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The abundance of arthropods and natural enemies on two growth phases of hybrid corn, Solok District, Indonesia

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Abstract. *Hervani D, Sari SP. 2022. The abundance of arthropods and natural enemies on two growth phases of hybrid corn, Solok District, Indonesia. Biodiversitas 23: 2966-2972.* Solok District, West Sumatra, Indonesia is one of Indonesia's hybrid corn production regions. As yet, the study of arthropods is still limited. This study aimed to study the abundance and diversity of arthropods in the hybrid maize agroecosystem in Solok District, West Sumatra. The research was conducted from May to November 2020 in Tanah Garam Sub-district, Solok District. The sampling was carried out four times in two growth phases of hybrid corn: vegetative (the age of 20 and 40 days after planting/DAP) and the generative phase (the age of 60 and 80 DAP). The arthropod collection was conducted using a yellow trap and a modified vacuum technique. The identification process was carried out at the Insect Bioecology Laboratory, Andalas University. The study found two classes of arthropods in a hybrid cornfield in Solok District, namely Arachnida and Insecta. The Shannon-Weiner diversity index value (H') was 1.383, and the evenness index of species (J') was 0.997. A total of 2,927 individual arthropods, 80 families, 8 orders, and 3 classes, were recorded in the hybrid corn ecosystem in Solok District. Insect class (2,866 individuals) dominated the diversity of arthropods, where the majority of the arthropods found belong to groups of natural enemies such as predators and parasitoids. Conservation of natural enemies (predators and parasitoids) is one of the main factors in supporting the success of pests biologically, so the act of identifying natural enemies in an area is very important.

Keywords: Abundance, diversity, evenness index of species, maize, Shannon-Wiener index

INTRODUCTION

Corn (*Zea mays* L.) is the most productive and widely cultivated crop in the world. Corn cultivation covers more than 100 million ha of land in 125 countries (Shiferaw et al. 2011). By 2050, the demand for maize is predicted to double (Rosegrant et al. 2009). For the people of Indonesia, corn is the second most important food crop. Apart from being a staple food, corn has other functions as forage and as raw material for bioethanol.

One type of corn that is cultivated in Indonesia is hybrid corn. Solok District, West Sumatra Province is one of the hybrid corn-producing areas in Indonesia. The area has long been the center of PT. Citra Nusantara Mandiri Solok is one of the national hybrid corn seed producers. Arthropod exploration needs to be carried out as biomonitoring of the hybrid corn area.

According to Nakamura et al. (2007), one of the important indicator species in the agroecosystems is arthropods, which are an essential group of terrestrial ecosystems. Arthropods have an important role in the function and stability of an ecosystem (Santos et al. 2007). As components of biodiversity, arthropods are also important in agricultural ecosystems (Gonçalves et al. 2012), which can act as natural enemies for insect pests, and are also used as indicators of damage to agroecosystems or the environment (Schowalter 2000).

Biodiversity is a term used to describe the diversity of plants, animals, and microorganisms that exist and interact in an ecosystem. Biodiversity exists in a variety of life. Thus it is often divided into several levels, such as genetic diversity, species, and between species in the ecosystem. At the highest level, biodiversity includes all the different species on earth. On a smaller scale, biodiversity is studied in a particular ecosystem by identifying the specific organisms that live in it (UNESCO 2010). Arthropod biodiversity and natural enemies in the ecosystems of hybrid corn need to be explored more. Information on the biodiversity of arthropods in the agroecosystem is known for its abundance through identification and exploration.

Previous studies have been conducted on the abundance of arthropods in various agricultural ecosystems in Indonesia. Kurniawan et al. (2018) conducted research on the diversity of arthropods in the Semedi Show Cave in Gunungsewu Karst Area, Pacitan, East Java, Indonesia. A total of 1095 Arthropoda individuals consisting of 102 morphospecies, which belong to 6 classes, and 19 orders were recorded in that research. Furthermore, Karenina et al. (2019) studied the abundance and species diversity of predatory arthropods inhabiting rice surrounded by refugia and vegetables and by those being applied with synthetic insecticide in the rice field of freshwater swamps. For the result, they found twenty-five herbivores and 24 species of predatory insects of 12 families were found on rice during a planting season. The lowest herbivore population and spider abundance were found on synthetic insecticide sprayed rice, and they were significantly different from those of refugia-rice plots. Amarullah et al. (2017), the abundance of arthropods in the ecosystem is influenced by the diversity of plant species that dominate an agricultural area. Afterward, Nelly et al. (2017) also said that location affects the insect diversity index. The highest index of natural enemy diversity was in West Pasaman, while the highest evenness index was in Limapuluh Kota. This can happen because different locations will have different vegetation patterns. The highest insect diversity was found in rice plants with refugia at the edge of the rice fields compared to fields without refugia in the Solok area, West Sumatra (Nelly et al. 2020).

