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The potential of soil arthropods as bioindicator of soil quality in relation to environmental factors at apple farm, Batu, East Java, Indonesia

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Abstract. The objectives of this study are to determine community structure, abundance and diversity of soil arthropods which potential as the bioindicator of soil quality, and analyze the correlation between chemical parameters of the environmental factor on the abundance of soil arthropods. This study was conducted at the conventional and semi-organic Apple Farm, Bumiaji, Batu, East Java Province, Indonesia, from April to September 2017. Soil Arthropods sample has been taken from three different zones of Apple Farm soil which divided into ten sampling stations. *Shannon (H'), Margalef, Evenness and Indicator Value (IndVal) Index* were applied to determine the diversity of soil Arthropods. Whereas, the correlation between soil environmental factors and abundance of soil Arthropods were analyzed using *Multivariate Analysis* included *Principal Component Analysis (PCA), similarities,* and *Canonical Correspondence Analysis (CCA)*. The total of soil Arthropods belonging to 22 genera, 12 families, and six orders genera, had been identified, with *Lepidocyrtus* were considered as the most abundant of Genus. Nevertheless, diversity of soil Arthropods in the semi-organic farm were higher than conventional farm ones, this related to soil chemical properties which included pH, C, N, C/N ratio, P, K and other organic matters. Based on indicator value indicated that *Euborellia* Genus from Apple conventional farm, and *Brachymyrmex* and *Homidia* Genus from Apple semi-organic farm was considered as the potential bioindicator of soil quality.

1. Introduction

Soil Arthropods are essential in farm and plantation ecosystem processes where they are able to regulate nutrient dynamics and soil quality, increase pressures on soil biodiversity and degradation and are useful as biological indicators of ecosystem condition [1, 2]. Preventing their existence is one effort to maintain the stability of the ecosystem especially in apple production system.

Batu City, East Java Province is widely known as apple city in Indonesia, is one of the largest apple farm area in Indonesia, with high production of apple fruit every year. Indahwati et al., [3] stated that apple farm area in Batu City is 2.993.89 ha located in Bumiaji Sub district included the village of Tulungrejo, Sumbergondo, Sumberbrantas, Punten, Bulukerto, Bumiaji, Giripurno and Gunungsari. The village which has the largest apple farm is Tulungrejo Village, which is 900 ha with a population of 24.000 apple plant. The average of apple production in Tulungrejo is 11.000 tons per harvest season with the productivity of 2.5 tons/ha. According to data from BPS Kota Batu (2017), apple plant populations in Batu City at the first quarter were 2.122.829 plant, with apple production 163.017 kw and were experienced a decline in the fourth quarter to 2.118.679 plant with production of 146.362 kw.

There are several reasons for the decline of apple production within these upcoming years. The use of either synthetic fertilizer or pesticide were thought to be the main problem of apple production, as well they also affected for the outbreak of pesticide-resistant pest which indirectly affects for the decline of apple production [3]. Therefore, in this study, we focused on comparing the existence of soil arthropods at the conventional and semi-organic Apple Farm to assess the soil quality of both ecosystems as well as to determine the soil arthropods which could be used as soil bioindicator. Arthropods provided many important ecosystem services on farmland, including the pollination of crops and control of damaging pest species [4]. The result obtained from this study was expected to figure out the complexity of soil arthropods in conventional and semi-organic apple farm as the bioindicator of soil health as well as to increase the attraction of both policy-makers and farmers to choose best agricultural practice to increase apple production as main attraction tourism at Batu city.

2. Material and Methods

2.1. Study Area

The study was conducted at two apple farm areas that applied different plant management system, Bumiaji district, Batu city, East Java Province, Indonesia, from April to September 2017. The conventional apple farm in Punten Village and semi-organic apple farm in Sumber Brantas Village, both apple farms are located in Bumiaji district, Batu city, East Java Province, Indonesia, with coordinate number latitude: 7°49'23.42"S and longitude: 112°31'38.62"E for semi-organic apple farm, latitude: 7°49'0.40"S and longitude: 112°31'43.49"E for conventional Apple Farm.

