

## Diversity and Abundance of Natural Enemies of *Helopeltis antonii* in Cocoa Plantation Related with Plant Pattern and Insecticide Application

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### Abstract

Natural enemy is an important factor in management of cacao pests. One way to increase its diversity and abundance is through agroecosystem management techniques that support. The study was conducted for one year from February 2014 to February 2015 in Banjarsari Plantation and a cocoa farm of Kaliwining Experimental Station, Jember, which applied different cropping patterns and use of insecticides. The purpose of this research was to study the effect of cropping pattern and use of insecticide on diversity and abundance of predators, parasitoids, abundance and intensity of *Helopeltis antonii* attack. Observation of pests and natural enemies was done visually, using sweep net, yellow pan traps, malaise trap and pitfall trap. Intensity of the attack used Pedigo & Buntin equations. Diversity index used Shannon Diversity Index ( $H'$ ) and Simpson's dominance index ( $C$ ). Differences in predator abundance, parasitoid, air temperature, relative humidity, light intensity and rainfall used Wilcoxon test. Results of this study showed that monoculture and intensive use of synthetic insecticides caused lower diversity and abundance of predators and parasitoids, while the abundance and intensity of *H. antonii* attacks were higher compared with polyculture without insecticide. Banjarsari cocoa plantation that applied monoculture and intensive use of synthetic insecticides, had lower diversity and abundance predators and parasitoids compared with cocoa plantation in Kaliwining that applied polyculture planting without using insecticide. Dominant predators in Banjarsari and in Kaliwining cocoa plantations were *Dolichoderus thoracicus* and *Araneus diadematus*, while dominant parasitoid in Banjarsari and in Kaliwining cocoa plantations was *Araneus diadematus*.

**Keyword:** Cocoa agroecosystem, *Helopeltis antonii*, insecticide, natural enemies, planting patterns, predator, parasitoid

### INTRODUCTION

Cocoa (*Theobroma cacao* L.) is an important commodity for Indonesian plantation. According to data from the International Cocoa Organization (ICCO) (2015), Indonesia is the biggest cocoa producer in Oceania.

*Helopeltis antonii* is an obstacle in the cultivation of cocoa. Beside attacking cocoa pods, it also attacks shoots. Severe attack on shoots can reduce yields of cocoa by 36–75% (Sulistyowati & Mufrihati, 2006). Some cocoa plantation companies in Indonesia manage their plantations with monoculture

cropping pattern with intensification of synthetic insecticide use to control the main pests of cocoa plants. Several synthetic insecticides used for the main crop pest control (*H. antonii* and *Hyposidra talaca*) are insecticides with active ingredient of alpha-cypermethrin 50 g/L with concentration 0.02, BPMC 500 g/L active ingredient, with concentration 0.02 % applied take turns. The dose used is 500 liters per hectare. Dosage and concentration may change based on efficacy test results (Syarief, 2016).

Based on the work program of ICCO (2015), there has been a program of reduction of pesticide residue hazard in cocoa beans. This program is conducted to maintain market access in accordance with the standards and regulations issued by cocoa importing countries (ICCO, 2013). Therefore, efforts should be made to reduce the use of synthetic insecticides in cocoa pest management by considering the role of natural enemies in form of predators and parasitoids. It is necessary to study the diversity and abundance of natural enemies of *H. antonii* in various agroecosystem management of cocoa. The results of which are expected to be used as a solution to optimize the synergy between the various components of Integrated pest management, so that the stability of the agroecosystem can be improved. Natural enemies have important roles in the structure and processes in maintaining the biological diversity of an ecosystem (Price, 1997). Agroecosystem management factors affect the diversity of natural enemies (Mattson *et al.*, 1984; Altieri, 1989; Letourneau & Altieri, 1999). Swift *et al.* (1996) suggests that biodiversity in agroecosystems can be used as a pest control concept.

This research aimed to determine the effect of cocoa cropping pattern and insecticide applications on diversity and abundance of predators, parasitoids, abundance and intensity of *H. antonii* attack.

