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The Potency of Soil Insect As Soil Quality Bioindicators in Citrus Plantations Poncokusumo District, Malang Regency

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Abstract

Insects have great potential to be used as soil bioindicators. The research aims to analyze abundance and diversity of soil insects genus and determine the soil insects genus that have potential as soil quality bioindicators in citrus plantations. The study was conducted in conventional and semiorganic citrus plantations in Poncokusumo District, Malang Regency. The research used pitfall trap and hand sorted methods. Data were analyzed to find out diversity index, Canonical Correspondence Analysis and Indicator Value Index. The data analysis used PAST program version 3.15 and software R. The research results were obtained 20 genus of soil insects. The highest abundance of soil insects is occupied by the genus Aphaenogaster. The diversity of soil insects in semiorganic citrus plantations is higher than conventional citrus plantations. The soils insects that have potential as bioindicators of soil quality in conventional citrus plantations is the genus Formica, while in the semiorganic citrus plantations are the genus Cyrtepistomus, Pangeus, Tenebrio, Euborellia, Allonemobius, Stelidota, Gryllus and Chlaenius.

1. INTRODUCTION

Citrus plantation have existed in Indonesia for hundreds years. Citrus is a fruit commodity that can be traded domestically and abroad. Citrus consumption for households during the 2015-2019 period is projected to increase with an average growth of 0.52% per year (Pusat Data dan Sistem Informasi Pertanian, 2015). Poncokusumo is a distric in Malang regency that has high citrus production, in 2017 the citrus production is 20,454 quintal and increase in 2018 wich is 205,744 quintal (Statistic of Malang Regency, 2019).

Citrus production can decrease due to the attack of pests. Most farmers overcome this attack by applying pesticides (Endarto and

Martini, 2016). This happens because farmers do not yet have awareness and understanding of the dangers of pesticides on the environment (Suheriyanto, 2008). Untung (2006) states that farmers begin to realize and recognize the importance of health to the environment and the products, so that the develops of organic farming system.

Soil quality is demonstrated by the soil ability to function in the ecosystem and interact positively with the surrounding ecosystem. The assessment of soil quality must reflect the processes and interactions of biological, chemical and physical properties of the soil (Karlen *et al*., 2003).

Farmers need early warning indicators of soil quality and monitoring tools to guide soil management, because the cost of preventing soil degradation is cheaper than the cost of corrective action (Barrios *et al*., 2006). Indicators that can be used to determine soil quality are physical indicators, chemical indicators, biological indicators and visible indicators (Nortcliff, 2002). According to Doran and Zeiss (2000), the criteria for quality indicators and soil health are related to their use in determining ecosystem processes and integrating physical, chemical and biological properties, their sensitivity in climate management and variation, as well as their accessibility and utilization by agricultural experts, producers, environmental conservation, and policy makers.

The old method used to evaluate soil quality is based on the use of physical, chemical and microbiological indicators. The use of these indicators requires expensive costs for analysis. New methods based on soil arthropods have been proposed to evaluate soil quality. Soil arthropods were chosen because they provide sensitive responses to land management practices, are inexpensive and are positively correlated with soil function (Parisi *et al*., 2005). The vast majority of living organism have been scientifically described is arthropod (66%). Insects represent 75% of all animals (Chapman, 2013), so that the insect has great potential to be used as a soil bioindicator. Insects give a good response, but the response varies depending on species and environmental changes that occur. Classes of insects that are potentially used as environmental bioindicators are the order Coleoptera, Diptera, Lepidoptera, Hymenoptera, Hemiptera and Isoptera (da Rocha *et al*., 2010).

Ants are one of the best biological indicators used to determine ecosystem integrity. Ants have a high wealth and abundance, have an important role in the ecosystem, are sensitive to environmental changes, hopefully captured, separated and identified (Delabie *et al*., 2009).

The research aims to analyze the abundance and diversity of soil insect genus, and determine the genus of soil insects that have potential as soil quality bioindicators in citrus plantation Poncokusumo District, Malang Regency.

