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Full Length Research Paper

Soil arthropods recovery rates from 5 – 10 cm depth within 5 months period following dichlorov (an organophosphate) pesticide treatment in designated plots in Benin City, Nigeria

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Soil arthropods recovery rate was monitored for five months (April - August) 2007 to ascertain whether the application of dichlorov (an organophosphate) pesticide, in varying concentration levels of 0 L(control), 0.25 L (low) and 0.75 L (high) per 25 m^2 would adversely affect the rate of sampling soil arthropods within a 5 - 10cm depth. Berlese Tullgren Extraction method, sorting and identification of sampled species were adopted and soil physiochemical properties were measured. Insects from eight different groups were consistently sampled. They are members Collembola, Coleoptera, Acarina and Isoptera. Others include Hymenoptera, Myriapoda, Crustaeca and Arachnida. There was an initial decrease in the monthly number of sampled soil arthropods in the treated plots from April to May but increased from June to August. Members of Acarina, Coleoptera and Myriapoda showed the highest fauna abundance while species from Hymenoptera, Crustaeca and Arachnida showed least fauna abundance. Members of Acarina (mites) exhibited the highest recovery rate while Arachnidan species were least. The result revealed that, the mean number of sampled soil arthropods was significantly different ($p < 0.05$) on the basis of the amount of dichlorov pesticide concentration used compared with the control with high concentration region being the most toxic to the arthropods, hence recording the least number of sampled soil arthropods. On the basis of concentration of applied organophosphate, the soil hydrocarbon content (0.03 - 3.95), soil pH (6.3 - 6.9), soil temperature (25.0 - 29.7°C) and soil moisture (3.2 - 6.9) were not significant ($p > 0.05$). However, increase in soil moisture from April to August was observed to result in the increase in mean numbers of soil arthropod groups sampled. The implication of this study is that, the depth of 0 - 5 cm mark into the soil litter is not the only arthropod bound zone and soil micro arthropod abundance in the soil is dependent among others on the concentration of pesticide applied. Where application is not indiscriminate, soil micro arthropods have high recovery rate which could enhance high productivity from the soil in the long run.

Key words: Dichlorov, organophosphate pesticide, soil, microarthropod, recovery rate, Benin City.

INTRODUCTION

The soil can be referred to as a world of its own life and biodiversity, consisting of various forms of life in an endless series of interlinked caves with lots of food and stable environmental conditions like a rainforest (Williams, 1999). It is a natural body, comprised of solids, liquids and gases that occur on the land surface, occupies space, and is characterized by one or both of the following; horizons, or layers that are distinguishable from the initial materials as a result of additions, losses, transfer and transformations of energy and matter or the ability to support rooted plant in a natural environment (Coleman, 2000). Soil is not a solid indivisible block but

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consist of innumerable number of pores. Life in the soil is lived on a micro scale and these small pores are largely habitable spaces to organisms that use them including micro arthropods. Soil pore size and number play important role in the population structure and ecology of the soil. Soil dwelling organisms include bacteria, fungi, nematodes, protozoa, molluscs, arthropods and even some vertebrates.

Soil arthropods are a vital link in the food chain as decomposer and without these organisms, nature would have no way of recycling organic material on its own (Trombetti and Williams, 1999). The process of decomposition are controlled largely by soil arthropods in conjunction with some soil invertebrates like protozoa and worms which also contribute to the soil community by mixing, loosening and aerating the soil (Evans, 1984). There is therefore an increasing need to ascertain the ease with which these valuable soil dwellers that contribute immensely to soil fertility and general nutrient recycling processes in nature to be studied on the premise of their ability to re-colonise pesticide treated farmlands.

Many studies have found that community structure, abundance and diversity of soil micro arthropods are influenced by the availability of organic matter, substrate quality, concentrations of macro and micro nutrients, and age and biodiversity of the rehabilitating habitat (Loranger et al., 1998). Environmental fate and behaviour of source component (e.g. mobility, volatility and biodegradability) is affected by time and edaphic factors (e.g. soil organic matter content, moisture, temperature and pH), and biological activities and management such as tillage, nutrient addition, moisture or thermal manipulations all interact to make possible predictions of toxic concentration from gross parameters (Mehlman, 1992).

