Research article

Evaluation of Soil Ecosystem Health in Different Farming Systems by Observing Diversity of Soil Arthropods

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Abstract Organic or natural farming practices are known to promote soil fertility as well as biological diversity. Organic matter recycling, multiple cropping and ecological corridors are available as reservoirs for biological control agents such as predators or parasitic insects. These practices allow ecosystem services to reduce the presence of phytophagous insects and microorganisms. The objective of this study is to analyze the effect of the different farming systems on the diversity of arthropods. The sampling of arthropods was performed by pitfall trap method. The traps buried at surface level of the ground were set at 3.5 m intervals for 24 hours in the line of the cultivated crops. In addition to this method, Tullgren funnel method is applied in this study. In the experimental results, there were no significant differences in richness and abundance of observed arthropods. In the natural farming system, taxonomic group of Araneae, Acari and Coleoptera was observed. In the conventional farming system, the group of Formicidae was dominant. Using the Simpson's (inverse) index and Shannon-Weaver's index, the diversity was calculated. The results indicated there was more diversity of arthropods in the natural farming compared to conventional farming system. It is evident that agricultural practices (natural or conventional) may affect the diversity of arthropods within an agroecosystem.

Keywords beneficial arthropods, pitfall traps, pest management

INTRODUCTION

Soil health is associated with biological diversity and stability. Plant and animal diseases outbreaks can be considered as indicators of instability and poor ecosystem health. Therefore, there is likely also to be a link between soil health, the ability of the biological community to suppress plant pathogens, the population density of plant pathogens in soil, and ultimately disease incidence and severity (van Bruggen and Grunwald, 1996). The organic and natural farming is a production system that promotes processes which improve soil fertility and biological activity. Pest population density is related to factors such as climate and population of predators. The climate generates immediate and drastic changes in the population of the pests, but the control through natural enemies is more complex. In a successful biological control of pest, the natural enemy reduces the pest to a level that does not cause harm, but does not eliminate it completely, since the natural enemy requires a minimum population of pest for its survival (Nicholls, 2008). The idea of biological control is to keep the natural community in balance, and unlike chemical control it is safe, selective, efficient and works for long term. Those practices such as buffer zones, rotation and intercropping system, promote biodiversity and it would provide more shelter, food and reproductive possibilities, allowing the natural enemies to establish themselves as a tool for biological control of pests. And these practices also will make the production system more stable and productive in the medium and long term. Therefore, this study focuses on analyzing the richness and abundance of arthropods in two different production systems. By measuring the diversity of arthropods, it could indicate the stability and health of the soil ecosystem of the farms.

MATERIALS AND METHODS

The study was conducted at a natural farm in Saitama prefecture and a conventional farm in Tokyo City, both located in Kanto region of Japan. The difference between them is that the natural farm does not use chemical products and uses a system of rotation and intercropping. Which means that to control pests and diseases they have a complex vegetation structure in the farm to distract insects and prevent them from attacking their production. The macro or meso arthropods were collected using pitfall traps and microarthropods were extracted using Tullgren funnel method. The samples were preserved in 70% ethyl alcohol and were identified at taxonomic order.

Data Analysis

For all the statistical analyses EstimateS 9.1.0 (Colwell, 2013) was used. For estimates of species richness, Abundance based Coverage Estimator of species richness (ACE) was used (Chao and Lee, 1992; Chao et al., 1993). ACE is based on relative abundance data, those species with ≤ 10 individuals in the sample (Chao et al., 1993; Chazdon et al. 1998). Ace takes the form

$$S_{ace}=S_{common}+\frac{S_{rare}}{C_{ace}}+\frac{F_1}{C_{ace}}\gamma^2{}_{ace} \tag{1}$$

where S_{common} is number of common species, S_{rare} is number of rare species, C_{ace} is the sample abundance coverage estimator and Υ_{ace} is the estimated.

