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The diversity and ecological roles of insects and arachnids in arabica coffee (*Coffea arabica*) plantation in Palasari, Bandung Regency

Keanekaragaman dan fungsi ekologis serangga dan arachnid pada ekosistem kopi arabika (*Coffea arabica*) di Palasari, Kabupaten Bandung

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ABSTRACT

The diversity of arthropod communities is often used as a bioindicator of environmental changes, specifically in coffee farms with various management systems. Significant impacts of the environmental changes lead to alterations in the community structure and function of arthropods. The aim of this research was to determine the diversity and ecological roles of insect and arachnids in arabica coffee plantations in Bandung Regency. Sampling was conducted on five plots measuring 100 m^2 each, with a separating distance of 50 m, in coffee farms located in Legok Nyenang Village, Bandung Regency. This was performed five times per weekly intervals using sweep nets, yellow tray traps, and beating sheets. Subsequently, collected samples were identified based on morphological characters at the Pest Laboratory, Faculty of Agriculture, Padjadjaran University. A total of 269 insects species (11 orders and 98 families, total 669 individuals) and 23 species of Arachnida (one order and 13 families, total 44 individuals) were found, The most abundance of natural enemies were the parasitoid, *Megacampsomeris prismatica* (Hymenoptera: Scoliidae) and the predator, *Tetragnatha* sp. (Araneae: Tetragnathidae). Meanwhile, the ecological function of the group with the lowest number was pollinators (Hymenoptera: Apidae). Although the diversity of insects and arachnids species found in coffee farms was high (H' = 5.10), the evenness and dominance index were relatively low. These results showed the potential of coffee plantations as ecosystems for conserving predatory arthropods biodiversity. Consequently, coffee cultivation practices and pest management strategies must prioritize the protection of beneficial insects such as natural enemies and pollinators.

Key words: intercropping, landscape, natural enemies, pest, pollinator

ABSTRAK

Keanekaragaman komunitas artropoda dapat dijadikan sebagai bioindikator perubahan lingkungan khususnya pada sistem budi daya kopi dengan sistem pengelolaan yang beragam. Sistem pengelolaan lahan yang beragam akan menimbulkan perubahan struktur komunitas dan fungsi ekologis artropoda.

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Tujuan dari penelitian ini untuk menganalisis keanekaragaman dan peranan serangga dan Arachnida pada perkebunan kopi Arabika di Kabupaten Bandung. Sampel diambil dari perkebunan kopi di Desa Legok Nyenang, Kabupaten Bandung dengan menetapkan lima plot sampel berukuran 100 m^2 per plot dengan jarak antar plot sejauh 50 m. Serangga dan Arachnida terestrial diambil menggunakan jaring ayun, perangkap nampan kuning, dan *beating sheet.* Sampel yang diperoleh diidentifikasi berdasarkan karakter morfologi hingga tingkat morfospesies. Sebanyak 269 jenis serangga (11 ordo dan 98 famili, total 669 individu) dan 23 jenis Aachnida (satu ordo dan 13 famili, total 44 individu) berhasil dikumpulkan dari perkebunan kopi Arabika Palasari. Peran ekologi yang paling beragam adalah fitofag. Spesies fitofag yang dominan adalah *Nysius* sp. (Hemiptera: Lygaeidae). Musuh alami yang dominan, yaitu parasitoid *Megacampsomeris prismatica* (Hymenoptera: Scoliidae) dan predator, *Tetragnatha* sp. (Araneae: Tetragnathidae), sedangkan fungsi ekologis yang jumlahnya paling rendah adalah serangga penyerbuk (Hymenoptera: Apidae). Keanekaragaman jenis serangga dan Arachnida yang ditemukan pada pertanaman kopi di Kabupaten Bandung termasuk dalam kategori tinggi (H' = 5,10), meskipun indeks kemerataan dan dominansinya tergolong rendah. Hasil penelitian ini menunjukkan bahwa pertanaman kopi merupakan ekosistem yang potensial bagi konservasi keanekaragaman hayati serangga dan Arachnida predator sehingga praktik budi daya dan pengelolaan hama harus diarahkan untuk melindungi serangga menguntungkan, seperti musuh alami dan polinator.

