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Research Article

Diversity, Abundance, and Distribution Patterns of Natural Enemy Insects on Chili (*Capsicum annum* L.) in Bincau Village, Banjar Regency, South Kalimantan

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Abstract

The chili cultivation practice will influence the soil structure and the variety of insects that are produced. The management of pests using pesticides has been one of the traditional cultivation practices carried out by farmers. This study aims to determine the diversity, abundance, and distribution patterns of natural enemy insects in chili plantation (*Capsicum annum* L.) at Bincau Village, Martapura District, Banjar Regency, South Kalimantan. The sample was collected by pitfall trap, yellow pan trap, and sweep net method. Obtained data were analyzed by Shannon Wienner index (H'), Meyer abundance index, Morisita index (Id), and PCA method for environmental parameter analysis. The results showed the diversity of natural enemy insects on chili plants was moderate (H' = 2.396). Furthermore, the highest abundance in research is demonstrated on Hymenoptera order, which consisted of 9 families, 16 species, and 1,009 individuals. The distribution pattern of natural enemy insects in chili plantations is clustered (Id > 1). Based on the PCA analysis method, the temperature has the most impact on natural enemy insects' presence in this study.

Keywords: Diversity, Abundance, Distribution Patterns, Insect, Chili

1. Introduction

Chili (*Capsicum annum* L.) pepper is mostly found worldwide as a seasoning (Sativa et al., 2017). It has a phytochemical composition, and a lot of its nutritional properties Chili occupies the largest crop area, around 2.5 million ha, among the vegetables cultivated in Asia. In Indonesia, the annual production of Chili reaches approximately 5 percent of the global supply (Mariyono & Bhattarai, 2009). Chili has become a potential commodity of vegetables with high economic value and potentially continuity developed (Tsurayya & Kartika, 2015; Adnyana et al., 2020). Since 2001, Chili production has increased by an average of 20 percent per year, from about 190,000 hectares to cross more than 1 million tons in 2005, accounting for about 12 percent of vegetables' production. In Java, with Western Java, more than 60 percent of Chilli is produced (198,000 tons)(Morgan & Shearer, 2007).

Chili (*Capsicum annum* L.) is a very complex plant even though it grows rapidly. Several factors are affecting Chili's productivity, such as soil, irrigation, fertilizing. (Trianto et al., 2020). In Indonesia, the seasonal and frequent fluctuations in chili prices are relatively high, more than for other vegetables and rice, and pose a significant risk to chili farmers. Crop production, annual supply, and market stability are also significantly affected by losses caused by insect infestation (Adnyana et al., 2020). Indonesian farmer has been applying insecticides to control the disease for more than decades. Pesticides increase crop yields, minimize production costs, and enhance quality, thus increasing farmers' income. However, it has been found that the use of chemical insecticides is hazardous to human and animal health or the environment (Hu, 2020; Pazikowska-Sapota et al., 2020).

Pesticides promise the successful control of harmful bugs, but the risks associated with their use have exceeded their beneficial effects. Nonselective pesticides and the targeted ones eliminate animals that act as a natural enemy, such as predatory insects and parasitoids (Putra & Utami, 2020). Application of chemical insecticides has still occurred in Bincau Village, Banjar Regency, South Kalimantan, which possible to influence the ecology of natural enemy insects in chili plantations. Therefore, this study was purposed to calculate the diversity, abundance, and distribution pattern of natural enemy insects on chili (*Capsicum annum* L.) plantations in Bincau Village, Banjar Regency, South Kalimantan. This study aimed to determine the presence of natural enemies in chili cultivation, which can be used as initial information in reducing natural pest populations in an ecosystem.

2. Material and Method

This research was conducted at Chili Plantation, Bincau Village, Banjar Regency, South Kalimantan Province (Figure 1). Data were collected from April to May 2020. Sample was identified in the Entomology Laboratory, Faculty of Biology, Universitas Gadjah Mada.

