Research Article

Diversity of insect flower visitors of cayenne pepper in agricultural landscapes, Banggai, Central Sulawesi

Keanekaragaman serangga pengunjung bunga cabai rawit pada lanskap pertanian di Banggai, Sulawesi Tengah

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Recived: January 2023
Accepted: February 2023
Published: February 2023

p-ISSN: 2723-7974
e-ISSN: 2723-7966
doi: 10.52045/jca.v3i2.411

Website: https://ojs.untika.ac.id/index.php/faperta

Abstract: The existence of semi-natural habitats around agricultural land has the potential to support ecosystem services by providing resources for beneficial insects. The study aimed to analyze the abundance, diversity index, and evenness of the insects visiting cayenne flowers. This research was carried out in cayenne cultivation areas in the Banggai Regency. Sampling locations were divided into two categories: cayenne fields close to and far from forests or semi-natural habitats. Insect collection was carried out from June 2022 to August 2022, in the morning and evening, using insect nets. The results showed that 16 families and 52 cayenne flower-visiting insects were identified. *Lasioglossum* sp.3, *Lasioglossum* sp.5, *Megachile* sp.2, *?Parancistrocerus* sp. and *Rhynchium* sp. have a higher abundance than the others. The highest Shannon and Wiener diversity index was found in cayenne fields in Tolisu Village (H'= 2.491), Mansahang (H'= 2.216), Salodik (H'= 2.145) and the lowest in cayenne fields in Kembang Merta Village (H'= 1.211), Dale-Dale (H'= 1.112), and Beringin Jaya (H'= 1.149). The highest evenness index (E) was found in the fields in Lembah Makmur Village (E= 0.9721) and Mansahang (E= 0.9172), and the lowest was found in cayenne fields in Petak Village (E= 0.3975) and Lenyek (E= 0.4405). The highest species richness was found in cayenne fields in Tolisu (14 species), Salodik (14 species) and Petak (12 species). Cayenne fields in the three villages are close to semi-natural habitats. Our findings show that agricultural land adjacent to semi-natural habitats has increased the species richness of cayenne flower visitor insects. Thus, semi-natural habitats are critical to sustaining insect communities in agricultural landscapes.

Keywords: Semi-natural habitats, species richness, flower-visiting insects.

Abstrak: Keberadaan habitat semi-alami di sekitar lahan pertanian memiliki potensi untuk mendukung jasa ekosistem, dengan menyediakan sumber daya bagi serangga bermanfaat. Penelitian bertujuan untuk menganalisis kelimpahan, indeks keanekaragaman, dan kemerataan serangga pengunjung bunga cabai. Penelitian ini dilaksanakan di lahan pertanaman cabai di wilayah Kabupaten Banggai. Lokasi pengambilan sampel dibagi menjadi dua kategori yakni pertanaman cabai yang dekat dan jauh dari habitat semi-alami. Kolekasi serangga dilakukan sejak bulan Juni 2022 sampai Agustus 2022, pada pagi dan sore hari menggunakan jaring serangga. Hasil penelitian menunjukkan 16 famili dan 52 spesies serangga pengunjung bunga cabai teridentifikasi. *Lasioglossum* sp.3, *Lasioglossum* sp.5, *Megachile* sp.2, *?Parancistrocerus* sp. dan *Rhynchium* sp. memiliki kelimpahan yang lebih tinggi dari yang lain. Indeks keanekaragaman Shannon-Wiener tertinggi terdapat pada lahan cabai di Desa Tolisu (H'= 2.491), Mansahang (H'= 2.216), Salodik (H'= 2.145) dan yang terendah terdapat pada lahan cabai di Desa Kembang Merta (H'= 1.211), Dale-Dale (H'= 1.112), dan Beringin Jaya (H'= 1.149). Indeks kemerataan spesies (E) tertinggi terdapat pada lahan di Desa Lembah Makmur (E= 0.9721) dan Mansahang (E= 0.9172) dan yang terendah terdapat pada lahan cabai di Desa Petak (E= 0.3975), dan Lenyek (E= 0.4405). Kekayaan spesies tertinggi terdapat pada lahan cabai di desa Tolisu (14 spesies), Salodik (14 spesies) and Petak (12 spesies). Lahan cabai di tiga desa tersebut jaraknya dekat dengan habitat semi-alami. Temuan kami menunjukan bahwa lahan pertanian yang berdekatan dengan habitat semi-alami telah terbukti meningkatkan kekayaan spesies serangga pengunjung bunga cabai. Sehingga, habitat semi-alami sangat penting untuk mempertahankan komunitas serangga di lanskap pertanian.