MATERIALS AND METHODS

Research location

This study was conducted in Nagari Lubuk Sikarah, Tanah Garam Subdistrict, Solok District, West Sumatra, Indonesia from May to July 2020. It is located at 0°47'10"S 100°36'24"E. The location map can be seen in Figure 1.

The study was conducted over a survey on two growth phases of hybrid corn, the vegetative (20 and 40 DAP) and the generative phase (60 and 80 DAP). This experiment covered an area of 5 ha of the hybrid cornfield.

Collection of samples

Two sampling techniques were used in this study, namely yellow trap and modified vacuum technique. Yellow traps are commonly used to obtain qualitative and quantitative data on soil arthropods since they are easy to apply in the field. Arthropod sampling was carried out four times, on May 5, May 25, June 14, July 24, 2020. Sampling started from 08.00 am - 12.00 pm. Samples were cleaned with water and put into a 1.5 ml microcentrifuge tube containing alcohol 96%. For identification, samples were taken to the Insect Bioecology Laboratory, Faculty of Agriculture, Andalas University, Padang, Indonesia.

Arthropods identification

Samples were sorted and separated based on the order, then proceeded with the identification up to the morphospecies level (code only), which was to differentiate the types of species based on their morphological characters. The identification referred to several works of literature such as; The arthropods were identified using essential books; Kalshoven (1981), Goulet and Huber (1993), Borror et al. (1996), online identification keys (official website https://www.bugguide.net). This identification process was carried out under a light microscope Carton SPZ50.

Data analysis

Arthropod diversity and abundance data were compiled manually using Microsoft Excel. Then the diversity index (H') and species evenness index (J') were calculated using the PRIMER 5 application.

