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Studies on the biodiversity of soil microarthropod and their responses to precipitation regimes

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ABSTRACT: In an attempt to determine the responses of soil microarthropods to precipitation regimes, samples were collected during dry season, simulated wet and rainy season periods. Also, biodiversity indices showed variation in soil microanthropod diversity and abundance in relation to cultivated, uncultivated and leaf litter sites. Generally, soil microanthropod abundance and species richness showed preference for the moisture rich sampling sites, with highest biodiversity indices recorded during the rainy periods. However the simulated wet periods of the dry season merely influenced abundance and had little or no relationship with species richness, as it was noticed in the three studied sites. Results also show that different families of soil microanthropods had different habitat preferences and their abundance correlated positively with varying soil pH and soil moisture but negatively with soil temperatures of their habitats. This suggests that physiochemical parameters affect soil microanthropod biodiversity.

Key Words: Biodiversity; Microarthropods; Precipitation regimes.

Introduction

The amount of literature on the biodiversity of soil microarthropods and their responses to changes in environmental conditions is inexhaustible, yet a lot is still being done in this millennium where environmental management is given utmost attention. Existing work has been mainly on soil mites and collembolans because of their overriding significance when compared with other microarthropod groups.

In most terrestrial ecosystems, Collembola are considered, together with mites, the most abundant group of soil mesofauna reaching densities up to 100,000 individuals per m^2 (Hopkin, 1997),

Their role in soil processes is sometimes neglected or underestimated due to their small size and low biomass, and their contribution as catalyst of organic matter decomposition is important (Hasegawa and Takeda, 1995). These minute arthropods are known to suppress plant pathogens and represent a significant biological control potential (Elroy, 1988).

The complexity of the soil as a habitat and the patchiness of the distribution of its inhabitants caused by their tendency to aggregate, has continually presented problems for researchers who have attempted to delineate the specific pathways and relative importance of the variance microanthropod group (Ingham *et al*., 1986).

However, as is eloquently shown by the results of Lubben (1989), there is great variation of response, not only within family groupings, but also within genus. For instance, in an experiment with heavy metal contaminated sewage, *Isotoma notabilis* showed a large increase in population numbers after sewage application whereas *Isotoma productus* showed a significant decrease. Complicating matters further, many microarthropod, and other soil invertebrates exhibit a flexibility of feeding which make it difficult to the static roles used in conventional food webs to the organisms concerned. That omnivory, or feeding on more than one tropic level, exists has been stressed by MacFayden (1978).

Most oribatids depend on plant material, but some are necrophagous (Hartenstein, 1962), some are coprophagous (Wallwork, 1958), and some are predators (Vizhum, 1943; Graves, 1960), including a report of nematophagy (Rockett and Woodring, 1966). Curry (1994) reports considerable and consistent reductions in Collembola numbers subsequent to both cattle slurry and pig slurry applications between April and August. Edwards and Lofty (1969) and King and Hutchinson (1980) found Collembola numbers in grassland increase as a result of fertilizer application.

Alternatively, Bardgett *et al*. (1993) found a decrease in soil microarthropods especially Collembola and mites, with a decrease in sheep grazing pressure. It is well known that a high water content in loam soils reduces Collembola numbers though it has the opposite effect in sandy soils (Filser, 1995).

The responses of microarthropods to the addition of organic manures of grassland soils are varied. Curry (1994) reports considerable and consistent reductions in Collembola numbers subsequent to both cattle slurry and pig slurry applications between April and August. Edwards and Lofty (1969) and King and Hutchinson (1980) found that Collembola numbers in grassland increase as a result of fertilizer application. Hopkin (2000) described British springtails.

Gamasid mites (Mesostigmata) are universally present in soil, though not as numerous as orbatid mites or collembolans. They however contain fewer species than oribatid mites, with about 75 families. They make up the largest suborder in the parasitiformes and include predaceous, scavenging and parasitic forms. Similar to spiders, they inject digestive liquid into the prey they catch, and then suck up dissolved tissues. The abundance and community structure of these mites attack small arthropods (Collembolans, soft-bodied mites, insect larvae and eggs). Several genera are considered good bioindicators of habitat and soil condition (Masha, 2000). Information on soil microarthropod distribution in relation to seasons and other conditions in the tropics are not available.