Figure 1. The sampling area in chili plantation

Sampling was carried out using a 2x2 m plot of 25 plots and was carried out randomly in the sampling area (chili plantations). Samples were taken four times to obtain maximum results. Insects in each plot were caught by the direct method using a sweep net, yellow pan trap, and pitfall trap. The traps are set twice a day, in the morning (07.00 am) and in the afternoon (4.00 pm). The sweep net exertion by swinging it along the chili plantation bed while walking. The swing is done vertically (up and down). Each plot is placed in 1 trap in the form of a yellow pan trap and a pitfall trap. The yellow pan trap used a yellow container with a diameter of 15 cm, while the pitfall trap used a plastic cup with 5 cm of diameters and 15 cm of high. Both traps were filled with a detergent solution in a ratio of 1:2 (water and detergent). Yellow pan traps are placed in the open area to be attracted to the yellow color, while pitfall traps are installed by burying them with the glass mouth parallel to the ground. The insects obtained were then washed with distilled water and transferred to a sample bottle containing 70% alcohol for identification.

Identification of insect species and their roles was made using Hymenoptera of The World, Annotated Keys to the Genera of *Neartic Chalcidoidea*, A Handbook of The Families of *Neartic Chalcidoidea* (Hymenoptera), and Manual of the New World Genera of the Family Braconidae (Hymenoptera). Besides, the identification process is also carried out using identification journals such as (Gunawardene & Taylor, 2012). The abiotic conditions measured in this study were temperature using a thermometer, humidity using a hygrometer, and light intensity using a lux meter. Furthermore, the results obtained will be analyzed using the PCA method using PAST3 software (Trianto & Purwanto, 2020; Yudha et al., 2019).

Data Analysis

All data were analyzed using Biodiversity Pro software. Several indexes used in this research were the diversity index of Shannon-Wienner, Shannon-Evennes and dominance index of Simpson, the abundance of Meyer, and the distribution pattern analyzed by the index of Morisita (Magurran, 2004; Schinner et al., 2014). Other analyses used were diversity indices using the following:

Diversity Index ($H = -\sum(ni/N) \ln (ni/N)$)

Information:
H: Diversity index
ni: Number of individual types
N: Total number of individuals

Abundance Index ($N = IS / A$)

Information:
N: Abundance index
IS: Median number of individual
A: Area of the sampling point

Distribution Pattern ($Id = n ((\Sigma xi2 - \Sigma xi) / (\Sigma xi)2 - \Sigma xi))$)

Information:
Id: Morisita index
n: Total of plot
xi: Number of individual of i-th species

While the standardized of Morisita index calculated by the equation:

$Ip : 0.5 + 0.5 ((Id - Mc) / (n - Mc))$; if $Id \geq Mc > 1$

$Ip : 0.5 ((Id - 1) - (Mc - 1))$; if $Mc > Id \geq 1$

$Ip : 0.5 ((Id - 1) / (Mu - 1))$; if $1 > Id > Mu$

$Ip : 0.5 + 0.5 ((Id - Mu) / (Mu))$; if $1 > Mu > Id$

Furthermore, a distribution pattern is calculated by the equation of Mu and Mc:

$$\mathbf{Mu = (x^2_{0.975} - n + \Sigma xi) / (\Sigma xi) - 1}$$
$$\mathbf{Mc = (x^2_{0.025} - n + \Sigma xi) / (\Sigma xi) - 1}$$

Information:

Mu: Morisita index on the distribution pattern of uniform

Mc: Morisita index on the distribution pattern of cluster

$x^2_{0.975}$: The value of x^2 with n-1 degree of freedom and confidence interval 97.5%

$x^2_{0.025}$: The value of x^2 with n-1 degree of freedom and confidence interval 2.5%

n: Number of plot

xi: Number of individual on i-th plot

Criteria of distribution pattern:

Jika $Ip < 0$: Uniform

Jika $Ip = 0$: Random

Jika $Ip > 0$: Cluster

Principal Component Analysis (PCA)

Data on abiotic environmental conditions with the number of individual natural enemy insects in chili plantations were analyzed by the PCA method with PAST3 software (Trianto & Purwanto, 2020; Yudha et al., 2019).

3. Results and Discussion

3.1. Results

Diversity of Natural Enemy Insect

This study indicates that insects' natural enemy's diversity index in chili plants is moderate (2.396) (Table 1).

Table 1. Shannon-Wienner (H') diversity index of natural enemy insects in chili plants

No	Sampling Time	H'	Value*	Category*
1	First	2,322	H'≥2.0	Moderate
2	Second	2,361	H'≥2.0	Moderate
3	Third	2,336	H'≥2.0	Moderate
4	Fourth	2,885	H'≥2.0	Moderate
5	Fifth	2,086	H'≥2.0	Moderate
6	Sixth	2,220	H'≥2.0	Moderate
7	Seventh	2,163	H'≥2.0	Moderate
8	Eighth	2,690	H'≥2.0	Moderate
9	Ninth	2,461	H'≥2.0	Moderate
10	Tenth	2,432	H'≥2.0	Moderate
	Mean	2,396	H'≥2.0	Moderate

The abundance of Natural Enemy Insect

There are seven insect orders (1.196 individuals and 17 species), which acted as predators, and three insect orders (236 individuals and 13 species) as parasitoid insects in the chili plantations at the research location. The order with the highest number of individuals and species is Hymenoptera (Table 2).

