Biosaintifika 18 (2) (2026): 381-391 p-ISSN 2085-191X | e-ISSN 2338-7610
Journal of Biology & Biology Education https://journal.unnes.ac.id/nju/index.php/biosaintifika

Insect Diversity in Horticultural Crops Frequently Sprayed with Pesticides

Dyah Rini Indriyanti[1]*, Priyantini Widiyaningrum[1], Orchida Puspa Jelita[1], Laila Khoirun Nada[1], Delia Alifia Farreza[1], Putri Eka Erwanti[1], Noorhidayah Mamat[2]

[1]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Semarang City, Central Java, Indonesia
[2]Institute of Biological Sciences, Faculty of Science, Universiti Malaya, Kuala Lumpur, Malaysia

*Corresponding author: dyahrini@mail.unnes.ac.id

Submitted: 2026-04-07. Revised: 2026-06-12. Accepted: 2026-08-13.

Abstract. Insect diversity reflects the complex interaction between insects and their environment, as demonstrated by their various functional roles, including pollinators, predators, parasitoids, decomposers, and phytophage. In horticultural ecosystems, insect diversity can indicate environmental stability because insects help maintain ecosystem balance and support crop productivity through various ecological interactions. This study aimed to analyze insect diversity in horticultural crops frequently sprayed with pesticides located in Bawen, Semarang Regency, Indonesia. The research was conducted in horticultural plantations to collect insect diversity data using hand-collecting and pitfall trap methods. The insect diversity data were analyzed using the Shannon-Wiener diversity index (H), the evenness index (E) and Simpson's dominance index (D), and Environmental factors. The results show that 4,142 insects were found in this study, belonging to 8 orders, 43 families, and 69 species. The insect diversity index indicates a highly diverse insect community with relatively even distribution of individuals among species and low species dominance, suggesting that the horticultural crops in Bawen are ecologically stable, despite routine pesticide application. Seasonal transition and pesticide use show limited variation in their influence on insect diversity. This study supports the Sustainable Development Goals (SDGs), particularly SDG 15 (Life on Land), by conserving insect biodiversity in horticultural ecosystems.

Keywords: Horticultural crops; Insect diversity; Sprayed with pesticides

How to Cite: Indriyanti, D. R., Widiyaningrum, P., Jelita, O. P., Nada, L. K., Farreza, D. A., Erwanti, P. E., & Mamat, N. (2026). Insect Diversity in Horticultural Crops Frequently Sprayed with Pesticides. *Biosaintifika: Journal of Biology & Biology Education, 18(2)*, 381-391.

DOI: http://dx.doi.org/10.15294/biosaintifika.v18i2.54405

INTRODUCTION

Horticultural crops play an important role fulfilling food, nutritional, and economic needs. The productivity of horticultural crops often declines due to environmental changes, excessive pesticide use, and imbalances in agricultural ecosystems that may affect the presence of organisms surrounding the crops. In the field, farmers often control insect pests by spraying pesticides because the effects are immediately visible. However, continued use kills pests' natural enemies and drives pest resistance. One major issue in horticultural land is declining insect diversity due to agricultural intensification and habitat alteration, leading to ecological imbalance.

In agroecosystems, insects play diverse ecological roles, including pests/ phytophages, pollinators, predators, parasitoids, decomposers, saprophages, vectors, and detritivores that contribute to ecosystem stability. Pollinator insects help fertilization, predators and parasitoids naturally suppress pest populations. Decomposers, saprophages, and detritivores help break down dead plant and animal remains so nutrients can be returned to the soil. Insect larvae, such as maggots, also feed on decaying matter, accelerating the decomposition process. However, pest insects (phytophages) can damage crops, reduce yield quality and quantity, and thereby impact plant productivity.

Agroecosystems with high insect diversity reflect complex habitat conditions that support the survival of various organisms within the ecosystem. Diverse habitats provide food resources, shelter, breeding sites, and suitable microhabitats for different insect species (Ikhsan, 2024). These conditions make the ecosystem more stable and balanced through more complex ecological interactions, such as predation and parasitism. These ecological interactions play an important role in maintaining the natural stability of agroecosystems. Research on insect diversity in horticultural crops frequently treated with pesticides is important for evaluating the ecological condition of the agricultural environment and for identifying the composition and ecological roles of the insects present in the ecosystem.

Information regarding insect diversity may provide insight into ecosystem stability, the presence of beneficial insects, and the potential occurrence of pest insects in horticultural areas. Additionally, studies on insect diversity are essential to support environmentally friendly and sustainable agricultural management practices, particularly through the optimization of natural biological control and the reduction of excessive chemical pesticide use. Frequent pesticide application may affect insect diversity and abundance by causing mortality among exposed insects. Therefore, understanding insect diversity in frequently pesticide-treated horticultural crops is important to evaluate the condition of insect communities in agricultural ecosystems.

The research questions: What is the insect diversity (Diversity Index (H'), evenness index (E) and dominance index (C) in Horticultural Crops frequently sprayed with Pesticides? What insect orders are most abundant, and what are the ecological roles of those insects? This study was conducted to analyze the insect diversity, determine the abundant orders, and identify the ecological roles of the insects found in Horticultural Crops frequently sprayed with Pesticides. The results of this research are expected to provide scientific information regarding insect diversity in horticultural crop ecosystems and contribute to the development of sustainable agricultural management strategies.

METHOD

This study has examined insect diversity in horticultural crops. The units of analysis comprise all insects residing on or perching on the plants, as well as those present in the immediate vicinity. This study was conducted at a crop plantation in Bawen, Semarang Regency, Indonesia. The horticultural plantation in Bawen covers 25 hectares, with 90% of the land dedicated to fruit crops and 10% to organic vegetable crops.

