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IMPACT OF MANAGEMENT PRACTICES IN COCOA FARMS ON SOIL DWELLING ARTHROPODS IN THE EASTERN REGION OF GHANA

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ABSTRACT

In Ghana, several farm management practises are employed by cocoa farmers to control insect pests in cocoa farms. In present study, four plots of the Cocoa Research Institute of Ghana, New Tafo-Akim, Ghana, were monitored for four months (October 2014 – January 2015) to determine the impact of farm management practices on abundance and richness of soil arthropods within the litter and 0-10 cm depth of the soil. Berlese funnel extraction method was used for the extraction of the litter and soil arthropods. From each of the plots, soil surface litter was collected from five randomly selected spots from a 0.3 X 0.3 m quadrat. The soil was collected using a PVC Core sampler with a diameter of 76.2 mm and height 10 cm. Soil arthropods in the taxa Collembola, Acarina, Hymenoptera, Araneae, Diptera, Coleoptera, Blattaria and Myriapoda were collected from the litter and soil of the studied quadrats. Among these, Collembola, Acarina and Hymenoptera constituted the most abundant while Araneae and Blattaria were collected in less numbers. The use of herbicides as a farm management practice to control weeds had significant effect on Collembola, Acarina and Araneae in the litter and on Diptera and Myriapoda in the soil. The soil physicochemical parameters (soil pH, soil moisture content and soil hydrocarbon) had no significant effect on the abundance and richness of soil arthropods. However, soil pH within the farm management system was observed to have a significant effect on the richness and abundance of soil arthropods.

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1 Introduction

Cocoa (*Theobroma cacao* L.), is cultivated as an economic crop in 58 countries and on more than 17 million acres (6.9 million ha) worldwide, with 72% of the production in West and Central Africa (Francis & Clay, 2007). About six million people depend on its farming (Baah & Garforth, 2008; Fairtrade Foundation, 2015).

So far, Cocoa is most important agricultural export crop of Ghana (Dormon et al., 2004; Kolavalie & Vigneri, 2011), contributing more than 40% of total export revenue and about 20% of Ghana's GDP (Fiamor, 2005). In 2010/11, Ghana cocoa exports reached a record high of 1,004,000 MT and Ghana continues to maintain its position as the world's second largest exporter of cocoa after Ivory Coast (Cocoa Report, 2012; Fairtrade Foundation, 2015). The popular saying ''cocoa is Ghana, Ghana is cocoa'' depicts the significance of cocoa production in Ghana (GCB, 2015).

The cocoa bean is an economically important portion of the crop and is the raw material for chocolate, cocoa powder and different sorts of confectioneries and beverages. By-products from cocoa are used for beverage, pomade and detergents. The pod husk is processed into feed for livestock production (Asare, 2011), and potash for soap and fertilizer.

Regardless of the efforts to revamp cocoa production in Ghana and other producing countries, the incidence of pests and diseases continues to remain a major problem (Dormon et al., 2004; ICCO, 2010). As reported by Dormon et al., (2007), annually 30% of the cocoa produced in Ghana is lost due to pests and diseases.

Further, Sarpong-Akosa (2001) observed that pests and diseases management practices especially for the management of mirids attack and black pod disease in cocoa production is heavily dependent on synthetic pesticides and as a result, the Cocoa Diseases and Pests Control Programme (CODAPEC), dubbed "Mass Spraying", was re-introduced in 2001. The programme has also enhanced the effective and efficient application of good agriculture practices alongside fungicides spraying to achieve improved yields. The agricultural use of chemical agents to control pests has been practiced since the latter part of 19th century (Cherry, 2006). Worldwide pesticide use in 1997 was estimated at 2.58 billion kg (Aspellin et al., 1992; Kumar & Kumar, 2007).

Soil represents one of the most important reservoirs of biodiversity, reflecting ecosystem metabolism since all or most bio-chemical processes of different ecosystem components are combined within it. Soil fauna is an important reservoir of biodiversity and play essential role in several soil ecosystem functions (Cole et al., 2005). Soil arthropods are abundant small invertebrates that live in the soil and litter layer. Typical arthropods in such environments include mites, springtails, pseudoscorpions, ants, termites, Isopoda, Myriapoda and insect larvae (Ruiz et al., 2008).