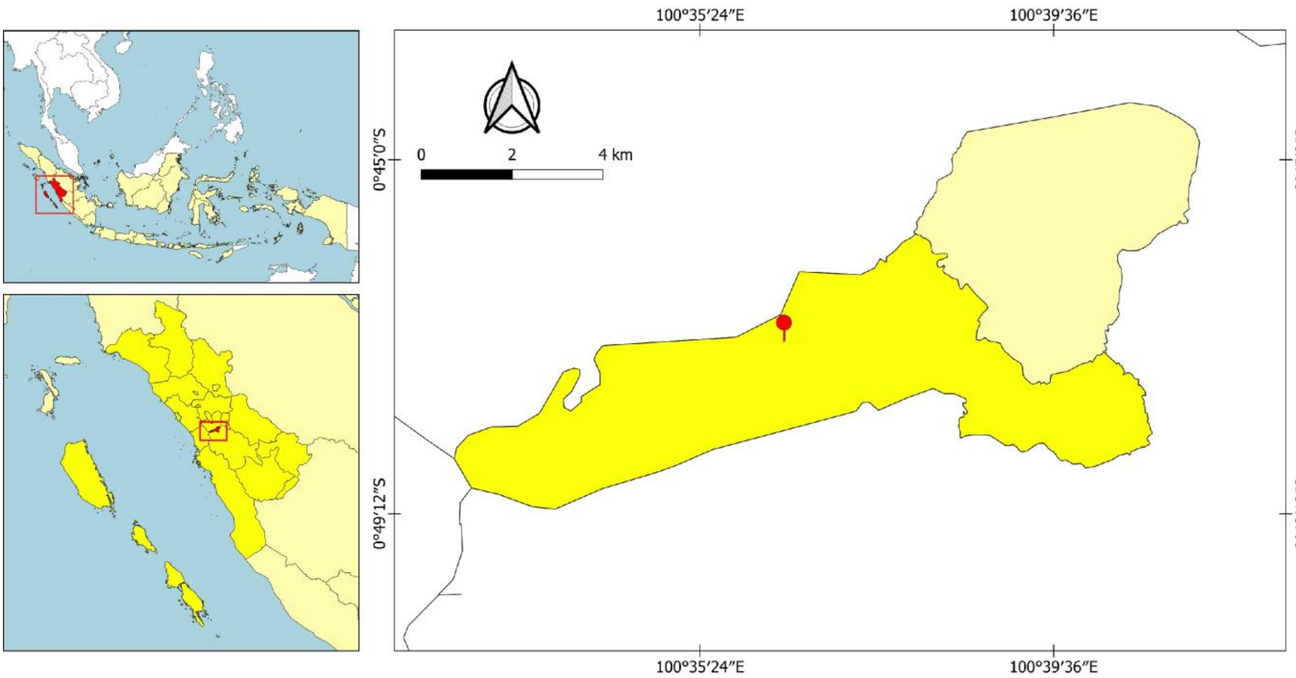

Figure 1. Map of hybrid corn plantation in Nagari Lubuk Sikarah, Solok District, West Sumatra, Indonesia. (Source: altimeter and google maps)

RESULTS AND DISCUSSION

A total of 2,927 arthropods were found in two-phase hybrid maize growth in Solok District, West Sumatra. The arthropods found were grouped into two classes, namely Insecta and Arachnida. The Insect class consisted of 7 orders, while the Arachnida class consisted of 1 order. The insect class dominated the diversity of arthropods in the hybrid maize ecosystem with 2,866 individuals, and the rest were in the arachnid class with 61 individuals. The results of the analysis of the Shannon-Wiener diversity index showed that the arthropod diversity value in the hybrid corn ecosystem in Solok District was classified as moderate, namely 1.383, and the species evenness index (J') was classified as high, namely 0.997. That means the hybrid corn ecosystem is quite balanced for the development of arthropods. The age of the plant greatly affects the abundance of species in the hybrid corn ecosystem in Solok District which varies at several ages corn plants. Based on the growth phase of corn plants, the age of 20 DAP and 40 DAP were included in the vegetative phase of corn plants, while 60 DAP and 80 DAP were included in the generative phase. The fluctuation of arthropod diversity in the hybrid corn ecosystem is influenced by the age of the hybrid corn plant (Figure 1).

The higher abundance of Arthropoda was at the age of 60 DAP, although at 80 DAP the abundance of arthropods decreased. However, in general, the pattern of arthropod abundance in the hybrid maize ecosystem increased with the increasing age of the hybrid maize plant. The age of 60 and 80 DAP on hybrid maize is included in the generative phase. This means that the difference in plant age, which reflects differences in plant phenology and architecture (plant height and wider midrib), indirectly affects the abundance of individual arthropods through the formed macroclimate, which in turn affects the structure of the arthropod community as a whole. This means that the age of hybrid maize affects the arthropods in the hybrid maize landscape. This study obtained 8 orders and 80 families of arthropods in the hybrid corn ecosystem in Solok District. The number of arthropods in each order and family varies according to the technique used (yellow trap and modified vacuum technique). Yellow traps were used to collect pollinating insects or insects attracted by yellow, while a modified vacuum was used to collect active flightless insects such as the order Hymenoptera, Diptera, and some Coleoptera (Table 1).

In collecting arthropods in the hybrid corn ecosystem in Solok District, we used two kinds of traps. Based on the results obtained, Hymenoptera was the most common order found in this study (32.47%), while the order with the least number was Mantodae (0.034%). The yellow tray attracted more insects from the order Hymenoptera, while the modified vacuum caught more insects from the order Coleoptera.

Most of the arthropods in the hybrid corn ecosystem in Solok District are more attracted to the color yellow, both the arachnid class and the insect class. It can be seen from the number of arthropods obtained by the yellow trap method more than the modified vacuum method.

The family with the highest abundance of arthropods was Formicidae (225 individuals), and the lowest was Mantidae, Scoliidae, Tetragnathidae, and Therevidae (1 arthropod) for yellow tray traps. As for the modified vacuum trap, the highest abundance was in family Coccinellidae (261 arthropods) and the lowest was in family Melyridae (1 arthropod). In this study, several families were found to act as natural enemies in the hybrid corn ecosystem in Solok District. Some of these natural enemies are classified as predators, and some are classified as parasitoids.

