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Comparative Assessment of Heavy Metals Accumulation and Soil Arthropods Diversity in Organic and Conventional Agricultural Farms

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Abstract: Agriculture is one of the most important components of our society and plays a great role for the advancement of human life. This research is aimed to assess the concentration of heavy metals accumulation and soil arthropods diversity in two different agricultural farms such as organic and conventional farms. Totally four heavy metals (Cr, Fe, Mn and Al) were detected in organic farm soil in the concentration of 12.66±4.18, 58.42±8.7, 1.23±0.72 and 22.46±1.98 while eight metals (Cu-81.95±13.65, Zn-63.67±27.57, Cr- 159.87±27, Fe-9680.57±732.032, Ni- 121.43±50.58, Mn-2.15±0.62, Al- 124.79±27.06 and Mo-126.49±51.48) were detected in conventional farm soil. Four metals detected additionally in conventional farm soil. Besides, this study also investigates the soil arthropods diversity in both farms. The soil arthropods diversity in the organic farm was high when compared to the conventional farm. Totally, 8983 soil arthropods belonging to twenty-seven families were observed among these 4969 (53.32%) individuals from the organic farm and 4014 (44.68%) from the conventional farm. In both farms, the higher number of arthropod was found in the month of November (1016, 807) and low in the month of September (423, 318). In this study, the concentrations of heavy metals detected in conventional farm were significantly high and it may one of the reasons for decline the soil arthropods diversity. This heavy metals concentrations and diversity fluctuations between these two farms may be due to the use of synthetic pesticides and fertilizers in agricultural farms for better crop yields.
Keywords: Soil physico-chemical parameters, Heavy metals, Arthropods diversity.

Abbreviations used: EC (Electrical conductivity); Cu (Copper); Zn (Zinc); Cr (Chromium); Fe (Iron); Ni (Nickel); Mn (Manganese); Al (Aluminum); Mo (Molybdenum)]

INTRODUCTION

Agriculture is one of the most important components of our society and plays a great role for the advancement of human life. It is the backbone of our economic system as well as it has enabled humans to manipulate ecosystems and maximize population growth [1]. However, the simplification of agricultural production has led to weakening of the natural defences of agricultural ecosystems [2]. The agriculture relies only on healthy soils. The soil is a diverse complex that contains a mixture of compounds, minerals, living and non-living things. The soil health can be defined as "the capacity of the soil to function within the ecosystem boundaries to sustain biological productivity, maintain the good environment and promote plant and animal health. Based on the farming practices, the farms can be distinguished into two types such as organic and conventional farms.

In organic farms, to retain the soil fertility, green manures and animal manures are used as fertilizers. While using the organic fertilizers, it must ensure that the farm soil remains fertile for hundreds of years. However, with the augment use of chemical fertilizers today, the land is rapidly becoming infertile. The chemical fertilizers such as superphosphate, copper sulfate and iron sulfate had high amounts of Cu, Zn, and Pb as the ingredient [3]. Further, the use of chemical pesticides also paves the way to accumulate metals in agricultural soils. Agricultural soil comprises numerous organisms ranging from microscopic bacteria to large soil animals such as springtails, mites, earthworms, ants, termites and ground beetles. Moreover, the small mammals such as rats, mice, moles, and voles are also inhabit the soil. The use of these kinds of metallic fertilizers can lead to the accumulation of heavy metals in agricultural soils and it affects the soil-dwelling arthropods diversity [4]. Moreover, the pesticide application on crops not specifically target the pests, it also affects the non-target animals as well [5].

It was previously studied, that the diversity of soil arthropods particularly in agricultural farms affected by intensive farming methods leads to the impoverishment of agro ecosystem [6]. Whereas, in regulated management systems with lower intensity, for example, organic farms showed a better diversity index than the more intensive farms [7]. In the present study, the main objectives are to assess the concentration of heavy metals accumulation and soil arthropods diversity in organic and conventional agricultural farms.