Addison et al. (2007) stated that, frequent pesticide application caused soil and environmental degradation and this has led to a substantial reduction and the simplification of animal and plant communities. Species that are able to withstand stress predominate and those taxa that were once abundant and not resistant, disappeared.

With increased pesticide use, questions on potential effects regarding public health and the environment have emerged, especially when pesticide applied at rates higher than recommended, accidental spills or long *in-situ* residence time in soil are some common issues which associated with the application of pesticides. It is therefore necessary to investigate the relationship between farm management practises and soil fauna because information regarding this topic is limited (Lindsey et al., 2013). Therefore, this study has been conducted to determine the impacts of farm management practices in cocoa farms and on soil dwelling arthropods.

2 Materials and Methods

2.1 Experimental site

The study was conducted at the Cocoa Research Institute of Ghana (CRIG), New Tafo-Akim, in the Eastern Region of Ghana and the Entomology laboratory, Department of Crop and Soil Sciences, Faculty of Agriculture, KNUST, Kumasi, Ghana. New Tafo-Akim was selected for the study because wide range of documentation on the farming activities and pesticides use are available for this area. Pesticide application in these cocoa plots is all-year-round due to the CODEPEC spraying programme. Additionally, New Tafo-Akim hosting CRIG is a well-known cocoa production area in Ghana since the early 1920's (Dade, 1937).

New Tafo-Akim is in the forest zone and its soil belongs to the forest ochrosol (Adu & Mensah-Ansah, 1969). The region experiences semi-equatorial climate with bimodal rainfall pattern with a mean rainfall between 1200 mm and 1930 mm. The major rainy season is between April and July with short dry spell in August. The minor rainy season begins in September and ends in November, followed by a dry, hot period from December to March (CRIG Meteorological Station, 2015). The relative humidity is high during the rainy season, reaching its peak of 90% between May and June. Maximum temperature of 30^0 C is experienced between March and April with the mean monthly temperature of about 27^0 C (Anornu et al., 2009)

2.2 Experimental design

Four plots from CRIG were selected to determine the effect of farm management practices on soil dwelling arthropods. These plots were:

Plot N18 - this plot is managed by the Plant Pathology unit of CRIG, and is used mainly for fungicide trial to manage black pod disease. This plot is located at N 06^0 13.794'', W 00^0 21. 200'', elevation: 222 m is sparely shaded and weeds on it are managed using glyphosate

Plot J8A - this plot is managed for fungicide screening and earthworm cast study. The farm is located at N 06^0 13.839'', W 000^0 21.172'', elevation: 233 m. The cocoa trees grown in this plot are matured and consist mixture of hybrids with continuous canopy. Overhead shade is mainly provided by tall *Terminalia ivorensis* and *T. superba* (A. Chev). There is no undergrowth.

Plot K6-02 - this plot is used for fertilizer experiment. The plot is situated at N 06^0 13.787'', W 000^0 21.172'', with 236 m elevation. The cocoa trees are matured and consist of mixture of hybrids with continuous canopy. It has no overhead shading and there are lots of undergrowth since weeding is done by under-brushing.

Plot C6 - this plot is assign for the study of physiological effect of shade or growth development on cocoa yield. The plot is located in 06^0 13.966'' N and 000 20.750 W" with 236 m elevation. The cocoa trees are matured and consist of mixture of hybrids with continues canopy. Overhead shading is mainly provided by *Gliricidia sepium* (Jacq), which is a nitrogen fixing plant.

All these plots are managed with the same insect pest management system by spraying confidor® 200 SL (imidacloprid, active ingredient) as an insecticide at every four weeks interval, starting in August and repeating in September, October and December. November was normally omitted since a lot of crop harvesting and other farm activities were done during this period.

2.3 Collection of soil samples and soil arthropods Extraction

2.3.1. Soil Surface Litter

From each plots, soil surface litter was collected from five randomly selected spots from a 0.3 X 0.3 m quadrat (Owusu-Manu, 1999). It mainly consisted of undecomposed and partly decomposed cocoa leaves and other undergrowth. These were put into labelled Ziplock polythene bags and were taken to the insect laboratory for processing and identification of the macro- and meso- arthropods, for this a multifaceted extractor (Berlese Tullgren funnel) was used for the extraction of the micro-arthropods.