The diversity of insect species has an important role in creating a balanced ecosystem. Natural enemies (predators and parasitoids) can naturally control insect pests that attack plants at all levels of plant age when the surrounding environment supports the proliferation of these natural enemies. According to Lawalata and Anam (2020), the development of natural enemies in Indonesia is driven by agricultural ecosystems with a tropical climate, thus enabling the development of natural enemies effectively to suppress and control rice pest populations in Jayapura District.

Based on the identification results, the total abundance of natural enemies found in the hybrid corn ecosystem in Solok District was 1531 arthropods (1123 as predators and 408 as parasitoids). The six orders found as predators in the hybrid maize ecosystem were Araneae, Coleoptera, Diptera, Hemiptera, Mantodae, and Orthoptera. Meanwhile, Hymenoptera was the only order found as a parasitoid in the hybrid corn ecosystem in Solok District. Yellow traps are used to trap arthropods in the soil that are classified as natural enemies, both predators and parasitoids, such as the order Hymenoptera. While the modified vacuum catches more insects from the orders Coleoptera and Diptera.

Hymenoptera parasitoids are more specialized so that some types of parasitoids can find their hosts in hidden places. In contrast to the parasitic Hymenoptera, other parasitoids of the order Diptera family Tachinidae are more generalists and cannot also find hosts in hidden places (Kalshoven 1981). Evaniidae is an egg parasitoid that generally attacks insects of the order Blattodea (Goulet and Huber 1993). Then Idris et al. (2001) also stated that yellow traps are an excellent tool for collecting parasitoids, such as Ichneumonidae. In contrast to parasitoids, predators are generally polyphagous, meaning they can prey on more than one prey and do not depend on one prey (Henuhili and Aminatun 2013).

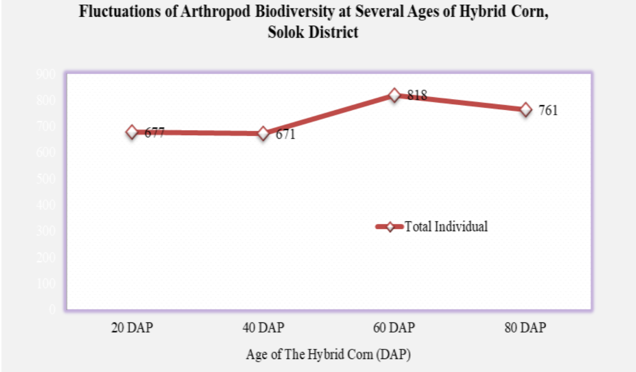

Figure 1. Fluctuations of arthropod biodiversity at several ages of hybrid corn, Solok District, West Sumatra, Indonesia

Table 1. Arthropods and natural enemies on two growth phases of hybrid corn in Solok District, Indonesia

