Inornatus: Biology Education Journal
Volume 3, Issue 1 (2023): 1 – 13
DOI: 10.30862/inornatus.v3i1.376

The diversity of insects in polyculture farms, Palangka Raya, Central Kalimantan, Indonesia

Rina Yanti, Nina Mauliani, Kiki Yulianingsih, Febry Claudia Ningsih, Muhammad Abrar Chaidir Adam*, Agus Haryono, Shanty Savitri

University of Palangka Raya, Indonesia
*Corresponding author, email: chaidir.adam@ppiig.upr.ac.id

Submitted: 19-11-2022

Accepted: 05-12-2022

Published: 01-01-2023

Abstract: Polyculture farming is an agricultural practice of growing several types of crops on the same land. The sustainability of polyculture farming is influenced by the presence of insects, both ecologically beneficial and detrimental. In agricultural ecology, insects have an important role as pollinators, predators, and pests that significantly affect the health of agricultural crops, including in polyculture farms. As an effort for sustainable polyculture management, especially in pest control, an exploratory study with mixed methods was conducted to determine the diversity, distribution, and categories of insects based on their ecological roles. This study was conducted in an agricultural area with a polyculture system in Palangka Raya, Central Kalimantan, Indonesia. A total of 12 insect species were identified from polyculture farms belonging to the orders Coleoptera, Diptera, Hemiptera, Lepidoptera, and Hymenoptera. The diversity of insects found in polyculture farming in this study was categorized into low diversity with a Shannon-Wiener index (H') of 2.186. Hemiptera is known to be the most abundant with 7 species identified. Based on the number of individuals, *Componotus japonicus* is the most abundant species with 9 individuals. The structure of the insect community based on their ecological role in polyculture farming consisted of 58.33% insect pests, 33.33% predatory insects, and 8.33% pollinating insects.

Keywords: Agricultural management, ecology, insects, peatlands, polyculture

Abstrak: Pertanian polikultur adalah praktik pertanian di mana beberapa jenis tanaman ditanam di lahan yang sama. Keberlanjutan pertanian polikultur juga dipengaruhi oleh keberadaan serangga, baik yang secara ekologis menguntungkan maupun merugikan. Dalam ekologi pertanian, serangga memiliki peran penting sebagai polinator, predator, dan hama yang secara signifikan berpengaruh terhadap kesehatan tanaman pertanian, termasuk di pertanian polikultur. Sebagai upaya pengelolaan pertanian polikultur berkelanjutan, khususnya dalam mengontrol hama, penelitian eksploratif dengan *mixed method* ini dilakukan untuk mengetahui keanekaragaman, sebaran, dan kategori serangga berdasarkan peran ekologisnya. Penelitian ini dilakukan di lahan pertanian dengan sistem polikultur di Palangka Raya, Kalimantan Tengah, Indonesia. Sebanyak 12 spesies serangga diidentifikasi dari pertanian polikultur yang termasuk dalam ordo Coleoptera, Diptera, Hemiptera, Lepidoptera, dan Hymenoptera. Keanekaragaman serangga yang ditemukan pada pertanian polikultur pada penelitian ini termasuk dalam keanekaragaman rendah dengan indeks Shannon-Wiener (H') sebesar 2,186. Hemiptera diketahui paling melimpah dengan 7 spesies yang teridentifikasi. Berdasarkan jumlah individunya, *Componotus japonicus* merupakan spesies yang paling melimpah dengan 9 individu. Struktur komunitas serangga berdasarkan peran ekologisnya di lahan pertanian polikultur terdiri dari 58,33% serangga hama, 33,33% serangga predator, dan 8,33% serangga pollinator.

Kata kunci: Manajemen pertanian, ekologi, serangga, lahan gambut, polikultur

INTRODUCTION

Polyculture farming is an agricultural practice of growing several types of crops on the same land. A polyculture is a form of alternative agricultural intensification program that is appropriate for obtaining optimal crop yields. The advantage of the polyculture cropping pattern is the frequency of harvesting more than once a year, maintaining soil fertility (Vandermeer, 1998; Weißhuhn et al., 2017), and providing year-round ground cover thereby reducing erosion rates (Prasetyo et al., 2009). The polyculture system is a cropping pattern that can support sustainable agriculture because a variety of crops are planted on the same land and at the same time can increase land efficiency and productivity.

The sustainability of polyculture farming is influenced by the presence of insects, both ecologically beneficial and detrimental. In agricultural ecology, insects have an important role as pollinators, predators, and pests that significantly affect the health of agricultural crops, including in polyculture. According to Warman and Kristiana (2018), factors that influence the success of the polyculture cropping pattern are spacing, selection of varieties, and the presence of insects. Insect pests are one of the factors that cause less than optimal yields. They significantly damage agricultural products intended for human food and animal feed. In addition, these biotic agents cause indirect damage by leaving contaminants such as body or exoskeleton fragments, eggs, and bad odors in the product (García-Lara & Saldivar, 2016; Keshavareddy & Kumar, 2016; Mylonas et al., 2020).