2.3.2 PVC Soil Sampler

Five soil samples were randomly collected from the various plots using a PVC Core sampler with a diameter of 76.2 mm and height 10 cm. Collection was done between October 2014 and January 2015. Four plots from CRIG were selected to determine the impact of different farm management practices on soil dwelling arthropods. Sixty soil samples per month were taken and a total of 240 samples were collected for the four-month sampling period. All the collected soil samples were placed in Ziplock polythene bags and labelled accordingly. Then these samples were transported to the Insect laboratory at KNUST where the multifaceted Berlese Tullgren funnel was used for the extraction of the soil arthropods. The extraction method was design to suit behaviours and body structures of the organism (Wallwork, 1976b). The soil in the PVC samplers was placed on a sieve of 1 mm size at the top of the each funnel and the organisms were collected in containers containing 70% ethanol over a 96-hour period.

2.4 Sorting and Identification

After the organisms were extracted and collected, they were immediately sorted and counted under a stereo microscope at 20X magnification using the method described by Ogedegbe & Egwuonwu (2014). The species contained in the debris were removed by carefully pouring the content in a Petri dish and observing under the microscope. All arthropods were identified up to the Order level by using the Dichotomous Keys.

2.5 Measurement of Soil Physicochemical Properties

Various soil physicochemical properties including soil pH, soil moisture content and soil total hydrocarbon were monitored and measured on monthly basis. These parameters were determined at the soil Microbiology Laboratory of the Faculty of Agriculture, KNUST.

2.5.1 Soil pH

This was determined using glass electrode (Schott Instruments Lab 860) pH meter in a 1:2.5 soil to distilled water ratio (Mclean, 1982). Ten grams of the soil was weighed into a 100 ml beaker. For this, 25 ml distilled water was added in to the 10gms sample, stirred thoroughly and was allowed to stand for 30 minutes. After calibrating the pH meter with buffer solution at pH 4.0 and 7.0, the pH was read by immersing the electrode into the upper part of the suspension.

2.5.2 Soil Moisture Content

The moisture content of the soils was determined using the procedure described by the America Association of Cereal

Chemists (AACC, 2000). Twenty grams of the sample was weighed into a moisture dish which had been previously dried in an oven and weighed. This uncovered dish was dried in the oven for 24 hours at a temperature of 105 ± 5˚C. The dish was covered and transferred to desiccators and weighed immediately after cooling. The moisture content was determined using the formula below;

$$\text{Moisture (\%)} = \frac{\text{weight loss}}{\text{weight of sample}} \times 100$$

2.5.3 Soil total hydrocarbon

Five grams of the soil samples collected from the various farms were solar-dried in a desiccator and kept in bottle containers. Then 25 ml of n-hexane was added to each container in order to extract the soil total hydrocarbon. These were shaken for 10 minutes on mechanical shaker and left for 10 minutes to stand. The prepared n-hexane standard was used to standardize the spectrophotometer before introducing the sample solutions into the spectrophotometer for the absorbance reading. The soil total hydrocarbon content (SHC) concentration in part per million for each sample was then calculated as follows;

Soil SHC content (ppm) = instrument reading x reciprocal of slope x 25 ml/5g (Iloba & Ekrakene, 2009).

Whereas The instrument reading (IR) is the spectrophotometer reading, The reciprocal of slope was calculated for each sample based on the reading of the spectrophotometer and Volume of extraction reagent was 25 ml, the weight of each sample used was 5 g

2.6 Data analysis

Data collected were subjected to ANOVA using SAS software (2010), after square root transformation. Treatment means were separated using Tukey at 5% level of probability. Correlation analysis was done to determine the relationship between the soil physicochemical parameters and the arthropods

3 Results

3.1 Effect of Farm Management Practices on Arthropod Abundance

During study, intense survey has been carried out and total eight orders of Arthropods have been identified within the litter and soil.

