BIODIVERSITAS
Volume 25, Number 1, January 2024
Pages: 240-248

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d250127

Diversity and foraging activity of coffee insect pollinators in land near and far from the forest of North Sumatra, Indonesia

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Manuscript received: 4 December 2023. Revision accepted: 24 January 2024.

Abstract. *Sinaga RR, Maryana N, Hidayat P. 2024. Diversity and foraging activity of coffee insect pollinators in land near and far from the forest of North Sumatra, Indonesia. Biodiversitas 25: 240-248.* Coffee (*Coffea* spp.) is among the plant species that depend on insects to aid in its pollination process, where insect pollinators serve as intermediaries facilitating plant pollination. This study examined the diversity, abundance, and visiting activity of insect pollinators in coffee cultivation located in different areas, specifically those near the forest and those far from the forest in Simalungun District, North Sumatra. The study was carried out from September 2022 to February 2023 in six coffee cultivation sites spread across four sub-districts in Simalungun District, i.e., Silimakuta, Pematang Silimakuta, Purba, and Dolok Silau. The study's results revealed the presence of 16 species of insect pollinators in coffee cultivation near the forest and 13 species in those located far from the forest. The identified insect pollinators species were from Order Hymenoptera; *Apis cerana*, *Lasioglossum* sp., *Dolichovespula norvegicoides*, Diptera; *Stomorhina discolor*, *Musca domestica*, *Bactrocera papayae*, *Nephrotoma flavescens*, *Episyrphus viridaureus*, *Oebalia* sp., Coleoptera; *Pachnaeus* sp., *Cantharis* sp., Scarabaeidae sp.1., *Maladera japonica*, Lepidoptera; *Agrotis segetum*, *Bradina diagonalis*, and *Nyctemera baulu*s. Notably, the abundance of coffee insect pollinators was more pronounced in close proximity to the forest compared to areas far from the forest. Regarding the visiting duration of these insects, *S. discolor* exhibited the longest visit duration of 76.46±1.19 seconds per flower, and the shortest duration in *A. cerana* was recorded at 8.35±0.23 seconds per flower.

Keywords: Abundance, *Apis cerana*, arabica coffee, foraging rate, *Stomorhina discolor*

INTRODUCTION

Coffee is an important plantation commodity in fostering Indonesia's economic expansion, actively contributing to the nation's foreign exchange (Rico et al. 2021). Coffee is a globally high traded soft commodity (Moreaux et al. 2022). Following Brazil, Vietnam, and Colombia, Indonesia is fourth among the top global coffee bean producers (Directorate General of Plantations 2022). The current production of coffee plantations in Indonesia has surpassed 1.25 million hectares, predominantly led by smallholder plantations, contributing an average of 98.14% to large plantations of 1.86% (Directorate General of Plantations 2022). Coffee plantations in Indonesia are spread across the main islands, including Sumatra, Bali, Java, Maluku, Nusa Tenggara, Sulawesi, and Papua. Indonesia's top five coffee-producing provinces are on the island of Sumatra, i.e., Aceh, North Sumatra, South Sumatra, Bengkulu, and Lampung (Directorate General of Plantations 2022). Simalungun District, located in North Sumatra Province, is recognized as one of the Arabica coffee-producing areas (North Sumatra Central Statistics Agency 2018). The coffee commodity has long been part of the farming business of the highland communities in Simalungun District.

Coffee is one of the plants whose pollination process is assisted by insects (Gomez et al. 2023). Pollination is moving pollen from the anther to the stigma, which occurs naturally or with the assistance of humans or animals (Prado et al. 2020). In the pollinating diverse flowering plants within natural and agricultural environments, insect pollinators play a significant role (Bentrup et al. 2019). Insects that aid in the pollination process of plants mainly from the orders Diptera (flies), Hymenoptera (wasps and bees), Coleoptera (beetles), and Lepidoptera (butterflies and moths) (Rader et al. 2015). Various crops cultivated globally exhibit a positive association between crop production and the abundance and diversity of pollinators (Garibaldi et al. 2016). Pollination exemplifies an ecosystem service critical for agricultural production, influencing 75% of globally crucial crop varieties yield (Hipolito et al. 2018).