About 20-30 out of a total of more than six million insect species are important pests for major agricultural crops (García-Lara & Saldivar, 2016). The presence of insect pests that damage agricultural production forces farmers to apply pesticides excessively by ignoring beneficial insects on agricultural land (Hidrayani et al., 2014). Understanding the biology and behavior of insect pests and the types of damage they cause is key to proper insect pest management for sustainable agriculture (García-Lara & Saldivar, 2016; Hagstrum & Subramanyam, 2006).

Most of the land in Palangka Raya, Central Kalimantan, Indonesia, is peatland which is less than ideal for agricultural land, so farmers need to convert the land to make it suitable for planting. The polyculture system is the choice of farmers in this area to overcome the excessive conversion of peatlands (Melhanah et al., 2020), considering the importance of peatlands as the largest carbon storage for the ecosystem (Beaulne et al., 2021; Cobb et al., 2020; Dunn & Freeman, 2011). Preliminary exploration indicated the presence of various insect species on plants in polyculture farms in Palangka Raya, Central Kalimantan, Indonesia, some of which were suspected to be insect pests due to some damage to the crop parts in the presence of these insects. Mahmood-ur-Rahman et al. (2014) stated that the presence of insect pests is the main source of biotic stress on crops. This is a challenge in managing sustainable agricultural land with a polyculture system.

As an effort for sustainable polyculture management in Palangka Raya, Central Kalimantan, Indonesia, especially in controlling pests, an exploratory study with mixed methods was conducted to determine the diversity, distribution, and categories of insects based on their ecological roles.

METHOD

Study site and sample collection

This study is an exploratory study with mixed methods that combines and integrates qualitative and quantitative approaches to collect and analyze data related to insect community structure in polyculture farms. This study was conducted on a polyculture farm in Palangka Raya, Central Kalimantan, Indonesia, which was planted with 3 crop types, namely Maize (*Zea mays*), Asparagus Bean (*Vigna unguiculata* ssp. *sesquipedalis*), and Eggplant (*Solanum melongena*) (Figure 1). Insect samples were collected by active sampling method directly from crops in polyculture farms, then stored in sample bottles filled with alcohol.

Figure 1. Study site: Polyculture farms, Palangka Raya, Central Kalimantan, Indonesia (Map Source: QGis

Insect identification

Insect specimens collected were then observed for their morphological characteristics. The results of observations are used as the basis for the taxonomic identification of insect species. Several previously published works are used as a guide at the identification stage, e.g., Borror & DeLong (1971) and Borror & White (1998). The parameters used in observing the morphological characteristics of insect specimens are the head, antennae, wings, legs, body color, and size of insects (Table 1).

Table 1. Morphological characteristics observation parameters

No.	Morphological Characteristic Parameters	Descriptions
1	Head	texture, head type, and mouth type
2	Antennae	antenna segment and type
3	Wings	color, texture, and shape
4	Legs	number of segments and types of limbs
5	Body Coloration	Coloration patterns of the insect body
6	Size	Body Length

Data analysis

The data analysis method used in this study includes qualitative and quantitative analysis. Qualitative analysis was carried out on the results of the morphological observation to describe the characteristics of each insect specimen. Quantitative analysis was carried out on the data of the number of species and individuals to determine the level of insect diversity using the following formula of the Shannon-Wiener Diversity Index (H'):

$$H' = -\sum_{i=1}^{s} p_i ln\, p_i \quad (1)$$

(Ortiz-Burgos, 2016)

Annotation(s):
H' = Shannon-Wiener Diversity Index
s = Number of Species
pi = proportion of individuals belonging to the i^{th} species
ln = Natural Logarithm

Table 2. Classification scheme of Shannon-Wiener diversity index

No.	H'	Relative Value
1	> 3.50	Very High
2	3.00 – 3.49	High
3	2.50 – 2.99	Moderate
4	2.00 – 2.49	Low
5	< 1.99	Very Low

RESULTS AND DISCUSSION

1. Species composition and diversity

A total of 12 insect species were identified from polyculture farms belonging to the orders Coleoptera, Diptera, Hemiptera, Lepidoptera, and Hymenoptera as presented in

Figure 2, and Figure 3. Hemiptera is known to be the most abundant with 7 species identified. Based on the number of individuals, *Componotus japonicus* (Formicidae, Hymenoptera) is the most abundant species with 9 individuals followed by *Brachyplatys subaeneus* (Plataspidae, Hemiptera) with 8 individuals.