Taxa	Role	Vegetative phase		Generative phase		Yellow trap	Vacuum modified
		20 DAP	40 DAP	60 DAP	80 DAP		
Class Arachnida							
Araneae		**24**	**7**	**7**	**23**	**45**	**16**
Agelenidae*	Predator	0	0	4	13	12	5
Ctenidae*	Predator	1	2	1	1	2	3
Gnaphosidae*	Predator	1	2	2	1	2	4
Leptonetidae	-	6	0	0	4	10	0
Axyopidae*	Predator	9	2	0	0	11	0
Salticidae*	Predator	2	1	0	3	2	4
Tetragnathidae*	Predator	0	0	0	1	1	0
Theridiidae*	Predator	5	0	0	0	5	0
Class Insecta							
Class Colembola		**3**	**2**	**0**	**2**	**0**	**7**
Entomobrydae	Decomposer	1	1	0	1	0	3
Isotomidae	Decomposer	2	1	0	1	0	4
Coleoptera		**87**	**136**	**200**	**152**	**222**	**353**
Anthicidae	Predator	11	14	19	24	15	53
Carabidae*	Predator	1	3	4	6	11	3
Chrysomelidae	Herbivor	7	23	52	34	88	28
Coccinellidae*	Predator	66	86	106	74	71	261
Curculionidae	Herbivor	1	1	2	1	5	0
Meloidae	-	0	1	3	4	6	2
Melyridae*	Predator	0	0	0	1	0	1
Nitidulidae	Mycophagus	1	6	10	5	17	5
Scarabaeidae	Herbivor	0	2	4	3	9	0
Diptera		**203**	**202**	**148**	**189**	**401**	**341**
Agromyzidae	Pest	32	13	11	11	45	22
Asilidae*	Predator	0	4	17	4	25	0
Bibionidae	Pest	1	4	0	3	4	4
Calliphoridae	Pest	1	1	1	0	0	3
Cecidomyzidae	Pest	5	31	17	11	59	5
Ceratopogonidae	Pest	36	6	6	5	15	38
Chloropidae*	Parasitoid	9	13	11	10	5	38
Conopidae*	Parasitoid	1	1	0	1	0	3
Culicidae	Pest	1	2	3	4	7	3
Delphacidae	Pest	0	3	0	3	6	0
Dolichopodidae*	Pest	29	8	2	20	52	7
Drosophilidae*	Pest	30	35	14	32	47	64
Empididae	Pest	0	0	0	2	2	0
Ephydridae	Pest	7	7	8	3	9	16
Fannidae	Pest	10	17	11	29	43	24
Lonchochaedidae	Fitopag	1	5	5	0	4	7
Milichidae	Fitopag	10	20	14	23	25	42
Muscidae	Pest	21	13	12	11	12	45
Mycetophilidae	Pest	0	3	0	9	12	0
Mycropezidae	Pest	3	6	7	7	11	12
Phoridae*	Parasitoid	3	4	4	0	11	0
Platypezidae	Fitopag	1	2	1	0	2	2
Sciaridae	Mycophagus	0	1	1	1	0	3
Tanyderidae	Fitopag	0	1	1	0	2	0
Tephritidae	Parasitoid	1	2	2	0	2	3
Therevidae*	Predator	1	0	0	0	1	0
Hemiptera		**157**	**110**	**127**	**123**	**333**	**184**
Aphididae	Pest	12	43	77	73	102	103
Delphacidae	Pest	118	49	28	35	194	36
Lygacidae	Pest	24	9	10	6	19	30
Milichidae	Fitopag	0	6	6	0	12	0
Reduviidae*	Predator	3	3	6	9	6	15

Hymenoptera		**193**	**193**	**313**	**251**	**649**	**301**
Bethylidae	-	2	4	9	4	7	12
Braconidae*	Parasitoid	18	13	35	17	76	7
Ceraphronidae*	Parasitoid	4	5	13	15	32	5
Chalcididae*	Parasitoid	0	0	0	2	2	0
Diapriidae*	Parasitoid	8	6	7	16	21	16
Encyrtidae	Parasitoid	1	1	2	3	7	0
Eucoilidae*	Parasitoid	5	10	11	7	28	5
Eulophidae*	Parasitoid	1	3	4	4	8	4
Evaniidae*	Parasitoid	10	1	0	0	11	0
Formicidae*	Predator	89	106	152	87	225	209
Halictidae*	Parasitoid	4	8	10	11	28	5
Ichneumonidae*	Parasitoid	23	7	19	13	57	5
Mymaridae*	Parasitoid	0	1	1	11	13	0
Platygastriidae*	Parasitoid	1	9	13	11	26	8
Pompilidae*	Parasitoid	7	2	2	1	12	0
Scelionidae*	Parasitoid	17	14	27	43	81	20
Scoliidae	Fitopag	0	0	0	1	1	0
Specidae*	Parasitoid	0	1	1	0	2	0
Tiphiidae*	Parasitoid	2	1	0	5	5	3
Tricogrammatidae*	Parasitoid	0	1	5	0	6	0
Vespidae*	Predator	1	0	2	0	1	0
Mantodae		**0**	**0**	**0**	**1**	**1**	**0**
Mantidae*	Predator	0	0	0	1	1	0
Orthoptera		**10**	**21**	**23**	**20**	**54**	**20**
Acrididae	Pest	3	1	0	1	2	3
Gryilotalpidae	Pest	0	4	8	1	11	2
Gryllacrididae	Omnivora	3	0	0	0	2	0
Gryllidae	Omnivora	0	1	0	5	6	0
Pyrgomorphidae	Herbivora	0	1	1	0	2	0
Tetrigidae	Pest	3	12	13	12	28	12
Tettigoniidae*	Predator	1	2	1	1	2	3
Grand total (individuals)		**677**	**671**	**818**	**761**	**1705**	**1222**

Insect diversity is influenced by food quality and quantity factors, including the number of suitable host plants, host plant density, host plant age, and stand composition (Haneda et al. 2013). Integrated plant management can suppress the proportion of insects and maintain a high proportion of natural enemies and neutral insects from the early vegetative phase to the fallow period (Macfadyen et al. 2015). The diversity of insects can determine the stability of the agroecosystem because it can cause interactions between phytophagous insects and entomophagous insects (Azmi et al. 2014; Sumini 2016). Planting and utilizing plants that can become natural enemy habitats is the main alternative in integrated plant management because it has a high impact on biodiversity and insect abundance (Heong et al. 2014). Besides, organic production systems also can increase the number of beneficial insects that may affect pests and diseases in agricultural ecosystem (Dela Peña and Ratilla 2022).