Plants that insects pollinate are capable of achieving higher yields compared to those that undergo self-pollination (Depra et al. 2014). In coffee, particularly the arabica variety, even though it is not categorized as a dependent crop due to its autogamous nature, pollinators have the potential to enhance productivity, with an average increase of 31% (Hipolito et al. 2018). In addition to the quantitative results, insect pollinators can enhance the quality of coffee, as indicated by the size and weight of the berries, as well as the overall quality of the coffee beans (Classen et al. 2014). The assistance of insect pollinators in nature could contribute to the success of pollination, thereby improving the quality and quantity of coffee fruits produced (Parikesit et al. 2018). The mutualistic symbiosis among insect pollinators and flowering plants occurs as flowers supply insects with pollen and nectar as food, and in turn, plants benefit from the pollination process (Ranjitha et al. 2019).

The surrounding habitat conditions influence the diversity of insect pollinators in an agricultural habitat. Preserving natural habitats contributes effectively to the diversity of pollinator communities (Senapathi et al. 2015). According to Williams (2011), forests demonstrate a more valuable diversity and abundance of insect pollinators than other areas like plantations and rice fields managed by humans. Consequently, ecosystems close to natural habitats, such as forests, are anticipated to possess a higher diversity and abundance of insect pollinators than those far from forests. Medeiros et al. (2019) demonstrated that forest cover influences bee diversity, indicating that communities with low forest cover have less insect diversity than those with higher cover. This study explored the diversity, abundance, and visiting activity of insect pollinators in coffee cultivation located in different areas, specifically those near and far from the forest in Simalungun District, North Sumatra, Indonesia.

MATERIALS AND METHODS

Study area and period

The study was conducted at six locations within four sub-districts of Arabica coffee production in Simalungun District (Figure 1) from September 2022 to February 2023. The four sub-districts are Silimakuta, Pematang Silimakuta, Purba, and Dolok Silau (Table 1). The insect pollinators were identified at the Insect Biosystematics Laboratory, Department of Plant Protection, Faculty of Agriculture, Institut Pertanian Bogor, Indonesia.

Table 1. Study location description in Simalungun District, North Sumatra, Indonesia

Sub-district	Coordinates	Altitude (m asl)	Coffee age (years)	Wide (m^2)	Distance from the forest (m)
Silimakuta/Saribu Dolok-1	2° 56'55.3"S 98° 36'53.0"T	1,396	6	7,500	< 500
Silimakuta/Saribu Dolok-2	2° 57'51.7"S 98° 35'57.0"T	1,386	5	5,000	< 500
Pematang Silimakuta/Rakut Besi	2° 58'10.7"S 98° 37'09.9"T	1,400	4	10,000	< 500
Purba/Bandar Mariah	2° 58'33.3"S 98° 40'06.1"T	1,284	5	5,000	> 4,000
Silimakuta/Sinar Baru	2° 58'05.3"S 98° 39'06.3"T	1,275	6	7,500	> 4,000
Dolok Silau/Panribuan	3° 01'10.8"S 98° 38'03.5"T	1,291	5	7,500	> 4,000

