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Studies on the Biodiversity of Soil Microarthropods and Their Responses to Crude Oil Spills

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Abstract: Soil microarthropods influence vital ecosystem processes such as decomposition, microbial spore dispersal and nutrient mineralization. Based on evidence that these micro species thrive best in moisture rich environment, this study was carried out in the rainy season. With all other physiochemical parameters relatively constant, responses of these soil microarthropods to three varying concentrations of crude oil spills within the same environment was viewed. A total of 314 soil microarthropods were collected in the crude oil spilled areas over 3 months. While the control site recorded high indices of biodiversity and species richness, the disturbed sites recorded low values with the highest species population size in the site with the lowest spill and vice-versa. Basically, results show that the crustaceans were the most sensitive species, The acarina were the most resistant and dominant while the collembolans were the most resilient groups of soil microarthropods to varying concentrations of the crude oil spills. However, the perturbation also influenced microbial populations as the control site had the highest aerobic viable count while the site with the highest spill had the lowest count.

Key words: Microarthropods, biodiversity, crude, oil

INTRODUCTION

Current paradigms in soil ecology suggest that soil microarthropods play an important role as regulations of organic matter decomposition and soil nutrient fluxes. Indirect effects involving micro-arthropod-microbial interactions are generally considered to be more important than direct effects. Basically, the direct ecological effects of these minute arthropods include the reduction in the mass of organic matter and microbial tissue as a result of their ingestion and assimilation of such materials, their respiration and excretion which is important in influencing the oxygen-carbon dioxide ratio of the soil and the nutrient made available from breakdown of feacal pellets. On the average, their turnover of secondary production on which other organisms way up the food chain depends, is fundamental.

The grazing of the microbial flora of soils by these microarthropods is no longer in doubt. Hence, they both stimulate the growth and productivity of the microbial community, as well as control their numerical strength by grazing on them, on that ecosystem balance is efficiently maintained within optimal limits (Anderson and Ineson, 1985).

Soil micro-arthropods-microbial community relationship is essential in maintaining soil fertility. It becomes important when these microbes are essentially responsible for the biodegradation and remediation of heavy carbon containing soil pollutants i.e., crude oil. Such microbes include organisms of the Genera, *Pseudomonas, Flavobacterium, Arthrobacter* and *Azotobacter* (Larry and Wackett, 2001). The principal effect of oil discharges on the microbial community is one of stimulation,

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especially of heterotrophic organisms, which utilize hydrocarbons as energy source. The consequent effect however, is the increase in oxygen demand of these microbes due to an elevation of microbial and metabolic activities. If there is no additional aeration, oxygen depletion and anoxic conditions sets in and it negatively affects other soil organism, leading to their death.

A number of factors influence the rate of biodegradation including oxygen availability, temperature, the type of soil spilled, the amount of emulsification and the availability of nutrients especially nitrogen and phosphorus.

In Nigeria there are frequent vandalizations or accidental bursting of pipelines which inundate vast areas of farm land and swamps causing untold hardship to farmers and fishermen. There is need for baseline data on possible agents of bioremediation this study aims at.

- Ascertaining the responses of these soil microarthropods to varying concentrations of crude oil spills within a single habitat.
- Viewing the relationship in population dynamics between soil microarthropods and soil microbes (bacteria and fungi) in oil polluted soil.

MATERIALS AND METHODS

The sites where samples were collected and analyzed were monitored at weekly intervals. There were 3 sampling stations marked X_1, X_2 and X_3 measuring 2×2 m in area. They are the same soil type (sandy-loam), well drained, uncultivated and having guinea grass and herbs like *Sida acuta* as coverage.

Station X_1: This was polluted with 0.5 L of crude oil (Atan blend)
Station X_2: This was polluted with 1.5 L of crude oil (Atan blend)
Station X_3: This was polluted with 3 L of crude oil (Atan blend)

The split core sampler was used to collect soil samples from a depth of 10 cm and the samples were placed in black cellophane bags and labeled. These samples (300 g each) were then taken to the laboratory for onward extraction Berlese Tullgren funnel.

Sampling was done fortnightly between 9.00 a.m. and 10.00 a.m. and 2 samples were collected from every station/sub-station at random. These were sorted under a binocular dissecting microscope and individnal species were removed and placed in glass specimen bottles containing 70% alcohol. The slides were prepared and the specimens were identified using appropriate keys.

Other parameters that were monitored and measured included soil pH, soil moisture content, soil temperature, soil total hydrocarbon content. The four soil samples were also examined for total aerobic plate count.

