Functional Composition of Arthropoda and Population Density of Larvae *Conopomorpha cramerella* Snell. (Lepidoptera: Gracillariidae) and Natural Enemies in Different Shade Cocoa Plantations

1st Moh Hibban Toana
Faculty of Agriculture
Tadulako University
Central Sulawesi 94118, Indonesia
Corresponding Author, email:
moh.hibbantoana@gmail.com

2nd Burhanuddin Hi Nasir
Faculty of Agriculture
Tadulako University
Central Sulawesi 94118, Indonesia
email: burhajinasir@gmail.com

3rd Moh Rizqi Chaldun Toana
Faculty of Agriculture
Tadulako University
Central Sulawesi 94118, Indonesia
email: m.rizqi_toana@yahoo.co.id

4th Fitriah Balosi
Faculty of Agriculture
Tadulako University
Central Sulawesi 94118, Indonesia
email:
mohammadridwan299@gmail.com

Abstract--The functional composition of arthropods and population density of Conopomorpha cramerella Snellen larvae (Lepidoptera: Gracillariidae) and natural enemies in different shade cocoa plantations play an important role in maintaining sustainability by using natural resources without damaging the environment. Observation of the number of arthropod species using Light Trap and Pitfall Trap, population density of C. cramerella larvae, and natural enemies in a single shade and multi-shade cocoa plantations. The results of the study on the percentage of ecological services of functional species of arthropods accumulatively on cocoa plantations were Herbivores (29.91%), Predators (37.38%), Parasites (8.41%), and other functional species (24.30%). The population density of C. cramerella larvae in one-shade cocoa plantations (8.08 heads/cocoa pod) was higher than in multi-shade cocoa plantations (5.21 heads/cocoa pod). multi-shade and one-shade cocoa plantations found one type of natural enemy, namely Predator Solenopsis xyloni (Hymenoptera: Formicidae)

Keywords: Arthropods Conopomorpha cramerella Cocoa

I. INTRODUCTION

Cocoa plantations are one the important plantations in Indonesia because they generate foreign exchange for the country, are a source of income for farmers and other communities [1]–[3], create jobs [4]. and make a major contribution to the national economy [5]. Indonesia's cocoa production ranks third after Ivory Coast and Ghana [6]. see the third place after palm and rubber commodities [7]. Indonesian cocoa that is exported is generally not fermented so the quality is not good [4]. If Indonesian cocoa is fermented, it can produce a strong volatile aroma [8] and avoid price discounts on the world market (Raharto, 2016), fermented cocoa has a high melting point [9]. Indonesian cocoa powder does not contain pyrethroid residues and has no non-carcinogenic effect so it is safe for consumption [10]. The area of Indonesian cocoa plantations in 2020 is 1,611,014 ha consisting of 98.33% community plantations and the rest are private plantations (0.90%) and state (0.77%). Cocoa production reached 1,315,800 tons/year. [11]. Cocoa is growing because of the demand for products that have a high cocoa content in the agro-industry sector [12].

The challenge facing cocoa plantations today is “sustainability” [13] by using natural resources without using or damaging the environment [14]. Efforts for the development of cocoa plantations are carried out by the government by revitalizing cocoa plantations through cocoa gernas [15]. Expansion of cocoa plants is carried out by planting cocoa plants in primary and secondary forests [14], but expanding cocoa plants is not followed by an increase in cocoa yields [16], this is due to the attack of the Cocoa Pod Borer (CPB) *Conopomorpha cramerella* Snellen [17]. *C. cramerella* larvae attack by burrowing cocoa pods has caused damage to the fruit and cocoa, reduced the quality and quantity of beans, and lost yields [18]. Another contributing factor is the change in habitat, causing the ecosystem to become vulnerable to plant-eating insects. [19]. Farmers grow cacao under multi-shade trees (fruit trees and forest trees), and cocoa under one shade tree (candlenut trees). One-shade cocoa plantations have sacrificed natural vegetation causing reduced diversity [14].