A number of workers have studied the effect of insecticides or pesticides on the ecosystem. Among them are Brown and Gange (1989); Frampton (1994); Janseen et al. (2006); Trombetti and Williams (1999); Jones and Hopkin (1996); Reed (1997) and Frouz (1999). In their various work, they examined the toxic effects of the pesticides as well as the responses of the individual groups and the consequences of other environmental factors. Badejo (1982); Badejo and Akinwole (2006) and Badejo et al. (2002) emphasised the relationship between soil moisture content and the density of micro arthropods within the 0-5 cm soil litter. This present work became imperative In view of the numerous benefits accruing from the continual presence of soil micro arthropods to the field of Agriculture and ecosystem balance. Its strength is also hinged in the fact that, the use of pesticides (organophosphates) on soil in farmland management has become a general routine by farmers and Agriculturists and research data focussed on the deeper earth are few. These have prompted this investigation on the rate of recovery of soil micro arthropods within 5 - 10 cm depth, following treatment with organophosphate (dichloroy) pesticide.

MATERIALS AND METHODS

Study area

This study was carried out at the Research Field of Animal and Environmental Biology Department of the University of Benin, Ugbowo main Campus, Benin City. It is situated on the Southern part of Nigeria (6° 19'N°, 6° 36' E), located in the rain forest zone of humid tropic. Benin City is characterized by both rainy and dry seasons, with rainy season and dry season lasting March to October and November to March respectively.

Sampling sites

The investigated area is an expanse of land measuring about 10 × 10 m of the study area. The study area was delineated into four stations numbered 1, 2, 3 and 4. Each station was further divided into three sub- stations marked as A, B and C thus giving a total sampling units of twelve (12) . Sub-stations A, B and C represented field areas treated with 0.75 L of wide spectrum organophosphate pesticide in 20 L of water, 0.25 L of wide spectrum organophosphate pesticide in 20 L of water and 20 L of water respectively. By these formulations, Sub-stations A, B and C represented field areas with high concentration of organophosphate, low concentration of organophosphate and Control respectively. The sub-stations were well delineated and marked out as presented in Figure 1 to avoid any form of interference.

Collection and extraction

Samples from the stations were collected with a split core sampler (5 × 5.7 cm). Collection of soil samples was done on fortnight basis from April - August (months). The split core sampler was first pushed into the soil by the vertical application of pressure which was used to turn the split core sampler until it reached the 5 cm mark. This exercise was used to remove the top 0 – 5 cm before repeating the same exercise to sample the 5 - 10 cm depth. The obtained soil samples from the different stations and sub-stations were placed in separate black cellophanes and labelled accordingly. This was followed by their movement to the Laboratory where the multifaceted extractor (Berlese Tullgren Funnel) was adopted. Extraction methods were designed to suit, behaviours and body structures of the organisms (Wallwork, 1970). The Berlese Tullgren funnel extractor is best for extracting soil micro arthropods with efficiency of about 90% (Hopkins, 1997). A volume of 128cc of soil sample was placed on the sieve mesh size of (1 mm) at the top of each funnel and the organisms collected in containers with 70% alcohol within 3 days.

Sampling was done fortnightly between the hours of 10 - 11 am and 12 samples were collected at each sampling period from all stations.

Sorting and preservation

After the organisms were extracted and collected, they were immediately sorted under a binocular dissecting microscope where individuals were removed from the lot by using a sucking pipette. Individual species were then placed in separate specimen bottles with 70% alcohol for preservation and were later mounted and used for identification.