RESULTS

Figure 1(a-f) show variation in bio-diversity and abundance of soil mecroarthopod over a six months period. The total hydrocarbon pH soil temperature and moisture content are shown in Table (1-4).

Generally, soil pH increased with decreasing total hydrocarbon content, decreasing soil temperatures and increasing moisture content from March to May of each station.

With respect to response of soil microarthropod to different concentration of crude oil, spill, there was a significant negative correlation (-0.99), between faunal abundance and crude oil spill, with an appreciably high regression coefficient (-43.94). in terms of species response, as shown by Table (1-3)

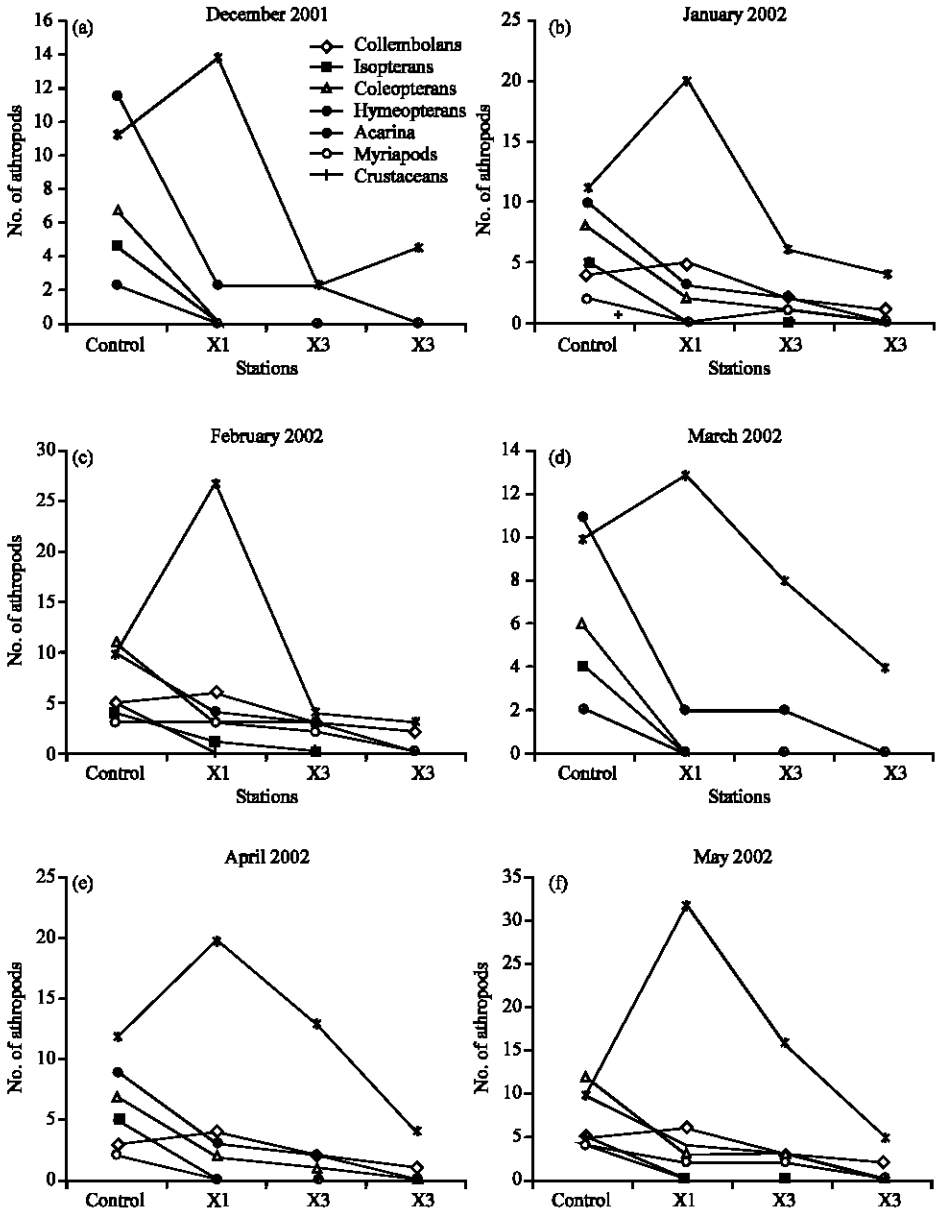

Fig. 1: Distribution of microarthropods for December 2001 to May 2002

with a summation of result in Table 4, the crustaceans were the most sensitive group of soil microarthropod fauna with a significant absence through out the three – month sampling period in the Stations X_1, X_2 and X_3. However, the acarina were the most resistance group of soil microarthropod to varying concentration of crude oil spill and were seen to make up about 52.2% of the total microarthropod (314) collected in the crude oil spilled areas. These mites, especially the oribatid mites had coverage of about 80% in the total faunal composition of Station X3 with the highest spill.

