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Selecting Effective *Insectary Plants* to Enhance Coccinellidae Preference and Diversity in Rice Agroecosystems

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Abstract

Background: *Insectary plants are widely recognized for enhancing natural enemy populations, however comparative evidence on how different plant species influence the preference and community structure of Coccinellidae in rice agroecosystems remains limited. In addition, the selection of appropriate insectary plants is often not well justified despite differences in floral traits, nectar availability, and accessibility that affect predator attraction and retention. This study examined the preference and diversity of Coccinellidae associated with three insectary plant species (Cosmos sulphureus, Zinnia elegans, and Turnera subulata) in a rice agroecosystem in Mojokerto, Indonesia.* **Methodology:** *The research was conducted using a field-based quasi-experimental design with separate treatment blocks and repeated sampling at 15, 30, 60, and 75 days after planting. Adult Coccinellidae were collected using D-vac suction sampling on insectary plants and sweep nets in adjacent rice fields (3 m from insectary plants). Data were analyzed using Shannon–Wiener diversity (H'), Pielou's evenness (E), Simpson's dominance (D), and Margalef's richness (R).* **Findings:** *A total of 277 individuals belonging to five species consisted of Micraspis lineata, Micraspis discolor, Cheilomenes sexmaculata, Coccinella transversalis, and Coelophora inaequalis were recorded, with communities dominated by Micraspis lineata in C. sulphureus, T. subulata, and control plots. Z. elegans supported the highest diversity (H'= 0.7054), evenness, and species richness, indicating a more balanced community structure, whereas other treatments showed lower diversity due to species dominance. Ecologically, this dominance reflects a simplified community structure with reduced functional complementarity.* **Contributions:** *These findings highlight the importance of insectary plants selection in shaping predator communities and demonstrate that appropriate refugia can enhance ecological stability. This study provides empirical and practical insights for optimizing habitat management to support conservation biological control in sustainable rice agroecosystems.*

Keywords: *Biodiversity; Coccinellidae; Insectary Plants; Rice Agroecosystem; Zinnia elegans*

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INTRODUCTION

Rice agroecosystems are highly vulnerable to pest attacks. Yield losses due to plant pests in global food commodities including rice, are reported to reach 20–40%, causing significant economic losses and threatening global food security (Castilla, 2022). Various pest species, such as brown planthoppers, stem borers, and aphids, often cause significant damage, forcing farmers to rely heavily on chemical insecticides. Intensive pesticide use has been shown to have various negative impacts, including pest resistance, population resurgence, environmental pollution, and the decline of natural enemies, which play a crucial role in biological control (Sharma et al., 2019). Furthermore, high levels of pesticide use are also known to disrupt ecosystem services, including natural biological control, which ultimately increases dependence on chemical inputs. This situation emphasizes the need for a more environmentally friendly and sustainable Integrated Pest Management (IPM) approach.

One ecological strategy in IPM that is gaining increasing attention is the use of *insectary plants* or *refugia*, which provide additional resources for natural enemies. *Insectary plants* are known to increase the abundance, survival, and activity of predators and parasitoids by providing nectar, pollen, shelter, and suitable microhabitats (Landis et al., 2000; Gurr et al., 2016). In rice ecosystems, the use of flowering plants has been shown to be effective in increasing populations of entomophagous arthropods, which can naturally suppress pest populations (Horgan et al., 2016). However, most of this research has focused on increasing the abundance of natural enemies in general, while studies on how *insectary plants* influence predator community structure, particularly the diversity and composition of Coccinellidae species in rice agroecosystems, are still limited.