Kata kunci: hama, konservasi, lanskap, musuh alami, penyerbuk

INTRODUCTION

Arabica coffee (*Coffee arabica*) is among the most preferred varieties cultivated worldwide, including in West Java. Indonesia ranks as the fourth country with the largest coffee production (ICO 2021), and the increasing demand for arabica coffee has led to an expanded area of plantations in Bandung district (BPS 2022). Most coffee plantations in West Java are community-owned, with three types of cultivation systems comprising monoculture, horticultural intercropping, and agroforestry.

In 2020–2022, coffee production in Indonesia declined significantly (BPS 2023) due to climate change, which shortened the life cycle of pests, resulting in rapid population growth as well as horizontal and vertical expansion of distribution ranges. To combat pest challenges, farmers commonly use chemical pesticides, but the intensive application can kill non-target insects such as parasitoids, predators, and pollinators. The death of these beneficial insects disrupts the ecological balance in the coffee ecosystems, leading to an increase in the population of pests (Merhi et al. 2022).

Members of the arthropods phylum, particularly insects, and predatory arachnids, play important roles in ecosystems. The species diversity and functional complexity of insects are influenced by landuse forms or types. Heterogeneous or complex landscape types feature high species diversity (Karp et al. 2013; Vandermeer & Perfecto 2010). This phenomenon is evident when comparing arthropod abundance in agroforestry systems with monoculture or open-land intercropping scenarios (Pumariño et al. 2015; Rosati et al. 2021). However, ecosystems subjected to high input management and intensive use of pesticides tend to experience diminished biodiversity (Cerda et al. 2017; Wei et al. 2018).

The coffee plantation in Palasari used as the research site is intensively managed. Meanwhile, intensive land management practices influence pest infestation rates and the abundance of natural enemies, specifically in peripheral areas or land adjacent to agroforestry (Pumariño et al. 2015; Schroth et al. 2000). Immense adoption of intensive management systems in large coffee plantations (Zewdie et al. 2020) tends to reduce spatial heterogeneity and biodiversity (Geeraert et al. 2019; Steffan-Dewenter et al. 2007).

The presence of beneficial insects is significantly influenced by management level, with natural enemies such as predators and parasitoids being more abundant in poorly managed systems (Diehl et al. 2013; Martin et al. 2013; Rusch et al. 2010; Jonsson et al. 2015; Medeiros et al. 2019; Whitehouse et al. 2018). The abundance of natural enemies residing in intensively managed sites is directly and indirectly affected by several cultivation mechanisms, including pesticide application, microclimatic conditions, as well as the absence of nectar-producing crops and alternative hosts (Medeiros et al. 2019; Tscharntke et al. 2007). Therefore, it is necessary to understand and monitor pest management practices along with the local environment in supporting coffee production sustainability (Escobar-Ramírez et al. 2019).

Based on the contexts described, there is a need to monitor insects and other arthropods present in the coffee ecosystems. The diversity and abundance status of insects reflect the health of the local environment, which is essential for determining the land management level in the area. Therefore, this research aimed to investigate the diversity and ecological roles of insects and arachnids in the arabica coffee ecosystems in Palasari, Bandung Regency. The results will serve as a basis for policy formulation regarding land management and environmental preservation to support sustainable coffee production.

MATERIAL AND METHOD

Sampling site

Insects and arachnids were collected from a coffee plantations in Legok Nyenang Village, Cimenyan District, Bandung Regency (6°52’00.1” S, 107°42’40.9” E) with an observation area of 10,000 m^2. These were located at an altitude of 1268.76 m above sea level (m asl) and approximately 500 m from the edge of an industrial plants forest (pine and clove). Furthermore, the types of coffee plantations used had an intercropping system comprising horticultural crops including chili, mustard, tomatoes, onions, and bananas, along with food crops, such as maize, while the observation plot was on open land without shade.

Samplings

Samples were collected diagonally from five plots measuring 10 m x 10 m, with a separating distance of 50 m, using three methods including insect netting, yellow pan traps (Ø 30 cm), and beating sheets (40 cm x 40 cm) positioned below coffee tree canopies. These were collected from each observation plot through the process performed with 10 single insect net swings, 5 yellow pan traps, and 5 beating sheets. The yellow pan traps are placed according to the diagonal line on the sampling plot. Samplings was conducted in the morning between 07.00–11.00. Samplings were persisted for five weeks spanning from July to September 2023. The insects and arachnids obtained from each observation plot were preserved in 50 ml plastic tubes containing 70% ethanol for further processing. Climate data was sourced from BMKG Bandung Regency.

