BIODIVERSITAS
Volume 26, Number 3, March 2025
Pages: 1211-1219

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d260320

Diversity, abundance, and ecological roles of insect pollinators in red guava flowers (*Psidium guajava*) in East Java, Indonesia

BUDI PURWANTININGSIH[1,♥], AMIN SETYO LEKSONO[2], BAGYO YANUWIYADI[2], ZULFAIDAH PENATA GAMA[2], SAIFUL ARIF ABDULLAH[3,4]

[1]Doctoral Program of Biology, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya. Jl. Veteran, Malang 65145, East Java, Indonesia. Tel./fax.: +62-341-554403, ♥email: budipurwanti@student.ub.ac.id

[2]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya. Jl. Veteran, Malang 65145, East Java, Indonesia

[3]Adjunct Professor at Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Brawijaya. Jl. Veteran, Malang 65145, East Java, Indonesia

[4]Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia. 43600 UKM Bangi, Selangor Darul Ehsan, Malaysia

Manuscript received: 19 December 2024. Revision accepted: 9 March 2025.

Abstract. *Purwantiningsih B, Leksono AS, Yanuwiyadi B, Gama ZP, Abdullah SA. 2025. Diversity, abundance, and ecological roles of insect pollinators in red guava flowers (*Psidium guajava*) in East Java, Indonesia. Biodiversitas 26: 1211-1219.* Red guava *(Psidium guajava)* is a high-value crop with relatively easy cultivation requirements. However, the decline in pollinating insects is a global issue that has led to reduced *P. guajava* productivity and harvest yields. This study aimed to analyze the abundance, richness, diversity, evenness, and dominance of insects visiting *P. guajava* flowers, as well as to visually examine their visitation patterns across five locations in East Java, Indonesia: Pademonegoro, Tlekung, Oro-Oro Ombo, Junrejo, and Mulyoagung, and assess the ecological roles. A total of 3432 individual insects from 17 families and five orders were identified, with pollinators dominating in all locations. Junrejo exhibited the highest abundance (29.11%) but low diversity (0.78), whereas Pademonegoro had the highest diversity (1.80) with moderate abundance. Statistical analysis revealed no significant differences in insect composition between locations (p>0.05), although PCA analysis indicated variations in insect characteristics at certain sites. Insect activity was influenced by flowering periods, temperature, and light intensity, with peak activity varying across locations. These findings underscore the critical role of pollinators, particularly the Apidae family, in *P. guajava* pollination, highlighting their significant contribution. The study also highlights the diverse adaptations of insect communities to their local environments, providing insights into sustainable agroecosystem management through pollinator conservation.

Keywords: Diversity, guava, insect visitors, pollinators, species abundance

INTRODUCTION

Red guava (*Psidium guajava*) is a tropical fruit from the Myrtaceae family. It is known for its various advantages, such as easy cultivation, sweet taste, large fruit size, and relatively simple maintenance. The fruit originated in America and has now been widely cultivated in various countries, including India, Mexico, Brazil, Pakistan, Sri Lanka, Bangladesh, Myanmar, Indonesia, Malaysia, and the Philippines (Saji et al. 2022). In East Java, *P. guajava* ranks 10^{th} in fruit productivity, with total production reaching 797,984 quintals per year (BPS, 2023). However, despite its popularity, the quality of *P. guajava* fruit often receives little attention from producers, such as inconsistent ripeness, flavor, size, and texture. This issue is closely tied to the pollination process, which primarily relies on insect activity as the main pollinating agent.

Furthermore, recent reports indicate a declining trend in *P. guajava* production and quality in certain regions. Factors such as climate variability, habitat loss, and a decrease in pollinator populations have been identified as key contributors to these issues (Omar et al. 2021). The reduced availability of pollinators, particularly bees and other insect species, has led to irregular fruit sets, smaller fruit sizes, and inconsistencies in taste and texture. Addressing these challenges requires a deeper understanding of pollination dynamics and the implementation of effective agricultural management strategies.

Physiologically, *P. guajava* is a flowering plant whose reproduction is highly dependent on pollination. Pollination in *P. guajava* is mainly carried out by insect activity, which acts as the main pollinating agent (Hansen et al. 2020). Honey bees (*Apis* sp.) are the main pollinators of *P. guajava* plants that contribute to cross-pollination, ranging from 25.70% to 41.30% (Khalifah et al. 2021; Omar et al. 2021). Globally, pollinating insects play an important role in maintaining ecosystem sustainability, especially in the agricultural sector. However, declines in pollinating insect populations have been observed in many regions, including Europe and North America (Llorente et al. 2023). In Asia, especially Indonesia, data on wild insects that act as pollinators are still relatively limited.

Pollinator populations face increasing threats due to environmental changes caused by human activities, such as land conversion, pesticide use, and climate change (Leksono et al. 2020). The role of pollinating insects in tropical agroecosystems remains under-exploited, providing opportunities to fill knowledge gaps and develop locally appropriate conservation strategies (Huda 2021).

Insects generally visit flowers due to attractants such as pollen and nectar (primary attractants), as well as scent (secondary attractants) (Abidin et al. 2020; Widhiono et al. 2022). Some insects hold economic value through their role as pollinators (Basualdo et al. 2022). Many insect species visit flowers, but not all of them serve as pollinators. Some visit flowers to forage for food, and pollination occurs during this process as pollen is transferred from one flower to the stigma of another or within the same flower (Hemberger and Gratton 2023; Indhu et al. 2022).

The decline and extinction of pollinators have been widely observed in Europe and North America, while data on wild insects in Asia remains relatively scarce. Studies on flower-visiting insects offer opportunities to understand the ecological interactions between plants and insects. These insects not only act as pollination agents but also serve as indicators of overall ecosystem health (Purwantiningsih et al. 2024). By identifying the types of pollinators for *P. guajava* plants, environmentally friendly and efficient agroecosystem management strategies can be developed, such as utilizing natural pollinators to enhance crop yields (Amin et al. 2022).

Several studies related to flower-visiting insects have been conducted, but the results vary across locations. For example, Rizal et al. (2018) reported that aphids, fruit flies, whiteflies, beetles, scale insects, and thrips were *P. guajava* pests in Jordan. Sarjan et al. (2023) reported that many predatory insects attacked *P. guajava* pests. Considering these prospects, this study aims to analyze the abundance, species richness, diversity, evenness, and dominance of flower-visiting insects across five red *P. guajava* orchards. The results of this study are expected to provide important information to support efforts in pollinator conservation and sustainably increase *P. guajava* productivity in Indonesia.