The intrinsic value of biodiversity in an agricultural ecosystem is very important because it affects crop production and ecological functions in sustainable agricultural systems (Truter et al. 2014). Yaherwandi and Syam (2007) stated that species biodiversity is one of the most important things in the study of the effects of environmental change and how biodiversity affects the stability of natural communities. In this study, the Shannon-Wiener diversity index (H') of arthropods in maize cultivation in Solok District was 1.383, the species evenness index (J') was 0.997, and the number of arthropods (N) was 2927 individuals. Most of the individual insects found in the corn ecosystem act as natural enemies, like predators and parasitoids.

The relationship between landscape complexity and agricultural biodiversity in some organisms is well known (Finke and Snyder 2010; Holzschuh et al. 2010). The abundance and diversity of natural enemies were lower in simple landscapes than in complex landscapes. This is because simple landscapes are not able to provide the needs of natural enemies, such as alternative hosts and food (Ge´neau et al. 2012). In addition to increasing the diversity and abundance of natural enemies on agricultural land, complex landscapes can also increase the effectiveness of natural enemies in controlling insect pests (Clough et al. 2007). Aspects observed to analyze biodiversity include number of species, abundance, distribution, dominance, variation of species in habitats, and ecosystems. One of the factors that influence insect diversity is habitat (Romero-Alcaraz and Avila 2000; Klein et al. 2002; Hosang 2003). In this study, it can be concluded that the abundance of arthropods in hybrid maize fields is influenced by several factors, such as plant age, plant growth and development phase, and sampling technique. This can be seen from the uneven number of arthropods obtained in each age group, as well as in the growth and development phases of hybrid maize (vegetative and generative).

According to Price et al. (1980), the interaction of three trophic levels that plants not only affect the herbivorous insects that eat them, but also affect the natural enemies of these herbivorous insects, either directly or indirectly. In addition, increasing the age of hybrid maize plants can increase the canopy and shade formed, while the intensity of incoming light decreases so that the microclimate, vegetation types, and the availability of food for arthropods will also change. This means that the availability of food sources can affect the abundance of arthropods in the landscape. Other factors that influence the abundance and biodiversity of arthropods are habitat, rainfall, and cultivation practices (such as pesticide application and weed management).

The richness and abundance of predatory insects can be influenced by the conditions of the surrounding vegetation and the availability of prey. The abundance of predatory insects will be higher in a more complex and diverse habitat structure. The existence of non-agricultural land around the planting area can increase the wealth and abundance of natural enemies. Non-agricultural land includes shrubs, grasslands, open land, and water areas (rivers or irrigation canals). Most of the Hymenoptera species found in this study belong to the parasitoid group. According to Speight et al. (1999), ordo Hymenoptera spreads in all vegetations, forests, or other places that provide food, such as flowering plants and horticultural crops. The majority of Hymenoptera are active on sunny days in search of food, such as insects, pollen and nectar, or nesting material. Some parasitoids can be nocturnal if the host insect is nocturnal.

The order Hymenoptera is a taxon group that has abundant species richness. The majority of Hymenoptera act as parasitoids and have a function to regulate the herbivorous insect population. Many species of Hymenoptera have been used for biological control in agriculture. Among the various groups of Hymenoptera, Ichneumonidae, and Braconidae are two very important families in the world, which are frequently found attacking the larvae of Lepidoptera, Coleoptera, and Diptera. Parasitoids from the Hymenoptera group play an important role in biological control (Sousa et al. 2016).