3.1 Soil Dwelling Arthropods Sampled from the Litter

Results presented in Table 1 showed that the number of arthropods collected from the various plots were significantly different ($P < 0.05$) only for November. Further, significantly higher arthropods numbers were obtained from the litter of J8A plot as compared to K6-02 and N18 plots.

Table 1 Monthly mean number of soil dwelling arthropods isolated from the litter of cocoa plots (farms) under different agronomic management system at the Cocoa Research Institute of Ghana, New Tafo-Akim, Ghana.

Sampling months	Farm management (plots)	Mean number of arthropods (± SEM)
October	K6-02	1.94 ± 0.21 [a]
	C6	2.34 ± 0.18 [a]
	J8A	2.45 ± 0.26 [a]
	N18	2.01 ± 0.33 [a]
November	K6-02	2.17 ± 0.19 [bc]
	C6	2.64 ± 0.05 [ab]
	J8A	2.89 ± 0.15 [a]
	N18	1.86 ± 0.21 [c]
December	K6-02	1.57 ± 0.21 [a]
	C6	1.62 ± 0.06 [a]
	J8A	1.65 ± 0.18 [a]
	N18	1.65 ± 0.10 [a]
January	K6-02	1.28 ± 0.21 [a]
	C6	1.55 ± 0.13 [a]
	J8A	1.56 ± 0.11 [a]
	N18	1.31 ± 0.16 [a]

Each value is the mean of five replications. Means followed by the same letter are not significantly different ($P < 0.05$) from each other, using Tukey test.

Significant differences ($P < 0.05$) were observed between plot J8A and N18 for Collembola and Hymenoptera, while in case of Araneae, significant difference was observed between plot C6 and N18 from the litter. Further, no significant differences ($P > 0.05$) were reported in the number of Acarina, Diptera, Coleoptera, Blattodea and Myriapoda collected from all plots (Table 2).

For Collembola, significantly more arthropods population were reported in plot J8A than N18. However, the number of arthropod collected from J8A plot was similar to K6-02 and C6. Further, no significant difference ($P > 0.05$) was obtained between plot J8A, K6-02 and C6 in terms of Hymenoptera population (Table 2), but significant difference ($P < 0.05$) was obtained between plot J8A and N18. With respect to Araneae, significantly more was collected from plot C6 than N18.

Table 2 Mean number of soil dwelling arthropods sampled from the litter from cocoa plots (farms) under different agronomic management system at the CRIG, New Tafo-Akim, Ghana

Arthropods order	Farm Management (Plots)	Mean number of arthropods (±SEM)
Collembola	K6-02	2.23 ± 0.24 [ab]
	C6	3.03 ± 0.31 [ab]
	J8A	3.19 ± 0.30 [a]
	N18	2.11 ± 0.20 [b]
Acarina	K6-02	2.08 ± 0.24 [a]
	C6	2.59 ± 0.27 [a]
	J8A	2.69 ± 0.32 [a]
	N18	2.05 ± 0.20 [a]
Hymenoptera	K6-02	1.76 ± 0.19 [ab]
	C6	2.21 ± 0.22 [ab]
	J8A	2.45 ± 0.23 [a]
	N18	1.55 ± 0.12 [b]
Araneae	K6-02	0.89 ± 0.19 [ab]
	C6	1.42 ± 0.15 [a]
	J8A	1.15 ± 0.26 [ab]
	N18	0.68 ± 0.17 [b]
Diptera	K6-02	1.55 ± 0.25 [a]
	C6	1.57 ± 0.20 [a]
	J8A	1.33 ± 0.22 [a]
	N18	1.48 ± 0.23 [a]
Coleoptera	K6-02	1.42 ± 0.22 [a]
	C6	1.38 ± 0.19 [a]
	J8A	0.97 ± 0.19 [a]
	N18	1.23 ± 0.18 [a]
Blattodea	K6-02	1.00 ± 0.19 [a]
	C6	0.57 ± 0.16 [a]
	J8A	0.97 ± 0.22 [a]
	N18	0.46 ± 0.13 [a]
Myriapoda	K6-02	1.17 ± 0.21 [a]
	C6	1.13 ± 0.19 [a]
	J8A	1.29 ± 0.18 [a]
	N18	1.45 ± 0.38 [a]

Each value is the mean of five replications. Means followed by the same letter are not significantly different (P < 0.05) from each other, using Tukey test

3.2 Soil Dwelling Arthropods Sampled from the Soil

Results of monthly soil arthropods number in soil samples revealed significant differences (P < 0.05) between the plots for the month of November only (Table 3). Further, plot N18 harboured significantly less number of the arthropods than plot J8A.