Sample sorting and identification

Samples were grouped per week of observation and subsequently sorted for identification performed based on morphological characters to distinguish between taxa. The identification process used several related literature sources such as An Introduction to The Study of Insect Sixth Edition (Borror et al. 1996), Insect of Australia (Lawrence & Britton 2000), Hymenoptera of The World: An Identification Guide to Families (Goulet & Huber 1993), journals, and websites presenting insect identification keys.

Selected arthropod samples were stored in 5 ml tubes to identify the genus and morphospecies level through observation using an Olympus SZ61 microscope. The entire series of identification and documentation processes was conducted in the Pest Laboratory of the Entomology Division, Faculty of Agriculture, Universitas Padjadjaran.

Data analysis

Insects and arachnids data collected were analyzed to assess species diversity, evenness, and dominance. The calculation of species diversity, evenness, and dominance index was performed based on the Shannon-Wiener (H’), Pielou (E), and Simpson (D) indexs using the following formula.

Diversity index (H’)

$$H' = -\sum_{i=1}^{s} Pi \ln Pi \text{ , in which}$$

H': species diversity; S: the number of species; Pi: the ratio of the number of individuals of the i-th species of total number of individuals of the entire species. The H’ diversity index is grouped into three catagorized, low: H’ < 1; moderate: 1 ≤ H’ ≤ 3; and high: H’ > 3.

Evenness index (E)

$$E = \frac{H'}{\ln(S)} \text{ , in which}$$

H': Shannon’s diversity index; S: the number of species. Range of evenness index values: E approaching 0 indicates that the spread of individuals between types is uneven; E approaching 1 indicates that the distribution of individuals of inter-species is flattening.

Dominance index

$$D = \sum_{i=1}^{s} (\frac{ni}{N})^2 \text{ , in which}$$

D: Simpson's dominance index; *ni*: number of individuals of i^{th} species; *N*: number of individuals of the entire species. Dominance indicators range from 0 to 1, with values closer to 1 signifying the dominance of a particular species.

RESULT

Abundance of insects and arachnids in coffee ecosystems

The identification results showed that in the explored coffee plantation, the Insecta was much more abundant than the Arachnida. A total of 757 individuals of arthropods, consisted of 669 individuals of insects (94%) and 44 individuals of spiders (6%) were collected from the field. The insects found consisted of 269 species (11 orders and 98 families) while the spiders consisted of 23 species (one order and 13 families). In the Insecta class, the Hymenoptera order was the most abundant (204 individuals = 29%), followed by the Hemiptera (165 individuals = 23%), and Diptera order (164 individuals = 23%). Furthermore, the lower number of individuals (3) was found in the Mantodea, Dermaptera, and Psocoptera order, as presented in Figure 2. Insect abundance in the field fluctuated during the observation period, with the highest population (213 individuals) occurring in second observation (30 July 2023) and tending to decrease until the last observation (20 August 2023) (Figure 3). This suggested that as the intensity of rainfall increased, the number of insects would decrease.

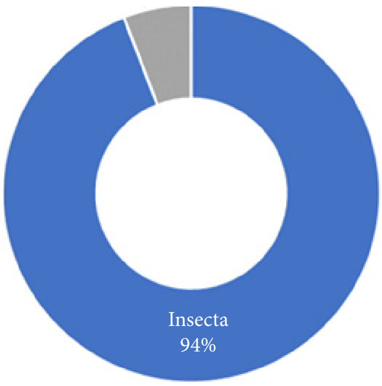

Figure 1. Proportion of insects and arachnids abundance in coffee ecosystems.

Species diversity and composition of insects and arachnids in coffee ecosystems

The diversity of insects and arachnids in the arabica coffee ecosystems in Palasari was high (H' = 5.10). The high abundance of a species does not mean that the species is dominant in the local ecosystem. This is proven by the evenness and dominance index values which were relatively low. In general, the distribution of insects and arachnids species in the coffee ecosystems was uneven with an evenness index value of 0.37, while dominance was low with a value of 0.02 (Table 1). Evenness and dominance