In this study, two different type of apple farm management was selected in respect to seeking the variety of geophysical characteristic of soil Arthropods. The conventional apple farm management has applied synthetic fertilizer, herbicide, and pesticide on its plantation soil, whereas use of synthetic fertilizer, herbicide, and pesticide have been reduced by 50% (fifty percent) at semi-organic apple farm management. The semi-organic apple farm management has accentuated application of organic fertilizer such as manure and humus for its plantation soil.

Figure 1. Location of soil arthropods sampling collection at semi-organic apple farm, Sumber Brantas, Bumiaji, Batu City, East Java Province, Indonesia; at conventional apple farm, Punten, Bumiaji, Batu City, East Java Province, Indonesia.

2.2. Experimental Design and Arthropod Collection

Soil Arthropods have been collected from two types of apple farm, conventional and semi-organic apple farm area. Each type of apple farm was set into three different zones where each zone was divided into ten sampling stations with 5 m distance between them to ensure the independence of data. Research equipment which was used in this study included soil driller of 25cm x 25cm x 10cm, ruler, binocular microscope, *Thermohygrometer*, tweezers, while research materials included 70% alcohol and detergent. Both the soil in the conventional and semi-organic farm were sampled through *Pitfall Trap* and *Hand Sorted* methods.

Pitfall Trap made of plastic glass with 10 cm in diameter and 7 cm in height was fit into a hole dug in the soil. The plastic glass has contained a mixture of 25 ml of 70% of alcohol and 6.25 ml of detergent known as *the Scheerpeltz* liquid. Observation of each trap was conducted during 24 h, the soil Arthropods that had been trapped were conserved with 70% alcohol for further study in the laboratory.

Hand sorted method was applied by collecting soil in each sampling station with 25 cm in length, 25 cm in width, and 30 cm in height. The soil Arthropods which had been found from collected soil were separated and conserved with 70% alcohol for further identification. Each sample was processed in the laboratory, separating and classifying the arthropods. With a binocular microscope, all the adult and juvenile specimens were classified to the order level or taxonomic categories.

2.3. Environmental Factor Analysis
Environmental factor included the physical and chemical characteristic of soil apple farm in each sampling station were analyzed. For physical characteristics, temperature and humidity either soil surface or underneath of soil surface were analyzed using *Termohygrometer*. Furthermore, the chemical characteristic which included pH, C, N, C/N ratio, P, K, and other organic matters were analyzed through collecting 5 mg soil of each sampling station.

2.4 Statistical Analysis
The Shannon-Wiener (H), Margalef, Evenness and Indicator Value (IndVal) Index using R software were applied to determine the diversity indices of soil Arthropods. Whereas, the correlation between soil chemicals characteristic and soil Arthropods abundance was analyzed using *Multivariate Analysis* included *Principal Component Analysis (PCA), similarities,* and *Canonical Correspondence Analysis (CCA).*

3. Result and Discussion
3.1. Identification and Diversity of Soil Arthropods
A Total of 22 genera consisted of 6 orders, and 12 families were identified from the conventional and semi-organic apple farm, Bumiaji, Batu, East Java Province, Indonesia, with Coleoptera and Hymenoptera were the most abundant order. Those nine families of Coleoptera and six families of Hymenoptera had been identified as shown in table 1.

Table 1. Identification of soil Arthropods in conventional and semi-organic apple farm, Bumiaji, Batu

Ordo	Family	Genus	Role	Number at Conventional Apple Farm (∑)	Number at Semi-Organic Apple Farm (∑)
Blattaria	Blattidae	*Ischnoptera*	Detritivor	5	16
	Blattidae	*Periplaneta*	Detritivor	4	7
Coleoptera	Staphylinidae	*Anotylus*	Predator	1	5
	Carabidae	*Chlaenius*	Predator	4	8
	Tenebrionidae	*Conoderus*	Herbivore	1	5
	Carabidae	*Coptodera*	Predator	7	9
	Tenebrionidae	*Hemicrepidius*	Herbivore	11	24