MATERIALS AND METHODS

Study area

Two agricultural farms in Pollachi were chosen for this study. One is the organic farm, is located at a latitude of 10.5344^{o}N and longitude of 76.9774^{o} E at the base of Anaimalai Hills, 70 Km away from Coimbatore. This organic farm was initiated in 1997 is maintained as such till date. Another one is conventional farm was located 5 to 10 km away from the organic farm. In both farms, the farmers cultivate many crops. In this conventional farm, the farmer had used large amounts of synthetic fertilizers and pesticides for their better yields of crops, but not in the organic farm, they use only natural products instead of synthetic fertilizers and pesticides.

Soil sample collection

For physico-chemical parameters and heavy metals analysis, the soil samples were collected randomly from both the study areas up to a depth of 5 to 15cm with the help of a soil auger. Before the soil sample collection, the debris on the surface of the soil was removed carefully and the samples were passed through a 2mm sieve to remove the remnant debris and large stones. The randomly collected soil samples were put in labelled polythene covers hermetically sealed and transferred to the laboratory for the further analysis.

Physico-chemical parameters analyse

The physico-chemical parameters such as pH, EC, Organic carbon, Nitrogen, Phosphorus, and Potassium of both farm soils were analyzed in SOTAC laboratory, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India.

ICPMS analyse

For ICP-MS analyse, the soil samples were digested using triacid. For the triacid preparation, Nitric acid, Sulphuric acid and Perchloric acid were mixed in the ratio of 9:2:1 respectively. 1 g of soil samples were mixed with 10 ml of triacid and digested at 80^{o}C. After digestion, the samples were made up to 100ml and they were used to analyse the heavy metals accumulation in Soils through ICP-MS (NeX Ion 300 X, Perkin).

Arthropods sampling

The soil arthropods were collected from the study area during August 2017 to March 2018. Pitfall traps and hand picking methods were used for soil arthropods collection. For pitfall traps, plastic cups (diameter= 25cm, height = 15cm) were used. The pitfall traps were buried in soil using a soil auger. The rim of pitfall traps was adjusted to soil surface level. Each pitfall traps were filled with 3% of formalin solution and detergent. In each field, 15 pitfall traps were placed in three parallel lines. After each sampling, the arthropods are stored in 70% ethyl alcohol. The identification of collected arthropods was done with help of Entomologist in Tamil Nadu Agricultural University (TNAU) and Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore. Tamil Nadu, India.

STATISTICAL ANALYSIS

Statistical analyses were conducted by using the SPSS software program (Version 20.0) for comparison of heavy metals accumulation in both farms (‘t’ test was applied). The diversity index such as Shannon Wiener index, Simpson index, Dominance and Evenness was calculated by PAST software.

RESULTS

The Physico-chemical parameters of the farm soils such as pH, EC, Organic carbon, Nitrogen (N), Phosphorus (P) and Potassium (K) are tabulated in table 1. The pH of the organic farm soil shows slightly alkaline (7.3±0.36) and conventional farm soil shows alkaline nature (8.21±0.11). The electrical conductivity of the organic farm soil was 0.14±0.05 ds m^{-1}, whereas in conventional farms soil a higher electrical conductivity was observed (2.42±0.21). Among the nutrients, such as organic carbon, nitrogen and phosphorus except the potassium was high in the organic farm than the conventional farm. The organic carbons were detected 1.96±0.47 % in organic farm and 1.6±0.14 % in conventional farm. The level of nitrogen detected in the organic farm was 284.33±1.53 Kg ha^{-1} and in conventional farm 253±8.9 Kg ha^{-1}. Phosphorus was high in organic farm soil (47.3±7.02 Kg ha^{-1}) than the conventional farm soil (36.6±2.5 Kg ha^{-1}). However, a contrast to the other nutrients the potassium was high in the conventional farm (556.3±5.50 Kg ha^{-1}) compared to the organic farm (484±15.04 Kg ha^{-1}) respectively.