The aims and objectives of this study are as follows:

a. To study the biodiversity relationships of soil microarthropods in three selected and varied habitats within the same locality.

b. To test the influence of changes in environmental conditions of dry and rainy seasons on distribution, specie richness and abundance of soil microarthropods.

c. To test the influence of rainfall simulations in dry season on soil microarthropods biodiversity.

Materials and Methods

The area chosen for the study is located in the University of Benin Ugbowo Campus. The sites where samples were collected and analysed are a large expanse of land 150 x 120m were monitored at weekly interval. There were 3 sampling stations, all located within the study area. These stations were marked A, B and C.

Station A, B and C were the sampling stations for the sampling exercise which started in December, 2001 and ended in May, 2002, a period of six months. The three stations are interspersed by distance between 20m and 30m piece as described below:

Station A: This is an old cultivated piece of land covered with *Sida acuta*, and herb like *Chromolaena odorata* dotted the areas is sumps. However, a clump of babana shrubs (*Musa sapientum*) is found near the Land’s border. It has good drainage and the soil texture is more of humus – sandy.

Station B: This is a large old heap of leaves that is constantly undergoing decay. However, leaf-burning affairs have been associated with this site over time, but during the period of this study, it was totally prevented. The heap is gotten from leaf drop from two main trees near it, *Terminalia cattappa* and *Magnifera indica*.

Station C: This is a cultivated well-drained piece of farmland with plantings of *Lycopersicon esculentum* and *Amaranthus sp*. It is made of ridges and soil beds.

It is important to note that these three stations A, B and C were divided into 2 sections each interspersed by a distance or about 3m, during the dry season sampling (December, 2001 to February, 2002). A section witnessed rainfall simulations during this period while the other did not. However, the three stations did not have this partitioning during the wet season sampling (March to May, 2002).

Collection and Extraction

In the collection of the samples from the different stations, the split core sampler used for soil samples from A, C, while the hand trowel was used for station B. Sampling was done randomly to a depth of about 10cm below surface level. Samples were placed in black cellophane bags and labelled. For leaf litter samples, a hand trowel was used to scoop the litter and placed in similar bags and labelled. These samples (300g each) were then taken for extraction.

The extraction method is the Berlese-Tullgren funnel extractor and the organisms collected in containers with 70% alcohol after 48 hours.

Sampling was done fortnightly between 9.00 a.m. and 10.00 a.m. and 3 samples were collected from every station/sub-station at random.

Sorting was done, under a binocular dissecting microscope, and individual species were removed from the lot by suction using a sucking pipette and placed in glass specimen bottles containing 70% alcohol. Slides were prepared by the method of Hopkin (2000) and specimens were identified.

The various parameters monitored and measured included soil pH, soil moisture content, soil temperature, and soil total hydrocarbon content.

During the study, simulations of rainfall during the dry months sampling was carried out.

To simulate rainfall, 50 litres was poured onto a section of about 4 x 4m of station once every week, and the adjoining section was left without simulations of rainfall. This was done using a watering can for uniformity.

Results

During the collection of the soil micro-arthropods, which lasted a period of six months, 14 families were recorded in all from 4 classes of the phylum Arthropod (Tables 1- 3). Of the 14 families, 15 species were represented. Every family had a species representation except for the family Formicidae that had two representative species.

The result of the collection shows a relationship between the occurrence and abundance of microarthropod and the variation in physical and chemical factors of weather (natural) as well as the simulations of precipitation regimes. These factors are soil temperature, pH, and moisture content and total hydrocarbon content.

For the purpose of understanding the relationship that exist in term of biodiversity with respect to precipitation regimes, tables were prepared to show three phases of study. The dry period, the simulated wet period and the rainy period.