The collembolans were the most resilient group of soil microarthropod with a significant absence in the first month of the spill across the three stations. They however constituted about 12.9% of fauna collected in the second month, 14.28% relative composition in third month of sampling across the three stations and about 20% relative abundance in station X_3 (with the highest spill (3.0 L).

They were the first colonizers after the environmental disturbance and would serve as good agent of bio-remediation.

Hymenopterans were next in abundance to the Acarina with a total of about 16.8% composition followed by the Coleopterans (12.74%).

Table 1: The average monthly distribution of soil microarthropods in station x1 in response to cmde oil spillage (o.5 L), with soil ph, soil temperature, moisture content and total hydro carbon content (THC) readings

		Months					
		December		January		February	
Class	Family	X1	Control	X1	Control	X1	Control
Insecta	Sminthuridae	0.00	0.00	0.00	1.00	0.00	2.00
	Entomobryidae	0.00	0.00	2.00	1.00	5.00	2.00
	Isotomidae	0.00	2.00	3.00	2.00	4.00	4.00
	Rhinotermitidae	0.00	4.00	0.00	6.00	1.00	7.00
	Carabidae	0.00	2.00	2.00	5.00	2.00	7.00
	Chrysomelidae	0.00	3.00	0.00	2.00	1.00	2.00
	Tenebrionidae	0.00	1.00	0.00	0.00	1.00	3.00
	Curulionidae	0.00	1.00	0.00	1.00	0.00	2.00
	Formicidae	2.00	12.00	3.00	10.00	7.00	12.00
Acari	Mesostigmatidae	4.00	7.00	7.00	8.00	12.00	5.00
	Oribatidae	12.00	3.00	18.00	5.00	22.00	6.00
Myriapoda	Symphylidae	0.00	2.00	0.00	2.00	3.00	3.00
	Polydesmidae	0.00	0.00	0.00	0.00	0.00	2.00
Crustacea	Armadillidae	0.00	2.00	0.00	6.00	0.00	7.00
Mean soil pH		6.31	6.41	6.42	6.40	6.92	6.21
Means soil temp (°C)		28.30	29.70	26.40	28.40	25.70	26.20
Mean moisture content (%)		22.50	21.00	24.80	24.30	24.00	23.20
THC (%/PPM)		162.50	50.09	121.50	50.01	107.40	49.20

Table 2: The average monthly distribution of soil microarthropods in station ×2 in response to crude oil spillage (1.5 L), with soil pH, soil temperature, moisture content and total hydro carbon content (THC) readings

		Months					
		December		January		February	
Class	Family	X2	Control	X2	Control	X2	Control
Insecta	Sminthuridae	0.00	0.00	0.00	1.00	0.00	2.00
	Entomobryidae	0.00	0.00	2.00	0.00	3.00	2.00
	Isotomidae	0.00	2.00	0.00	2.00	1.00	4.00
	Rhinotermitidae	0.00	1.00	0.00	6.00	0.00	7.00
	Carabidae	0.00	2.00	1.00	5.00	3.00	7.00
	Chrysomelidae	0.00	3.00	0.00	2.00	0.00	2.00
	Tenebrionidae	0.00	1.00	0.00	0.00	1.00	3.00
	Curulionidae	0.00	1.00	0.00	1.00	0.00	2.00
	Formicidae	2.00	12.00	2.00	10.00	3.00	12.00
Acari	Mesostigmatidae						
	Oribatidae	2.00	7.00	7.00	8.00	6.00	5.00
Myriapoda	Symphylidae	0.00	2.00	1.00	2.00	2.00	3.00
	Polydesmidae	0.00	0.00	0.00	0.00	0.00	2.00
Crustacea	Armadillidae	0.00	2.00	0.00	6.00	0.00	7.00
Mean soil pH		6.79	6.41	6.80	6.40	6.82	6.21
Means soil temp (°C)		28.70	29.70	27.40	28.40	26.30	26.20
Mean moisture content (%)		22.50	21.00	24.70	24.30	24.10	23.20
THC (%/PPM)		506.50	50.09	203.03	50.01	194.80	49.20

Table 3: The average monthly distribution of soil microarthropods in station x3 in response to crude oil spillage (3.0 L), with soil ph, soil temperature, moisture content and total hydro carbon content (THC) Readings