The concentration of heavy metals in soil samples collected from the study area are presented in table 2. Totally four metals such as Cr, Fe, Mn and Al in the concentration of 12.66±4.18 mg/kg, 58.42±8.7 mg/kg, 1.23±0.72 mg/kg and 22.46±1.98 mg/kg were detected in organic farm soil. Whereas in conventional farm soil, totally eight metals such as Cu- 81.95±13.65 mg/kg, Zn- 63.67±27.57 mg/kg, Cr- 159.87±27 mg/kg, Fe- 9680.57±732.03 mg/kg, Ni-121.43±50.58 mg/kg, Mn-2.15±0.62 mg/kg, Al- 124.79±27.06 and Mo-126.49±51.48 mg/kg were detected. Four metals such as Cu, Zn, Ni and Mo were additionally detected in conventional farm soil. The detected heavy metal

between organic and conventional farms shows the significant.

Table-1: Physico-chemical parameters of organic and conventional farm soils

Parameters	Organic farm soil	Conventional farm soil
pH	7.3±0.36	8.21±0.11
Ec (ds m^{-1})	0.14±0.05	2.42±0.21
Organic carbon (%)	1.96±0.47	1.6±0.14
Nitrogen (kg ha^{-1})	284.33±1.53	253±8.9
Phosphorus (kg ha^{-1})	47.3±7.02	36.6±2.5
Potassium (kg ha^{-1})	484±15.04	556.3±5.50

Each value is mean±standard deviation of three individual observations

Table-2: Concentration of heavy metals detected in organic and conventional farm soils and its t-value

Heavy metals	Organic farm soil (mg/kg)	Conventional farm soil (mg/kg)	t-Value	Sig
Cu	ND	81.95±13.65	-10.399	0.009
Zn	ND	63.67±27.57	-4.000	0.057
Cr	12.66±4.18	159.87±27	-11.173	0.008
Fe	58.42±8.7	9680.57±732.032	-23.041	0.002
Ni	ND	121.43±50.58	-4.158	0.053
Mn	1.23±0.72	2.15±0.62	-1.189	0.356
Al	22.46±1.98	124.79±27.06	-4.256	0.051
Mo	ND	126.49±51.48	-7.067	0.019

ND- Not Detected

Each value is mean±standard deviation of three individual observations

#, values are significant (P<0.05) by paired samples *t'* test

In diversity indices, the species richness was higher in organic farm when compared to the conventional farm. Dominance was also observed high in the organic farm than the conventional farm. The Shannon Weiner index, Simpson index and evenness are also high in the organic farm than the conventional farm. The month wise diversity indices of the organic and conventional farm are given in table 3 and 4. The Shannon Weiner index of the organic farm was high in the month of November (1.735) and low in March (1.598) whereas in conventional farm it was high in October month (1.764) and least in February (1.447). The Simpson index of the organic farm was high in the month of December (0.792) and low in February (0.757). Likewise, in the conventional farm, the Simpson index was high in October (0.803) and low in February month (0.73). The evenness of organic farm was high in the month of January (0.655) and low in November month (0.515). Whereas, in conventional farm, the evenness was high in the month of September (0.706) and lowest in March (0.506). The species richness in the conventional farm was slightly lower when compared to the organic farm.