The diversity of insect species has an important role in creating a balanced ecosystem. In this study, there were 2,927 arthropods, 3 classes, 8 orders, and 80 families in the hybrid corn ecosystem in Solok District. Insect class dominates the diversity of arthropods, where the majority of the arthropods found belong to groups of natural enemies such as predators and parasitoids. Conservation of natural enemies (predators and parasitoids) is one of the main factors in supporting the success of pests biologically, so the act of identifying natural enemies in an area is very important. Through the identification of natural enemies, it is hoped that it can preserve and increase the population of natural enemies in an agricultural ecosystem.

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REFERENCES

Amarullah ET, Trizelia, Yaherwandi, Hamid H. 2017. Diversit of plant species in paddy ecosystem in West Sumatra, Indonesia. Biodiversitas 18 (3): 1218-1225. DOI: 10.13057/biodiv.d180346.

Azmi SL, Leksono AS, Yanuwiadi B, Arisoesilaningsih E. 2014. Diversity of herbivorous arthropods visiting red rice in organic rice fields in Sengguruh village, Kepanjen. Jurnal Pembangunan dan Alam Lestari 5 (1): 57-64. [Indonesian]

Borror DJ, Triplehorn CA, Johnson NF. 1996. The introduction of lessons insects. Gadjah Mada University Press. Yogyakarta. [Indonesian]

Clough Y, Kruess A, Tscharntke T. 2007. Local and landscape factors in differently managed arable fields affect the insect herbivore community of a non-crop plant species. J Appl Ecol 44: 22-28. DOI: 10.1111/j.1365-2664. 2006. 01239.x.

Dela Peña WB, Ratilla BC. 2022. Assessment of pests, natural enemies and soil microorganisms in lowland rice field under organic and inorganic production systems. Asian J Agric 6: 40-46. DOI: 10.13057/asianjagric/g060106.

Finke DL, Snyder WE. 2010. Conserving the benefits of predator biodiversity. Biol Conserv 143 (10): 2260-2269. DOI: 10.1016/j.biocon. 2010.03.002.

Ge´neau CE, Wa¨ckers FL, Luka H, Daniela C, Balmer O. 2012. Selective flowers to enhance biological control of cabbage pests by parasitoids. Basic Appl Ecol 13 (1): 85-93. DOI: 10.1016/j.baae.2011.10.005.

Gonçalves MF, Pereira JA. 2012. Abundance and diversity of soil arthropods in the olive grove ecosystem. J Insect Sci 12: 20. DOI: 10.1673/031.

Goulet H, Huber JT. 1993. Hymenoptera of The World: An Identification Guide to Families. Minister of Supply and Services, Ontario.

Haneda NF, Kusuma C, Kusuma FD. 2013. Insect diversity in mangrove ecosystems. J Trop Silvic 4 (2): 42-46. DOI: .29244/j-siltrop.4.1.%25p.

Henuhili V, Aminatun T. 2013. Conservation of natural enemies as biological pest control with rice field ecosystem management. J Sci Res 18 (2): 29-40. DOI: 10.21831/jps.v18i2.2138.

Heong KL, Wong L, Reyas JHD. 2014. Addressing Planthopper Threats to Asian Rice Farming and Food Security: Fixing Insecticide Misuse. Rice Planthoppers.

Holzschuh A, Steffan-Dewenter I, Tscharntke T. 2010. How do landscape composition and configuration, organic farming, and fallow strips affect the diversity of bees, waps, and their parasitoids?. J Anim Ecol 79 (2): 491-500. DOI: 10.1111/j.1365-2656.2009.01642x.

Idris AB, Zaneedarwaty NN, Gonzaga AD, Zaidi MI, Azman S, Salmah YA. 2001. Study of four methods of sampling Ichneumonidae and Braconidae at two different habitats of Frasers Hill, Malaysia. Pak J Biol Sci 4: 1515-1517.

Kalshoven LGE. 1981. Pest of Crop in Indonesia. PT. Ichtiar Baru Van Houve, Jakarta.

Karenina T, Herlinda S, Irsan C, Pujiastuti Y. 2019. Abundance and species diversity of predatory arthropods inhabiting rice of refuge habitats and synthetic insecticide aion in freshwater swamps in South Sumatra, Indonesia. Biodiversitas 20 (8): 2375-2387. DOI: 10.13057/biodiv/d200836.

Klein AM, Steffan-Dewenter I, Tscharntke T. 2002. Predator-prey ratios on cocoa along a land-use gradient in Indonesia. Biodiversity and Conservation 11: 683-693. DOI: 10.1023/A:1015548426672.