		Months					
		December		January		February	
Class	Family	X3	Control	X3	Control	X3	Control
Insecta	Sminthuridae	0.00	0.00	0.00	1.00	0.00	2.00
	Entomobryidae	0.00	0.00	1.00	0.00	2.00	2.00
	Isotomidae	0.00	2.00	0.00	2.00	0.00	4.00
	Rhinotermitidae	0.00	4.00	0.00	6.00	0.00	7.00
	Carabidae	0.00	2.00	0.00	5.00	0.00	7.00
	Chrysomelidae	0.00	3.00	0.00	2.00	0.00	3.00
	Tenebrionidae	0.00	1.00	0.00	0.00	0.00	3.00
	Curulionidae	0.00	1.00	0.00	1.00	0.00	2.00
	Formicidae	0.00	10.00	0.00	12.00	0.00	12.00
Acari	Mesostigmatidae	1.00	7.00	2.00	8.00	1.00	5.00
	Oribatidae	3.00	3.00	3.00	5.00	4.00	6.00
Myriapoda	Symphylidae	0.00	2.00	0.00	2.00	0.00	3.00
	Polydesmidae	0.00	0.00	0.00	0.00	0.00	2.00
Crustacea	Armadillidae	0.00	2.00	0.00	6.00	0.00	7.00
Mean soil pH		6.07	6.41	6.32	6.40	6.77	6.21
Means soil temp (°C)		28.80	29.70	28.20	28.40	27.50	26.20
Mean moisture content (%)		22.40	21.00	24.60	24.30	24.40	23.20
THC (%/PPM)		1224.50	50.09	483.20	50.01	127.40	49.20

Table 4: The combined results of the distribution of the different soil microarthropods groups in stations X1-X3 and control station (CTRL), with soil pH, soil temperature, soil moisture and total hydro carbon content readings

	Months											
	March				April				May			
Groups	CTRL	X1	X2	X3	CTRL	X1	X2	X3	CTRL	X1	X2	X3
Collembolans	2.00	0.00	0.00	0.00	3.00	5.00	2.00	1.00	8.00	9.00	4.00	2.00
Isopterans	4.00	0.00	0.00	0.00	6.00	0.00	0.00	0.00	7.00	1.00	0.00	0.00
Coleopterans	7.00	0.00	0.00	0.00	8.00	2.00	1.00	0.00	14.00	4.00	4.00	0.00
Hymenopterans	12.00	2.00	2.00	0.00	10.00	3.00	2.00	0.00	12.00	7.00	3.00	0.00
Acarians	10.00	16.00	9.00	4.00	13.00	25.00	15.00	5.00	11.00	34.00	24.00	8.00
Myriapods	2.00	0.00	0.00	0.00	2.00	0.00	1.00	0.00	5.00	3.00	2.00	0.00
Crustaceans	2.00	0.00	0.00	0.00	6.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00
Mean soil Ph	6.41	6.31	6.79	6.07	6.40	6.46	6.80	6.32	6.21	6.92	6.81	6.77
Mean soil temp (°C)	29.70	28.30	28.70	28.80	28.40	26.40	27.40	28.20	26.20	25.70	26.30	27.50
Mean moisture Content (%)	21.00	22.50	22.50	22.40	24.30	24.80	24.70	24.60	23.20	24.00	24.20	24.40
THC (%/ppm)	50.09	162.53	506.51	1224.52	50.01	121.51	203.33	483.21	49.20	107.40	194.80	127.50

Table 5: Result of total aerobic viable count at 31°C for 24 h

Dilutions	Colony counted (cfu/g)
Station X_1 (0.5 L)	
10^{-1}	$40 = 4\times10^{2}$
10^{-2}	$17 = 17\times10^{3}$
10^{-3}	$8 = 8\times10^{5}$
10^{-4}	$4 = 4\times10^{4}$
Mean Count = 17×10^{5}	
Station X_2 (1.5 L)	
10^{-1}	$65 = 6.5\times10^{2}$
10^{-2}	$37 = 3.7\times10^{3}$
10^{-3}	$20 = 8\times10^{4}$
10^{-4}	$12 = 1.2\times10^{5}$
Mean Count = 33.5×10^{5}	