Kata kunci: Habitat semi-alami, kekayaan spesies, serangga pengunjung bunga.

Citation:
Alingan PU, Sataral M & Qodri A. 2023. Diversity of insect flower visitors of cayenne pepper in agricultural landscapes, Banggai, Central Sulawesi. *Celebes Agricultural*. 3(2): 100-114. doi: 10.52045/jca.v3i2.411

INTRODUCTION

Plants coexisting with insects visiting flowers often form complex webs of interaction (Dupont & Olesen, 2009). One form of beneficial interaction is mutualistic interaction between insects and plants, namely as pollinators (Rollin et al., 2016; Nepi et al., 2018). Insect pollination is a globally important ecosystem service and provides economic benefits (Losey & Vaughan, 2006; Gill et al., 2016). Plant productivity benefits from the presence of pollinating insects or insects that visit flowers, so a decrease in the abundance of these insects can impact global agricultural production (Aizen et al., 2009). Flower visitor insects are essential insects in various types of plants (Soesanthy & Trisawa, 2011). On agricultural land, familiar flower visitors are bees (Meilin & Nasamsir, 2016). Insect attraction to plant flowers is influenced by various factors, including the number of flowers, flower colour, and flower size (Andrian & Maretta, 2017).

Many plants depend on insect pollination (Nicholls & Altieri, 2013). Cayenne pepper (*Capsicum annuum*) is an important horticultural crop with a high economic value (Ashour et al., 2021). Many factors affect the increase in cayenne production, including the flower visitor insect (Sataral et al., 2022). A widely reported decline in flower-visiting insect populations has been associated with limited resources (Høye et al., 2013). The research results by Pereira et al. (2015) show that increasing resources, including food sources in agricultural landscapes, can increase the number of insects visiting cayenne plants.

Maintenance of high-quality habitat around farms and local management practices can offset the intensive impact of monoculture farming (Kennedy et al., 2013). Retaining or promoting areas of native vegetation (Carvalheiro et al., 2012), flowering plants, and shrubs adjacent to farmland (Nicholls & Altieri, 2013; Peters et al., 2013; Blaauw & Isaacs, 2014) is a strategy to attract beneficial insects, thereby increasing pollination and yields. Due to the importance of the ecosystem services of flower visitor insects for crop production, it is critical to understand how the presence of semi-natural habitats around agricultural landscapes is affected. We hypothesize that semi-natural habitats around agricultural landscapes may influence flower-visiting insects communities. We analyze whether semi-natural habitats around agricultural landscapes can increase the diversity, richness and abundance of insect species that visit cayenne flowers.

MATERIALS AND METHODS

Study site

This research was carried out in cayenne cultivation areas in the Banggai Regency, namely in ten sub-districts (Figure 1). Insect collection was carried out from June 2022 to August 2022. Locations were chosen based on the distance from semi-natural habitats, namely far and near (Table 1). The characteristics of semi-natural habitats in this study are habitats with trees and shrubs.

Cayenne Flower Visitor Insect Collection

A sampling of cayenne flower-visiting insects was carried out along the cayenne fields. The collection was carried out by walking slowly between the rows of plants and observing the cayenne flower units on each row of plants and collected using a broom net. Sampling points were divided into two categories: cayenne plants near and far from forests or semi-natural habitats where planting used a monoculture cropping pattern. The collected samples of cayenne flower-visiting insects were put into a bottle containing cotton dripped with ethyl acetate liquid. After that, the insects were placed on papilot paper for dry collection, which was then taken to the laboratory of the Faculty of Agriculture, Tompotika Luwuk University.

