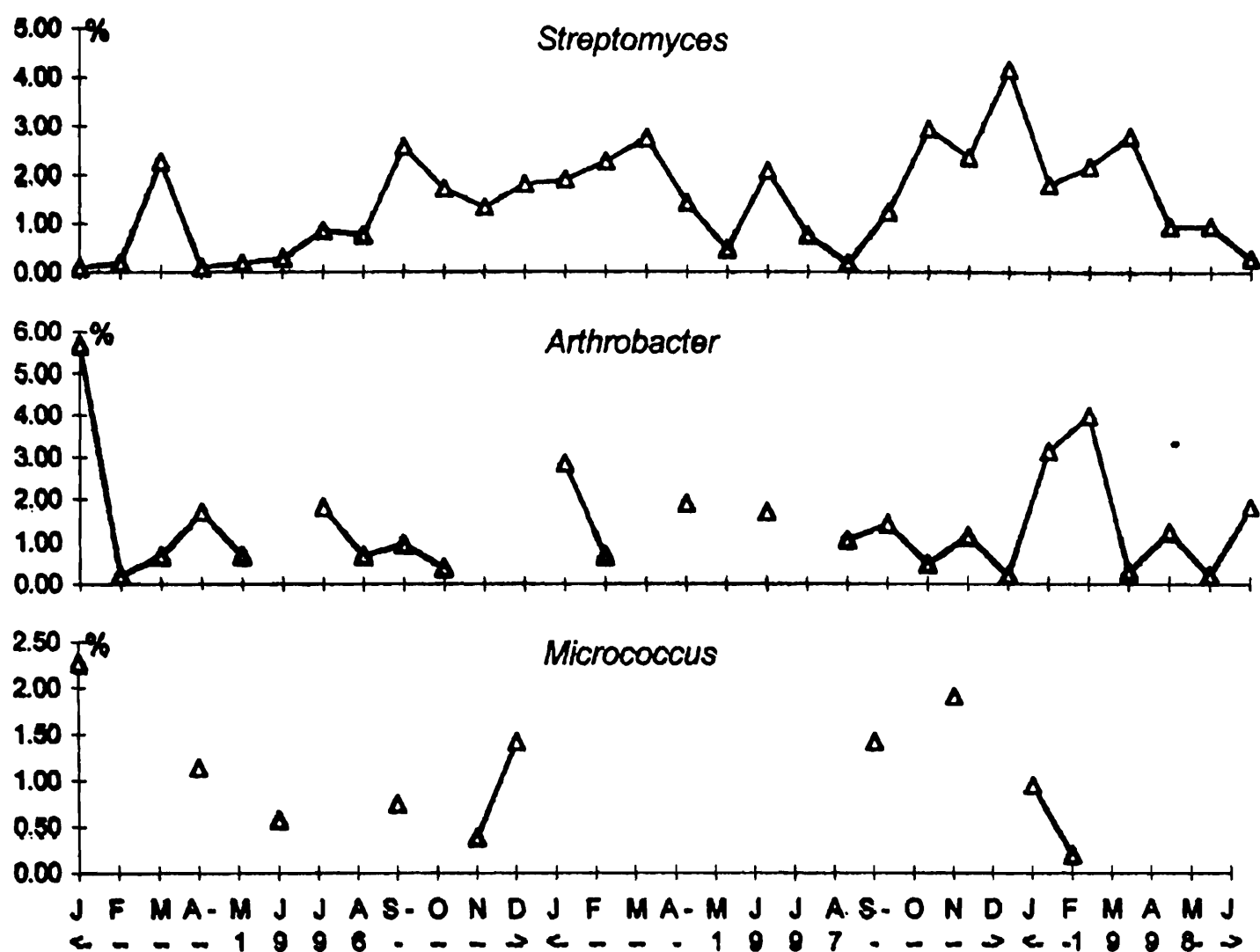


Fig. 3i : Monthly fluctuatiions of dominant bacteria-actinomycetes genera in site III : SRS

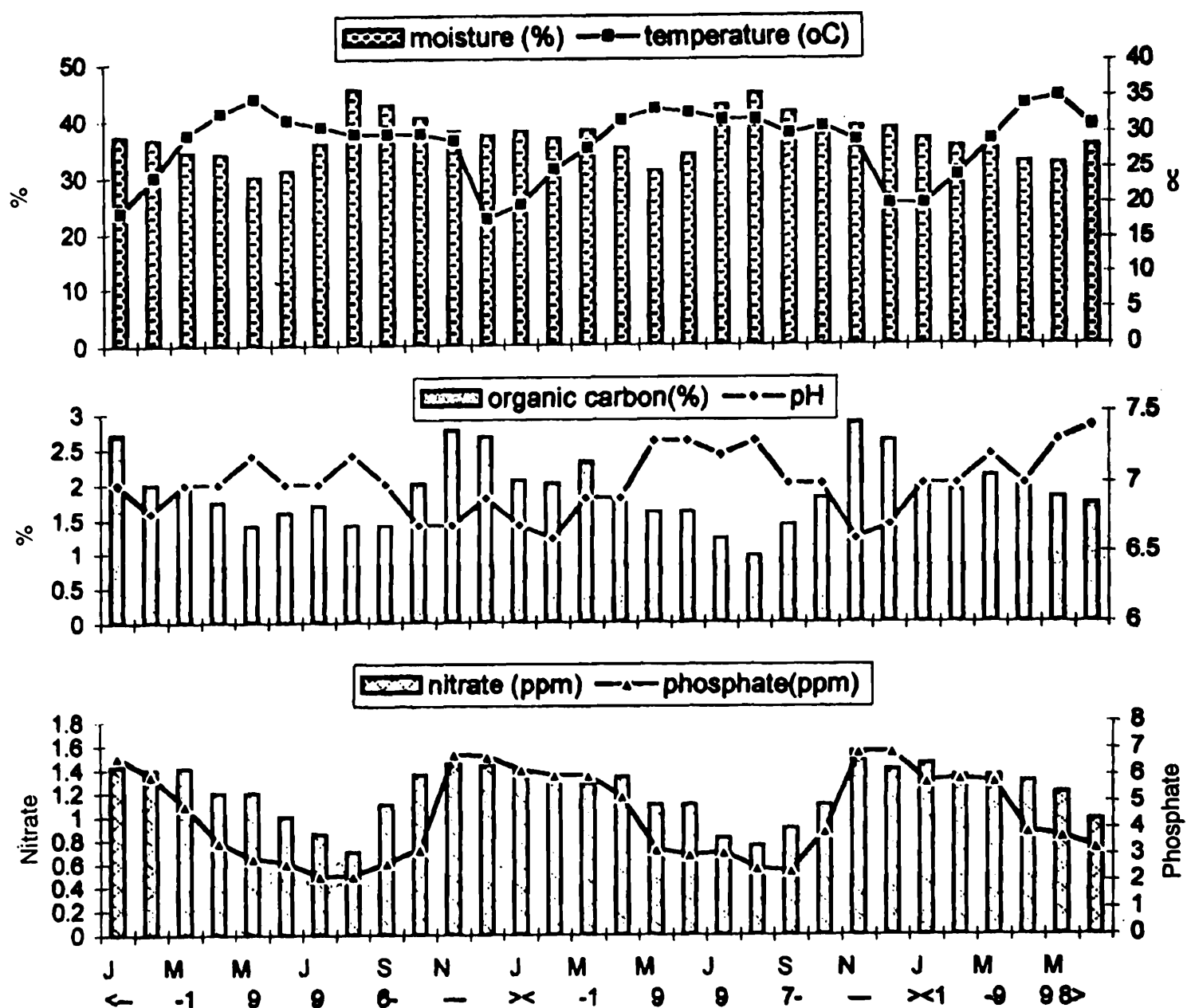


Fig. 4a : Monthly changes of edaphic factors at site IV : RRS

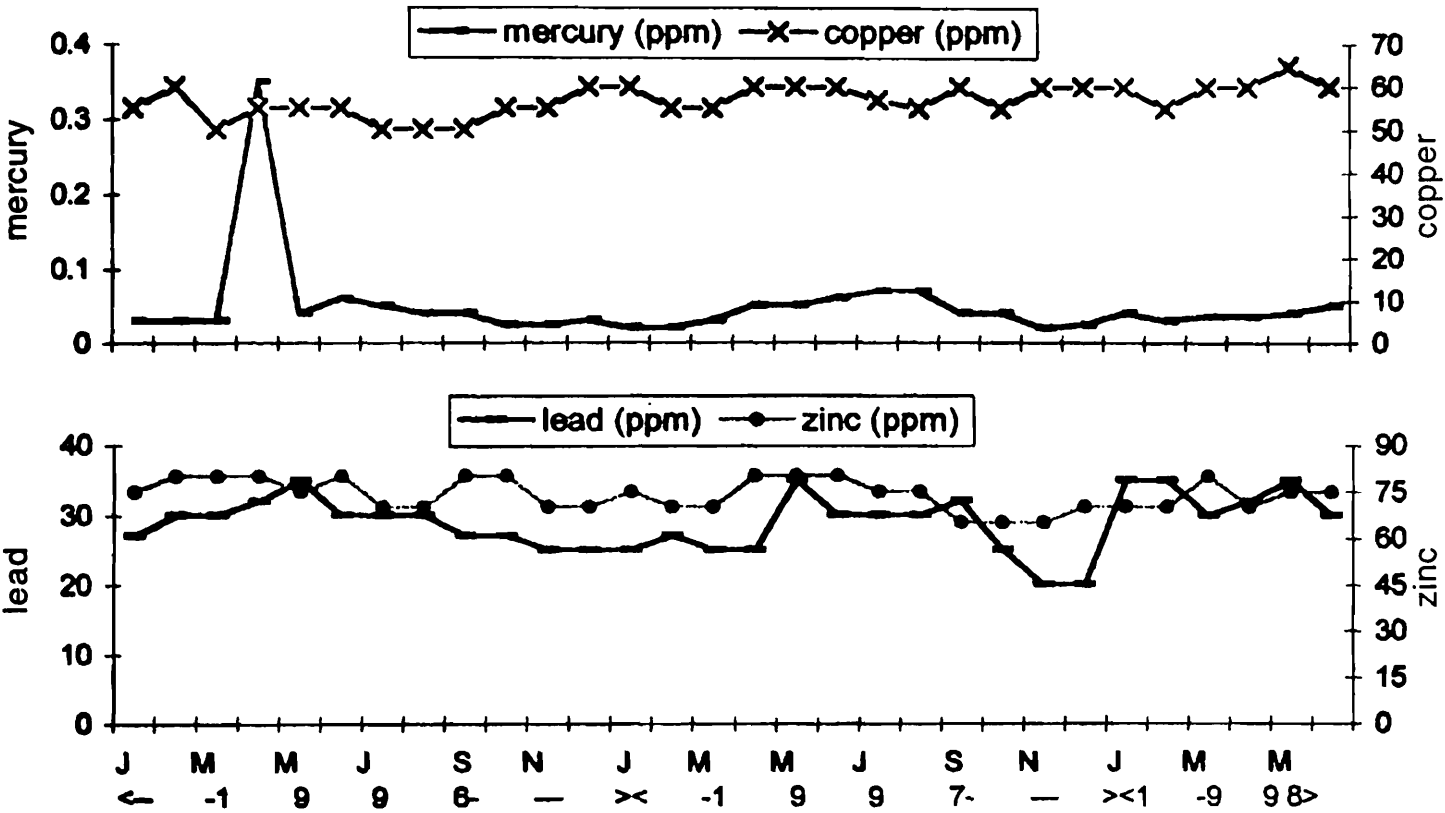


Fig. 4b : Monthly changes of heavy metal levels in soil at site IV RRS

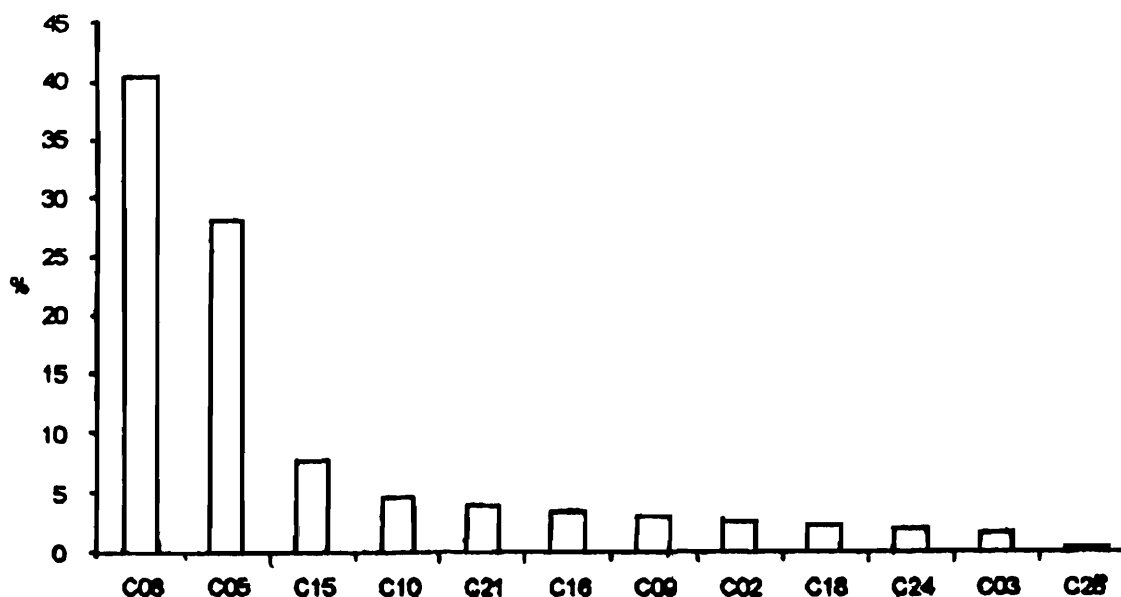


Fig. 4c : Composition of collembolan community in site IV : RRS

C08. *Lepidocyrtus suborientalis*; C05. *Isotomurus balteatus*; C15. *Isotomiella minor*; C10. *Cryptopygus thermophilus*; C21. *Sminthurides cf. aquaticus*; C16. *Lepidocyrtus exploratorius*; C09. *Lepidocyrtus heterolepis*; C02. *Xenylla obscura*; C18. *Lepidocyrtus* sp.; C24. *Sminthurides purvulus*; C03. *Cyphoderus javanus*; C28. *Entomobrya* sp.

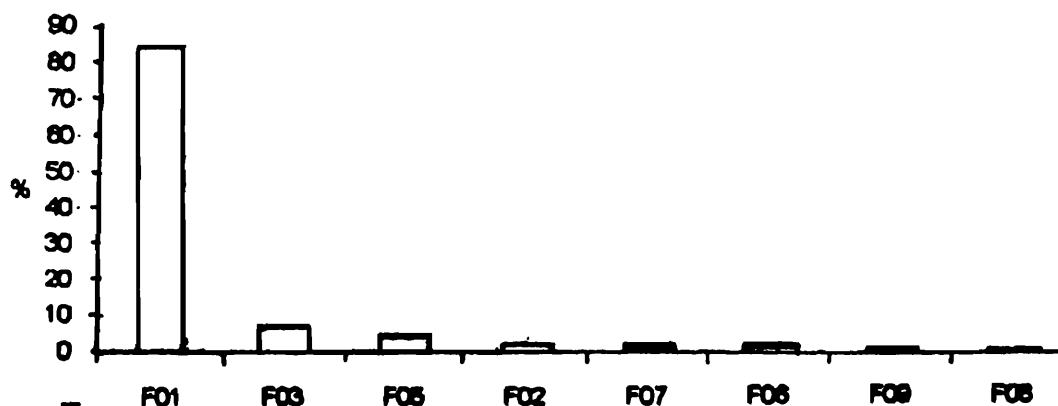


Fig. 4f : Composition of fungal community in site IV : RRS

F01. *Penicillium*; F03. *Fusarium*; F05. *Rhizopus*; F02. *Aspergillus*; F07. *Sclerotium*; F06. *Mucor*; F09. *Curvularia*; F08. *Cephalosporium*.