Note: m asl.: meters above sea levels

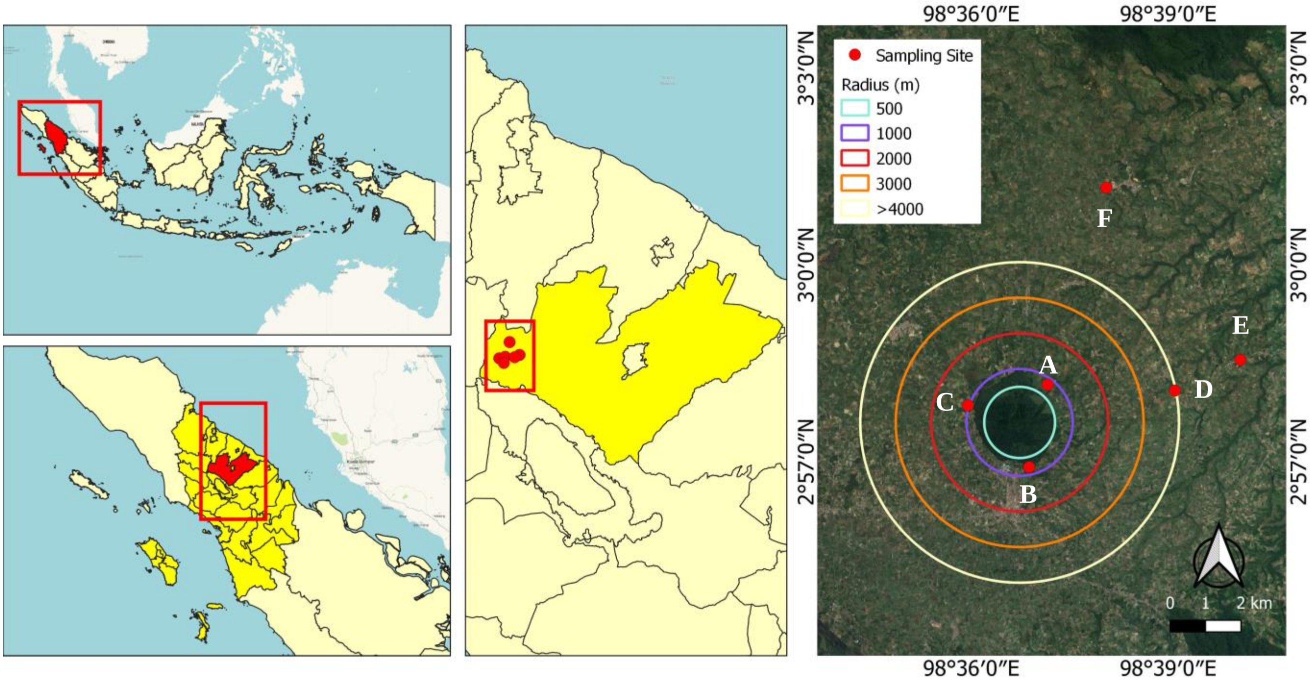

Figure 1. Map of the study area in Simalungun District, North Sumatra, Indonesia. A. Silimakuta/Saribu Dolok-1, B. Silimakuta/Saribu Dolok-2, C. Pematang Silimakuta/Rakut Besi, D. Purba/Bandar Mariah, E. Silimakuta/Sinar Baru, F. Dolok Silau/Panribuan

Determination of research locations and plots

The research location was a farming area that met several criteria, i.e., 1) having coffee cultivation fields in the flowering stage, 2) a minimum coffee cultivation area of 0.50 hectares, and 3) a minimum distance research locations from one site samplings to the other site samplings in the same land type (near or far from the forest) was 2,000 meters. The study consisted of two different land locations: land near the forest (<500 m) and land far from the forest (>4,000 m). The coffee cultivation near the forest was located around Mount Singgalang. The research plots were established using a systematic diagonal method, resulting in five sub-plot observation points; each research sub-plot involved observing five plants, totaling 25 plants to be observed in each land area.

Observation of insect pollinator diversity

The observation of insect pollinator diversity was conducted in four periods: morning from 08.00 to 10.00 a.m., daylight from 10.00 to 12.00 a.m., afternoon from 01.00 to 03.00 p.m. during clear or non-rainy weather, and evening from 07.00 to 09.00 p.m. Insect sampling was carried out on 25 plants in each field, and each field consisting of 5 research sub-plots which was observed for 20 minutes/sub-plot. Each field was observed six times. Insect pollinator sampling from coffee flowers was performed using an insect net. The insects obtained were conserved in 70% ethanol before identification. During the sampling process at each location, environmental variables measurements were also conducted at specific hours, i.e., at 08.00, 09.00, 11.00 a.m., and 01.00 p.m. The environmental variables measured included wind velocity using anemometer, relative humidity using thermo-hygrometer, air temperature thermo-hygrometer and, light intensity using luxmeter.

Observation of insect pollinator visitation activity

Observing insect pollinators' visitation activities in coffee cultivations was visually conducted using the focal sampling method on *Apis cerana* bees and *Stomorhina discolor* flies with a stopwatch (Figure 2). In this observation, insects were not captured; instead, only their visiting activities were observed. The observed visitation activities included the number of flowers visited per minute (foraging rate), the duration of each visit (handling time), and the total time spent on plant visitation. The observation of visitation activities was carried out between 08.00 a.m. to 04.00 p.m. every day and continued for a period of 12 days (6 days for *A. cerana* and 6 days for *S. discolor*), by calculating the mean of ten sub samples each.

Insect identification

Insects obtained from the field were identified to the family, subfamily, genus, or species level. Identification was conducted based on observations of the morphological characteristics of insect pollinators using identification keys according to Alexander and Byers (1981), Foote and Steyskal (1992), Huckett and Vockeroth (1992), Shewell (1992), Vockeroth and Thompson (1992), Goulet and Huber (1993), Michener (2000), Buck et al. (2008), Gibbs (2010), Engel (2012), Wright and Skevington (2013), Yang et al. (2014), and Larasati et al. (2016). The morphological characters used for identification were wings, antennae, mouth type, legs, thorax, and abdomen.