The Coccinellidae family is an important predator group in rice cultivation. Several Coccinellidae species act as predators of various pests such as aphids, planthoppers, mites, and other small insects, thus offering significant potential for supporting biological control (Snyder, 2009; Shanker et al., 2018). However, the presence and diversity of Coccinellidae are largely determined by the availability of habitat and additional food sources. Plants such as *Cosmos sulphureus*, *Zinnia elegans*, and *Turnera subulata* are known to have ecological value in attracting predatory insects due to their striking flower colors, open flower structures, and abundant nectar and pollen content (Lailiyah & Haryadi, 2021; Fadhilah et al., 2023). These three species were chosen because they have distinct morphological and phenological characteristics, such as variations in flower color, shape and size, and a relatively long flowering period, thus potentially providing a more diverse resource for Coccinellidae. This *refugia* is relatively easy to cultivate, adaptable to tropical rice agroecosystem conditions, and has been recommended in several studies as potential *insectary plants*, making it relevant to test its effectiveness comparatively in a single cropping system.

Studies on the effectiveness of *insectary plants* on the presence of Coccinellidae have been reported in various ecosystems, but research directly comparing the preferences and diversity of Coccinellidae on various *insectary plant* species in rice fields is still limited. However, selecting the right plant species is crucial for the successful conservation of natural enemies in supporting pest control. Furthermore, understanding the dynamics of Coccinellidae presence during the rice plant growth phase is also important to determine when the *insectary plants* effect is most optimal for attracting Coccinellidae.

Based on this, this study was conducted to examine the preferences and diversity of Coccinellidae on three *insectary plant* species: *Cosmos sulphureus*, *Zinnia elegans*, and *Turnera subulata* in rice agroecosystems. The study included analysis of population abundance, peak presence times, species composition, and calculation of diversity, evenness, dominance, and species richness indices. The results are expected to provide a scientific basis for determining the most effective *insectary plant* species to support natural enemy conservation in rice ecosystems, thus enabling their implementation as a sustainable IPM strategy.

METHOD

Study Area

This study was conducted from June to September 2024 in the rice agroecosystem of Jabon Village, Mojoanyar District, Mojokerto Regency, East Java (latitude 7°48'48.61"S, longitude 112°45'87.56"E). The design used a field-based quasi-experimental design. Each *insectary plants* (*Cosmos sulphureus*, *Zinnia elegans*, *Turnera subulata*) and control were placed in separate field blocks.

The study area (0.2 hectare) was divided into four blocks, each containing four embankments of 16 meters in length. Each treatment was established within a single block, spatially separated by approximately 40 m to minimize interference was established to minimize the potential for dispersal of Coccinellidae between treatments. Although adult Coccinellidae are capable of flight, these predators exhibit limited routine dispersal at the field scale and tend to remain in favorable habitats unless resources become scarce (Schellhorn et al., 2014). Within each block, repeated sampling was conducted over time and across sampling points to capture temporal and spatial variation in Coccinellidae populations. Therefore, the sampling units represent subsamples within each treatment and not true independent replications.

Sample

The samples consisted of adult (imago) Coccinellidae individuals collected from three types of insectary plants: *Cosmos sulphureus*, *Zinnia elegans*, and *Turnera subulata*. Only adult individuals were recorded to ensure accurate species level identification. Sampling was conducted on both the *insectary plants* and the adjacent rice plants located approximately 3 m from the *insectary plants*, in order to assess the distribution of Coccinellidae between refugia and the rice crop.

Instrument

Instruments include a sweep net, D-vac, sample bottles, hand counter, 70% alcohol, stereo microscope, insect tweezers, and digital camera.