## MATERIALS AND METHODS

This study in form of survey research was conducted since February 2014 to February 2015 in two locations of cocoa plantations at Jember District that apply different pest management i.e. Banjarsari Plantation and Kaliwining Experimental Station of ICCRI. Banjarsari was located at 50 m asl. Kaliwining was located at 45 m asl. Both locations belonged to climate type D according to Schmidt–Ferguson classification. Cocoa plant population was 770 plants/ha. The clones of cocoa plants were: DR 1, DR2, DR 38 and DRC with planting year of 2008, monoculture cropping pattern. Shade tree were *Leucaena leucocephala* and coconut trees. The population of *L. leucocephala* were 555 trees per hectare and coconut 92 trees per hectare. The clones of cocoa plants at Kaliwining were DR 1, DR 2, DR 38, and DRC with cocoa plant population were 200 plants of planting year 2008, polyculture cropping pattern. Cacao trees were planted among tree species with irregular spacing: coconut (*Cocos nucifera*), breadfruit (*Artocarpus altilis*), starfruit (*Averrhoa carambola*), lime (*Citrus hystrix*), *Morinda citrifolia*, banana (*Musa paradisiaca*), *Nauclea orientalis*, teak (*Tectona grandis*), *Chrysophyllum cainito*, guava (*Psidium guajava*), papaya (*Carica papaya*), bamboo (*Bambusa* sp.), jackfruit (*Artocarpus heterophyllus*) and cassava (*Manihot utilissima*).

In Banjarsari plantation, synthetic insecticide used was an active ingredient of alpha-cypermethrin 50 g/L with a concentration of 0.02%, BPMC 500 g/L active ingredient, with 0.02% concentration applied by turns with dose used of 500 L/ha. Meanwhile Kaliwining Experimental Station applied polyculture without insecticides. Sampling of plants in Banjarsari systematically two-dimensional cacao plant located on the row and second lane as the first sample. The next

sample was toward the row and the one-hose lane of a plant (Mudjiono, 1987). Sampling in Kaliwining was done randomly according to the condition of plants. The sample plant population was 200 plants in each location. The collected data were species of natural enemies, temperature, humidity and light intensity done every week for a year. Natural enemies observations were done visually using sweep nets, yellow pan traps, malaise traps and pitfall traps carried out every week for a year. In visual observations, presence of *H. antonii* and natural enemies species observed surrounding a sample plant with attacked pods or new shoots. Sweep net was used by swinging between the lines of cocoa plants into the shelter of natural enemies. Yellow pan traps containing a solution of water and detergent was placed one meter above the ground, for 24 hours, a distance of 20 m and a total of 20 traps per cocoa plantation. Pitfall traps containing a solution of water and detergent was laid flat on the ground, for 24 hours, a distance of 20 m and total of 20 traps per cocoa plantation. One malaise trap per site was placed in the middle of the plantation, for 24 hours.

Measurement of temperature and humidity using the Thermo/hygro/clock VICTOR VC 230 Series, which was placed at 1.5 m above the ground. The intensity of the light was measured using MASTECH brand Lux meter, MS 6612 Series, which was laid on the ground (Klein *et al.*, 2001). The observation was done between 08.00 A.M. until 11.00 A.M. every week. Daily rainfall data was obtained from the nearest climatological station.

Identification of *H. antonii* predator and parasitoid was done at Jember Polytechnic Plant Protection Laboratory until species level using Pests of Crops in Indonesia by Kalshoven (1981), Manual of Nearctic Diptera (McAlpine, 1987). Identification of

several species was done with taxonomic assistance at the Zoology Museum, Indonesian Institute of Sciences, Bogor.

The data of abundance and intensity of *H. antonii* attack were shown in box-plot form. Different parameters of predator species abundance, parasitoid, environmental parameters i.e. air temperature, humidity, light intensity and rainfall and diversity index using Wilcoxon Test. Relationship between predator abundance, parasitoid and *H. antonii*, environmental parameters and attack intensity using Spearman correlation. Overall data analysis using SPSS software version 15. The intensity of *H. antonii* attack use the Pedigo & Buntin equation (2003) as follows:

$$P = a/b \times 100\%$$

P is the intensity of affected plants (%), a is the number of affected plants and b is the total plant observed. The diversity index is calculated by the Shannon-Wiener formula:

$$H = -\sum_{i=1}^s \frac{ni}{iN} \log \frac{ni}{N}$$

where H is the diversity index of Shannon, ni is the total individual species i, N is the total individual of all species. Criteria for the Shanon-Wiener diversity index is explained by Krebs (1989).