TABLE 1

AVERAGE MONTHLY DISTRIBUTION OF SOIL MICROARTHROPODS IN THE DRY AND WET SECTIONS OF *STATION A, B, AND C.*

CLASS	FAMILY	STATION A						STATION B						STATION C					
		DECEMBER		JANUARY		DECEMBER		FEBRUARY		FEBRUARY		FEBRUARY		FEBRUARY		FEBRUARY		FEBRUARY	
		DRY	WET	DRY	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY	WET	DRY
INSECTA	SMINTHURIDAE	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	1	0	1
	ENTOMOBRYIDAE	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	3
	ISOTOMIDAE	0	0	0	0	0	0	0	2	0	2	0	3	0	1	0	1	0	2
	RHINOTERMITIDAE	0	3	1	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0
	CARABIDAE	0	1	0	0	1	0	1	4	2	3	1	4	0	0	0	0	0	0
	CHRYSOMELIDAE	0	2	0	0	2	0	0	3	1	2	2	5	0	0	0	1	0	1
	TENEBRIONIDAE	0	0	0	0	0	0	0	0	1	3	0	2	0	0	0	0	0	0
	CURULIONIDAE	0	0	0	0	0	0	0	1	0	3	0	2	0	0	0	1	0	0
	FORMICIDAE	0	6	3	0	6	3	2	12	4	8	2	14	2	6	1	4	0	5
ACARI	MESOSTIGMATIDAE	0	3	0	0	3	0	1	2	0	2	0	4	0	0	0	0	1	0
	ORIBATIDAE	0	4	2	0	4	2	0	2	0	3	1	3	0	0	0	2	1	0
MYRIAPODA	SYMPHLIDAE	0	2	0	0	2	0	1	2	1	1	1	3	1	1	1	2	0	2
	POLYDESMIDAE	0	2	1	0	2	1	1	1	2	1	2	3	0	0	0	0	0	1
CRUSTACEA	ARMADILLIDAE	1	3	0	1	3	0	2	4	1	6	2	4	2	4	2	4	0	3
Mean soil pH		6.04	6.05	6.06	6.04	6.05	6.06	6.81	6.83	6.80	6.82	6.90	6.93	5.40	5.42	5.37	5.40	5.42	5.50
Means soil temp (°C)		33.0	31.4	33.5	33.0	31.4	33.5	30.9	30.2	32.5	31.9	33.2	32.0	33.2	32.0	33.5	32.1	34.6	33.2
Mean moisture		5.3	17.1	5.0	5.3	17.1	5.0	2.3	11.2	2.2	11.4	3.4	14.3	3.7	14.4	4.7	17.5	5.2	21.1
content (%)											2								

TABLE 2

THE AVERAGE MONTHLY DISTRIBUTION OF SOIL MICROARTHROPODS IN STATIONS A, B, AND C DURING RAINY SEASON PERIOD WITH SOIL Ph.

CLASS	FAMILY	STATION A			STATION B			STATION C		
		MARCH	APRIL	MAY	MARCH	APRIL	MAY	MARCH	APRIL	MAY
INSECTA	SMINTHURIDAE	0	0	0	2	2	5	3	4	6
	ENTOMOBRYIDAE	0	2'	4	1	2	3	2	4	5
	ISOTOMIDAE	0	2	3	1	3	2	1	3	3
	RHINOTERMITIDAE	7	9	20	0	0	0	2	7	6
	CARABIDAE	2	5	6	2	3	2	2	1	3
	CHRYSOMELIDAE	2	4	4	0	4	5	0	2	2
	TENEBRIONIDAE	3	1	3	1	1	0	0	0	1
	CURULIONIDAE	1	2	1	3	3	5	0	1	2
	FORMICIDAE	20	21	25	12	17	21	6	12	14
ACARI	MESOSTIGMATIDAE	4	4	6	2	4	3	2	5	5
	ORIBATIDAE	5	7	6	3	3	5	8	12	16
MYRIAPODA	SYMPHLIDAE	2	3	3	2	3	5	2	3	3
	POLYDESMIDAE	0	1	2	0	1	3	2	4	3
CRUSTACEA	ARMADILLIDAE	1	4	7	3	2	4	5	8	12
Mean soil pH		6.21	6.34	6.31	6.94	6.97	6.98	5.6	6.2	6.3
Means soil temp (°C)		30.2	28.4	27.5	32.1	30.4	29.2	30.3	28.5	28.5
Mean moisture content (%)		21.2	24.3	23.5	15.6	17.2	17.6	20.4	24.1	23.8