Componotus japonicus is an ant species in the family Formicidae, commonly known as the Japanese carpenter ant. *C. japonicus* lives in monogynous or polygynous colonies with a large number of individuals consisting of about 3000 worker ants (Akre et al., 1994; Changlu et al., 1991). *The worker ants of C. japonicus* are found in symbiosis with aphids on crops in polyculture farms to collect honeydew (Guénard & Dunn, 2012). This behavior of forming large colonies and foraging behavior is thought to be the main factor influencing *C. japonicus* to become the most abundant species. Insect species that occur with low abundance were also observed in this study consisting of only one individual consisting of 3 species belonging to the order Hemiptera (e.g., *Bothrogonia addita, Cosmolestes picticeps,* and *Euthochtha galeator)* and 1 species belonging to the order Coleoptera (*Harmonia axyridis*).

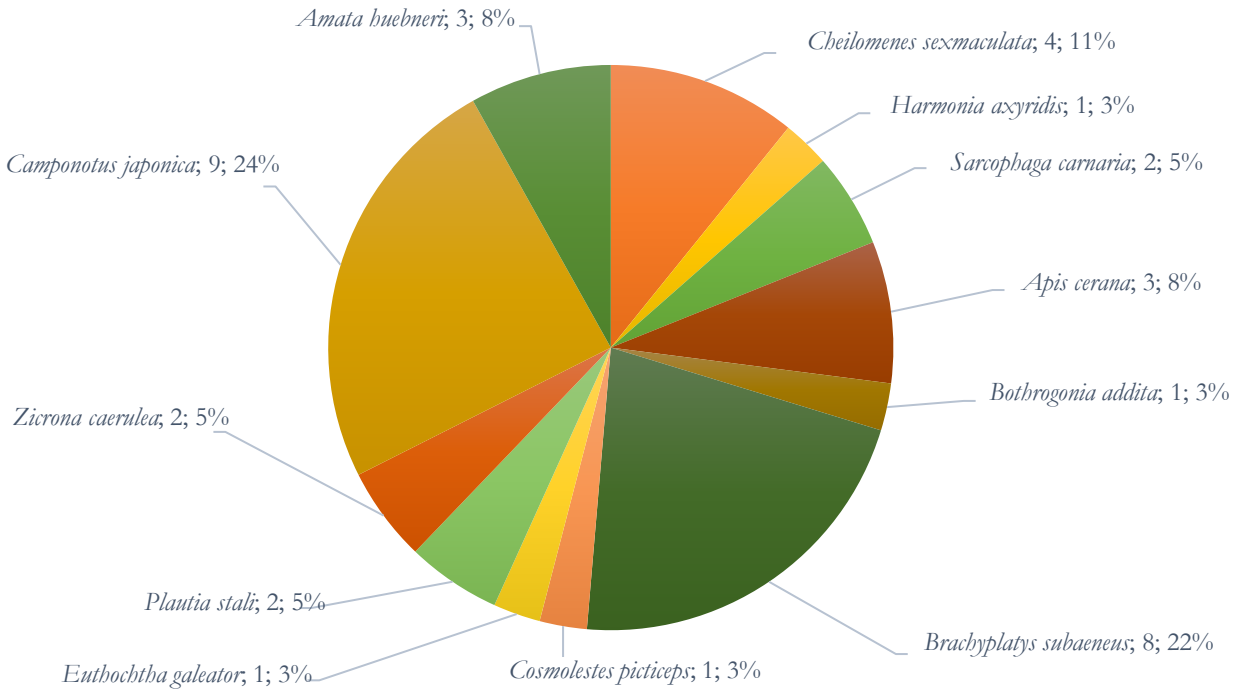

Figure 2. Insect Species Composition of Polyculture Farms

Figure 3. (a) *Bothrogonia addita*; (b) *Plautia stali*; (c) *Brachyplatys subaeneus*; (d) *Cosmolestes picticeps*; (e) *Euthochtha galeator*; (f) *Componotus japonica*; (g) *Cheilomenes sexmaculata*; (h) *Harmonia axyridis*; (i) *Amata huebneri*; (j) *Apis cerana* ; (k) *Sarcophaga carnaria*; (l) *Zicrona caerulea*

Insect diversity found in polyculture farming in this study was categorized into low diversity with a Shannon-Wiener index (H') of 2.186 (Table 3). The low level of insect diversity is influenced by the number of crop types grown in polyculture farming which only consists of 3 types, namely Maize (*Zea mays*), Asparagus Bean (*Vigna unguiculata* ssp. *sesquipedalis*), and Eggplant (*Solanum melongena*). Several published studies indicate that insect diversity (including species richness and abundance) is strongly influenced by vegetation composition and floral abundance (Yeo et al., 2021; Zurbrügg & Frank, 2006). Plant diversity is a good predictor of insect diversity in most habitats (Yeo et al., 2021).