MATERIALS AND METHODS

Study area

The research was conducted at five red guava (*P. guajava*) orchards located at different elevations but with similar land management practices, plant species, and approximately 15-year-old cultivation. The study was carried out from August 2023 to January 2024. The research locations were in five villages of East Java Province, Indonesia, as follows: (i) Pademonegoro (7°23'55.75"S, 112°39'27.19"E, 10 m asl.); (ii) Tlekung (7°54'44.01"S, 112°32'3.39"E, 904 m asl.); (iii) Oro-Oro Ombo (7°54'43.22"S, 112°31'29.29"E, 1004 m asl.); (iv) Junrejo (7°54'54.46"S, 112°33'31.11"E, 694 m asl.); (v) Mulyoagung (7°55'5.35"S, 112°34'54.08"E, 593 m asl.). The purpose of selecting these research sites was to assess differences in the composition of insect abundance, species richness, diversity, evenness, and dominance across the locations (Figure 1).

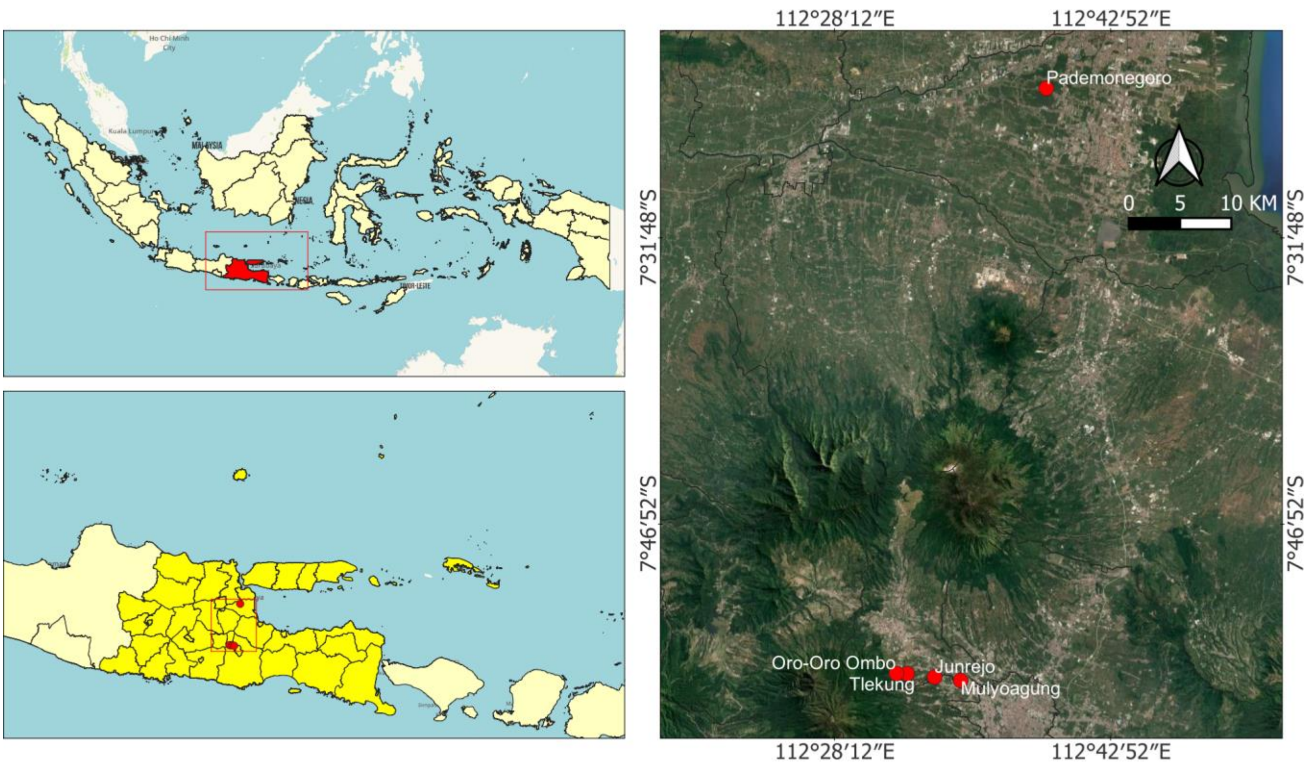

Figure 1. Study area map showing the location of the research site in Pademonegoro, Tlekung, Oro-Oro Ombo, Junerjo, Mulyoagung villages of East Java Province, Indonesia

Sampling design and methods

Insect observations were conducted directly on *P. guajava* flowers by establishing observation points measuring 10x10m for 15 minutes on each plant. Observations were made once a week for six months, resulting in 20 repetitions at each site. The visual observations were divided into three periods: Period I from 08:00 to 11:00, Period II from 11:00 to 14:00, and Period III from 14:00 to 17:00.

Data analysis

After the data was collected for each period and repetition, data analysis was conducted using the following formulas:

Abundance Index (DI)

DI = (Ki)/(∑k) x100%, with criteria of low (<15%), moderate (15-20%), and high (>20%).

Species Richness Index (R)

R = (S-1)/(Ln (N0)), with criteria of low (<3), moderate (3-5), and high (>5).

Diversity Index Shannon-Wiener (H')

H' = ∑(ni/N) x (ni/N), with criteria of low (H'<1), moderate (1<H'<3), and high (H'>3).

Evenness indices (E)

E = (H')/(In (S)), with criteria of small, depressed communities (0<E<0.4), medium, stable communities (0.4<E<0.6), and stable evenness (0.6<E<1.0).

Dominance Index (D)

D = ∑ (pi)² = ∑(ni/N)² with criteria of low (0<C<0.5), moderate (0.5<C<0.75), and high (0.75<C<1).

An ANOVA was performed using SPSS to evaluate differences in the average abundance of insect visitors across different sites. The Bray-Curtis Index was applied to assess the similarity in species composition across different periods and sites, followed by Principal Component Analysis (PCA).

RESULTS AND DISCUSSION

Abundance, species richness, diversity, evenness, and dominance of insect visitors to *Psidium guajava* flowers

A total of 3432 individual insect visitors were found across the five locations from five orders and 17 families. The highest number of orders was Hymenoptera, followed by Diptera, Lepidoptera, Coleoptera and Hemiptera. The number of families identified including Apidae, Vespidae, Tephritidae, Halictidae, Formicidae, Calliphoridae, Muscidae, Syrphidae, Lauxaniidae, Pieridae, Aphididae, Stratiomyidae, Drosophilidae, Nymphalidae, Hesperiidae, and Lycaenidae, Coccinellidae (Table 1).

The abundance of insect visitors to *P. guajava* flowers was higher in Junrejo (29.11%), followed by Mulyoagung (24.45%) and Tlekung (22.87%), both exceeding 20%. In contrast, Pademonegoro recorded the lowest abundance at 5.42%. The highest species richness was observed in Pademonegoro (5.36), classified as high, while Tlekung (4.20), Oro-Oro Ombo (4.35), Junrejo (4.05), and Mulyoagung (4.16) were categorized as moderate. The highest diversity of insect visitors was in Pademonegoro (1.80), while the lowest was in Junrejo (0.78), the latter being classified as low. The evenness of insect visitors was relatively similar across all locations, with most sites falling under the "low" category due to values below 0.4. The highest dominance of insect visitors was recorded in Junrejo (0.68), where *Apis cerana* was the dominant species.

