

## Impact of 2-years practice of organic coffee farming on soil arthropod diversity

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### Abstract

Organic farming has been recommended by many experts in the world because of its positive ecological impacts such as increasing biodiversity. In Indonesia, the practice of organic farming is very widespread, including in smallholder coffee plantations. This study was intended to determine the impact of the organic farming system applied by smallholder coffee farmers for 2 years on soil arthropod diversity. On the two coffee farmlands, the conventional and organics (1 ha each), 10 plots of 5 x 20 meters were set and in each of these plots 5 sampling points were defined for collecting soil arthropods using pit-fall technique. The analysis of arthropod diversity in the two fields was quantified using the Shannon-Wiener diversity index model. The results showed that the two compared coffee farming systems had the same index of diversity ( $H'$ ) and evenness ( $E$ ). However, statistical tests using the Hutcheson t-test revealed that the variance in diversity of arthropods in organic coffee farms was significantly higher than in conventional ones ( $\alpha < 0.001$ ). Therefore, it can be concluded that the practice of organic coffee farming, although in a short time, has been able and potent to increase the population and/or diversity of soil animals.

**Keywords:** Conventional farming; Organic farming; Organic coffee plantation; Soil arthropods diversity

### 1. Introduction

In Indonesia, organic farming was only introduced in the first decade of the 21st century, but entering the second decade of organic farming developed very rapidly relying on grassroots initiatives [1]. The background for the development of organic farming systems in Indonesia is more or less the same as that in developed countries, namely the increasing demand for healthy organic food and increasing environmental concerns [2]. If in the beginning, organic farming was mostly applied to rice fields and horticulture, nowadays the organic system is also applied in smallholder coffee plantations [3].

From a food health point of view, organic agriculture has many benefits, but ecologically, this no-tillage farming system still leaves many questions. One of the key issues for organic farming is whether the application of this agricultural system in the long term and covering large areas of land provides greater benefits to biodiversity [4].

A study of the long-term impact of organic farming on coffee plantations compared to conventional ones found that organic systems in a long-term (12 years) improved soil properties, increased soil microbial and meso-fauna populations [5]. The question is whether the impact of organic coffee farming on biodiversity can only be known after decades, or can it be assessed in a shorter period? To determine the effect of organic coffee farming on soil biodiversity, we conducted a soil arthropod survey in organic coffee plantations that had only been implemented for 2 years.

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## 2. Material and methods

### 2.1. Study site

The organic and conventional coffee farms studied were smallholder plantations located an altitude of 497-525 meters above sea level in the Gedung Surian District (5°06'44" S, 104°27'38"E), West Lampung Regency, Lampung Province, Indonesia. The two coffee plantations compared in this study are intercropping plantations. In the conventional system, the existing intercrops are durian (*Durio zibethinus*), jackfruit (*Artocarpus heterophyllus*), cocoa (*Theobroma cacao*), citrus plants (*Citrus* spp.), Banana plants (*Musa* spp.) and pepper (*Piper nigrum*). Whereas in the organic coffee farmland, besides these plants, there is also a mimosoid tree (*Leucaena leucocephala*). In the organic system all soil management techniques have been abandoned and the fertilizers used were natural-organic materials such as compost and livestock manure. In contrast, on conventional coffee farms the synthetic pesticides, chemical fertilizers and mechanical equipments are still used in weeding the land.

### 2.2. Sampling design

Sampling design used in this study is a purposive sampling technique. The land area of the two types of plantations surveyed, conventional and organic, was ± 1 ha each. On each of the 1 ha of coffee farmlands in question, 10 plots of 5 x 20 meters were set. In each of these plots, there were 5 sampling points for trapping soil arthropods. With this design, on organic and conventional coffee farms, totally there were 50 sampling points each.

### 2.3. Collecting the Arthropods

In this study, the targeted soil animals were ground-dwelling arthropods. To collect them we used pitfall trapping technique, one of the most frequently used techniques for collecting ground-dwelling arthropods. The pitfall traps consisted of open plastic cups (6 cm in diameter and 9 cm deep). The trap cups were buried into the ground until the rim of the cup is level with the ground. The cup is filled with a mixture of water and detergent and spiked with table salt as a preservative. Trapped animals were collected daily (24 hours after burial) and repeated for three days. The determination of arthropods is carried out to the Genera level using various reference books such as: Helmbergerand Wickings (2017), Borrer et al. (1989), and Thomas (1990) [6-8].

