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Diversity of pollinator insects in vegetable gardens, Kabawo District, Muna Regency

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ABSTRACT

Pollinator insects play an important role in pollination to increase the productivity of flowering plants. The aim of this study was to analyze the abundance, diversity, and specific taxon of insect pollinators among different vegetable crops in local farmers' gardens. Insects were sampled from four gardens, namely polyculture long bean (KKP), eggplant polyculture (KT), curly chili monoculture (KCK), and Indofood chili monoculture (KCI) used nets and light traps. The results showed that the abundance and diversity of pollinator insects varied between gardens. The pollinator insect community in KCI was most similar to that in KCK; KT was similar to the KCI and KCK groups, while KKP were separate from the KT, KCK and KCI groups. The richest genus occurs in KKP, while chili plantations are the poorest. The apis genus in KKP and KT, and the Nomina genus in KCK and KCI were dominant. The specific pollinator insect genus in KKP is the richest. It concluded that plant species and cropping patterns contribute to the composition and diversity of the pollinator insect community.

Keywords:
Abundance, Composition, Cropping pattern, Plant type, Pollinator

1. Introduction

Mutualistic interactions between insect pollinators and plant flowers are key biotic factors that play an important role in the successful reproduction of plants through pollination [1–3]. The production of fruit and seeds from flowering plants that are consumed by humans is highly dependent on the presence of pollinators in tropical ecosystems [4,5]. Nutrient content (such as lipids in the form of oil, available vitamin C, available folate, vitamin A, provitamin A, and α- and γ-tocopherol), and several minerals in fruit and flowers consumed for the maintenance of human health come from flowering plants that depend on insect pollinators [6]. Fruit, vegetables and seeds consumed by humans come from 87 types of food plants that depend on animal/insect pollination, and 28 types do not rely on animal/insect pollinators [7,8]. The diversity of insect pollinators determines the level of production and quality of fruit and seeds from agricultural plants [9]. The richness of pollinator species is correlated with plant yield, where a high richness of pollinators visiting plant flowers has implications for increasing plant yield, and vice versa [10].

Plant type influences the composition and abundance of insect pollinators in agriculture [11]. Pollinator insect taxa, which include bees, flies, beetles, butterflies and moths, make an important contribution through pollination services in increasing the production and quality of fruit and seeds of agricultural plants [12]. Horticultural gardens where fruit is harvested are a habitat for pollinator insects.

Pollinator insects visit flowering plants to obtain nutrients from the nectar of horticultural plants [13]. On the other hand, with the visit of these insects, plants whose flowers have bloomed have an optimal opportunity to reproduce [14]. The interest of pollinator insects in visiting flowering plants is greatly influenced by flower color, flower aroma, pollen, nectar, and the suitability of flower characters to the bodies of pollinator insects [15], and environmental factors, such as minimum air humidity, minimum air temperature, and other maximum air temperatures [16]. Changes in flower color are an attractive factor that greatly influences pollinator insect visits [17]. The diversity of insect pollinators influences the success of flower pollination of horticultural plants [18].

Increased plant species diversity can influence the abundance and richness of pollinator species visiting the area [19]. In addition, the abundance and diversity of pollinator insects are influenced by land use practices of forests and agricultural areas [20]. Differences in cropping patterns in agricultural areas provide different resources to fulfill the needs of insect pollinators, such as flower color, nectar, nests, places to lay eggs, and mating [21]. Increased use of chemicals and monocultures contributes to a decline in the abundance and diversity of pollinators in agricultural areas [22]. Each type of plant receives a different intensity of visits from the same type of pollinator. For example, Eberle et al. [23] reported that the visiting activity of pollinator insects on canola plants was always higher compared to pennycress (*Thlaspi arvense* L.). Groeneveld et al. [24] reported that flies (Diptera) and wild bees visited camelina and pennycress, but honey bees only visited camelina (*Camelina sativa*). The facts explained above indicate that the abundance and diversity of pollinator insects varies between types of agricultural crops. Pollinator insects play an important role in cross-pollination of a number of horticultural crops, including vegetable crops. A number of vegetable plants whose optimal production depends on the presence of insect pollinators include cucumbers, pumpkins, watermelons, cucumbers, tomatoes, capsicums and eggplants. The main pollinator insects that play a dominant role in cross-pollination of horticultural plants are honey bees, stingless bees, carpenter bees, bumblebees, megachilids, halictids, sphecids, andrenids and syrphids [25]. The study conducted by Siregar et al. [26] found that pollinator insect communities between oil palm plantations and rubber plantations were more similar than rubber forests.