Table 3. Shannon-Wiener diversity index analysis results

No	Species	Ordo	N	pi	ln pi	ABS (pi ln pi)
1	*Amata huebneri*	Lepidoptera	3	0.081	-2.512	0,204
2	*Apis cerana*	Hemiptera	3	0.081	-2.512	0,204
3	*Bothrogonia addita*	Hemiptera	1	0.027	-3.611	0,098
4	*Brachyplatys subaeneus*	Hemiptera	8	0.216	-1.531	0,331
5	*Camponotus japonicus*	Hymenoptera	9	0.243	-1.414	0,344
6	*Cheilomenes sexmaculata*	Coleoptera	4	0.108	-2.225	0,240
7	*Cosmolestes picticeps*	Hemiptera	1	0.027	-3.611	0,098
8	*Euthochtha galeator*	Hemiptera	1	0.027	-3.611	0,098
9	*Harmonia axyridis*	Coleoptera	1	0.027	-3.611	0,098
10	*Plautia stali*	Hemiptera	2	0.054	-2.918	0,158
11	*Sarcophaga carnaria*	Diptera	2	0.054	-2.918	0,158
12	*Zicrona caerulea*	Hemiptera	2	0.054	-2.918	0,158
	Total		37	1	-33.391	**H' = 2.186**

Annotation: ABS = Absolute Value

2. Distribution

All insect species identified in this study were distributed unevenly on each crop type in polyculture farms. The highest number of insect species was found in asparagus bean (*Vigna unguiculata* ssp. *sesquipedalis*) with 7 species followed by maize (*Zea mays*) with 6 species, and eggplant (*Solanum melongena*) with 2 species. Maize and asparagus bean have 3 overlapping species consist of *Bothrogonia addita, Cosmolestes picticeps,* and *Apis cerana.* In addition, unique species found maize and asparagus bean were 3 species (e.g., *Sarcophaga carnaria, Cheilomenes sexmaculata,* and *Amata huebneri*). and 4 species (e.g., *Brachyplatys subaeneus*, *Harmonia axyridis, Zicrona caerulea,* and *Camponotus japonicus*) respectively. Only 2 species were distributed in eggplant, namely *Plautia stali* and *Euthochtha galeator.*

As previously mentioned, the presence of insects is strongly influenced by the composition of the vegetation (Yeo et al., 2021; Zurbrügg & Frank, 2006). In natural habitats with changing host plant availability and quality, herbivorous insects are under selection pressure to find quality hosts (Bruce, 2015). This circumstance is one of the factors in the uneven distribution of insects on each type of plant in polyculture farms.

