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A Comparative Assessment of Soil Arthropod Abundance and Diversity in Practical Farmlands of University of Ibadan, Nigeria

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Abstract

The study comparatively assessed the impacts of farm activities on the abundance and diversity of soil arthropods and soil physico-chemical parameters of the Practical Year Training Programme (PYTP) farmlands, University of Ibadan, South Western Nigeria. Soil arthropods were collected from September, 2010 to February, 2011 in five sampling sites of PYTP farmlands using BerleseTullgren Extraction method. Soil physico-chemical parameters were determined by standard procedures. A total of 19 orders of soil arthropods were obtained. Acari and Collembola accounted for the most abundant order while the Neuropterans were the least in abundance.Sites 1 and 4 (control) recorded the highest diversity (Shannon Wiener index) values of 1.88 and 1.96 respectively while site 5 recorded the highest equitability value. The ANOVA result showed no significant difference in the values of the different parameters across the sites ($P>0.05$). Chi-square test showed a significant association between the number of soil arthropods and the parameters of the five sampling sites. Pearson's correlation coefficient (r) revealed a positive significant relationship between soil moisture content and the Collembolans and a negative significant relationship with Coleopterans. This study revealed a reduction in the abundance and diversity of soil arthropods in the PYTP farmlands due to consistent agricultural activities that impact the environment. Sustainable farming practices should be adopted so as to ameliorate the impact of cultivation practices on soil organisms and restore the integrity of the soil ecosystem.

Keywords: Abundance; Diversity; Soil arthropods; Physico-chemical parameters; PYTP farmlands.

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1. Introduction

The soil is a large ecosystem which accommodates diversity of complex activities. In soil, most nutrients available for plant growth depend on complex interactions between plant roots, microorganisms and soil fauna (Bonkowski *et al.*, 2000). Biodiversity is the key factor of the structure and function of ecosystems (Lee, 1991 and Wall *et al.*, 2005). There is a significant loss of biodiversity in agricultural ecosystems compared to natural ecosystems due to intensive agricultural practice. Soil biological and chemical properties as well as habitat conditions alter drastically when there is a conversion from natural to agricultural habitat. Curry (1998) and Lee (1991) highlighted frequent tillage and use of agrochemicals as having major impact on soil organisms and habitats. Agricultural activities have positive or negative impact on abundance, diversity and activity of soil fauna mostly following the changes in soil temperature, moisture as well as quantity and quality of organic matter (Hendrix and Edwards, 2004). Fields which are more diverse, stable, isolated and managed with low intensity have preference for ongoing ecological processes compared with simple and disturbed agricultural systems. Uncultivated habitats between fields could enhance species diversity of many organism groups, and function as refuges (Lagerlof and Wallin, 1993 and Lagerlof *et al.*, 2002). Spatial variability in dispersion of soil organisms can be key to understanding the structure and function of soil biodiversity (Ettema and Wardle, 2002).

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 soil (Evans, 1992). Arthropods also serve as the largest prey base for small predators, thus sustaining other arthropods. Without arthropods most terrestrial ecosystem would rapidly collapse (Iloba and Ekrakene, 2008). Arthropods have been able to fill every niche available in the ecosystem. The direct ecological effects of these minute arthropods include the reduction in the mass of organic matter and microbial tissue. This is as a result of their ingestion and assimilation of such materials, their respiration and excretion which is important in influencing oxygen-carbon dioxide ratio of the soil and nutrient made available from the breakdown of faecal pellets (Filser, 1995). Therefore, their secondary production turnover is very fundamental because this is the basis on which the organisms, way up the food chain are dependent upon.

Many soil arthropods, including Collembola, Oribatida, Isopoda or Diplopoda, live a sedentary life in soil in close relationship with the external conditions of their ecological niches. As a consequence, the structure of the micro arthropod community closely reflects the environmental factors affecting the soil, including

the impact of human activities, and could be considered a bio indicator of soil health (Knoeppa *et al*., 2000; Linden *et al*., 1994 and Sparling, 1997). Heavy anthropogenic activities alter the equilibrium of the environment owing to the introduction of cultivated and inhabited areas, as well as other human-induced change (Arroyo and Iturrondobeitia, 2006). Land management affects soil animal populations by altering the quality and quantity of detritus and non-detritus inputs, and by influencing the physical and chemical qualities of soil microhabitats (Curry, 1986).