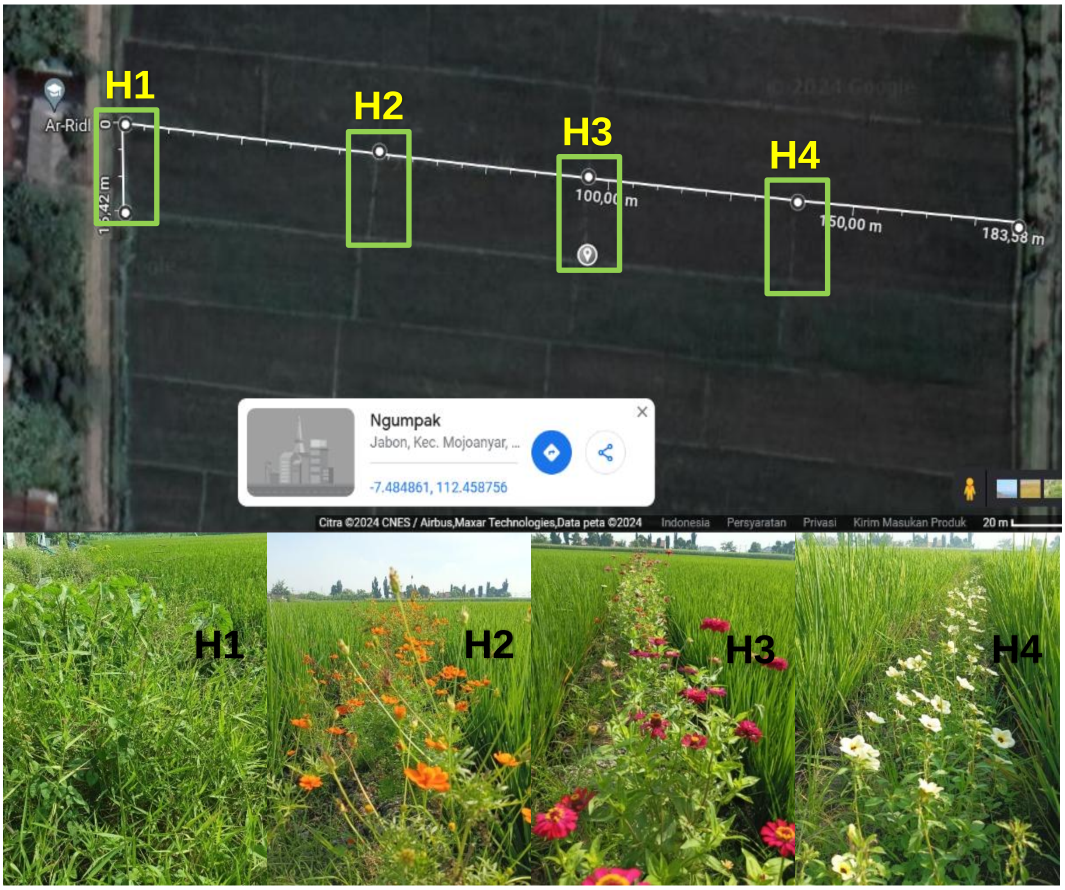

Figure 1. Sampling location of *insectary plants* block (green box), H1. Control block, H2. *Insectary plants* block *Cosmos sulphureus*, H3. *Insectary plants* block *Zinnia elegans*, H4. *Insectary plants* block *Turnera subulata.*

Data Collection

Sampling was conducted at four observation times (15, 30, 60, and 75 days after planting) at 08:00 - 10:00 A.M., when Coccinellidae are actively foraging (Yudiawati & Pertiwi, 2020). At each sampling time, collections were performed within each treatment block on insectary plants using a D-vac along a 10 m transect. Additional sampling was conducted in adjacent rice fields located approximately 3 meters from the insectary plants along a 10 m transect using sweep nets. All collected Coccinellidae individuals were placed in insect collection boxes and transported to the Pest Laboratory of the Food Crop and Horticulture Protection Work Unit, Mojokerto, for further identification.

Identification of Coccinellidae

Coccinellidae obtained from the field were identified morphologically based on morphological characters using a stereo microscope and visual observation of the Coccinellidae identification key refers to Gordon (1985); Ślipiński (2007);

and the websites https://www.gbif.org/, https://www.insectimages.org/ and https://www.inaturalist.org/.

Data Analysis

The analysis of Coccinellidae diversity was conducted by calculating the diversity, evenness, dominance, and species richness indices of Coccinellidae in each insectary plant block. The analyses used were the Shannon-Weiner diversity index, Pielou evenness index, Simpson dominance index, and Margalef species richness index.