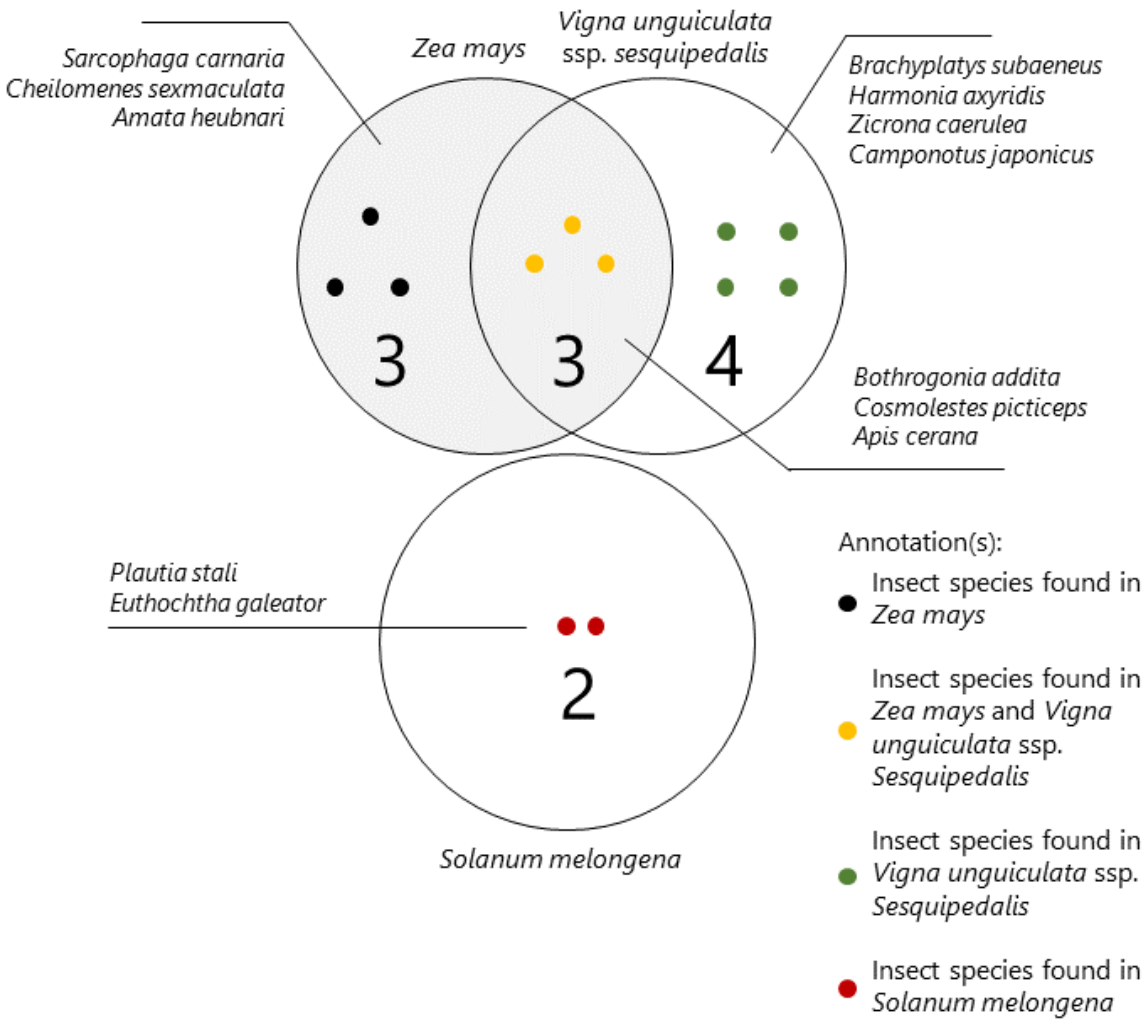

Figure 4. Venn diagram of insect species distribution on each crop type in polyculture farms

3. Insect categories based on their ecological roles

Insect species found in this study were classified into three categories based on their ecological roles. The three categories are pest, predator, and pollinator. About 58.33% of the insects found in this study were insect pests consisting of *Bothrognia addita, Amata huebneri, Sarcophaga carnaria, Plautia stali, Brachyplatys subaeneus, Camponotus japanicus*, and *Euthochtha galeator*. Damage to polyculture agricultural crops in this study due to the presence of insect pests was mainly observed in almost all parts of the organs, e.g., leaves, fruits, and flowers. Foliage-eating insects cause severe leaf tearing in maize plants (Figure 5a). In this study, traces of leaf-miner were also observed on Asparagus Bean leaves (Figure 5d). Some types of damage are more important than others depending on the part of the plant damaged and the part harvested (Hill, 2008). Damage to the parts harvested in this study was observed in eggplants damaged by insect pests (Figure 5c).

Insects considered as predators consisted of 4 species (33.33%), e.g., *Cheilomenes sexmaculata, Harmonia axyridis, Zicrona caerulea,* and *Cosmolestes picticeps*. These predatory insects prey on smaller insects. *C. sexmaculata* and *H. axyridis* are known as natural predators of small

insects from the Aphididae such as *Macrosiphoniella sanborni* and *Myzus persicae* (Endarto & Wuryantini, 2019; Tobing & Nasution, 2007). *Zicrona caerulea* (Blue Shield Bug) is known for its predatory activity on flea beetles of the genus *Altica*. *Z. caerulea* uses cuticular hydrocarbons to identify prey (Xue et al., 2018). *Cosmolestes picticeps* or Yellow Assassin Bug is known as a predatory insect that has an important role in the biological control of herbivorous pests in plantations (Jamian et al., 2017; Nazilah et al., 2020).

Apis cerana (Honey Bee) is the only insect species found in this study that categorized as a pollinator. This bee species is already known as an excellent pollinator for various agricultural crops (Gurmani et al., 2016; Putra et al., 2014; Stanley et al., 2017; Udayani et al., 2020). Honey bees have high pollination efficiency, are generally bred by local bee farmers, and have a wider foraging area making them ideal insect pollinators (Putra et al., 2014).