Insect visit periods

Insect foraging activity varies depending on the flowering period, temperature, and light intensity (Leksono 2017). Insects forage at different times throughout the day. At Pademonegoro and Junrejo, peak foraging activity of *T. laeviceps* and *A. cerana* was recorded from 08:00 to 11:00, followed by a decline from 13:00 to 17:00. Similarly, in Mulyoagung, *Xylocopa* sp. exhibited peak foraging activity in the morning. In contrast, in Tlekung, peak foraging of *T. laeviceps*, occurred in the afternoon, while at Oro-Oro Ombo, peak visits were recorded at midday (Figure 2).

Abundance, species richness, diversity, evenness, and dominance of pollinating insects

The abundance and percentage of pollinators were highest in Junrejo (926; 33.23%) and Mulyoagung (722; 25.91%). Despite having the highest abundance, Junrejo had a low diversity index (0.47) and high dominance (0.78). Mulyoagung also showed high pollinator abundance (722; 25.91%) and pest presence (36), with a dominance value of 0.58, suggesting dominant species and no predators other than pollinators. In contrast, diversity of pollinators and predators in Tlekung (0.83; 0.61) and diversity of pollinators and predators in Oro-Oro Ombo (0.94; 0.69) exhibited more balanced species distributions. These locations also had a high number of pollinators and predators, which may help reduce pest populations. Pademonegoro had the lowest pollinator abundance (5.63%) and a relatively high predator dominance (0.44). Overall, the insect visitor community structure varied across the five locations, with pollinators dominating, followed by predators, pests, and a few detritivores (Table 2).

Composition of pollinators at each location

The composition of flower-visiting insects on *P. guajava* differs across locations. Junrejo exhibited the highest abundance with the widest distribution, reflecting the dominance of a certain insect compared to other locations. Mulyoagung also showed a significant abundance spread, with high maximum values, though the median was lower than in Junrejo. Tlekung and Oro-Oro Ombo displayed moderate variation, with lower maximum values. Pademonegoro had the lowest insect abundance (Figure 3.A). At the same time, the role of pollinators dominated the abundance at all locations. The greatest variation was found in pollinators and detritivores, while pests showed the least and most consistent abundance (Figure 3.B).

Table 1. Abundance, species richness, diversity, evenness, and dominance of insect visitors to *Psidium guajava* flowers

Ordo	Species (Family)	Location					Total	Role
		PN	TL	OR	JR	MA		
Hymenoptera	*Apis cerana* (Apidae)	-	135	237	816	186	**1374**	Pollinator
	Tetragonula laeviceps (Apidae)	62	270	279	81	160	**852**	Pollinator
	Xylocopa sp. (Apidae)	48	-	34	5	376	**463**	Pollinator
	Vespa affinis (Vespidae)	1	10	-	42	-	**53**	Predator
	Stenodynerus histrionalis (Vespidae)	15	-	13	5	-	**33**	Predator
	Bactrocera sp. (Tephritidae)	-	-	-	-	25	**25**	Pest
	Apis mellifera (Apidae)	16					**16**	Pollinator
	Polistes sp. (Vespidae)	-	-	-	16	-	**16**	Predator
	Camponotus sp. (Formicidae)	12	-	-	-	-	**12**	Predator
	Lassioglosum sp. (Halictidae)	1	-	-	-	-	**1**	Pollinator
Diptera	*Lucilia sericata* (Calliphoridae)	-	121	-	-	9	**130**	Detritivore
	Musca sp. (Muscidae)	-	186	-	7	72	**265**	Detritivore
	Episyrphus balteatus (Syrphidae)	2	17	4	14	-	**37**	Pollinator
	Minettia longipennis (Lauxaniidae)	-	10	24	-	-	**34**	Detritivore
	Drosophilla sp. (Drosophilidae)	-	20	-	-	-	**20**	Detritivore
	Hydrotaea houghi (Muscidae)	-	-	14	-	-	**14**	Detritivore
	Sargus flavipes (Stratiomyidae)	-	5	-	-	-	**5**	Predator
	Paragus haemorrhous (Syrphidae)	-	3	-	-	-	**3**	Pollinator
Lepidoptera	*Yptima* sp. (Nymphalidae)	24	1	-	-	-	**25**	Pollinator
	Potanthus sp. (Hesperiidae)	-	-	-	10	-	**10**	Pollinator
	Eurema hecabe (Pieridae)	3	-	-	-	-	**3**	Pollinator
	Pieris sp. (Pieridae)	-		2	-	-	**2**	Pollinator
	Zizula hylax (Lycaenidae)	1	-	-	-	-	**1**	Pollinator
Coleoptera	*Coccinella* sp. (Coccinellidae)	1	-	16	-	-	**17**	Predator
	Henosepilachna sp. (Coccinellidae)	-	3	-	-	11	**14**	Pest
	Phengodes sp. (Coccinellidae)	-		-	3	-	**3**	Predator
	Cole sp. (Coccinellidae)	-	2	-	-		**2**	Predator
Hemiptera	*Sitobion* sp. (Aphididae)	-	2	-	-	-	**2**	Detritivore
No. individuals		**186**	**785**	**623**	**999**	**839**	**3432**	
Percentage		5.42	22.87	18.15	29.11	24.45		
Species Richness		5.36	4.20	4.35	4.05	4.16		
Shannon_H		1.80	1.70	1.32	0.78	1.43		
Evenness_e^H/S		0.34	0.26	0.21	0.11	0.21		
Dominance_D		0.21	0.23	0.35	0.68	0.29		

Notes: PN: Pademonegoro; TL: Tlekung; OR: Oro-Oro Ombo; JR: Junrejo; MA: Mulyoagung

Table 2. Average abundance, species richness, diversity, evenness, and dominance of insects in the organic orchard of *Psidium guajava* in East Java, Indonesia

