Arthropods Diversity in Insectary Plant on Cocoa Cultivation Ecosystems

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Abstract. The purpose of this research to determine the population abundance and arthropod diversity on insectary plants that are among the cocoa plantation ecosystems. The research was conducted on five types of insectary plants which were used as objects for observing arthropods, that is; *H.annuus* L., *T.erecta* L., *Z.elegans* Jaqc., *G.globose* L. and *C.argentea*. Arthropod observations were carried out using three methods the results of which were identified and then the Shannon-Wiener species diversity index (H'). The results showed that the total abundance of arthropods in the five types of insectary plants was 374 individuals with the highest total arthropods being found in *T.erecta* with 118 individuals, followed by *H.annuus* 79 individuals, *C.argentea* purple 70 individuals, *Z.elegans* 55 individuals, and the lowest in 52 individual *G.globose*. The number of arthropods found was 98 individuals acting as pollinators, 111 individuals predators, 53 individuals decomposers, 9 individuals parasitoids, 96 individuals pests and 7 individuals as neutral insects from 10 orders, 34 families and 51 species. The species diversity index (H') value for all types of insectary plants is included in the moderate category with a value of 1.0 <H'> 3.322 which means sufficient productivity, balanced ecosystem conditions and moderate ecological pressure.

1 Introduction

The diversity of a plant type (biodiversity) around the cocoa plant affects the number of insects present, the more the number of a plant species, the higher the population of visiting insects such as insects as natural enemies both as parasitoids and predators and pollinators. In natural ecosystems, pest populations and their natural enemies are generally stable so that the presence of insect pests in plantations is no longer detrimental. This fact needs to be developed, because so far pest control efforts in the field generally still use chemical insecticides which are proven to have negative effects on the environment which can reduce the abundance and diversity of arthropod species [3].

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One of the efforts to improve the condition of cocoa planting land is through habitat management which can restore the balance of the agro-ecosystem to increase the quality and quantity of cocoa [11, 1]. Habitat management is an effort to create a healthy agro-ecosystem by managing the planting area and the surrounding environment [10]. According to Altieri [2], improving this habitat will significantly increase soil fertility and create a healthy agroecosystem.

Habitat management in cocoa plantations is a concept as well as an integrated pest management (IPM) strategy with an ecological approach and economic efficiency in the framework of re-establishing biodiversity and ecosystem balance which has an impact on improving crop productivity in an environmentally sound and sustainable manner. One of the ecological applications of IPM is to use attractant plants, namely flowering plants (insectary plants) which act as a source of food (nectar and pollen) as well as temporary shelters that can meet the needs of natural enemies. attracting pests so as not to attack core crops [4]. Flowering plants (insectary plants) are easy to grow, develop quickly and have striking colors and distinctive aromas that are favored by insects as natural enemies. The presence of natural enemies can balance the pest population to a non-detrimental limit [5].

Families of plants that are often found attractive to various insects that are useful as natural enemies, *e.g.*, Apiacea dan Asteracea. Apiacea is one of the very good insectary plants because it can provide a large amount of nutrients needed by parasitic insects. Asteracea is known to be attractive to parasitoids including *Helianthus annuus*, *Tagetes erecta*, *Celosia argentea* var. cristata. and *Zinnia elegans*, the plant is a producer of conspicuous flower composites, which are beneficial to many parasitoids as well as predatory and parasitoid insects [21].

The cocoa plant habitat management system by using several types of insectary plants will indirectly lead to the diversity of arthropods in the ecosystem. Therefore, it is necessary to conduct research to identify the diversity of arthropods in five different types of insectary plants, including; *Helianthus annuus*, *Tagetes erecta*, *Zinnia elegans*, *Gomphrena globose* and *Celosia argentea* var. cristata. The purpose and usefulness of this study are expected to be used as basic information material to determine the type, population density and diversity of predatory arthropods, parasitoids, decomposers, pollinators and pests in five types of insectary plants that are in the cocoa planting ecosystem in Gantarangkeke Village, Gantarangkeke District, Bantaeng Regency.

2 Method

2.1 Place and time

This research was carried out in a cocoa plantation, Gantarang Keke Village, Gantarang Keke District, Bantaeng Regency, South Sulawesi Province from May to July 2022 and identification activities were carried out in the Entomology Testing Room, Mamuju Class II Agricultural Quarantine Station Laboratory, Agricultural Quarantine Agency, Ministry of Agriculture.