Simpson's dominance index is to know the dominance of certain species, using the formula:

$$C = \sum \left( \frac{ni}{N} \right)^2$$

where C is the index value of dominance, ni is the number of individuals in one species, N is the total number of individual species found. Odum (1993) stated that the criterion of dominance is as follows: if the value of C approaches 0 (<0.5), then no species

predominate. If the value of C approaches 1 ( $\geq 0.5$ ), then there is a dominating species.

## RESULTS AND DISCUSSION

Based on the survey, diversity and abundance of *H. antonii* predators in Banjarsari plantation found 5 orders, 8 families and 8 species, while at Kaliwining Experimental Station found 6 orders, 11 families and 11 species (Table 1). Diversity and abundance of *H. antonii* parasitoids in Banjarsari plantation found 2 orders, 4 families and 4 species, while at Kaliwining plantation found 2 orders, 6 families and 6 species (Table 2). Based on the Table 1 and Table 2, the abundance of *H. antonii* predators in Banjarsari plantation between Banjarsari and Kaliwining are different. Banjarsari is higher than Kaliwining. It is caused by several factors i.e. cropping patterns and the use of insecticides. This is due to the availability of food for species of natural enemies. Cropping factor relates to the ability of agro-ecosystem in providing food for survival and breeding species. Monoculture can provide very minimal availability of food for species of predators, parasitoids. Meanwhile, polyculture does not provide plants that are focused on a particular species, so

that the population of predators, parasitoids on polyculture is in balance. According to Jervis *et al.* (2004), monoculture can reduce the number and activity of natural enemies due to limited source of food. For example, pollen, nectar and prey or alternative hosts need natural enemies to eat and breed as well as a place for refugia and survive in the agro-ecosystem. Dryer & Landis (1996) and Idris *et al.* (2002) similarly argue that polyculture provides a variety of resources such as alternative hosts, food, shelter, where appropriate, pollen and nectar (Plowright *et al.*, 1993), cultivation near wild vegetation (Menalled *et al.*, 1999), shade (Davis *et al.*, 2001), vegetation as a breeding ground of natural enemies (Karindah *et al.*, 2011a, 2011b). Nurindah & Sunarto (2008) state that a polyculture system on agro-ecosystem has a more varied crop diversity, and the diversity and population of natural enemies (parasitoids and predators) are relatively high.

Natural enemies diversity in Banjarsari that apply synthetic insecticide, shows the lower number of natural enemies species than Kaliwining. Number of predators and parasitoids in Banjarsari is lower than Kaliwining (Table 2 and Table 3). Application of synthetic insecticides can kill predators and parasitoids,

Table 1. Diversity and abundance of predators of *H. antonii* in Banjarsari plantation and Kaliwining Experimental Station

Order/Family	Species	Banjarsari (Mean $\pm$ SD)	Kaliwining (Mean $\pm$ SD)
<i>HYMENOPTERA</i>			
Vespidae	<i>Vespa affinis</i>	6.19 $\pm$ 8.54 a	4.67 $\pm$ 6.25 b
Formicidae	<i>Dolichoderus thoracicus</i>	31.06 $\pm$ 0.33 a	62.167 $\pm$ 0.983 b
<i>COLEOPTERA</i>			
Coccinellidae	<i>Coccinella transversalis</i>	6.67 $\pm$ 10.75 a	17.89 $\pm$ 11.47 b
<i>MATODEA</i>			
Mantidae	<i>Mantis religiosa</i>	2.07 $\pm$ 1.64 a	14.44 $\pm$ 11.32 b
<i>ARAENAE</i>			
Lycosidae	<i>Araneus diadematus</i>	18.69 $\pm$ 30.52 a	23.05 $\pm$ 20.82 b
Tetragnathidae	<i>Leucauge decorata</i>	0.00 a	2.00 $\pm$ 1.41 b
Linyphiidae	<i>Pardosa pseudoannulata</i>	3.00 $\pm$ 2.65 a	1.07 $\pm$ 0.37 b
Oxyopidae	<i>Peucetia longipalpis</i>	1.00 $\pm$ 0.00 a	4.08 $\pm$ 2.48 b
<i>ODONATA</i>			
Libellulidae	<i>Orthetrum testaceum</i>	2.59 $\pm$ 1.58 a	4.26 $\pm$ 3.88 b
Calopterygidae	<i>Vestalis amoena</i>	0.00 a	6.85 $\pm$ 7.63 b
<i>NEUROPTERA</i>			
Chrysopidae	<i>Chrysopa oculata</i>	0.00 a	14.00 $\pm$ 5.66 b