The objective of this study is to comparatively assess the abundance and diversity of soil arthropods, soil physico-chemical parameters and the impacts of agricultural activities on soil arthropods of the Practical Year Training Programme (PYTP) farmlands, University of Ibadan, South Western Nigeria.

2. Materials and methods

2.1. Study area

This study was carried out at the Practical Year Training Programme (PYTP) farmland of the faculty of Agriculture, University of Ibadan, Oyo State, Nigeria. It is situated on the south west part of Nigeria ($7^0\ 8^1\ 9^{11}$ N, $5^0\ 15^1\ 7^{11}$ E) as shown in Fig. 1. Ibadan is characterized by both rainy and dry seasons, with rainy season and dry season lasting from April to October and November to March respectively (Akoroda, 2008). Practical Year Training Programme (PYTP) farmlands are sites used by the faculty of Agriculture, University of Ibadan for experimental agriculture. Heavy agricultural activities commence in PYTP farmlands with the onset of rainy season. The investigated area is an expanse of 2.5 hectares of land. It was delineated into five stations numbered 1, 2, 3, 4 and 5. Stations 1 and 4 served as the control owing to the presence of trees and stream with less anthropogenic activities. Stations 2, 3 and 5 were areas of intensive agricultural activities characterized by consistent soil tillage and the application of various chemical substances such as NPK fertilizers and organochlorinepesticides. The stations were well delineated and marked out so as to avoid any form of interference.

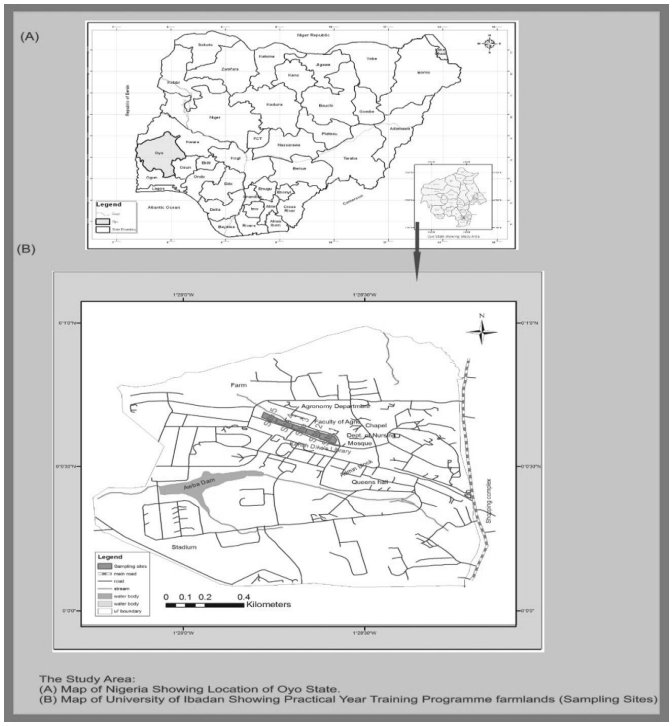

Figure1. Map showing sampling sites

2.1. Sample collection and Analysis

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 September, 2010 to February, 2011. Sampling was done fortnightly between the hours of 10am to 12pm and five samples were collected at each sampling period from all stations.

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 5cm mark. The obtained soil samples from the different stations were placed in separate black cellophanes, labeled accordingly and moved to the laboratory where the multifaceted extractor (Berlese Tullgren Funnel) was adopted for the extraction process. Extraction method was designed to suit behavior and body structures of the organisms (Wallwork, 1976). A volume of 128cc of soil sample was placed on the sieve mesh at the top of each funnel and the organisms collected in containers with 70% alcohol within three days.

After the organisms were extracted and collected, they were immediately sorted under a binocular dissecting microscope where individuals were removedfrom 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. Species identification was carried at Department of Crop Protection and Environmental Biology laboratory, Faculty of Agriculture, University of Ibadan and Entomology Unit of the Department of Zoology, University of Ibadan, Ibadan, Nigeria.

The method described by Bates (1954) was adopted for the determination of soil pH. 20g of air dried soil collected within the 5cm from each station was put in a 50ml beaker and 20ml of distilled water was added and allowed to stand for 30 minutes. The mixture was stirred occasionally with a glass rod. The electrode of each pH meter was then inserted into partly settled suspension from each station and reading recorded. The soil pH readings were taken fortnightly. Soil moisture content was determined by weighing and placing 50g of soil samples from each site in the oven for 24hrs till constant weight were obtained.