And for indices of species diversity, Shannon – Weaver's coefficient of variation of F_1 for rare species. This estimator has been found to give good results and is highly recommended (Chazdon et al. 1998; Hortal et al. 2006). diversity index (H´) and Simpson´s (inverse) diversity (D) index were used.

$$H' = -\sum_{i=1}^{s}(pi)(\ln pi) \tag{2}$$

where H' is species diversity index, s is number of species and pi is proportion of the total sample belonging to i th species. Shannon-Weaver's index (H´) considers the relative abundance and number of species and expresses the uniformity of the values of importance across all the species in the sample. In addition, it assumes that individuals are randomly selected, and that all species are represented in the sample (Magurran, 2004).

$$D = \sum\left(\frac{ni(ni-1)}{N(N-1)}\right) \tag{3}$$

where *ni* is the number of individuals in the *i* th species and *N* is the total number of individuals. As *D* increases, diversity decreases. Simpson's index is therefore usually expressed as 1-D or 1 ⁄ D (Magurran, 2004). This index is heavily weighted towards the most abundant species in the sample, while being less sensitive to species richness. For comparing both diversity indices, *t*-test was used (Hutcheson, 1970). This test was developed to compare the diversity of two communities samples for Shannon-Weaver's index and Simpson's index.

RESULTS AND DISCUSSION

Richness and Abundance of Species between Natural and Conventional Farming System

The arthropods collected in conventional system are represented by 7 taxa of arthropods. They were: Acari, Araneae, Collembola, Coleoptera, Hymenoptera, Orthoptera and Thysanoptera. In natural agroecosystem in addition to those named, 6 taxa more were recorded: Dermaptera, Diptera, Chilopoda, Hemiptera, Homoptera and Lepidoptera. In the conventional agroecosystem, 21 species and an abundance of 174 individuals were found, whereas in the natural agroecosystem 47 species and 270 individuals were registered. Figure 1 shows the distribution of total abundance among the different taxonomic groups registered in both farming systems. The most abundant taxonomic group in natural farming were Formicidae (33%), Orthoptera (14%) and Acari (12%). In the conventional one the Collembola (45%), Orthoptera (16.7 %), Formicidae (18.4 %) and Other Hymenoptera (11.5 %) were the taxa with greater abundance of individuals.

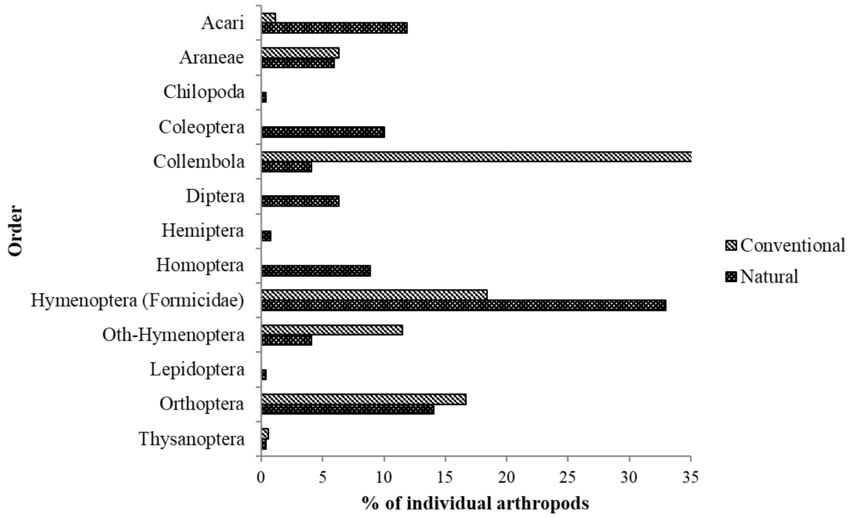


Fig. 1 Percentage of abundance of individuals per taxonomic group for both systems

With these results, we could discuss the significance of the different taxonomic groups in agroecosystems. Ground beetles predators (Carabidae and Staphylinidae) were found because they are usually found in arable lands. These species as well as spiders (Araneae) are non-specific predators, unlike parasitic wasps that are specific predators. Mites (Acari) are important in the soil as fungivores, bacterivores and nematode predators (Largerlof and Andren, 1988). In addition, they are related with the decomposition of organic residue in the soil.