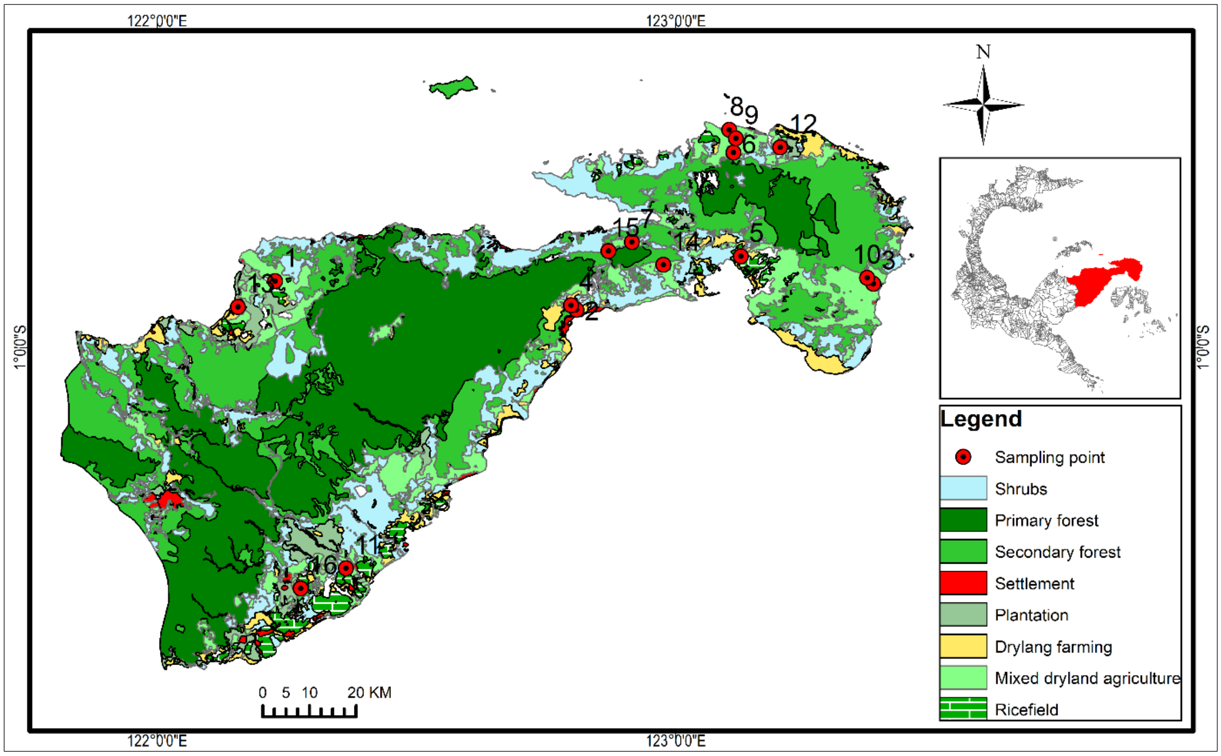

Figure 1. Map of the sampling locations for cayenne flower-visiting insects

Table 1. Sampling points for cayenne flower-visiting insects

No	Location	Geographical Coordinate	Distance from semi-natural habitat
1	Beringin Jaya	0°52'16"S, 122°13'39"E	Far
2	Bungin Timur	0°55'36"S, 122°48'30"E	Near
3	Dale-Dale	0°52'35"S, 123°22'51"E	Far
4	Keleke	0°55'04"S, 122°47'52"E	Far
5	Kembang Merta	0°49'24"S, 123°07'32"E	Far
6	Lembah Makmur	0°37.3930'S, 123°6.6710'E	Near
7	Lenyek	0°47'45"S, 122°54'55"E	Far
8	Longkoga Timur 1	0°34.7670'S, 123°6.1980'E	Near
9	Longkoga Timur 2	0°35.7380'S, 123°6.9670'E	Far
10	Mamping	0°51'54"S, 123°22'08"E	Near
11	Mansahang	1°25'31"S, 122°21'50"E	Far
12	Nipa Kalimoa	0°36.7780'S, 123°12.0970'E	Far
13	Petak	0°55'16"S, 122°09'20"E	Near