	Staphylinidae	*Omalium*	Predator	3	3
	Curculionidae	*Pachyrhinus*	Herbivore	7	9
	Scirtidae	*Serica*	Herbivore	1	8
	Nitidulidae	*Urophorus*	Herbivore	1	6
Collembola	Entomobryidae	*Homidia*	Decomposer	149	350
	Entomobryidae	*Lepidocyrtus*	Decomposer	322*	363*
Dermaptera	Forficulidae	*Euborellia*	Herbivore	42	12
Hymenoptera	Formicidae	*Brachymyrmex*	Predator	20	196
	Formicidae	*Formica*	Predator	73	88
	Formicidae	*Myrmecocystus*	Predator	14	29
	Formicidae	*Myrmica*	Predator	6	16
	Formicidae	*Ponera*	Predator	283	93
	Formicidae	*Stigmatomma*	Predator	0	12
Orthoptera	Gryllidae	*Acheta*	Herbivore	2	1
	Gryllotalpidae	*Scapteriscus*	Herbivore	3	12

* The highest taxa number of genus

Those Coleoptera able to adapt in various kind of habitat included underneath of soil surface [5]. Most of Coleoptera are detected as herbivores, predators, and scavengers [6].

In this study, it was confirmed that genus *Lepidocyrtus* (Entomobryomorpha: Entomobryidae) had higher abundance value and the higher number both in conventional and semi-organic apple farm, Bumiaji, Batu of 322 taxa and 363 taxa, respectively (table 1). The genus of *Lepidocyrtus* member of Collembola, are cosmopolitan, small-to-minute, soft-bodied, widespread and often found in various kind of habitat [2]. Moreover, most Collembola lives in land-related habitats such as soil, soil surface, rotting litter, animal dung, animal nests, and burrows, require a moist habitat, feed on plant and wood litter [7]. Each habitat has a different composition of Collembola diversity.

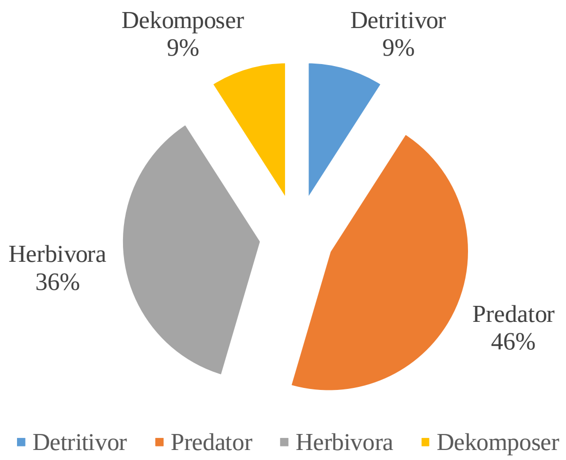

Figure 2. The role percentage of the soil Arthropods in conventional and semi-organic apple farm, Bumiaji, Batu

Concerning classification of the soil Arthropods in conventional and semi-organic apple farm, Bumiaji, Batu, the role percentage of soil Arthropods included 46% as predators, 36% as herbivores, and 9% as decomposer and detritivore respectively (figure 2).

Table 2. The diversity indices of soil Arthropods in conventional and semi-organic apple farm, Bumiaji, Batu

No.	Variable	Conventional Apple Farm	Semi-Organic Apple Farm
1.	Number of Genus (R)	21	22
2.	Number of Individual (N)	959	1.272
3.	Shannon Index (H)	1.797	2.031
4.	Margalef Index (R)	2.913	2.938
5.	Evenness Index (E)	0.287	0.347

The Shannon diversity indices were calculated for the conventional and semi-organic apple farm, significant differences were detected for indices between conventional and semi-organic apple farm with Shannon value of 1.797 and 2.031 respectively, with semi-organic apple farm contain significantly higher diversity than conventional apple farm according to both indices (table 2). Related to the diversity indices, based on table 2, Number of Genus (R) of 22, Number of Individual (N) of 1.272, Margalef Index (R) of 2.938, and Evenness Index (E) of 0.347 of semi-organic apple farm were also higher than conventional apple farm (table 2).