Ecosystems with various spatial structures have arthropod compositions from simple to complex, so that on a wider scale (landscape) can affect local biodiversity and ecological functions [20]. In the cocoa plantation ecosystem, the diversity of arthropods varies from simple to complex [21]. The functional composition of Arthropods in general has a very important strategic role in providing ecological

N. Edy et al. (eds.), *Proceedings of the 2nd International Interdisciplinary Conference on Environmental Sciences and Sustainable Developments 2022 Environment and Sustainable Development (IICESSD-ESD 2022)*, Advances in Biological Sciences Research 36,
https://doi.org/10.2991/978-94-6463-334-4_17

services to the ecosystem in maintaining stability. Agricultural production and simplification of landscape structures have harmed the arthropod community [20], without the presence of arthropods, the stability of the ecosystem will be disturbed and balance will not be achieved [22]. The ecological services of arthropods in the ecosystem include herbivores, decomposers, predators, and parasitoids, which have different functional compositions from arthropods [23]. Changes in the strata of the cocoa plantation shade cause changes in the habitat of the cocoa plantation ecosystem. Information on this change is not yet available enough as an effort to develop a *C. cramerella* pest control strategy. Therefore, it is necessary to research to determine the functional composition of arthropods, the population density of *C. cramerella* larvae, and their natural enemies in cocoa plantations with different shade

II. MATERIAL AND METHODS

A. Research Place and Time

The research was carried out on one-shade and multi-shade cocoa plantations in Rahmat Village, Palolo District, Sigi Regency, Central Sulawesi Province. The research was conducted from March 2022 to December 2022.

B. Materials and Tools

The materials used in this study were arthropods found in cocoa plantations, eggs, larvae, and imago of *C. cramerella*, cocoa pods, liquid soap, and 70% alcohol. The tools used include plastic bags, paper labels, knife cutters, traps, light traps, gauze, tweezers, brushes, refrigerators, digital cameras, aspirators, USB microscopes, and writing instruments.

C. Arthropod Trapping Procedures

Arthropod trapping in two models of cocoa plantations, each with an area of 2 Ha, namely 1). Cocoa plantation with one shade, namely candlenut tree (*Aleurites moluccana* Willd). 2). Multi-shade cocoa plantation (fruit trees and forest trees).

Observation of the number of arthropod species was carried out using 2 types of traps, namely: 1). The light trap is placed on top of a basin containing 500 cm^3 of water and 2 cm^3 of detergent at a height of 1m from the ground, turned on at 18.00 - 06.00 WITA. Distance between traps 18 m. 2). The pithfall trap is planted until the top surface is parallel to the ground level. In the trap is put 100 cm^3 of water and 0.5 cm^3 of detergent. placed for 24 hours, the distance between the traps is 20 m as many as 5 traps. Sampling was carried out once a week 5 times. Observation Population density of *C. cramerella* larvae. based on the line transect method on cocoa plantations. The sampling of cacao pods was adjusted to the phenology of *C. cramerella*, namely cacao pods measuring 8 - 20 cm long. The sampling was carried out at 10.00 – 12.00 WITA. Observations of predators were carried out by observing predators that preyed on the larvae, pupae, and imago of the *C. cramerella* pest.

D. Observation Variable

The variables observed in this study were:
a. Number of functional species of arthropods
b. Population density of *C. cramerella* larvae
c. Natural enemies

Arthropoda specimens were collected based on taxonomy and trophic structure, carried out at the Laboratory of the Department of Plant Pests, Faculty of Agriculture, Tadulako University.

E. Data Analysis

The research data were analyzed using tabulation and graph analysis with the help of Excel 2010 and using the t-test.

III. RESULTS

A. Number of Functional Species of Arthropods

The The results of the study on the composition of functional species of arthropods in cocoa plantations found that there were 4 functional statuses of arthropods, namely herbivores, parasitoids, predators, detrivores, and other insect groups. All functional species statuses of arthropods were found in all types of cocoa plantations with different functional species compositions of arthropods and a varying number of functional species.

Table 1. Composition of ecological services of Arthropoda functional species in different shader strata of cocoa plantations.