Table-3: Arthropod diversity indices in organic farm during the study period

Diversity indices	August	September	October	November	December	January	February	March
Individuals	574	423	579	1016	800	682	435	460
Dominance	0.209	0.211	0.213	0.216	0.207	0.216	0.242	0.234
Shannon Weiner –H	1.731	1.694	1.719	1.735	1.723	1.656	1.502	1.598
Simpson-1-D	0.790	0.789	0.786	0.783	0.792	0.783	0.757	0.765
Evenness	0.564	0.604	0.557	0.515	0.560	0.655	0.561	0.549

Table-4: Arthropod diversity indices in conventional farm during the study period

Diversity indices	August	September	October	November	December	January	February	March
Individuals	442	318	496	807	626	527	354	444
Dominance	0.205	0.203	0.196	0.214	0.214	0.217	0.27	0.253
Shannon Weiner –H	1.744	1.732	1.764	1.686	1.666	1.663	1.447	1.518
Simpson-1-D	0.795	0.796	0.803	0.785	0.785	0.782	0.73	0.746
Evenness	0.635	0.706	0.648	0.599	0.587	0.659	0.607	0.506

Summarizing the sampling periods, the higher number of arthropods was found in both fields for the month of November. In November, totally, 1016 individuals were recorded from organic farms and 807

individuals were recorded from the conventional farm. Meanwhile, the lowest number of individuals was recorded in the month of September (423, 318) in both fields (Figure 1). Among the eleven orders, the order Coleoptera was highly recorded in both fields (1384, 894) followed by Hymenoptera (1156) in organic farm and Blattodea (1019) in the conventional farm (Figure 2). Results from the present study show that the soil nature and soil arthropod populations were found better in the organic farm when compared to the conventional farm. The difference between these two farms may be due to the various farming practices such as soil tillage and the use of agrochemicals and fertilizers.