No	Location	Geographical Coordinate	Distance from semi-natural habitat
14	Pohi	0°50'23"S, 122°58'34"E	Far
15	Salodik	0°48'48"S, 122°52'12"E	Near
16	Tolisu	1°27'51"S, 122°16'36"E	Near

Insect Identification

Samples of cayenne flower visitor insects were identified based on morphological characters down to the species level or morphospecies referring to various references, among others CSIRO, (1990); CSIRO, (1991); Goulet & Huber, (1993); Triplehorn & Jhonson, (2005); Michener, (2007); Ohl & Höhn, (2011); Nadimi et al., (2013); Sheffield & Genaro, (2013); Dörfel & Ohl, (2015); Gulmez & Can, (2015); Broad & Shaw, (2016); Narendran & Van Achterberg, (2016); Pannure et al., (2016); Pham & Kumar, (2016); Augul, (2017); Engel et al., (2017); Straka et al., (2017); Okayasu et al., (2018); Ramage et al., (2018); Selis, (2018); Li et al., (2019); Astafurova et al., (2020); Fateryga et al., (2020); Handru et al., (2020); Ben Khedher et al., (2020); Taylor & Barthélémy, (2021); Yue et al., (2021), and some official web specimen catalogues i.e the barcode of life data systems (https://v3.boldsystems.org), Beaty Biodiversity Museum (https://www.zoology.ubc.ca/entomology/main), Plazi: Treatment Bank (http://treatment.plazi.org), and Global Biodiversity Information Facility (https://www.gbif.org/species/search).

Data analysis

Obtained insect data is tabulated in a pivot table using Microsoft Excel software. Insect data were analyzed using the Shannon-Wiener diversity index (H'), evenness index, and Bray-Curtis similarity index using PAST (Paleontological Statistics) version 4.03 (Hammer et al., 2001). The Bray-Curtis similarity index is displayed in the form of a dendrogram.

RESULTS

The number of insects visiting cayenne flowers found at the study site was 444 individuals, consisting of 16 families and 52 species (Table 2). Of the 16 observation points, the highest number of individuals sequentially was in the cayenne fields of Salodik Village (83 individuals), Petak (52 individuals), Bungin Timur (45 individuals), Lenyek (39 individuals), Longkoga Timur 1 (32 individuals), Longkoga Timur 2 (26 individuals), Tolisu (25 individuals), Kembang Merta (24 individuals), Pohi (22 individuals), Keleke (21 individuals), Mansahang (18 individuals), Dale-Dale (15 individuals), Nipa Kalimoa (13 individuals), Mamping (11 individuals) and the lowest was found in Lembah Makmur and Beringin Jaya Villages, respectively (9 individuals) (Table 3).

Table 2. Morphospecies and the number of individual cayenne flower-visiting insects found at the study site.

Ordo	Family	Species	Number of individuals
Diptera	Conopidae	*Conopidae* sp.	1
Diptera	Syrphidae	*Dideopsis* sp.	4