Around 126,286 ha of land that can be cultivated are used as agricultural land in Muna Regency. Kabawo District is one of the sub-districts on Muna Island with an area of around 204.94 km^2 with climate and geographical conditions that are good enough for plant growth so that various commodities such as eggplant, large chilies, cayenne peppers, long beans, kale, cucumbers, watermelon, tomatoes and pumpkins [27]. The main types of vegetables (eggplant, long beans and chilies) cultivated by local farmers in the Kabawo District area show that increasing production requires the presence of insect pollinators [28–30]. Until now, studies related to insect pollinator communities in this region have been neglected. This research is aimed at (i) studying the diversity of insect pollinators between gardens, and (ii) assessing the similarity of insect pollinator communities between local farmers' gardens.

2. Methods

2.1. *Site and Time*

This research was carried out in local farmers' gardens in Kontumere Village, Kabawo District, Muna Regency at the longitude 122°29′16″ E, latitude 5°0′50″ S, and in the Agrotechnology Laboratory of the Agronomy Unit, Faculty of Agriculture, Halu Oleo University, Kendari from October to December 2022.

2.2. *Determination of Sample Gardens*

Determining sample gardens using the purpose sampling method focused on horticultural plantations that had entered a generative period marked by the appearance of flowers at different locations in Kontumere Village. Based on the results of observations, the sample gardens were grouped into four gardens (Figure 1), namely (a) polyculture long bean plantations (KKP) located at longitude 122°29′16" E, latitude 5°0′50" S, and altitude 82 m above sea level (asl), (b) polyculture eggplant gardens (KT) located at longitude 122°29′17″E, latitude 5°0′49″ S, and altitude 98 m asl, (c) monoculture curly chili gardens (KCK) located at 122°29′04″east longitude, 5°0′40″ south latitude, and altitude 75 m asl, and (d) the Indofood monoculture (KCI) chili plantation is located at longitude 122°29′15″ east longitude, latitude 5°0′49″ south latitude, and altitude 82 m asl.

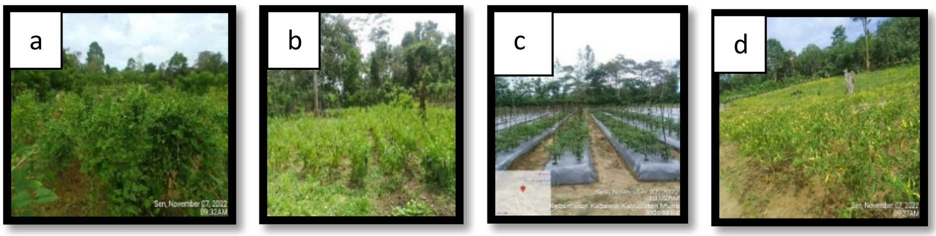

Figure 1. Location of farmers' gardens for sampling pollinator insects

2.3. *Placement of Plots in Each Garden*

The sample gardens mentioned above are referred to as treatments. Plot placement using purpose sampling followed a randomized block design procedure in each garden, as presented in Figure 2. Flowering plants that had entered the generative period marked by the appearance of flowers were used as the sampling area for each garden. The area of the sample long bean garden and Indofood chili garden is 80 m × 60 m each, and the eggplant and curly chili gardens are each 100 m × 120 m. In each garden three plots are made, the size is 20 m × 20 m. The plot is referred to as a repeat.

2.4. *Catching Pollinator Insects*

For catching the insects use a 25 cm diameter net and light traps. Insect catching using nets in each garden were carried out for two days during sunny weather. Insects were caught in each garden twice a day, about 06.00–09.00, and about 15.00–18.00 central Indonesian time. The catcher walks in each plot for each garden along a line transect at a relatively constant speed while swinging the insect trap net and catches visiting insects by trapping insects into the trap net. Catching insects in each plot takes 60 minutes. Insects caught in nets in each plot for each garden were preserved in sample bottles containing 70% alcohol, and counted.