Table 2. The role and number of individuals of natural enemy insect species in chili plantation by sweep net, yellow pan trap, and pitfall trap

Role of Insect	Species	Methods			Total
		Sweep net	Yellow pan trap	Pitfall trap	
Predator	*Agriocnemis pygmaea*	57	27	43	127
	Orthetrum sabina	6	2	4	12
	Pantala flavescens	3	0	0	3
	Ischiodon scutellaris	7	0	2	9
	Cyrtorhinus lividipennis	6	1	5	12
	Anoplolepis gracilipes	139	32	86	257
	Dolichoderus thoracicus	21	4	10	35
	Odontoponera denticulata	4	1	1	6
	Paratrechina longicornis	372	68	144	584
	Vespa analis	2	0	0	2
	Conocephalus longipennis	17	7	8	32
	Metioche vittaticollis	11	5	9	25
	Chilocorus nigritus	18	9	7	34
	Coccinela repanda	2	1	0	3
	C. transversalis	28	11	6	45
	Coleosoma octomaculatum	2	0	0	2
	Forficula auricularia	5	1	2	8
Parasitoid	*Anagrus optabilis*	2	1	1	4
	Apanteles glomeratus	3	1	0	4
	Brachimeria femoralis	4	3	4	11
	Cardiochiles nigriceps	8	2	5	15
	C. saltator	3	0	2	5
	Eurytoma dentata	13	5	10	28
	Goryphus basilaris	22	3	7	32
	Platygaster oryzae	8	1	6	15
	Tamarixia radiata	2	0	1	3
	Tetrastichus schoenobii	2	1	2	5
	Trichopria drosophilae	1	1	1	3
	Exorista sp.	52	19	34	105
	Stylops sp.	3	1	2	6
Total		823	207	402	1.432

Distribution Pattern of Natural Enemy Insect

The ecosystem consisted of three basic distribution patterns, namely clustered, uniform, and random. In this study, the distribution pattern of natural enemy insects in chili plantations is clustered (Table 3).

Table 3. Distribution pattern of natural enemy insect species in chili plantation

No	Sampling Time	Id	Mu	Mc	Ip	Distribution Pattern
1	First	1.68	0.98	1.04	0.56	Clustered
2	Second	1.66	0.96	1.02	0.52	Clustered
3	Third	1.68	0.98	1.04	0.56	Clustered
4	Fourth	1.66	0.96	1.02	0.52	Clustered
5	Fifth	1.67	0.97	1.03	0.54	Clustered
6	Sixth	1.69	0.99	1.05	0.58	Clustered
7	Seventh	1.68	0.98	1.04	0.56	Clustered
8	Eighth	1.66	0.96	1.02	0.52	Clustered
9	Ninth	1.66	0.96	1.02	0.52	Clustered
10	Tenth	1.67	0.97	1.03	0.54	Clustered

Environmental Parameters

The median temperature obtained is 27.72 ^{o}C, humidity is 74.9%, dan light intensity is 1117.8 (Tabel 4).

Table 4. Measurement of environmental parameters on chili plantation in Bincau Village, Banjar District, South Kalimantan

No	Sampling Time	Temperature (C)	Humidity (%)	Light Intensity (Lux)
1	First	27.2	73	1013
2	Second	28.5	72	1052
3	Third	27.3	76	1133
4	Fourth	28.3	73	1081
5	Fifth	27.0	75	1120
6	Sixth	29.4	76	1143
7	Seventh	28.5	78	1205
8	Eighth	28.5	75	1109
9	Ninth	27.0	74	1115
10	Tenth	28.1	77	1207
Median		27.71	74.9	1117.8

Correlation analysis between cluster yields eigenvalue and % variance, as shown in Table 5. While the Scatter plot is shown in Figure 2, and the loading plot of the component is shown in Figure 3.

