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### Arthropods Diversity and Population Dynamic of *Helopeltis antonii* Sign. (Hemiptera: Miridae) on Various Cocoa Agroecosystems Management

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#### ABSTRACT

As an important pest, *Helopeltis Antonii* reduces cocoa yields ca. 32-44 %. Related to *H. antonii*, this research aimed to identify the arthropods diversity, population and attack intensity of *H. antonii* in three different managements of cocoa plantations i.e. Kedaton, Banjarsari and Nogosari, Jember district, East Java, Indonesia from February 2014 to February 2015. The arthropod collection was done by visually, sweep net, yellow pan, malaise and pitfall traps. Arthropods diversity and similarity were analyzed by Margalef species richness index (R), Shannon-Wiener diversity index (H'), Evenness index (E), Simpson dominance index (C) and Sorensen Similarity index (SS). The different number of arthropod, population and attack intensity of *H. antonii* between plantations were examined by Wilcoxon test. The research showed that the highest species richness, diversity and evenness index values was in Nogosari and it was in a stable condition. About 10 orders, 35 families and 41 species of arthropods in Nogosari, it was higher than two other cocoa plantations. Nogosari was different from Kedaton and Banjarsari based on Sorensen Similarity Index with 78.26 and 77.78 % respectively. In addition, population dynamic and attack intensity of *H. antonii* in the three cocoa plantations were different in a year.

#### INTRODUCTION

Cocoa (*Theobroma cacao* L.) is a strategic commodity for Indonesian plantation. Indonesia is the biggest cocoa producer in Oceania (ICCO, 2012; 2013). *Helopeltis antonii*, an obstacle in the cultivation of cocoa attacks the fruits and shoots (Atmaja, 2010; Purwaningsih, Mudjiono, & Karindah, 2014). Severe attack on shoots can reduce yields of cocoa ranged from 32 to 44 % (Purwaningsih, Mudjiono, & Karindah, 2014). Arthropod plays an important role in the structures and processes in maintaining the biological diversity of an ecosystem (Altieri & Rogé, 2010; Yatno, Pasaru, & Wahid, 2013). Agroecosystem management factors affect the diversity of arthropods (Kogan & Lattin, 1993; Nicholls & Altieri, 2004; Wilby et al., 2006).

There are several types of agroecosystem i.e. modern annual monocultures, modern orchards,

organic farming system and traditional polycultures (Altieri & Nicholls, 2004). All agroecosystems can be distinguished based on crops diversity, temporal performance, isolation, stability, genetic diversity, human control and natural pest control. Each agroecosystem is dynamic and exposed to different levels of management (Altieri & Nicholls, 2004).

In the agroecosystem management, there are several practices such as intercropping, agroforestry, shifting cultivation, and other traditional farming methods as imitator of natural ecological processes. The natural analogies can be adopted to design the agroecosystem that manage the effective soil nutrients, rainfall, use of sunlight and biological resources (Altieri & Nicholls, 2004). Based on some agricultural practices and designs, the best management practices provide the ecological services by enhancing or regenerating of biological pest control, nutrient cycling, water and

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soil conservation (Altieri & Nicholls, 2004).

The best management practices will provide multiple benefits to agroecosystem. In example, changing from monoculture to longer rotations improves the efficiency of nutrient- and water-use. The increasing of natural enemies, reducing of weeds, improving of the soil can be stimulated by cover crops (Altieri & Nicholls, 2004; Altieri, Nicholls, & Fritz, 2005). The use of energy and external inputs will be resulted by polycultures than modern orchards, field crops, and vegetable cropping systems to provide a stability of arthropods population (Altieri & Nicholls, 2004).