Loss in weight = initial weight - final weight

$$\text{Soil Moisture Content in \%} = \frac{Lossinweight}{Ovendried} \times 100$$

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

Temperature readings were collected between 8am – 9am and 5pm – 6pm. Temperature reading was achieved by digging a small 5cm deep hole and followed by tightly fitting the thermometer to the circumference of the hole before covering it. Reading on the thermometer was obtained after 2 minutes. This was repeated thrice and average value taken for both the morning and evening sampling periods.
The soil total hydrocarbon was determined using a spectrophotometer, pipette and 250ml separating glass funnel, mechanical shaker and n-hexane. A 20g weight of soil sampled from within the upper 0-5cm from each site was dried and kept in bottle containers. 20g of each soil sample was extracted for the oil and grease content with 250ml of n-hexane in a Soxhletapparatus at the rate of 20 cycles/hr for 4 hours. 5ml of the oil/grease extracted was re-dissolved in 50ml of hexane and treated with 1.5g of silica gel in a 100ml volumetric flask, stoppered and stirred on a magnetic stirrer for 5 minutes to remove the fatty acids present leaving only the hydrocarbons. The mixture was filtered through a Whatman No 42 filter paper was washed with 10ml hexane twice and the filtrates combined. The combined filtrates were placed on water bath set at 60^0C in order to remove the hexane by evaporation, leaving only the hydrocarbon.

$$\text{Hydrocarbon in mg/kg} = \frac{weightofhydrocarbonobtainedinmg}{weightofsampletakening} \times 1000$$

Rainfall and relative humidity data were collected from the Geospatial laboratory of International Institute for Tropical Agriculture (IITA), Ibadan,

Nigeria and the Geographic Information System (GIS) Unit of the Department of Geography, University of Ibadan, Nigeria respectively.

2.2. Data Processing

The mean and standard deviation of each of the soil physiochemical parameters were calculated. Analysis of Variance (ANOVA) was used to test for statistical differences between the means of the physical and chemical parameters of the five sites while correlation coefficient was used to determine the possible relationship between the investigated parameters and different soil arthropods. The Chi-square test was used to ascertain whether there is significant association between the abundance of soil arthropods and the five sampling sites (Zar, 1984).

The overall percentage occurrence and relative numerical abundance of soil arthropods were calculated. Densities of the abundance species were analyzed for each of the sampling stations. Diversity of the soil arthropods was determined using Shannon – Wiener Index (H) and equitability (E) of species (Shesshan, 1984 and Ajao, 1990).

Shannon – Wiener Index was expressed as: $H = \frac{NlogN - \sum_{i=0}^{n} fi \log fi}{N}$

Equitability measures how evenly the species are distributed in a sample community. It was expressed as: $E_H = \frac{H}{LogS}$

Where S = number of species, N = total number of individual in the sample, f_i = the number of occurrence of species I in the sample, H = Shannon – Wiener Index and E_H = Shannon Equitability Index.

Microsoft Office Excel 2007, PASW Statistics 18 (SPSS) and PAST soft wares were used for the statistical analysis.

3. Results

A total of 19 orders of phylum arthropoda were recorded at the Practical Year Training Programme (PYTP) farmlands, University of Ibadan (Table 1). Acari occurred in all the sites and also had the highest numerical abundance in the four sites with range of relative abundance of 32.42% - 49.65%. Collembola had the highest numerical abundance in site 3 and second to Acari in numerical abundance in four other sites with 13.12% - 39.99% as its range of relative abundance. Neuroptera occurred in only site 4 and had the lowest numerical abundance with a relative abundance of 0.35%. Other arthropods with very low relative abundance include Pseudoscorpionida (0.71% - 1.23%), Lepidoptera (0.43% - 0.71%), Opiliones (0.46% - 1.84%), Protura (0.43% - 1.83%), Araneae (1.23% - 1.42%) and Isoptera which occurred only in site1 with relative abundance of 2.13%.