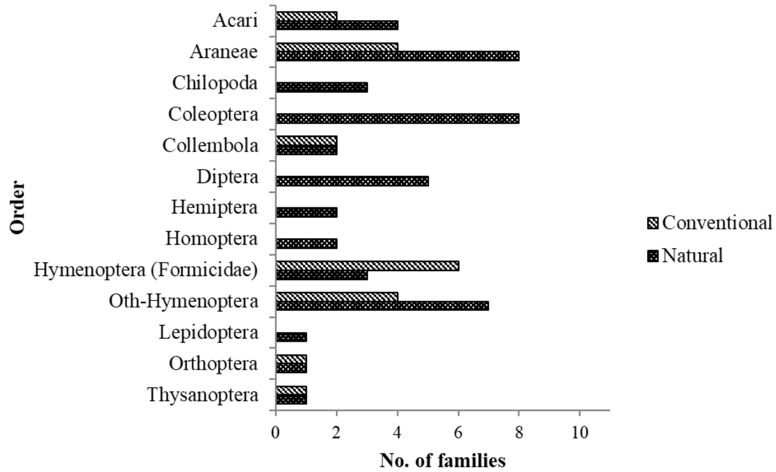


Fig. 2 Number of families per order for both systems

Figure 2 shows the distribution of the total richness among the taxonomic groups recorded in both evaluated sites. In natural agroecosystem the taxa with the highest number of families were: Coleoptera (17%), Araneae (17%) and Other Hymenoptera (15%). In contrast, in the conventional agroecosystem the taxa with the highest percentage of species were: Formicidae (29%), Araneae (19%), Other Hymenoptera (19%) and Collembola (14%). An advantage of species richness is that it provides a broad measure of the complexity of communities and perhaps their resilience to change. Its disadvantage lies in the practical difficulty of distinguishing invertebrate species and how little it reveals about species interactions. However, species richness has the potential to tell us more about invertebrate communities and soil quality than straight biomass, density or abundance (Stork and Eggleton, 1992).

Diversity Functional Group between Natural and Conventional Farming System

Although there was no significant difference in richness and abundance in both cropping systems, in an agroecosystem, we can discuss the function that has each arthropod. From an ecological system it is important to know this since not all invertebrates that we find in the system could have different functions. That is, although there is more diversity, it could not mean that there are more functional groups. In Fig. 3, we can see that in the two systems, we could find a higher percentage of predators abundance in the natural system than in the conventional one.

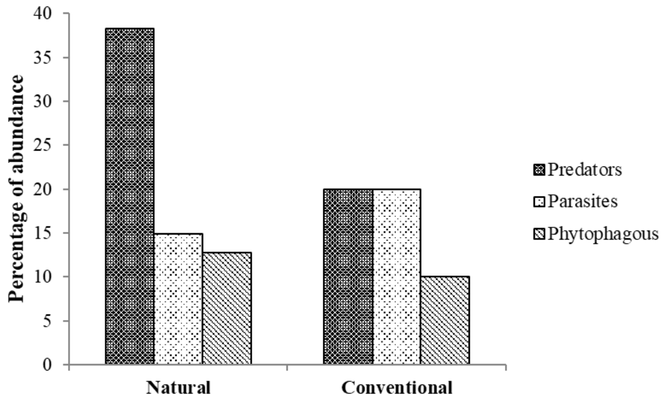
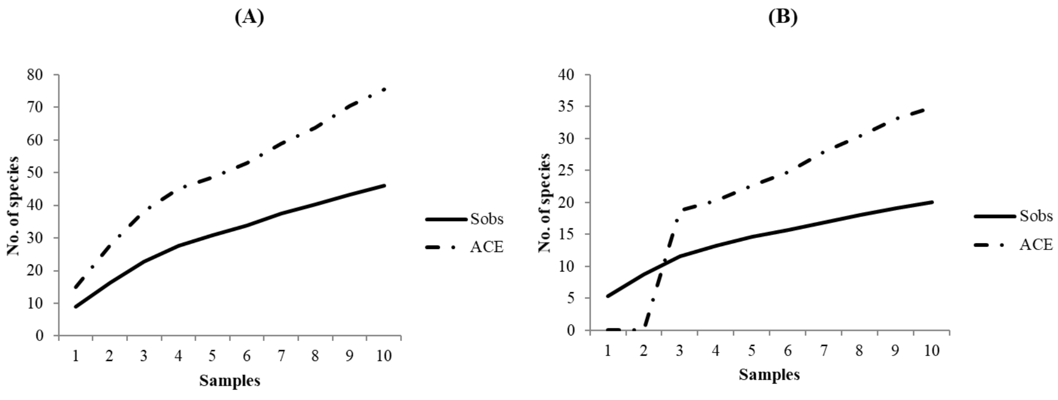


Fig. 3 Percentage of the abundance for functional group in both systems

Species Accumulation Curves (ACE) between Natural and Conventional Farming System

In order to understand the correlation between the observed and the estimated, Fig. 4 could be used to analyze the scenarios. In this figure we can see that the effort of the samples was insufficient in both systems. But we could conclude that despite that, in both systems the natural one is more diverse than the conventional one, since it is estimated that in the natural system, there are more than twice as many species as in the conventional one.