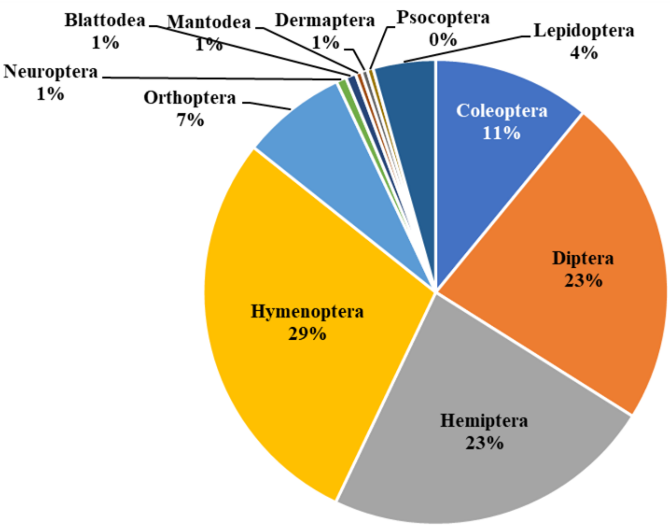

Figure 2. Proportion of insect order abundance in coffee ecosystems.

index was low its means that there are several groups whose abundance is almost the same (no group dominance). In this study, two groups of insects were found that were almost the same in abundance, i.e Diptera and Hymenoptera.

Analysis showed that species diversity in each order of insects and arachnids was in the low category. The Shannon Winner (H') diversity index value of each order was close to the same value, ranging from 0.02–1.42. This value signified that the species or morphospecies diversity belonged to the same order and tended to form the same pattern with the abundance of species (Table 2). Additionally, the results presented the Hymenoptera order as the most common group of insects found with the greatest number of species or morphospecies (H' = 1.42).

Insects and arachnids community structure in the arabica coffee ecosystems

The insects and arachnids community of coffee plants consists of four function levels playing crucial ecological roles, namely phytophages, pollinators, natural enemies (predators and

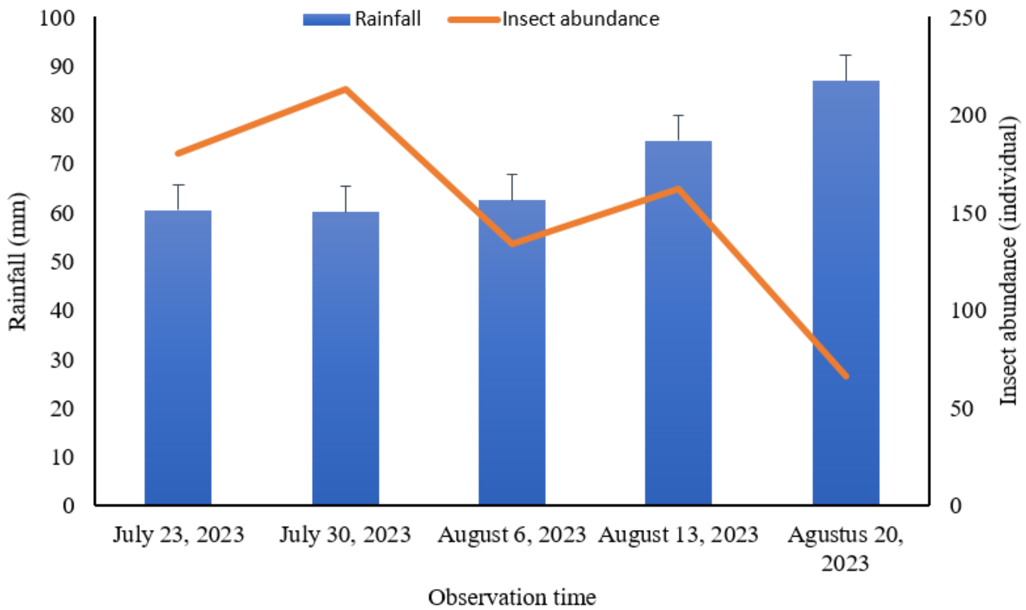

Figure 3. Fluctuations in insect abundance and weekly rainfall during observations.