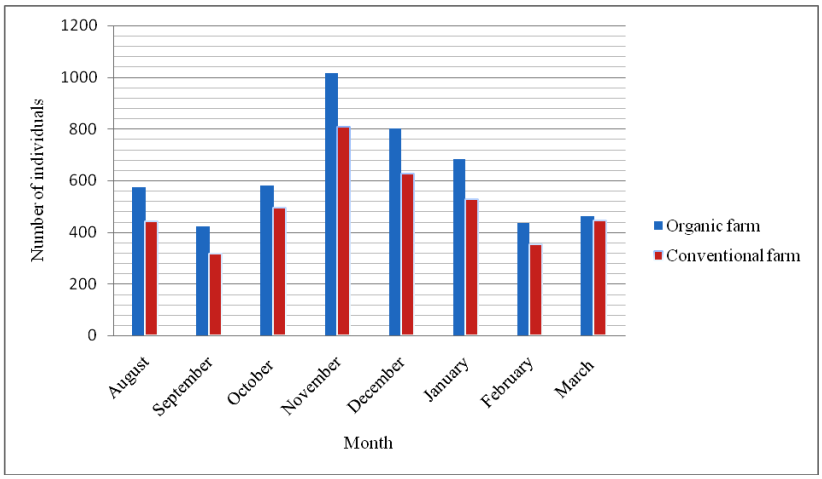

Fig-1: Month-wise abundance of soil arthropods in organic and conventional farms

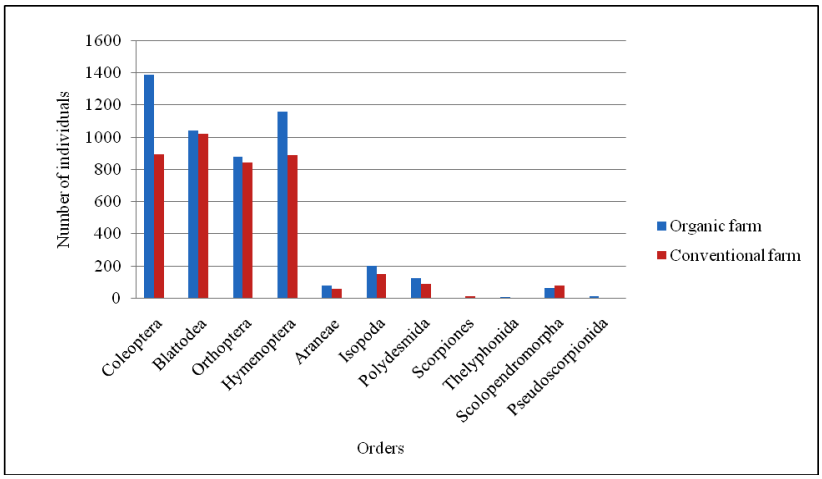

Fig-2: Order-wise abundance of soil arthropods in organic and conventional farms

DISCUSSION

The soil physico-chemical parameters are crucial for soil fertility. In this study, the physico-chemical parameters such as pH, Electrical conductivity, Organic carbon, Nitrogen, Phosphorus and Potassium shows some differences in both organic and conventional farm. This difference between the two farms may be due to the difference in nutrients application. Consider the major nutrients; the level of Potassium was high in the conventional farm when compared to the organic farm. Numerous studies have shown that the level of Potassium deficiency in organic farms due to the lower input of nutrients [8].

In the ecosystem, the concentrations of heavy metals in soil are influenced by many factors such as climate, parent material, and anthropogenic activities [9]. The adding of heavy metals in agricultural soils may be due to the use of metallic fertilizers and pesticides and soil amendments [10]. Application of major nutrient fertilizers in soil particularly the NPK (Nitrogen, Phosphorus and potash) may provide chance to accumulate the heavy metals in soil because of its impurities of raw materials [11]. The fertilizer superphosphate and some other fertilizers contain trace metal impurities like Cu, Cr, Cd, Pb, Zn, Hg [12]. This study also reveals that four metals such as Cr, Fe, Mn and Al were detected in organic farm soil and eight metals (Cr, Fe, Mn, Cu, Ni, Zn, Al and Mo) were detected in conventional farm soil. Additionally, four metals (Cu, Ni, Zn and Mo) were detected in conventional farm soil, because the Farmer would have used the metallic fertilizers in their fields. In the present paper, the result of physico-chemical parameters and

heavy metal concentration revealed that the organic farm soil shows fertile nature than the conventional farm soil.

A meta-analysis was done by Bengtsson *et al*. [13] found that 30% of species richness and 50% of organism abundance was higher in organic farms when compared to the conventional farm. Likewise, in our study, the species richness and abundance of the organism in the organic farm were found to be higher (55.32%) than the conventional farm (44.68%).

The report by Kulandaivelu Velmourougane **[**14**]** stated that the soil practiced in an organic farm under long-term has better soil properties when compared to the conventional farm. Besides, this organic farm also has more faunal diversity when compared to the conventional farm. The result by Gkisakis *et al*. [15] also suggested that the reduction of external inputs such as fertilizers and pesticides increases the soil fertility and arthropods diversity in agricultural farms. Skubala *et al.* [16]; Tyokumbur [17]; Manu *et al*. [18] are studied on the negative impact of heavy metals on soil arthropods diversity and its abundance. The results of these studies denote that the Cu, Zn, and Pb have the negative impacts on soil arthropods diversity. In the present study the heavy metal such as Cu, Zn are not detected in organic farm soil, but moderately detected in conventional farm soil and it may be one of the chances to decline the soil arthropods diversity in the conventional farm.

Nowadays, the organic farms recognized as a key to economic and ecological sustainability in agriculture. The main objective of the organic farm is to promote the soil fertility and arthropods diversity in the agricultural farm. Our results suggest that the intensive agricultural practice affects the soil health and soil arthropods diversity in the agricultural farm. So, considerations towards soil health and soil arthropods diversity in agricultural landscapes must be promoted by prohibiting the use of fertilizers and pesticides.

CONCLUSION

This study predicts that the indiscriminate use of pesticides and metallic fertilizers are one of the main reasons for the accumulation of heavy metals at high levels in agricultural soils. The soil arthropods are cofactors and play their role for soil fertility. Therefore, the accumulated heavy metals at a high level have lead to decline the soil arthropods diversity in conventional farm when compare to the organic farm. Therefore, the farmers are asked to use the natural products instead of metallic fertilizers and pesticides in agricultural farms.

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