The plantation includes more than 20 fruit crops, each with a wide variety of cultivars. Insect sampling was conducted at several locations within the plantation, specifically in *Psidium guajava* (192 plants), *Citrus nobilis* (150 plants), *Dimocarpus longan* (156 plants), and *Anona muricata* (162 plants). Insect diversity observations were conducted from April to July 2025. The study began with a preparation stage comprising field observation, insect sampling, measurement of environmental factors, insect identification, and data analysis.

Pesticide applications were performed regularly to protect crops from insect pest infestation. Routine pesticide applications used an insecticide with Chlorantraniliprole as the active ingredient, applied at a concentration of 3 mL/L of water. Spraying frequency differed among horticultural crops: Psidium guajava was sprayed every three weeks, Dimocarpus longan and Citrus nobilis once a month, and Annona muricata one to two times a month; spraying was applied to the leaves (interview with the plantation manager).

Insect Sampling

Insect sampling was conducted using the transect sampling technique with sampling points established along predetermined transect lines within the horticultural crop area. Several sampling methods were applied, including:

Hand Collecting. The hand-collecting method involved directly capturing insects and placing them in bottles containing 70% alcohol (Paliama et al., 2022). The hand-collecting method can be done using gloves and tweezers. Flying insects, such as butterflies and dragonflies, were collected with an insect net.

Pitfall Trap. The pitfall trap method used plastic cups buried in the soil with the rim positioned level with the ground surface. The cups were filled with water and detergent to reduce the water surface tension (Tůma et al., 2025). This trap was used to capture ground-dwelling insects actively moving on the soil surface. The traps were left in the field for 48 hours, after which they were collected and filtered to obtain insect specimens.

Environmental Factor Measurement

Environmental factors were measured to determine the conditions affecting insect activity. Temperature, humidity, and light intensity were recorded weekly (08.00-11.00) (Agustina et al., 2025). Data collection was conducted during the dry season, although occasional rainfall still occurred, potentially affecting environmental conditions at the study site. Temperature and humidity were measured using a digital thermo-hygrometer capable of displaying temperature in degrees Celcius (°C) and relative humidity in percentage (%). Light intensity was measured using a digital lux meter to determine the lighting level in the research area. The measurement results were used as supporting data in the insect diversity analysis.

Insect Identification

The collected insect samples were identified to determine their types and species. Identification was carried out morphologically using a magnifying glass for small-sized insects. Identification was based on the handbook Entomology Pertanian (2000), the handbook Kunci Determinasi Serangga (1991), and image-based software such as iNaturalist (https://www.inaturalist.org). The scientific names and taxonomic classifications were verified using the Integrated Taxonomic Information System (https://www.itis.gov). Identification was conducted carefully to distinguish pests/ phytophages, pollinators, predators, parasitoids, decomposers, saprophages, vectors, and detritivores.

Data Analysis

Following identification, an ecological analysis of the insects was conducted by calculating the following index:
Diversity Index (Shannon-Wiener Index, H') (1949).
The diversity index was used to analyze the number of individuals of each species found. The calculation was performed using the Shannon-Wiener equation as follows:

$$H' = -\Sigma \text{ (Pi InPi)}$$

The diversity index criteria are as follows:
H' < 1 = Low species diversity
1 ≤ H' ≤ 3 = Moderate species diversity
H' > 3 = High species diversity

Evenness Index (E)

The evenness index is used to determine the balance of the community based on the similarity in the number of individuals among species. The evenness index formula is as follows:

$$E = \frac{H'}{In\, S}$$

E < 0.4 = Low species evenness
0.4 ≤ E ≤ 0.6 = Moderate species evenness
E > 0.6 = High species evenness
Pielou (1969)

Dominance Index (C)

The dominance index was used to assess a species' dominance within the community. The calculation was conducted using Simpson's formula as follows:

$$C = \Sigma\ (Ni/N)^2$$

The dominance index criteria are as follows:
0 < C ≤ 0.50 = Low dominance
0.50 < C ≤ 0.75 = Moderate dominance
0.75 < C ≤ 1 = High dominance
(Simpson, 1949)

RESULTS AND DISCUSSION

The Observations at the fruit orchard in Bawen (Table 1) revealed an insect community comprising eight orders, 43 families, and 69 species, with a total of 4,142 individuals. The Shannon-Wiener diversity index H' (3.41), Pielou evenness index E (0.75), and Simpson dominance index C (0.05) indicate that the insect community possesses relatively high diversity, high evenness, and a low level of dominance. These findings suggest that the fruit orchard provides diverse resources and microhabitats that support insects with varied ecological roles, despite frequent pesticide applications; a significant number of insects were still collected.

The diversity index (H') obtained is 3.41 (Table 1). The high species diversity index is supported by the diversity of plant species in horticultural plantations, indicating that these plantations provide sufficient resources to sustain a variety of insect species. Several studies have shown that vegetation composition and flower abundance influence diversity and abundance. Even though pesticides are sprayed monthly, insect diversity remains quite high. This indicates that the variety of vegetation in the horticultural plantation can still provide habitats and shelter that support various insect species.

The evenness index (E) value of insects in horticultural plantations is 0.75 (Table 1), which is relatively high. The high evenness index indicates that individuals are distributed relatively evenly among species, with little imbalance in species abundance (Alhafizin et al., 2025). The even distribution of insects plays an important role in ecosystem stability, species interactions, and ecological balance.

The insect dominance index (C) in horticultural plantations is relatively low, at 0.05 (Table 1). A low dominance index value indicates that no single species dominates in horticultural plantations. Low insect dominance indicates that the ecosystem provides diverse, evenly distributed food sources for insects. This stable community structure indicates that horticultural plantations provide food sources, shelter, and suitable conditions for all insect individuals. A low dominance value also indicates that the insect community can maintain ecosystem balance, as evidenced by the presence of predators and parasitoids that control other insect populations. In addition, horticultural plantation conditions support insect diversity by providing all components of the life cycle.