Further, significant differences (P < 0.05) were reported in case of arthropods collected from various plots with respect to Diptera and Myriapoda (Table 4). Plot J8A harboured significantly more number of species of Diptera than plot N18. Plot C6 had significantly higher number (P < 0.05) of species of Myriapoda, as compared to plot K6-02. Further, no significant differences were observed (P > 0.05) among the studied plots in respect to populations of Collembola, Acarina, Hymenoptera, Araneae, Coleoptera and Blattodea.

3.3 Soil Physicochemical Parameters of Research plots of the Cocoa Research Institute of Ghana

The soil pH of plot C6 was significantly different (P < 0.05) from that of plot J8A and N18 but not statistically different from plot

Table 3 Monthly mean number of soil dwelling arthropods isolated from soil sample collected from the from cocoa plots (farms) at the CRIG, New Tafo-Akim, Ghana

Sampling months	Farm Management (Plots)	Mean number of arthropods (± SEM)
October	K6-02	1.80 ± 0.17 [a]
	C6	1.96 ± 0.28 [a]
	J8A	2.40 ± 0.21 [a]
	N18	1.77 ± 0.19 [a]
November	K6-02	1.98 ± 0.19 [ab]
	C6	2.20 ± 0.27 [ab]
	J8A	2.75 ± 0.17 [a]
	N18	1.78 ± 0.26 [b]
December	K6-02	1.60 ± 0.10 [a]
	C6	1.53 ± 0.22 [a]
	J8A	2.06 ± 0.11 [a]
	N18	1.68 ± 0.21 [a]
January	K6-02	1.27 ± 0.21 [a]
	C6	1.36 ± 0.13 [a]
	J8A	1.28 ± 0.21 [a]
	N18	1.36 ± 0.22 [a]

Each value is the mean of five replications. Means followed by the same letter are not significantly different (P < 0.05) from each other, using Tukey test

Table 4 Mean number of soil dwelling arthropods isolated from soil sample collected from cocoa plots (farms) under different agronomic management system at the CRIG, New Tafo-Akim, Ghana

Arthropods Orders	Farm Management (Plots)	Mean number of arthropods (± SEM)
Collembola	K6-02	2.87 ± 0.23 [a]
	C6	2.85 ± 0.28 [a]
	J8A	3.17 ± 0.32 [a]
	N18	2.76 ± 0.29 [a]
Acarina	K6-02	2.08 ± 0.19 [a]
	C6	2.12 ± 0.27 [a]
	J8A	2.15 ± 0.27 [a]
	N18	2.00 ± 0.25 [a]
Hymenoptera	K6-02	1.39 ± 0.19 [a]
	C6	1.36 ± 0.23 [a]
	J8A	0.94 ± 0.22 [a]
	N18	1.14 ± 0.19 [a]
Araneae	K6-02	0.20 ± 0.09 [a]
	C6	0.41 ± 0.15 [a]
	J8A	0.53 ± 0.14 [a]
	N18	0.35 ± 0.11 [a]
Diptera	K6-02	1.70 ± 0.19 [ab]
	C6	1.95 ± 0.22 [ab]
	J8A	2.47 ± 0.25 [a]
	N18	1.45 ± 0.22 [b]
Coleoptera	K6-02	1.09 ± 0.19 [a]
	C6	1.05 ± 0.18 [a]
	J8A	0.66 ± 0.18 [a]
	N18	0.81 ± 0.16 [a]
Blattodea	K6-02	0.74 ± 0.18 [a]
	C6	0.43 ± 0.16 [a]
	J8A	0.76 ± 0.18 [a]
	N18	0.60 ± 0.19 [a]
Myriapoda	K6-02	0.96 ± 0.17 [b]
	C6	1.87 ± 0.25 [a]
	J8A	1.56 ± 0.30 [ab]
	N18	1.09 ± 0.17 [ab]

Each value is the means of five replication. Means followed by the same letter are not significantly different ($P < 0.05$) from each other, using Tukey test

K6-02 (Table 5). There were no significant differences ($P > 0.05$) between the plots in terms of the soil total hydrocarbon and soil moisture.