Table 5: Continue

Dilutions	Colony counted (cfu/g)
Station X_3 (3.0 L)	
10^{-1}	$17 = 6.5\times10^{3}$
10^{-2}	$9 = 3.7\times10^{2}$
10^{-3}	$3 = 8\times10^{3}$
10^{-4}	$1 = 1.2\times10^{4}$
Mean Count = 7.5×10^{4}	
Control Station	
10^{-1}	$448 = 4.48\times10^{3}$
10^{-2}	$27 = 2.7\times10^{3}$
10^{-3}	$6 = 6\times10^{3}$
10^{-4}	$3 = 3\times10^{4}$
Mean Count = 4.6×10^{5}	

Microbial count result from analysis carried out at the end of the sampling period as a baseline data, because of their significance in the soil ecosystem balance shows varied population in different dilutions of samples from stations X_1-X_3 and Control station. The control station recorded the highest mean count of 4.6×10^{5}, while station X_3 had the lowest mean count of about 7.5×10^{9} as shown in Table 5.

DISCUSSION

The hydrocarbon content of the soil, with respect to the various stations that experienced the crude oil spills was taken to monitor the bioremediation rates. On addition of the crude oil, the plant species on and around the sites began to diminish after two weeks. The rates were highest in the site with highest concentration of spill and vice-versa. Yellowing of leaves prevailed till the end of sampling in Station X_1 though a recovery was noticed after two weeks, while station X_3 failed to recover till the end of sampling. The reason for this could be associated with the subsequent decrease in soil microarthropods and microbes abundance as a result of the toxicity of the crude oil (Duncan *et al*., 2003).

Soil temperatures increased with increasing spills of crude oil. This could be linked with the hyper stimulation of hydrocarbon degrading microbes in the event of such spills. The resultant effect is an increase in metabolic rates and a subsequent increase in heat production.

Bacterial numbers generally outnumbers the population other microbes in natural ecosystem. Hassink *et al*. (1993) have found that in soils they studied, the mass of soil bacteria was 9 times as great as the combined mass of fungi, protozoa and nematodes. Bacterial counts are essential to understand the microbe-micro arthropod relationships in disturbed soils.

It is important to note that the mean microbial count was highest in the control station and lowest in the station with the highest concentration of spill (Station X_3). The patter of this relationship is towards maintaining ecosystem balance. The spore dispersal potential of the microarthropods may be responsible for this microbial abundance. There is also a possibility that the process of comminution may be responsible for this microbial growth. The collembola may be actively involved as observed by Shaw (1988). Comminution is the breakdown of the organic matter into smaller particles, which allows more moisture to reach the substrate and attack, thus increasing growth rate of bacteria and fungi and accelerating the process of decomposition. However, these groups were represented in the control stations. Basically, soil microbes are significantly affected by fluctuations in their enviroumental optimum conditions. Their neutral pH mark preference is also important. Station X_2 had a uniform soil pH level across the three months with an average of 6.80 (near neutral mark of 7.0) and this could be the reason for it's rather high microbial count.

On the average, increase in concentration of crude oil spills had an adverse effect on microbial distribution. It merely stimulated the hydrocarbon degrading microbes, but renders other forms inactive. Station X_3 had both the lowest abundance of micro-arthropods and microbes in the same way that the control station had the highest peaks for both. There seems to be a mutual (symbiotic) relationship between the microarthropods and the microbial community. Such that increase in one gives a corresponding increase in the other. It was summarized in the study of Set *et al*. (1990), who noticed in an experiment involving micro flora with and without microarthropods. He found increased levels of N and P availability with the presence of microarthropods. The summary of the symbiotic relationship is that while the microarthropods make nutrient available to these microbes, increase the surface of activities by comminution, disperse their spores (propagules), the microbes serves as food sources to them. This regulates their population and prevents overcrowding.

Finally, the Acarina increased substantially in numbers across the spill season, maybe because of their structural adaptations, as well as their operating a more or less monopolistic tendency in feeding, besides the absence of competition.

In conclusion the various populations or the biotic community of an established ecosystem is generally stable. However, the ability of a system in equilibrium to recover from a disturbance is an indication of its resilience. The biodiversity studies shows that disturbance in the form of crude oil pollution disrupted the activities of soil microarthropods rendering some dead and others redundant. If indeed these soil microarthropods are functionally essential in maintaining soil ecosystem balance, their individual responses to perturbations becomes crucial.

With the identification of sensitive, resistant and resilient species of soil microarthropods to crude oil pollution, it becomes easier to specify species that could serve as good bio-indicators of soil pollution. It has been proposed that there exist a strong inter-relationship between soil microarthropods and soil microflora (bacteria and fungi) which seem somewhat symbiotic in nature. Hence, soil microarthropods could also serve as good agents of bioremediation of organic pollution since microbes are functioually responsible for the break down of organic pollutants.

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