Habitat manipulation effects insect population including beneficial insects. Landscape composition and habitat type, selected plant species and their characteristics, manipulation of plant resources like honey dew and artificial food spray e.g. sucrose are the responsible components for effective habitat management (Hassan, Pervin, Mondal, & Mala, 2016). The use of one or more plant component of agroecosystem is commonly option in habitat manipulation. Monoculture is a crop system that are dominated by a single plant species. It only provides resources to the select organisms. In agroecosystems, monoculture is an example of agroecosystem type with low diversity and more susceptible to pest or disease outbreaks (Altieri, Nicholls, & Fritz, 2005). Management and external inputs support the low diversity agroecosystems. On the other hand, diverse plantings or polyculture support the increasing of natural enemies by availability of some suitable plants. Related to crop protection program, crop systems as a part of habitat management can be suitable option to manage the pest populations below economic injury level by enhancing the activity of natural enemies (Altieri, Nicholls, & Fritz, 2005; Hassan, Pervin, Mondal, & Mala, 2016).

Currently, many farmers tend to develop the environmental friendly approaches such as the low insecticides use. The term of "ecological-based pest management" or "ecological pest management" was known as ecological approach that treats the whole farm as a complex system (Altieri & Nicholls, 2004; Altieri & Roge, 2010). The conventional approach pursues to reduce one hundred percent of each pest using agrichemical for each pest. Ecological pest management as the new approach, purposes to manage farms and preserve pests under economic threshold by combining some complementary

strategies (Altieri & Nicholls, 2004; Altieri, Nicholls, & Fritz, 2005). Ecological pest management is a preventive approach to address pest problems in farms or farms (Altieri & Nicholls, 2004; Nicholls & Altieri, 2004). Ecological pest management needs to understand the life cycles of pests and their natural enemies that can make the better decision to the built-in natural defenses in agroecosystem (Altieri & Nicholls, 2004; Nicholls & Altieri, 2004).

Cocoa plantations companies in Jember district commonly apply synthetic insecticides intensively to control pests of cocoa to date. Based on the work program of ICCO year 2012/2013, has done the reduction program of pesticide residues in cocoa beans. The program is carried out to maintain market access in accordance to the standards and regulations issued by the importing countries cocoa (ICCO, 2012; 2013). Altieri & Nicholls (2004) suggested that biodiversity in agroecosystem is an environmental principle that can be applied in the crop protection program. Related to environmental principles, the study of arthropods diversity population dynamic and attack intensity of *H. antonii* on varied cocoa agroecosystem management are important. From this study, strategy to manage population of *H. antonii* can be adopted based on ecological approach.

## MATERIALS AND METHODS

This research was conducted on three cocoa plantations that applied different pest management i.e. Kedaton, Banjarsari, and Nogosari from February 2014 to February 2015. Kedaton is at 162 m above sea level (asl) in Panti village and located at -8°8'30,48" latitude, 113°36'58" longitude. Banjarsari is at 50 m asl in the Banjarsari village with -8°10'28" latitude, 113°35'22" longitude. Nogosari is located at 45 m asl, with -8°14'25,08" latitude, 113°35'47" longitude. Each location belonging to D type according to Schmidt and Ferguson, clones of cocoa plants and planting times are similar i.e. DR1, DR2, DR38 and DRC planting in 2008.

In Kedaton and Banjarsari, cocoa was planted in a monoculture system that planted coconut trees and *Leucaena leucocephala* in a regular spacing, did a cocoa pruning and shaded trees, catching pit, weed control, fertilizers, irrigation and synthetic insecticides application. In Nogosari, cocoa was planted differently from Kedaton and Banjarsari. Cocoa agroecosystem managements in Kedaton, Banjarsari and Nogosari cocoa plantation were

described in Table 1. Two hundred plant samples per location of cocoa plantation were chosen as research plot for each cocoa plantation.

Arthropod observation was done by visually and traps (sweep net, yellow pan, malaise and pitfall). A visual observation was conducted to investigate the presence of *H. antonii* and other arthropods in surrounding a sample plant. Sweep net was conducted to collect arthropods located between the lines of cocoa plants. Twenty yellow pan traps were put on 1 m above ground for 24 hours and 20 m distance between each yellow pan trap in the cocoa plantations. Twenty pitfall traps contained a solution of water and detergent were put on the ground for 24 hours and 20 m distance for each trap. One malaise trap was placed in the middle of each plantation for 24 hours. The collected arthropods were identified in the Laboratory of Plant Protection, Polytechnic of Jember and Laboratory of Zoology, Research Center for Biology, Indonesian Institute of Science.