Table 5. Eigenvalue and %Variance

PC	Eigenvalue	% variance
1	3541.12	85.296
2	610.183	14.698
3	0.265036	0.006384

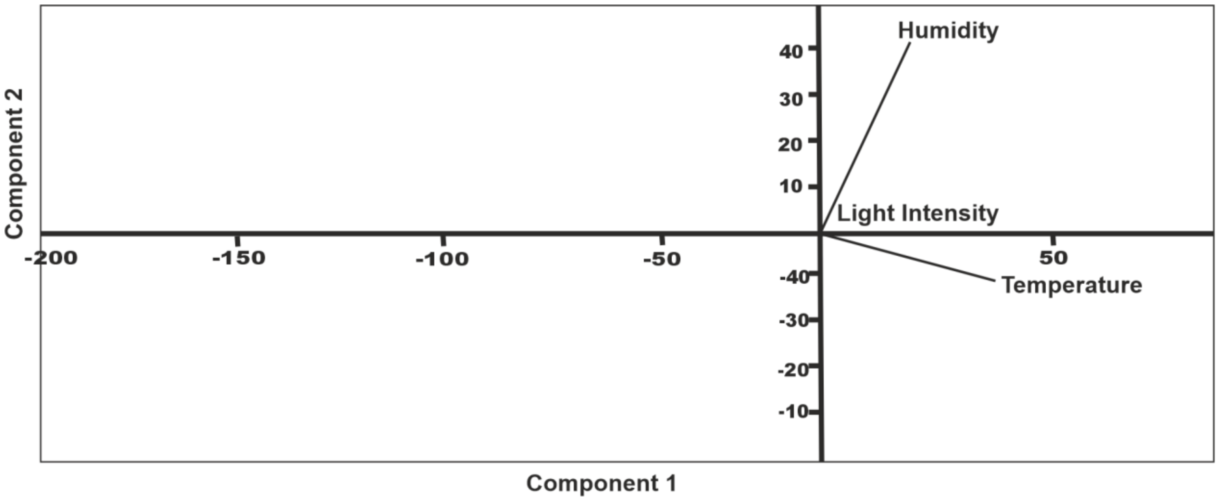

Figure 2. The PCA results of the scatter plot

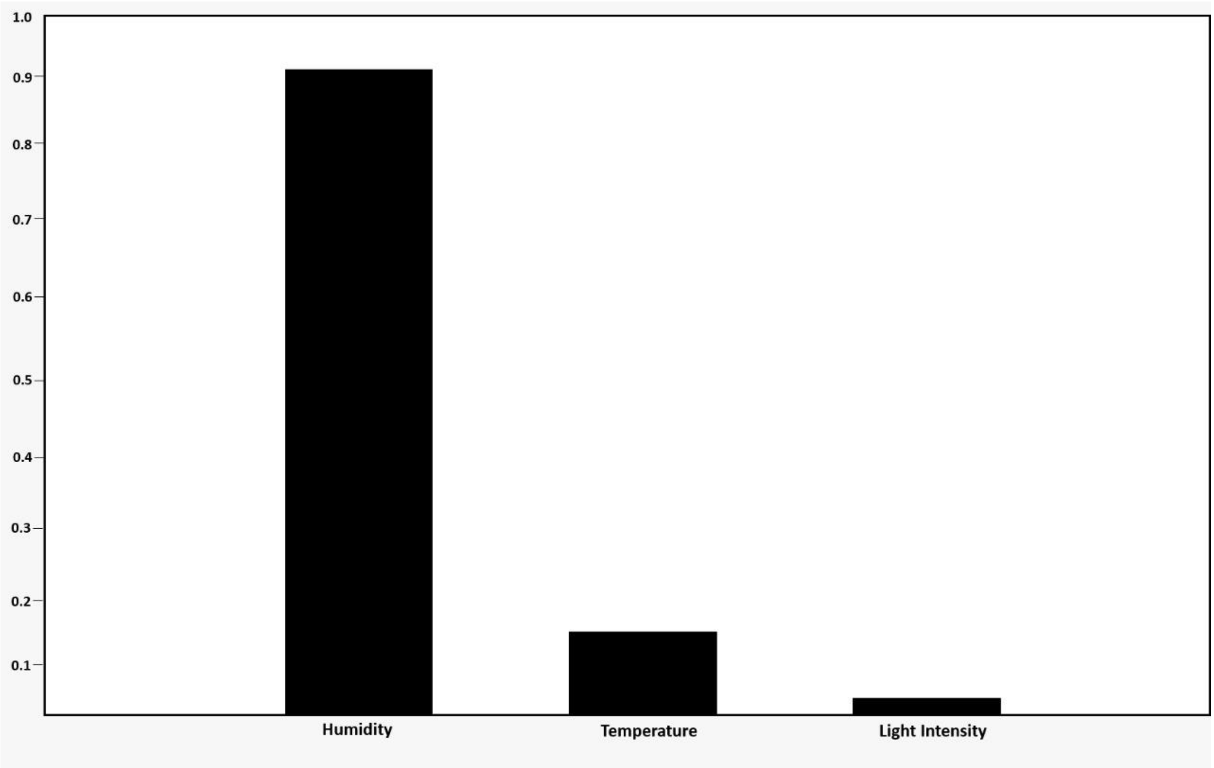

Figure 3. The loading plot of component

3.2. Discussion

Diversity of Natural Enemy Insects

Table 1 represented the diversity of natural enemy insects in chili plantations in Bincau Village was moderate. This is due to community activities' influence on natural enemy insects at the research location. The research location used is a location directly adjacent to the community house and other cultivated plants. On the left and right, it is directly adjacent to the residents' houses, while at the front, it is directly adjacent to the village road where there is a long bean planting area across it. It can also occur because there are not many types of plants found at the research location. The fewer plants found in an ecosystem will affect natural enemy insects' existence in the ecosystem (Kurniawati, 2015). It is consistent with research from Ghazali et al. (2016), who obtained results that the insects found on polyculture land were more abundant and varied than on monocultures. It was further explained that this could happen because plants' diversity influenced it in the area.

The natural enemy insect families that dominate in this study are Formicidae, Coccinellidae, and Braconidae. It follows the research results reported by Putra & Utami (2020), who researched chili plants in Wiyoro Village, Banguntapan District, Bantul Regency, Yogyakarta Special Region. Souza et al. (2019) investigated red chili plantations in Pakem District, Sleman Regency, Yogyakarta Special Region, that the three families are natural enemy insect families that dominate in chili plantations. Furthermore, Souza et al. (2019) added that the diversity of natural enemy insects in chili plants is indeed low, namely that only a few species are found consisting of one family.

In addition, it can be seen from the research results that the level of natural enemy insect diversity, which is classified as moderate, is also followed by evenness data, which is not classified as high either. It can occur because several species of natural enemy insects dominate the research area, for example, *Paratrechina longicornis*, *Anoplolepis gracilipes*, and *Exorista sp*. The results obtained are different from those reported by Putra & Utami (2020) that the evenness of the species of natural enemies they get is high. The difference in yields obtained can occur because other plants influence them near the chili plantations (Bernstein et al., 1991).