Data analysis

The obtained data was tabulated using Microsoft Excel 2016 and R Studio software. Subsequently, a one-way Analysis of Variance (ANOVA) was employed for data analysis, and significant distinctions were identified through the Tukey test with a confidence level of 95%. Additionally, Pearson correlation was utilized to examine the connection between environmental data and the abundance of individuals and species of insect pollinators. The analysis results were presented as boxplots, diagrams, and tables.

RESULTS AND DISCUSSION

Diversity of insect pollinators in coffee flowers

Based on the observation results, there were four orders of insect pollinators in coffee cultivations, i.e., Hymenoptera, Lepidoptera, Coleoptera, and Diptera. The highest percentage of insect pollinators in coffee flowers was observed in the location near the forest, with the following distribution: Hymenoptera (1,215), Diptera (1,094), Coleoptera (307), and Lepidoptera (113). In contrast, in the location far from the forest, the distribution was as follows: Diptera (1,405), Hymenoptera (460), Coleoptera (200), and Lepidoptera (50) (Figure 3). The insect pollinators in areas near the forest comprised 16 species, while those far from the forest comprised 13.

Based on observations conducted in coffee cultivations near the forest, *Apis cerana* was the most abundant insect pollinator with the highest number of individuals (1,123 individuals; 41.15%), followed by *Stomorhina discolor* (635 individuals; 23.27%), and *Musca domestica* (234 individuals; 8.57%) (Table 1). In contrast, observations in coffee cultivations far from the forest reveal that *Stomorhina discolor* was the predominant insect pollinator with the highest number (1,238 individuals; 58.53%), followed by *Apis cerana* (389 individuals; 18.39%), and *Musca domestica* (153 individuals; 7.23%) (Table 2). The abundance of coffee insect pollinators in areas near the forest (2,729 individuals) was higher than those far from the forest (2,115 individuals). This difference was attributed to the varying distances between cultivations and the forest and the species of insect pollinators visiting the area.

Figure 2. Coffee Insect Pollinators; A. *Apis cerana* Bees; B. *Stomorhina discolor* Flies

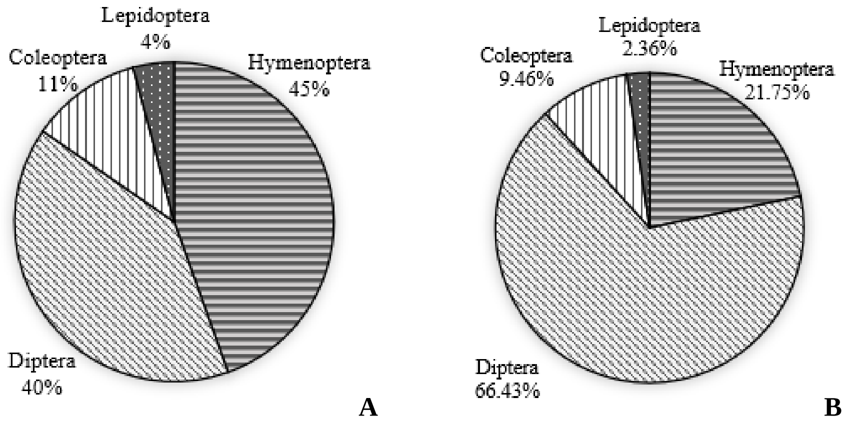

Figure 3. Percentage of individuals for each order of insect pollinators in coffee flowers. A. Location near the forest. B. Location far from the forest

Table 1. Species and number of insect pollinators in the coffee cultivation near the forest

Order Family Species	Number of individuals Morning (08-10 a.m.)	 Daylight (10-12 a.m.)	 Afternoon (01-03 p.m.)	 Evening (07-09 p.m.)	Total	Percentage (%)
Hymenoptera						
Apidae						
Apis cerana	794	196	133	0	1,123	41.15
Halictidae						
Lasioglossum sp.	73	18	0	0	91	3.33
Vespidae						
Dolichovespula norvegicoides	0	1	0	0	1	0.04
Diptera						
Calliphoridae						
Stomorhina discolor	171	317	134	13	635	23.27
Muscidae						
Musca domestica	113	66	55	0	234	8.57
Tephritidae						
Bactrocera papayae	54	43	39	0	136	4.98
Tipulidae						
Nephrotoma flavescens	7	0	1	12	20	0.73
Syrphidae						
Episyrphus viridaureus	29	20	17	0	66	2.42
Sarcophagidae						
Oebalia sp.	0	3	0	0	3	0.11
Coleoptera						
Curculionidae						
Pachnaeus sp.	2	36	4	0	42	1.54
Cantharidae						
Cantharis sp.	44	37	27	18	126	4.62
Scarabaeidae						
Scarabaeidae sp 1.	30	61	22	0	113	4.14
Maladera japonica	0	0	0	26	26	0.95
Lepidoptera						
Noctuidae						
Agrotis segetum	0	0	0	42	42	1.54
Crambidae						
Bradina diagonalis	0	0	0	43	43	1.58
Erebidae						
Nyctemera baulus	0	0	0	28	28	1.03
Number of individuals	1,317	798	432	182	2,729	100
Number of species	10	11	9	7	16	