The observed variables were the number of arthropod species, the number of individuals of each species and *H. antonii* population. Temperature was observed by using a Thermo-Hygro-Clock Victor brand, series VC 230 from 8.00 a.m. that put on 1.5 m from the ground in each plantation (Klein, Steffan-Dewenter, & Tschardtke, 2002). The light intensity was observed by using a Lux meter Mastech brand, MS6612 series that put on the ground (Klein, Steffan-Dewenter, & Tschardtke, 2002). Rainfall data were obtained from the nearest Climatological Station.

Alpha diversity was used to analyze arthropod data such as: Margalef species richness index (R), Shannon-Wiener diversity index (H'), evenness index (E), Simpson dominance index (C) .and Sorensen similarity index.

1. The species richness index was calculated by using equation 1.

$$R = S - 1 / \ln N \dots\dots\dots 1)$$

Where: R, S, and N are the index of species richness, the range of species, the number of individuals respectively (Krebs, 2014).

2. Shannon-Wiener diversity index (H') was measured by using equation 2.

$$H' = \sum_{i=1}^s (p_i) (\log_2 p_i) \dots\dots\dots 2)$$

Where: H' is index of species diversity, S is number of species and pi is proportion of total sample belonging i to th species (Krebs, 2014; Kwak &

Peterson, 2007; Tarno, Septia, & Aini, 2016). Based on criteria of Shannon-Wiener diversity index, if the value of H' is < 1.0, it means that it has is low diversity and productivity and unstable ecosystem. The value of H' ranged from 1.0 and 3.22 is moderate diversity or adequate productivity and balance ecosystem. If the value of H' is more than 3.22, it means it has high diversity and productivity and in stable ecosystem (Krebs, 2014; Tarno, Septia, & Aini, 2016).

3. Simpson dominance index was calculated by using equation 3).

$$C = \sum_{i=1}^n \left[ \frac{n_i}{N} \right]^2 \dots\dots\dots 3)$$

Where: C, ni, N are Simpson dominance index, the number of individuals of species i, the total number of individuals of all species respectively. If the value of x approaches then 0 (< 0.5), it means there is no species dominates. If the value of C near then 1 (≥ 0.5), there is a species that dominates (Krebs, 2014

4. Simpson dominance index was calculated by using equation 3).

$$E = H' / \ln(S) \dots\dots\dots 4)$$

Where: H', ln and S are indexes of species diversity, exponential logarithm, and proportion of individuals of species (Pawhestri, Hidayat, & Putro, 2015)

5. Simpson dominance index was calculated by using equation 3).

$$S = \frac{2a}{2a + b + c} \dots\dots\dots 5)$$

Where: SS, a, b and c are a similarity index Sorensen, the number of species in the cocoa plantation a, b and c (Chao, Chazdon, Colwell, & Shen, 2006; Krebs, 2014).

To compare the arthropods population between each cocoa plantation, Wilcoxon test was used by using SPSS version 15.00 (Coakes, Steed, & Price, 2008). The Wilcoxon signed-rank test is a non-parametric statistical hypothesis test (Geyer, 2003) used when comparing two related samples, matched samples, or repeated measurements on a single sample to assess whether their population mean ranks different.