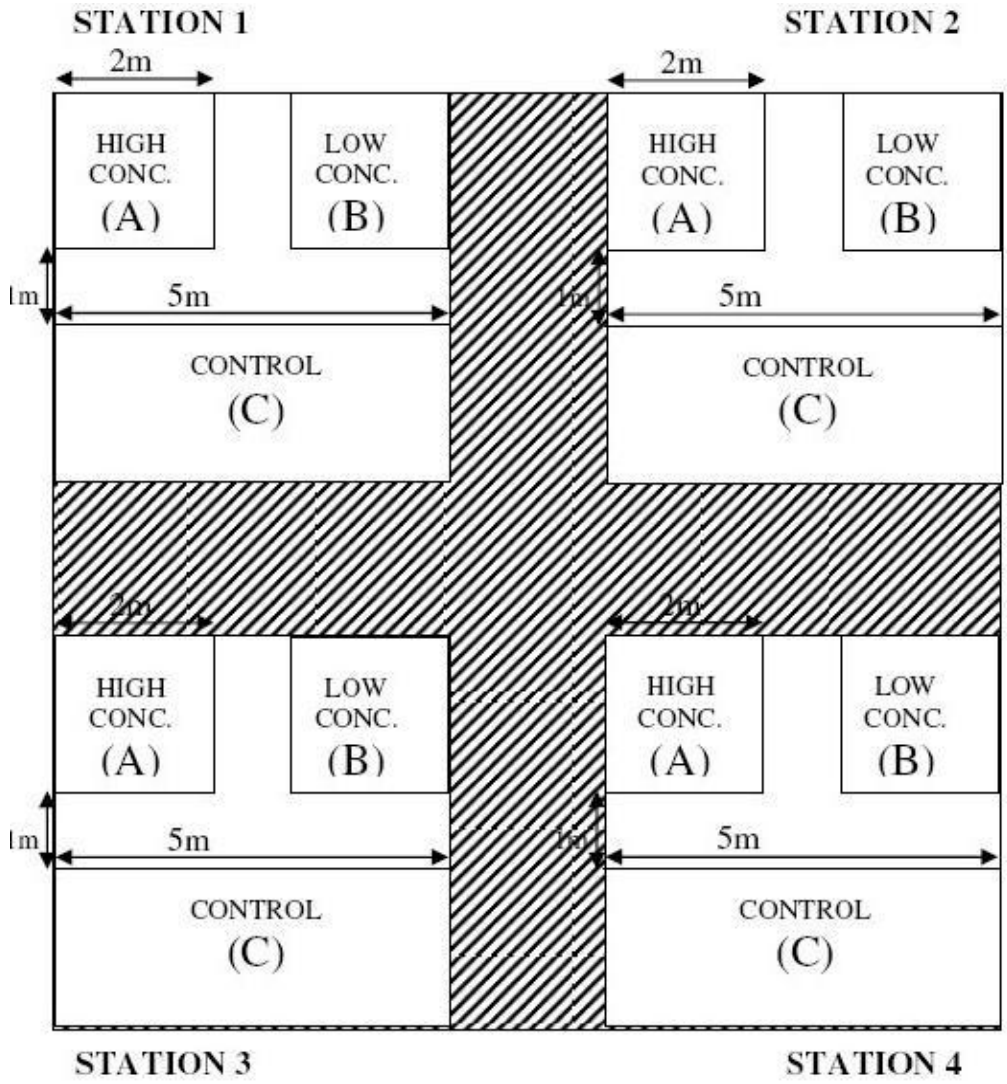

Figure 1. Description of the experimental layout adopted.

Preparation of slides

As result of the small sizes of organisms involved, it was necessary to mount them on slides for examination. The method of making permanent slide described by Hopkin (2000) was adopted to mount the organisms in Canada balsam.

Identification of collected soil micro arthropods species

Species identification was carried out at the International Institute for Tropical Agriculture, Entomology Unit, Ibadan, Nigeria.

Measurement of physiochemical parameters

Soil pH, soil temperature and soil moisture content were the parameters monitored and measured.