Notes: Different letters in the same row, are significantly different according to the Wilcoxon test).

that were not the targeted of insecticides. According to Arifin *et al.* (2011) and Amalin *et al.* (2009), an arthropod species and populations can be affected by pesticides. Pesticides indirectly affect through the food chain (Brown, 1987). Activities of predators and parasitoids can affect the susceptibility to insecticides. Predators and parasitoids are active and more susceptible to insecticides because of more frequent contacts with insecticide residues that stick to the surface of plants. Insecticides also can affect indirectly against predators for pest prey contaminated with insecticide.

The abundance and intensity of *H. antonii* attack in Banjarsari higher than Kaliwining (Figure 1 and Figure 2). Based on Spearman correlation analysis, the correlation coefficient between the abundance and intensity of *H. antonii* attack is 0.617\*\*. This can be affected by cropping patterns and the use of insecticides. Monoculture that applied in the Banjarsari can provide feed resources concentrated on *H. antonii* throughout the year. Meanwhile, polyculture in Kaliwining is no source of concentrated feed to *H. antonii*. Synthetic insecticide application can kill the natural enemies of *H. antonii* which was not a target. *H. antonii* predators populations i.e. *Coccinella transversalis* and

*Araneus diadematus* in Banjarsari lower than Kaliwining. The populations of *C. transversalis* were  $6.67 \pm 10.75$  in Banjarsari and  $17.89 \pm 11.47$  in Kaliwining. Populations of *A. diadematus* were  $18.69 \pm 30.52$  in Banjarsari and  $23.05 \pm 20.82$  in Kaliwining. (Table 2.). Amalin *et al.* (2009) stated that the predator is mostly sensitive to insecticides from the family of Coccinellidae. Populations of *C. transversalis* and *A. diadematus* on the cocoa agro-ecosystem sprayed with synthetic insecticides were lower than that did not use insecticides.

Differences cropping pattern between Banjarsari and Kaliwining show the difference of temperature, humidity, and light intensity. This may lead to differences in *H. antonii* abundance. Spearman correlation analysis showed that between light intensity and *H. antonii* abundance was negatively correlated ( $r = -0.542^{**}$ ), humidity with *H. antonii* abundance was positively correlated ( $r = 0.201^*$ ). Rainfall with *H. antonii* abundance is positively correlated ( $r = -0.291^{**}$ ). The condition of the plantation which is more humid and the lower light intensity such as the condition at Banjarsari (Table 5) shows the of *H. antonii* abundance is higher than Kaliwining. Higher moisture conditions and

Table 2. Diversity and abundance of parasitoids of *H. antonii* in Banjarsari plantation and Kaliwining Experimental Station

Order/Family	Species	Banjarsari (Mean ± SD)	Kaliwining (Mean ± SD)
HYMENOPTERA			
Braconidae	<i>Psytalia fletcheri</i>	18.81 ± 25.61 a	37.30 ± 30.67 a
Platygastridae	<i>Telenomus fariai</i>	1.25 ± 0.44 a	7.90 ± 12.32 a
Braconidae	<i>Euphorus helopeltidis</i>	2.00 ± 0.00 a	7.90 ± 12.32 a
Braconidae	<i>Apanteles</i> sp.	0.00 a	1.78 ± 0.67 a
Eulopidae	<i>Oomyzus sokowskii</i>	0.00 a	2.20 ± 2.44 a
DIPTERA			
Sarcophagidae	<i>Sarcophaga aurifrons</i>	1.727 ± 1.032 a	2.903 ± 1.248 a

Notes: Different letters in the same row, are significantly different according to the Wilcoxon test).