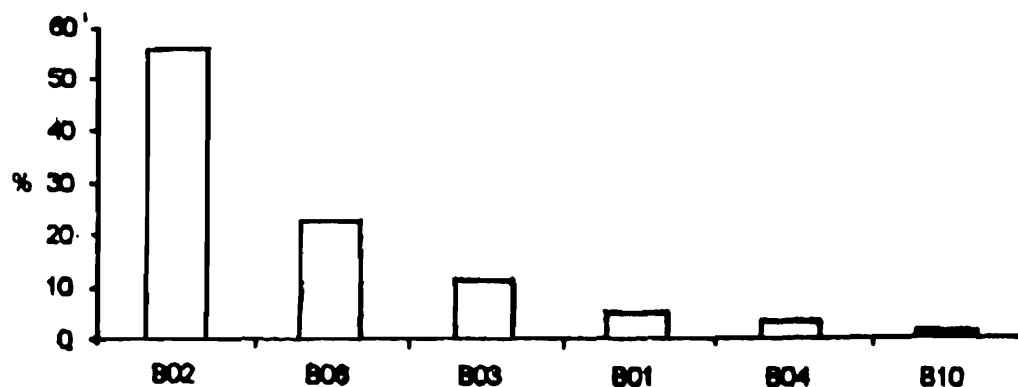


Fig. 4h : Composition of bacteria-actinomycetes community in site IV : RRS

B02. *Streptomyces*; B06. *Nocardia*; B03. *Arthrobacter*; B01. *Bacillus*; B04. *Micrococcus*; B10. *Pseudomonas*.

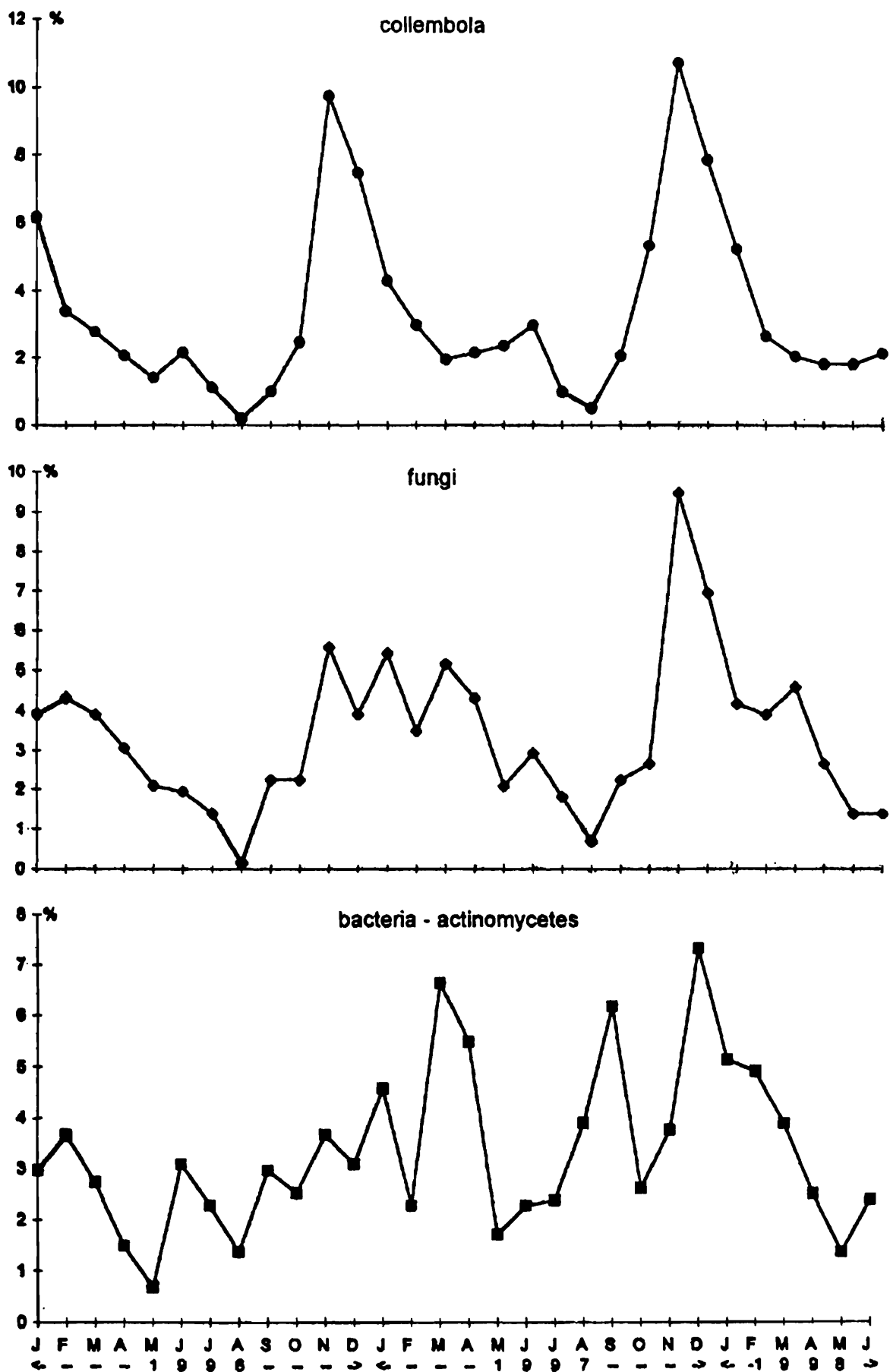


Fig. 4d : Monthly fluctuation of Collembola, Fungi and Bacteria-actinomycetes population in site IV : RRS

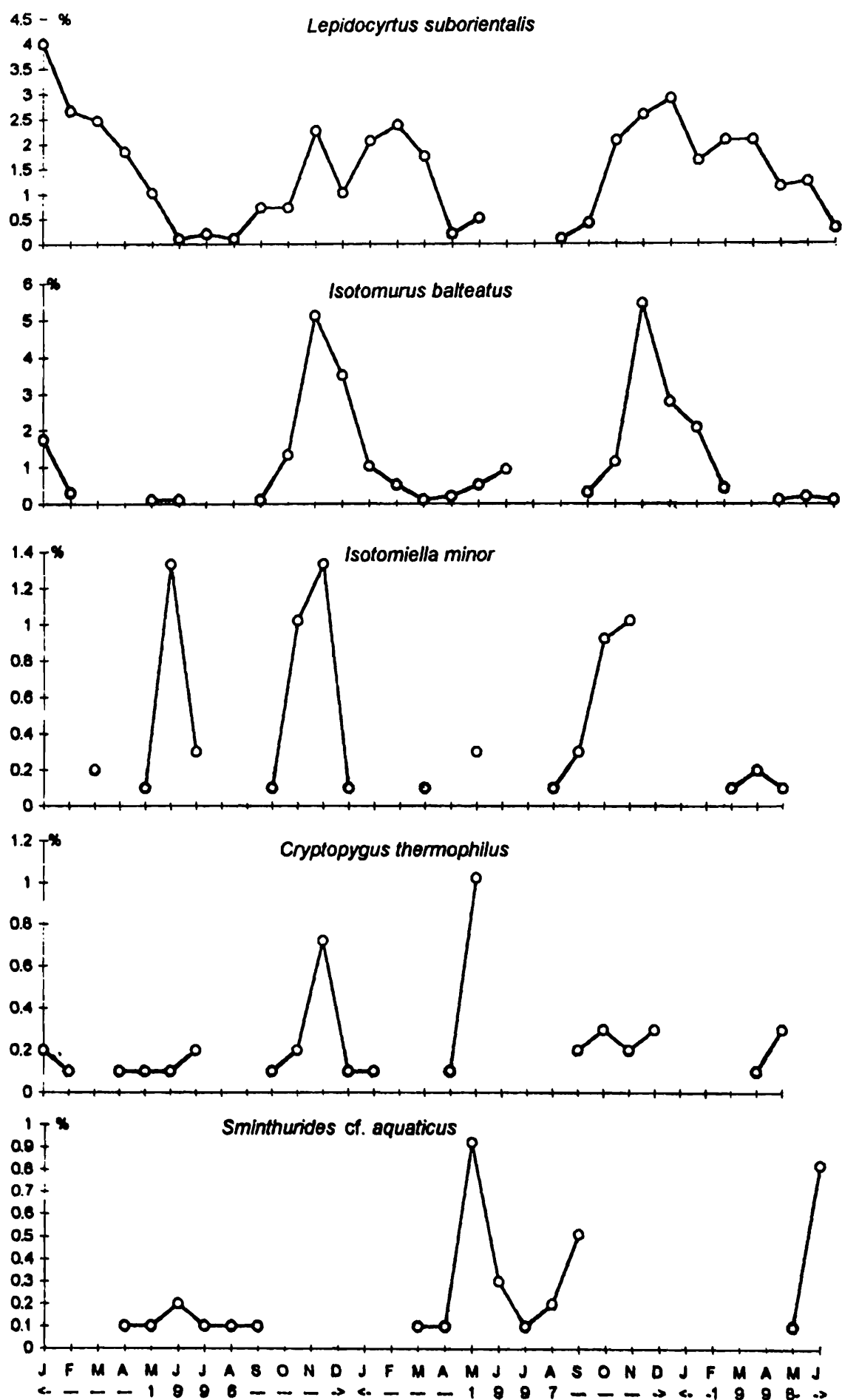


Fig. 4e : Monthly fluctuations of dominant species of Collembola in site IV : RRS

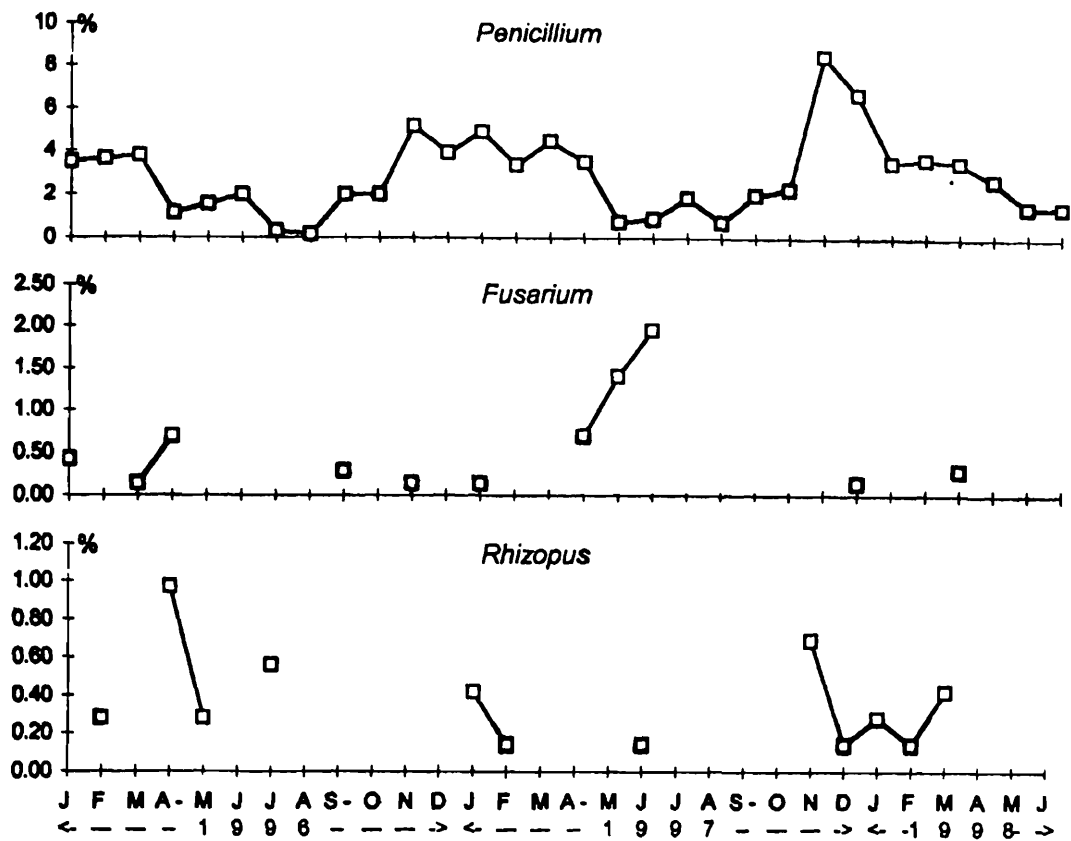


Fig. 4g : Monthly fluctuations of dominant fungal genera in site IV : RRS

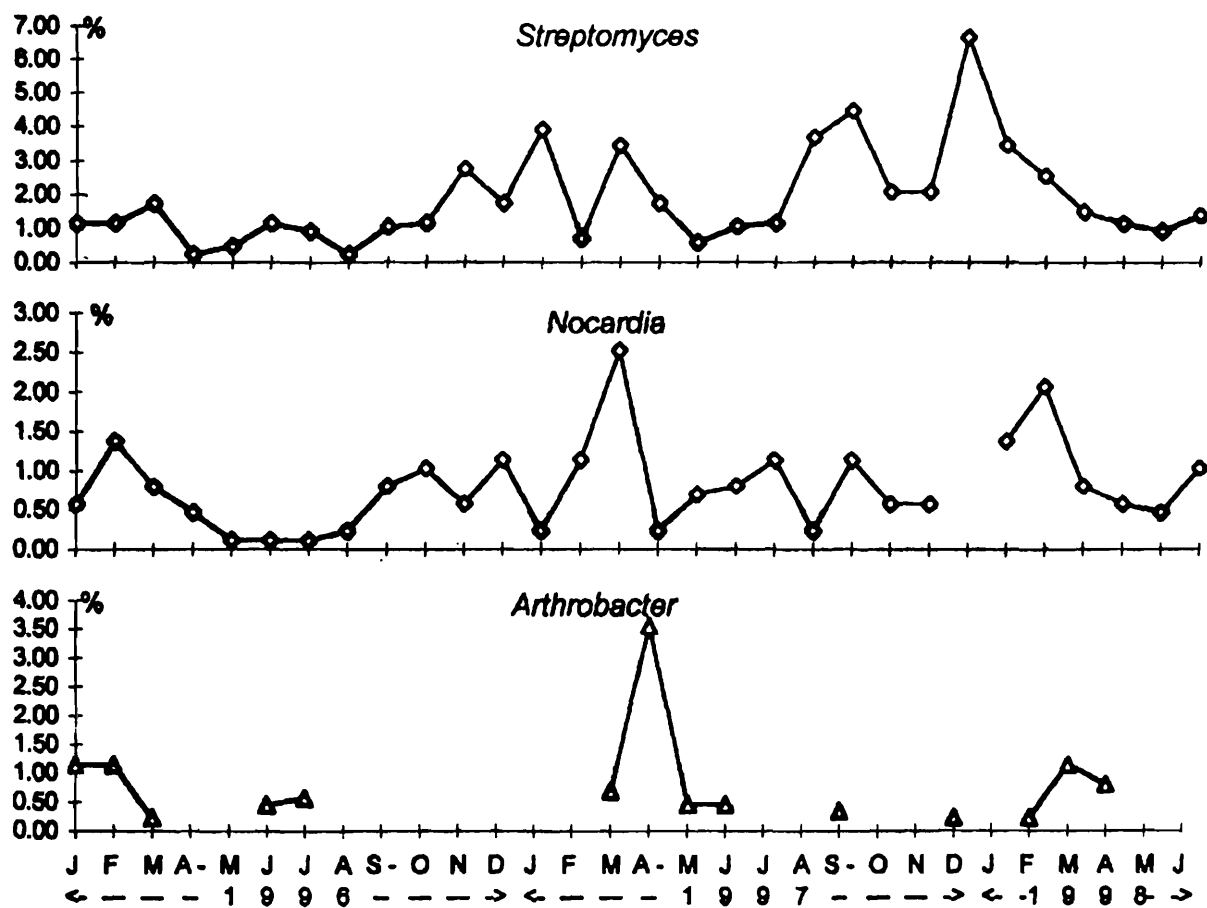


Fig. 4i : Monthly fluctuations of dominant Bacteria-actinomycetes genera in site IV RRS