Ordo	Family	Species	Number of individuals
Diptera	Syrphidae	*Ischiodon scutellaris*	2
Hymenoptera	Apidae	*Amegilla* sp.	4
Hymenoptera	Apidae	*Tetragonula* sp.1	17
Hymenoptera	Apidae	*Tetragonula* sp.2	17
Hymenoptera	Apidae	*Thyreus* sp.	3
Hymenoptera	Apidae	*Xylocopa aestuans*	1
Hymenoptera	Apidae	*Xylocopa* sp.	4
Hymenoptera	Chalcididae	*Brachymeria* sp.1	3
Hymenoptera	Chalcididae	*Brachymeria* sp.2	2
Hymenoptera	Chalcididae	*Chalcididae* sp.	1
Hymenoptera	Chrysididae	*Stilbum cyanurum*	1
Hymenoptera	Crabronidae	*Cerceris* sp.1	2
Hymenoptera	Crabronidae	*Cerceris* sp.2	2
Hymenoptera	Crabronidae	*Dasyproctus agilis*	1
Hymenoptera	Dryinidae	*Dryinidae* sp.	1
Hymenoptera	Halictidae	*Halictidae* sp.1	2
Hymenoptera	Halictidae	*Halictidae* sp.2	4
Hymenoptera	Halictidae	*Lasioglossum* sp.1	4
Hymenoptera	Halictidae	*Lasioglossum* sp.2	5
Hymenoptera	Halictidae	*Lasioglossum* sp.3	115
Hymenoptera	Halictidae	*Lasioglossum* sp.4	2
Hymenoptera	Halictidae	*Lasioglossum* sp.5	62
Hymenoptera	Halictidae	*Sphecodes* sp.1	1
Hymenoptera	Halictidae	*Sphecodes* sp.2	1
Hymenoptera	Ichneumonidae	*Enicospilus* sp.	1
Hymenoptera	Megachilidae	*Anthidiini* sp.	4
Hymenoptera	Megachilidae	*Coelioxys* sp.	3
Hymenoptera	Megachilidae	*Megachile* sp.1	5
Hymenoptera	Megachilidae	*Megachile* sp.2	37
Hymenoptera	Megachilidae	*Megachile* sp.3	7
Hymenoptera	Megachilidae	*Megachile* sp.4	1
Hymenoptera	Megachilidae	*Megachile* sp.5	11
Hymenoptera	Mutillidae	*Eurymutilla* sp.	1
Hymenoptera	Pompilidae	*Pompilidae* sp.	2
Hymenoptera	Scoliidae	*Campsomeriella collaris*	3
Hymenoptera	Scoliidae	*Phalerimeris phalerata*	6
Hymenoptera	Sphecidae	*Ammophila* sp.	1
Hymenoptera	Sphecidae	*Chalybion sulawesii*	1
Hymenoptera	Sphecidae	*Sceliphron* sp.	2
Hymenoptera	Sphecidae	*Sphex* sp.1	4

Ordo	Family	Species	Number of individuals
Hymenoptera	Sphecidae	*Sphex* sp.2	4
Hymenoptera	Tiphiidae	*Tiphiidae* sp.	1
Hymenoptera	Vespidae	*Ancistrocerus* sp.	5
Hymenoptera	Vespidae	*Delta campaniforme*	8
Hymenoptera	Vespidae	*Eumenes* sp.	2
Hymenoptera	Vespidae	*Parancistrocerus* sp.	46
Hymenoptera	Vespidae	*Rhynchium* sp.	12
Hymenoptera	Vespidae	*Polistes celebensis*	5
Hymenoptera	Vespidae	*Ropalidia marginata*	6
Hymenoptera	Vespidae	*Vespa tropica*	4
			444

Table 3. Diversity and evenness of cayenne flower-visiting insects

Location	Number of individuals	Number of species	Shannon-Wiener index	Evenness index
Beringin Jaya	9	4	1.149	0.789
Bungin Timur	45	11	1.851	0.579
Dale-Dale	15	4	1.112	0.761
Keleke	21	6	1.502	0.749
Kembang Merta	24	6	1.211	0.559
Lembah Makmur	9	5	1.581	0.972
Lenyek	39	9	1.377	0.441
Longkoga Timur 1	32	9	1.537	0.517
Longkoga Timur 2	26	10	2.101	0.818
Mamping	11	6	1.594	0.821
Mansahang	18	10	2.216	0.917
Nipa Kalimoa	13	6	1.586	0.814
Petak	52	12	1.562	0.398
Pohi	22	10	1.996	0.736
Salodik	83	14	2.145	0.610
Tolisu	25	14	2.491	0.862