In the diverse conditions, a species cannot be more dominant than the others, whereas, in the less diverse communities, one or two species can be dominant than others [8]. The more number of species and the more evenly distributed species are in their abundance, the greater the diversity of communities in high-diversity communities, a population of a particular species cannot become dominant [1].

3.2. Chemical Characteristic of soil at the apple farm, Bumiaji, Batu, East Java Province, Indonesia

Tabel. 3. Comparison of Chemical Characteristic between soil at Conventional and Semi-Organic Apple Farm, Bumiaji, Batu

No.	Environmental Factor	Conventional Apple Farm	Grading Criteria*	Semi-Organic Apple Farm	Grading Criteria*
1.	pH	4.93	Acid	5.83	Tend to Alkali
2.	C-organic (%)	2.38	Middle	3.25	High
3.	N total (%)	0.27	Middle	0.26	Middle
4.	C/N ratio	8.67	Low	1.67	Middle
5.	Organic Matters (%)	4.12	High	5.62	Very High
6.	P (mg 100 g^{-1})	140.23	Very High	212.86	Very High
7.	K (mg 100 g^{-1})	1.07	High	2.81	Very High

*Soil grading criteria was conducted based on grading criteria of soil chemical characteristic by Sulaeman *et al.* 2005

Chemical characteristic analysis of soil at conventional and semi-organic apple farm (table 3) revealed that according to grading criteria of soil chemical characteristic [9], the soil of semi-organic apple farm was rich in organic matters (5.62), carbon (C) (3.25%), phosphor (P) (212.86 mg 100 g^{-1}), and potassium (K) (2.81 mg 100 g^{-1}). Moreover, soil of semi-organic apple farm content nitrogen (N) (0.26%) and C/N ratio (13.67) with middle grading criteria, with pH 5,83 was tended to alkali. In contrast with semi-organic apple farm, the most higher content of chemical characteristic at soil of conventional apple farm was P (140.23 mg 100 g^{-1}), followed by total organic matters (4.12%), K (1.07 mg 100 g^{-1}), middle content of N (0.27%) and C-organic (2.38%), low content of C/N ratio (8.67).

This study showed that the community was more abundant and diverse in the soil with the high organic matter. The semi-organic apple farm contains higher organic matter such as C-organic, organic matters, P and K (Table 3) than the soil of conventional apple farm in Bumiaji, Batu. Most of soil organic matter at semi-organic apple farm may originate from apple plant tissue mentioned as the residue of the apple crop. The residue of apple crop added to the soil are decomposed by soil macro- and micro-organisms, increasing the organic matter content of the soil. Although present in small amounts, those soil organic matters are very important for soil fertility management. Moreover, the application of organic fertilizer on the soil of semi-organic apple farm may also increase the richness of C-organic, organic matters, P, and K content. The main source of P in the soil is derived from weathering of parental

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material, mineralization of P organic which immobilized P produced by the decomposition of plant and animal residue [1,10].

In addition to N total, the content of C-organic and C/N ratio at conventional apple farm is lower than the content of C-organic and C/N ratio at the semi-organic apple farm. The application of synthetic fertilizer, herbicide, and pesticide on conventional apple farm periodically may interfere with the decomposition process and reduce soil organic matter. Furthermore, the process of decomposition is the release of complex carbon bonds into simple bonds due to the use of C elements by organisms to get their life energy through the process of respiration and biosynthesis releasing CO2, so that organic materials that have undergone the process of decomposition will have a lower C content than the C content of fresh ingredients [1].