Soil pH: The method described by Bate (1954) was adopted. 20 g of air dried soil from each station collected from 5 - 10 cm below the soil surface was put in a 50 ml beaker and 20 ml of distilled water was added and allowed to stand for 30 min. The mixture was stirred occasionally with a glass rode. The electrode of each pH meter was then inserted into partly settled suspension from each station and reading recorded. The pH meter was calibrated to 7.0, pH 4.0 before use with soil pH readings taken fortnightly.

Soil moisture content: 50 g of soil sample each from the stations were collected from the 5 - 10 cm below the soil surface and weighed and were thereafter placed in the oven for 24 h till constant weights were obtained.

Final weight of sample recorded
Loss in weight = initial weight – final weight

$$\text{Soil moisture content in \%} = \frac{\text{loss in weight} \times 100}{\text{Oven dried}}$$

The soil moisture content was also taken fortnightly along with the sampling time of other parameters.

Soil temperature: Temperature readings were collected between

Table 1. Monthly Mean number of soil micro arthropods sampled at the different concentrations (±S.D).

Sampling months	Conc. (pesticide vol. in litres per 20 L of water)	Mean numbers of arthropod sampled (±S.D)
April	.00	7.25 ± 4.37[a]
	.25	4.00 ± 2.45[b]
	.75	3.63 ± 2.50[c]
May	.00	6.75 ± 3.15[a]
	.25	0.50 ± 1.07[b]
	.75	0.00 ± 0.00[b]
June	.00	10.88 ± 5.87[a]
	.25	3.25 ± 2.38[b]
	.75	2.25 ± 1.91[b]
July	.00	13.88 ± 6.42[a]
	.25	8.63 ± 5.60[b]
	.75	6.63 ± 3.38[c]
August	.00	16.25 ± 8.21[a]
	.25	11.25 ± 4.46[b]
	.75	9.38 ± 4.17[b]

Each value is the mean of four replicates. Means followed by the same letter are not significantly different (P > 0.05) from each other, using New Duncan's Multiple Range Test.

8 – 9 am in the morning and 5 - 6 pm during the evening hours. Temperature reading was achieved by digging first a small 5 cm deep and 5 cm wide hole followed by the insertion of a thermometer so as to enable a depth of the lower 5 - 10 cm to be covered. Reading on the thermometer was obtained after 2 min. This was repeated thrice and average value taken for both the morning and evening sampling periods.

Soil total hydrocarbon: The soil total hydrocarbon was determined using a spectrophotometer, pipette, and 250 ml separating glass funnel, mechanical shaker and n-hexane. A 5 g weight of soil from each site collected from 5 - 10 cm deep was dried and kept in bottle containers. To each bottle container was added 25 ml of n-hexane to extract the soil total hydrocarbon from the soil. These were placed on the mechanical shaker and shaken for 10 min to ensure thorough mixing and thereafter left to stand. A standard of n-hexane was prepared and used to standardize the spectrophotometer before introducing the THC from the soil into the spectrophotometer for the absorbance reading. The soil total hydrocarbon content (THC) concentration in part per million for each was then calculated as follows;

Soil total hydrocarbon content (ppm) = Instrument Reading × Reciprocal of slope × 25 ml/5 g

Where; Instrument reading (IR) was from the spectrophotometer.

The reciprocal of slope was calculated for each based on spectrophotometer reading,

Volume of extraction reagent was 25 ml,
Weight of each soil sample used was 5 g.

RESULTS

The monthly mean number of soil micro arthropods from the different plots (stations) treated with varying concentrations is presented in Table 1. Monthly mean number of sampled arthropods from the treated stations significantly decreased from April to May (high conc. 3.63 - 0.00; low conc. 4.00 - 0.5) and increased steadily from June to August (high conc. 2.25 - 9.38; low conc. 3.25 - 11.25). Though a monthly mean decrease of arthropod sampled was observed from April to May (7.25 - 6.75) in the control station, this was insignificant compared to decreases recorded in the treated stations for the same period. It is also pertinent to note that, the decrease recorded in the treated stations was more pronounced in the plot treated with more of the pesticide as presented in Table 1.