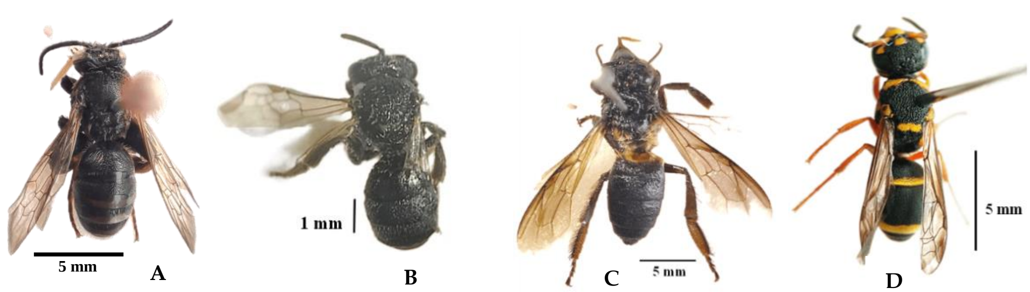

Figure 2. The dominant cayenne flower-visiting insects found at the study site: *Lasioglossum* sp.3 (A), *Lasioglossum* sp.5 (B), *Megachile* sp.2 (C), and ?*Parancistrocerus* sp. (D).

The highest number of cayenne flower-visiting insects were *Lasioglossum* sp.3 (115 individuals), followed by *Lasioglossum* sp.5 (62 individuals), and *Megachile* sp.2 (37 individuals), which is a type of bee and *?Parancistrocerus* sp. (46 individuals) and *Rhynchium* sp. (12 individuals) are types of wasps (Figure 2). Based on the value of species diversity using the Shannon-Wiener diversity index (H'), relatively high values were found in cayenne fields in the villages of Tolisu (H'= 2.491), Mansahang (H'= 2.216), Salodik (H'= 2.145), Longkoga Timur 2 (H'= 2.101) and the lowest was in cayenne fields in the villages of Kembang Merta (H'= 1.211), Dale-Dale (H'= 1.112), Beringin Jaya (H'= 1.149). The highest species evenness index (E) was found in the fields in Lembah Makmur Village (E= 0.9721), Mansahang (E= 0.9172), Tolisu (E= 0.8621), Mamping (E= 0.8207) and the lowest was in the cayenne fields in Petak Village (E = 0.3975), Lenyek (E = 0.4405) and Longkoga Timur 1 (E = 0.5166).

Based on Magurran (2004) H′ < 1.5 indicates low species diversity, H′ = 1.5 - 3.5 indicates moderate species diversity, and H′ > 3.5 indicates high diversity. The magnitude of E < 0.3 indicates low evenness, E = 0.3 – 0.6 moderate evenness, and E > 0.6 high evenness. Based on the Bray-Curtis similarity index, cayenne flower-visiting insects are similar (60%) to cayenne flower-visiting insect communities in the Dale-Dale, Pohi, Mamping, and Beringin Jaya areas, while in other areas, the community similarity level is below 50% (Figure 3).