Table 1. Species identification and the ecological role of insects, insect diversity index, evenness index, and dominance index in horticultural plantations.

Order	Family	Species	Number of Individuals	Ecological role
1. Hymenoptera	Apidae	*Apis cerana*	30	Pollinator
	Formicidae	*Anoplolepis gracilipes*	49	Predator, Omnivore
	Formicidae	*Camponotus japonicus*	37	Predator, Omnivore
	Formicidae	*Camponotus* spp.	434	Predator, Omnivore
	Formicidae	*Crematogaster subnuda*	78	Predator, Omnivore
	Formicidae	*Dolichoderus thoracicus*	101	Predator, Omnivore
	Formicidae	*Hypoponera opacior*	268	Predator
	Formicidae	*Odontoponera* sp.	167	Predator
	Formicidae	*Oecophylla smaragdina*	65	Predator
	Formicidae	*Pheidole pallidula*	169	Predator
	Formicidae	*Solenopsis* sp	569	Predator
	Vespidae	*Polybia occidentalis*	11	Predator
2.Hemiptera	Aleyrodidae	*Aleurodicus dugesii*	38	Phytophage-Sap sucker
	Alydidae	*Leptocorisa oratorius*	60	Phytophage-Sap sucker
	Flatidae	*Lawana imitata*	21	Phytophage-Sap sucker
	Flatidae	*Sanurus indecora*	115	Phytophage-Sap sucker
	Flatidae	*Sanurus* sp.	78	Phytophage-Sap sucker
	Miridae	*Helopeltis antonii*	145	Phytophage-Sap sucker
	Pseudococcidae	*Planococcus lilacinus*	194	Phytophage-Sap sucker
	Ricaniidae	*Pochazia shantungensis*	85	Phytophage-Sap sucker
	Ricaniidae	*Scolypopa australis*	54	Phytophage-Sap sucker
	Tropiduchidae	*Numicia viridis*	79	Phytophage-Sap sucker
	Aphididae	*Aphis gossypii*	86	Phytophage-Sap sucker
	Reduviidae	*Zelus longipes*	11	Predator
3.Diptera	Calliphoridae	*Chrysomya megacephala*	8	Decomposer
	Sarcophagidae	*Sarcophaga* sp.	8	Decomposer
	Stratiomyidae	*Hermetia sexmaculata*	5	Decomposer
	Muscidae	*Musca domestica*	25	Decomposer
	Chironomidae	*Paratendipes albimanus*	7	Detritivore
	Tipulidae	*Tipula* sp	13	Detritivore
	Culicidae	*Culex* sp.	8	Blood Feeder
	Culicidae	*Psorophora ciliata*	7	Blood Feeder
	Drosophilidae	*Drosophila melanogaster*	380	Saprophage
	Micropezidae	*Microcaria pupillata*	7	Saprophage
	Nitidulidae	*Colopterus annularis*	10	Saprophage
	Chloropidae	*Ragwelellus suspectus*	10	Saprophage
	Tephritidae	*Bactrocera* sp.	83	Phytophage - Fruit pest
	Dolichopodidae	*Amblysilopus scintillans*	6	Predator
4.Coleoptera	Coccinellidae	*Cheilomenes sexmaculata*	7	Predator
	Coccinellidae	*Chilocorus stigma*	45	Predator
	Coccinellidae	*Coccinella transversalis*	30	Predator
	Coccinellidae	*Coelophora inaequalis*	6	Predator
	Coccinellidae	*Cryptolaemus montrouzieri*	41	Predator
	Coccinellidae	*Halmus chalybeus*	28	Predator

	Scarabaeidae	*Canthon viridis*	18	Decomposer
	Tenebrionidae	*Adelium* sp.	6	Detritivore
	Tenebrionidae	*Opatrum sabolosum*	7	Detritivore
	Cerambycidae	*Chlorophorus annularis*	9	Phytophage - Wood borer
	Curculionidae	*Phyllobius viridearis*	65	Phytophage - Leaf feeder
5.Lepidoptera	Crambidae	*Chrocidolomia pavonana*	6	Phytophage, Pollinator adult
	Erebidae	*Amata huebneri*	7	Phytophage, Pollinator adult
	Erebidae	*Clemensia albata*	10	Phytophage, Pollinator adult
	Erebidae	*Nyctemera annulata*	12	Phytophage, Pollinator adult
	Geometridae	*Agriopis aurantiaria*	24	Phytophage, Pollinator adult
	Noctuidae	*Anticarsia gemmatalis*	12	Phytophage, Pollinator adult
	Nymphalidae	*Hypolimnas bolina*	14	Phytophage, Pollinator adult
		Mycalesis sp.	15	Phytophage, Pollinator adult
	Pieridae	*Eurema sari*	12	Phytophage, Pollinator adult
		Leptosia nina	46	Phytophage, Pollinator adult
6.Blattodea	Blattidae	*Blattella asahinai*	63	Detrivore
		Blattella germanica	12	Detrivore
		Blatella sp.	22	Detrivore
	Tryonicidae	*Tryonicus parvus*	13	Detrivore
7.Orthoptera	Alydidae	*Metochus uniguttatus*	8	Phytophage - Seed sucker
	Gryllidae	*Gryllus assimilis*	41	Omnivore, Detrivore
	Gryllidae	*Modicogryllus consobrinus*	22	Omnivore, Detrivore
	Tettigoniidae	*Tettigonia viridissima*	8	Predator, Omnivore
8. Odonata	Libellulidae	*Orthetrum sabina*	7	Predator
	Corduliidae	*Somatochlora sahlbergi*	5	Predator
	Total Number of Individuals		4142	
	Number of Family		43	
	Number of Species		69	
	Shannon-Wienner Index (H’)		3.41	
	Pielou’s Evenness Index (E)		0.75	
	Simpson's Dominance Index (C)		0.05	

The distribution of insects by order is shown in the following diagram (Figure 1).