Catching insects with a light trap uses a 12 watt magic solar lamp as a light source and a small 30 cm container filled with water as a container for insects that land on the lamp. This light trap was installed at 17:00 and samples were taken at 06:00 in the morning. The trapped insects were put into a jar containing 70% alcohol, and counted. All insect sample bottles were transported to the Agrotechnology Laboratory, Agronomy Unit, Faculty of Agriculture, Halu Oleo University Kendari for identification. Each insect was identified for its morphological characteristics to the genus level using guidelines from CSIRO (Australia) [31] and Borror et al. [32]. Insect genera are separated into pollinator and non-pollinator groups according to the literature. Next, individuals from each group were counted for the purposes of analyzing the pollinator insect community for each garden.

2.5. Determination of the Ecological Diversity of Insect Pollinators

Data from the abundance of pollinator insect genera were obtained, and then the Shannon-Wiener, Simpson, and Evenness diversity index was calculated [33]. The Shannon-Wiener Diversity Index is calculated using the formula:

$$H^{'} = -\sum_{i=i}^{n} (\rho i \ln(\rho i)\text{, and } \rho i = \frac{ni}{N} \tag{1}$$

Where:
H' is represents the Shannon-Wiener diversity index
ρi is represents the proportion of individuals belonging to genus i of a sample
i is represents the number of individuals of the i-th genus
N is represents the total number of individuals throughout the genus

Simpson diversity index (D1) is calculated using the formula:

$$D2 = 1 / \sum \rho i^2 \tag{2}$$

Where:
D2 is represents Simpson's dominance index
ρi is represents the proportion of individuals belonging to genus i of a sample.

Simpson Evenness Index (E) is calculated using the formula:

$$\text{Evenness} = \frac{D1}{S} \tag{3}$$

Where:
D1 is represents Simpson's diversity index
S is represents the number of individuals in the sample unit.

2.6. Statistics Analysis

Pollinator insect diversity index data between gardens was analyzed using variance (ANOVA), while differences in pollinator insect diversity index between gardens used the least significant difference test (LSD) at the level of $p<0.05$. The similarity of pollinator communities between gardens was analyzed using free downloads PAST software. Specific pollinators were traced from data on the frequency of presence of the relevant pollinator genus in each garden.

3. Results and Discussion

3.1. Results

3.1.1. Pollinator in Insect Communities

A total of 252 insects were caught, consisting of 6 orders, 25 families and 29 genera. The total genus caught had 13 genera classified as pollinators, and 16 other genera classified as non-polinators. A total of 187 individual pollinator insects were collected belonging to 13 genera consisting of *Amata, Catopsilia, Ceraunus, Delta1, Delta2, Muscidae, Hylaeus, Lagsioglossum, Nomia, Sarcophagidae, Polistes, Apis, and Xylocopa*. Analysis of variance showed that garden type had a significant effect ($p<0.05$) on the abundance of *Hylaeus* (df3:6; F = 7.506; sig = 0.019), *Nomia* (df3:6; F = 18.010; sig = 0.002), and *Apis* (df3: 6; F = 20.920; sig = 0.001), while the abundance of other genera was not significant ($p>0.05$). Differences in the abundance of each genus of pollinator insects in each garden are presented in Table 1.

Table 1. Differences in the abundance (mean ± SD) of pollinator insect genera between four gardens in Kontumere Village, Kabawo District, Muna Regency

Genus	Abundance of Pollinator Insect's			
	KKP	KT	KCK	KCI
Amata	0.00 ± 0.00 a	0.33 ± 0.71 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Catopsilia	0.00 ± 0.00 a	1.33 ± 1.41 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Ceraunus	0.33 ± 0.71 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Delta 1	0.00 ± 0.00 a	0.33 ± 0.71 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Delta 2	0.33 ± 0.71 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Muscidae	0.33 ± 0.71 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Hylaeus	6.67 ± 2.21 b	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Lagsioglossum	1.00 ± 2.21 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Nomia	0.00 ± 0.00 a	**3.00 ± 0.00 ab**	**3.67 ± 2.12 b**	**3.67 ± 0.71 b**
Sarcophagidae	0.33 ± 0.71 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Polistes	0.33 ± 0.71 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a
Apis	**30.0 ± 4.24 b**	**7.33 ± 0.71 a**	0.00 ± 0.00 a	0.00 ± 0.00 a
Xylocopa	0.33 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a	0.00 ± 0.00 a

Numbers in the same column followed by different letter superscripts are significantly different according to the LSD test at the $p<0.05$ level. KKP is long bean gardens; KT is eggplant gardens; KCK is curly chili gardens; and KCI is the Indofood chili gardens.