Table 3. Shannon diversity index (H') and dominance index (C) in Banjarsari plantation and Kaliwining Experimental Station

Diversity index	Plantation	
	Banjarsari (±SD)	Kaliwining (±SD)
H'	1.690 ± 0.413 a	2.608 ± 0.544 b
C	0.302 ± 0.173 a	0.113 ± 0.112 b

Notes: Different letters in the same row, are significantly different according to the Wilcoxon test).

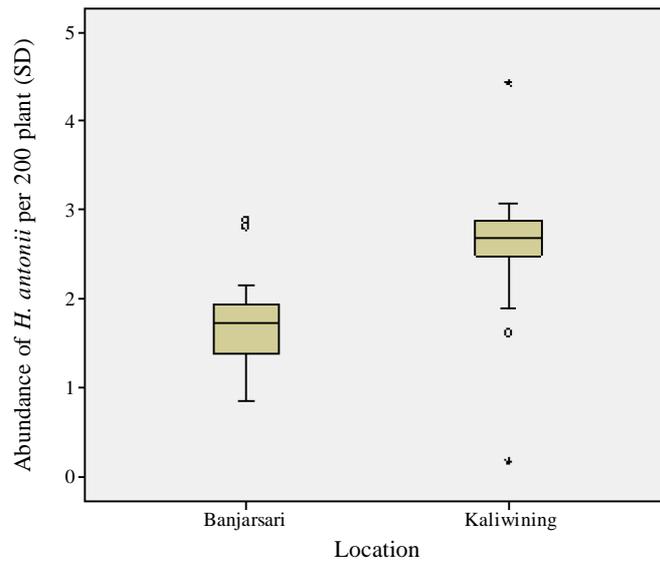


Figure 1. Abundance of *H. Antonii*

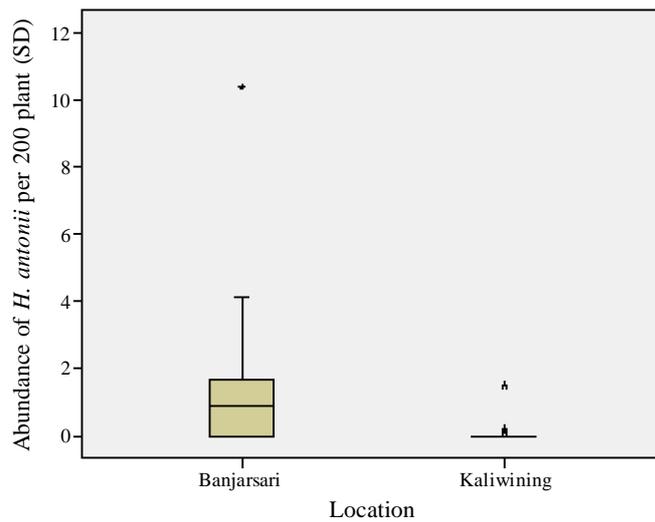


Figure 2. Intensity of *H. antonii* attack

lower light intensity will benefit the development of *H. antonii*. *Helopeltis antonii* prefer humid, and low temperature conditions but not for high light intensity. Fluctuations in insect populations of the genus *Helopeltis* are highly sensitive to direct sunlight (Kalshoven, 1981). Conditions of high rainfall will inhibit the movement of *H. antonii*. According to research results of Karmawati

*et al.* (1999) in Wonogiri & Karmawati *et al.* (2010) in West Lombok states that the population and appearance of *H. antonii* is determined by rainfall and micro moisture. The high indicator of *H. antonii* abundance in Banjarsari is indicated by Shannon diversity index which is lower than Kaliwining and dominance index which is higher than Kaliwining (Table 4).