2. MATERIALS and METHODS

Time and Location

The study was conducted on July 2018 until October 2018 at Conventional Citrus Plantation (8°3'19.24"S 112°47'55.77"E) and Semi Organic Citrus Plantation (8°4'43.38"S 112°44'56.94"E) in Poncokusumo District, Malang Regency (Figure 1).

Research Methods

At each location, soil insect sampling was taken at 3 observation station. At each station 10 observation points were determined with a distance between 5 m observation points. The method used to obtain insects samples is:.

1. Pitfall Trap Method

Pitfall traps used to collect soil insects are made of plastic glass with a diameter of 10 cm and a height of 7 cm. Plastic cups filled with 25 ml 70% alcohol solution and 3 drops of detergent solution, then the plastic cups are planted in the ground, so that the top is parallel to the soil surface. Pitfall traps are installed for 24 hours, insects that enter the trap are taken and stored in bottles containing

70% alcohol. Samples are taken to the laboratory for identification.

2. Hand Sorted Method

Collection of soil insects by hand sorted method by means of soil samples taken at each observation point with length, width and depth size: 25 cm, 25 cm and 30 cm. The soil is placed on a white layer and separated by hand. The soil insects found are calculated according to the group. Insect samples were taken and stored in bottles containing 70% alcohol. Samples are taken to the laboratory for identification.

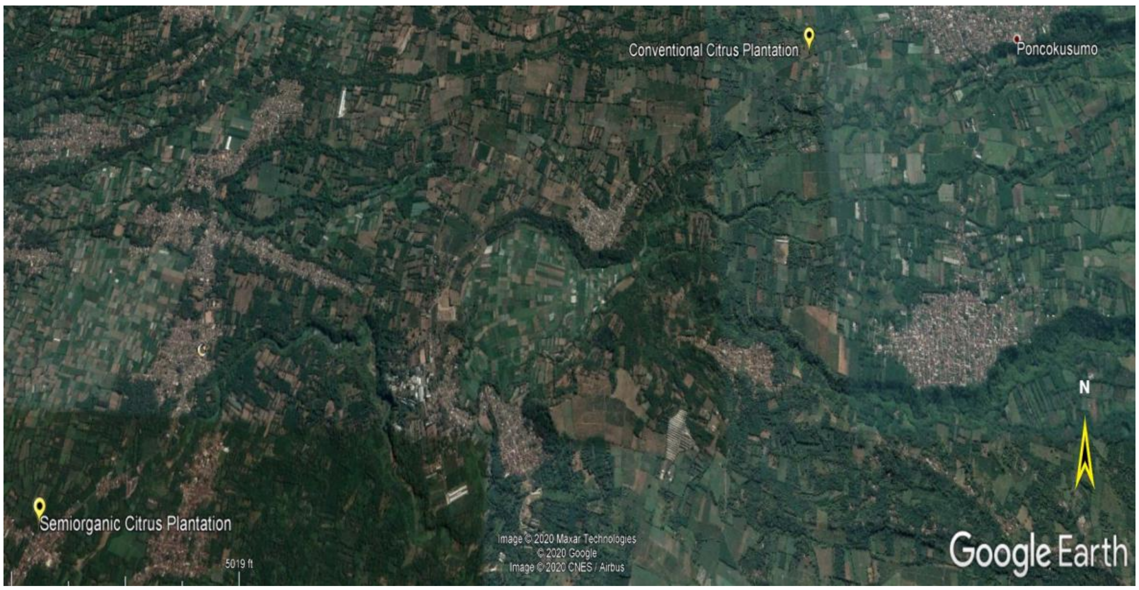

Figure 1. The study site at Conventional and Semi Organic Citrus Plantation in Poncokusumo District, Malang Regency (Adapted from Google earth, 2020)

Measurement of Soil Physical Properties

At each observation point are measured soil temperature and soil humidity. Measurement of soil temperature and humidity used a thermohygrometer.