Table 1. Index of diversity, evenness, and dominance of arthropods in the arabica coffee ecosystem

Observation	Value analysis	Categories
Diversity index (H')	5.10	High
Evenness index (E)	0.37	Low
Dominance index (C)	0.02	Low

Table 2. Index of diversity and abundance of insects and arachnids in arabica, Palasari coffee plantation

Order	Abundance (individual)	Species richness	Value analysis	Categories
Coleoptera	78	40	0.59	Low
Diptera	164	54	1.12	Moderate
Hemiptera	165	45	0.94	Low
Hymenoptera	204	87	1.42	Moderate
Orthoptera	52	22	0.37	Low
Neuroptera	5	2	0.04	Low
Blattodea	5	4	0.04	Low
Lepidoptera	31	8	0.17	Low
Mantodea	3	3	0.03	Low
Dermaptera	3	1	0.02	Low
Psocoptera	3	3	0.03	Low
Araneae	44	23	0.32	Low

parasitoids), and detritivores. The abundance and diversity of phytophagous groups are higher compared to the other ecosystem function groups (Figure 4). The abundance lower in a group is not necessarily directly proportional to the low diversity of species in the group. Proven in the parasitoid group (Figure 4), that the diversity of its species is quite high despite its low abundance. The results showed that plant phase influenced the presence and abundance of insects in the ecosystems. From the observations performed, coffee plants were in early conditions of fruit formation and some were still flowering, leading to a lesser number of pollinator insects.

DISCUSSION

The Palasari coffee plantation is located near the edge of an industrial pine forest. The pine forest can support the diversity of arthropods in the area, including in the coffee plantation, by providing habitat for various insect and spider species. The abundance of arthropods is strongly influenced by the ecosystem type including vegetation complexity as well as tillage and environmental factors such as rainfall and humidity. Insects are the arthropod group with the largest number of species as well as the fastest and best adaptability (Sheffield & Heron 2018).

Hymenoptera, Hemiptera, and Diptera have the highest abundance found in the coffee ecosystems. These three orders insect belong to a group comprising the highest number of species in the world (Sheffield & Heron 2018), while Coleoptera is the fourth largest order. Moreover, the type of ecosystem has a significant impact on the abundance and diversity of insect natural enemies such as parasitoid populations. According to Kasmiatun et al. (2022), the abundance and diversity the Coleoptera Order were higher in forest ecosystems compared to plantations.

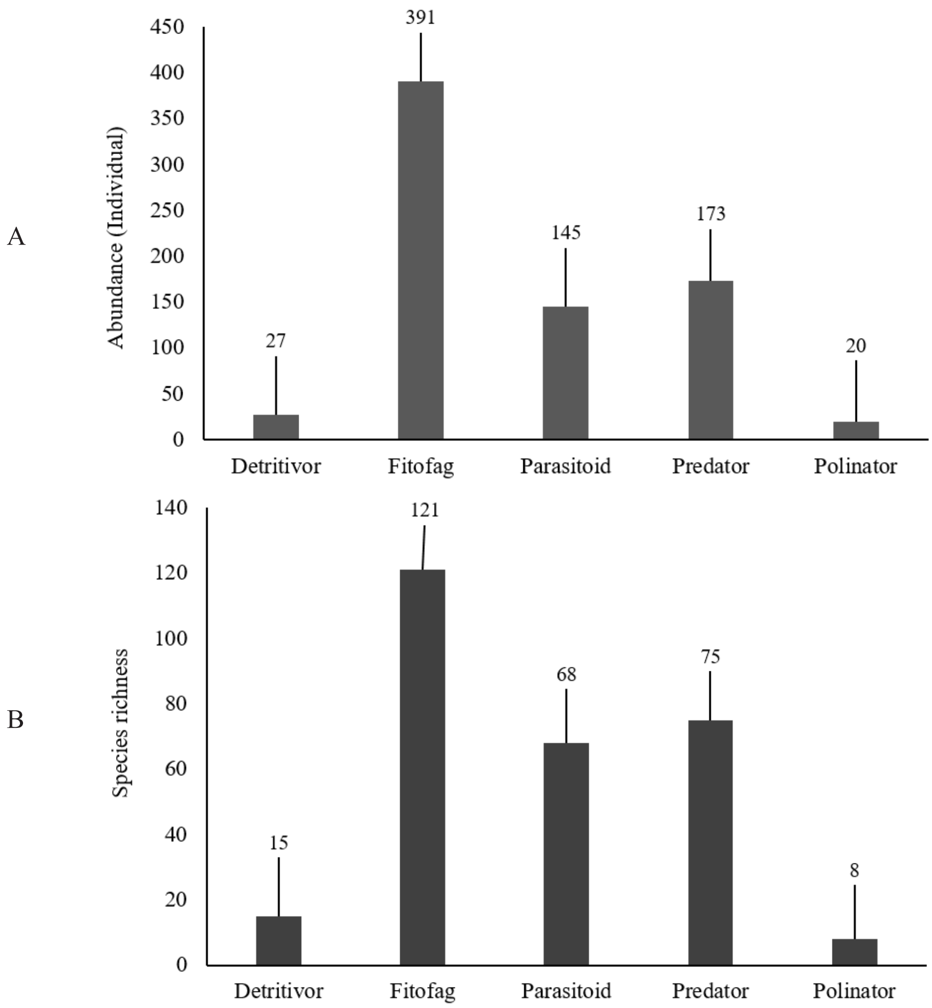

Figure 4. The insects abundance (A) and species richness (B) in the five ecological role groups obtained from the entire coffee plant samples.