**Table 1.** Management of cocoa agroecosystem in Kedaton, Banjarsari and Nogosari.

Cocoa agroecosystem management	Cocoa plantations		
	Kedaton	Banjarsari	Nogosari
Planting pattern	Monoculture	Monoculture	polyculture
Cocoa plant spacing	Regular	Regular	Irregular
Shade trees spacing	Regular	Regular	Irregular
Cocoa plant pruning	Applied	Applied	Applied
Shade trees pruning	Applied	Applied	Not applied
Cathpit	Applied	Applied	Not applied
Weed control	Applied	Applied	Not applied
<i>Crotalaria juncea</i> cultivation	Applied	Not applied	Not applied
Irrigation	Applied	Applied	Not applied
Fertilization	Applied	Applied	Not applied
Pests monitoring	Applied	Applied	Not applied
Application of insecticides	Applied	Applied	Not applied

**Table 2.** Diversity indexes and taxonomic group numbers of arthropods in Kedaton, Banjarsari and Nogosari.

Ecological Indexes	Cocoa plantations		
	Kedaton	Banjarsari	Nogosari
<b>Diversity indexes</b>			
Margalef species richness (R)	1.781	2.208	4.414
Shannon-Wiener diversity (H')	1.146	1.690	2.608
Evenness index (E)	0.505	0.647	0.823
Simpson dominance (C)	0.502	0.302	0.113
<b>Taxonomic group</b>			
No. of Order	9	9	10
No. of Family	27	30	35
No. of Species	29	31	41
No. of Individual arthropods	21,523	13,440	12,777

## RESULTS AND DISCUSSION

Based on Table 2, diversity indexes that described by Margalef species richness (R), Shannon-Wiener diversity (H'), Evenness index (E), and Simpson dominance (C) shows Nogosari cocoa plantation are 4.414, 2.608, 0.823 and 0.113 respectively. The highest species richness, diversity and evenness index values is meant that Nogosari cocoa plantation on stable condition. It is supported by the lowest value of Simpson dominance (0.113). Nogosari cocoa plantation should be safe to the pest and disease attacks.

From the number of taxonomic groups, Nogosari cocoa plantation contained 10 orders, 35 families and 41 species of arthropods. Number of arthropods based on taxonomic groups in Nogosari cocoa plantation was higher than two other cocoa plantations, i.e.: Kedaton and Banjarsari.

Table 3 describes the similarity of three cocoa plantations. Differences between Nogosari, Kedaton

and Banjarsari are justified by Sorensen Similarity Index with 78.26 % (Nogosari and Kedaton) and 77.78 % (Nogosari and Banjarsari). In case of Banjarsari and Kedaton, both cocoa plantations are similar.

**Table 3.** Sorensen similarity index between each cocoa plantation.

Cocoa Plantations	Sorensen similarity index (%)
Kedaton and Banjarsari	81.35
Kedaton and Nogosari	78.26
Banjarsari and Nogosari	77.78

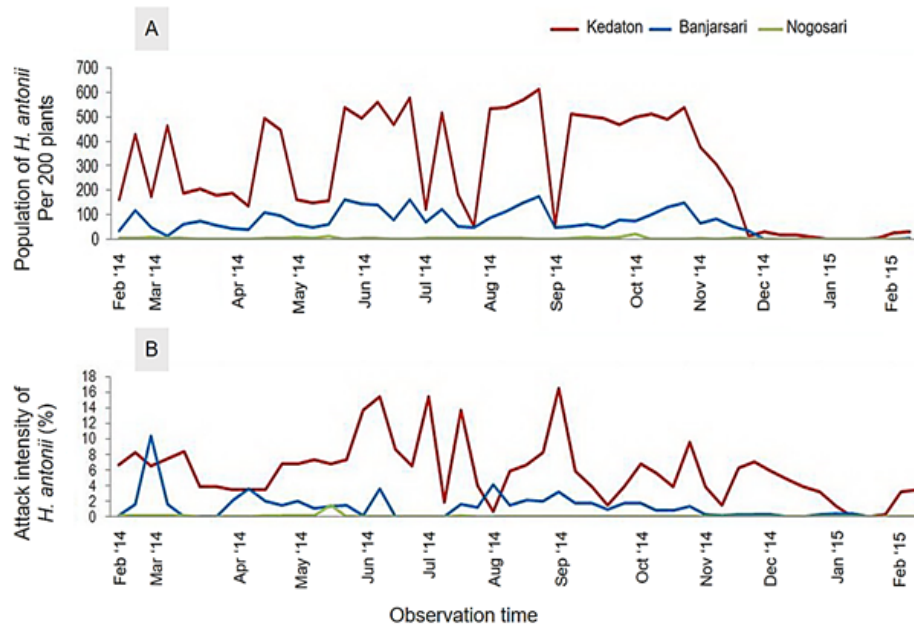
Remarks: From 80 to 100 % means that arthropod diversity between both plantations is similar, 50 % to <80 % is different, and < 50 % is significantly different (Chao, Chazdon, Colwell, & Shen, 2006; Odum, 1975)