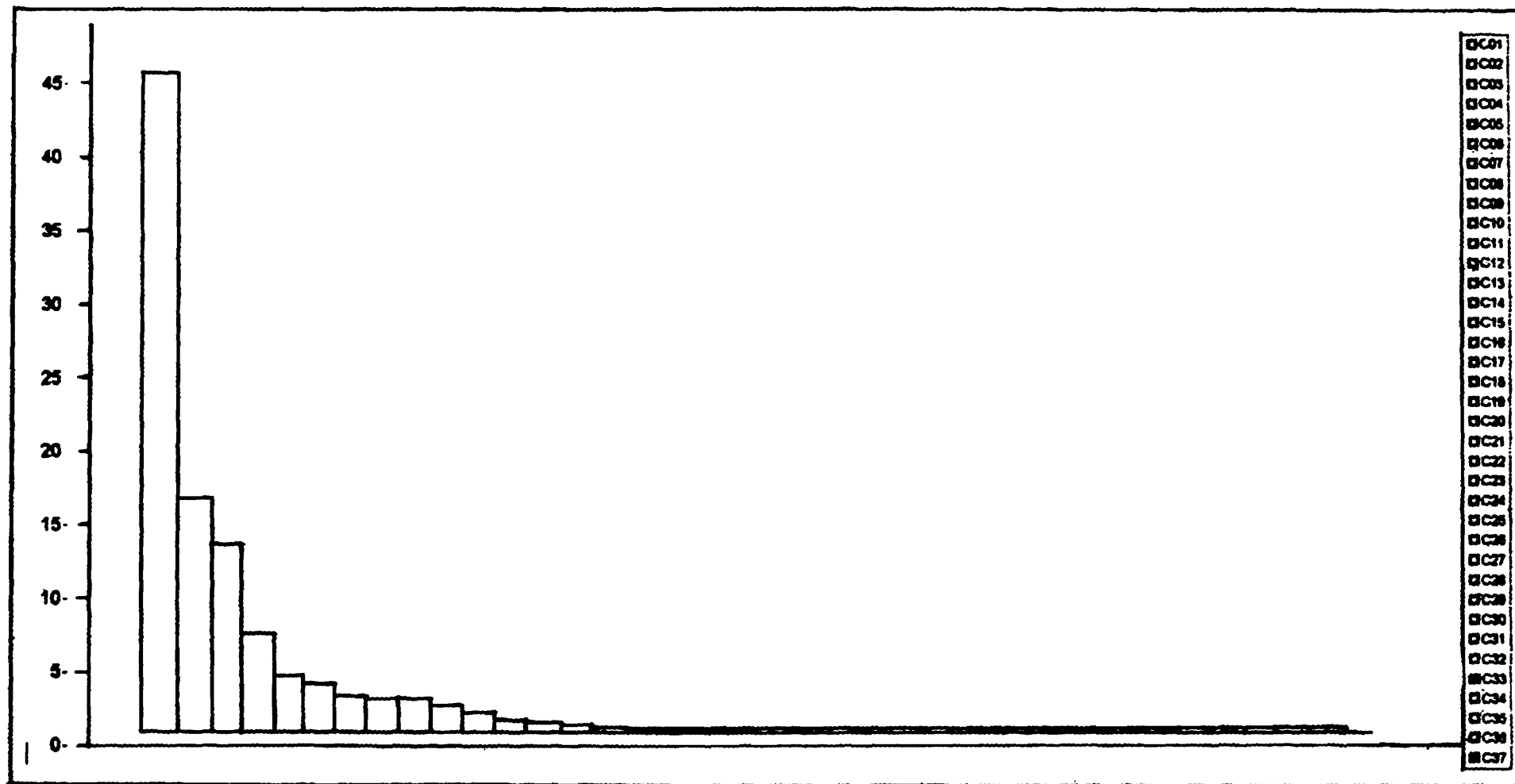


Fig. 5 : Abundance of different collembolan species obtained

C01. *Lepidocyrtus cyaneus*; C02. *Xenylla obscura*; C03. *Cyphoderus javanus*; C04. *Lepidocyrtus magnificus*; C05. *Isotomurus balteatus*; C06. *Homidia* sp.; C07. *Salina indica*; C08. *Lepidocyrtus suborientalis*; C09. *Lepidocyrtus heterolepis*; C10. *Cryptopygus thermophilus*; C11. *Yosiia dehradunia*; C12. *Seira indica*; C13. *Sminthurides appendiculatus*; C14. *Lepidocyrtus medius*; C15. *Isotomiella minor*; C16. *Lepidocyrtus exploratorius*; C17. *Friesea yosii*; C18. *Lepidocyrtus* sp.; C19. *Proisotoma (C) fitchioides*; C20. *Ballistrura bengalensis*; C21. *Sminthurides cf. aquaticus*; C22. *Sphaeridia* sp.; C23. *Calx* sp.; C24. *Sminthurides purvulus*; C25. *Bourietiella* sp.; C26. *Folsomides exigus*; C27. *Sminthurides* sp.; C28. *Entomobrya* sp.; C29. *Entomobrya* sp.; C30. *Dicyrtomina* sp.; C31. *Deuterosminthurus* sp.; C32. *Sinella montana*; C33. *Heteromuricus cercifer*; C34. *Dicranocentrus* sp.; C35. *Archerontiella* sp.; C36. *Willemia* sp.; C37. *Dicranocentroides* sp.;

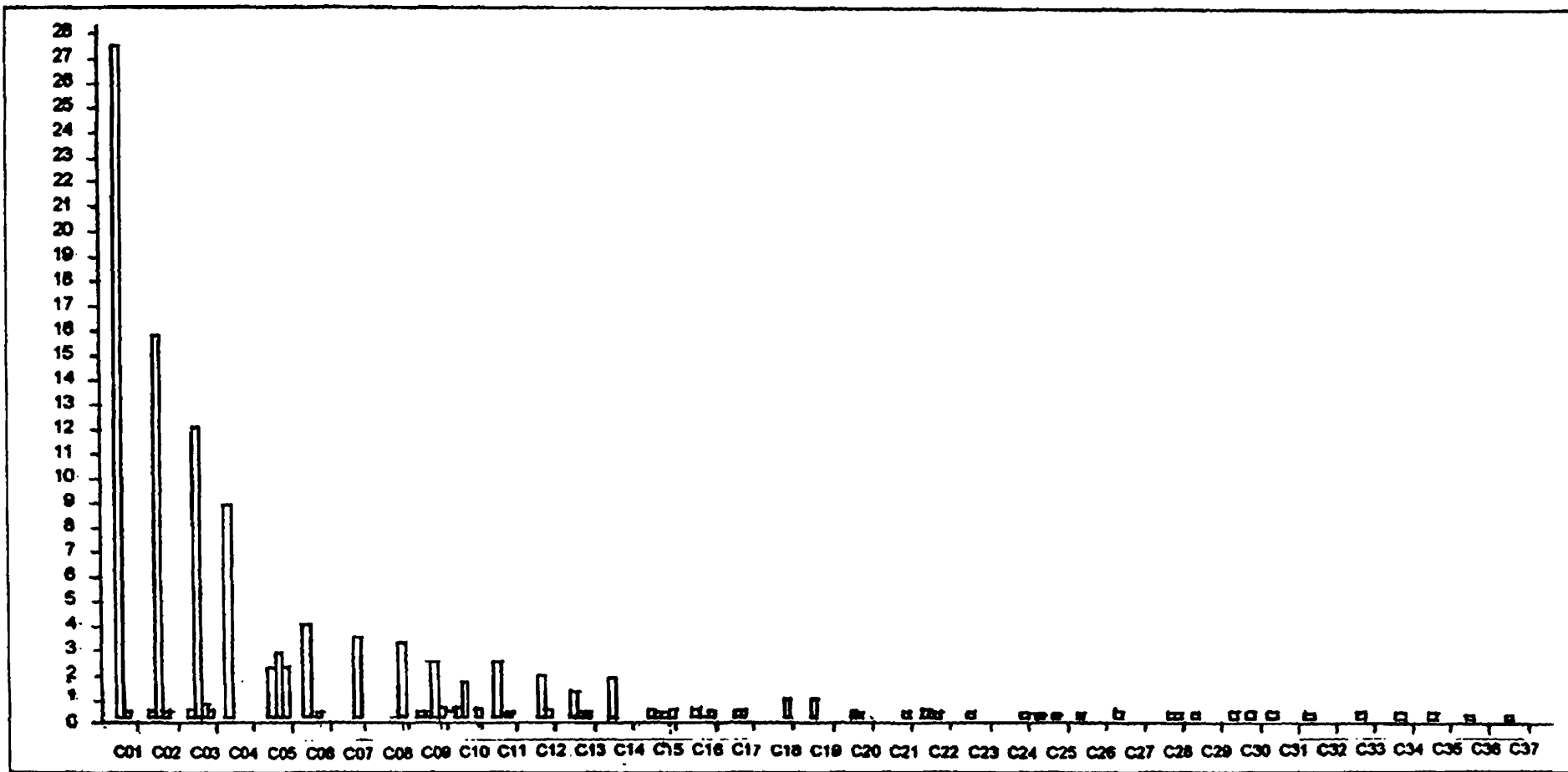


Fig. 6 : Relative abundance of individual collembolan species in different sampling sites.

C01. *Lepidocyrtus cyaneus*; C02. *Xenylla obscura*; C03. *Cyphoderus javanus*; C04. *Lepidocyrtus magnificus*; C05. *Isotomurus balteatus*; C06. *Homidia* sp.; C07. *Salina indica*; C08. *Lepidocyrtus suborientalis*; C09. *Lepidocyrtus heterolepis*; C10. *Cryptopygus thermophilus*; C11. *Yosiia dehradunia*; C12. *Seira indica*; C13. *Sminthurides appendiculatus*; C14. *Lepidocyrtus medius*; C15. *Isotomiella minor*; C16. *Lepidocyrtus exploratorius*; C17. *Friesea yosii*; C18. *Lepidocyrtus* sp.; C19. *Proisotoma (C) fitchioides*; C20. *Ballistrura bengalensis*; C21. *Sminthurides cf. aquaticus*; C22. *Sphaeridia* sp.; C23. *Calx* sp.; C24. *Sminthurides purvulus*; C25. *Bourietiella* sp.; C26. *Folsomides exigus*; C27. *Sminthurides* sp.; C28. *Entomobrya* sp.; C29. *Entomobrya* sp.; C30. *Dycyrtomina* sp.; C31. *Deuterosminthurus* sp.; C32. *Sinella montana*; C33. *Heteromuricus cercifer*; C34. *Dicranocentrus* sp.; C35. *Archerontiella* sp.; C36. *Willemia* sp.; C37. *Dicranocentroides* sp.;

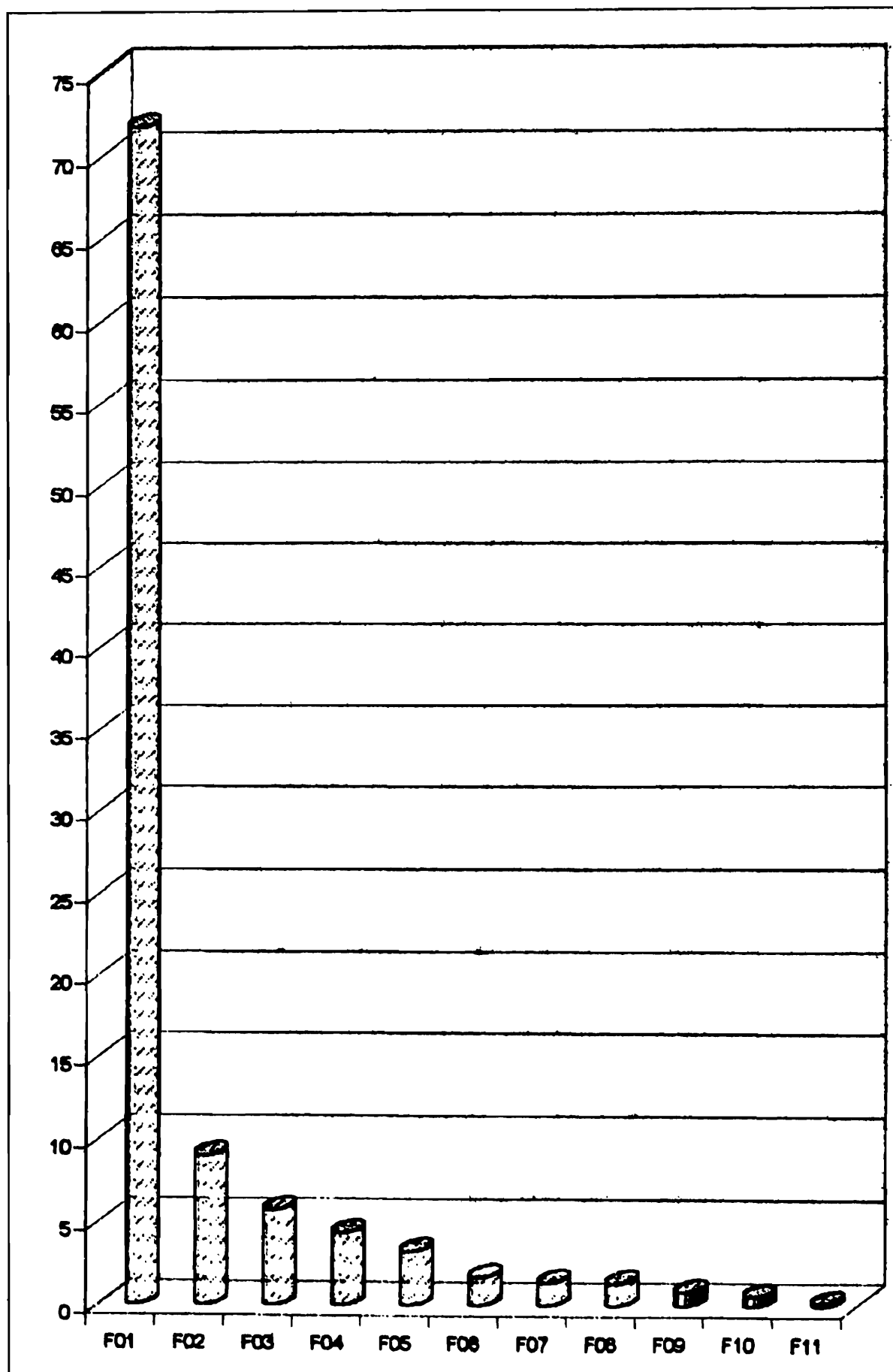


Fig. 7 : Abundance of different fungal genera obtained

F01 *Penicillium*; F02. *Aspergillus*; F03. *Fusarium*; F04. *Trichoderma*; F05. *Rhizopus*; F06. *Mucor*; F07 *Sclerotium*; F08. *Cephalosporium*; F09. *Curuvslaria*; F10. *Cladosporium*; F11. *Nigrosporium*.