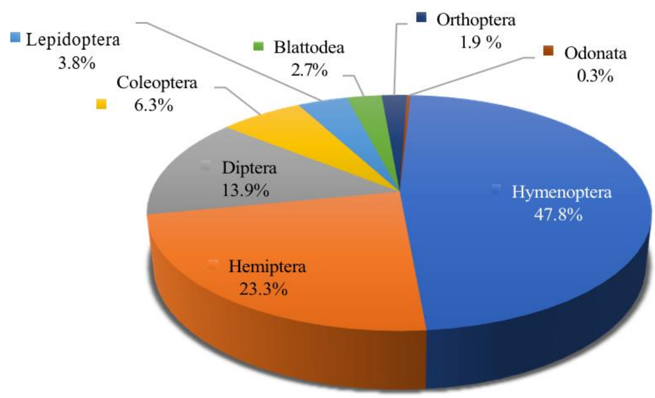

Figure 1. Distribution of Insect Individuals by Order (%) in Bawen Horticultural Plantation Based on Sampling from Guava (*Psidium Guajava*), Siam Honey Orange (*Citrus nobilis*), Soursop (*Annona muricata*), and Longan (*Dimocarpus longan*) plants.

The order Hymenoptera was the most abundant order, comprising 1,978 individuals (Table 1) or approximately 47.8% of all captured insects (Figure 1). This high number was primarily due to the family Formicidae (Table 1). Insect abundance at the study site is closely related to each species' ecological role in the ecosystem. The high number of individuals and species indicates that insect communities have diverse functions in maintaining ecosystem balance (Diyaolu &

Folarin, 2024).

The order Hymenoptera is characterized by thin and membranous wings with two pairs or one pair in some species (Mallorquí et al., 2025). Hymenoptera refers to insects that have hind wings smaller than the forewings, a slender waist connecting the thorax and abdomen, and mouthparts adapted for nectar feeding (Saputri et al., 2024).

The dominance of Hymenoptera indicates that the Bawen fruit plantation ecosystem has a robust component of natural enemies and insect pollinators. This is crucial for agroecosystem sustainability, as predators help regulate herbivorous insects, while pollinators support plant reproduction. The high abundance of Hymenoptera was dominated by the family Formicidae, particularly *Solenopsis invicta* and Camponotus spp (Table 1). According to Perfecto & Philpott, (2023), ants possess a high adaptability to agricultural environments and play important roles as predators/omnivore within the ecosystem. The diversity of plants in horticultural crops provides a variety of food sources and habitats for ants, resulting in their abundant presence. Flowering plants also support ant populations and other predators by providing nectar for insects that serve as a food source for ants (Sparer et al., 2024). Ants have large colonies, nests that are relatively well protected in the soil or leaf litter, and a strong ability to adapt to environmental changes, allowing part of the population to survive after pesticide application.

The order Hemiptera, also known as true bugs, ranked second with 966 individuals (Table 1) or 23.3% (Figure 1). This group was dominated by phytophagous, or pest, insects such as Planococcus lilacinus, Helopeltis antonii, Leptocorisa oratorria, and *Pochazia shantungensis*. Most of these species have a piercing-sucking mouthpart located on the head and extending forward (Opoke & Opiro, 2026). According to Pradeep et al. (2022), some members of the order Hemiptera also act as predators by piercing and sucking their prey, helping reduce pest populations.

Ecologically, Hemiptera are primary consumers. High Hemiptera populations indicate the presence of plant resources that support herbivore or sap-sucker populations. An interesting aspect is the potential relationship between Hymenoptera and Hemiptera; highly abundant Formicidae can interact with certain honeydew-producing Hemiptera, such as Aphididae and Pseudococcidae (Table 1). The high population of Hemiptera indicates that horticultural crops are suitable food sources for herbivorous insects. The variety of horticultural crops at the study site, such as guava, longan, orange, soursop, avocado, and melon, provides insects with an abundant food source. Routine pesticide spraying on plants doesn't significantly affect certain insect species that live on them. Most Hemiptera members have a habit of staying and sucking plant fluids on the underside of leaves. One Hemiptera insect, P. lilacius, has a fairly high population because it lives on the underside of leaves and has a protective wax layer that can guard against water and pesticides (Puspitasari et al., 2023). This position can reduce direct exposure to pesticide spray, especially if the application does not evenly cover the underside of the leaves. Insects also can fly or move around, so they might move to other plants or to surrounding vegetation that hasn’t been directly sprayed. *H. anonii* is one of the major pests of *P. guajava* and *A. muricata* plants, it causes damage by sucking the sap from the fruit and causing spots on the fruit and leaves, *H. antonii* can fly high and quickly avoid danger. Several species within this order are known to potentially cause crop damage and reduce agricultural productivity (Suhanda et al., 2025).

The order Diptera fulfill a wide range of ecological functions, namely: decomposer, detritivore, saprophage (Dufek et al., 2025; Hore & Banerjee, 2017), phytophage, fruit pest (Koswanudin et al. 2025), predator (Burgio et. al., 2024), and non-crop-associated insect (Lapshin, 2024). A total of 577 (13.9%) (Figure 1), individuals belonging to the order Diptera were recorded. The relatively high number of Diptera was primarily driven by *D. melanogaster* (380 individuals), whereas *Bactrocera* sp. (83 individuals) (Table 1). Ecologically, Diptera play a role in the decomposition and utilization of organic matter; however, some members are potential crop pests such as *Bactrocera* sp., which is classified as a phytophage or fruit pest. Diptera thus demonstrate the relationship between ecosystem functions and potential threats to crops.