Table 2. Species and number of insect pollinators in coffee cultivation far from the forest

Order Family Species	Number of individuals					
	Morning (08-10 a.m.)	Daylight (10-12 a.m.)	Afternoon (01-03 p.m.)	Evening (07-09 p.m.)	Total	Percentage (%)
Hymenoptera						
Apidae						
Apis cerana	262	106	21	0	389	18.39
Halictidae						
Lasioglossum sp.	37	27	4	0	68	3.22
Vespidae						
Dolichovespula norvegicoides	0	0	3	0	3	0.14
Diptera						
Calliphoridae						
Stomorhina discolor	574	386	261	17	1,238	58.53
Muscidae						
Musca domestica	54	29	70	0	153	7.23
Tephritidae						
Bactrocera papayae	1	8	5	0	14	0.66
Coleoptera						
Curculionidae						
Pachnaeus sp.	1	15	13	0	29	1.37
Cantharidae						
Cantharis sp	1	7	15	0	23	1.09
Scarabaeidae						
Scarabaeidae sp 1.	1	82	35	0	118	5.58
Maladera japonica	0	0	0	30	30	1.42
Lepidoptera						
Noctuidae						
Agrotis segetum	0	0	0	18	18	0.85
Crambidae						
Bradina diagonalis	0	0	0	22	22	1.04
Erebidae						
Nyctemera baulus	0	0	0	10	10	0.47
Number of individuals	931	660	427	97	2,115	100
Number of species	8	8	9	5	13	

Table 3. Pearson correlation between the number of species, number of individuals, and environmental variables

Environmental variables	Correlation value (r)		p-value	
	Number of species	Number of individuals	Number of species	Number of individuals
Air temperature	-0.015	-0.651	0.97	0.16
Humidity	-0.100	0.670	0.85	0.15
Light intensity	0.765	-0.210	0.08	0.69
Wind velocity	0.400	-0.095	0.43	0.86

Abundance of insect pollinators based on observation time and environmental factors

Based on observations, the total peak of insect pollinator visits in all observations occurred from 08.00 to 10.00 a.m., started to decline from 01.00 to 03.00 p.m., and was very low from 07.00 to 09.00 p.m. (Figure 4). The research results also indicated that the number of insect pollinator visits in different periods was higher in coffee cultivations near the forest compared to coffee cultivations far from the forest. The three dominant species found in coffee cultivations in land near and far from the forest were *Apis cerana*, *Stomorhina discolor*, and *Musca domestica*. These three species individuals were high at 08.00-10.00 a.m. (*Apis cerana* and *Musca domestica*) and 10.00-12.00 a.m. (*Stomorhina discolor*) inland near the forest. Meanwhile, these three species were high inland, far from the forest at 08.00-10.00 a.m. The peak visits to land near and far from the forest occurred at 09.00 a.m.

Environmental variables, such as wind velocity, temperature, air humidity, and light intensity, influenced insect pollinators' diversity. Based on Pearson correlation analysis, the number of insect species was not correlated with temperature, humidity, and wind velocity but was positively correlated with light intensity, although not significantly. Additionally, the analysis indicated that the number of individuals correlated with temperature and humidity, but not significantly, whereas there was no correlation between light intensity and wind velocity (Table 3). The activity of insect pollinators in searching for food will be increased with increasing air temperature and decreasing air humidity.

Abundance of *Apis cerana* Bees

Bees were usually found on flowering plants. The total abundance of *A. cerana* in land near and far from the forests was high in the morning, followed by a decline in the daylight to afternoon (Figure 5). Insect pollinator visits typically occurred in the morning, which was related to plant resources, notably pollen, and the accessibility of nectar as a food source for insect pollinators. The abundance of *A. cerana* in coffee cultivations near the forest was three times higher than in coffee cultivations far from the forest (Figure 6); the distance between the coffee cultivation and the forest influenced this. The closer the distance between the coffee cultivation and the forest, the easier it was for insect pollinators to get the nutrients and food they needed. As a semi-natural habitat, the forest edge provided essential resources for insect pollinators and could help sustain pollination services in agroecosystems.