The abundance of Natural Enemy Insects

In this study, seven insect orders (1,196 individuals and 17 species) act as predators and three insect orders (236 individuals and 13 species) as parasitoids in chili plantations at the research location. The order with the highest abundance of individuals and species was Hymenoptera (Table 2). The Hymenoptera order is an order that has a large number of families in nature when compared to other orders. The Hymenoptera order is divided into two suborders, namely the Symphyta and Apocrita suborders (Trianto & Marisa, 2020). These two suborders are mostly recognized as natural enemies and are key species in an area (Forbes et al., 2018). It is also supported by Stahlhut et al. (2013) stated that most insect species belonging to the order Hymenoptera act as natural enemies. It was further explained that more than 250 species of the order Hymenoptera are parasitoid insects. In nature, Hymenoptera is known as an insect that lives side by side with the agricultural world, both as a (Bischoff et al., 2013; Miall et al., 2020) parasitoid, predators, and only a few play a role as insect pests (Miall et al., 2020; Stahlhut et al., 2013).

Furthermore, the results obtained in this study are also following those reported by Kurniawati (2015) that the order with the most incredible abundance of individuals and families found and acting as natural enemy insects is Hymenoptera. Meanwhile, the least abundant orders of individuals and families are Dermaptera and Strepsiptera (Table 3). Both orders are members of insects with a low abundance compared to other orders (Pohl & Beutel, 2013). According to Kurniawati (2015), the order Dermaptera is an insect with the characteristics of living in hiding, so the possibility of being found is very low. Meanwhile, the Strepsiptera order itself is a type of endoparasite for several kinds of insects, either acting as pests or pollinators. The low abundance of the Strepsiptera order is because this type lives attached to the host's body, making it difficult to find.