3.3 Correlation between soil chemical characteristic and soil arthropods abundance at the conventional and semi-organic apple farm

The Canonical Correspondence Analysis (CCA) was applied to analyze the correlation between soil chemical characteristic and soil arthropods abundance at the conventional and semi-organic apple farm, Bumiaji, Batu. The CCA analysis shown that there was the significant correlation between the soil chemical characteristic included pH, C-organic, N total, C/N ratio, organic matters, P and K, with soil arthropods abundance. The correlation which appeared at conventional apple farm is characterized by a total N which associated with the genus *Hemicrepidius*. Whereas at the semi-organic apple farm are characterized by pH and K which associated with the genus *Omalium*, C-organic, organic matters and K associated with the genus *Myrmecocystus* and P associated with the genus *Pachyrhinus* and *Periplaneta* (figure 3).

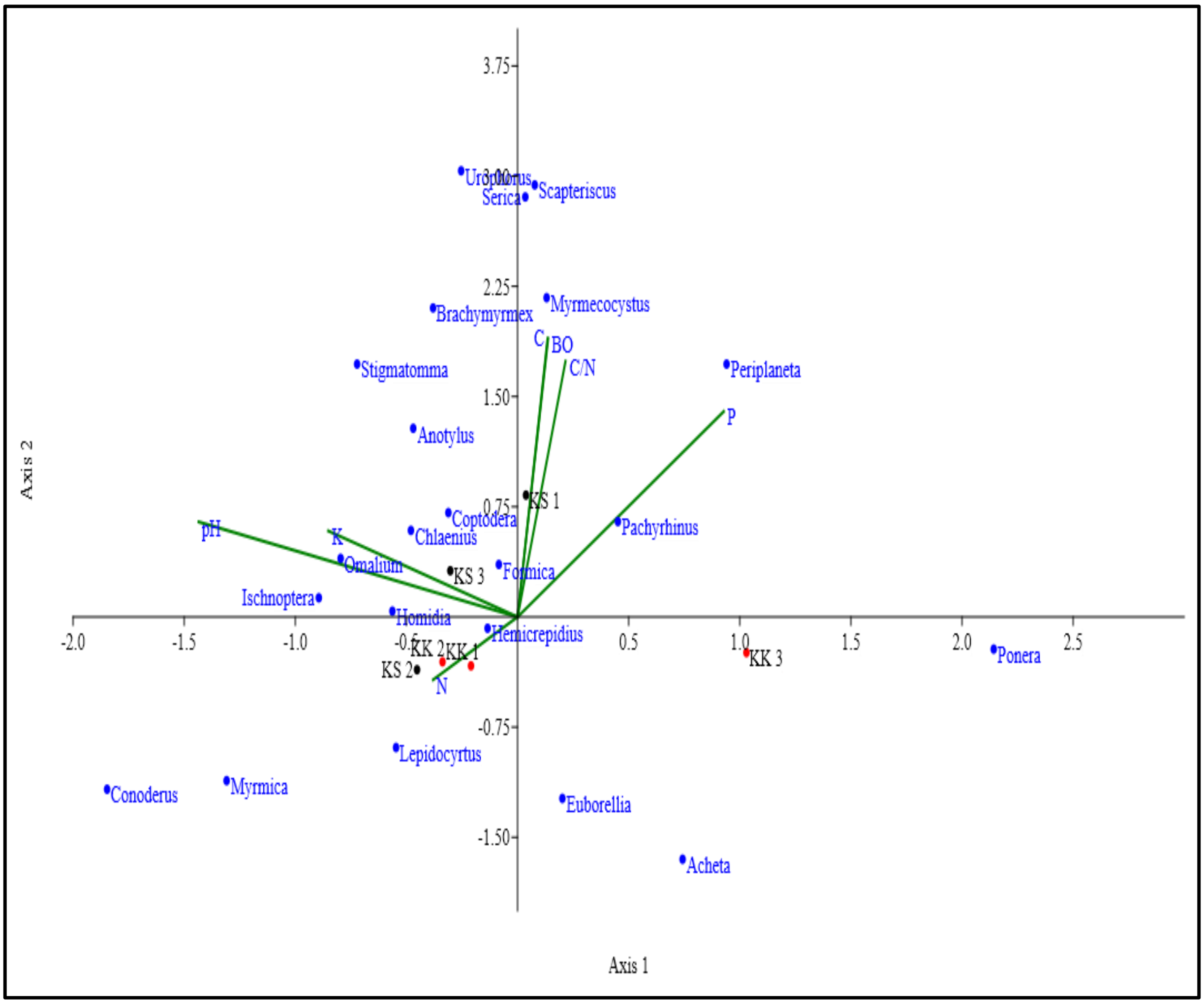

Figure 3. The canonical correspondence analysis (CCA) between soil chemicals characteristic and soil arthropods abundance