The high abundance of *D. melanogaster*, despite regular monthly pesticide applications, is related to its high reproductive capacity and relatively short life cycle (Rand et al., 2023). *D. melanogaster* can reproduce quickly on ripe and rotting fruits that are commonly found in horticultural plantations. *D. melanogaster* is found primarily on rotting guavas and oranges that have fallen to the ground. In addition, adult *D.*

melanogaster are good fliers, which allows them to avoid pesticide exposure during spraying or migrate from areas around crops.

The high abundance of Diptera was associated with the availability of organic matter and decaying fruits around the plantation area. Some Diptera species serve as decomposers that break down organic matter, although several species may also act as pests or disease vectors (Manisha et al., 2024). In addition, some Diptera were found to act as predators; these insects can serve as biological control agents by suppressing pest insect populations and preventing pest outbreaks in agricultural ecosystems (Sousa et al., 2023).

The order Coleoptera. A total of 262 individuals (6.3%)(Figure 1) belonging to the order Coleoptera were recorded. This order plays diverse ecological roles, most of which belonged to the family Coccinellidae. The family Coccinellidae is particularly significant, as all recorded species, such as Chilocorus stigma, Coccinella transversalis, and Cryptolaemus montrouzieri, are predators. In contrast, the Curculionidae function as leaf feeders, the Cerambycidae as wood borers, and the Scarabaeidae and Tenebrionidae as decomposers or detritivores. Thus, Coleoptera contribute to two primary functions: natural control through predation and the utilization of plant matter and organic materials. The presence of Coccinellidae alongside Hemiptera can be ecologically significant, as some Coccinellidae prey on sap-sucking insects. Thus, an abundance of Hemiptera can provide a food source for predatory Coleoptera, establishing a trophic relationship: plant → Hemiptera → Coccinellidae.

The order Coleoptera possesses chewing mouthparts and is generally active at night (nocturnal) (Saputri et al., 2024). A high abundance of Coleoptera species indicates a high abundance of insect pests in the environment. When their numbers are comparable to those of insect pests, a balance is established. Several members of the order Coleoptera serve as decomposers, contributing to the breakdown of organic matter and supporting nutrient cycling within the ecosystem. The presence of Coleoptera indicates ecological interactions that support agroecosystem balance.

The order Lepidoptera was represented by 158 individuals (3.8%) (Figure 1), Lepidoptera accounted for 158 individuals, or 3.8% of the total. All Lepidoptera groups (Table 1) are categorized as phytophages in their larval stage and pollinators in their adult stage. The ecological role of Lepidoptera is intriguing due to the functional differences between the larval and adult stages. The larval stage is generally associated with consuming plant tissue, whereas adults can pollinate. Consequently, Lepidoptera fulfill a dual role within the agroecosystem: acting as herbivores during the larval stage and as pollinators during the adult stage. This demonstrates that a single insect group can perform distinct ecological functions throughout its life cycle. Spraying pesticides on the leaves can reduce the presence of Lepidoptera larvae that live there and become pests on the plants, while the adults can avoid the sprayed pesticides by flying away.

The presence of this order is influenced by the availability of vegetation as food sources and breeding habitats. The order Lepidoptera is easily recognized by its distinctive wings, which display unique and attractive patterns in each species. Lepidoptera wings are membranous and covered with scales that form characteristic color patterns (Suka et al., 2022). Members of this order possess a coiled sucking mouthpart located under the head, known as a proboscis or siphon, and large compound eyes (Vieira et al., 2022). The presence of Lepidoptera can indicate environmental health, as these insects are highly sensitive to pollution and chemical exposure.

The orders Blattodea, a total of 110 individuals (2.7%) (Figure 1), is categorized as non-crop-associated insects or detritivores. The ecological role of Blattodea is primarily linked to the utilization of organic matter and the process of detritivory. This group can form part of a detritus-based energy flow, in contrast to Hemiptera, which primarily derive energy directly from living plants.

The order Orthoptera comprises 91 individuals (1.9%) of the total (Figure 1). Table 1 indicates the presence of phytophages/seed suckers, detritivores, and predators/omnivores. This implies that Orthoptera also fulfill diverse ecological functions, although their relative abundance is low compared to Hymenoptera, Hemiptera, and Diptera.

The order Odonata was the order with the fewest individuals, with only 12 individuals (0.3%) of total (Figure 1). Odonata larvae play important roles as natural predators of small insects in aquatic environments, such as rivers (Sentis et al., 2022; Bílková et al., 2025). Despite their low numbers, Odonata remain ecologically significant because, as predators, they can help regulate other insect populations. Therefore, low abundance does not necessarily imply a diminished ecological role.

The insects found at the research site are mostly herbivorous. Herbivorous insects are phytophagous, attacking cultivated plants and acting as primary consumers that utilize plant tissues, including leaves, stems, and plant fluids (Firmanto et al., 2025). High abundance of herbivorous insects can become a pest problem. Species such as *Aphis gossypii, Planococcus lilacinus, Helopeltis antonii, Leptocorisa oratorius, Chrocidolomia pavonana*, and *Anticarsia gemmatalis* are among the insects that are harmful to plants. Abundant food sources and habitats allow herbivorous insect species to adapt easily (Jones et al., 2022).