Table 4. The average of temperature, humidity, light intensity and rainfall in Banjarsari Plantation and Kaliwining Experimental Station

Microclimate	Plantation	
	Banjarsari ( $\pm$ SD)	Kaliwining ( $\pm$ SD)
Temperature ( $^{\circ}$ C)	31.93 $\pm$ 2.48 a	31.59 $\pm$ 1.46 a
Humidity (%)	68.40 $\pm$ 4.52 b	66.42 $\pm$ 6.39 a
Light intensity (Lux)	6,814.60 $\pm$ 687.71 a	19,737.60 $\pm$ 1,605.04 b
Rainfall (m.m)	54.14 $\pm$ 68.78 b	39.96 $\pm$ 75.01 a

Notes: Mean followed by different letters in the same row is significantly different according to the Wilcoxon test

The lower diversity of species in agroecosystems, the higher species abundance. This is caused by the dominance of *H. antonii* in Banjarsari cocoa plantation. This is in accordance with Price (1997) opinion, which states that if the high diversity of the type of dominance of a species is low. The lower diversity of species in the agroecosystem, resulted in higher species abundance. This is caused by the dominance of *H. antonii* in Banjarsari. This is in accordance with Price (1997) opinion, which states that if diversity is high then the degree of dominance of a species is low.

## CONCLUSIONS

Monoculture and intensive use of synthetic insecticides, showing lower diversity and abundance predators and parasitoids, while the abundance and intensity of *H. antonii* attacks were higher than polyculture without insecticide. Banjarsari cocoa plantation that apply monoculture and intensive use of synthetic insecticides, showing lower diversity and abundance predators and parasitoids than Kaliwining cocoa plantation that apply the pattern of planting polyculture without using insecticide. The dominant predators in the Banjarsari and Kaliwining cocoa plantation were *Dolichoderus thoracicus* and *Araneus diadematus*, while the dominant parasitoid in Banjarsari and Kaliwining cocoa plantations was *Araneus diadematus*.

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## REFERENCES

- Altieri, M.A. (1989). Agroecology: A new research and development paradigm for word agriculture. *Agriculture, Ecosystems, and Environment*, 27, 37–46.
- Amalin, D.M.J; E. Pera; R. Duncan; J. Leavengood & S. Koptur (2009). Effects of pesticides on the Arthropod Community in the agricultural areas near the Everglades National Park. *Proceedings of Florida State Horticulture Society*, 122, 429–437.
- Arifin, M.; I.B.K. Suryawan; B.H. Priyanto & A. Alwi (2011). Diversity of Arthropods in the various techniques of rice cultivation in Pemalang, Central Java. *Food Crops Research*, 15, 5–12.
- Brown, A.W.A. (1987). *Ecology of Pesticides*. John Wiley and Sons Inc., New York.
- Davis, A.J.; J.D. Holoway; H. Huijbregts; J. Krikken; A.H. Kirk-Spriggs & S.L. Sutton (2001). Dung beetle as indicator of change in the forest Northern Borneo. *Journal Applied Ecology*, 38, 593–616.
- Dryer, L.E. & D.A. Landis (1996). Effect of habitat, temperature and sugar availability on longevity of *Eriborus terebrans* (Hym: Ichneumonidae) in corn fields. *Environmental Entomology*, 25, 1192–1201.