Insect pollinators visitation activity

The insect pollinator's visitation activity showed differences in the duration of visits per flower, the number of flowers visited per minute, and the total visitation duration per plant. The longest visitation duration occurred in the fly *S. discolor* (76.46±1.19 seconds/flower) (mean ±SD), and the shortest in the bee *A. cerana* (8.35±0.23 seconds/flower). Therefore, *A. cerana* visited the highest number of flowers per minute (7.51±0.13 flowers/minute), while *S. discolor* visited the fewest flowers per minute (0.78±0.02 flowers/minute). The shortest total visitation duration per plant occurred in the bee *A. cerana* (2.62±0.24 minutes), and the longest occurred in the fly *S. discolor* (35.15±1.82 minutes) (Figure 7). The research results indicated that the bee pollinator *A. cerana* visited flowers for a shorter duration than the fly pollinator *S. discolor*. The shorter duration of insect visitation activity per flower allows bee pollinators to visit more flowers per unit of time.

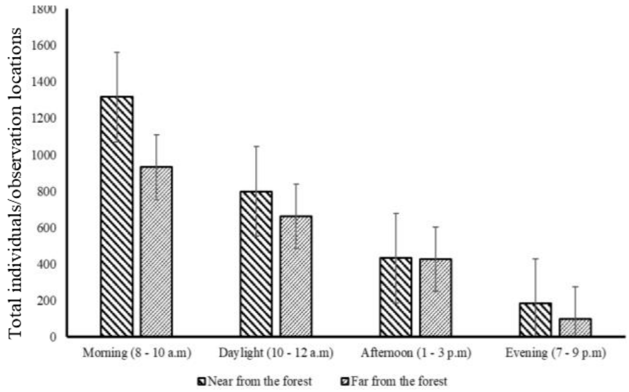

Figure 4. Coffee pollinator insects are abundant at different periods near and far from the forest. Bars indicate standard error

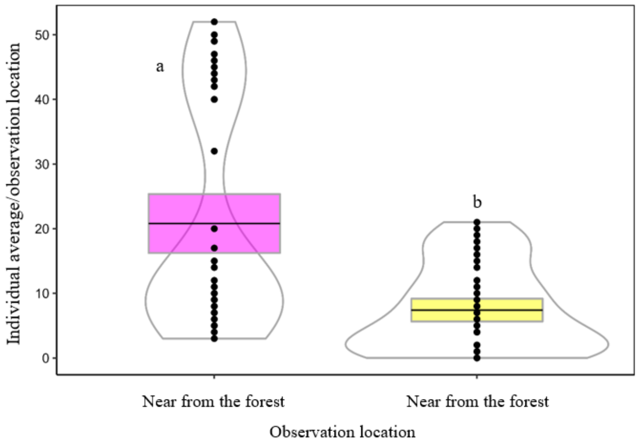

Figure 6. Average abundance of *Apis cerana* bees in near and far from the forest. The same letters above the boxplot indicate no significant difference in the Tukey test with α = 5%