Location	Ecological roles	Abundance	Percentage	Species richness	Shannon_H	Evenness	Dominance_D
Pademonegoro	Pollinator	157	5.63	2.37	1.44	0.29	0.28
	Predator	29	20.57	2.08	0.94	0.28	0.44
	Pest	-	-	-	-	-	-
	Detritivore	-	-	-	-	-	-
Tlekung	Pollinator	426	15.29	1.98	0.83	0.14	0.50
	Predator	17	12.06	2.82	0.61	0.22	0,10
	Pest	3	7.69	1.82	-	-	1.00
	Detritivore	339	72.90	1.03	0.95	0.16	0.38
Oro-oro Ombo	Pollinator	556	19.52	1.90	0.94	0.15	0.44
	Predator	29	20.57	2.38	0.69	0.20	0.51
	Pest	-	-	-	-	-	-
	Detritivore	38	8.17	1.65	0.50	0.14	0.14
Junrejo	Pollinator	926	33.23	1.76	0.47	0.07	0.78
	Predator	66	46.81	1.91	0.97	0.23	0.47
	Pest	-	-	-	-	-	-
	Detritivore	7	1.51	2.65	-	-	1.00
Mulyoagung	Pollinator	722	25.91	1.82	1.02	0.16	0.39
	Predator	-	-	-	-	-	-
	Pest	36	92.31	0.56	0.62	0.17	0.58
	Detritivore	81	17.42	1.37	0.16	0.04	1.79

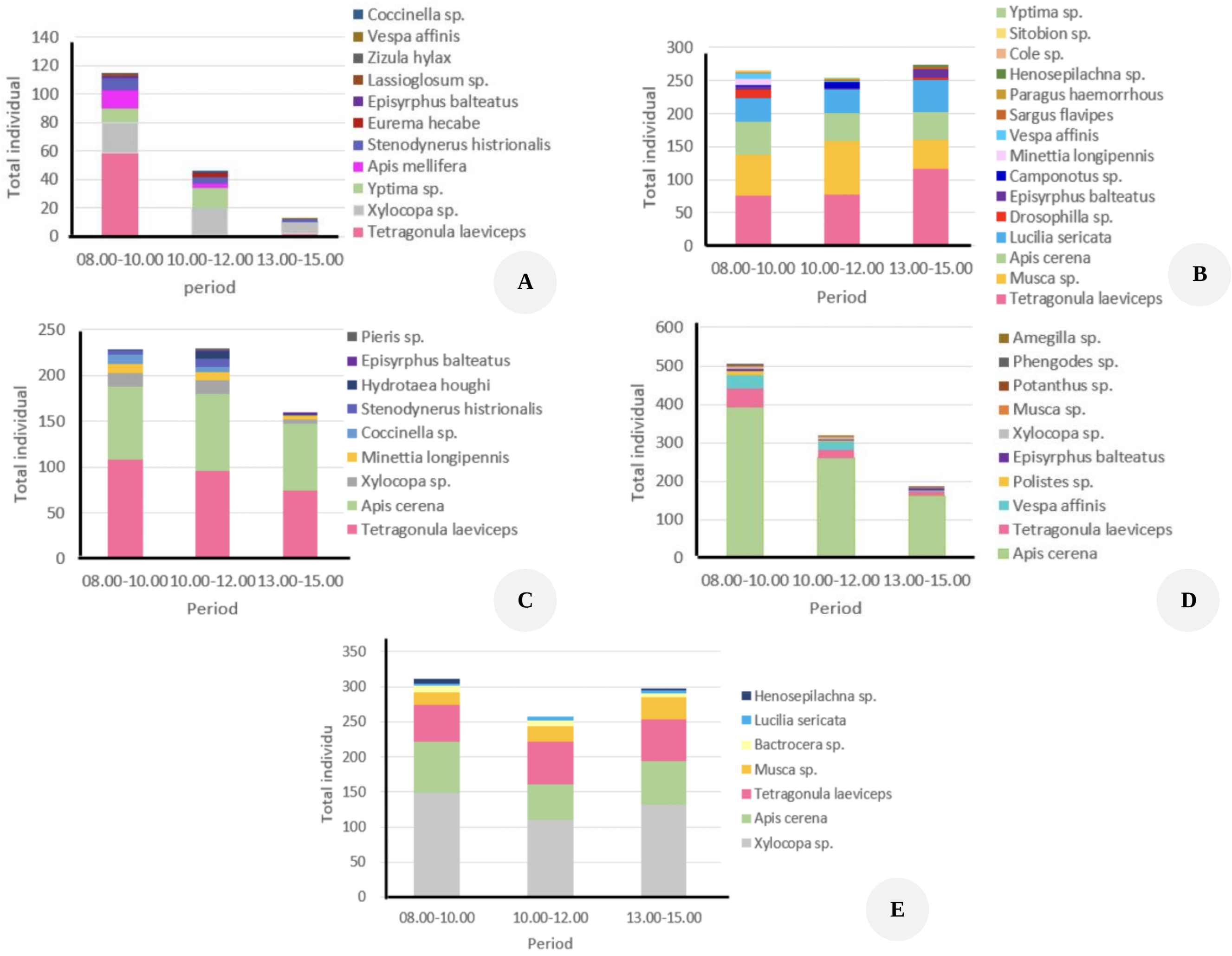

Figure 2. Insect visitation periods on *Psidium guajava* flowers at the study sites in East Java, Indonesia: A. Pademonegoro; B. Tlekung; C. Oro-Oro Ombo; D. Junrejo; E. Mulyoagung

Pademonegoro has a composition of pollinating insects (84%) consisting of families Apidae, Syrphidae, Pieridae, Nymphalidae, Halictidae, and Lycaenidae, while 16% are predators. Tlekung has a pollinator composition of 54%, including families Apidae, Syrphidae, and Nymphalidae, with other insects being predators (2%), pests (1%), and detritivores (43%).

Oro-Oro Ombo has a composition of 89% pollinators, including families Apidae, and Syrphidae. Predators make up 5%, and detritivores account for 6%. Junrejo has a pollinator composition of 93%, mainly from the families Apidae, Syrphidae, and Hesperiidae. Other insects include predators (6%) and detritivores (1%). Mulyoagung has 86% pollinators, predominantly from families Apidae, while other insects are pests (4%) and detritivores (10%) (Figure 4).

The ANOVA test showed no significant difference in the abundance of pollinators between locations ($F_{(5,239)}$: 0.571, P: 0.718>0.05). Similarly, there were no significant differences in predator composition ($F_{(5,239)}$: 1.08, P: 0.380>0.05), pest composition ($F_{(5,239)}$: 1.51, P: 0.199>0,05), and no significant differences in detritivore composition ($F_{(5,239)}$: 0.51, P: 0.730>0.05) across the location.

Analysis of the composition of *P. guajava* pollinator using the Bray-Curtis Index revealed similarities in pollinator species between Junrejo, Mulyoagung, and the other three locations. However, the insect visitors in Junrejo were more similar to those in Pademonegoro and different from those in Mulyoagung in terms of pollinator species composition (Figure 5). Based on correlation analysis, the Eigenvalue (9.3584) >1, a crucial finding, indicates that the correlation requirement is met, allowing for further analysis using PCA (Principal Component Analysis). The PCA results reveal the relationship between location, environmental factors, and insect roles based on two main components. The distribution of pollinator insect abundance varies across the five locations, with Pademonegoro showing the most distinct differences, while Tlekung, Oro-Oro Ombo, and Junrejo exhibit similarities.