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Commenting on the physical parameters with respect to these phases, soil pH seemed uniform in the dry, simulated wet and rainy periods of each station, with a range of ±0.2. The rainy periods of Station B recorded the highest pH (6.98) in May (Table 5), while the dry period of Station C recorded the lowest pH (5.37) in January (Table 3). Similarly, soil temperature was apparently uniform in the three phases of the three stations.

For soil moisture content, the dry periods where generally low with a range of 2.2% in January of station B and 6.2% in February of station A (Tables 2 and 1 respectively). However, the simulated and rainy period had high moisture content records with highest in April of the rainy period of station A (24.3%) and lowest in the simulated periods of station b (11.2%) in December (Tables 4 and 2 respectively).

The abundance of soil microarthropod however, showed correlation with varying environment conditions.

In terms of species richness, station C had the highest record in the rainy period's (2.47), while the same recorded the lowest species index (1.36) in the dry periods. For general diversity, indices show station C as having the highest biodiversity of soil microarthropod (1.38) in the rainy season, as well as the lowest (0.57) in the dry period. It showed extreme distribution in both species richness and diversity.

Evenness̊ indices also shows station C as being the most uniformstation with highest peaks of 0.95 and 1.2, in the dry and rainy periods respectively. A total of about 850 soil microarthropod were collected for the period of 6 months as witnessed in the dry, simulated and rainy periods (Table 3). In terms of abundance, station A contributed 37.17% of the total. Station B and C had a percentage contribution of 34.23% and 28.63% respectively (Table 3).

In the dry period, 0.07% of this total population was collected while the simulated period and rainy periods recorded 31.29% and 68.64% of this population respectively across the station.

Significantly, station A contributed about 26.64% of this total population followed by station C (21.52%) and then station B (16.82%), all of the rainy periods. The family Formicidae had the highest record of abundance across the three phases of the three stations with about 27.17% contribution, followed by the Oribatid mite (11.29%), the crustacean (*Armidilliduim vulgare*) (10.58%) and the family Rhinotermitidae (8.47%). However, and the families Tenebionidae and Curculionidae recorded the lowest abundance of 1.76% and 2.94% respectively because of their significant absence in the dry periods across the stations (Table 3).

On an average analysis, according to Table 2, the soil microarthropod groups were distributed in terms of abundance in the following descending order: Hymenopterans (27.83%), Acarians (18.1%), Coleopterans (14.95%), Crustaceans (9.8%), myriapods (9.03%) and finally the Isopterans (8.84%). The microarthropods fauna was generally low in the dry period especially, the collembolans and *Opatrinus ovalis* that were clearly absent (Table 3). The *Solenopsis spp* was represented uniformly in the dry period while the myriapods were represented sparsely. In the simulated and rainy periods, the termite had a significant increase as well as the Acarina especially, the Oribid mites. Like the Oribatid mites, collembolans were significantly higher in the cultivated station than in others, as temperature decreased.

Correlation was established between microarthropod abundance and physiochemical parameters. A positive correlation (0.94) was established between soil pH variations and microarthropod bio-diversity and abundance with extreme positive regression coefficient (122.45). The preference was towards neutrality mark. However, positive correlation (0.908) was also established between soil moisture content and soil microarthropod abundance with a low regression coefficient (3.66). On the contrary, there was negative correlation (-0.88) between soil temperature and abundance with a regression coefficient of about -10.15.

Discussion

The complexity of soil as a habitat and the frequency of the distribution of its inhabitants caused by their tendency to aggregate has continually presented problems for researchers who have attempted to delineate specific pathways and relative importance of various microarthropod groups (Ingham *et al*., 1986).