Cocoa agroecosystem which was managed differently showed the difference in arthropod diversity. It was caused by several factors i.e. cropping, spacing of cocoa, spacing of shade

trees, diversity of trees, pruning cocoa trees, shade trees pruning, pit catch, weed control, irrigation, fertilization, pests monitoring, synthetic insecticide application and abiotic factors i.e. temperature, humidity, light intensity and rainfall. Each of these factors alone or integrated affect the diversity of arthropods.

The crop factor is related to the ability of agroecosystem in providing food for survival and breeding species of arthropods. Monoculture cropping system can provide abundant food for herbivores, but provide limited food for others such as predators, parasitoids and pollinators. While polyculture that provide the various species of crops can stimulate population of herbivores, predators, parasitoids, pollinators on polyculture cropping system in balance condition. Nurindah & Sunarto (2008) states that a polyculture system on agroecosystem has a more varied crop diversity, diversity and population of natural enemies (parasitoids and predators) are relatively high. Nectar and pollen resources to natural enemies commonly provided by polyculture that contain many types of vegetations included flowering plants. Flowering plant will attract natural enemies such as predators, parasitoids and pollinators to visit polyculture cropping system (Rodriguez-Saona, Blaauw, & Isaacs, 2012). The same thing was stated by (Dyer

& Landis, 1996; Idris, Nor, & Rohaida, 2002) that the polyculture provided a variety of resources such as alternative hosts, food, shelter, where appropriate, pollen and nectar (Plowright, Thomson, Lefkovitch, & Plowright, 1993) cultivation near wild vegetation (Menalled, Marino, Gage, & Landis, 1999), shade (Davis et al., 2001), the vegetation as a breeding ground of natural enemies (Karindah, Purwaningsih, Agustin, & Astuti, 2011; Karindah, Yanuwadi, Sulistyowati, & Green, 2011; Machovina, Feeley, & Ripple, 2015). In a monoculture cropping system, the number of natural enemies is low caused by poor crop diversity including elimination of hedgerow and shelterbelts. It resulted the doubling of crop losses (Gurr, Wratten, & Altieri, 2004), especially in large plantations, homogenization of agricultural system which increased vulnerability of crops to insect pests and diseases (Altieri & Nicholls, 2004). In addition, Purwaningsih, Mudjiono, & Karindah (2014) stated that the stability of an ecosystem can be seen from the composition of detritivores, parasitoids, predators and herbivores that at one time there are no populations of certain species dominates. The presence of predators and parasitoids in cocoa plantations, can manage naturally herbivorous population stability through the activity of predation, parasitism thus maintained stability and sustainable of the ecosystem.



**Fig. 1.** Population dynamic (A) and attack intensity (B) of *H. antonii* in three cocoa plantations from February 2014 to February 2015