Measurement of Soil Chemical Properties

A 0.5 kg soil sample was taken from each observation point. Soil is taken to the laboratory for analysis: pH, soil organic matter, soil organic carbon, total N, P and K.

Data Analysis

Data of the abundance of soil insect genus were analyzed to find out the Shannon diversity index (H '), Margalef index (R), Evenness index (E) and Indicator Value index (IndVal). Canonical Correspondence Analysis (CCA) is used to determine the relationship between abundance of soil insects with physical and chemical properties of the soil. Analysis of H, R, E and CCA using the PAST program version 3.15 while IndVal analysis using R software.

3. RESULTS

The soil insects that are found in the conventional citrus plantation of Poncokusumo Subdistrict, Malang Regency are 6 orders, 15 families and 18 genus. While in the semiorganic citrus plantation there are 6 orders, 15 families and 20 genus of soil insects (Tabel 1).

2 genus are not found in the conventional citrus plantation, namely family Curculionidae (Coleoptera: Curculionidae) and family Geocaridae (Hemiptera: Geocaridae).

The highest abundance of soil insects in conventional and semiorganic citrus plantations (Table 1) is occupied by genus *Aphaenogaster* (Hymenoptera: Formicidae).

Table 1. The soil insects in conventional and semiorganic citrus plantations, Poncokusumo District, Malang Regency

Order	Family	Genus	Number (individu)	
			Conventional	Semiorganic
Blattodea	Blaberidae	*Pycnoscelus*	44	70
	Blattidae	*Blatella*	19	35
Coleoptera	Brachyceridae	*Notiodes*	1	21
	Carabidae	*Chlaenius*	38	61
	Curculionidae	*Cyrtepistomus*	0	31
	Nitidulidae	*Phenolia*	49	57
		Stelidota	12	45
	Scarabaeidae	*Onthopphagus*	84	104
	Staphylinidae	*Neobisnius*	39	63
	Tenebrionidae	*Tenebrio*	6	32
Dermaptera	Anisolabididae	*Euborellia*	14	40
Hemiptera	Cydnidae	*Pangaeus*	1	25
	Geocaridae	*Isthmocoris*	0	13
Hymenoptera	Formicidae	*Aphaenogaster*	174*	184*
		Camponotus	165	135
		Formica	170	60
		Paratrechina	100	22
Orthoptera	Gryllidae	*Allonemobius*	16	32
		Gryllus	26	52
	Gryllotalpidae	*Neoscapteriscus*	65	96

Note: *: the highest number of soil insects genus

4. DISCUSSION

Based on Table 1, the order Coleoptera is the most common order found, which is 7 family and 8 genus. The results of this study is same with the research conducted by Suheriyanto *et al.* (2019) in conventional and semiorganic apple plantation, Bumiaji distric, Batu city shows that order Coleoptera is the most abundant order. According to Resh and Carde (2003) about 850,000 to 1,000,000 of all species that have been identified are insects. Of the 30 insect orders that have been described, the order Coleoptera has the most number of species which is about 300,000 to 400,000 species.

Genus *Aphaenogaster* (Hymenoptera: Formicidae) is found to be very abundant. This genus is a group of ants that live as social insects forming colonies. Capinera (2008) stated that genus *Aphaenogaster* has high mobility. It causes many member of the genus to be trapped.

The soil insect diversity in conventional citrus plantations Poncokusumo District, Malang Regency is lower than semiorganic citrus plantations. From Table 2 can be known that in semiorganic citrus plantations has number of genus: 20, number of individuals: 1,178, Shannon index: 2.78, Margalef index: 2.69 and Evenness index: 0.93 is higher than in conventional citrus plantations that is number of genus: 18, number of individuals: 1,023, Shannon index: 2.42, Margalef index: 2.45 and Evenness index: 0.84.

The use of chemical fertilizers and pesticides in semiorganic citrus plantations is increasingly reduced when compared to conventional citrus plantations. Fertilizing on semiorganic citrus plantations uses compost, while pest control uses botanical pesticides and natural enemies.