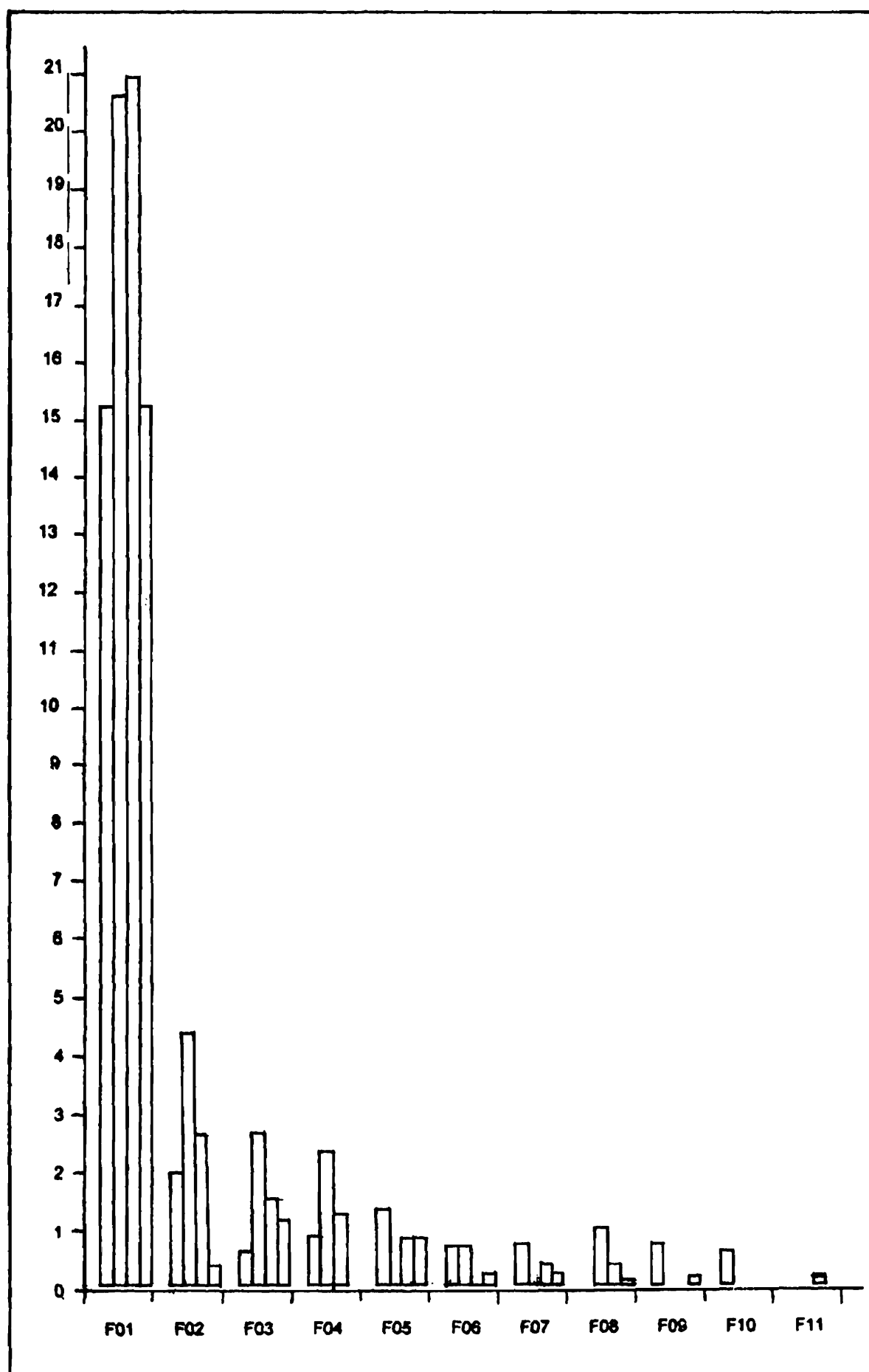


Fig. 8 : Relative abundance of individual fungal genera in different sampling sites

F01 Penicillium; F02. Aspergillus; F03. Fusarium; F04. Trichoderma; F05. Rhizopus; F06. Mucor; F07. Sclerotium; F08. Cephalosporium; F09. Curuvslaria; F10. Cladosporium; F11 Nigrosporium.

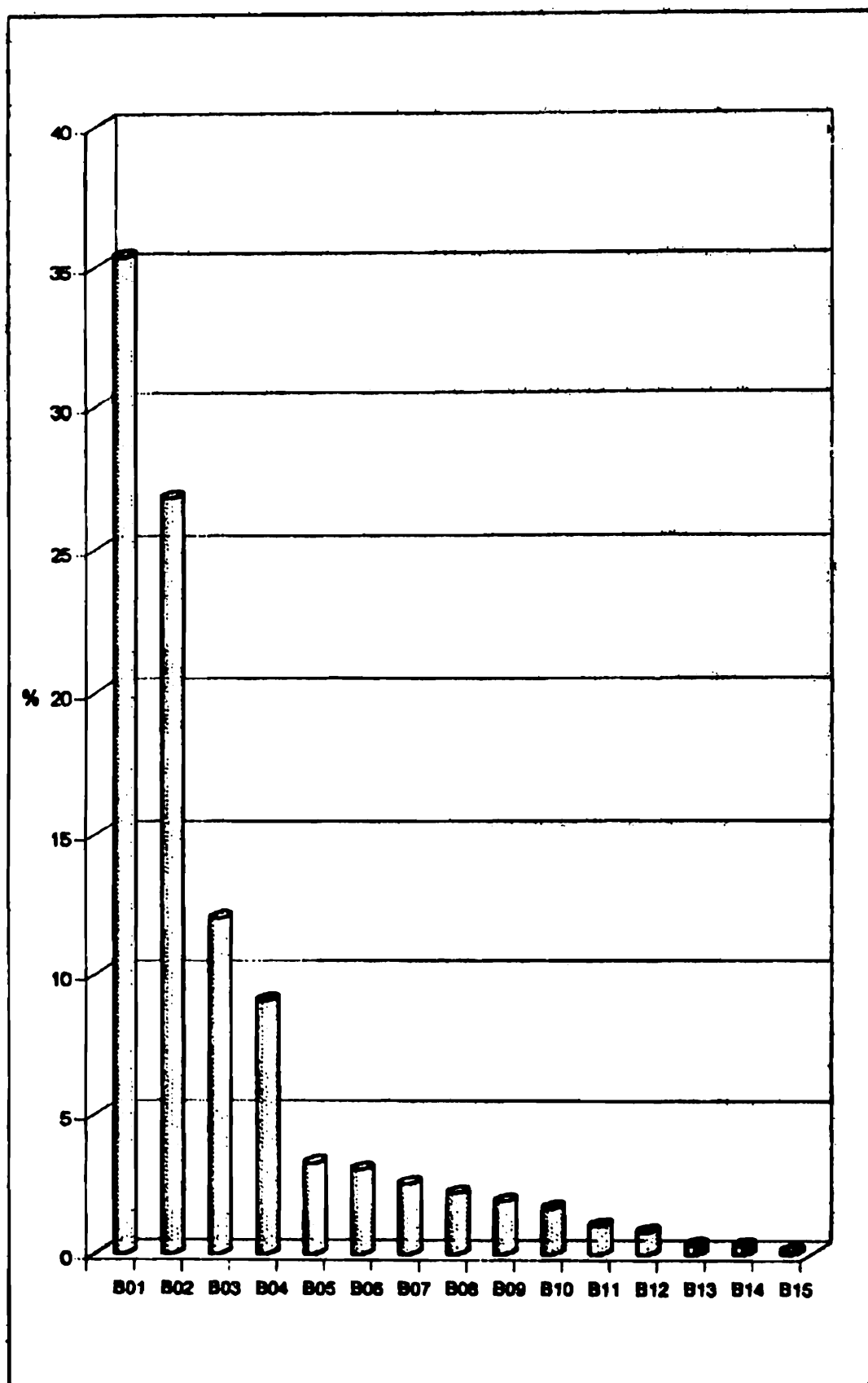


Fig. 9 : Abundance of different bacteria-actinomycetes genera obtained—

B01 *Bacillus*; B02. *Streptomyces*; B03. *Arthrobacter*; B04. *Micrococcus*; B05. *Cytophaga*; B06. *Nocardia*; B07. *Listeria*; B08. *Cellulomonas*. B09. *Promicromonospora*; B10. *Pseudomonas*; B11. *Corynebacterium*; B12. *Staphylococcus*; B13. *E. coli*; B14. *Xanthomonas*; B15. *Rhizobium*.

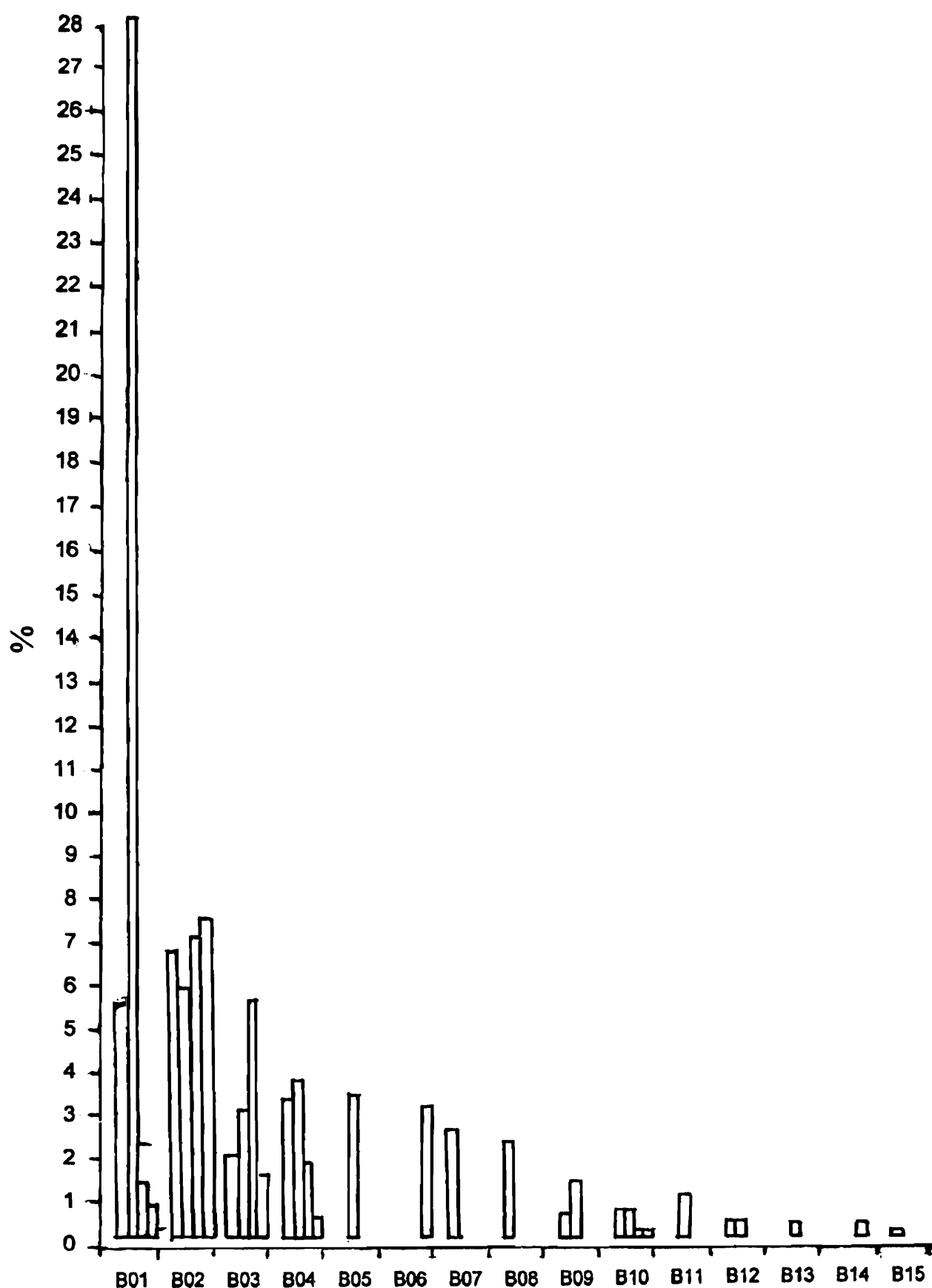


Fig. 10 : Relative abundance of individual bacteria-actinomycetes genera in different sampling sites
 B01. *Bacillus*; B02. *Streptomyces*; B03. *Arthrobacter*; B04. *Micrococcus*; B05. *Cytophaga*; B06. *Nocardia*;
 B07. *Listeria*; B08. *Cellulomonas*. B09. *Promicromonospora*; B10. *Pseudomonas*; B11. *Corynebacterium*;
 B12. *Staphylococcus*; B13. *E. coli*; B14. *Xanthomonas*; B15. *Rhizobium*.

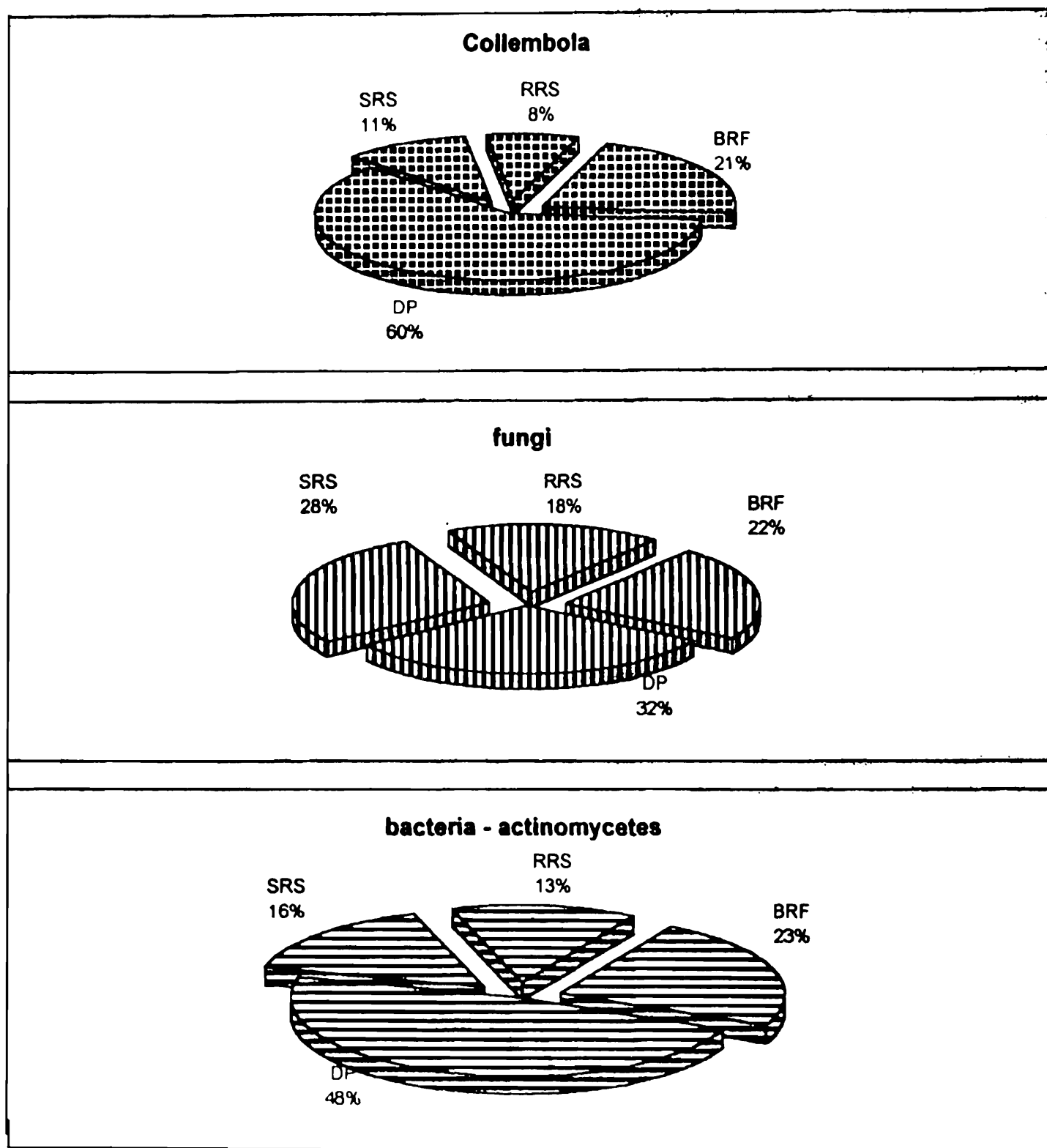


Fig. 11 : Sitewise abundance of total population of Collembola, Fungi & Bacteria-actinomycetes