Variations in diversity and evenness of different soil arthropods in the various sampling sites are also shown in Table 1.The control sites (Site 1 and 4) recorded

the highest species diversity (Shannon Wiener index) values of 1.88 and 1.96 respectively. The lowest species diversity of soil arthropods was recorded in site 2 (1.67) and site 3 (1.63). Equitability values were relatively high in site 1 (0.68), site 4 (0.67) and site 5 (0.70) while site 2 and site 3 recorded the lowest equitability value of 0.63 and 0.66 respectively. Table 2 shows the monthly mean with standard error and range of physico-chemical parameters of PYTP farmlands. Table 3 shows the six months mean with standard error and range of physico-chemical parameters of the sampling sites. The results of ANOVA showed no significant difference in all the values of the different parameters across the sites at $P>0.05$. However, results from Chi-square showed a significant association between the numbers of soil arthropods and the soil parameters of the five sampling sites ($P< 0.05$, df =72, $X^2_{tab} = 92.81$ and $X^2_{cal.} = 211.04$).

Table 1. Overall composition, relative abundance, diversity and equitability values of soil arthropods in five sampling sites of PYTP farmlands, University of Ibadan

Arthropod Taxa	Sites										Total
	1		2		3		4		5		
	No	%	No	%	No	%	No	%	No	%	
Collembola	30	12.77	57	27.54	81	36.99	37	13.12	30	18.40	235
Acari	109	46.38	86	41.55	71	32.42	140	49.65	73	44.79	479
Psocoptera	6	2.55	12	5.80	24	10.96	16	5.67	15	9.20	73
Lepidoptera	1	0.43	1	0.48	0	0	2	0.71	1	0.61	5
Diplopoda	6	2.55	2	0.97	1	0.46	3	1.06	3	1.84	15
Chilopoda	5	2.13	1	0.48	0	0	10	3.55	6	3.68	22
Isopoda	6	2.55	4	1.93	2	0.91	14	4.96	0	0	26
Symphyla	4	1.70	0	0	4	1.83	6	2.13	5	3.07	19
Coleoptera	5	2.13	2	0.97	1	0.46	8	2.84	6	3.68	22
Araneae	3	1.28	0	0	0	0	4	1.42	2	1.23	9
Hymenoptera	33	14.04	9	4.35	16	7.31	11	3.90	4	2.45	73
Opiliones	2	0.85	1	0.48	1	0.46	0	0	3	1.84	7
Diplura	4	1.70	6	2.90	2	0.91	7	2.48	0	0	19
Protura	1	0.43	1	0.48	4	1.83	0	0	0	0	6
Hemiptera	0	0	1	0.48	0	0	2	0.71	2	1.23	5
Diptera	15	6.38	24	11.59	12	5.48	19	6.74	11	6.75	81
Pseudoscorpionida	0	0	0	0	0	0	2	0.71	2	1.23	4
Neuroptera	0	0	0	0	0	0	1	0.35	0	0	1
Isoptera	5	2.13	0	0	0	0	0	0	0	0	5
Total no of taxa (S)	16		14		12		16		14		72
Total no of individuals (N)	235		207		219		282		163		1106
Shannon index(H)	1.88		1.67		1.63		1.96		1.85		
Equitability values	0.68		0.63		0.66		0.67		0.70		

Table 2. Mean, standard error and range of physico-chemical parameters from September, 2010 to February, 2011 of PYTP farmlands, University of Ibadan

Parameters	Months						
	September	October	November	December	January	February	Range
Soil Temp(°C)	25.66±0.42	26.60±0.49	28.28±0.59	29.65±0.52	26.40±1.16	30.44±1.67	25.66-30.44
Soil pH	6.55±0.10	6.44±0.30	6.70±0.24	6.83±0.08	6.46±0.17	6.39±0.15	6.39-6.83
SMC (%)	25.88±8.64	29.46±11.06	25.37±9.18	10.09±3.46	5.60±3.52	13.50±2.86	5.60-29.46
THC($mgkg^{-1}$)	8.85±3.54	8.85±3.54	8.85±3.54	8.85±3.54	8.85±3.54	8.85±3.54	8.85
Rainfall(mm)	294.70±00	349.90±00	162.10±00	0.50±00	0.00	134.60±00	0.00-349.90
R.Humidity(%)	73.30±00	72.55±00	77.50±00	41.29±00	33.03±00	47.93±00	33.03-77.50

Each value is the mean of five replicates (five sites).