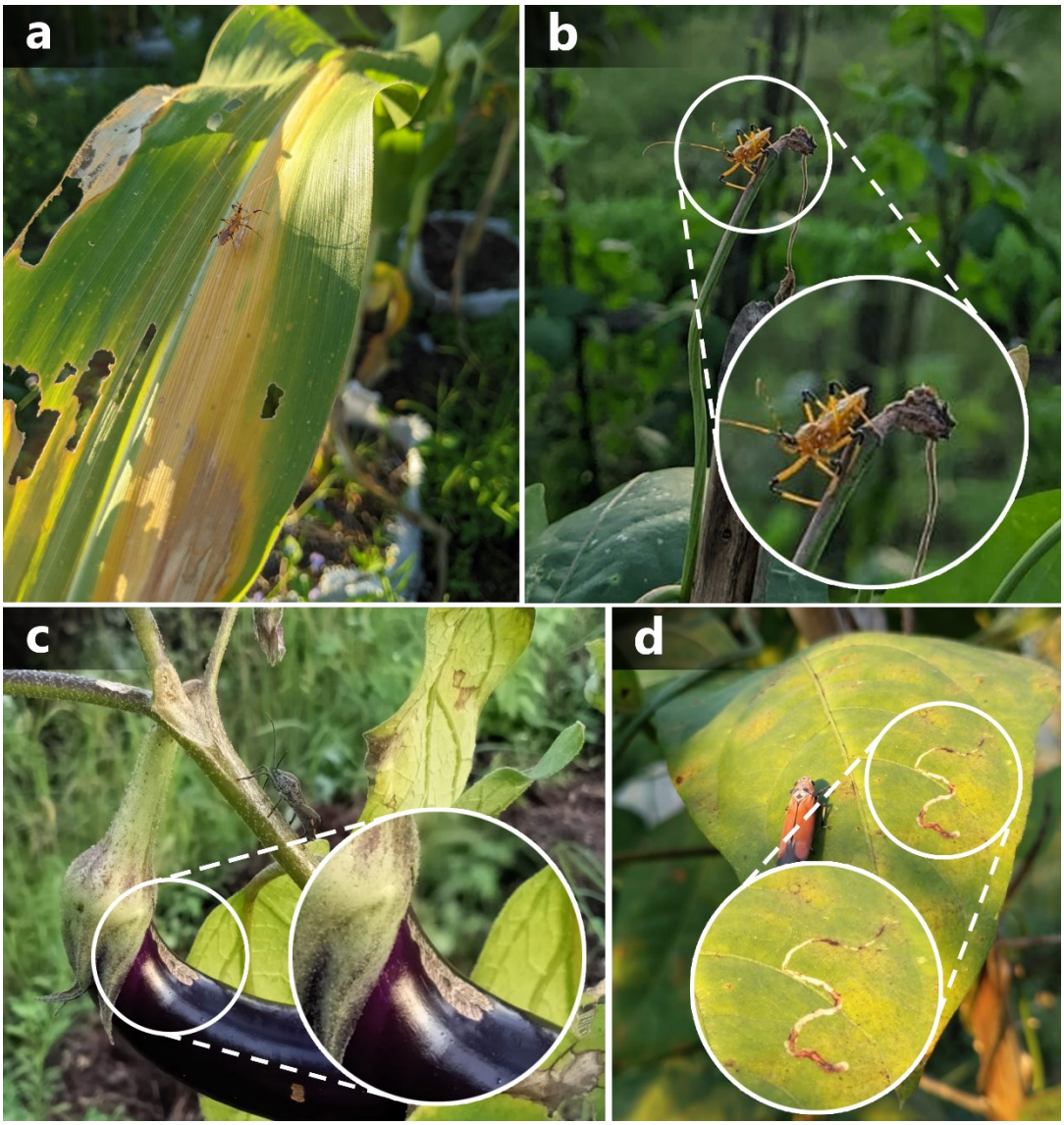

Figure 5. Crop damage by insect pests: (a) Maize (*Zea mays* L.) leaf torn; (b) asparagus bean (*Vigna unguiculata ssp. sesquipedalis*) flower damage; (c) Eggplant (*Solanum melongena*) fruit damage; and (d) traces of leaf miner on asparagus bean leaves

CONCLUSION

A total of 12 insect species were identified from polyculture farms belonging to the orders Coleoptera, Diptera, Hemiptera, Lepidoptera, and Hymenoptera. The diversity of insects found in polyculture farming in this study was categorized into low diversity with a Shannon-Wiener index (H') of 2.186. Hemiptera is known to be the most abundant with 7 species identified. Based on the number of individuals, *Componotus japonicus* (Formicidae, Hymenoptera) is the most abundant species with 9 individuals The structure of the insect community based on their ecological role in polyculture farming consisted of 58.33% insect pests, 33.33% predatory insects, and 8.33% pollinating insects.

REFERENCES

Akre, R. D., Hansen, L. D., & Myhre, E. A. (1994). Colony size and polygyny in carpenter ants (Hymenoptera: Formicidae). *Journal of the Kansas Entomological Society*, *67*(1), 1–9. http://www.jstor.org/stable/25085485

Beaulne, J., Garneau, M., Magnan, G., & Boucher, É. (2021). Peat deposits store more carbon than trees in forested peatlands of the boreal biome. *Scientific Reports*, *11*(1), 2657. https://doi.org/10.1038/s41598-021-82004-x

Borror, D. J., & DeLong, D. M. (1971). *An introduction to the study of insects*. (Issue Ed. 3). Rinehart & Winston.