2.2 Observation and sampling

Observation and sampling of flowering plants (insectary plants) was carried out using three methods, namely the visual method (direct observation), the insect net method (sweep net) and the yellow trap method which were determined by purposive random sampling around cocoa plantations. The samples selected were five types of flowering plants (insectary plants),

and for each type of flowering plant 3 sample plant tree points were selected which grew and were not adjacent to other flowering plants among the cocoa plantations that had been determined with the same clone. Installation of traps for sampling using the sweep net method and the yellow trap method is carried out by installing traps placed around the canopy of flowering plants. The direct observation method, insect nets and yellow traps were carried out 8 times with an interval of once a week for 2 months.

The insect samples obtained were then collected and separated and then put into sample bottles to be identified in the Entomology Testing Room, Mamuju Class II Agricultural Quarantine Station Laboratory, Agricultural Quarantine Agency, Ministry of Agriculture. Then insects are grouped based on their role.

1. Visual Method (direct observation)
   The visual method is a method of direct observation of insects visiting flowering plants at a certain time. This method is intended to observe insects that are not actively flying using tweezers. Insect collection was carried out at 07.00-10.00 UTC+08:00 by observing the presence of insects in flowering plants (insectary plants). The insects found were then collected into a plastic cup container filled with 70% alcohol solution.
2. Insect Net Technique (Sweep Net)
   This method uses a cone-shaped sweep net, the mouth of the net is made of circular wire with a diameter of ± 30 cm and the net is made of gauze with a stalk length of ± 1 m. How to use a sweep net is to hold the end of the sweep net tightly and the end of the circle touches the crowns of flowering plants (insectary plants) then the net is swung in a zig-zag manner 10 times with double swings. swing nets are intended to catch or collect insects that are actively flying and are carried out at 07.00-10.00 UTC+08:00. The caught insects were cleaned and then put into a plastic cup containing 70% alcohol and taken to the laboratory for identification.
3. Yellow Trap
   This method uses yellow adhesive traps that are hung as much as 1 (one) fruit at each point of the flowering plant tree which is used as the sample tree for observation. This trap is set at 07.00 UTC+08:00 and the time for collecting insects is at 07.00 UTC+08:00 the next day or 24 hours after. Insects obtained in these traps are collected, labeled according to the plant sample and the point of observation, then put into a plastic cup container to be identified.

2.3 Statistical analysis

Insects caught were calculated with the average percentage per time period, the Shannon-Wiener species diversity index (H'), the species uniformity index (E) and the species dominance index (C).

Species diversity index

The diversity of arthropod species can be calculated using the Shannon-Wiener (H') formula in [8]:

$$H' = -\sum (ni/N \ln ni/N) \quad (1)$$

Where H' Shannon-Wiener Diversity Index, ni Number of individuals of type-i, N Total number of individuals and ln Natural logarithm

Shannon-Wiener (H') species diversity index criteria:

H' < 1.0 = low diversity (low number of species and individuals, one species is dominant)

1.0 < H' > 3.322	=	Medium diversity (moderate number of species and individuals, the number of individuals does not vary)
H' > 3.322	=	High diversity (high number of species and individuals, no dominant species)

Species uniformity index

Arthropod type uniformity can be calculated by the formula (E) in [9]:

$$E = H' / \ln S \quad (2)$$

Where E Species Uniformity Index, H' Shannon-Wiener Diversity Index, ln natural logarithm and S Number of Types

Uniformity index criteria (E):

$0 < E \leq 0.4$ = Low uniformity (Community is depressed)
$0.4 < E \leq 0.6$ = Moderate uniformity (unstable community)
$0.6 < E \leq 1$ = High uniformity (stable community)

Species dominance index

The uniformity of arthropod species can be calculated using the Shimpon (C) formula in [15]:

$$C = \sum (ni/N)^2 \quad (3)$$

Where C Species Dominance Index, ni Number of individuals of type-i and N Total number of individuals

Type dominance index criteria (C):

$0 < C \leq 0.5$ = Low Dominance
$0.5 < C \leq 0.75$ = Moderate Dominance
$0.75 < C \leq 1$ = High Dominance

3 Results and discussion

3.1 Arthropod taxonomic diversity in insectary plants

The results of observing and identifying arthropods in Insectary Plants based on taxonomy can be seen in Figure 1:

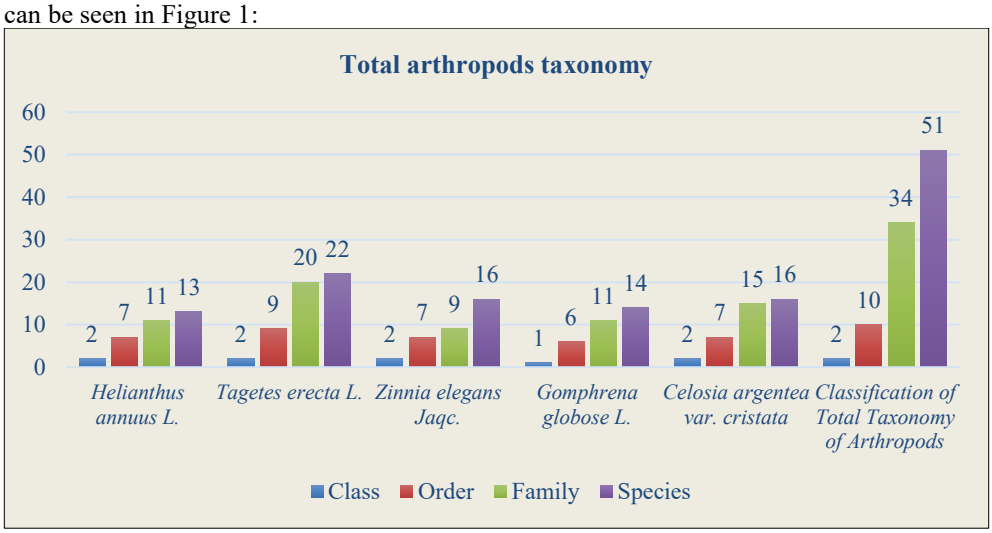

Fig. 1. Total arthropods by taxonomy in insectary plants.

Based on the results of observations and identification, the diversity of arthropods that were found during eight observations on five types of insectary plants within the cocoa plantation ecosystem were 2 classes, 10 orders, 34 families and 51 species (Figure 1). The highest taxonomic type of arthropod was found in *Tagetes erecta* with 2 Classes, 9 Orders, 20 Families and 22 Species, while observations of other insectary plants showed almost the same number of taxonomic types except for *Zinnia elegans* only the insecta class (Figure 1). The high or low order of each insectary plant corresponds to the supporting habitat, namely the number and growth phase of plants that provide a food source for the development of arthropods [23]. Meanwhile, the types of orders and families of the five insectary plants can be seen in Figure 2:

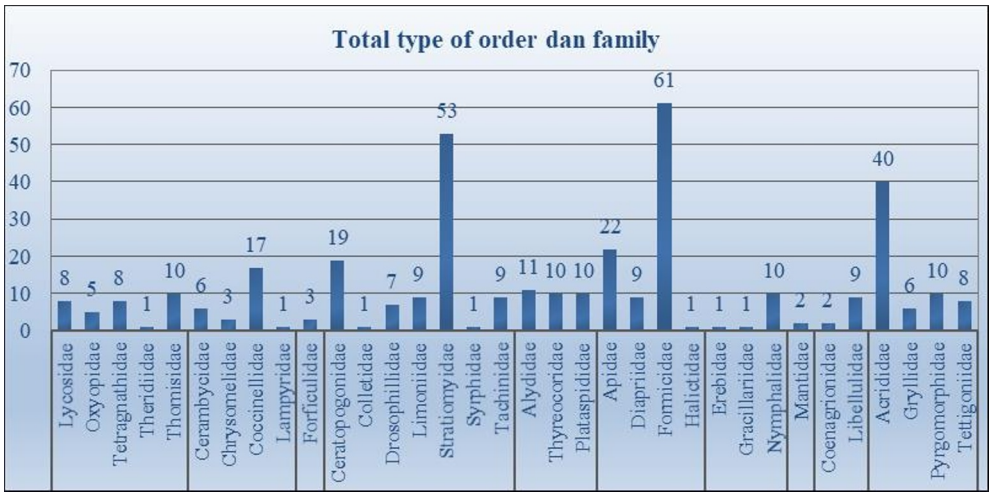

Fig. 2. Number of orders and families in insectary plants.