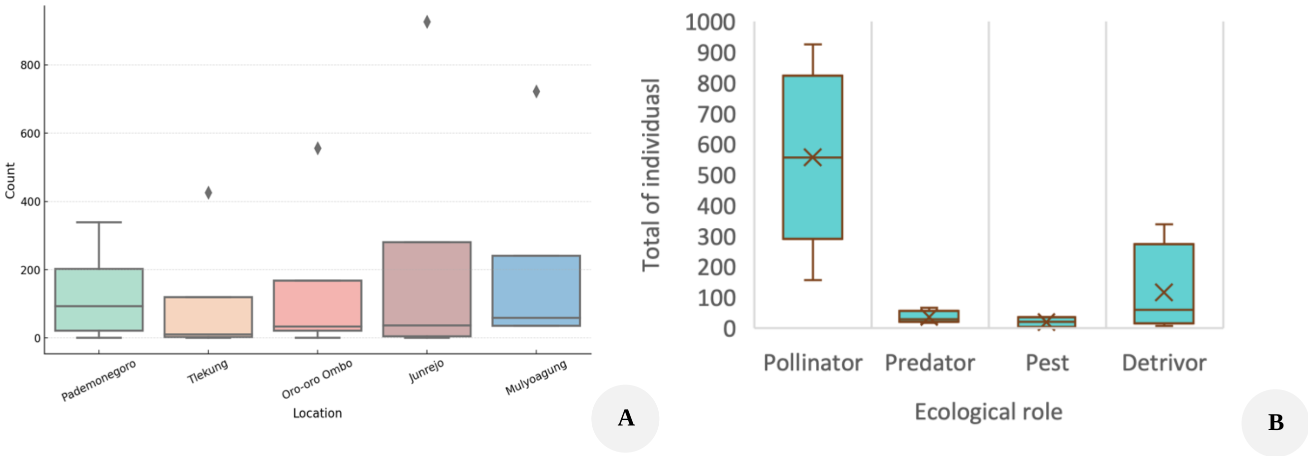

Figure 3. A. Distribution of abundance across sites; B. Distribution of ecological roles across sites

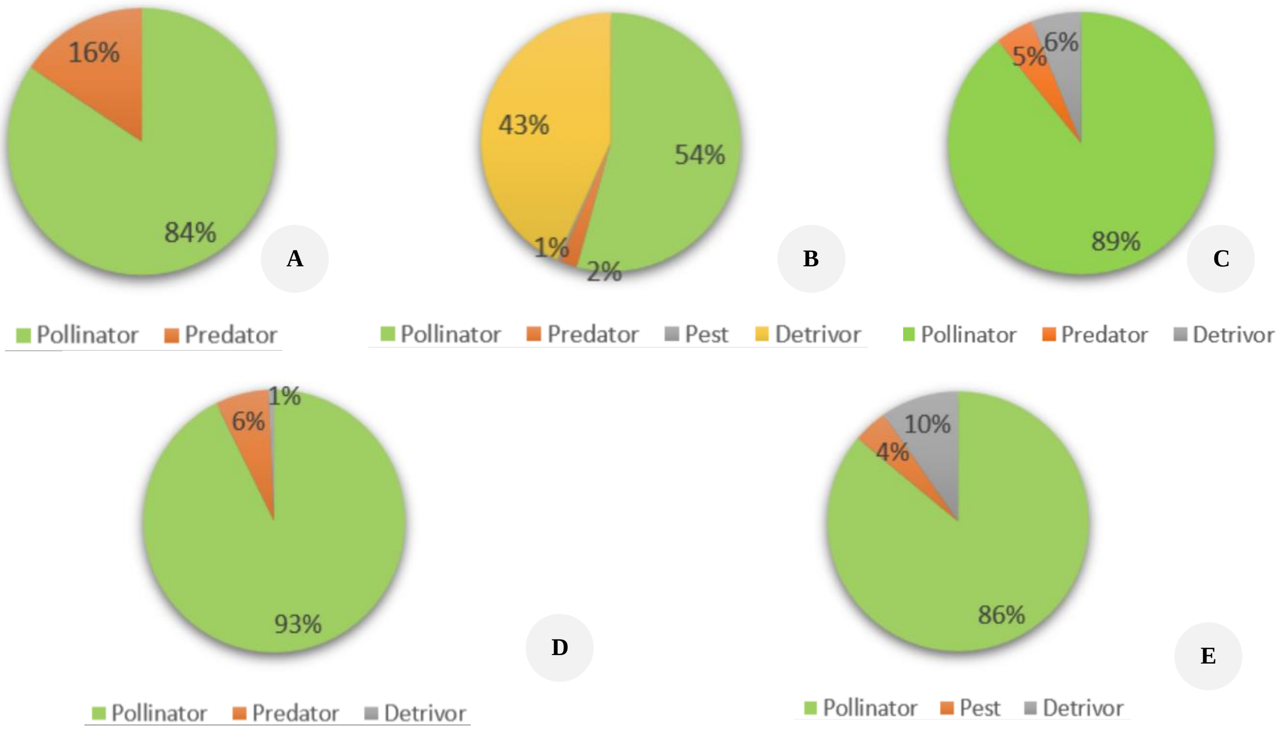

Figure 4. Composition of pollinating insects and others on *Psidium guajava* orchard in East Java, Indonesia. A. Pademonegoro; B. Tlekung; C. Oro-Oro Ombo; D. Junrejo; E. Mulyoagung

Component 1 (X-axis) is primarily influenced by temperature, predators, and wind speed, whereas Component 2 (Y-axis) is more affected by rainfall, humidity, and detritivores. Junrejo stands out in Component 1 due to its high temperature and the presence of predators, while Mulyoagung and Tlekung are more influenced by humidity and rainfall. Pademonegoro is characterized by temperature and predator influence, whereas Junrejo is more associated with wind speed.

The insect community composition also differs among locations. *Apis mellifera*, *Trigona laeviceps*, *Xylocopa* sp., *Zizula hylax*, *Eurema hecabe*, and *Lasioglossum* sp. dominate Pademonegoro. Tlekung is characterized by *Polistes haemorrhous*, *Drosophila* sp., *Lucilia sericata*, *T. laeviceps*, and *Episyrphus balteatus*. Oro-Oro Ombo is defined by *Pieris* sp., Junrejo by *Potanthus* sp. and *Apis cerana*, and Mulyoagung by *A. cerana*, *Potanthus* sp., and *Xylocopa* sp.

In the PCA analysis, pollinators are positioned at the center, indicating that their presence is influenced by environmental factors such as light intensity and rainfall. Meanwhile, predators are more dominant in areas with lower temperatures, such as Pademonegoro, whereas detritivores are more closely associated with high humidity in Mulyoagung (Figure 6).