Borror, D. J., & White, R. E. (1998). *A field guide to insects: America north of Mexico* (Vol. 19). Houghton Mifflin Harcourt.

Bruce, T. J. A. (2015). Interplay between insects and plants: dynamic and complex interactions that have coevolved over millions of years but act in milliseconds. *Journal of Experimental Botany*, *66*(2), 455–465. https://doi.org/10.1093/jxb/eru391

Changlu, W., Jian, W., & Gangrou, X. (1991). A study on the bionomics and predatory effect of *Camponotus japonicus* to *Dendrolimus punctatus*. *Forest Research*, *4*(4), 405–408. http://lykxyj.xml-journal.net//article/id/19910410

Cobb, A. R., Dommain, R., Tan, F., Hwee En Heng, N., & Harvey, C. F. (2020). Carbon storage capacity of tropical peatlands in natural and artificial drainage networks. *Environmental Research Letters*, *15*(11), 114009. https://doi.org/10.1088/1748-9326/aba867

Dunn, C., & Freeman, C. (2011). Peatlands: our greatest source of carbon credits? *Carbon Management*, *2*(3), 289–301. https://doi.org/10.4155/cmt.11.23

Endarto, O., & Wuryantini, S. (2019). Daya mangsa predator *Harmonia axyridis* terhadap kutu daun *Mizus persicae* pada tanaman jeruk. *Jurnal Agronida*, *5*(2 SE-Articles). https://doi.org/10.30997/jag.v5i2.2311

García-Lara, S., & Saldivar, S. O. S. (2016). *Insect Pests* (B. Caballero, P. M. Finglas, & F. B. T.-E. of F. and H. Toldrá (Eds.); pp. 432–436). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-384947-2.00396-2

Guénard, B., & Dunn, R. R. (2012). A checklist of the ants of China. In *Zootaxa* (Vol. 77, Issue 3558). https://doi.org/10.11646/zootaxa.3558.1.1

Gurmani, H. T. W., Jaleel, W., Saeed, S., Gurmani, A. R., Saeed, Q., Naqqash, M. N., Ghouri, F., Munawar, M. S., Sial, M. U., Rahman, S., & Aine, Q. U. (2016). The pollination potential of Apis cerana Feb., Apis mellifera L. (Hymenoptera; Apidae) on yield of apricot (Prunus armeniaca). *PeerJ Preprints 4:E2396v1*. https://doi.org/https://doi.org/10.7287/peerj.preprints.2396v1

Hagstrum, D. W., & Subramanyam, B. (2006). Introduction to Part I: Ecology and Decision Aids. In D. W. Hagstrum & B. B. T.-F. of S.-P. E. Subramanyam (Eds.), *American Associate of Cereal Chemists International* (p. 1). AACC International Press. https://doi.org/https://doi.org/10.1016/B978-1-891127-50-2.50005-3

Hidrayani, H., Rusli, R., & Lubis, Y. S. (2014). Keanekaragaman Spesies Parasitoid Telur Hama Lepidoptera dan Parasitisasinya pada Beberapa Tanaman di Kabupaten Solok, Sumatera Barat. *Jurnal Natur Indonesia*, *15*(1), 9. https://doi.org/10.31258/jnat.15.1.9-14

Hill, D. S. (Ed.). (2008). *Pest damage to crop plants BT - Pests of Crops in Warmer Climates and Their Control* (pp. 59–80). Springer Netherlands. https://doi.org/10.1007/978-1-4020-6738-9_5

Jamian, S., Norhisham, A., Ghazali, A., Zakaria, A., & Azhar, B. (2017). Impacts of 2 species of predatory Reduviidae on bagworms in oil palm plantations. *Insect Science*, *24*(2), 285–294.