No	Functional species	Multi-shade cocoa plantation	One-shade cocoa plantation
1.	Herbivora	14	18
2.	Parasitoid	4	5
3.	Predator	16	24
4.	Etc	11	15
	Number of species	45	62

The results of the study on the composition of the ecological services of arthropod functional species in multi-shade cocoa plantations (Table 1.) found that there were 45 arthropod species divided into 4 functional status groups that play a role in the ecological services of the cocoa plantation ecosystem, namely 14 herbivorous species, 4 parasitoid species, 16 species. predators and 11 other functional status species. In the cocoa plantation, one shader of the ecological service composition of arthropod functional species was found as many as 62 arthropod species which were divided into 4 functional status groups, namely 18 herbivorous species, 5 parasitoid species, 24 predatory species, and 11 other functional status species.

Accumulatively, the percentage of ecological services of functional species of arthropods in cocoa plantations are Herbivores (29.91%), Predators (37.38%), Parasites (8.41%), and other functional species (24.30%) (Figure 1.).

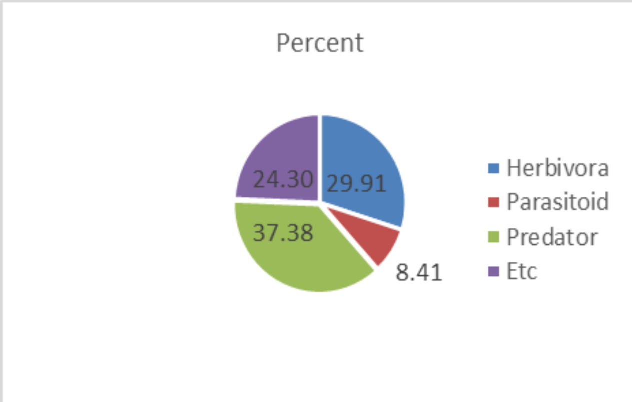

Figure 1. Diagram of the percentage of ecological services of functional species of arthropods in cocoa plantations.

B. Population Density of C. cramerella Larvae

The results of the t-test analysis of the population density of *C. cramerella* larvae in one-shade cocoa plantation (8.08 heads/cocoa pod) were significantly higher than the multi-shade cocoa plantation model (5.21 heads/cocoa pod) (P=0.001) (Figure 2).

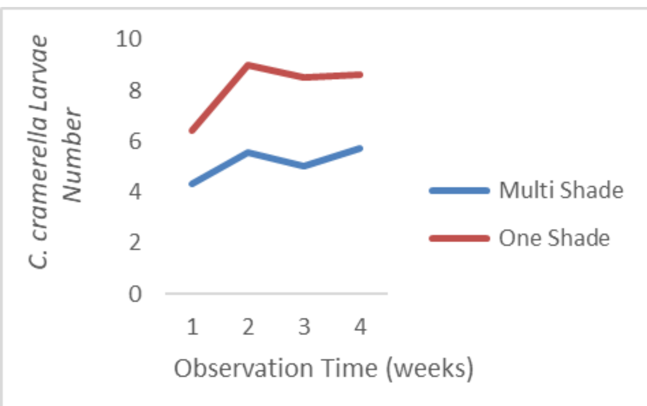

Figure 2. Population density of *C. cramerella* larvae per cocoa pod in multi-shade and one-shade cocoa plantations

Cocoa plantations with different shades significantly affected the population density of *C. cramerella* larvae. The population density of C. cramerella larvae that burrow into cocoa pods on one-shade cocoa plantation from the first observation to the last observation was higher than that of *C. cramerella* larvae on multi-shade cocoa plantations.

C. Natural Enemy of CPB C. cramerella

Observations on multi-shade and one-shade cocoa plantations found that one type of natural enemy that was active in preying on *C. cramerella* larvae was Predator *Solenopsis xyloni* (Hymenoptera: Formicidae) (Figure 3).

Figure 3. A Natural enemy of larvae *C. cramerella* Predator *S. xyloni*

IV. DISCUSSION

Arthropods are an important component of ecosystems in maintaining balance [24] and ecosystem health [25]. leaves, snoring leaves, sucking liquid, and so on. It is because of this that arthropods are considered to be detrimental, even though the role of arthropods in ecological services is more beneficial [26].