- Griffin, C.T.; D. Chaerani; A.P. Fallon, Reid & M.J. Downes (2000). Occurrence and distribution of the entomopathogenic nematodes *Steinernema* spp. and *Hetero rhabditisindica* in Indonesia. *Journal of Helminthology*, 74, 143–150.
- Idris, A.B.; S.M. Nor & R. Rohaida (2002). Study on diversity of insect community at different altitudes of Gunung Nuang in Selangor, Malaysia. *Journal of Biological Sciences*, 2, 505–507.
- ICCO (2015) *Annual Report 2014/2015*. International Cocoa Organization, London.
- Jervis, M.A.; J.C. Lee & G.E. Heimpel (2004). Use of behavioural and life-history studies to understand the effects of habitat manipulation. *In*: G.M. Gurr; S.D. Wratten & M.A. Altieri (Eds.), *Ecological Engineering for Pest Management*. Comstock Publishing Associates, New York.
- Kalshoven, L.G.E. (1981). *Pests of Crops in Indonesia*. (Revised and translated by P.A. van der Laan & G.H.L. Rothschild). P.T. Ichtar Baru–Van Hoeve, Jakarta.
- Karindah, S.; A. Purwaningsih; A. Agustin & L.P. Astuti (2011a). Ketertarikan *Anaxipa longpennis* Servile (Orthoptera: Gryllidae) terhadap beberapa jenis gulma di sawah sebagai tempat bertelur. *Journal Entomologi Indonesia*, 8, 27–35.
- Karindah, S.; Y. Bagyo; S. Liliek & P.T. Green (2011b). Abundanche of *Metiochevit talicollis* (Orthoptera: Gryllidae) and natural enemies in rice agroecosystem as influenced by weed species. *Journal of Agrivita*, 33, 133–141.
- Klein, A.M.; I.S. Deventer & T. Scharnke (2002). Predator–prey ratios on cocoa along a land-use gradient in Indonesia. *Biodiversity and Conservation*, 11, 683–693.
- Karnawati, E.; Siswanto & E.A. Wikardi (1999). Peranan semut (*Oeophyla smaragdina* dan *Dolichoderus* sp.) dalam pengendalian *Helopeltis* sp. dan *Sanurus indecora* pada jambu mete. *Jurnal Penelitian Tanaman Indonesia*, 12, 1–7.
- Karnawati, E.; Z. Mahmud; M. Syakir; J. Munarso; I.K. Ardana & Rubiyo (2010). *Budidaya dan Pascapanen Kakao*. Pusat Penelitian dan Pengembangan Kakao. Bogor.
- Krebs, C.J. (1989). *Ecology: Experimental Analysis of Distribution and Abundance*. 4 ed. Hoper International Ed., New York.
- Letourneau, D.K. & M.A. Altieri (1999). Biology of parasitic Hymenoptera. *In*: T.S. Bellows & T.W. Fisher (Eds.), *Handbook of Biological Control: Principles and Applications of Biological Control*. Academic Press, San Diego.
- Mattson P.C.; M.A. Altieri & W.C. Gagne (1984). Modification of small farmer practice for better pest management. *Annual Review of Entomology*, 29, 303–402.
- Menalled, F.D.; P.C. Marino; S.H. Gage & D.A. Landis (1999). Does agricultural landscape structure affect parasitism and parasitoid diversity. *Ecological Application*, 9, 634–641.
- Nurindah & D.A. Sunarto (2008). Konservasi musuh alami serangga hama sebagai kunci keberhasilan PHT kapas. *Balai Penelitian Tanaman Tembakau dan Serat*, 7, 01–11.
- Pedigo, L.P. & G.D. Buntin (2003). *Handbook of Sampling Methods for Arthropods in Agriculture*. CRC Press, London-Tokyo.
- Plowright, R.C.; J.D. Thomson; L.P. Lefkovich & C.M.S. Plowright (1993). An experimental study of the effect of colony resource level manipulation on foraging for polen by worker bumble bees. *Canadian Journal of Zoology*, 71, 1393–1396.
- Price, P.W. (1997). *Insect Ecology*. (3<sup>rd</sup> Ed.) John Wiley and Sons Inc. New York, Chisheester, Weinkeim, Brisbane, Singapore, Toronto.
- Sulistiyowati, E. & Mufrihati (2006). Struktur dan fungsi antropoda pada ekosistem

- tanaman kakao. *Warta Pusat Penelitian Kopi dan Kakao Indonesia*, 22, 71–81.
- Swift, M.J.; J. Vandermeer; P.S. Ramakrisnan; J.M. Anderson; C.K. Ong & B.A. Hawkins (1996). Biodiversity and agroecosystem function. **In:** *Functional Roles of Biodiversity : A Global Perspective* (Eds. H.A. Hooney). John Wiley.
- Syarief, M. (2016). *Diversitas Arthropoda dan Status Helopeltis antonii pada Berbagai Pengelolaan Agroekosistem Kakao*. Dissertasi. Fakultas Pertanian, Universitas Brawijaya, Malang, Indonesia.

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