Table 2. The diversity index of soil insect in conventional and semiorganic citrus plantations, Poncokusumo District, Malang Regency.

Variable	Conventional	Semiorganic
Number of genus (R)	18	20
Number of individuals (N)	1,023	1,178
Shannon index (H)	2.42	2.78
Margalef index (R)	2.45	2.69
Evenness index (E)	0.84	0.93

In organic farming systems more species are found, possibly due to the presence of organic material for their feed and no pesticides. Whereas in conventional agriculture, the use of pesticides causes the number of species to be small (Bettiol *et al*., 2002). The use of insecticides can disrupt environmental balance, so some phytophagous species increase rapidly and cause pest outbreaks. The outbreaks of pests are usually caused by reducing predators due to insecticide applications (Souza *et al*., 2012).

When the demand for organic plant products increases, the path of interaction of natural preservation in the soil, above the ground and between the both, will improve crop quality, benefits for farmers, and ecosystem welfare (Price *et al*., 2011).

Table 3. The comparison of soil properties in conventional and semiorganic citrus plantations, Poncokusumo District, Malang Regency

Soil Properties	Conventional	Rating	Semiorganic	Rating
Temperature (°C)	25.51 *	optimum	28.54 *	optimum
Humidity (%)	72.77 *	optimum	74.10 *	optimum
pH	5.07 **	Acid	5.75 **	Rather acid
C-organic (%)	1.79 ***	Medium	1.93 ***	High
N total (%)	0.15 ***	Low	0.18 ***	Medium
C/N ratio	11.96 ***	Low	10.91 ***	Low
Organic matter (%)	3.09 ***	High	3.32 ***	High
P (mg 100 g^{-1})	13.55 ***	Medium	21.83 ***	High
K (me 100 g^{-1})	18.07 **	Low	25.19 **	Medium

*: BAPPENAS (2000), **: Sulaiman *et al.* (2005), ***: Hazelton and Murphy (2007)

From Table 3 is known that the soil properties in conventional citrus plantations, Poncokusumo District, Malang Regency are temperature and humidity: optimum, pH: acid, N total, C/N ratio and K: low, C-organic and P: medium and organic matter: high. While the soil properties in semiorganic citrus plantations are temperature and humidity: optimum, pH: rather acid, C/N ratio low, N total and K: medium, C-organic, organic matter and P: high.

The result of Canonical Correspondence Analysis (CCA) between soil insects abundance and soil properties (Figure 2) show that conventional citrus plantations are characterized by C/N associated with the genus *Onthopphagus* (beetle), *Phenolia* (beetle) and *Camponotus* (ant). Semiorganic citrus plantations are characterized by C-organic, organic matter, humidity, K, P, N, temperature, and pH associated with the genus *Tenebrio* (beetle), *Gryllus* (cricket), *Neobisnius* (beetle), *Cyrtepistomus* (beetle), *Euborelia* (earwig), *Pangeaeus* (beetle) and *Isthmocoris* (bug).