The roles of arthropod species in the ecosystem include predators, parasitoids, and herbivores in an ecosystem [26]. This shows that the functional services of arthropods are very important in maintaining ecosystem stability. The presence of arthropods to maintain the balance of plant-eating insect populations is important because of the ability of parasitoids to parasitize and the ability of predators to prey on them [27]. Ecosystem stability can be maintained by the composition of parasitoids, predators, and herbivores when there is no dominance by these species [28].

The population density of *C. cramerella* larvae on cocoa pods was different because the shade between the two cocoa plantations was different. In multi-shade cocoa plantations, there are fruit trees and forest trees as well as cocoa trees whose crowns meet and cover each other so that sunlight entering the cocoa is blocked, this causes the cocoa plantation to be darker during the day. The microclimate conditions formed were suitable for the growth and development of *C. cramerella*, which is not attracted to light and likes dark places. A suitable microclimate should increase the population density of *C. cramerella* eggs and larvae, but this does not happen because in multi-shade cacao plantations there are natural enemies that are actively working to suppress the development of *C. cramerella* larvae populations, viz. Predator *Solenopsis xyloni* (Hymenoptera: Formicidae). This natural enemy works to suppress the development of the larval population of *C. cramerella* so that the population density of *C. cramerella* larvae in multi-shade cocoa plantations is lower than the larval population density of single-shade cocoa plantations. Parasitoids and predators as natural enemies of plant pests can protect plants from damage caused by herbivorous insects [29].

In the one-shade cocoa plantation model, the sunlight that enters the cacao plants is suitable for normal cacao growth, but because the cacao canopy is not properly maintained, the cacao crowns meet and close together, causing the cocoa plantation to be quite dark during the day. The microclimate conditions formed under the cocoa canopy were suitable for the growth and development of *C. cramerella*. triggered an increase in the population density of *C. cramerella* larvae, which was higher than that of multi-shade cocoa plantations.

The high population density of *C. cramerella* larvae has a very significant function because it poses a threat to cocoa production. The high and low population density of *C. cramerella* larvae that fluctuated from time to time could be used to determine the factors controlling the population density of *C. cramerella*. The presence of predators controlling *C. cramerella* larvae is a density-dependent factor that causes *C. cramerella* population density in cocoa plantations to be suppressed. The presence of natural enemies of predators, parasitoids, and pathogens in a crop will suppress the development of insect pest populations and the role of this group is important in the natural regulation of phytophagous insect populations [30]. that one-shade cocoa plantation had a lower number of herbivore species than multi-shade cocoa plantations, due to the low number of parasitoid and predatory species

CONCLUSION

Functional species composition of Arthropods in multi-shade (45 species) and one-shade (62 species) cocoa plantations include Herbivores, parasitoids, predators, and other roles. Population density of *C. cramerella* larvae in one-shade cocoa plantations (8.08 heads/cocoa pod) and multi-shade cocoa plantations (5.21 heads/cocoa pod). Natural enemy species that prey on *C. cramerella* larvae in multi-shade and one-shade cocoa plantations, namely *Solenopsis xyloni*.

ACKNOWLEDGMENT

Our gratitude is for Kementerian Pendidikan, Kebudayaan, Ristek dan Pendidikan Tinggi of the Republic of Indonesia who has funded this research

REFERENCES

[1] J.-M. Jung, D. Byeon, S.-H. Kim, Sunghoon-Jung, and W.-H. Lee, "Estimating economic damage to cocoa bean production with changes in the spatial distribution of Tribolium castaneum (Herbst) (Coleoptera: Tenebrionidae) in response to climate change," J. Stored Prod. Res., vol. 89, p. 101681, Dec. 2020, doi: 10.1016/j.jspr.2020.101681.