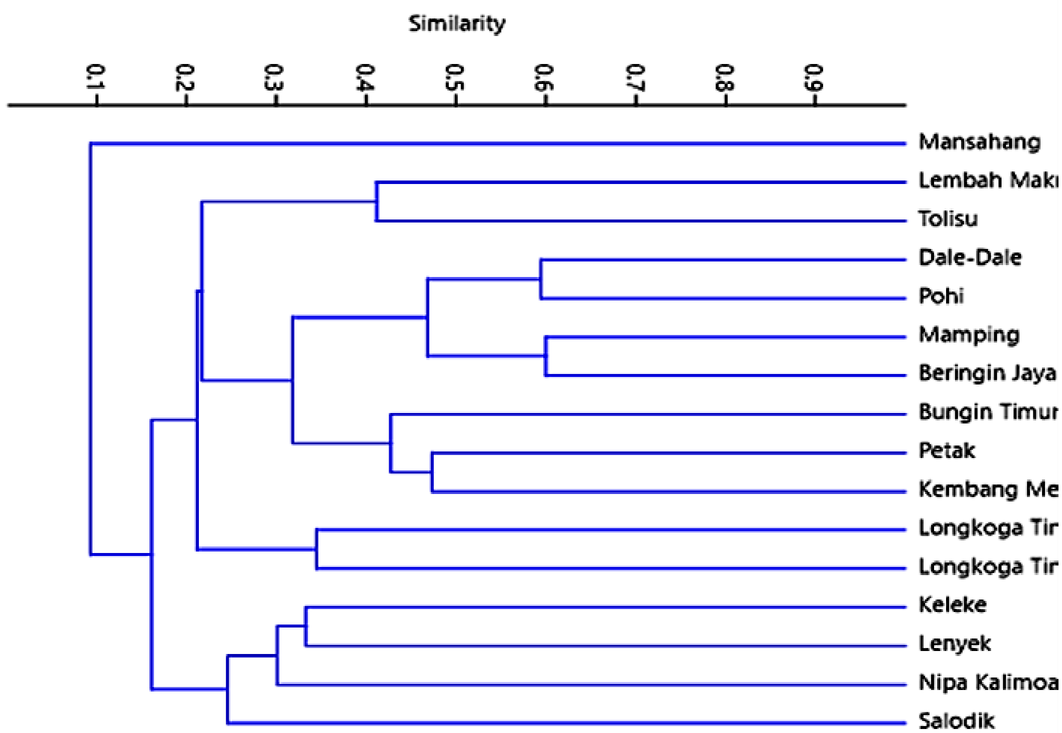

Figure 3 Dendrogram of the similarity of the cayenne flower-visiting insect community at various observation points based on the Bray-Curtis matrix, using the pair-group average method.

DISCUSSION

Habitat quality has a marked effect on the abundance and diversity of flower visitor insects (Kleijn & van Langevelde, 2006; Rizali et al., 2017). A suitable habitat, which is abundant and has a high diversity of flowering plants around the agricultural landscape, serves for the conservation of pollinating insects and other insects (Vrdoljak et al., 2016). The highest number of individual flower-visiting insects was in the village of Salodik, and the lowest was in the villages of Lembah Makmur and Beringin Jaya. The cayenne fields in Salodik Village are located close to natural habitats, so this condition is likely to cause a high number of insects visiting cayenne flowers. The distance between natural/semi-natural habitats and cayenne fields affects the diversity of insect species that visit cayenne flowers (Susilawati et al., 2017). In agricultural landscapes, semi-natural habitats are a significant driver of flower visitor insect diversity (Garibaldi et al., 2011; Scheper et al., 2013). Semi-natural habitats around agricultural land can facilitate the presence of flower visitor insects, including pollinating insects, and provide benefits for crops (Rizali et al., 2017). Semi-natural habitats provide essential resources such as pollen, nectar, alternative hosts, and insect shelter (Tscharntke et al., 2005).

The highest species abundance was found in the cayenne fields of Salodik and Tolisu Villages, and the lowest was in Dale-Dale and Beringin Jaya Villages. Like the cayenne fields in Salodik Village, the cayenne fields in Tolisu Village are also close to semi-natural habitats. The existence of natural or semi-natural habitats around agricultural landscapes is critical to conserving the presence of flower visitor insects (Ekroos et al., 2013; Kennedy et al., 2013). In agricultural landscapes, natural or semi-natural habitats can provide habitats for wild insects (Kennedy et al., 2013; Morandin & Kremen, 2013), nesting sites (Öckinger & Smith, 2007), and resources, including food sources for flower-visiting insects, even natural or semi-natural habitats can maintain food sources throughout the season (Cole et al., 2017; Requier et al., 2020). In addition, the presence of natural habitats (Kleijn & van Langevelde, 2006; Susilawati et al., 2017) and flowering plants around the plantations affect flower visitor insects and pollinating insects (Sataral et al., 2022). The ecological services provided by flower visitor insects for crop production have been recognized, especially in cultivated plants growing near natural habitats as opposed to those far from natural habitats (Bailey et al., 2014; Halinski et al., 2018; Hipólito et al., 2018).