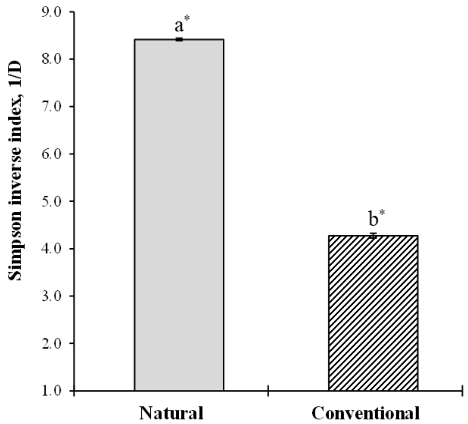


Sobs: observed species, ACE: estimated

Fig. 4 Species accumulation curves in natural system (A) and conventional system (B)

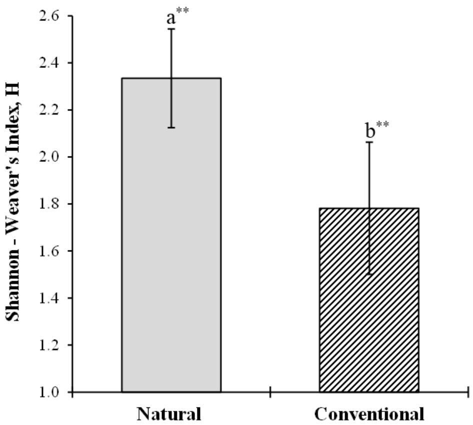
Diversity Indices between Natural and Conventional Farming System

Both diversity indices indicate a higher value in natural system than conventional system. Diversity in agroecosystem, or agro biodiversity, promotes the presence of beneficial fauna, optimizing the ecological processes that favor stability, and consequently favoring their sustainability (Altieri and Nicholls, 2000). But it should be clarified that it could not be quantified how an agroecosystem is only considering the relation that exists in the same space and time by a determined number of species. This is because the interaction between the same amounts of species in different conditions can vary (Ewel, 1986, 1999). The diversity indices give us an indication of the stability of the system, indicating that the farm of natural agriculture is more stable. And this indices at the same time coincides with the abundance and richness of the arthropods found in the two systems. A strong point of Simpson's index is that it considers rare species. These arthropods could indicate that they are specific to the system. In other words, rare arthropods include predators with general habits and parasitoids that are more specific, such as the parasitoid wasps which in total collected 11 species, 7 of which were in natural farm and 4 in conventional farm. Predators such as spiders and beetles recorded 18 species in natural agriculture and 4 species in the conventional.



(*) denotes significant difference at P<0.05

Fig. 5 Simpson Inverse Index in both farming system



(**) denotes significant difference at P<0.01

Fig. 6 Shannon – Weaver Index in both farming system

These results would support the hypotheses of Altieri and Letourneau (1984) and Altieri and Nicholls (2000) that diverse systems stimulate a greater diversity of arthropods. The first hypothesis is that more complex systems mean more diversity of species. And the diversity of species and structural plants would be associated with the diversity and abundance of insects because it would generate more food resources and temporary shelters. Increased abundance of predators and parasitoids in diverse plant associations reduces prey / host density (Root, 1973), so competition between herbivores is reduced, which in turn allows for the addition of new species of herbivores that support more species of natural enemies. And finally, they assume that the productivity of polycultures is greater, stable and predictable than in monocultures. Increased productivity and heterogeneity of the agroecosystem would mean that in a temporal and spatial environment, more species of arthropods could coexist.

CONCLUSION

There was no significant difference in richness and abundance, but more predators were observed in the natural system. Among the predators, the spiders and beetles population were dominant. The diversity indices were higher in the natural system, which means the distribution and abundance in the community is more equitable.

The farming system influences the diversity of arthropods in an agricultural environment. Therefore, if a system cannot conserve or increase the biodiversity of the farmland, it will be more unstable and with poor soil ecosystem health. However, more research is needed to better understand the interaction and roles of arthropods in a soil ecosystem.

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