### 2.4. Data analysis

The data analysis applied in the study followed the method introduced by Magurran (1988) [9], i.e. by analyzing the diversity of soil arthropods collected from each coffee farming system, conventional and organic, using Shannon-Wiener diversity index ( $H'$ ) and Evenness index ( $E$ ). Next, variance in the diversity of the conventional and organic farmlands was estimated and the statistical differences between the two were compared using Hutcheson t-test. The formulas for determining these parameters are presented in Table 1.

**Table 1** Ecological diversity parameters used in the data analysis of soil arthropods collected from conventional and organic coffee farmlands.

Parameter	Formula	Score criteria
Shannon-Wiener diversity index	$H' = - \sum pi \ln pi$ Where: $H'$ = Shannon diversity index at area $pi = (ni/N)$ proportion of the $i$ -th species $ni$ = number of $i$ -th species $N$ = total number of individual $\ln$ = natural logarithm	$< 1.0$ = Low diversity $- 3.22$ = Moderate $> 3.22$ = Highdiversity
Evenness index	$E = \frac{H'}{\ln S}$ Where: $E$ = evenness $H'$ = Shannon diversity index at area $S$ = total number of species	$< 0.4$ = low evenness $0.4-0.6$ = moderate evenness $>0.6$ = high evenness

Variance in the diversity	$\text{Var } H' = \frac{\sum pi(\ln pi)^2 - (\sum pi \ln pi)^2}{N} - \frac{S - 1}{2N^2}$ <p>The symbol description are the same as the previous formula</p>	The lower the variance, the higher the diversity
Hutcheson t-test	$t = \frac{H1' - H2'}{\sqrt{\text{Var } H1' + \text{Var } H2'}}$ <p>Where: t=student t test value; other symbol description are the same as the previous formula</p>	If $t_{\text{value}} > t_{(df, 0.05)}$ the diversity of species in the two farmlands is statistically different.
Degree of freedom	$df = \frac{(\text{Var } H1' + \text{Var } H2')^2}{[(\text{Var } H1')^2/N1] + [(\text{Var } H2')^2/N2]}$ <p>Where: <math>df</math>= requisite degree of freedom (<math>df</math>) in student t test; other symbol description are the same as the previous formula</p>	The higher the $df$ values, the more representative the sample size is.

### 3. Results and discussion

The broad picture of the diversity and population of the ground-dwelling arthropods our collected from two compared coffee farmlands, the conventional and organic, are presented in Table 2. The analysis of diversity, evenness, and variance in diversity of arthropods at the two coffee farms derived from the Shannon-Wiener diversity index model resulted in the values presented in Table 3. The results of statistical test using Student's t-test on variance in diversity between organic and conventional coffee farmlands are presented in Table 4. Based on the t-value (4.47007) which greatly exceeds the critical limit of the t-distribution with a  $df$  value of 2459, as presented in Table 4, it can be stated that the diversity index at the organic coffee farming system, significantly higher than that of conventional.

**Table 2** Overall genera and individual numbers of soil arthropods collected from organic and conventional coffee farms.

Genera	Familia	Ordo	Coffee Farming System	
			Conventional	Organic
<i>Entomobrya</i>	Entomobryidae	Collembola	281	356
Corylophidae Genera	Corylophidae	Coleoptera	249	326
<i>Onychiurus</i>	Onychiuridae	Collembola	247	265
<i>Cylisticus</i>	Cylistidae	Isopoda	119	138
<i>Drosophilla</i>	Drosophilidae	Diptera	24	98
<i>Formica</i>	Formicidae	Hymenoptera	17	82
<i>Solenopsis</i>	Formicidae	Hymenoptera	18	68
<i>Pheidole</i>	Formicidae	Hymenoptera	63	58
Phoridae Genera	Phoridae	Diptera	12	25
<i>Culex</i>	Culicidae	Diptera	11	24
<i>Argas</i>	Agasidae	Ixodida	22	23
<i>Lewisium</i>	Corylophidae	Coleoptera	3	19
<i>Dermestez</i>	Dermetidae	Coleoptera	8	18
<i>Anisolabis</i>	Labiduridae	Dermaptera	11	17