[2] R. Manalu, "Pengelolaan Mutu Biji Kakao Petani Perkebunan Rakyat Melalui Teknologi Fermentasi Untuk Memperoleh Nilai Ekonomi Yang Lebih Baik," J. Ekon. Dan Kebijak. Publik, vol. 9, no. 2, pp. 99–112, Feb. 2019, doi: 10.22212/jekp.v9i2.1006.

[3] B. Pokorny, V. Robiglio, M. Reyes, R. Vargas, and C. F. Patiño Carrera, "The potential of agroforestry concessions to stabilize Amazonian forest frontiers: a case study on the economic and environmental robustness of informally settled small-scale cocoa farmers in Peru," Land Use Policy, vol. 102, p. 105242, Mar. 2021, doi: 10.1016/j.landusepol.2020.105242.

[4] S. Raharto, "Institutional Development Model Cocoa Farmers in East Java Province District Blitar," Agric. Agric. Sci. Procedia, vol. 9, pp. 95–102, 2016, doi: 10.1016/j.aaspro.2016.02.131.

[5] Sacita, A.S dan Naim, M, "Tingkat Serangan Hama Helopeltis Spp Dan Penggerek Buah Kakao (Pbk) Pada Beberapa Dosis Pemupukan Tanaman Kakao," J. Pertan. Berkelanjutan, vol. 9, no. 3, pp. 202–207, Oktober 2021.

[6] FAO, "Food and Agriculture Organization. Production of Cocoa, beans: Top 10 Producers.," 2018. https://www.fao.org/faostat/en/#data/QC/visualize

[7] S. Abdoellah, "Analisis Kinerja dan Prospek Komoditas Kakao," Pusat Penelitian Kopi dan Kakao Indonesia, PT Riset Perkebunan Nusantara Jln. PB Sudirman 90 Jember 68118, Jawa Timur - Indonesia, vol. 2, no. 1, pp. 1–7, Pebruari 2021.

[8] N. A. Febrianto and F. Zhu, "Composition of methylxanthines, polyphenols, key odorant volatiles and minerals in 22 cocoa beans obtained from different geographic origins," LWT, vol. 153, p. 112395, Jan. 2022, doi: 10.1016/j.lwt.2021.112395.

[9] N. A. Tiro, H. Hatta, and Pirman, "The Effect of Using Cocoa NIB Fermentation On the Characteristic of Chocolate Physicochemistry.," vol. 23, no. 1, pp. 129–139, Mar. 2020, doi: http://dx.doi.org/10.21082/jpptp.v23n1.2020.p131-141.

[10] R. Yusiasih, M. M. Pitoi, E. S. Endah, M. Ariyani, and T. A. Koesmawati, "Pyrethroid residues in Indonesian cocoa powder: Method development, analysis and risk assessment," Food Control, vol. 119, p. 107466, Jan. 2021, doi: 10.1016/j.foodcont.2020.107466.

[11] K. Ruslan and O. R. Prasetyo, Produktivitas Tanaman Perkebunan: Kopi, Tebu, dan Kakao. 2021.

[12] C. P. Guirlanda, G. G. da Silva, and J. A. Takahashi, "Cocoa honey: Agro-industrial waste or underutilized cocoa by-product?," Future Foods, vol. 4, p. 100061, Dec. 2021, doi: 10.1016/j.fufo.2021.100061.

[13] D. Nadaraja, C. Lu, and M. M. Islam, "The Sustainability Assessment of Plantation Agriculture - A Systematic Review of Sustainability Indicators," Sustain. Prod. Consum., vol. 26, pp. 892–910, Apr. 2021, doi: 10.1016/j.spc.2020.12.042.

[14] C. Maney, M. Sassen, and S. L. L. Hill, "Modelling biodiversity responses to land use in areas of cocoa cultivation," Agric. Ecosyst. Environ., vol. 324, p. 107712, Feb. 2022, doi: 10.1016/j.agee.2021.107712.

[15] A. Tothmihaly, V. Ingram, and S. von Cramon-Taubadel, "How Can the Environmental Efficiency of Indonesian Cocoa Farms Be Increased?," Ecol. Econ., vol. 158, pp. 134–145, Apr. 2019, doi: 10.1016/j.ecolecon.2019.01.004.