Table 3. Mean, standard error and range of physico-chemical parameters of the five sampling sites

Parameters	Sites					
	1	2	3	4	5	Range
Soil Temp(°C)	26.60±0.62	27.80±0.88	28.04±1.27	26.52±0.76	30.24±1.17	26.52-30.24
Soil pH	6.55±0.16	6.72±0.05	6.89±0.06	6.58±0.14	6.08±0.20	6.08-6.89
SMC(%)	11.62±2.54	32.47±9.63	31.94±7.11	9.37±2.33	6.19±1.72	6.19-32.47
THC($mgkg^{-1}$)	0.26±00	16.38±00	15.64±00	11.34±00	0.64±00	0.64-16.38
Rainfall(mm)	156.97±59.40	156.83±59.40	156.97±59.40	156.97±59.40	156.97±59.40	156.97
R.Humidity(%)	57.43±7.74	57.43±7.74	57.43±7.74	57.43±7.74	57.43±7.74	57.43

Each value is the mean of six replicates (six months).
Soil Temp: Soil Temperature
SMC: Soil Moisture Content
THC: Total Hydrocarbon Content
R.Humidity: Relative Humidity

The month of February recorded the highest soil temperature with a mean of 30.44^{o}C (±1.67) while the month of September recorded the lowest with a mean value of 25.66^{o}C (±0.42). In addition, site 5 recorded the highest temperature with a mean value of 30.24^{o}C (±1.17) while site 4 recorded the lowest temperature with a mean value of 26.52^{o}C (±0.76).

The highest soil pH was recorded in December with a mean value of 6.83±0.08 while the lowest was recorded in February with a mean value of 6.39±0.15. Site 3 recorded the highest soil pH with a mean value of 6.89±0.06 while site 5 recorded the lowest with a mean value of 6.08±0.20.The highest mean value of 29.46% (±11.06) soil moisture content was obtained in October while the least mean value of 5.60% (±3.52) was recorded in January. In addition, site 2 recorded the highest soil moisture content with a mean value of 32.47% (±9.63) while site 5 recorded the lowest with a mean value of 6.19% (±1.72). Total hydrocarbon content (THC) of soil was 16.38 $mgkg^{-1}$ and 15.64 $mgkg^{-1}$ for site 2 and 3 respectively. These are

relatively higher to that obtained in site 1, 4 and 5 (0.26 $mgkg^{-1}$, 11.34 $mgkg^{-1}$ and 0.64 $mgkg^{-1}$ respectively).

Table 4 shows the Pearson's correlation coefficient (r) values between physico-chemical parameters and soil arthropods of the PYTP farmlands, University of Ibadan. There is a significant positive correlation between the order Collembola and soil moisture content ($P<0.05$). Order Coleoptera showed a significant negative correlation with soil moisture content ($P<0.05$).

Table 4. Pearson's Correlation Coefficient (r) values between physico-chemical parameters and soil arthropods of PYTP farmlands, University of Ibadan

	Parameters			
Soil Arthropods	Soil temperature	Soil PH	SMC	THC
Collembola	-0.001	-0.788	0.899*	0.815
Acari	-0.772	0.055	-0.460	-0.064
Psocoptera	0.298	0.330	0.392	0.572
Lepidoptera	-0.357	-0.363	-0.622	-0.192
Diplopoda	-0.362	-0.376	-0.641	-0.792
Chilopoda	-0.207	-0.545	-0.877	-0.468
Isopoda	-0.788	0.217	-0.294	0.158
Symphyla	-0.006	-0.390	-0.741	-0.462
Coleoptera	-0.129	-0.634	-0.920*	-0.554
Araneae	-0.390	-0.437	-0.873	-0.570
Hymenoptera	-0.640	0.326	0.040	-0.319
Opiliones	0.710	-0.724	-0.376	-0.763
Diplura	-0.813	0.475	0.155	0.461
Protura	-0.048	0.728	0.735	0.502
Hemiptera	0.352	-0.645	-0.546	-0.124
Diptera	-0.491	0.375	0.361	0.532
Pseudoscorpionida	0.327	-0.707	-0.750	-0.330
Neuroptera	-0.490	0.030	-0.390	0.176
Isoptera	-0.460	-0.026	-0.292	-0.607

*****Correlation significant at $P< 0.05$

4. Discussion

Consistent tillage and application of pesticides had a negative impact on the abundance and diversity of soil arthropods in PYTP farmlands, University of Ibadan.Tillage is an indispensable component of agricultural activities. Along with directly crushing soil arthropods, tillage breaks apart soil aggregates, modifying soil pores and pore connectivity (Martin, 1984 and Peachey *et al*., 2002). Tillage starts in PYTP farmlands with the onset of rainy season. Pesticides are equally used for pest control and management. This commences with the cultivation of maize and vegetables by the students of the faculty of Agriculture for their practicals.