Table 1 shows that the order of abundance of Hylaeus from most to least is as follows: KKP>KT=KCK=KCI, and the difference in abundance in KKP compared to others is significantly different (LSD at the $p<0.05$ level). Abundance of Nomia from most to least according to plantations in sequence, as follows: KCI=KCK>KT>KKP. The difference in Nomia abundance between KCI compared to KT and KKP is not significantly different (LSD at the $p<0.05$ level), while compared to KCK it is significantly different (BNT at the $p>0.05$ level). The abundance in KCK compared to KKP is significantly different (LSD at the $p<0.05$ level), whereas compared to KT it is not significantly different (LSD at the p>0.05 level). The difference in abundance between KT and KKP is not significantly different (BNT at the p<0.05 level).

The abundance levels of *Apis* in sequence according to vegetable gardens from most to least are as follows: KKP>KT>KCK=KCI. The difference in *Apis* abundance in long bean gardens compared to other vegetable gardens was significantly different (LSD at the p < 0.05 level), while the difference between KT, KCK, and KCI was not significant (LSD at the p level >0.05).

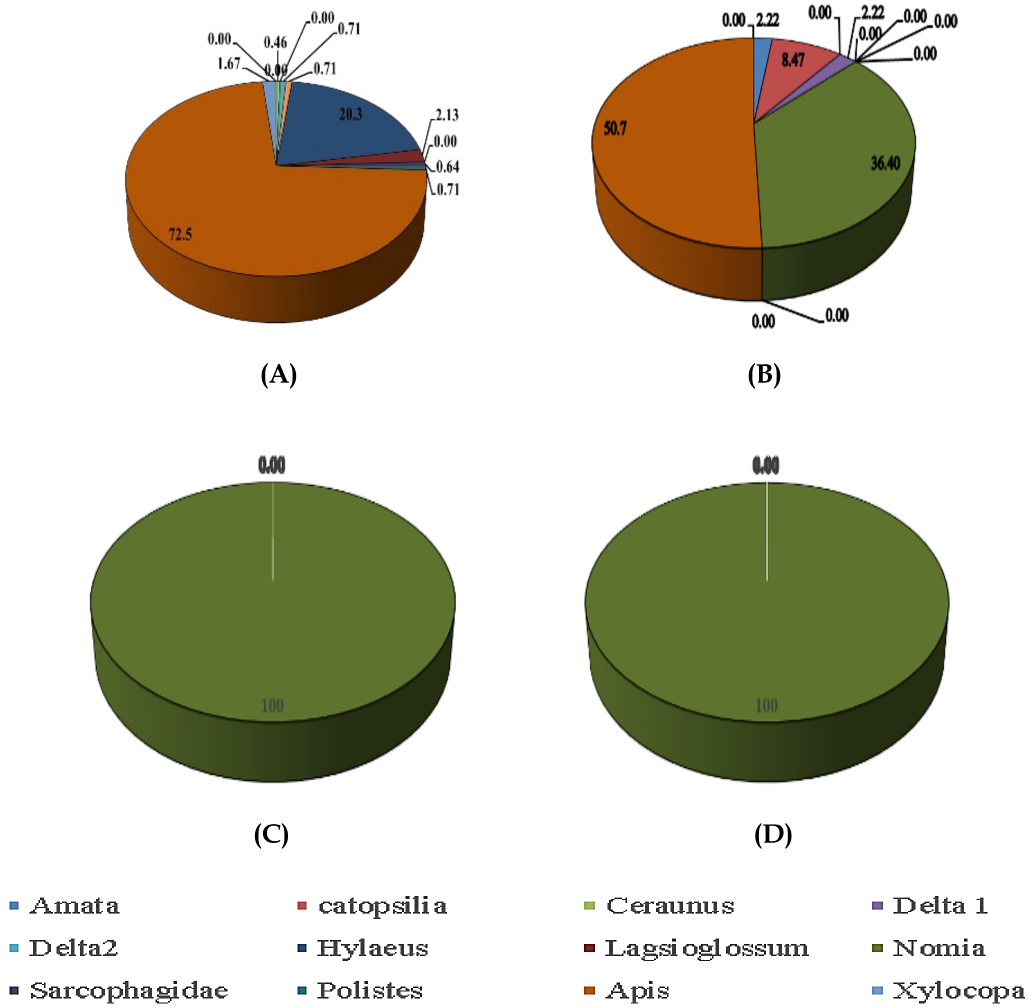

Figure 2. Relative abundance of pollinator insect genera in (A) long bean gardens; (B) eggplant; (C) curly chilies; (D) Indofood chili

In Figure 2 shows that the composition of the genera that make up the pollinator insect community in the KKP includes *Apis* is 72.5%, *Hylaeus* is 20.30%, *Lagsioglossum* is 2.13%, *Xylocopa* is 1.67%, *Polistes* is 0.71%, *Delta* 2 is 0.71 %, *Muscidae* is 0.71%, and *Ceraunus* is 0.46%. KT includes *Apis* is 50.7%, *Nomia* is 36.4%, *Catopsilia* is 8.47%, *Amata* and *Delta* 1 each is 2.22%. KCK and KC, genus *Nomia* are 100% respectively.

3.1.2. Ecological Diversity of Pollinator Insect Communities

Analysis of variance showed that garden type had a significant effect ($p<0.05$) on pollinator insect genus richness (df3:6; F = 13.530; sig = 0.004), and the Shannon-Wiener diversity index (df3:6; F = 27.420; sig = 0.001), while for the Simpson index, the Simpson dominance index and the Evenness index are not significant ($p>0.05$).