The climate plays an important role in presenting the community of arthropods and species abundance. Observation showed a daily temperature of around ranged from 27 to 32 ºC with relatively heavy daily rainfall. The presence of insects is greatly influenced by the climate, including the intensity of rain. In heavy rain conditions, the presence of insects tends to be low (Chen et al. 2019). Heavy rain conditions will also affect the condition of plants, especially flowering and fruiting plants. The lack of flowering plants will decrease the presence of pollinating insects. The presence of flowers on coffee plants affects the diversity of insects, specifically the pollinating groups, which are more attracted to blooming flowers for nectar retrieval.

The evenness level of arthropods (insects and arachnids) found in coffee plantations belonged to the low category. Moreover, the diversity of host plants and the type of arthropod feeding preferences may affect the low evenness level of species in the observation field. Host-specific arthropods depend largely on host availability, while generalist arthropods have a large host spectrum which promotes higher organism presence (Setiawan et al. 2016).

The type of cultivation carried out influences the type and presence of insects, hence, coffee plants in open monoculture or polyculture systems without shade trees tend to increase the population of phytophages. Shimales et al. (2023) reported a higher pest population in Ethiopia on coffee plantations than semi-forest land (agroforestry) or natural forest. This observation was similar to the results showing a higher species diversity of phytophagous insects or pests on arabica coffee plantations in Palasari, Bandung Regency compared to other insects and other functions. Furthermore, the balance of arthropod functions in the ecosystems was assumed to be affected by the lack of vegetation diversity. Agroforestry land presenting vegetation diversity creates more stable ecosystems, which makes the number of phytophages and natural enemies nearly balanced (Campera et al. 2022).

The presence of insect pests and the intensity of attacks can be affected by the availability of shade plants. The type of coffee land used during the observations was the open type lacking shade trees. The land use in Palasari Village comprises a plantation system, monoculture coffee, and small intercropping of coffee with horticultural (vegetable) groups. The reduction of shade plants in these ecosystems leads to high pest attacks as well as decreased parasitoid ability and parasitization processes (Shimales et al. 2023). The presence of shade trees in the land affects both ecosystem services (Priyadarshini et al. 2011) and the composition of insects (Rasiska & Khairullah 2017; Jonsson et al. 2015). In addition to shade tree species, flowering vegetation availability influences the composition of parasitoid and predatory insects (Supriyad et al. 2019).

Land management systems have been found to affect the diversity and composition of arthropods. Since the land observed in this research is intercropping coffee ecosystems with horticulture, the use of pesticides in controlling pests in horticultural crops can affect the abundance of insects. Management intensification can decrease the diversity and abundance of natural enemies, for example, by reducing vegetation complexity which can lead to scarcity of flowering plants, alternative hosts, and habitation of natural enemies (Medeiros et al. 2019; Vandermeer & Perfecto 2010). This negative situation also results from the impacts of pesticide application that affect natural enemies (Schmidt-Jeffris et al. 2022). However, the value of arthropods diversity index in the local ecosystems is high. This signifies the local coffee ecosystems can support the existence of insects, hence optimization of resources is needed to achieve sustainability.

Cultivation practices and pest management in coffee plants should be directed to protect beneficial organisms such as natural enemies and pollinators. Natural enemies effectively suppressing insect populations and pollinator can promoting optimal coffee production. Furthermore, ecological tillage management systems preserve natural enemies and other beneficial insects for coffee production sustainability (Medeiros et al. 2019). Exposure to important information regarding ecological land management could help farmers achieve sustainable coffee production.

CONCLUSION

In conclusion, the results showed a relatively high diversity of insects on coffee fields in Palasari, Bandung Regency, even though the group of phytophagous insects was the most commonly found. This high diversity of arthropods signified stable ecological functions, thereby suggesting the need for appropriate land management to support the existing diversity.

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