Predatory insects act as natural enemies that can control excessive insect populations, thereby maintaining ecosystem stability. Predatory insects such as the species *Solenopsis invicta*, *Camponotus* spp., *Hypoponera opacior, Odontoponera* sp., and *Zelus longipes* were found at the research site. The presence of predatory insects helps control populations naturally, preventing harmful insect population explosions, especially herbivorous insects that have the potential to become pests (Verma et al., 2023). The abundance of predatory insects indicates that the plantation ecosystem supports a diverse community of natural enemies, which may help regulate pest populations naturally.

Insects that help plants with pollination are also commonly found, such as *Hypolimnas bolina, Mycalesis* sp., *Eurema sari*, and *Leptosia nina*. Pollinating insects are vital for plants, supporting reproduction and maintaining ecosystem productivity. Decomposer insects in horticultural plantations, such as Blattella asahinai, also benefit plant growth. Decomposition is the process of breaking down organic matter into simpler organic or inorganic materials. It is often referred to as transformation or the conversion of something old into raw materials for new life (Verma et al., 2023). The presence of pollinators, decomposers, and detritivores also reflects the diversity of ecological functions that insects perform in maintaining ecosystem processes.

The high diversity index, despite routine pesticide application in plantations (2-4 times a week), may be attributed to the extensive area of horticultural plantations, which allows insects to migrate between neighbouring plantations. Insects' high mobility enables them to reappear after pesticide application. Routine pesticide spraying does not always directly affect insect communities. Insect populations can recover rapidly and increase through reproduction and migration from surrounding areas. Furthermore, pesticide applications focused primarily on plant foliage result in minimal exposure for non-target insects inhabiting the soil surface, allowing their populations to remain stable. Consequently, the insect community continues to consist of various functional groups. The high insect diversity, despite regular pesticide application, may be attributed to well-preserved surrounding vegetation, which provides suitable habitats and alternative resources for insects, as well as to the use of pesticides at recommended doses (Orczewska et al., 2024). These factors enable insect populations to survive and maintain their community structure

Environmental factors also influence the high diversity of insects in horticultural plantations. Temperature is an environmental factor that can affect insect life. Insects are poikilothermic animals that depend heavily on environmental temperature for survival (Kumar et al., 2024). Each insect has specific temperature requirements to survive in its environment. In general, insects can live at temperatures ranging from 15 to 45°C, with an optimum temperature of around 25°C. The temperatures recorded in plantations range from 20 to 30.7 °C; at these temperatures, conditions remain ideal for insect life (Table 2).

Table 2. Measurement of Abiotic Factors at the Research Sites

Temperature (°C)	Light intensity (Lux)	Humidity (%)
20 - 30.7	1,017 – 8,424	66 - 84

Light intensity in plantations ranges from 1,017- 8,425 lux. Maintenance practices such as pruning branches and leaves influence light intensity by allowing sunlight to penetrate between plants and reach insects. Light is important for insects, improving their ability to see, breed, fly in search of food, mate, and metabolize. Humidity is a factor that can affect insect behavior and physiology. Inappropriate humidity can increase insect mortality, reproduction, growth, and development rates. Humidity in fruit plantations ranges from 66% to 84%. The humidity obtained in horticultural plantations is sufficient for insects to live and reproduce, just as insects also have different humidity levels.

Data collection took place during the

transition period, from the rainy season to the dry season, resulting in relatively high humidity at the study site. Under these conditions, some plants at the study site were also entering their flowering phase, providing food sources such as nectar, pollen, and young leaves that insects utilized. Flowering plants attract pollinating insects, as evidenced by high numbers of Lepidoptera and an increase in herbivorous Hymenoptera that could become pests at the study site. The transitional season, with an abundance of food sources, is believed to contribute to the high diversity and abundance of insects (Agustina et al., 2025). The transitional season, accompanied by an abundance of food sources, is believed to be one of the factors contributing to the high diversity and abundance of insects.

In addition to seasonal conditions, the heterogeneous vegetation structure of the agricultural field likely enhanced insect diversity by providing a variety of food resources and microhabitats. Meidalima et al. (2017) reported similar observations, finding that vegetation surrounding agricultural fields functions as a source of food, shelter, and alternative hosts for arthropods, thereby supporting greater arthropod abundance and diversity. In the present study, the mixed-fruit plantation likely provided comparable ecological function, with guava, soursop, Siam honey orange, and longan trees creating a structurally diverse habitat that supported various insect taxa.

High insect diversity supports SDG 15 (Life on Land), reflecting healthy, well-functioning ecosystems. The variety of insect species serves as pollinators, predators, decomposers, and herbivores, helping maintain ecological balance, support biodiversity conservation, and enhance the sustainability of terrestrial ecosystems. This study supports the achievement of the Sustainable Development Goals (SDGs), particularly SDG 15 (Life on Land) through biodiversity conservation and ecosystem protection.

CONCLUSION

Based on the results of this study, insect diversity in the horticultural plantations of Bawen was high, with a diversity index (H') of 3.41, an evenness index (E) of 0.75 and a dominance index (C) of 0.05. These values indicate a highly diverse insect community with a relatively even distribution of individuals among species and low species dominance, reflecting a stable ecosystem.

The insect orders found in descending order of abundance are as follows: Hymenoptera, Hemiptera, Diptera, Coleoptera, Lepidoptera, Blattodea, Orthoptera, and Odonata.

The presence of diverse insect groups with various functional roles is as follows: Phytophage-Sap sucker, Phytophage-Fruit pest, Phytophage-Wood borer, Phytophage-Leaf feeder, Phytophage-Seed sucker, Phytophage, Pollinator adult, Phytophage-Saprophage, Pollinator, Predator, Predator-Omnivore, Decomposer, Detritivore, Blood Feeder, and Saprophage. Further research is recommended to examine the diversity of insects serving as natural enemies in fruit plantations.