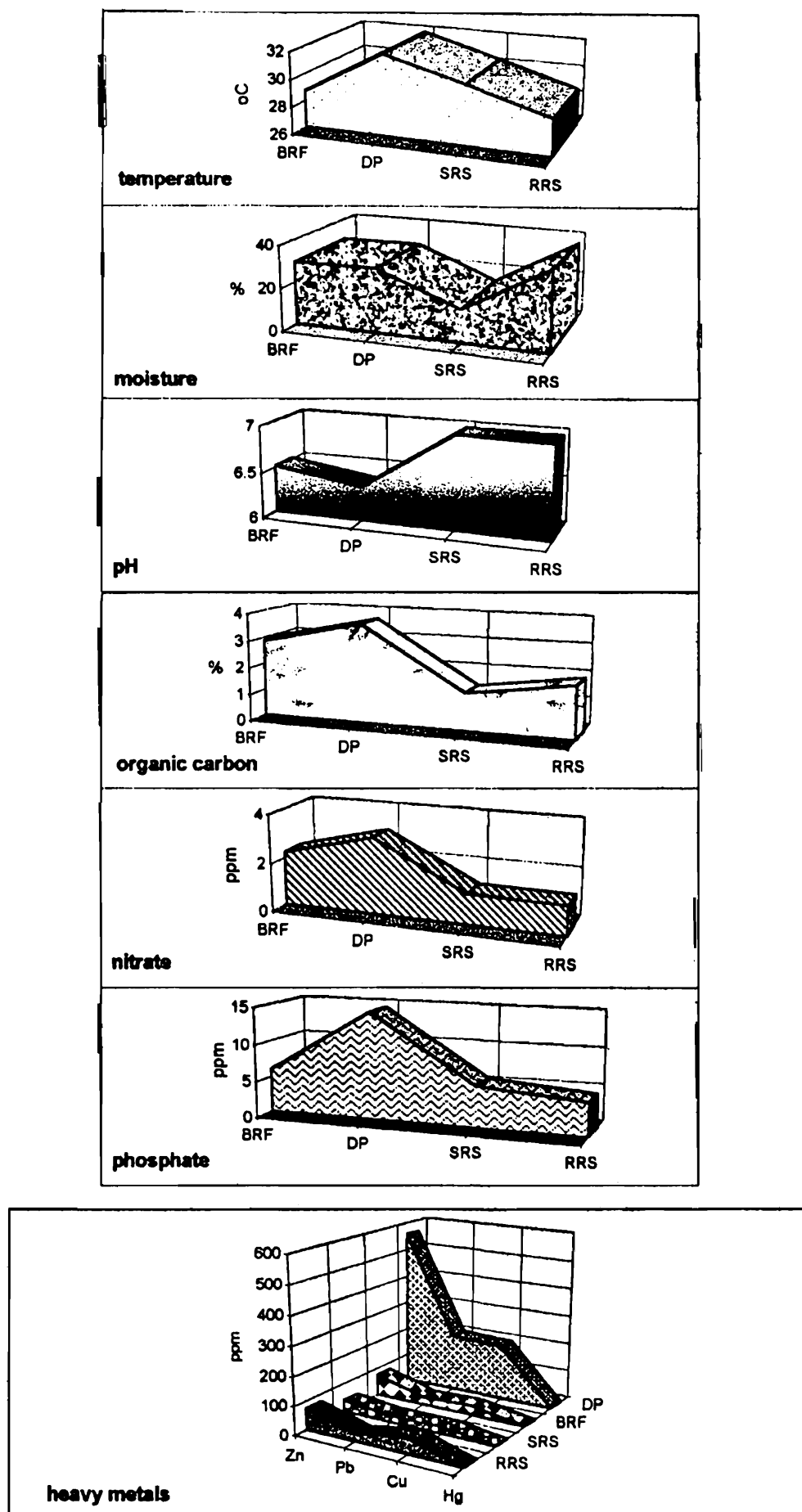


Fig. 12 : Mean values of edaphic factors & heavy metals in the studied sites.

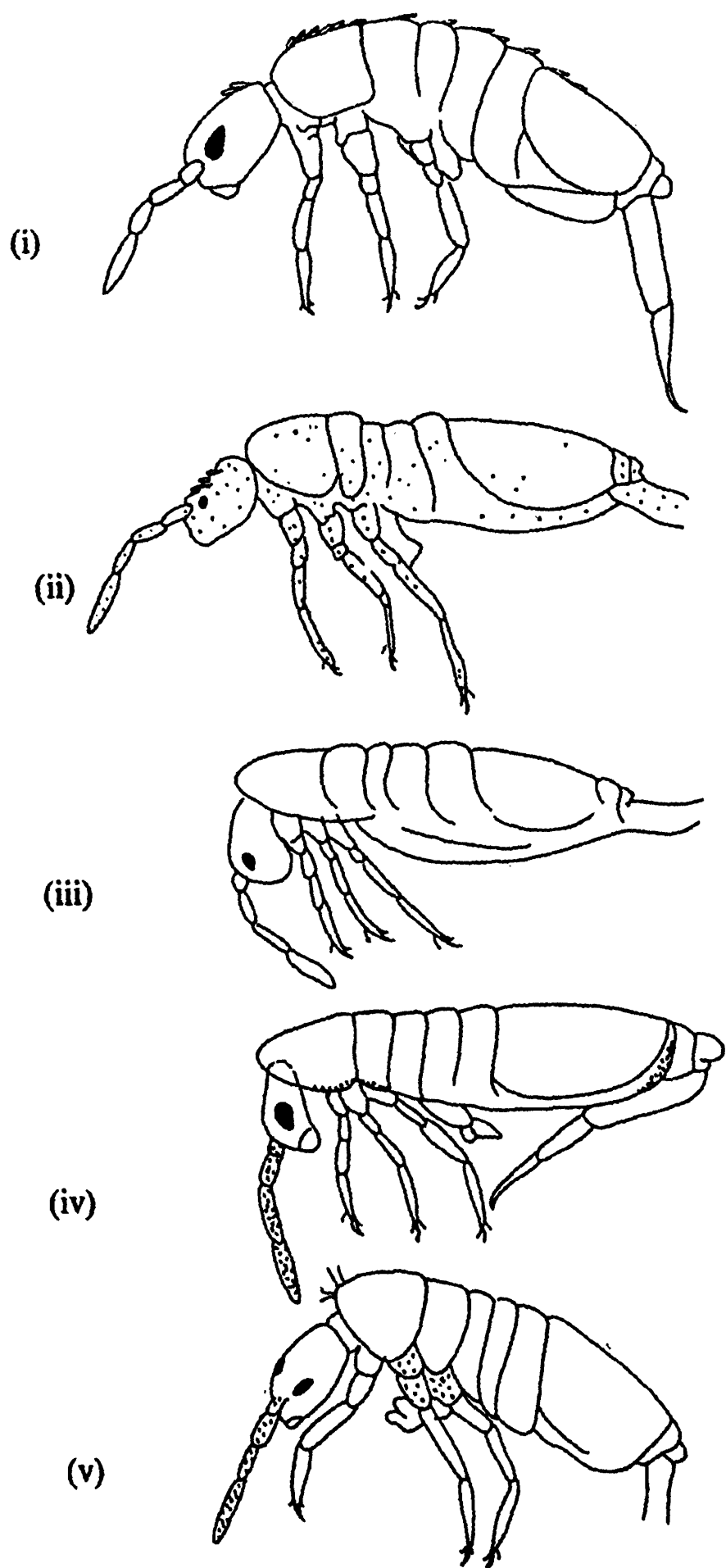


Plate 1. (i) *Lepidocyrtus cyaneus*, (ii) *L. heterolepis*, (iii) *L. medius*, (iv) *L. suborientalis*, (v) *L. exploratorius*.

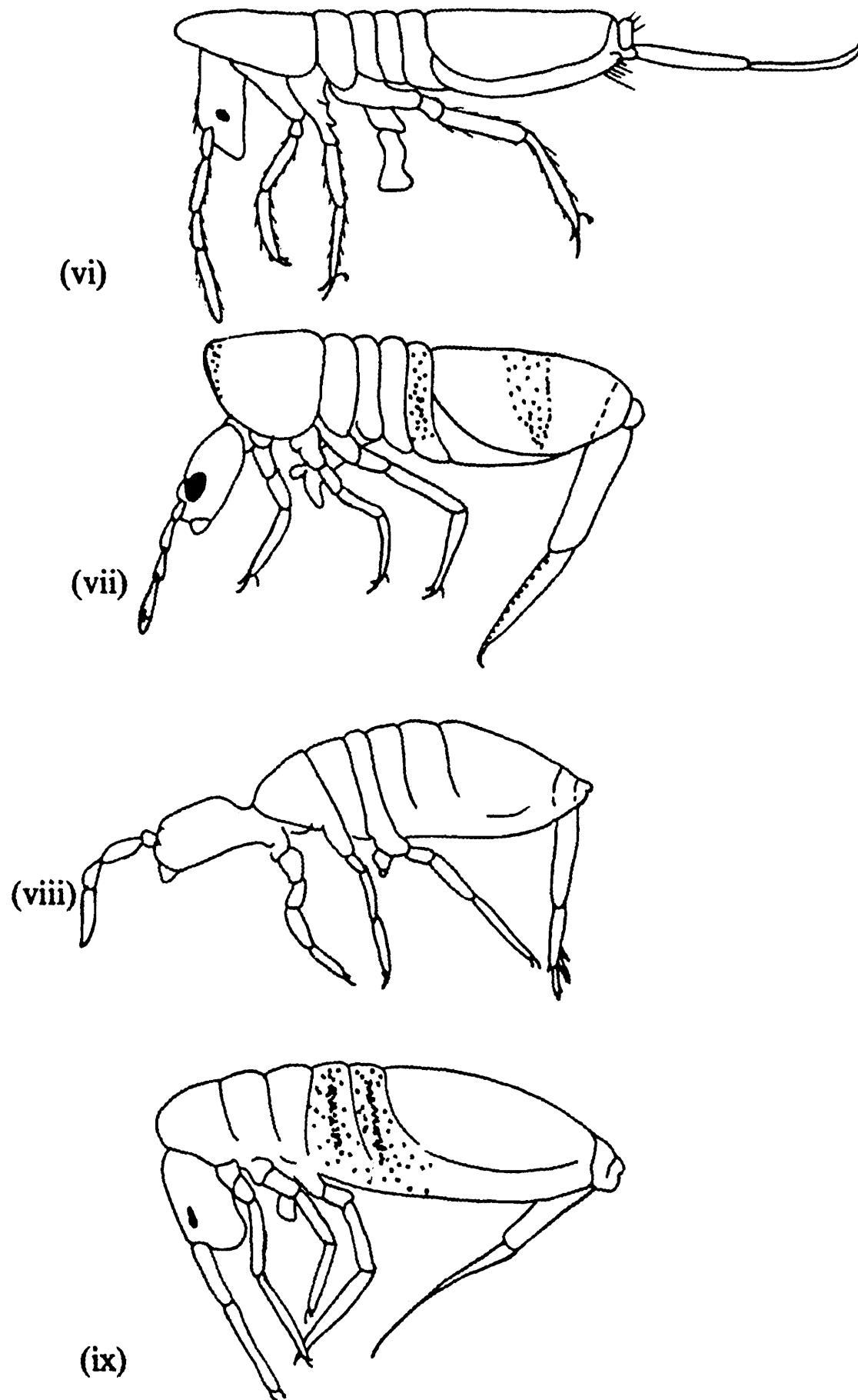


Plate 2. (vi) *L. magnificus*, (vii) *Lepidocyrtus* sp., (viii) *Cyphoderus*, (ix) *Seira indica*

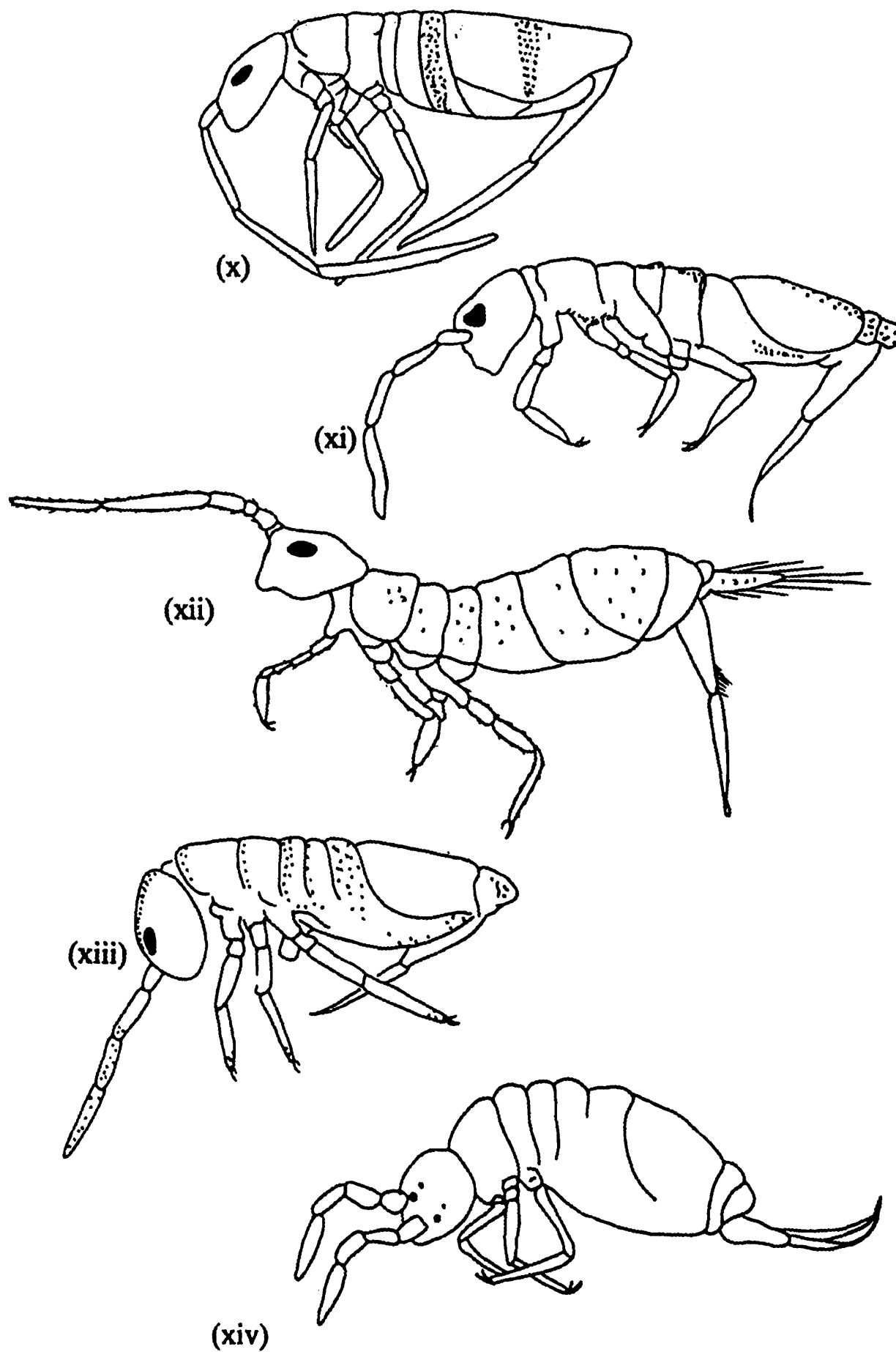


Plate 3. (x) *Homidia* sp., (xi) *Calx* sp., (xii) *Heteromuricus cercifer*, (xiii) *Entomobrya* sp., (xiv) *Sinella montana*.