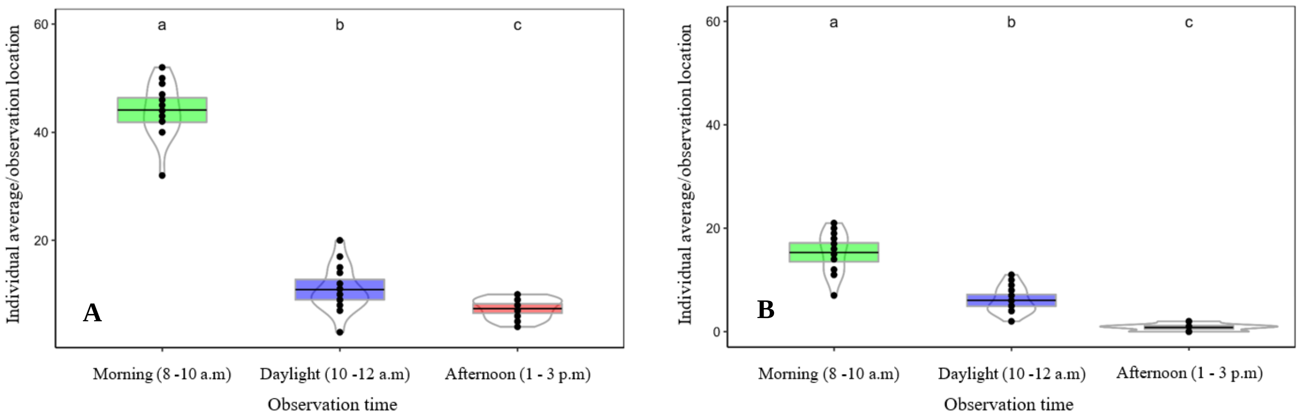

Figure 5. Average abundance of *Apis cerana* bees in different periods and locations. A. Near to the forest. B. Far from the forest. The same letters above the boxplot indicate no significant difference in the Tukey test with α = 5%

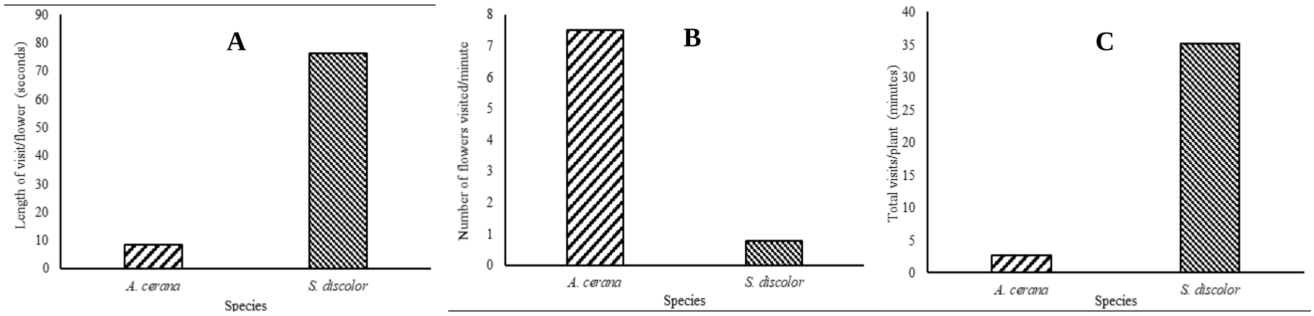

Figure 7. Activity of visits by *Apis cerana* and *Stomorhina discolor*. A. Length of visit per flower. B. Number of flowers visited per minute. C. Total duration of visit per plant

Discussion

The diversity and abundance of coffee pollinator insects were more commonly found in land near the forest compared to those far from the forest. This difference was attributed to variations in the distance between the coffee cultivations and the forest and the species of visiting insect pollinators. The results of the study conducted by Bravo-Monroy et al. (2015) indicated that the closeness of coffee agricultural areas to the forest amplified the abundance of insect pollinators. Sheffield et al. (2013) reported that the edge habitat of the forest has a higher abundance of insect pollinators than intensively managed agricultural lands. Research by Vergara and Badano (2009) also indicated that the diversity of insect pollinators is higher in coffee cultivations located under the forest canopy than in those not adjacent to the forest. Therefore, ecosystems near natural habitats like forests have greater diversity and abundance of insect pollinators than ecosystems distant from the forest (Widhiono and Sudiana 2016).

The most commonly found insect pollinators in coffee cultivations belong to the groups of bees (Hymenoptera) and flies (Diptera). Coffee flowers near the forest were more frequently visited by *Apis cerana*, while coffee flowers far from the forest were more commonly visited by *Stomorhina discolor*. This occurred because the forest edge offers nesting sites for insect pollinators, particularly bees (Koneri et al. 2021). Saturni et al. (2016) also asserted that natural habitats such as forests provide food and nesting resources for insect pollinators. The bees from Hymenoptera were the primary pollinators of flowers and played a crucial role in enhancing agricultural production (Shrestha 2008). While bees were acknowledged as crucial pollinators, it's important to note that non-bee species also play equally vital roles (Rader et al. 2015). The Diptera group, including Calliphoridae, Rhiniidae, and Sarcophagidae, is predominantly considered beneficial. Adult flies, especially males, visit flowers to seek nectar, and many species within this group serve as pollinators (El-Hawagry and El-Azab 2019). Several nocturnal pollinator insects were also found in coffee plantations near and far from the forest. The insects active during the night belonged to the orders Diptera, Coleoptera, and Lepidoptera. This research was supported by Knop et al. (2017), stating that there were diverse communities of nocturnal pollinators, including moths, flies, and beetles. The most commonly found pollinator in coffee plantations at night was the moth. Moths were recognized as the primary pollinators of various plants in different habitats worldwide (Macgregor et al. 2015).