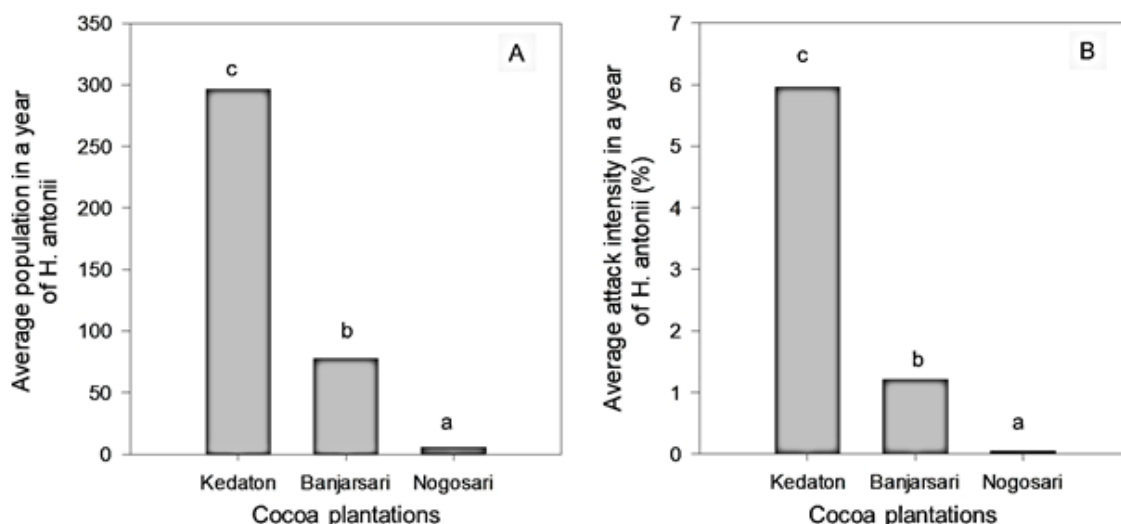


The application of synthetic broad-spectrum insecticides can kill predators, parasitoids, pollinators and detritivores that is not the targeted insecticide. The number of individual herbivore is high, due to the natural enemies cannot control the population of herbivores. Monitoring before spraying is only done on a major pest and intensity of the infected plants, regardless of the presence of predators, parasitoids, pollinators and detritivores. An arthropod species and populations can be affected by pesticides (Amalin, Peña, Duncan, Leavengood, & Koptur, 2009). Pesticides directly affect soil fauna and indirect impact of the application of insecticides through the food chain (Amalin, Peña, Duncan, Leavengood, & Koptur, 2009). The activities of predators and parasitoids can affect the susceptibility to insecticides. Predators, parasitoids and pollinators are active, are more susceptible to insecticides because of they frequently contact with insecticide residues that stick to the surface of plants. Insecticides can also indirectly affect against predators for pest prey contaminated with insecticide. Herbivores have enzymes that are able to detoxification of toxic compounds, whereas predators do not have this enzyme. The availability of food in the field such as pollen, nectar contaminated with insecticide have a negative effect on the parasitoid population, especially of the Hymenoptera (Pettis et al., 2013).

Based on Fig. 1, population dynamic and attack intensity of *H. antonii* in the three cocoa

plantations seem to be different in a year (from February 2014 to February 2015). The population of *H. antonii* fluctuated and at the high level for Kedaton and Banjarsari (Fig. 1A) especially from February to December 2014. Nogosari cocoa plantation showed the low level of *H. antonii* population in a year. Related to population of *H. antonii*, the attack intensity of *H. antonii* tended to follow the population pattern of *H. antonii*. Kedaton and Banjarsari cocoa plantations produce the higher percentage of attack intensity compared to Nogosari (Fig. 1B). Differences between three cocoa plantations based on population density and attack intensity of *H. antonii* are described in Fig. 2. Nogosari cocoa plantation is at low level for population and attack intensity of *H. antonii*. Correlation between population and the intensity of the *H. antonii* attacks is 0.763\*\* ( $p \leq 0.01$ ).

Agroecosystem management factors that cause differences in populations of *H. antonii* i.e. pruning, fertilizing, application of synthetic insecticides. The monoculture that adopted in the Kedaton and Banjarsari cocoa plantations can provide feed resources for *H. antonii* in a year. Pruning shoots cocoa plants and weeding *Ageratum conyzoides* L. conducted in Kedaton and Banjarsari provide suitable condition for *H. antonii* to start the laying eggs till they hatch into nymphs. *Helopeltis antonii* development from egg to adult needs ca. 15-17 days (Atmaja, 2010).