Discussion

The results of the study revealed that the number of insect visitors to *P. guajava* flowers across five *P. guajava* is a plant that requires pollination to produce optimal fruit. Some species that have been proven to act as *P. guajava* pollinating insects include: *Xylocopa* sp., *T. laeviceps*, *Apis* spp. (Hansen 2020; Khalifa 2021). The results of this study found that the number of insect visitors to *P. guajava* flowers in five locations reached 3,432 individuals with 17 families and five main orders: Hymenoptera, Diptera, Lepidoptera, Coleoptera, and Hemiptera. The abundance of flower visitor insects in each location showed significant variation. The Junrejo site had the highest abundance (29.11%), followed by Mulyoagung (24.45%) and Tlekung (22.87%) (Table 1). The dominance of *Apis cerana* species was evident in all three sites, especially in Junrejo, reflecting its important role as the main pollinator in supporting the pollination of *P. guajava* flowers.

The research findings on the diversity of *P. guajava* flower visitor insects in Pademonegoro and Tlekung have significant implications for ecosystem stability. The highest diversity was found in Pademonegoro (1.80), indicating a more even distribution of species compared to other locations. In contrast, Junrejo had low diversity (0.78) despite its high abundance of insect visitors (Table 1). The low evenness in certain locations, such as Junrejo, indicates the dominance of certain species that can affect ecosystem stability. This finding suggests that there is no extreme dominance of species, but there is also no completely even distribution. The higher diversity in Tlekung suggests that the habitat supports more species without the dominance of any one species (Purwantiningsih et al. 2024). This is relevant to the ecological principle that an even distribution increases ecosystem stability, as different species can play different ecological roles (Eisenhauer et al. 2024). Junrejo dominates species such as *A. cerana*, which may limit the opportunities for other species to thrive. Such dominance can create an imbalance, reducing the ecosystem's resilience to disturbance. With low diversity, ecosystem functions are more susceptible to disruption if dominant species decline (Runnel et al. 2024). The dominance of *A. cerana* species found on *P. guajava* flowers may reduce variation in pollination. Some species may have preferences for certain times or parts of the flower. When dominant species dominate, the diversity of pollination methods decreases, which in turn can affect fruit development (Osterman et al. 2024).

The Mulyoagung site also had a high abundance (24.45%) with a diversity value (1.43) in the medium category (Table 1). These findings suggest that the Mulyoagung habitat has better microhabitat diversity and a more even distribution of resources. This factor allows various insect species to coexist without excessive dominance by one species. Nectar and pollen resources are likely to be more dispersed, making them accessible to a wide range of pollinator species. It is also possible that the Mulyoagung orchard does not have species that are highly competitive or aggressive in dominating floral resources. This allows other species, including fixed species, to contribute to pollination activities. The composition of pollinator species in Mulyoagung, such as *A. cerana* and *Xylocopa* sp., allows the division of roles in pollination, besides the role of *Coccinell*a sp., which may also play a role in controlling the population of certain species so as to prevent domination.

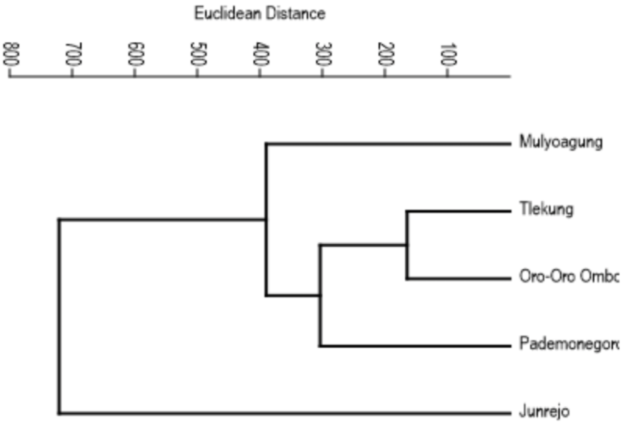

Figure 5. Bray-Curtis similarity index of insects across five locations of *Psidium guajava* orchard in East Java, Indonesia

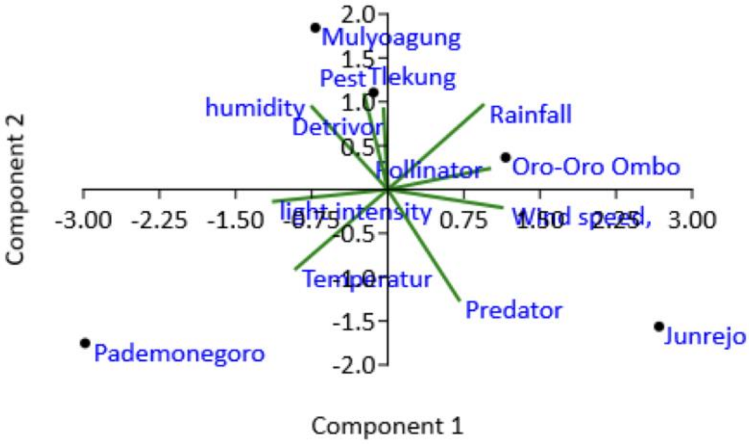

Figure 6. Relationship between sites, abiotic factors, and insect numbers using PCA analysis

The Junrejo location seems to be more favorable to the activities of flower-visiting insects compared to other locations. This can be attributed to the flight range of some flower-visiting insect species found in this location. For example, honey bees (*A. cerana*) and *T. laeviceps* have an average flight range of up to 1.5 km, while other bees, such as *Xylocopa* sp., can reach up to 2 km (Neto et al. 2009). *A. cerana* and *T. laeviceps* may build colony nests in tree cavities or artificial structures around the *P. guajava* site, while solitary bees such as *Xylocopa* sp. build their nests on the ground, dead wood, or natural cavities around the *P. guajava* orchard. In addition, the abundant flowering plants around Junrejo, such as those from Fabaceae and Asteraceae species, can provide an abundant source of nectar and pollen, supporting insect activity throughout the day. The combination of ideal environmental factors with the presence of abundant floral resources in Junrejo creates optimal conditions for various species of flower-visiting insects.

The Junrejo site is dominated by pollinators such as *A. cerana*. Two main factors influence differences in insect abundance and composition between sites: i) competition between species, where highly efficient honey bees (*A. cerana*) dominate nectar and pollen collection; ii) the displacement effect of other species. The dominance of *A. cerana* may lead to a decline in the abundance of less competitive pollinators, such as solitary bees (*Xylocopa* sp.), and stingless bees (*T. laeviceps*). These species may be outcompeted for floral resources, resulting in reduced foraging activity or relocation to other habitats with less competition (Patel et al. 2021; Purwantiningsih et al. 2024).