Table 3. Differences in ecological diversity (mean ± SD) of pollinator insect communities between gardens

Garden	Measures of ecological diversity				
	Genus richness (R)	**Shannon Index (H′)**	**Simpson1 Index (D1)**	**Simpson2 Index (D2)**	***Evennes* Index (E)**
KKP	4.33±1.41b	0.77±0.46b	0.41±0.05b	1.73±0.13b	0.11±0.01b
KT	2.33±1.41ab	0.86±0.36b	0.43±0.03b	1.80±0.14b	0.22±0.08b
KCK	1.00±0.00a	0.00±0.00a	0.00±0.00a	1.00±0.00a	0.00±0.00a
KCI	1.00±0.00a	0.00±0.00a	1.00±0.00a	0.00±0.00a	0.00±0.00a

Numbers in the same column followed by different letter superscripts are significantly different according to the LSD test at the $p<0.05$ level. KKP states long bean plantations; KT states eggplant gardens; KCK declares curly chili gardens; and KCI declares the Indofood chili plantation.

Table 3 shows that the genus richness between KKP gardens compared to other gardens is significantly different, whereas the Shannon index, Simpson1 index, Simpson2 index, and Evenness index between KKP and KT gardens are significantly different (LSD at the $p<0.05$ level), whereas compared to KCK and KCI it is different not significant (LSD at the $p>0.05$ level).

3.1.3. Similarities in Pollinator Insect Communities between Gardens

A dendrogram using the Bray-Curtis similarity index (Figure 3.) shows that the pollinator insect community in the Indofood chili garden (KCI) is most similar to the curly chili garden (KCK). The pollinator insect community in KT was similar with the KCI and KCK, while KKP are separate from KT, KCK and KCI groups. Table 4 shows the similarity of the KCI and KCK pollinator insect communities with a Bray-Curtis index of 1.00. The Bray-Curtis index between KT and KKP is 0.51, and KT with KCK and KCI is 0.36.

Table 4. Bary-Curtis index of similarity of pollinator insect communities between gardens

Garden	KKP	KT	KCK	KCI
KKP	1			
KT	0.51	1		
KCK	0	0.36	1	
KCI	0	0.36	1	1

KKP is long bean gardens; KT is eggplant gardens; KCK is curly chili gardens; and KCI is Indofood chili gardens.