The correlation matrix of soil arthropods and soil physicochemical properties of the CRIG cocoa plots under different farm management practices are presented in Table 6. There was positive correlation between arthropods and soil moisture content, but a negative correlation between arthropod, pH and soil hydrocarbon but all were not significant.

4 Discussion

Soil arthropods are vital links in the food chain as decomposers (Mattson, 1977), and according to Trombetti & William (1999), without these organisms, nature would have no way of recycling organic material. Therefore, it is essential to monitor the activities

Table 5 Mean value of soil physicochemical parameters of the Cocoa Research Institute of Ghana's Research plots in Ghana

Parameters	Farm management Plots	Mean value (± SEM)
Soil Total hydrocarbon	K6-02	0.012 ± 0.0024 [a]
	C6	0.011 ± 0.0031 [a]
	J8A	0.024 ± 0.0247 [a]
	N18	0.012 ± 0.0077 [a]
Soil pH	K6-02	5.85 ± 0.51 [ab]
	C6	5.15 ± 0.24 [b]
	J8A	6.08 ± 0.18 [a]
	N18	6.00 ± 0.29 [a]
Soil moisture content (%)	K6-02	20.80 ± 8.77 [a]
	C6	14.47 ± 5.29 [a]
	J8A	15.60 ± 8.06 [a]
	N18	13.65 ± 9.12 [a]

Each value is the means of the five replication. Means followed by the same letter are not significantly different ($P < 0.05$) form each other according to Tukey test

Table 6 Correlation matrix of arthropods and soil physicochemical properties of CRIG Research plots

	Arthropods	MC	pH	SHC
Arthropods	-			
MC	0.0027 [ns]	-		
PH	-0.3820 [ns]	-0.1153 [ns]	-	
SHC	-0.1712 [ns]	-0.1517 [ns]	-0.0603 [ns]	-

ns= not significant. MC = Moisture content, SHC = Soil Hydrocarbon.

of these vulnerable soil dwellers with a view to determine the impact of pesticide application and farm management practices on them and soil health as a whole.

During study period, a gradual reduction in arthropods abundance was reported from October to January. This might be due to several factors such as differences in environmental conditions or toxic effect of the applied chemical. The toxic effect of these synthetic chemicals can create unfavourable conditions that could cause death of the organisms especially during the dry season (December and January). Findings of present study are in agreement with report of Jones & Hopkins (1998) and Frouz

(1999) that environmental conditions are highly affected by pesticides and as a result, affect micro-arthropods existing in such treated areas. October and November had a higher arthropod populations and this may probably be due to the dilution effect of rain (since it coincided with the latter part of the wet season). Iloba & Ekrakene (2009) also observed a significant increase in arthropod population during the wet season.

Concerning the general soil fauna abundance, Collembola, Acarina and Hymenoptera were numerically most abundant fauna in both the litter and soil across the pesticide regimes. The results are in agreement with findings of Frampton (1994) who reported more Collembola in tree growing soil, followed by mites which colonized nearly every terrestrial environment. Trombetti & Williams (1999) and Gange & Brown (1989) as well as Iloba & Ekrakene (2008) also recorded more Collembola in the top layers of the soil (0-10 cm), the litter and soil surface layers of many forest trees.

In present study, Araneae abundance in the litter was observed to be significant. According to Pekár (2012) and Feber et al., (1998), Araneae, being one of the most abundant groups of natural enemies occurring in all agro ecosystems, are occasionally affected by pesticide applications. Spiders are primarily affected by insecticides and acaricides specifically the neurotoxic substances such as bifenthrin. Findings of present study are in line with findings of Adu-Acheampong & Ackonor (2005).