Keshavareddy, G., & Kumar, A. R. V. (2016). *Chapter 14 - Bacillus thuringiensis* (B. T.-E. P. M. for F. S. Omkar (Ed.); pp. 443–473). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-803265-7.00014-2

Mahmood-ur-Rahman, Qasim, M., Bukhari, S. A., & Shaheen, T. (2014). *Chapter 6 - Bt Crops: A Sustainable Approach towards Biotic Stress Tolerance* (P. Ahmad & S. B. T.-E. T. and M. of C. S. T. Rasool (Eds.); pp. 125–142). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-800876-8.00006-0

Melhanah, M., Supriati, L., & Saraswati, D. (2020). Struktur komunitas arthropoda nokturnal pada jagung manis dan kacang panjang organik dan konvensional di lahan gambut. *Daun: Jurnal Ilmiah Pertanian Dan Kehutanan*, *7*, 11–22. https://doi.org/10.33084/daun.v7i1.1603

Mylonas, I., Stavrakoudis, D., Katsantonis, D., & Korpetis, E. (2020). *Chapter 1 - Better farming practices to combat climate change* (M. Ozturk & A. B. T.-C. C. and F. S. with E. on W. Gul (Eds.); pp. 1–29). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-12-819527-7.00001-7

Nazilah, H., Sahari, B., Prabowo, R., & Buchori, D. (2020). Effect of cattle integration on the diversity of predatory Reduviidae in oil palm plantation, Central Kalimantan,

Indonesia. *IOP Conference Series: Earth and Environmental Science*, *468*(1), 12004. https://doi.org/10.1088/1755-1315/468/1/012004

Ortiz-Burgos, S. (2016). *Shannon-Weaver Diversity Index BT - Encyclopedia of Estuaries* (M. J. Kennish (Ed.); pp. 572–573). Springer Netherlands. https://doi.org/10.1007/978-94-017-8801-4_233

Prasetyo, Sukardjo, E. I., & Pujiwati, H. (2009). Produktivitas lahan dan NKL pada tumpang sari jarak pagar dengan tanaman pangan (Land productivity and land equivalent ratio at intercropping jatropha with annual crop). *Jurnal Akta Agrosia*, *12*(1), 51–55.

Putra, R. E., Permana, A. D., & Kinasih, I. (2014). Application of asiatic honey bees (*Apis cerana*) and stingless bees (*Trigona laeviceps*) as pollinator agents of hot pepper (*Capsicum annuum* L.) at Local Indonesia Farm System. *Psyche*, *2014*, 687979. https://doi.org/10.1155/2014/687979

Stanley, J., Sah, K., & Subbanna, A. R. N. S. (2017). How efficient is the Asian honey bee, Apis cerana in pollinating mustard, Brassica campestris var. toria? Pollination behavior, pollinator efficiency, pollinator requirements and impact of pollination. *Journal of Apicultural Research*, *56*(4), 439–451. https://doi.org/10.1080/00218839.2017.1329796

Tobing, M. C., & Nasution, D. B. (2007). Biologi predator *Cheilomenes sexmaculata* (Fabr.) (Coleoptera: Coccinellidae) pada kutu daun *Macrosiphoniela sanborni* Gilette (Homoptera: Aphididae). *Agritrop*, *26*(3). https://ojs.unud.ac.id/index.php/agritrop/article/view/3065

Udayani, I. G. A. P. I., Watiniasih, N. L., & Ginantra, I. K. (2020). Honey bee (*Apis cerana* F.) As Polinator Agent on Eggplants (Solanum melongena L.) at local farming system in Bali. *Metamorfosa: Journal of Biological Sciences*, *7*(2), 159–162. https://doi.org/10.24843/metamorfosa.2020.v07.i02.p03

Vandermeer, J. (1998). Maximizing crop yield in alley crops. *Agroforestry Systems*, *40*(2), 199–206. https://doi.org/10.1023/A:1006072303989

Warman, G. R., & Kristiana, R. (2018). Mengkaji sistem tanam tumpangsari tanaman semusim. *Proceeding Biology Education Conference*, *15*(1), 791–794. https://jurnal.uns.ac.id/prosbi/article/view/33354/21968

Weißhuhn, P., Reckling, M., Stachow, U., & Wiggering, H. (2017). Supporting agricultural ecosystem services through the integration of perennial polycultures into crop rotations. *Sustainability*, *9*(12), 2267. https://doi.org/10.3390/su9122267

Xue, H.-J., Wei, J., Huang, Z.-Z., Li, W.-Z., & Yang, X.-K. (2018). Your chemical coat tells me you are my delicacy: a predatory stink bug uses cuticular hydrocarbons to identify prey. *Chemoecology*, *28*(2), 69–73.

Yeo, D., Srivathsan, A., Puniamoorthy, J., Maosheng, F., Grootaert, P., Chan, L., Guénard, B., Damken, C., Wahab, R. A., Yuchen, A., & Meier, R. (2021). Mangroves are an

overlooked hotspot of insect diversity despite low plant diversity. *BMC Biology*, *19*(1), 202. https://doi.org/10.1186/s12915-021-01088-z

Zurbrügg, C., & Frank, T. (2006). Factors influencing bug diversity (Insecta: Heteroptera) in semi-natural Habitats. *Biodiversity & Conservation*, *15*(1), 275–294. https://doi.org/10.1007/s10531-004-8231-7