ACKNOWLEDGEMENT

The authors sincerely acknowledge the financial support provided by the Research and Community Service Program for Fiscal Year 2025, DIPA UNNES. Contract no. 752.14.3/ UN37/PPK.11/2025 (March 14, 2025).

AUTHOR CONTRIBUTION STATEMENT

Author DRI and PW conceived and designed the study and conducted the data analysis. Authors OPJ, LKN, DAF, and PEE were responsible for data collection and data visualization. Author NM provided substantial feedback during manuscript drafting. All authors read and approved the final manuscript and agreed to be accountable for all aspects of the work.

CONFLICT OF INTEREST STATEMENT

All authors declare that they have no conflict of interest regarding the publication of this manuscript.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The research conducting, analyzing the data, and preparation of the manuscript were completed by the authors without the use of AI-generated content. AI was used only as a language translation aid to assist in translating the manuscript and did not contribute to the research process, data analysis, or interpretation of the results

REFERENCES

Abudulai, M., Nboyine, J. A., Quandahor, P., Seidu, A., Traore, F., & Abudulai, M. (2022). *Agricultural intensification causes decline in insect biodiversity BT - Global Decline of Insects* (Vol. 1, pp. 43–64).

Agustina, D. K., Leksono, A. S., Yanuwiadi, B., Rizali, A., Abdullah, S. A., & Abdullah, M. (2025). Effects of Seasonal Transitions on Population Dynamics of Fruit Flies in *Capsicum annuum* and *Solanum lycopersicum* in Batu City, Indonesia. *Biosaintifika: Journal of Biology & Biology Education*, *17*(1), 143–155. https://doi.org/10.15294/Biosaintifika.V17I1.14288

Alhafizin, M., Ilhamdi, M. L., & Wirajagat, G. C. (2025). Diversity of Soil Insects in The Aiknyet Natural Tourism Area, West Lombok. *Jurnal Biologi Tropis*, *25*(3), 2477–2487. https://doi.org/10.29303/jbt.v25i3.9338

Bílková, E., Kornová, V., Ožana, S., Pyszko, P., Schindlerová, H., Chytilová, R., & Dolný, A. (2025). Dragonfly larvae rearing: experimental insights and best practices. *Environmental Entomology*, *54*(2), 394–406. https://doi.org/10.1093/ee/nvaf001

Burgio, G. M., L. Dindo, T. Pape, D. Whitmore, D. Sommaggio. (2024). Diptera as predators in biological control: applications and future perspectives. *BioControl*. Review. https://doi.org/10.1007/s10526-024-10281-2

Saputri, B, T., Anggraini, D., Pratiwi, A., Permata, M., Ulpatami, N., Wicaksono, A., Raden Fatah Palembang, N., & Selatan, S. (2024). Identification of Nocturnal Visitor Insects on Penda Emas Plants (*Xanthostemon chrysanthus*). *Jurnal Biologi Tropis*, *24*(1), 303–312. https://doi.org/10.29303/JBT.V24I1.6296

Diyaolu, C. O., & Folarin, I. O. (2024). The Role of Biodiversity in Agricultural Resilience: Protecting Ecosystem Services for Sustainable Food Production. *International Journal of Research Publication and Reviews*, *5*(10), 1560–1573. https://doi.org/10.55248/gengpi.5.1024.2741

Dufek, M.I., Moira, BH, Darío, DL., Pablo, RM. (2025). Decomposition dynamics: the influence of anthropogenic disturbance on organic matter degradation by sarcosaprophagous flies. *Journal of Medical Entomology*, 62 (3), 560–571), https://doi.org/10.1093/jme/tjaf035

Firmanto, R., Herlin, W., & Pujiastuti, Y. (2025). Diversity insect in the Vegetative Phase of *Arenga pinnata* (Wurmb) Merr. in Tanjung Miring Village, Muara Enim. *Jurnal Lahan Suboptimal: Journal of Suboptimal Lands*, *14*(2), 138–145. https://doi.org/10.36706/jlso.14.2.2025.746

Hore, G., & Banerjee, D. (2017). Necrophagous flies (Insecta: Diptera) and their role in maintaining ecosystem balance. ENVIS Centre Faunal Diver, 23, 2-6.

Ikhsan, Z. (2024). Diversity of Hymenoptera in Indonesian Rice Agroecosystems: A Systematic Review of Species Composition and Ecological Roles. *Andalasian International Journal of Entomology*, *2*(2), 122–132. https://doi.org/10.25077/aijent.2.2.122-132.2024

Jones, L. C., Rafter, M. A., & Walter, G. H. (2022). Host interaction mechanisms in herbivorous insects–life cycles, host specialization and speciation. *Biological Journal of the Linnean Society*, *137*(1), 1–14. https://doi.org/10.1093/biolinnean/blac070

Kumar, H., Sagar, D., Verma, S., Rajarushi, C. N., Rupali, J. S., Madhuri, E. V, & Sujatha, G. S. (2024). Heat stress and thermoregulation in insects: Unveiling molecular and physiological responses in light of climate change. *Journal of Advances in Biology & Biotechnology*, *27*(9), 820–834. https://doi.org/10.9734/jabb/2024/v27i91355

Koswanudin, D H. Widyanto, D. Hutapea, Wawan, R. Yuniawati, V.N.O. Subagyo, S. Utami,

I.M. Samudra, W. Darwiati. (2025). Ecological population dynamics, host preferences, and associated parasitoids of *Bactrocera carambolae* and *Bactrocera papayae* on fruits. Global J. Environ. Sci. Manage. 11(2): 631-652.