3.4 Soil Arthropods as Bioindicator of Soil Quality in Apple Farm, Bumiaji, Batu

The indicator value (Indval) analysis was conducted to determine the genus of soil arthropods which were potential as the bioindicator of soil quality at the conventional and semi-organic apple farm, Bumiaji, Batu (table 4). The result shown that genus *Euborellia* (Cocopet) is potential genus to be indicated as bioindicator of soil quality at conventional apple farm with Indval 0.882 and p-value of 0.022 (p-value < 0.05), furthermore at semi-organic apple farm, genus *Brachymyrmex* (ant) and *Homidia* (Collembola) were potential genera to be used as bioindicator of soil quality with Indval value of 0.953 and 0.786, and p-Value of 0.017 and 0,015 (p-value < 0.05), respectively (table 4).

Table 4. The genus of soil arthropods which were potential as the bioindicator of soil quality at the conventional and semi-organic apple farm, Bumiaji, Batu

Apple Farm Type	Genus	Indicator Value	p-Value
Conventional	*Euborellia*	0.882	0.022

Semi-organic	*Brachymyrmex*	0.953	0.017
	Homidia	0.786	0.015

According to indicator value that genus *Euborellia* (Cocopet) was one of potential bioindicator of soil quality at the conventional apple farm. In addition to bioindicator of soil quality, the genus *Euborellia* (Cocopet) may have the important role in biological control as insect predator which could significantly reduce the population of apple plant-destroying insect pests through the act as natural enemies.

The similar result, the ant can be used as potential bioindicators of soil quality, due to its role in maintaining soil quality. Ant is one of the genus *Brachymyrmex* which have high survival rate, sensitivity and most tolerant, although environmental condition and disturbance extremely change in their habitat [11]. Ants are one of the best biological indicators used to determine ecosystem integrity [12]. Ants have high richness and abundance, the important role in the ecosystem, high sensitivity to environmental changes, and easily identified.

4. Conclusion

In this study, a total of 22 genera consisted of 6 orders and 12 families were identified from the conventional and semi-organic apple farm, Bumiaji, Batu, East Java Province, Indonesia, with Coleoptera and Hymenoptera were the most abundant order. Moreover, genus *Lepidocyrtus* (Entomobryomorpha: Entomobryidae) had higher abundance value and the greater number both in conventional and semi-organic apple farm of 322 taxa and 363 taxa, respectively.

It is interesting to note that the semi-organic apple farm contains higher organic matter such as C-organic, organic matters, P and K (Table 3) than the soil of conventional apple farm in Bumiaji, Batu. The correlation between soil chemical characteristic and soil arthropods abundance appeared that at conventional apple farm are characterized by a total N which associated with the genus *Hemicrepidius*, whereas at semi-organic apple farm are characterized by pH and K which associated with the genus *Omalium*, C-organic, organic matters and K associated with the genus *Myrmecocystus* and P associated with the genus *Pachyrhinus* and *Periplaneta.* The result of indicator value (Indval) analysis shown that genus *Euborellia* (Cocopet) is indicated as the potential bioindicator of soil quality at the conventional apple farm, furthermore at the semi-organic apple farm, genus *Brachymyrmex* (ant) and *Homidia* (Collembola) were the potential genus to be used as bioindicator of soil quality.

The semi-organic apple farm has better environmental conditions than conventional apple farm. It is supported by the results of the study showed that the diversity of soil arthropods in semi-organic apple farm was higher than conventional apple farm. Based on this study recommend that the farmers can use Ant and Collembola groups as the bioindicator of soil quality in semi-organic apple farm.

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