Environmental variables, such as air humidity, temperature, wind velocity, and light intensity, influenced the diversity of insect pollinators (Atmowidi et al. 2007). In the research conducted, the average air temperature, humidity, and wind velocity at the peak of insect pollinators visit in coffee plantations near and far from the forest were found to be 24.50° C; 76%; 0.52 m/s and 25.70° C; 74%; 0.77 m/s, respectively. According to findings by Cholis et al. (2020), the peak visitation of insect pollinators was recorded at 8:00 a.m., with a temperature of 29.41° C and humidity of 72.77%, decreasing beyond 30° C. Putra and Kinasih (2014) also noted increased activities of honey bees and stingless bees around 30° C, while temperatures exceeding 30° C led to a decline in their activities. The foraging behaviors of insect pollinators were significantly affected by temperature fluctuations during their food search. Temperature plays a crucial role because the energy required by insect pollinators is contingent on the environmental temperature. The optimal temperature range for insect pollinators to feed was between 16-32°C. Insect pollinators refrained from engaging in activities when the temperature fell below 8°C, although some activities may occur at temperatures ranging from 8-16°C. Feeding activities were also halted when the temperature exceeded 32°C, with an average temperature of 24.79°C deemed optimal for insect pollinators to forage (Parikesit et al. 2018). Ruslan et al. (2015) stated that lower temperatures and high humidity lead to a decrease in bee activities on flowers. Bees utilize a thermoregulation mechanism to maintain body temperature during flight (Tan et al. 2014). Wind velocity also affects feeding activities, especially during flight. Strong winds will reduce or even stop the feeding activities of insect pollinators (Parikesit et al. 2018).

Honeybees were effective pollinators for various types of plants (Alpionita et al. 2021). The abundance of *A. cerana* was high in the morning due to increased pollen and nectar availability, which decreased in the afternoon. (Tschoeke et al. 2015). *A. cerana* demonstrated greater abundance in coffee cultivations near the forest than at a distance. This observation aligns with the findings of Widhiono and Sudiana (2016), who noted that the abundance of bees declines with the increasing distance from the forest's edge. The forest edge was an essential source of insect pollinators, providing a different partial habitat for bees (Bailey et al. 2014). Agriculture located at a considerable distance from natural areas was prone to experiencing decreased visitation by insect pollinator species and displaying more noticeable yield gaps compared to farms close to natural areas (Garibaldi et al. 2011).

The bee *A. cerana* visited flowers for a shorter duration than the fly pollinator *S. discolor*. This indicated that bees were more efficient as insect pollinators than flies (Masyitah et al. 2019). Bartomeus et al. (2014) asserted that elevated pollinator visits influenced the augmentation of crop yields. Foraging activity played a crucial role in comparing the efficiency of insect pollination (Joshi and Joshi 2010). The insect's behavior influenced the difference in visiting activity between bees and flies in obtaining pollen. The *A. cerana* bee actively gathered pollen and nectar through direct contact between its mouthparts and the anthers while extracting the nectar from the base of the flower. Pollen was collected in the corbicles found on the hind limbs of the insect's body and in the hairs found on the ventral part of the abdomen (Masyitah et al. 2019). *S. discolor* flies did not collect pollen and nectar but fed on pollen and nectar. This insect directly reaches the anther by attaching its mouthparts, and after the pollen is consumed, the fly moves to another anther. This feeding behavior causes the fly's visit to flowers to be long (Masyitah et al. 2019).

The research results concluded that the prevalence of diversity and abundance of insect pollinators in coffee cultivations was more frequent in land near the forest than in those farther away. The dominant insect pollinator in coffee cultivations near the forest was the *Apis cerana* bee. The *Stomorhina discolor* fly was the dominant insect pollinator inland far from the forest. The peak of pollinator visits in land near and far from the forest occurred in the morning, decreased from daylight to afternoon, and was lowest in the evening. This result only focused on observing the foraging rate of dominant insect pollinators with abundance exceeding 10%, indicating that the duration of the visit of *A. cerana* bees was shorter than that of *S. discolor* flies on coffee cultivations.

ACKNOWLEDGEMENTS

The authors would like to express their heartfelt appreciation to several people in the Laboratory of Insect Biosystematics, Department of Plant Protection, Institut Pertanian Bogor, Indonesia.

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