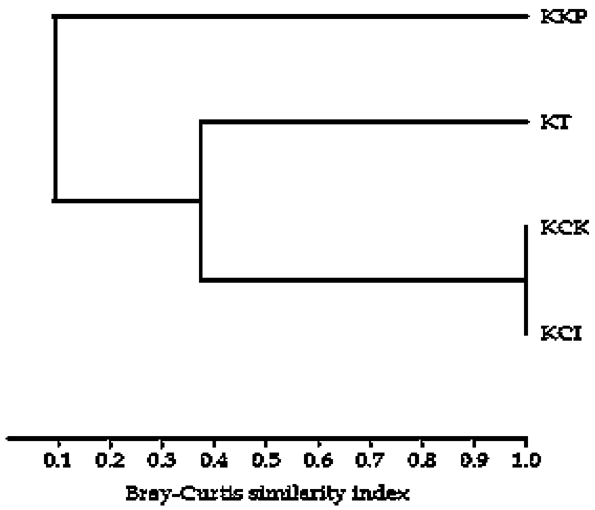

Figure 3. Dendrogram of pollinator insect communities among gardens

3.1.4. Specific Genus of Pollinator Insects

Table 5 shows that the genus of pollinator insects specific to the KKP consists of the genera *Ceraunus*, *Delta*2, *Muscidae*, *Hylaeus*, *Lagsioglossum*, *Polistes*, *Sarcophagidae* and *Xylocopa*. Eggplant gardens (KT) consist of the genera *Amata*, *Catopsilia* and *Delta*1, while in KCK and KCI there are no specific pollinator insects.

Table 5. Specific pollinator insect genera in four local farmers' gardens in Kontumere Village, Kabawo District, Muna Regency

Genus	Garden			
	KKP	KT	KCK	KCI
Amata	0	1	0	0
Catopsilia	0	1	0	0
Ceraunus	1	0	0	0
Delta1	0	1	0	0
Delta2	1	0	0	0
Muscidae	1	0	0	0
Hylaeus	1	0	0	0
Lagsioglossum	1	0	0	0
Nomia	0	**1**	**1**	**1**
Sarcophagidae	1	0	0	0
Polistes	1	0	0	0
Apis	**1**	**1**	0	0
Xylocopa	1	0	0	0

1 indicates present, and 0 indicates absent. KKP is long bean garden; KT is eggplant gardens; KCK is curly chili gardens; and KCI is Indofood chili gardens.

3.2. Discussion

The results showed that the abundance and diversity of insect pollinators differed between gardens. This fact explains again that each type of plant provides suitable habitat and different food resources for the activities of flower-visiting pollinator insects [20,34,35]. Some pollinator insect species prefer certain flowers to visit [26,36]. The frequency of pollinator insect visits to a flower is determined by the properties of the flower, such as flower reflectance, flower height/area, flower morphology, nectar-sugar concentration, and nectar-amino acid concentration [37]. In this study (Table 1), insect pollinators from the genus *Apis* were significantly more abundant in long bean gardens and eggplant gardens than in curly chili and Indofood chili gardens. Dingha et al. [38] also reported that *Apis* to be most abundant in long bean (*Vigna unguiculata*) gardens, because the violet color is one of the attracting factors for *Apis* visiting long bean flowers to obtain pollen [39]. Paschapur et al. [40] found that visiting *Apis* was more attracted to the color and richness of pollen from eggplant flowers. Based on the attracting factor of flower color on *Apis* visits, it is possible that the composition of the pollinator insect community between long bean gardens (KKP) and eggplant gardens (KT) is in one cluster (Figure 3) with a level of similarity according to the Bray-Curtis similarity index of 0.51 (Table 4). This means that there is a 51% similarity in the abundance of *Apis* visiting the two gardens, while the similarity in the abundance of other pollinator insect genera is smaller than 0.49. From Table 5, it can be seen that the Bray-Curtis similarity index of the pollinator insect community visiting the long bean garden with the curly chili garden and the Indofood chili garden is 0; this indicates that the pollinator insects visiting the gardens are not similar.