4.1 Monthly Trend of Arthropods Sampled in the Litter and Soil from CRIG plots

In this study, results in the month of November showed significant differences ($P < 0.05$) in arthropod (Collembola, Hymenoptera and Araneae) abundance among the plots (for both the litter and soil samples). There were significant differences ($P < 0.05$) between plot J8A and N18. This difference might probably be due to the fact that in November, cocoa farmers do not apply pesticides due to harvesting activities (Awudzi et al., 2012), and as a result, arthropods tend to start the recolonization in the environment. According to Iloba & Ekrakene (2008 & 2009), who evaluated the recovery rates of soil arthropods following dichlorvos pesticides treatment over a five-month period, there was a quick recovery ability of plot previously treated and they reported that the micro-arthropods show a greater tendency of re-colonizing an area which was previously uninhabited due to pesticide application.

The use of earthworm caste as soil amendment impacted positively on plot J8A arthropods activity resulting in significantly more arthropod colonization than in N18 where herbicides was used to manage weed. This significant difference could be due to the use of herbicides in addition to the fungicide and confidor® 200 SL (imidacloprid, active ingredient) for plot N18. Pereira et al. (2007) noted that the application of Glyphosate, which is a non-selective herbicide, can affect predatory arthropods (spiders, ground beetle, springtails, mites and earthworms) in agricultural field, causing behavioural changes and influence long-term survival even in residual exposure. In addition, herbicides can affect arthropod community dynamics, apart from their impact on the plant community and may influence biological control in agro-ecosystems.

Not much difference was reported between plot K6-02 (which is used for fertilizer trial), J8A (which is used for earthworm caste and fungicides trial) and C6 (Plot having nitrogen fixing trees which also provide shade). These management practices augment the soil properties and improve the microclimate providing conducive atmosphere for the arthropods to strive. According to Hati et al. (2007), the application of fertilizer tends to improve the population of Collembola.

4.2. Soil Physicochemical Parameters for Cocoa Farm Management

With respect to the various farm management practices, there were significant differences ($P < 0.05$) between the various practices and soil pH. Also weak and negative correlation was reported between soil pH and soil arthropods. This indicates that soil pH has negative impact on the arthropod population and if soil pH decreases, soil arthropod population increases and vice versa. The changes in pH might be as a result of the changes in chemical properties particularly the carbon content of the soil as a result of the pesticides and this probably impact the abundance of the soil arthropods (Michelle & Hopkin, 2004).

Like pH, weak negative correlation was also reported between soil arthropod and soil hydrocarbon, although the values recorded seem very low. Similar result was observed by Iloba & Ekrakene (2008) who stated that the low soil hydrocarbon could be as a result of the excessive leaching of the top soil occasioned by the series of rainfall.

Contradictory to pH and soil hydrocarbon, positive correlation was reported between the arthropods and soil moisture content.

This implies that soil moisture content impacts positively on arthropods abundance. Similar observation was made by Ogedegbe & Egwuonwu (2014), and was attributed to the rainy season.

Conclusion and Recommendation

Present study revealed that Collembola, Acarina and Hymenoptera constitute the most abundant while Araneae and Blattaria were least abundant in both the litter and soil sampled from the selected cocoa farms. There was a relative reduction in the number of arthropods populations across the sampled farm from October to January occasioned by differences in pest management practices. The use of herbicides as a farm management practices to control weeds had a significant effect on Collembola and Hymenoptera in the litter and on Diptera in the soil. Fertilizer application, shade management, nitrogen fixing trees and earthworm caste had a positive effect on the soil arthropods' abundance and richness. The soil physicochemical parameters (soil pH, soil moisture content and soil hydrocarbon) had no significant effect on the abundance and richness of soil arthropods sampled across the pest management practices. However, soil pH within the farm management system was observed to have a significant effect on the richness and abundance of soil arthropods. It is recommended that the work be repeated to cover a 12-month period to obtain the trend over a 12-month period. Other extraction methods such the pitfall trapping and Winkler should be combined with the Berlese Tullgren extraction method to capture other arthropods that could not be collected using our trapping device.

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Conflict of interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

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