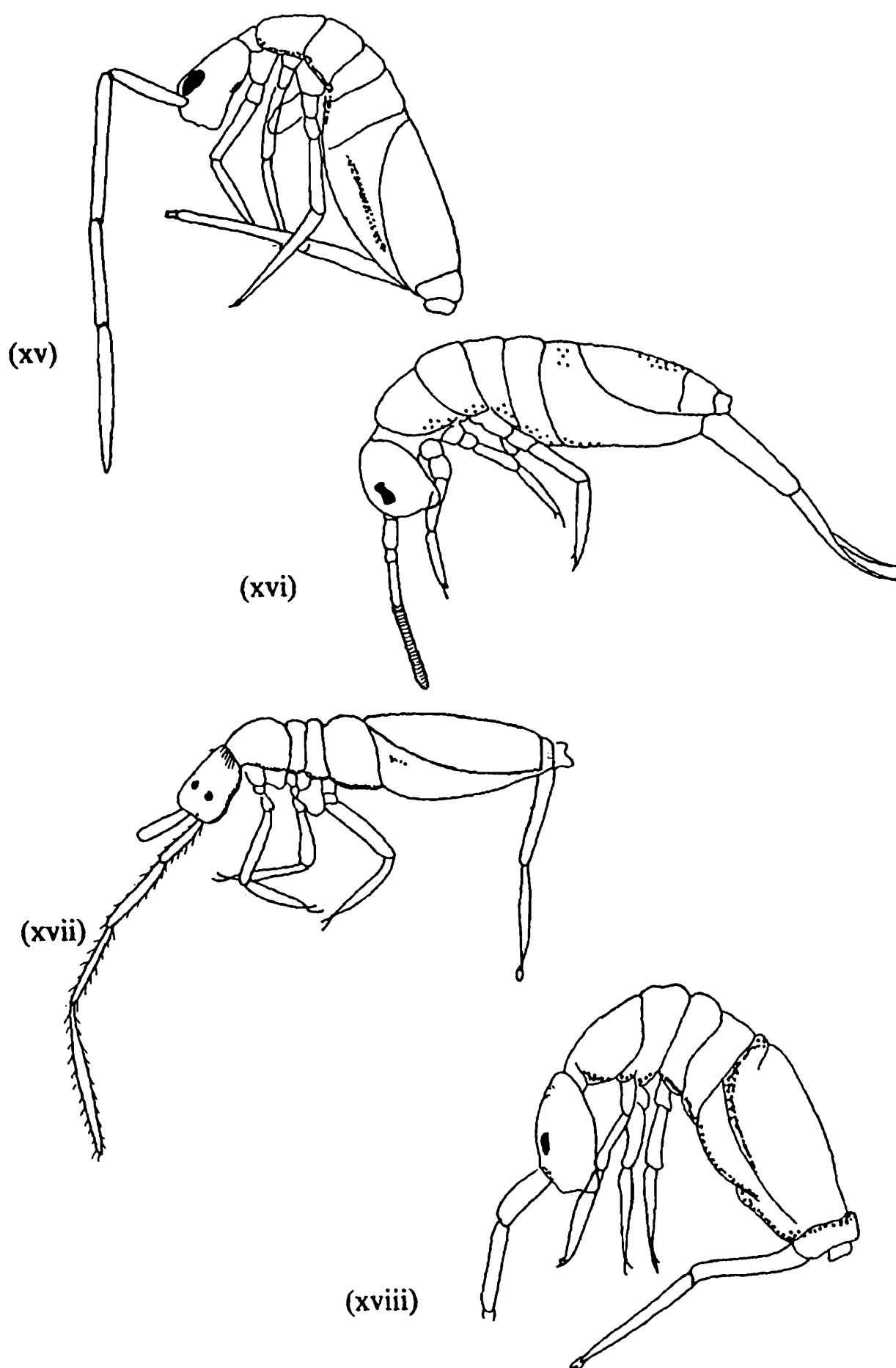


Plate 4. (xv) *Salina indica*, (xvi) *Dicranocentrus* sp., (xvii) *Yosia dehradunia*, (xviii) *Dicranocentroides* sp.

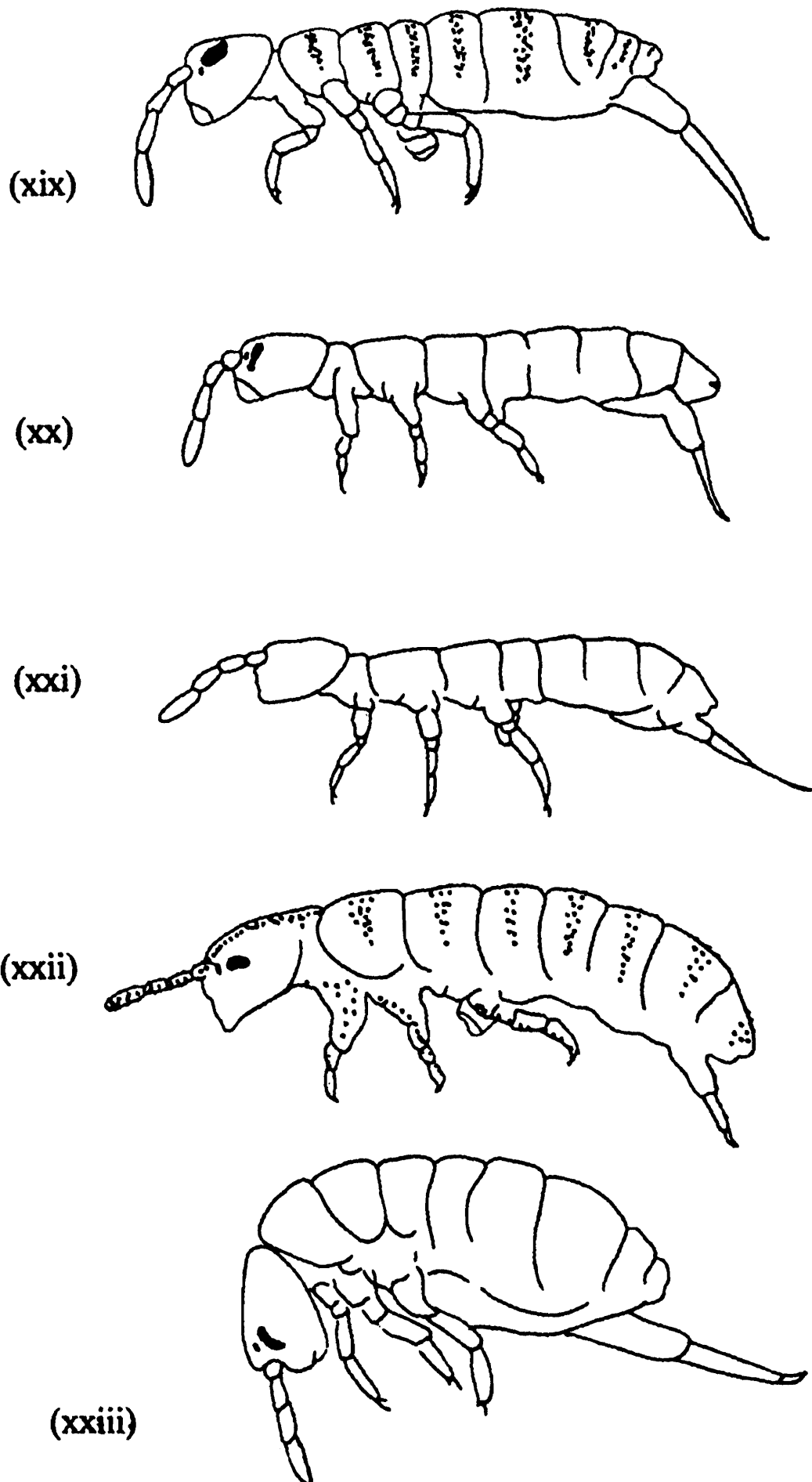
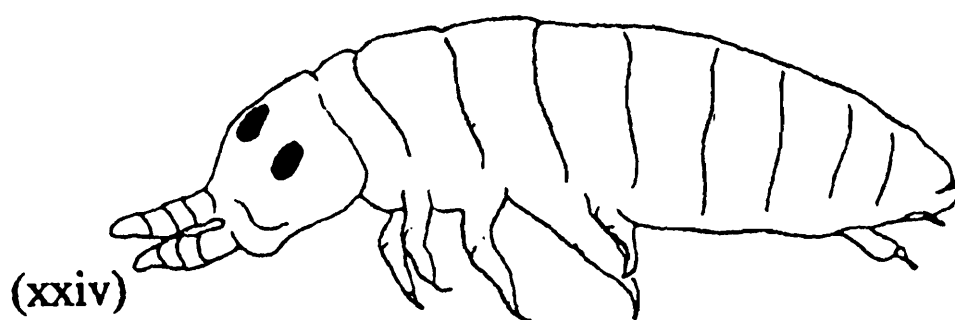
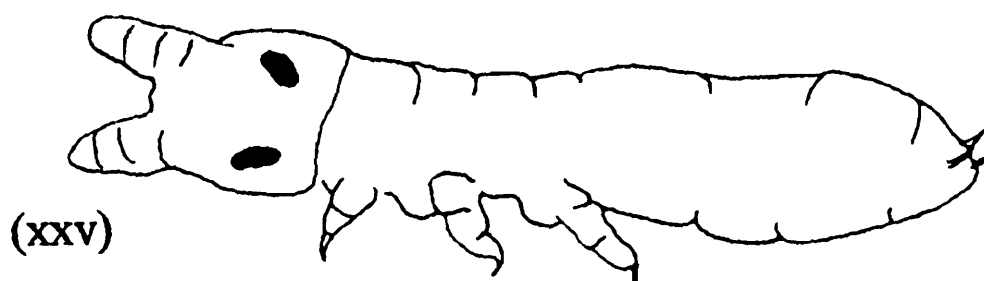


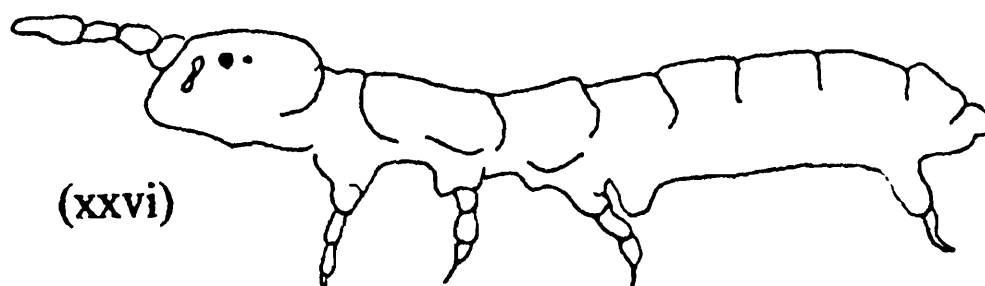
Plate 5. (xix) *Isotomurus balteatus*, (xx) *Cryptopygus thermophilus*, (xxi) *Isotomiella minor*, (xxii) *Proisotoma (Clavisotoma) fitchioides*, (xxiii) *Ballistrura bengalensis*.



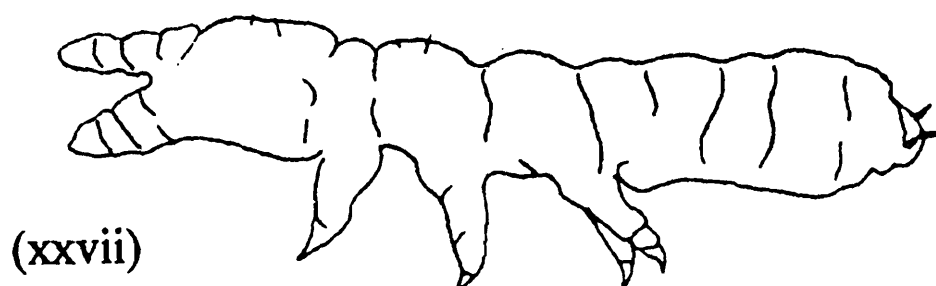
(xxiv)



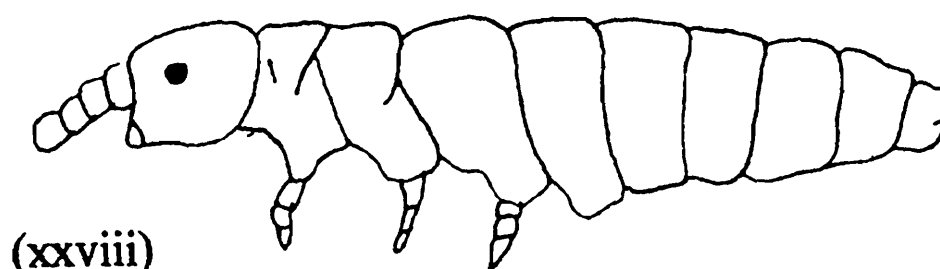
(xxv)



(xxvi)



(xxvii)



(xxviii)

Plate 6. (xxiv) *Xenylla obscura*, (xxv) *Firesea yosii*, (xxvi) *Folsomides exigus*,
(xxvii) *Willemia* sp., (xxviii) *Archerontiella* sp.