The soil micro arthropod groups showed varying mean values within the 5 months period of investigation. The mean number of soil micro arthropod group sampled is presented in Table 2 and Figure 2. For all soil arthropod groups implicated in this investigation, the level of concentration of organophosphorous pesticide used significantly affected the mean number of sampled soil arthropod group. The least number of soil arthropods was sampled from the plot treated with higher concentration of pesticide compared with the plot treated with low concentration while the control plot recorded the highest number of soil arthropods sampled. On group abundance, members of Acarina, Coleoptera, and Myriapoda were most abundant while Arachnida and Crustacea were least in abundance as presented in Table 2.

The mean value of investigated physiochemical parameters (soil temperature, soil moisture, soil pH and Soil hydrocarbon) is present in Figure 3. The period, April to

Table 2. Mean number of soil micro arthropods sampled at the different concentrations (±S.D).

Soil microarthropod groups	Conc. (pesticide vol. per 20 L of water)	Mean numbers of arthropod sampled (±S.D)
Collembola	.00	9.4 ± 2.88[a]
	.25	5.4 ± 4.34[b]
	.75	3.8 ± 2.59[b]
Coleoptera	.00	16.8 ± 6..30[a]
	.25	7.4 ± 5.32[b]
	.75	6.6 ± 5.64[b]
Isoptera	.00	9.0 ± 4.47[a]
	.25	3.6 ± 3.05[b]
	.75	3.2 ± 2.77[b]
Hymenoptera	.00	7.6 ± 2.51[a]
	.25	4.0 ± 3.08[b]
	.75	4.0 ± 2.74[b]
Acarina	.00	17.6 ± 6.69[a]
	.25	9.6 ± 6.50[b]
	.75	7.4 ± 5.55[b]
Myriapoda	.00	13.6 ± 6.69[a]
	.25	9.4 ± 7.80[b]
	.75	6.0 ± 6.48[c]
Crustacea	.00	5.2 ± 2.28[a]
	.25	2.8 ± 2.77[b]
	.75	2.6 ± 2.61[b]
Arachnida	.00	4.8 ± 2.05[a]
	.25	2.0 ± 3.08[b]
	.75	1.4 ± 2.19[c]

Each value is the mean of four replicates. Means followed by the same letter are not significantly different ($p > 0.05$) from each other, using New Duncan's Multiple Range Test.

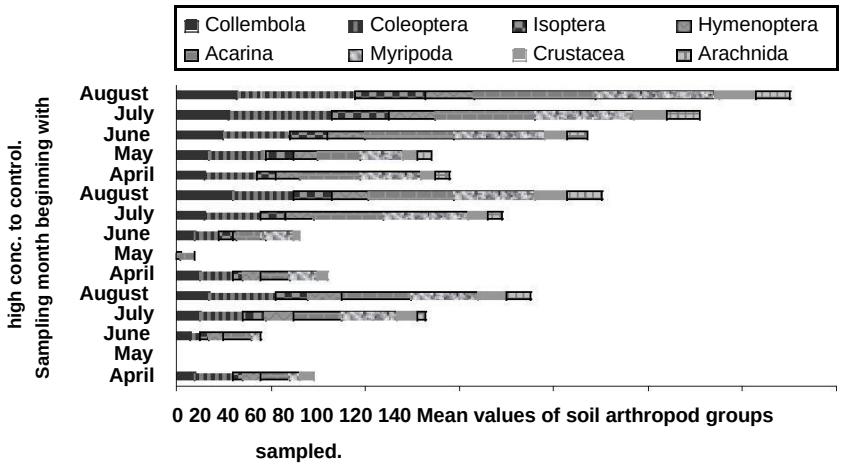

Figure 2. Monthly mean number of soil arthropod groups sampled progressively from High concentrated stations to controlled ones.