**Fig. 1.** Average population dynamic (A) and attack intensity (B) of *H. antonii* in a year of three cocoa plantations (Different letters show differences between each cocoa plantation according to the Wilcoxon test).

**Table 4.** Abiotic factors that recorded in three cocoa plantations.

Abiotic factors: Microclimate	Cocoa plantations		
	Kedaton ( $\pm$ SD)	Banjarsari ( $\pm$ SD)	Nogosari ( $\pm$ SD)
Temperature ( $^{\circ}$ C)	29.11 $\pm$ 0.98 a	31.93 $\pm$ 2.48 b	31.59 $\pm$ 1.46 b
Humidity (%)	75.94 $\pm$ 4.36 a	68.40 $\pm$ 4.52 b	66.42 $\pm$ 6.39 c
Light intensity (Lux)	2226.30 $\pm$ 469.15 a	6814.60 $\pm$ 687.71 b	19737.60 $\pm$ 1605.04 c
Rainfall (m.m)	55.02 $\pm$ 60.59 a	54.14 $\pm$ 68.78 b	39.96 $\pm$ 75.01 c

Fertilization was done in Kedaton and Banjarsari using organic fertilizer from the decomposition forage pruned of cacao plant, crop shade trees, weeds and pod husks into catchpit. They could avoid the loss of elements nutrients by erosion, as well as irrigation treatments applied in Banjarsari and Kedaton and improved soil fertility. An intensive application of synthetic insecticides in Kedaton and Banjarsari, resulted population of *H. antonii* higher than Nogosari that do not apply synthetic insecticides. Synthetic insecticide application can reduce the natural enemies of *H. antonii* such as *Coccinella transversalis* and *Araneus diadematus*. The most sensitive predator to food and insecticides belongs to Coccinellidae family (Amalin, Peña, Duncan, Leavengood, & Koptur, 2009; Garbach, Milder, Montenegro, Karp, & DeClerck, 2014; Santos-Cividanes, Anjos, Cividanes, & Dias, 2011).

Climate change caused changes in abiotic factors such as light intensity, temperatures, humidity and rainfalls, CO<sub>2</sub> levels influence agriculture, land resources and biodiversity (Backlund, Janetos, & Schimel, 2008). Ambrosia and Bark beetles and several species are expected to be favored by climate change (Marini et al., 2017; Tarno, Suprpto, & Himawan, 2015).

Based on Table 4, Kedaton and Banjarsari with lower light intensity, lower temperatures and higher humidity indicated that the number of *H. antonii* was higher than in Nogosari. The more humidity, lower temperatures and lower light intensity of agroecosystem such as in Kedaton and Banjarsari stimulated the increasing population of *H. antonii*. The lower temperatures, higher humidity and lower light intensity will provide the positive condition for *H. antonii* development. Fluctuations in insect populations of *Helopeltis* genus were very sensitive to direct sunlight, rainfall, temperature and humidity (Karmawati, 2010; Naik & Chakravarthy, 2013; Purwaningsih, Mudjiono, & Karindah, 2014; Siswanto, Muhamad, Omar, & Karmawati, 2008)

## CONCLUSION AND SUGGESTION

Based on the diversity indexes and population of taxonomic groups, between three cocoa agroecosystem management showed differences of arthropod diversity described by Margalef species richness (R), Shannon-Wiener diversity (H'), Evenness index (E), and Simpson dominance (C) in Nogosari cocoa plantation were 4.414, 2.608, 0.823 and 0.113 respectively. The highest species richness, diversity and Evenness index values in Nogosari cocoa plantation was in a stable condition. The number of arthropods based on taxonomic groups in Nogosari cocoa plantation contained 10 orders, 35 families and 41 species of arthropods. It was higher than two other cocoa plantations. Nogosari cocoa plantation was different from Kedaton and Banjarsari based on the Sorensen Similarity Index with 78.26 and 77.78 % respectively. In addition, population dynamic and attack intensity of *H. antonii* in the three cocoa plantations were different in a year.

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