The *Nomia* genus is more abundant in chili gardens, both curly chili gardens and Indofood chili gardens, compared to long bean gardens and eggplant gardens (Table 1). A study by Raw [41] found that bees visit chili flowers (*Capsicum anuum*) from the genera *Augochloropsis*, *Dialictus* and *Exomalopsis* to obtain pollen. The bee from genus *Nomia* belongs to the Halictidae family belonging to the group of solitary bees [42]. Solitary bees have a habit of eating to obtain nectar from the flowers they visit [43]. The nectar in chilies contains glucose, fructose and sucrose as agents that attract pollinators to visit chili flowers [44]. Pollinator visits to chili flowers increase with the sugar concentration in chili nectar [45]. This means that the abundance of the *Nomia* genus, possibly related to the production of sugar in the nectar from the flowers of the two chilies, is in high concentration. The dendrogram (Figure 3) shows that the composition of the pollinator insect community visiting the eggplant garden, curly chili garden and Indofood chili garden is similar to the Bray-Curtis index of 0.36; this means that 36% of the abundance of the pollinator insect genus visited these three gardens. The pollinator insects that visit the three gardens come from the genus *Nomina*. The curly chili and Indofod chili gardens are only visited by the genus *Nomina* (Table 5), so the Bray-Curtis similarity between these two gardens is 1.0 (Table 4), and forms a separate community cluster from the eggplant and long bean garden community clusters with Bray -Curtis by 0.36. This fact indicates that the *Nomina* genus has a preference for eggplant and chili flowers because of its interest in the color, morphology, nectar and pollen of the flowers served by these two plants [46,47], and habitat factors in garden ecosystems [48].

The diversity of pollinator insects depends on the type of plant [2]. In this study, it was found that the richness of pollinator insect genera between vegetable gardens was significantly different (Table 3). The pollinator insect genus, visitors to long bean gardens, is the richest, then eggplant gardens, while visitors to chili gardens, both curly chilies and Indofood chilies, are the poorest (Table 3). This fact indicates that the long bean garden not only provides flowers that attract visits from various pollinator insects, but also the physical environment of the garden is suitable for visits by pollinator insects [49]. The high visitation of various types of pollinator insects means that the number of flowers fully open is abundant so that nectar and pollen are widely available [50]. The low species richness is probably related to the limited resources provided by flowers and the suboptimal conditions (due to disturbances in the respective gardens, such as the use of pesticides) provided by the gardens limiting the visitation of various types of pollinator insects [51]. This research shows that the Shannon index of the pollinator insect community in eggplant gardens tends to be higher than in long bean gardens (Table 3), this shows that individual pollinator insects are distributed more evenly in the pollinator insect community in eggplant gardens compared to other gardens. This explanation is in line with the evenness index value of the pollinator insect community in eggplant gardens which is higher than in other gardens (Table 3). A low evenness index value indicates that there are one or two dominant pollinator insect communities within the garden [33]. In this study, the relative abundance of Apis in long bean gardens was very dominant with a relative abundance of 72.5%, while in eggplant gardens the highest relative abundance was 50.7% for Apis (Figure 2). The highest value for the Simpson index 1 is owned by the Indofood chili plantation, and the Simpson index 2 is for the curly chili plantation (Table 3). The difference in the simpson index shown by these two gardens is caused by the abundance of the domanian pollinator insect genus [33]. The Simpson index value for each garden is 1, this indicates that only one genus of pollinator insects visited the two chili gardens, namely the *Nomina* genus (Table 5). In Table 5 it is also recorded that the *Nomina* genus visited three different gardens, namely the eggplant garden, curly chili garden and Indofood chili garden, the *Apis* genus visited the long bean garden and eggplant garden, the genus *Ceraunus*, *Delta*2, *Muscidae*, *Hylaeus*, *Lagsioglossum*, *Sarcophagidae*, *Polistes* and *Xylocopa* only visits long bean gardens, and the genera *Amata* and *Catopsilia*. This fact indicates that plant species have certain properties, such as the flower morphology, nature of pollen, and emission of distinctive compounds from flowers that attract specific pollinator insects to visit [52,53].

4. Conclusion

Pollinator insect communities vary by plant type. The *Apis* genus is dominant in long bean and eggplant gardens, while *Nomia* is in chili gardens. The pollinator insect community in long bean gardens is more similar to eggplant gardens, and is separate from the community in chili gardens. The type of plant determines the composition of the pollinator insect community in the vegetable garden. Long bean gardens have more specific types of pollinator insects than eggplant and chili. Because the pollinator insect genus is very poor, the chili garden management is carried out carefully.

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