Kurniawan ID, Rahmadi C, Caraka RE, Ardi TE. 2018. Cave-dwelling arthropod community of Semedi Show Cave in Gunungsewu Karst Area, Pacitan, East Java, Indonesia. Biodiversitas 19 (3): 857-866. DOI: 10.13057/biodiv/d190314.

Lawalata JJ, Anam K. 2020. Observation of predatory types of rice plant pests in Karya Bumi village, Waibu Sub-district, Jayapura District. Median 12 (1): 13-20. DOI: 10.33506/md.v12i1.824. [Indonesian]

Macfadyen S, Davies AP, Zalucky MP. 2015. Assessing the impact of arthropod natural enemies on crop pests at the field scale. J Insect Sci 22: 20-34. DOI: 10.1111/1744-7917.12174.

Nakamura A, Catterall CP, House APN, Kitching RL, Burwell CJ. 2007. The use of ants and other soil and litter arthropods as bio-indicators of rainforest clearing and subsequent land-use impacts. J Insect Conserv (2): 177-186. DOI: 10.1007/s10841-006-9034-9.

Nelly N, Syahrawati M, Hamid H. 2017. Abundance of corn planthopper (*Stenocranus pacificus*) (Hemiptera: Delphacidae) and the potential natural enemies in West Sumatra, Indonesia. Biodiversitas 18 (5): 696-700. DOI: 10.13057/biodiv/d180236.

Nelly N, Hamid H, Yunisman, Pratama AS, Nawir W. 2020. The diversity of insects in West Sumatera's local rice by planting refugia as an effort to conserve natural enemies. IOP Conf Series Earth Environ Sci 497: 012032. DOI: 10.1088/1755-1315/497/1/012032.

Price PW, Bouton CE, Gross P, McPheron BA, Thompson JN, Weis AE. 1980. Interactions among three trophic levels: Influence of plants on interactions between insect herbivores and natural enemies. Ann Rev Ecol Syst 11: 41-65. DOI: 10.1146/annurev.es.11.110180.000353.

Romero-Alcaraz E, Avila JM. 2000. Effect of elevation and type of habitat on the abundance and diversity of Scarabaeoid dung beetle (Scarabaeoidea) assemblages in a Mediterranean area from Southern Iberian Penisula. Zool Stud 39 (4): 351-359.

Rosegrant MW, Ringer C, Sulser TB, Ewing M, Palazzo A, Zhu T, Nelson GC, Koo J, Robertson R, Siwa M, and Batka M. 2009. Agriculture and food security under global change: Prospect for 2025/2050. IFPRI, Washington DC.

Santos AP, Cabanas E, Pereira A. 2007. Abundance and diversity of soil arthropods in olive grove ecosystem (Portugal): effect of the pitfall trap type. Eur J Soil Biol 43: 77-83. DOI: 10.1016/j.ejsobi.2006.10.001.

Schowalter TD. 2000. Insect Ecology: An Ecosystem Approach. San Diego: Academic Press.

Shiferaw B, Prasanna BM, Hellin J, Banziger M. 2011. Past successes and future challenges to the role played by maize in global food security. Food Sec 3: 307-327. DOI: 10.1007/s12571-011-0140-5.

Sousa FF, Mendes SM, Santos A, Araújo OG, Oliveira EE, Pereira EJG. 2016. Life-history traits of *Spodoptera frugiperda* populations exposed to low-dose Bt maize. PLoS ONE 11(5): e0156608 DOI: 10.1371/journal.pone.015660

Speight MR, Hunter MD, Watt AD. 1999. Ecology of Insect: Concept and Application. Wiley-Blackwell, Hoboken. DOI: 10.1603/022.038.0448.

Sumini. 2016. Diversity of insect pests and natural enemies in rice plants applied bioinsecticide *Beauveria bassiana*. J Chlorophyll 11 (2): 85-88.

Truter J, Hamburg HV, Berg JVD. 2014. Comparative diversity of arthropods on Bt maize and non-Bt maize in two different cropping systems in South Africa. Environ Entomol 43 (1): 197-208. DOI: 10.1603/EN12177.

Yaherwandi, Syam U. 2007. Keanekaragaman biologi dan reproduksi parasitoid telur wereng coklat *Nillaparvata lugens* Stall. (Homoptera: Delphacidae) pada struktur lanskap pertanian berbeda. Jurnal Acta Agrosia 10: 76-86.