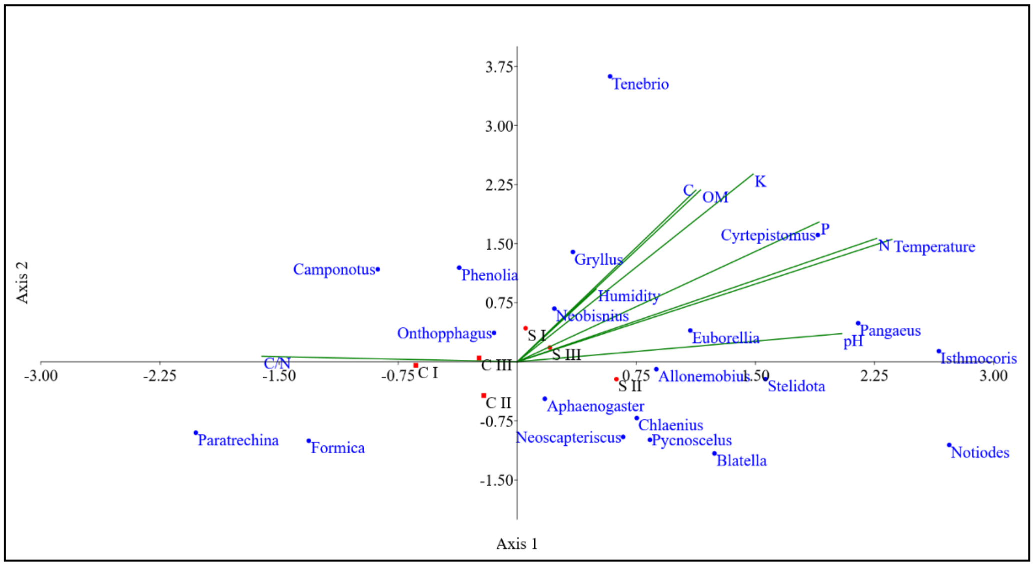

Figure 2. CCA between soil insects abundance and soil properties. C: conventional plantation, S: semiorganic plantation

The results of Indicator Value index (Tabel 4) show that soil insect has potential as soil quality bioindicators in conventional citrus plantations, Poncokusumo District, Malang Regency is the genus *Formica* (ant), while in the semiorganic citrus plantations are the genus *Cyrtepistomus* (beetle), *Pangeus* (bug), *Tenebrio* (beetle), *Euborellia* (earwig), *Allonemobius* (cricket), *Stelidota* (beetle) and *Gryllus* (cricket).

De Bruyn (1999) states that ants can be used as bioindicators of soil quality, because ants have an interest in maintaining soil quality. Ants are still able to survive on the ground, despite uncertain environmental conditions and disturbance in their habitat.

The use of bioindicators is important for monitoring the environment. The main characteristics of species as bioindicators are species richness and diversity, easily captured, ecologically have an important role, are sensitive to slight environmental changes and have a good response to environmental changes. Insects give a good response, but the response varies depending on species and environmental changes that occur. Insect class has the potential to be used as an environmental bioindicator, including the order Coleoptera, Diptera, Lepidoptera, Hymenoptera, Hemiptera, and Isoptera (da Rocha *et al*., 2010).

The use of bioindicators is important for monitoring the environment. The main characteristics of species as bioindicators are having the richness and diversity of species, being easily captured, having an important role in ecosystems, being sensitive to slight environmental changes and having a good response to environmental changes (da Rocha *et al*., 2010). Bioindicators are organisms that can provide information about environmental quality (Markert *et al*., 2003).

Table 4. Soil insects that have potential as soil quality bioindicators in conventional and semiorganic citrus plantations, Poncokusumo District, Malang Regency

Citrus Plantation	Genus	Indikator Value	p value
Conventional	*Formica*	0.775	0.021
Semiorganic	*Cyrtepistomus*	0.967	0.022
	Pangaeus	0.961	0.022
	Tenebrio	0.889	0.036
	Euborellia	0.839	0.022
	Allonemobius	0.816	0.044
	Stelidota	0.806	0.022
	Gryllus	0.801	0.036

Soil insects are quite good as soil bioindicators because they have sensitive responses to land and climate management practices, correlate well with beneficial soil properties and ecological functions such as water storage, decomposition and nutrient cycling, neutralization of toxic materials and suppression of pathogenic and harmful organisms (Doran and Zeiss, 2000)

5. CONCLUSION

The results obtained 20 genus of soil insects. The highest abundance of soil insects in conventional and semiorganic citrus plantations is occupied by the genus *Aphaenogaster* (ant). The diversity of soil insects in semiorganic citrus plantations is higher than conventional citrus plantations. The soils insects that have potential as bioindicators of soil quality in conventional citrus plantations is genus *Formica* (ant), while in the semiorganic citrus plantations are the genus *Cyrtepistomus* (beetle), *Pangeus* (bug), *Tenebrio* (beetle), *Euborellia* (earwig), *Allonemobius* (cricket), *Stelidota* (beetle) and *Gryllus* (cricket)..

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