Pollinator composition was dominated by the family Apidae or order Hymenoptera in all locations. Junrejo and Oro-Oro Ombo showed a very high proportion of pollinators (89-93%) (Figure 4), while Pademonegoro showed a more balanced distribution between pollinators and predators. The Hymenoptera order is the most useful group of insects in agriculture. Some members of this order serve as natural enemies of insect pests and as important pollinators for plants. Some pollinators from the Hymenoptera and Lepidoptera orders have mouthparts specialized in sucking nectar and other plant fluids. These devices support pollinators to survive very easily in extreme nectar environments and can still improve insect health (Faraz et al. 2023).

The role of pollinators visiting *P. guajava* flowers dominated in all locations, with the highest contribution in Junrejo (93%) and Oro-Oro Ombo (89%) (Figure 4). This suggests that these organisms play a key role in pollination, which is a vital process for plant reproduction and the sustainability of the *P. guajava* seed flower population. These data also underscore the species relationship between these plants and the local pollinator community. In contrast, the roles of predators, pests, and detritivores show a smaller distribution but are important for ecosystem balance. This suggests the presence of predators keeps pest populations in check, reducing the risk of excessive damage to the crop. As for pests, although they are considered detrimental, they are also part of the food chain that supports trophic balance; the presence of detritivores can also help recycle organic matter, improve soil quality, and support overall ecosystem health. The results of this study highlight the intricate interdependence of organisms in the ecosystem, underscoring the complexity and interconnectedness of nature. Referring to the results of this study, it emphasizes that even the smallest role in the distribution of organisms remains relevant to maintaining a sustainable ecological balance (Verma et al. 2023).

The daily activities of flower-visiting insects were observed to have different patterns in each location. In Pademonegoro and Junrejo, the peak activity of *A. cerana* and *T. laeviceps* occurred in the morning (08.00-11.00). In contrast, Tlekung showed a peak in the afternoon (14.00-17.00). This variation in activity time is influenced by temperature, humidity, flowering period, and light intensity (Trani et al. 2023). In addition, this difference can be attributed to the micro-climate in each location as well as the insect's specific preference for certain environmental conditions (Joanna et al. 2021). Environmental factors such as temperature, humidity, light intensity, and flower opening period affect the activity of flower-visiting insects. Sites with certain environmental factors, such as temperature and predators in Junrejo, favor pollinating insect activity, while sites with high humidity and rainfall favor detritivores (Figure 6).

The ecological implication of this study is that roles such as *A. cerana* and *Xylocopa* sp. are critical in maintaining the sustainability of *P. guajava* flower populations. However, the dominance of certain species, as was the case in Junrejo, can reduce the diversity of pollination methods, which in turn affects the reproductive success of plants (Osterman et al. 2024). The higher diversity in Tlekung reflects better ecosystem stability as the even distribution of species allows various ecological roles to be performed in a balanced manner (Eisenhaur et al. 2024).

In addition, pest predators and detritivore also contribute to maintaining ecosystem balance. The presence of predators helps control pest populations, while Detritivores play a role in recycling organic matter, improving soil quality, and supporting overall ecosystem health (Manna et al. 2021). Therefore, despite their small proportion, their role cannot be ignored in maintaining ecological balance.

In conclusion, the number of insect visitors to *P. guajava* flowers in Junrejo was higher compared to the other four locations, but its diversity was low, while Tlekung had the highest diversity. The pollinator composition was dominated by the Apidae family, with significant contributions from Apidae in several locations. The analysis indicated no significant differences in insect visitor composition among the five locations, but PCA results revealed variations in characteristics reflecting local environmental influences. Peak insect activity occurred between 08:00 to 11:00. Overall, despite differences in the number and types of pollinators across the five locations, the insect composition in Tlekung, Oro-Oro Ombo, Junrejo, and Mulyoagung generally resembled each other, with species such as *A. cerana* and *T. laeviceps*, except for Pademonegoro, which was dominated by *A. mellifera* and *Xylocopa* sp. This study shows that the presence of *A. mellifera* and *A. cerana* can influence and slightly reduce pests but does not drastically alter the insect dynamics in red *P. guajava* orchards. Additionally, it highlights the importance of pollinators, especially the Apidae family, in *P. guajava* pollination.

ACKNOWLEDGEMENTS

The author (B.P.) would like to thank the Ministry of Education, Research, and Technology of the Republic of Indonesia through the Center for Higher Education Funding and Assessment of (PPAPT), and the Center for Higher Education Funding and Assesment (LPDP), as well as the Indonesian Education Scholarship (BPI) with grant number 02142/J5.2.3./BPI.06/9/2022 for providing funding for this research. The author would also like to thank all the assistant researchers (Abdul Mutholib Sahar, Muhammad Hasan Ilyas, Mochammad Nur Izzul, Caesar Rasendria, Riska Putri Qurrotaayunina and Farhani Nurshafa Rahmania) respectively.

REFERENCES

Abidin Z, Leksono AS, Yanuwiadi B, Purnomo M. 2020. Refugia effect on arthropods in an organic paddy field in Malang District, East Java, Indonesia. Biodiversitas 21: 1415-1421. DOI: 10.13057/biodiv/d210420.

Amin MR, Khisa S, Rahman H, Shipa AS, Jannat R, Amin MR. 2022. Abundance and diversity of insects on guava and foraging behavior of pollinators. Bangladesh J Ecol 1 (1): 31-34.

Basualdo M, Cavigliasso P, de Avila RS, Aldea-Sánchez P, Correa-Benítez A, Harms JM, Ramos AK, Rojas-Bravo V, Salvarrey S. 2022. Current status and economic value of insect-pollinated dependent crops in Latin America. Ecol Econ 196: 107395. DOI: 10.1016/j.ecolecon.2022.107395.

Eisenhauer N, Mueller K, Ebeling A, Gleixner G, Huang Y, Madaj AM, Roscher C, Weigelt A, Bahn M, Bonkowski M, Brose U, Cesarz S, Feilhauer H, Guimaraes-Steinicke C, Heintz-Buschart A, Hines J, Lange M, Meyer ST, Mohanbabu N, Isbell F. 2024. The multiple-mechanisms hypothesis of biodiversity, stability relationships. Basic Appl Ecol 79: 153-166. DOI: 10.1016/j.baae.2024.07.004.

Faraz A, Jamali MM, Kumar G, Mir SJ. 2023. Advances in Agricultural Entomology. Akinik Publications, New Delhi.

Hansen K, Sritongchuay T, Bumrungsri S, Simmons BI, Strange N, Dalsgaard B. 2020. Landscape-level effects of forest on pollinators and fruit set of Guava (*Psidium guajava* L.) in orchards across Southern Thailand. Diversity 12 (6): 259. DOI: 10.3390/d12060259.

Hemberger J, Gratton C. 2023. Floral resource discontinuity contributes to spatial mismatch between pollinator supply and pollination demand in a pollinator-dependent agricultural landscapes. Landsc Ecol 38: 4439-4450. DOI: 10.1007/s10980-023-01707-w.