<i>Dendroctonus</i>	Scolytidae	Coleoptera	17	16
<i>Tridactylus</i>	Tridactylidae	Orthoptera	6	11
<i>Lathrobium</i>	Staphylinidae	Coleoptera	7	9
<i>Camponotus</i>	Formicidae	Hymenoptera	11	9
<i>Minettia</i>	Lauxaniidae	Diptera	2	9
<i>Ceraphron</i>	Ceraphronidae	Hymenoptera	7	8
<i>Lestremia</i>	Cecydomylidae	Diptera	2	8
<i>Dolichopus</i>	Dolichopodidae	Diptera	9	7
<i>Acheta</i>	Grylidae	Orthoptera	8	7
<i>Euchinetus</i>	Eucinetidae	Coleoptera	6	6
<i>Scydmaenus</i>	Scydmaenidae	Coleoptera	1	6
<i>Scydodes</i>	Scytodidae	Araneae	5	6
<i>Liposcelis</i>	Liposcelidae	Psocoptera	3	6
<i>Asaphes</i>	Mymaridae	Hymenoptera	3	5
<i>Dysdera</i>	Dysderidae	Araneae	2	5
<i>Chaoborus</i>	Chaoboridae	Diptera	3	4
<i>Lepolepis</i>	Lepidopsocidae	Psocoptera	1	4
<i>Blatella</i>	Blattidae	Blattodea	4	4
Total number of genera (S)			32	32
Total number of individuals (N)			1182	1647

**Table 3** The results of measurements of the ecological diversity of soil arthropods in conventional and organic coffee farms.

Parameters	Conventional system		Organic system	
	Values	Description	Values	Description
Shannon-Wiener index (H')	2.26694	Moderate diversity	2.47592	Moderate diversity
Evenness index (E)	0.65410	High evenness	0.71440	High evenness
Var H'	0.00133	Diversity tends to be high	0.00085	Diversity tends to be high

**Table 4** Statistical analysis result of the variance in the diversity between the two coffee farmlands.

Statistic	Critical limit	Values	Description
Hutcheson t-test	t-distribution for df >120 at $\alpha < 0.05 =$ 1.960	4.47007	Variance in diversity between conventional and organic coffee farming is significantly different.
Degree of freedom	df > 120	2459	Sampel size of arthropods in this study is representative.

The data in Table 1 factually shows that the composition and population of soil arthropods living in the two coffee farms are relatively the same. The similarity in composition and population of the arthropods may indicate that the physical conditions of the soil on the two coffee farms are also still relatively the same. Collembola, Coleoptera, Isopoda, Diptera and Hymenoptera are the top five groups of arthropods found in this study. As revealed from various studies, it is known that the five arthropod orders mentioned can be used as bio-indicators of soil quality [10].

The similarity of soil arthropod diversity in the two coffee fields was also strengthened by the closeness in the Shannon-Wiener diversity index (Table 3). Both are at a moderate level, where in conventional system the value of  $H' = 2.26694$ , while in organic one the value of  $H' = 2.47592$ . As interpreted and acknowledged by many researchers, in the range  $1.00 < H < 3.22$ , the diversity of species in a place is categorized as moderate [11].

Apart from similar diversity, the evenness of arthropod genera in the two coffee fields was also at the same level, namely  $E = 0.65410$  in the conventional and  $E = 0.71440$  in the organic fields. It suggests that the majority of the soil arthropods genera are evenly distributed in both farmlands surveyed [12].

Although in fact the diversity and evenness of soil arthropods on both coffee farms are the same, the variance in diversity of the two coffee farmlands, when estimated using Hutcheson t-test, are differ significantly ( $\alpha < 0.001$ ). This t-test result clearly corresponds to the value of degrees of freedom ( $df = 2459$ ) which is far beyond the critical limit ( $df > 120$ ). The high  $df$ -value statistically depict that the sample size of a study is very adequate [13].

As can be seen in Table 2 the total number of individual of soil arthropods found in organic coffee fields ( $N = 1647$ ) is higher compared to conventional ones ( $N = 1182$ ). This fact should be used as a basis for assuming that the physical quality of organic coffee fields, even though it has only been implemented for 2 years, has improved. No-tillage practices and the use of compost and manure have long been known to maintain soil structure that encourages populations of beneficial soil fauna [14].

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#### 4. Conclusion

Based on the descriptive data and the results of quantitative analysis of the diversity of arthropod genera obtained in this study, it can be concluded that the practice of organic coffee farming, although in a short time, has been able to increase the population and/or diversity of soil animals.

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#### Compliance with ethical standards

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##### *Disclosure of conflict of interest*

The authors declare no conflict of interests.

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