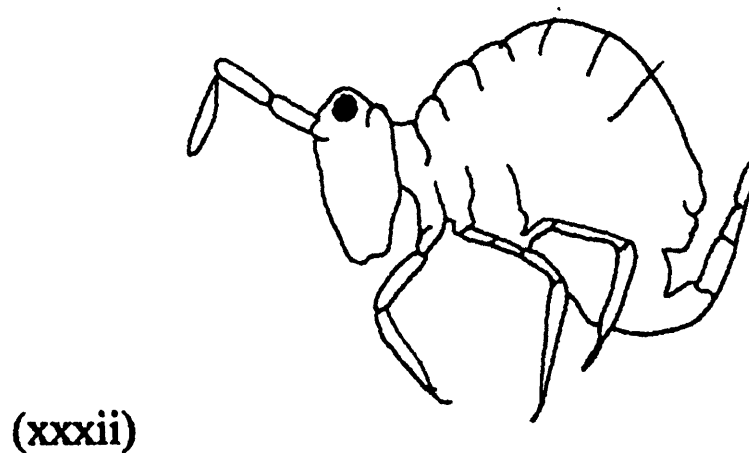
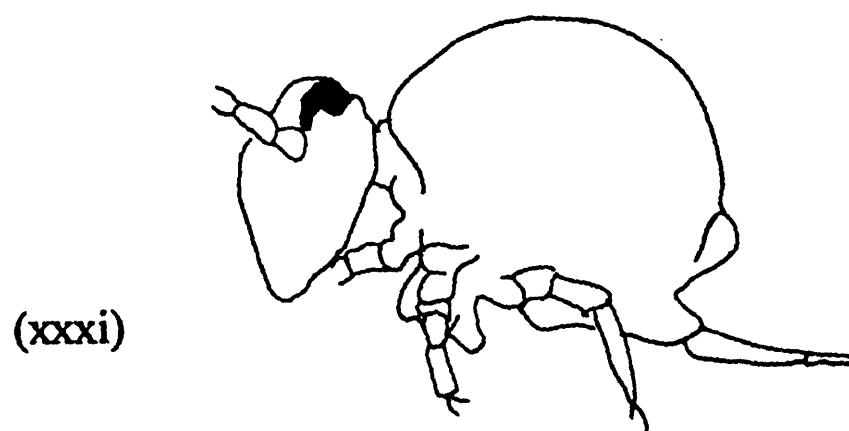
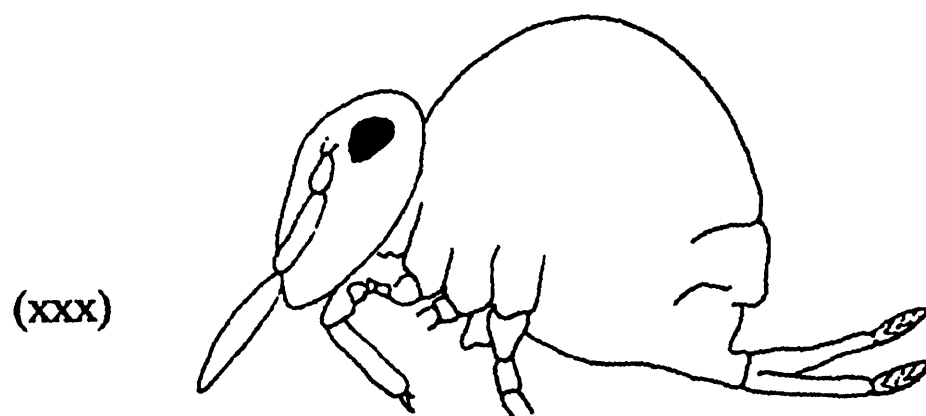
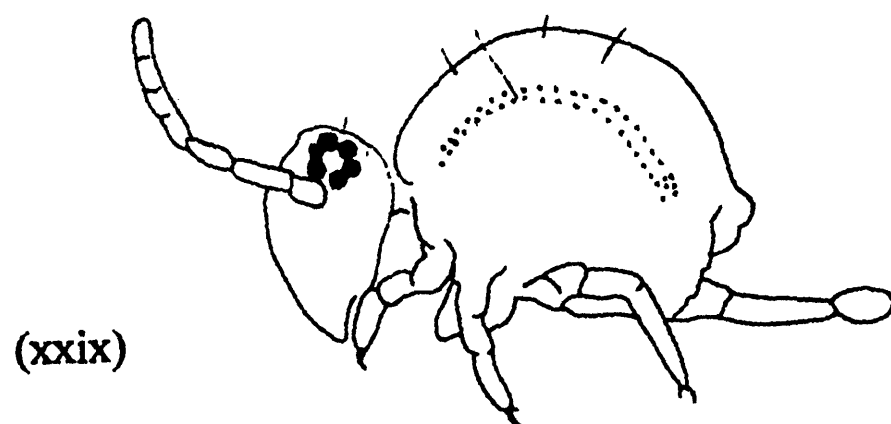


Plate 7. (xxix) *Sminthurides appendiculatus*, (xxx) *Sminthurides cf aquaticus*,
(xxxix) *Sminthurides* sp., (xxxii) *Sminthurides parvulus*.

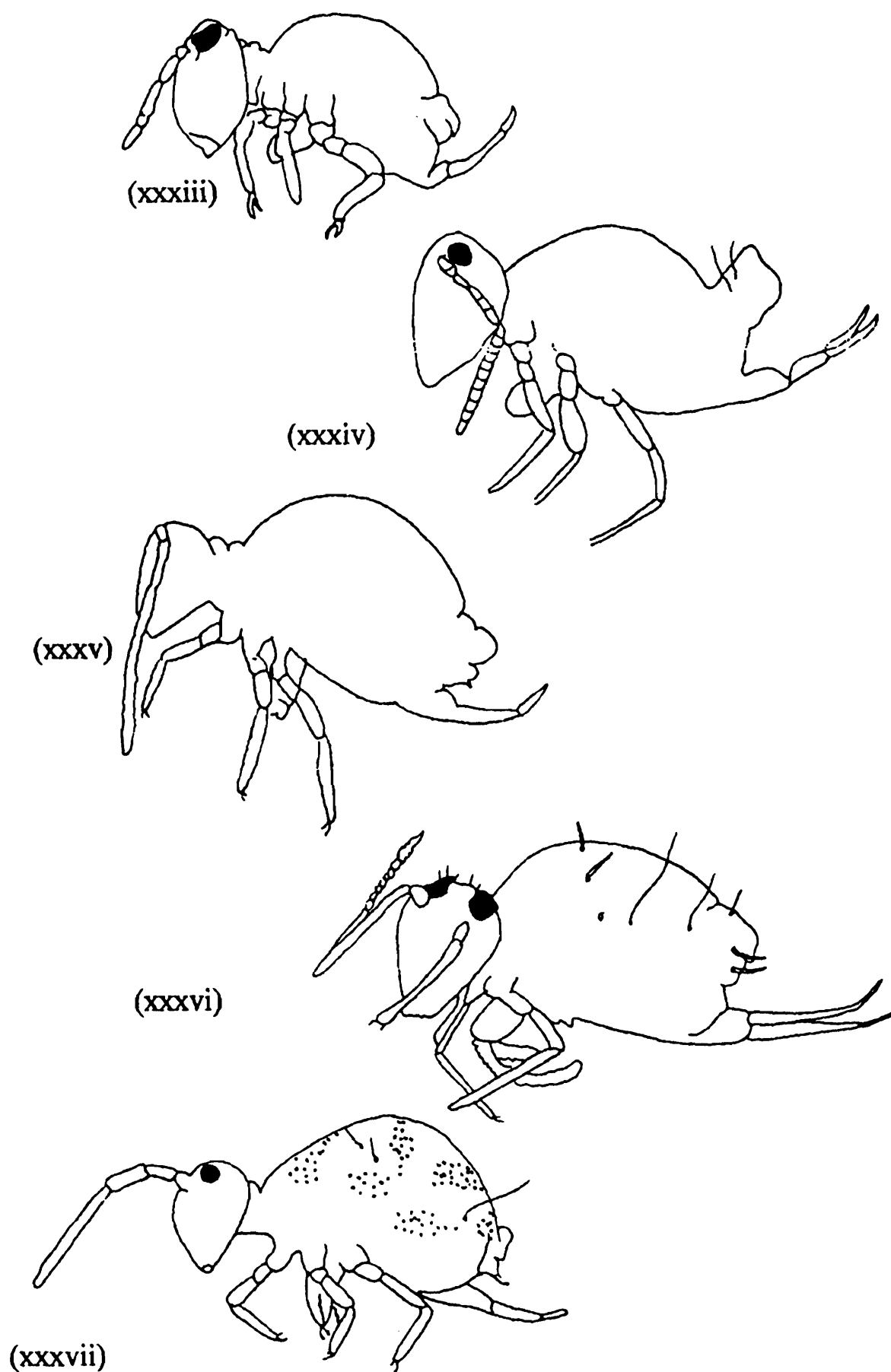


Plate 8. (xxxiii) *Sphaeridia* sp., (xxxiv) *Bourletiella* sp., (xxxv) *Pararrhopalites* sp., (xxxvi) *Dicyrtomina* sp., (xxxvii) *Deuterosminthurus* sp.

a.



b.



Photograph 1a-b. Sampling site at : Bethuadahari Reserve Forest/site I



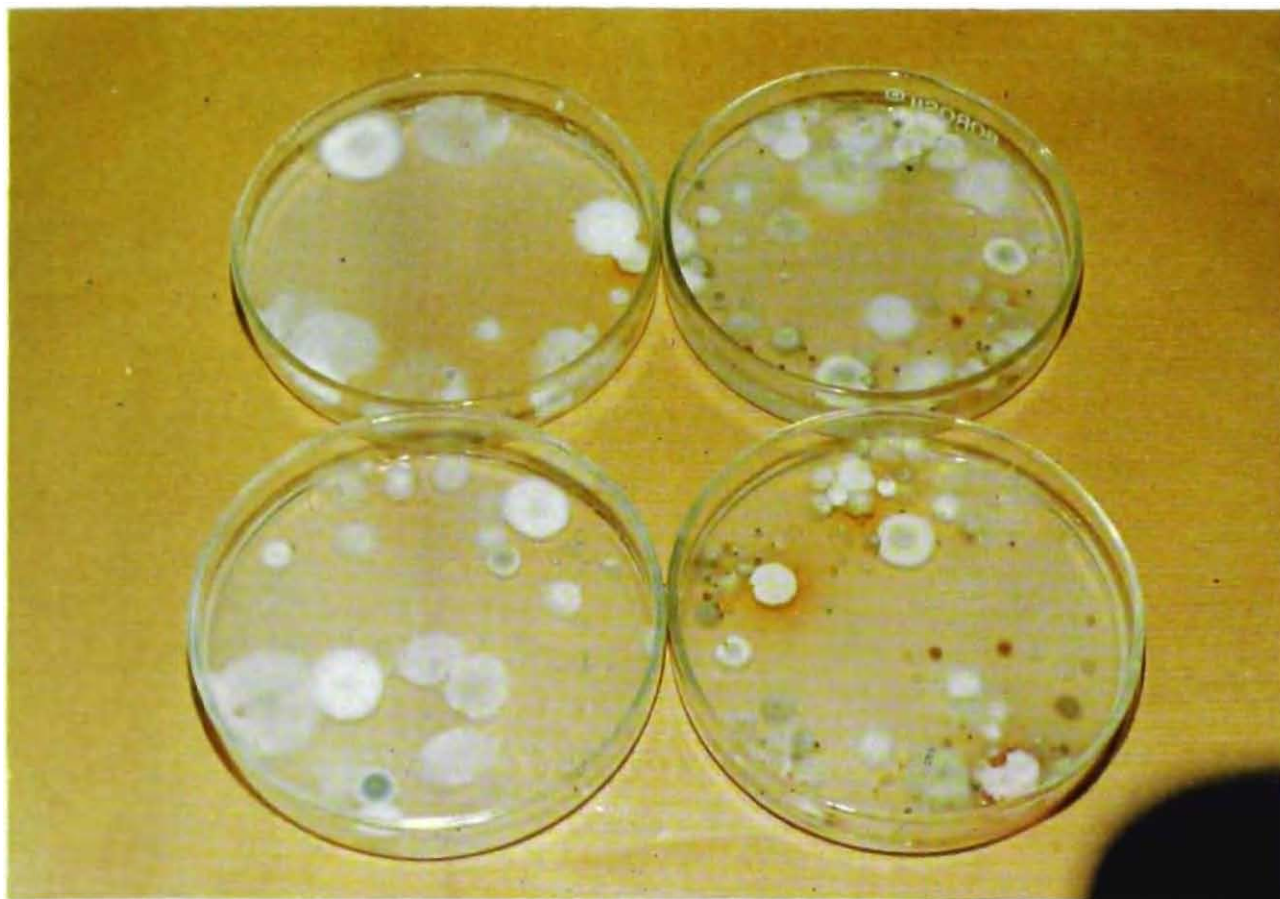
Photograph 2a-b. Sampling site at : Dhapa/site II



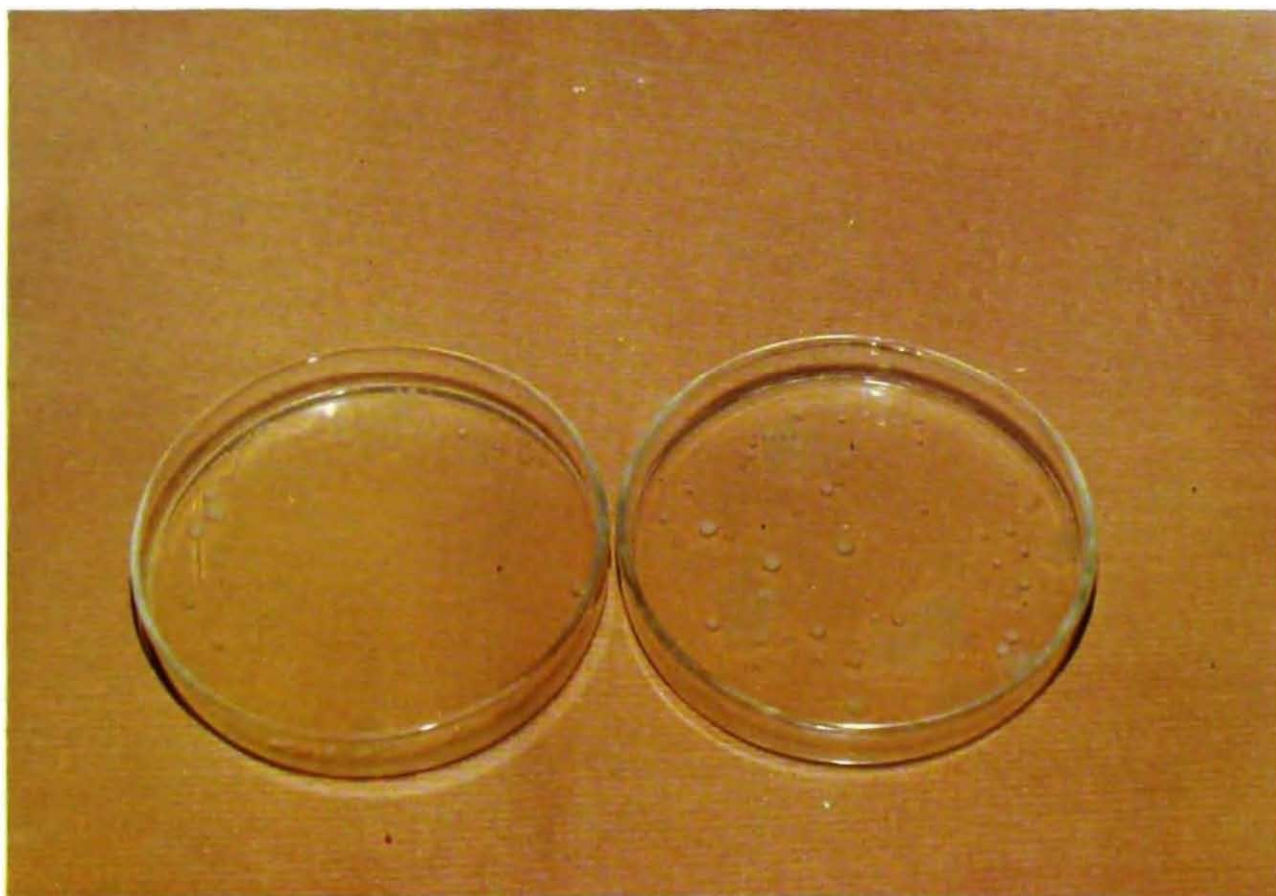
Photograph 3. Sampling site at : Sugarcane Research Station/site III