Ihsanuddin I, Hidayat K, Sukesi K, Keppi Y. 2021. The policy challenge of private land management for conservation of yellow-crested cockatoo and its habitat in Masakambing Island, Indonesia. Bhumi 5 (3): 53-61. DOI: 10.31292/jb.v5i3.390.

Indhu A, Lazar J, Prasad S, Anupapama K. 2022. Pollinators in tropical ecosystems of Southern India with emphasis on the native pollinators *Apis cerana indica* and *Tetragonula iridipennis*. Indian J Entomol 1: 1-13. DOI: 10.55446/ije.2021.369.

Joanna JJ, Fisher J, Rijal JP, Zalom FG. 2021. Temperature and humidity interact to influence brown marmorated stink bug (Hemiptera: Pentatomidae), survival. Environ Entomol 50 (2): 390-398. DOI: 10.1093/ee/nvaa146.

Khalifa A, Elshafiey EH, Shetaia AA, El-Wahed AAA, Algethami AF, Musharraf SG, AlAjmi MF, Zhao C, Masry AHD, Abdel-Daim MM, Halabi MF, Kai G, Naggar YA, Bishr M, Diab MAM, El-Seedi HR. 2021. Overview of bee pollination and its economic value for crop production. Insect 12 (8): 688. DOI: 10.3390/insects12080688.

Leksono AS. 2017. Ekologi Arthropoda. UB Press, Malang.

Leksono AS, Mustafa I, Afandhi A, Zairina A. 2019. Habitat modification with refugia blocks for improving arthropod richness and diversity in paddy field. Intl J Civil Eng Technol 10 (8): 256-263.

Leksono AS, Mustafa I, Gama ZP, Afandhi A, Zairina. 2020. Organic farming system of cocoa plantations in South Malang, Indonesia. IOP Conf Ser Earth Environ Sci 743: 012030. DOI: 10.1088/1755-1315/743/1/012030.

Llorente I, Odriozola MD, Baraibar-Diez E. 2023. Global Value Chains. In: Idowu SO, Schmidpeter R, Capaldi N, Zu L, Del Baldo M, Abreu R (eds). Encyclopedia of Sustainable Management. Springer, Cham.

Manna DW, Afandhi A, Tarno H. 2021. Diversity and abundance of insect on shallot (*Allium ascalonicum* L.) with Integrated Pest Management (IPM) and conventional patterns. Res J Life Sci 8 (3): 34-42. DOI: 10.21776/ub.rjls.2021.008.03.3.

Huda NA. 2021. Pollination in the tropics: Role of pollinator in guava production. Intl J Life Sci Biotechnol 4 (3): 623-639. DOI: 10.38001/ijlsb.907696.

Oi CA, Brown RL, Sumner S. 2024. Bee-Ing positive about wasp-negative media reporting: The opinions of scientists and their influence on the media. Insect Soc 71 (1): 29-42. DOI: 10.1007/s00040-024-00952-9.

Omar NA, Zariman NA, Huda AN. 2021. Pollination in the tropics: Role of pollinator in guava production. Intl J Life Sci Biotechnol 4 (3): 623-639. DOI: 10.38001/ijlsb.9076962021.

Osterman J, Mateos-Fierro Z, Siopa C, Castro H, Castro S, Eeraerts M. 2024. The impact of pollination requirements, pollinators, landscape and management practices on pollination in sweet and sour cherry: A systematic review. Agric Ecosyst Environ 374: 109163. DOI: 10.1016/j.agee.2024.109163.

Patel V, Pauli N, Biggs E, Barbour L, Boruff B. 2021. Why bees are critical for achieving sustainable development. Ambio 50: 49-59. DOI: 10.1007/s13280-020-01333-9.

Purwantiningsih B, Leksono AS, Yanuwiyadi B, Gama ZP. 2024. Inventory of plants as food source for *Apis* sp. and *Trigona* sp. in Tlekung Batu East Java Indonesia. IOP Conf Ser: Earth Environ Sci 1302 (1): 012065. DOI: 10.1088/1755-1315/1302/1/012065.

Purwantiningsih B, Leksono AS, Yanuwiyadi B, Gama ZP. 2024. Abundance and diversity of insect visitor to ground cover plants in organic orchard with bee hives (*Apis mellifera*) in Batu, Indonesia. Acta Univ Agric Silvic Mendel Brun 72: 153-164. DOI: 10.11118/actaun.2024.010.

Rizal AN, Putra NS, Suputa S. 2018. Comparison of feeding ability between *Ischiodon scutellaris* (Diptera: Syrphidae) and *Menochilus sexmaculatus* (Coleoptera: Coccinellidae) on *Aphis craccivora* (Hemiptera: Aphididae). Jurnal Perlindungan Tanaman Indonesia 22 (2): 210. DOI: 10.22146/jpti.26191.

Runnel K, Tedersoo L, Krah FS, Piepenbring M, Scheepens JF, Hollert H, Johann S, Meyer N, Bässler C. 2024. Toward harnessing biodiversity, ecosystem function relationships in fungi. Trends Ecol Evol 40 (2): 180-190. DOI: 10.1016/j.tree.2024.10.004.

Saji A, Nagarajaiah SB, Naik SNR. 2022. *Psidium guajava* L. single plant with abundant health benefits: A review. World Sci Res 9 (1): 1-19. DOI: 10.20448/wsr.v9i1.3842.

Sarjan M, Haryanto H, Supeno B, Jihadi A. 2023. Using the refugia plant as an alternative habitat for predatory insects on potato plants. Jurnal Biologi Tropis 23 (2): 203-207. DOI: 10.29303/jbt.v23i2.4426.

Trani JCD, Ramirez VM, Barba A, Anino Y. 2023. Foraging patterns of bees in watermelon (*Citrullus lanatus* Thunb.) flowers in Panama. J Anim Behav Biometeorol 11: E2023022. DOI: 10.31893/jabb.23022.

Verma RC, Waseem MA, Sharma N, Bharathi, Singh S, Rashwin A, Pandey S, Singh BV. 2023. The role of insects in ecosystems, an in-depth review of entomological research. Intl J Environ Clim Change 13 (10): 4340-4348. DOI: 10.9734/ijecc/2023/v13i103110.

Widhiono I, Sudiana E, Suryaningsih S. 2022. Short communication: Impact of introduction of managed honey bee colony on wild bee diversity and abundance in an agroecosystem in Indonesia. Biodiversitas 23 (2): 1099-1104. DOI: 10.13057/biodiv/d230254.

Zulfaidah PG, Agustina E. 2022. The dynamics of environmental change pose challenges to preserving the biocultural landscape in Indonesia. In: Abdullah SA, Leksono AS, Hong SK (eds). Conserving Biocultural Landscapes in Malaysia and Indonesia for Sustainable Development. Springer, Singapore.