[16] A. C. Wartenberg, W. J. Blaser, A. Gattinger, J. M. Roshetko, M. Van Noordwijk, and J. Six, "Does shade

tree diversity increase soil fertility in cocoa plantations?," Agric. Ecosyst. Environ., vol. 248, pp. 190–199, Oct. 2017, doi: 10.1016/j.agee.2017.07.033.

[17] I. Valenzuela, H. B. Purung, R. T. Roush, and A. J. Hamilton, "Practical yield loss models for infestation of cocoa with cocoa pod borer moth, Conopomorpha cramerella (Snellen)," Crop Prot., vol. 66, pp. 19–28, Dec. 2014, doi: 10.1016/j.cropro.2014.08.018.

[18] R. K. Day, "Effect of cocoa pod borer, Conopomorpha cramerella, on cocoa yield and quality in Sabah, Malaysia," Crop Prot., vol. 8, no. 5, pp. 332–339, Oct. 1989, doi: 10.1016/0261-2194(89)90052-5.

[19] M. A. Altieri, and C. I. Nicholls, Biodiversity and Pest Management in Agroecosystems, Second Edition. Food Products Press, 2004.

[20] R. Marja, T. Tscharntke, and P. Batáry, "Increasing landscape complexity enhances species richness of farmland arthropods, agri-environment schemes also abundance – A meta-analysis," Agric. Ecosyst. Environ., vol. 326, p. 107822, Mar. 2022, doi: 10.1016/j.agee.2021.107822.

[21] Moh. H. Toana, G. Mudjiono, S. Karindah, and A. L. Abadi, "Diversity Of Arthropods On Cocoa Plantation In Three Strata Of Shade Tree," Agrivita J. Agric. Sci., vol. 36, no. 2, Jun. 2014, doi: 10.17503/Agrivita-2014-36-2-p120-127.

[22] T. D. Schowalter, "Ecosystem Structure and Function," in Insect Ecology, Elsevier, 2011, pp. 327–358. doi: 10.1016/B978-0-12-381351-0.00011-1.

[23] M. V. Sanchez Domínguez, E. González, D. Fabián, A. Salvo, and M. S. Fenoglio, "Arthropod diversity and ecological processes on green roofs in a semi-rural area of Argentina: Similarity to neighbor ground habitats and landscape effects," Landsc. Urban Plan., vol. 199, p. 103816, Jul. 2020, doi: 10.1016/j.landurbplan.2020.103816.

[24] R. E. Caraka et al., "Ecological Show Cave and Wild Cave: Negative Binomial Gllvm's Arthropod Community Modelling," Procedia Comput. Sci., vol. 135, pp. 377–384, 2018, doi: 10.1016/j.procs.2018.08.188.

[25] H. Xiao, C. Du, X. Yuan, and B. Li, "Multiple floods affect composition and community structure of the ground-dwelling arthropods in the riparian zone of the Three Gorges Reservoir," Ecol. Indic., vol. 113, p. 106220, Jun. 2020, doi: 10.1016/j.ecolind.2020.106220.

[26] Jr. Ennis, W. B., Introduction to crop Protection. Medison: American Society of Agronomy Inc, 1979.

[27] I. Oka, Pengendalikan Hama Terpadu dan Implementasinya di Indonesia. Yogyakarta: Gadjah Mada University, 1995.

[28] G. Mudjiono, H. Tarno, and S. R. Prihadianto, "The Biodiversity Of Arthropods In Orchid Plantation With Different Altitude Field." Jurusan Hama dan Penyakit Tumbuhan Fakultas Pertanian Universitas Brawijaya, Malang, 2013.

[29] C. Rodriguez-Saona, B. R., and R. Isaacs, "Manipulation of Natural Enemies in Agroecosystems: Habitat and Semiochemicals for Sustainable Insect Pest Control," in Integrated Pest Management and Pest Control - Current and Future Tactics, S. Soloneski, Ed. InTech, 2012. doi: 10.5772/30375.

[30] K. Untung, Pengantar Pengelolaan Hama Terpadu. Gadjah Mada University Press, 2013.