Peachey *et al*., (2002) reported that tillage can physically crush soil arthropods thus reducing their populations. Application of pesticides is one of the practices associated with agricultural activities and as well has strong influence on the diversity and abundance of soil fauna (Adan *et al*., 1991 and Subias *et al*., 1985).

The relative abundance of Isopods in site 2 and 3 was relatively low (1.93% and 0.91% respectively). This could be attributed to the fact that Isopods generally respond quickly to environmental contamination and impact (Jones and Hopkins, 2000). Janssen *et al*., (2006) also added that Isopods have been convincingly useful for bio-monitoring in industrialized and urbanized areas. No Araneae was recorded in sites 2 and 3. This also could be attributed to relatively high soil total hydrocarbon content which is a function of high insecticidal influence. Frouz, (1999) reported that the toxicity of insecticides affect soil micro arthropods by directly influencing the soil conditions, soil mixture and input of dead organic matter and indirectly influencing plant species composition.

Data revealed the order Acari (mites) as the most abundant soil arthropod with the highest number of individuals (479) and a total relative abundance of 43.31%. This was followed by the order Collembola (235 individuals) with a total relative abundance of 21.25%. Soil mites (Acari) constitute the greatest percentage of the world's arthropods living in the soil. They are truly ubiquitous and have successfully colonized nearly every known terrestrial environment (Trombetti and Williams, 1999). This was also confirmed by Arroyo & Iturrondobeita, (2006). Brown and Gange, (1989) reported that Collembolans are among the abundant soil arthropods and play an important role in decomposing grasses.

The Pearson's correlation coefficient (r) values between the investigated physico-chemical parameters and soil arthropods in PYTP farmlands, University of Ibadan show a significant positive correlation between Collembolans and soil moisture content ($P<0.05$). This corroborates the findings of Badejo (1982), who observed that the density of most micro arthropods increased with increase in the soil moisture content. However, when soil moisture is in excess, it could lead to the death of soil insects, thus reducing the overall population. This could possibly be the reason why the Araneae showed a strong negative correlation to soil moisture content in September and November. In addition, Coleopterans showed a significant negative correlation with soil moisture content ($P < 0.05$). This could possibly be attributed to the strong body morphology (protective coat) of the Coleopterans and which could equally be responsible for their being favorably adapted to dry conditions than wet environments.

The soil temperature of the five sampling sites which ranges between 26.52 to 30.24^{o}C was moderate for the thriving of soil arthropods. This was confirmed by Madge and Sharma (1969), who showed that arthropods are normally active within the range of 10 to 35^{o}C except for few species that can withstand high temperatures.

The five sampling sites of PYTP farmland had a conducive pH range (6.08 to 6.89) for the proliferation of soil arthropods. This was an indication of soil alkalinity and is in conformity with the works of Madge and Sharma (1969), who reported that soil acidity has marked influence on the distribution of many kinds of soil organisms and only few organisms are found in very acid conditions. Site 2 and site 3 recorded the highest soil pH (6.72 and 6.89 respectively). This could possibly be as a result of the fact that the application of lime fertilizers in the course of the cultivation practices must have neutralized the acidity of the soil of the sites in question.

5. Conclusion and Recommendations

Irrespective of the fact that the importance of agriculture cannot be over-emphasized, there is a need to strike a balance between agriculture and the conservation of biodiversity. This can be achieved by adopting sustainable agricultural production systems which embraces sustainable farming practices (Agroecology/conservation agriculture). Components of sustainable farming include practices such as crop rotation, composting, mixed farming, intercropping, cover cropping, organic and biological pest control, zero- or reduced-tillage farming and biological control of weeds and pests. Implementation of sustainable practices is not always an easy task since it comes with some inherent risks. During the first year or two of the transition period, lower yields and reduced profits are often experienced. Nevertheless, with good understanding of the process of sustainable farming practices and careful planning, great success can be achieved in terms of increasing productivity and profitability.

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