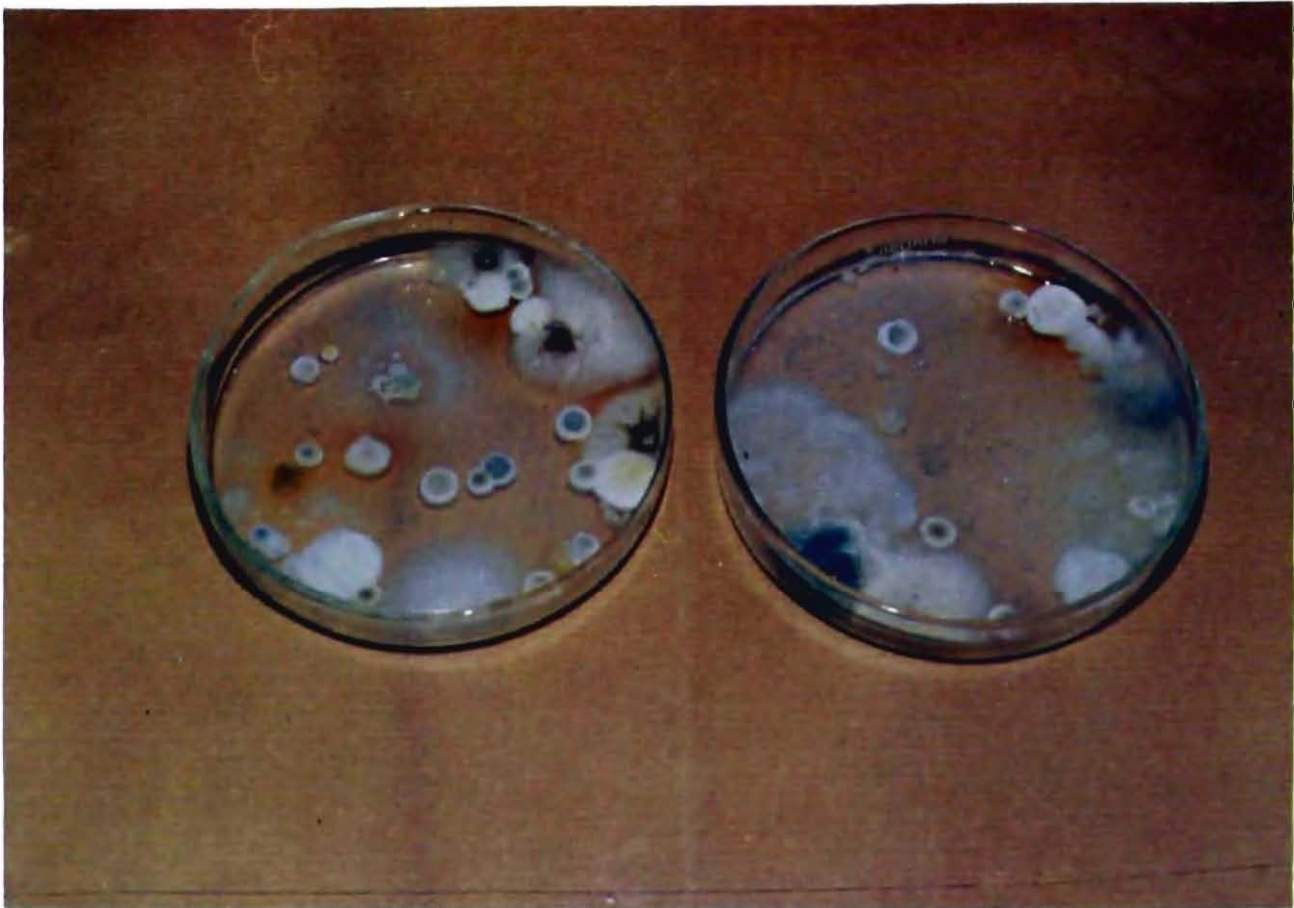
Photograph 4. Sampling site at : Rice Research Station/site IV



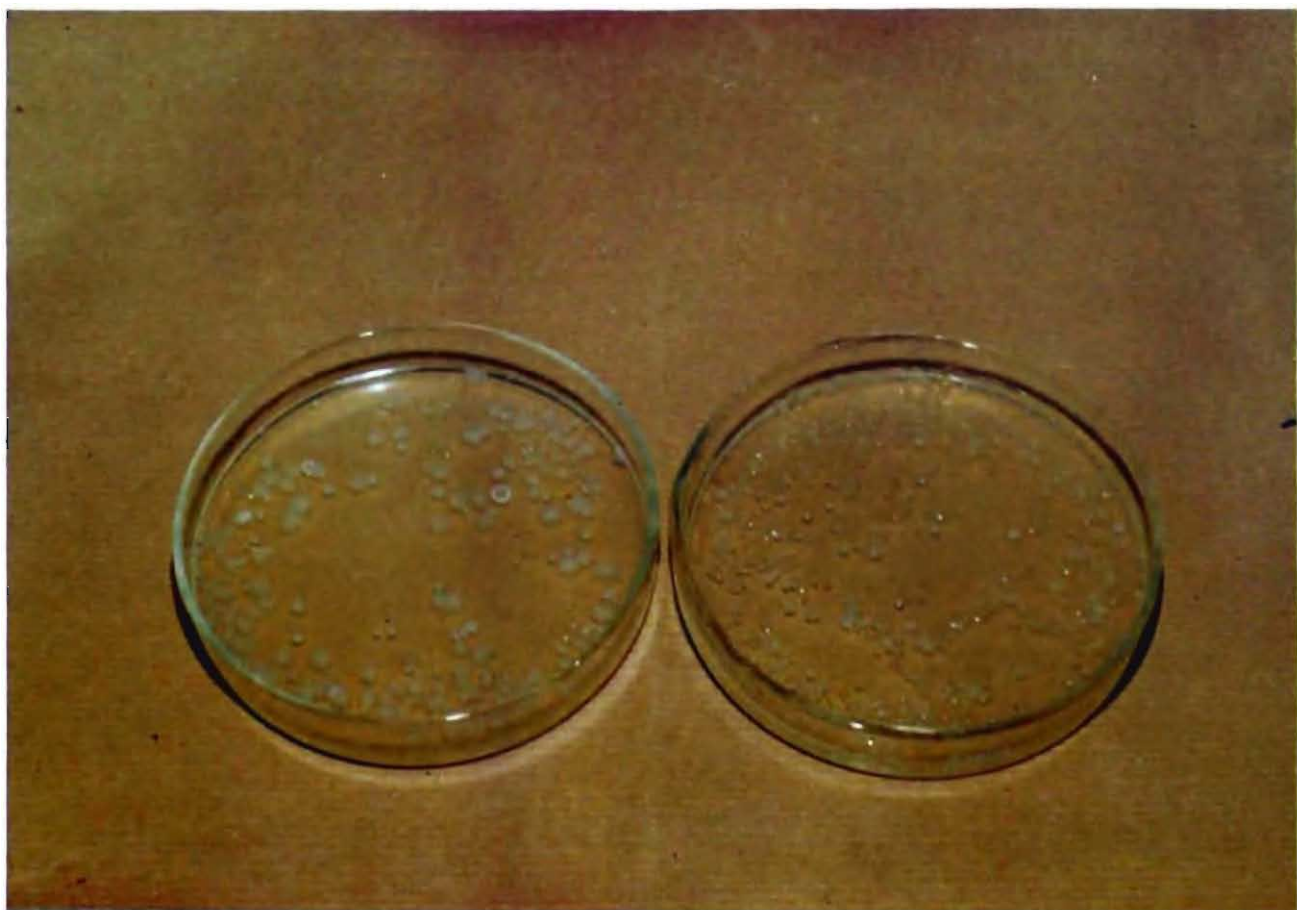
Photograph 5. Fungi of Site I/BRF (right) and site III/SRS (left)



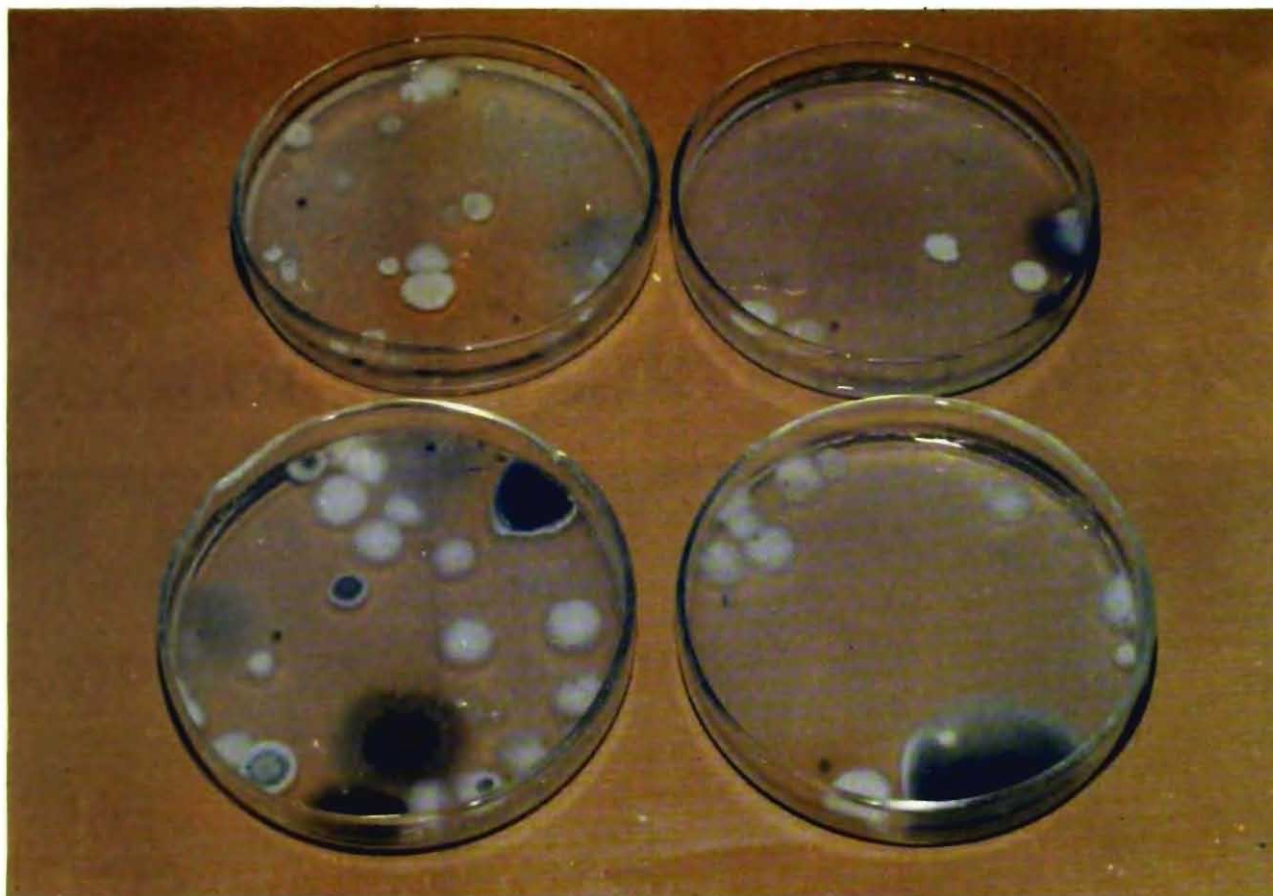
Photograph 6. Bacteria of Site I/BRF (right) and site III/SRS (left)



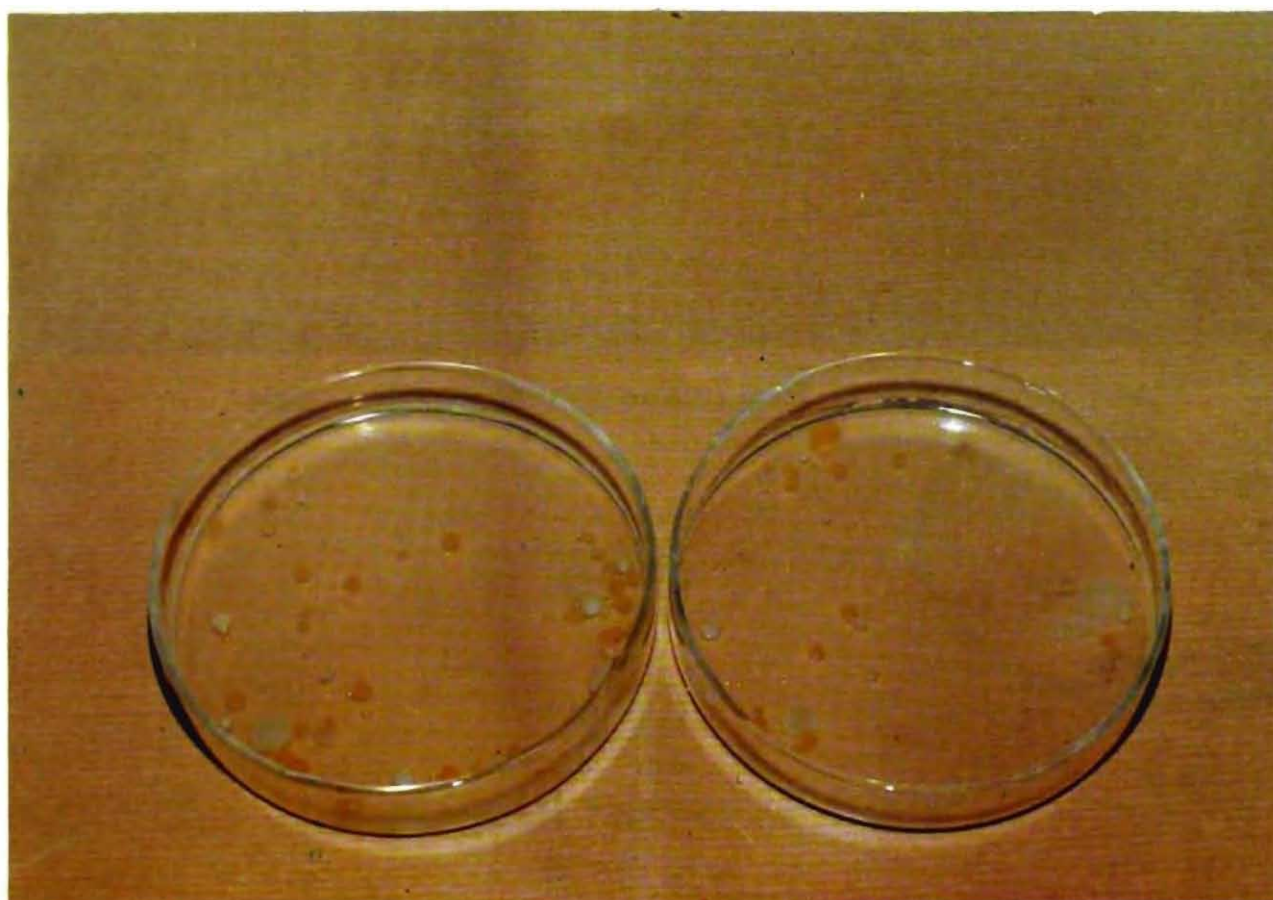
Photograph 7. Fungi of Site II/DP



Photograph 8. Bacteria of site II/DP



Photograph 9. Fungi of Site IV/RRS



Photograph 10. Bacteria of Site IV/RRS



Photograph 11. Pure culture slant of Bacterial strain