The results of the observational analysis showed that the highest number of individual arthropods in the Diptera order was found at around 99 individuals, followed by the Hymenoptera order with 93 individuals, Orthoptera with 64 individuals, Araneae with 32 individuals, Hemiptera with 31 individuals, and Coleoptera with 27 individuals. Lepidoptera 12 individuals, Odonata 11 individuals and the lowest is Dermaptera only 3 individuals (Figure 2). The large number of arthropods obtained from the orders Diptera and Hymenoptera is thought to be due to the use of yellow trap traps which attracted more of these two orders compared to other orders, this is in accordance with the opinion of [17], who stated that insects caught in yellow traps usually from the Diptera, Hymenoptera, Orthoptera and Hemiptera groups. Meanwhile, the families that were found mostly came from the Hymenoptera and Diptera orders, namely Formicidae with 61 individuals and the Stratiomyidae family with as many as 53 individuals. This is because the Hymenoptera order has a habit of colonizing so that when direct observations are made, the largest number is inhabited by the Formicideae family, for example: ants that can live in all places [6], as also in [18] research states that the Hymenoptera order is found in areas rice fields, plantations, forests, and open areas so that the number is very large, the availability of food and suitable habitat factors also affect the number of ants in the cocoa plantation area. While the Stratiomyidae family can be found, apart from the use of yellow traps, these insects are common insects and their numbers are found in many types of plants.

3.2 Arthropod population abundance in insectary plants

The results of data on the abundance of arthropods based on visual observations, the yellow trap method and the sweep net method for each insectary plant can be seen in Figure 3:

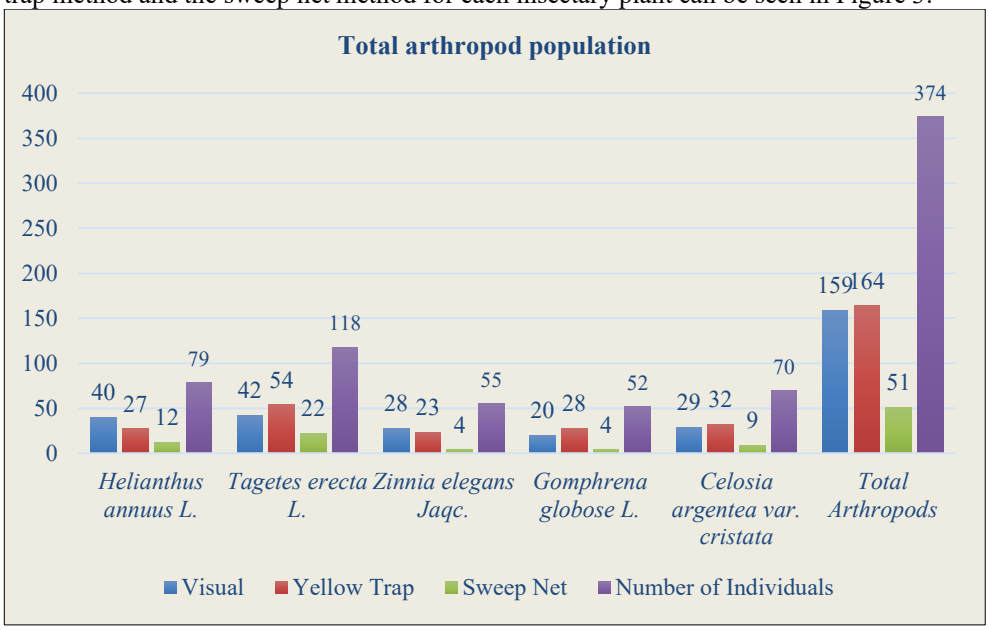

Fig. 3. Arthropod population in insectary plants.

Based on the results of observing and identifying arthropods using the visual, yellow trap and sweep net methods on five types of insectary plants that were among the cocoa plantation ecosystems, it was found that there were an abundance of arthropods as many as 374 individuals from 10 orders, 34 families and 51 species. The highest number of arthropods was found in *Tagetes erecta* with 118 individuals, followed by *Helianthus annuus* with 79 individuals, *Celosia argentea* var. cristata. 70 individuals, *Zinnia elegans* 55 individuals, and the lowest was in *Gomphrena globose* 52 individuals (Figure 3). The highest abundance of arthropod insectary plant *Tagetes erecta* was caused by having a population of more clumps compared to other insectary plant for each point of observation, the more clumps or denser an insectary plant, the more likely the arthropod insects to visit and take shelter. At the observation site, it can be seen that *Tagetes erecta* easily grows naturally through the debris of its seeds around cocoa plantations so that this condition can provide benefits for various Arthropods by providing shelter or an early food source. In addition, *Tagetes erecta* has a striking color and is generally yellow in color. Yellow color for insects indicates ripe flowers. Therefore, the yellow color of the *Tagetes erecta* plant is able to attract arthropod insects to take advantage of the pollen and nectar present in the plant. the plant. This is in accordance with the literature [22] which states that the *Tagetes erecta* plant has a striking color and distinctive aroma, so it can attract insects to come.