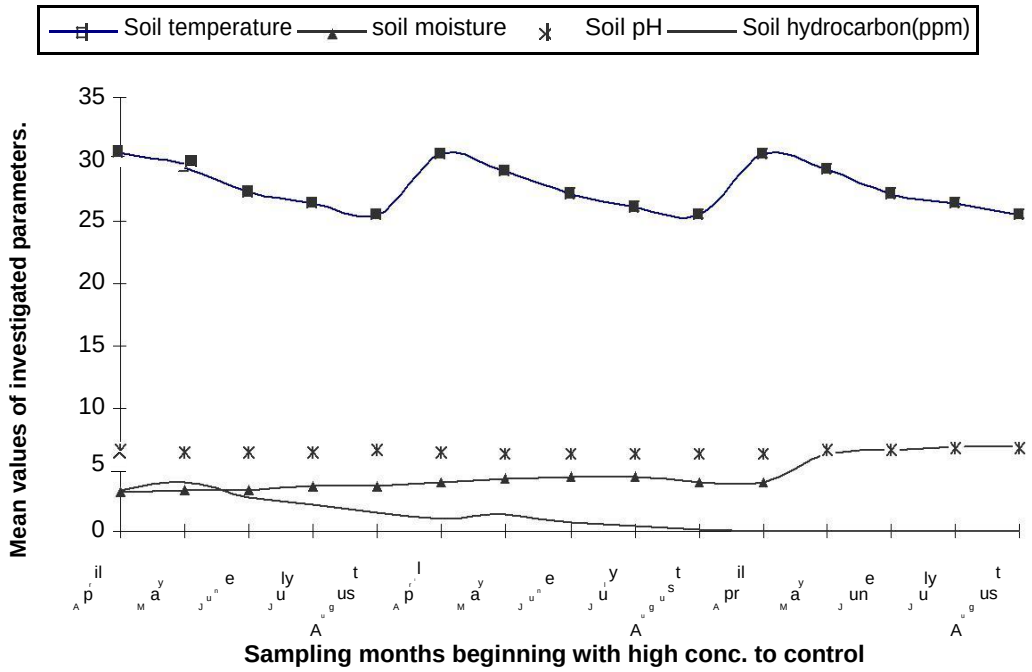

Figure 3. Mean values of investigated parameters.

August recorded decrease in mean value of soil temperature (29.6 - 25.0°C) while there was increase in soil moisture (3.2 - 6.9) irrespective of plots. However, Soil hydrocarbon content decreased from April to August in treated stations with no net change in values in the control station (High Conc. 3.36 -1.59; Low Conc. 1.12 - 0.22; Control 0.03 - 0.03) for the period. Soil pH mean values did not significantly change within the period.

DISCUSSION

Many workers including Badejo (1982) and Badejo and Akintola (2006) have emphasised that, most soil fauna especially the orbited mites enjoy better conducive micro environment within the top 5 cm of soil. The high number of soil arthropods sampled from the 5 - 10 cm depth in this investigation is an indication that, the soil ecosystem is not just a world with array of different species of life but the number that could be found per time at given depths is dependent among other factors, on the physiochemical nature of the soil at that time. This is an affirmation of the richness of the soil ecosystem when viewed from a broad perspective as soil arthropods are one group of living organisms found in the soil. Similar observation was made by Williams (1999). The monthly mean number of arthropod and the fluctuation (increase or decrease) shown in Table 1 and Figure 2 during the period could be attributable to two factors. One possible reason for the initial decrease in the number of soil arthropods as observed in the plots treated with the pesticide from April to May was perhaps the toxic effect of the dichloroy (an organophosphate pesticide) that was applied to the affected plots. The toxic effect of this pesticide has the ability to create harsh environment that could cause death of the soil fauna, thereby preventing them from responding to the extraction method of light rays. This would lead to low number of arthropod that could be sampled. This observation agreed with the ones earlier made by Frouz (1999); Jones and Hopkins (1998); Reed (1997) and Frampton (1994). Though they were not particular on the monthly decrease or increase, they observed that, the application of pesticide affects the environmental condition, thus affecting the number of micro arthropods present in such treated areas. Also significant in the reason for the decrease in the treated plots within April to May period is the amount of decrease observed in both the high and low pesticide concentrated treated plots. The reduction in number of soil arthropod was significantly more in plot treated with high concentration of the pesticide which recorded a zero value in the month of May. This could imply that, more concentration of pesticide would either have caused more of the soil arthropod to die or due to more toxic harsh environment created; it would lead to more downward migration of soil arthropods dwelling there. Hence, the justification for the differences in the arthropod reduction between high and low concentrated plots compared to the control. Significantly, the observed arthropod increase (June - August) after the period of decrease (April to May) may probably be due to either the effect of dilution of water on the pesticide (as its coincided with wet season), temporary absence of parasites or due to the low persistence nature of the pesticide (dichlorov) which ranges between 4 - 8 weeks.