From the bio-diversity of the family groups represented in this study, there are obvious relations between them and changes in environmental conditions. All the sites had a natural acidic nature with station C recording the highest level of acidity. This is associates with the historical record of the use fertilizers. However, there was a reduction in this low pH level towards the rainy season. This could be as a result of the dilution potential of water with increasing moisture content and the activities of micro organisms which make use of these nutrients (Zuberer, 2002; Kendeler and Eder, 1993). Station B however, recorded the highest pH as a result of its long history of organic matter decomposing by soil fauna (leaf litter decomposition). It is probable that station C has the highest temperature peak in February because of the absence of plant cover at the time. This is in accordance with the work of (Wallwork, 1970) who noticed a negative correlation between plant cover and temperature. Leaf litter canopy tends to minimize the amplitude of temperature and the moisture content fluctuation as observed in station B. Cover and high moisture content keeps temperature low (Wallwork, 1970). However, leaf litter does not possess a water retention capacity as do open field. This could be the reason for low temperature and high moisture content in simulated and wet periods of stations A and C. However, Petersen (1992)found an increase in moisture around injection slits of slurry and suggested that this be as a result of the particulate matter in the soil, helping to increase water retention rate.

Table 3: The mean monthly distribution of soilmicroarthropods in stations A-C with mean soil, soil temperature and moisture content readings.

CLASS	**FAMILY**	**MONTHS**					
		Dec.	**Jan.**	**Feb.**	**Mar**	**April**	**May**
INSECTA	Sminthuridae	0	0.3	0.5	1.6	2.3	4.7
	Entomobryidae	0.3	0.5	0.7	1.0	2.7	4.0
	Isotomidae	0.5	0.5	0.8	0.7	2.7	2.7
	Rhinotermitidae	0.5	1.2	1.8	3.0	5.3	8.7
	Carabidae	1.0	1.2	1.2	2.0	3.0	3.7
	Chrysomelidae	1.8	0.8	1.8	1.0	3.3	3.7
	Tenebrionidae	0	0.7	0.3	1.0	0.7	1.3
	Curulionidae	0.1	0.7	0.3	1.3	2.0	2.7
	Formicidae	5.0	5.0	5.0	12.7	16.7	20.0
ACARI	Mesostigmatidae	1.0	0.7	1.5	2.7	4.3	4.7
	Oribatidae	1.0	2.0	2.0	5.3	7.7	9.0
MYRIAPODA	Symphlidae	1.2	1.2	1.7	2.0	3.0	3.7
	Polydesmidae	0.7	1.0	1.7	0.7	2.0	2.7
CRUSTACEA	Armadillidae	2.6	2.3	2.3	3.0	4.7	7.7
Mean soil pH		6.09	6.08	6.15	6.25	6.50	6.53
Mean soil temp. (°C)		31.75	32.5	33.4	30.8	29.1	28.2
Mean moisture content (%)		9.0	9.59	11.6	19.06	21.8	21.6

Rise and fall in moisture content is related to the dry and rainy seasons. Station C showed both highest and lowest records of species richness, in the rainy and dry periods respectively. A significantly low pH was recorded in the recorded in the dry periods and this may have had an adverse effect on microbes which are known to thrive best at generally neutral pH levels (Zuberer, 2002). The fungi and bacteria are a food source for protozoa, nematodes, enchytraeids and various arthropods including Acari, Isopoda, Diplopoda and a number of the insecta (Curry, 1994). Lack of food source, low moisture content and high temperatures may be responsible for their low values. With increasing moisture as it began to rain, with temperatures becoming optimal (15-30°C), and a good base of inorganic nutrients, microbial growth is sure to increase (Zuberer, 2002).

Table 4: The combined results of different soil microarthropods groups in stations A-C with soil pH, soil temperature and moisture content readings.