The abundance and diversity of the number of arthropods in each insectary plant among cocoa plantations is not only due to the pull factors in the form of shape, color and aroma of flowers, usually also influenced by the production of secondary metabolites (volatile compounds) produced and the condition of the cocoa plants which are used as research plots. The generative period, namely the production of flowers and fruit. This is in accordance with [24] which states that secondary metabolites in plants have several functions, including as an attractant (attracting pollinating insects), protecting from environmental stress, protecting against pests/diseases (phytoalexins), protection from ultra violet rays, as a growth regulator

and to compete with other plants (alelopathy). Another thing that causes an abundance of arthropods in insectary plants is because they only use vegetable pesticides, even though they use synthetic pesticides but they are not applied intensively and sustainably so that it affects the presence of many species of arthropods. Insectary plants between cocoa plantations can be used to provide a source of food, nectar, pollen, shelter for bees and other pollinating insects [20].

The results of the analysis also showed that the number of arthropods species using the yellow trap method was greater, namely 164 individuals compared to the visual observation of 159 individuals and the sweep net method of only 51 individuals (Figure 3). This is because the nature of insects in general prefers and is attracted to the yellow color reflected by the yellow trap which has been smeared with adhesive glue so that eventually the approaching insects will stick to the trap, whereas in visual observations and the sweep net method the number of insects caught is relatively small because when catching insects is not always present in insectary plants and is influenced by high mobility [19].

3.3 The Role of arthropods in insectary plants

The results of insect identification based on their ecological role in each insectary plant can be seen in Table 1:

Table 1. Arthropods composition based on their ecological role in insectary plants

Insectary Plant	The Role of Arthropods						Number of Individuals
	Polinator	Predators	Decomposer	Parasitoid	Pest	Neutral	
Helianthus Annuus L.	32	18	12	0	17	0	79
Tagetes erecta L.	18	30	19	9	35	7	118
Zinnia elegans Jaqc	10	28	6	0	11	0	55
Gomphrena globose L.	15	17	8	0	12	0	52
Celosia argentea var. cristata	23	18	8	0	21	0	70
Total Arthropods	98	111	53	9	96	7	374
Total (%) Arthropods	26.2	29.7	14.2	2.4	25.7	1.9	100

Arthropod observations based on their ecological roles in five types of insectary plants found that 98 individuals (26,2%) insects acted as pollinators, 111 individuals (29,7%) as predators, 53 individuals (14,2%) as decomposers, 9 individuals (2,4 %) as parasitoids, 96 individuals (25,7 %) as pests and 7 individuals (1,9 %) as neutral insects. Arthropods that act as predators are more numerous than pollinators, decomposers, parasitoids, pests and those that act as neutral arthropods just to balance the ecosystem. This is because most groups of predatory arthropods are more active around the surface of insectary plants so they can be found at every observation point. Apart from being more active, predators are also generalist and polyphagous, meaning that even though there are only a few major insect pests in the field, predators such as spiders can eat other pests, making it more effective in controlling pests on cocoa plants surrounded by insectary plants [6].

3.4 Species diversity index (H'), species uniformity (E) and dominance index (C)

The value of the species diversity index (H'), species uniformity (E) and dominance index (C) in arthropod observations of five types of insectary plants can be seen in Figure 4:

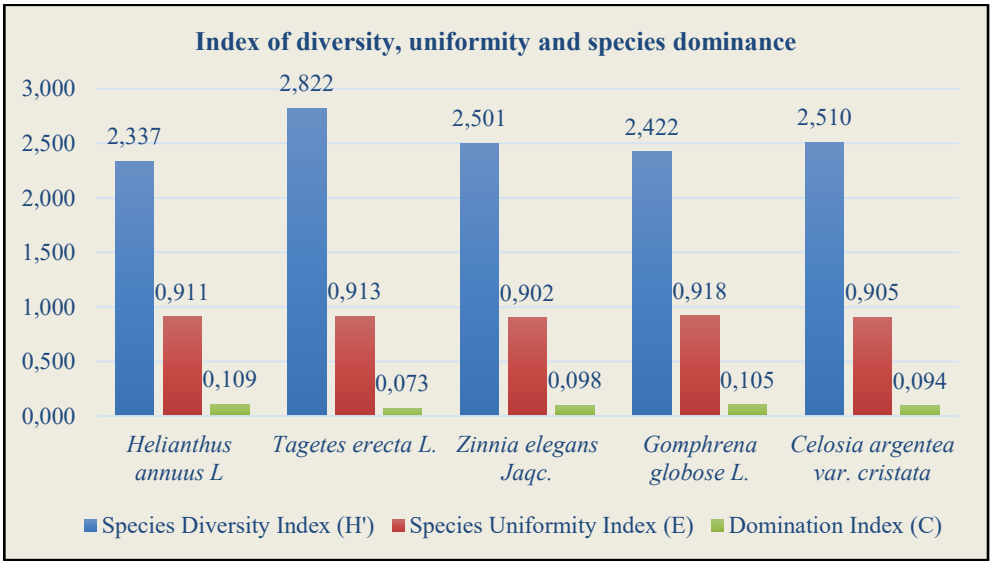

Fig. 4. Species diversity index (H'), species uniformity (E) and dominance index (C) in arthropod insectary plants.

Based on the results of Shannon-Weiner's species diversity (H') analysis on arthropod observations of five insectary plant species, it was shown that *Tagetes erecta* had a high species diversity index of 2.822, followed by *Celosia argentea* var. cristata. 2,510, *Zinnia elegans* 2.501, *Gomphrena globose* 2.422 and the lowest species diversity was *Helianthus annuus* 2.337 (Figure 4). This is because the number of Formicidae Family dominates the planting of insectary plants, so the high or low value of the species diversity index (H') is influenced by the number of families and the number of populations. If the number of species is greater but in one family, the diversity is low compared to the number of species that are fewer but belong to several families [16],[6]. The index of arthropod diversity in all insectary plant observations was included in the moderate category (1.0 <H'> 3.322) which means sufficient productivity, balanced ecosystem conditions and moderate ecological pressure. Ecosystem conditions that have a diversity index value between 1 - 3 indicate that the presence of insect pests and arthropod natural enemies is almost balanced, where the presence of natural predators and parasitoids can still control insect pests in the environment. According to [14];[7] states that the diversity index (H') is a number that has no units with a range of 0 - 3. The level of diversity will be high if the value of H' is close to 3, so this indicates good environmental conditions. Conversely, if the H' value is close to 0, then the diversity is low and the environmental conditions are not good.

The results of the analysis of the uniformity index values of the arthropods in the five types of insectary plants did not show any differences, namely the value (E) found in the observations of *Gomphrena globose* L. 0.918, *Tagetes erecta* 0.913, *Helianthus annuus* 0.911, *Celosia argentea* var. cristata. 905, and *Zinnia elegans* Jaqc. 0.902 (Figure 4), this condition indicates that all observations are in the high uniformity category with a value of $0.6 < E < 1$ which means the community is stable. [14],[19] states that evenness (E) values range between 0 and 1 or evenness gets closer to 1 then describes a better ecosystem condition

where all species are quite abundant. The reason for the high evenness of insect species in insectary plants is because there is no single family whose number dominates. This is in accordance with [13],[19] which states that evenness values will tend to be high if the population in a family does not dominate the population of other families, whereas evenness tends to be low if a family has a population that dominates other populations.

While the results of the analysis on the species dominance index (C) ranged from 0.073 to 0.109 or included in the low category with a value of $0 < C < 0.5$ which means it does not show dominance in all types of insectary plants (Figure 4). This is thought to be due to the intensive and sustainable application of synthetic pesticides which affect the presence of arthropods of various species so that no one dominates.

4 Conclusion

Based on the results of the research conducted, it was concluded that the taxonomic diversity of arthropods during eight observations using the visual method, yellow trap and sweep net on five types of insectary plants that were among the cocoa planting ecosystems found 2 classes, 10 orders, 34 families and 51 species. the number of arthropods found was 98 individuals (26%) acting as pollinators, 111 individuals (30%) as predators, 53 individuals (14%) as decomposers, 9 individuals (2.4%) as parasitoids, 96 individuals (26%) as pests and 7 individuals (1.9%) as neutral insects. The species diversity index (H') value for all types of insectary plants is included in the moderate category with a value of $1.0 < H' > 3.322$ which means sufficient productivity, balanced ecosystem conditions and moderate ecological pressure, while the species uniformity index value (E) is at high uniformity category with a value of $0.6 < E < 1$ which means the community is stable, but low on the species dominance index (C) is $0 < C < 0.5$ or does not show dominance in all types of insectary plants.

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