It can be seen from the abundance of natural enemy insect species obtained, the species with the highest number of individuals were *Paratrechina longicornis* (584 individuals) as predatory insects and *Exorista* sp. (105 individuals) as parasitoid insects (Table 2). *P. longicornis* is one of the insect species from the order Hymenoptera, and the family Formicidae obtained in this study. This species has the highest abundance compared to other predatory insect species because this is species has a way of living in colonies so that many individuals who fall into the traps. In addition, this can also occur because this species is known as "black crazy ant," which has an extensive range of ranges and very diverse types of feed, so it is possible to survive better than other species (Qodir et al., 2017). According to Vanderhaegen et al. (2019), *P. longicornis* is an insect species that is found in many residential areas. It is also one factor that causes this species to have a high abundance in the study area, considering that the research location is close to residential areas. Furthermore, *Exorista* sp. is one of the insect species from the order Diptera and the Tachinidae family found in the study. This species is a parasitoid that usually parasites the eggs of other insect species (Qodir et al., 2017).

Distribution Pattern of Natural Enemy Insect

In an ecosystem, there are three basic patterns of distribution of a species that has been recognized, namely random, clustered, and uniform (Ludwig & John, 1989). To identify the distribution pattern of a species, various distribution indices can be used, for example, the Morisita index, which has been standardized. Based on the distribution pattern analysis results in Table 3, the distribution pattern of natural enemy insects on chili plants in Bincau Village is grouped. This can be seen from the Morisita index value (Id) > 1 at all sampling times.

The distribution pattern of natural enemy insect groups in this study can occur because it is influenced by several factors, such as those caused by a combination of several factors in the environment, the social behavior of natural enemy insects, the ability to reproduce, the interaction of natural enemy insects, and a combination of the four these factors (McCoshum et al., 2016; Omkar & Pervez, 2016). Furthermore, the distribution pattern of natural enemy insects in this study is also influenced by the presence or absence of prey or hosts. It is consistent with the statement of Omkar & Pervez (2016) stated that the distribution of natural enemy insects in nature is influenced by the presence or absence of prey or hosts of these natural enemies in an ecosystem. Saeed et al. (2015) added that the presence or absence of other plants besides chilies in an area would undoubtedly affect the distribution of herbivorous insects, which are prey organisms or hosts of insect pests in an ecosystem. Hence, herbivorous insects in chili plants are also factors that can influence the formation of distribution patterns of natural enemy insects. It is also supported by the research results of and Staab & Schuldt (2020), which stated that the existence of natural enemies in nature would be influenced by the presence of an abundance of herbivorous insects. As additional information, Kurniawati (2015) explains that the presence of herbivorous insects is influenced by the presence or absence of host plants in an ecosystem.

Environmental Parameters

Based on the results of the calculation of environmental parameters on chili plantations in Bincau Village, the average temperature obtained was 27.72°C, humidity 74.9%, and light intensity 1117.8 (Table 4). Furthermore, the environmental parameter data obtained were analyzed using the PCA method with PAST3 software. The purpose of this analysis is to see the dominant characters that affect the diversity, abundance, and distribution patterns of natural enemy insects (Trianto & Purwanto, 2020).

Correlation analysis between groups produces Eigenvalue and% Variance, as shown in Table 5. While the Scatter plot is shown in Figure 2, and the loading plot of the component is shown in Figure 3. Based on the analysis results above, it is known that temperature is the environmental parameter that has the most influence on diversity. , abundance, and distribution patterns of natural enemy insects in chili plantations in Bincau Village. It can be seen from the line's length formed in Figure 2 and the height of the graph in Figure 3 (Trianto & Purwanto, 2020; Yudha et al., 2019). That is also following the statement by Medeiros et al. (2019) that temperature is one of the environmental parameters that affect the presence of natural enemy insects in an ecosystem. The temperature obtained in this study is the optimum temperature required by natural enemy insects to reproduce. According to Trianto et al. (2020), the optimum temperature required by natural enemy insects to support survival is in the range of 26-31°C.

Conclusion

This study concludes that the diversity of natural enemy insects in chili (*Capsicum annum* L.) in Bincau Village, Martapura District, Banjar Regency is moderate (H' = 2.396). Furthermore, the highest abundance in this study was Hymenoptera, which consisted of 9 families, 16 species, and 1,009 individuals. The distribution pattern of natural enemy insects in chili plantations is clustered (Id > 1).

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