Lapshin, D.N. (2024). The Auditory System of Blood-Sucking Mosquitoes (Diptera, Culicidae). Neurosci Behav Physi 54, 1447–1465. https://doi.org/10.1007/s11055-024-01744-1

Mallorquí, M. V, Vincent, J., Liston, A., Blagoderov, V., & Desmulliez, M. P. (2025). Knowledge from Hymenopteran Ovipositors: A Review of Past and Current Biomimetic Research. *Bioinspiration & Biomimetics*. https://doi.org/10.1088/1748-3190/adc3e2

Manisha, B. L., Satwika, M., Logeshkumar, P., & Singh, N. A. (2024). *Entomology vistas: Emerging trends in entomology* (B. L. Manisha, M. Satwika, P. Logeshkumar, & N. A. Singh, Eds.; 1st ed., Vol. 3). Stella International Publication TM.

Meidalima, D., Kawaty, R. R., & Gunawan, E. B.

(2017). The Diversity of Arthropods Predator on Wild Plant of Rice Field with and without Pesticides. *Biosaintifika: Journal of Biology & Biology Education*, *9*(1), 89–94. https://doi.org/10.15294/biosaintifika.v9i1.5124

Opoke, R., & Opiro, R. (2026). *Introductory Entomology BT - Fundamentals of Entomology: A Faculty Manual* (pp. 3–43). Springer Nature Singapore.

Orczewska, A., Dulik, A., Długosz, P., & Depa, Ł. S. (2024). Intensive agriculture vs. Invertebrate biodiversity: A case study of woodland islets in a matrix of arable land. *Agriculture*, *14*(8), 1400. https://doi.org/10.3390/agriculture14081400

Paliama, H. G., Latumahina, F. S., & Wattimena, C. M. (2022). Keanekaragaman serangga dalam kawasan hutan mangrove di Desa Ihamahu. *Jurnal Tengkawang*, *12*(1), 94–104.

Perfecto, I., & Philpott, S. M. (2023). Ants (Hymenoptera: Formicidae) and ecosystem functions and services in urban areas: a reflection on a diverse literature. *Myrmecological News*, *33*, 103–118. https://doi.org/10.25849/myrmecol.news_033:103

Pielou, E.C. (1969). An Introduction to Mathematical Ecology. Wiley.

Pradeep, P., Deshmukh, S. S., Kalleshwaraswamy, C. M., & Rajan, S. J. (2022). Biology and predation potential of the hemipteran predator, *Rhynocoris marginatus* (Fab., 1794) on the fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae). *Egyptian Journal of Biological Pest Control 2022 32:1*, *32*(1), 64-. https://doi.org/10.1186/S41938-022-00562-2

Sentis, A., Kaunisto, K., Chari, L., Morrill, A., Popova, O., Pomeranz, J., & Stoks, R. (2022). *Odonata trophic ecology BT - Dragonflies and damselflies: Model organisms for ecological and evolutionary research* (pp. 219–232).

Simpson, E.H. (1949). Measurement of Diversity. Nature 163: 688.

Shannon, C.E. & Weaver, W. (1949). The Mathematical Theory of Communication. University of Illinois Press.

Sharma, R. P., Boruah, A., Khan, A., Thilagam, P., Sivakumar, S., Dhapola, P., & Akanksha. (2023). Exploring the significance of insects in ecosystems: A comprehensive examination of entomological studies. *International Journal of Environment and Climate Change*, *13*(11), 1243–1252. https://doi.org/10.9734/ijecc/2023/v13i113276

Sousa, M., Ignell, R., Pollet, M., Green, K. K., Becher, P. G., & Birgersson, G. (2023). Antennal and maxillary palp morphology, and sensillar equipment, of the spruce bark beetle predators, *Medetera signaticornis* and *Medetera infumata* (Diptera: Dolichopodidae). *Arthropod Structure & Development*, *72*, 101229. https://doi.org/10.1016/J.ASD.2022.101229

Suhanda, R., Wulandari, T., Sakinah, A. N., & Putra, D. (2025). The Ground Surface Hemiptera (True Bugs) in the Muhammad Sabki City Forest Area of Jambi City. *Biospecies*, *18*(1), 67–72. https://doi.org/10.22437/biospecies.v18i1.42715

Suka, D. C. G., Sinulingga, N. G. H. B., Wardoyo, A. S., Sirait, B. A., Sihombing, I. F. L., Tavares, W. D. S., Kkadan, S. K., Tarigan, M., Duran, A., & Solovyev, A. V. (2022). First Report of *Parasa pastoralis* (Lepidoptera, Limacodidae) on *Acacia crassicarpa* (Fabaceae), and *Sycanus collaris* (Hemiptera, Reduviidae) as Its Predator in Sumatra, Indonesia. *Https://Doi.Org/10.18473/Lepi.76i1.A9*, *76*(1), 83–86. https://doi.org/10.18473/LEPI.76I1.A9

Tůma, M., Král, J., Forman, M., Purchart, L., Lubin, Y., & Pekár, S. (2025). Prey of Selected Epigeic Velvet Spiders (Araneae: Eresidae). *European Journal of Entomology*, *122*, 219–227. https://doi.org/10.14411/eje.2025.027

Verma, R. C., Waseem, M. A., Sharma, N., Bharathi, K., Singh, S., Anto Rashwin, A., & Singh, B.V. (2023). The Role Of Insects In Ecosystems, An In-depth Review of Entomological Research. *International Journal of Environment and Climate Change*, *13*(10), 4340–4348. https://doi.org/10.9734/ijecc/2023/v13i103110

Vieira, V., Oliveira, L., Soares, A. O., Borges, P. A. V., Borges, I., & Tavares, J. (2022). Diversity of Lepidoptera (Insecta) recorded in a forest nursery of Nordeste County on São Miguel Island (Azores). *Biodiversity Data Journal*, *10*, e89971. https://doi.org/10.3897/BDJ.10.E89971