GROUPS	**MONTHS**					
	Dec.	**Jan.**	**Feb.**	**March**	**April**	**May**
Collembolans	0.8	1.3	2.0	3.3	7.7	11.4
Isopterans	0.5	1.2	1.8	3.0	5.3	8.7
Coleopterans	1.9	3.4	2.6	5.3	9.0	11.4
Hymenopterans	5.0	5.0	5.0	12.7	16.7	20.0
Acarians	2.0	2.7	3.5	8.0	12.0	13.7
Myriapods	1.9	2.2	3.4	2.0	5.0	6.4
Crustaceans	2.6	2.3	2.3	3.0	4.7	7.7
Mean soil pH	6.09	6.08	6.15	6.25	6.50	6.53
Mean soil tem (°C)	31.7	32.5	33.4	30.8	29.1	28.2
Mean moisture content (%)	7.0	9.59	11.6	19.06	21.8	21.6

Station A had the highest record of relative abundance principally because of the overriding dominance of the isopteran as well as the hymenopteran groups. The high records however are similar to records of Badejo (1982) who highlighted the high level of social organization in this group, a basis for their aggregated number. Hence, a numeral strength record of these two groups in this work is not a true expression of their dominance.

The rainy phase of the sample recorded significantly higher abundance than the stimulated phase even though they had similar records of soil; moisture content. This is presumably because physiochemical parameters are not isolative in effect. They correlate significantly in their influence on faunal population. Hence, though the stimulated periods had high moisture content, temperatures were still high. This may have affected high temperature sensitive organism adversely. However, many soil microarthropods exhibit climatic and seasonal preferences, especially collembolans. Dhillon and Gibson (1962) recorded an annual peak of collembolans in late summer.

The family formicidae were more or less evenly distributed in three plots, with records even in the dry periods. This could be as a result of their phytophogous habit. The very fact that the plots were never completely dried accounted for the presence of ants (Wallwork, 1970).

Orbatid mites were generally low in the periods, especially in the cultivated section (Section C). Date from irrigation transect however indicated a negative impact of supplemental water on soil mites densities as shown by Edwards and Lofty (1969). This may be a reason why these groups showed a greater preference for the wet periods.

However, mites generally did not record very outstanding high occurrences as the ants. The soil mites are not capable of fast population growth and are restricted to relatively stable environments. Hence, their preference for station A. They are very resistant groups especially to environmental perturbations because of their structural features. According to Balogh and Balogh (1990) adult oribatid mites usually have strong exoskeleton, hardened by sclerotization, as in other mites. They can hence survive low temperatures. Another basis for the persistence of soil mites in soil ecosystems could be their omnivorous nature (MacFayden, 1978). They have a diversity of feeding habits. This could be a basis for their noticeable absence in station C, extremely low abundance in station A, but a significant abundance in station B. all of the dry simulated periods. Badejo (1979) had noticed the low number of the coleopteran group in cultivated plots because of the low level of litter. They are mainly biting and chewing insects.

Armadillidium vulgare recorded rather low numbers but evenly distributed across the periods and in every station of the sampling. They however showed preference for litter-rich stations. The same can be said of the myriapods, which were more or less evenly distributed also recorded low numbers.

The collembolans were a very distinguished group that showed very great sensitivities to altering environmental conditions. They had the highest significant records in station C because of the organic matter component. Kings and Hutchinson (1980) had earlier noticed an increase in Collembola numbers as a result of fertilizer application. The pathway is however establish as thus: increase in fertilizer application increase microbial growth, and ready food source of grazing collembolan communities. Their abundance was not substantially significant in this study, and the reason could be based on their high degree of selectivity in feeding (Shaw, 1988). Another reason for collembolan low abundance could include extreme sensitivity to precipitation regimes. Filser (1995) stated that water content and soil bulk density are important factors in determining Collembola population structures.

Conclusion

However small and significant these soil microarthropods may seem, their role in the below ground food web in many terrestrial ecosystems cannot be overemphasized.

Though efforts are mainly diverted towards preventing the extinction of macro species, care should be taken not to contribute to the disappearance of these micro species from the ecosystem either by acts of omission or commission.

Hence, there is a need to understand perfectly the ecological pathways that exist in soil system and how they can be modified and enhanced for better efficiency and productivity of their resident species.

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