Arthropod species richness in soil is not contestable as 8 groups were consistently sampled. The arthropod groups and how the concentration of the pesticide affected the number sampled are presented in Table 2. The survival and re-colonisation ability of individual insect groups differs. Members of the Acarina were more abundant followed by Coleoptera and Myriapoda while members of Arachnida and Crustacea groups were least in abundance. All arthropod groups implicated were affected by the level of pesticide concentration used as none was sampled in the month of May. Members of Collembola, Isoptera and Hymenoptera groups exhibited the weakest ability in being able to withstand the application of the pesticide as they were observed to have drastically reduced between May and June but resurfaced strongly in July. This drastic reduction in these groups of soil fauna could be as a result of their soft body which possibly offered least protection against the toxicity of the pesticide. The soft-bodied morphology contrast those of Coleoptera, Myriapoda and Crustacea which enjoy protection based on morphological toughness and fast movement away from areas of contamination. Though the Hymenopteran, Collembolan and Isopteran groups showed least ability among others to withstand the application, they exhibited a great tendency to re-colonise with Acarina group showing the greatest tendency of re-colonisation of the treated areas while Crustacean was least as shown in Figure 2. This may have been facilitated by two factors. It might be that, either the pesticide affected the parasites or predators that parasitise or prey on these groups of soil fauna or the toxicity of the pesticide reduced considerably, thus leading to an initial rapid increase in their numbers from July to August as shown in Figure 2.

The soil pH, soil temperature and soil moisture content did not significantly varied among the different areas treated with the different concentrations of dichlorov pesticide and the control. Though these parameters did not vary significantly, field observation revealed a steady increase in soil moisture as the period coincided with rainy season. This increase in soil moisture shown in Figure 3 was observed to lead to increase in soil fauna sampled. This observation is similar to that made by Badejo (1982), when he asserted that there was an increase in the density of soil arthropods with increase in soil moisture. Increased soil water has the ability to dilute the pesticide thereby reducing its toxic effect on both the soil fauna and the environment. However, the concentration of pes-ticide used resulted in varying amount of THC in (ppm) in the studied stations. The station treated with high concentration of pesticide recorded highest mean of 0.41 ppm while the control station obtained least mean value of 0.03 ppm. The increase in total hydrocarbon content in the stations treated with the pesticide may be due to the chemistry of the applied pesticide, thus leading to the THC values of treated stations as compared to the control in Table 2. How this increase in THC value affected the sampled soil micro arthropods was not clearly understood in this investigation.

The findings of this investigation have significant implications. Whereas, one would have thought that, pesticide application could have a persistently reducing effect on the soil fauna, it revealed that all things being equal, arthropod reduction is with time and re-colonization after a period is imminent. This notion tends to alleviate the fears of soil ecosystem imbalances as a temporary phenomenon with no much adverse effect on the productivity ability of the soil in the long run when the pesticide is not indiscriminately applied. Also, the depth below the immediate zone of litter fermentation is significantly important due the number of soil arthropods it houses. It is expected that more research would be focussed on even deeper depth for the purpose of comparism of arthropod groups on the basis of depth.

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