The three most abundant cayenne flower visitor insects are *Lasioglossum* sp.3, *Lasioglossum* sp.5, *?Parancistrocerus* sp., and *Megachile* sp.2. The research results by Landaverde-González et al., (2017) also showed that bees from the genus *Lasioglossum* were the most abundant group in cayenne fields compared to other bee species. Aminatun et al. (2019) also reported that *Lasioglossum* bees are pollinators in cayenne pepper. Meanwhile, Ercan & Onus (2003), Vishwakarma & Singh (2018), and Soli et al. (2020) reported that *Megachile* bees pollinate cayenne and can even produce better yields and fruit quality. Bees are a group of flower visitors positively correlated with the proportion of natural or semi-natural habitats in agricultural landscapes (Scheper et al., 2021). For the wasp *Parancistrocerus* sp., it is unclear what role he played in visiting cayenne flowers. It is still rare to report the ecological role of the wasp *Parancistrocerus* sp.

The value of the diversity index depends on the number of individual types of each species obtained. The smaller the variation in the number of individuals for each species, the smaller the diversity of an ecosystem, and vice versa. Insects visiting cayenne flowers found in the villages of Tolisu, Mansahang, Salodik, and Longkoga Timur 2 have a diversity index value of Shannon-Wiener (H') belonging to the medium category (H' = 1.5 – 3.5). For the evenness index of insect species visiting cayenne flowers in the villages of Lembah Makmur, Mansahang, Tolisu, and Mamping, the value of E' > 0.6 means that the evenness of species is high. The complexity of the landscape and structure of semi-natural habitats also influences the diversity and evenness of flower visitor insects in cayenne fields. However, the habitat type around cayenne fields also affects the presence of insects on cayenne pepper. The research results by Susilawati et al. (2017) showed that differences in the distance between plantations and natural habitats affected the diversity of flower-visiting insect species. The study conducted by Geslin et al. (2016) provides evidence of detrimental effects on insects' abundance and functional diversity due to agricultural land far from natural habitats. Therefore, natural or semi-natural habitats around agricultural landscapes are critical. The highest diversity of insect species was found in cayenne fields in Tolisu village (H=2.491). The cayenne land is located close to a forest or semi-natural habitat. This allows insect species in or around the forest to migrate to cayenne fields. The results of research by Koneri et al. (2021) show that species richness, diversity, and evenness of insect pollinators are highest in land near forests. Evenness index values can be increased if no individual concentration is on a particular species (Magurran et al., 2013).

Analysis of community similarity based on the Bray-Curtis similarity index showed a similarity (60%) to the community of cayenne flower-visiting insects in the villages of Dale-Dale, Pohi, Mamping, and Beringin Jaya. This is because these areas have similar habitat conditions and the types of species found, even though they have different landscape conditions. The high or low community similarity indicates a dynamic composition of insect visitors to cayenne flowers according to their habitat conditions. Meanwhile, in other areas, community equity is below 50%.

CONCLUSIONS

Cayenne flower-visiting insects at the study site comprised 444 individuals, 16 families, and 52 species. Based on the diversity index value of Shannon and Wiener (H'), the highest value was found in cayenne fields in Tolisu Village (H'= 2.491), and the lowest was found in cayenne fields in Dale-Dale Village (H'= 1.112). The highest species evenness index (E) value was found in cayenne fields in Lembah Makmur Village (E= 0.9721), and the lowest was found in cayenne fields in Petak Village (E= 0.3975). The insect species that visit cayenne flowers are *Lasioglossum* sp.3, *Lasioglossum* sp.5, *Megachile* sp.2, and *?Parancistrocerus* sp. have a high abundance. The similarity of insect communities visiting cayenne flowers based on the Bray-Curtis similarity index shows a similarity (60%) between insect communities in the villages of Dale-Dale, Pohi, Mamping, and Beringin Jaya. The highest species richness was found in cayenne fields in Tolisu, Salodik, and Petak. Cayenne fields in the three villages are close to semi-natural habitats. Agricultural land adjacent to semi-natural habitats has been shown to increase the species richness of cayenne flower visitor insects.

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