Diversity index (Shannon & Weaver, 1949; Bufebo et al., 2021):

$$H' = -\sum_{i=1}^{n} Pi\ ln\ Pi \quad (1)$$

Description,
H' : Diversity Index
Pi : ni/N (number of individuals of one species/total number of all species)
ni : Number of individuals of species i
N : Number of individuals of all species

Evenness Index (Pielou, 1966; Jannat et al., 2020):

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

Description,
E : Evenness index
H' : Shannon-Weiner diversity index
S : Total number of species

Dominance Index (Simpson, 1949; Jannat *et al.*, 2020):

$$D = \Sigma\ Pi^2 \quad (3)$$

Description,
D : Dominance index
Pi : ni/N (number of individuals of one species/total number of all species)
Ni : Number of individuals of species i
N : Number of individuals of all species

Species Richness Index (Margalef, 1968; Bufebo et al., 2021):

$$R = \frac{S-1}{LnN} \quad (3)$$

Description,
R : Species richness index
S : Total species
N : Total number

RESULT AND DISCUSSION

Preference Coccinellidae in insectary plants

The preference of Coccinellidae in *insectary plants* is shown by level of their presence in each *insectary plants* block. Presence of Coccinellidae in the *insectary plants* block was higher than in the control (Table 1). The highest presence of Coccinellidae was found in the *Zinnia elegans* block (H3) with a population of 116 individuals, accounting for approximately 41.9% of the total observed individuals. This was followed by the *Turnera subulata* block (H4) with 80 individuals (28.9%), and the *Cosmos sulphureus* block (H2) with 57 individuals (20.6%), while the control (H1) showed the lowest population with only 24 individuals (8.7%). Thus, the abundance of Coccinellidae in the *Z. elegans* block was approximately 4.83 times higher than the control, followed by *T. subulata* (3.33 times higher) and *C. sulphureus* (2.38 times higher). These results indicate a clear increasing trend in Coccinellidae abundance from the control to insectary plant treatments, with the strongest enhancement observed in the *Z. elegans* block, suggesting a substantial positive effect of *insectary plants* on predator presence.

Table 1. Number of Coccinellidae Populations in Each *Insectary Plants Block*

Insectary plants block	Observation time (DAP)				Amount population
	15	30	60	75	
H1	2	7	8	7	24
H2	7	10	18	22	57
H3	3	30	53	30	116
H4	1	10	36	33	80
Total	**13**	**57**	**115**	**92**	**277**

Notes : H1. Control ; H2. *Cosmos sulphureus* ; H3. *Zinnia elegans* ; H4. *Turnera subulata*

The presence of *insectary plants* significantly influenced the abundance of Coccinellidae in the study area. The *insectary plants Zinnia elegans*, *Turnera subulata*, and *Cosmos sulphureus* were more effective in attracting predatory insects from the Coccinellidae family compared to the control. Specifically, Coccinellidae abundance increased by approximately 383.3% in the *Z. elegans* block, 233.3% in the *T. subulata* block, and 137.5% in the *C. sulphureus* block relative to the control. Planting flowers such as *Zinnia elegans, Turnera subulata* and *Cosmos sulphureus* is engineering ecology For create a viable habitat give service for Coccinellidae provides shelter and a place to find prey (Snyder, 2019). Third type plants can provide source nectar and supportive habitat the presence of Coccinellidae which plays a role important in control biological insect pests (Aldini et al., 2019).

Attendance rate Coccinellidae which is more height on the *insectary plants* block is caused existence power the visual appeal of the striking flowers (Nalepa et al., 2005) as well as availability source food (Aldini et al., 2019). These factors become base main thing that improves Coccinellidae visit to *the insectary plants* area. Fadhilah et al., (2023) stated that that presence predatory insects on *insectary plants* due to the presence of colored plant flowers striking as well as can provide nectar and pollen that become source food complement for insects. Conditions this also indicates that integration plant flowering in system agriculture can increase population enemy experience in a way sustainable.

The number of Coccinellidae populations present in the *insectary plants* block *Zinnia elegans* own level presence highest compared to other types of flowers. *Zinnia elegans* capable interesting more Lots member Coccinellidae family compared with *Turnera subulata* and *Cosmos sulphureus* Because characteristics morphology and physiology the flowers are more support existence predatory insects. *Zinnia elegans flowers* own open and flat structure, and produce easy nectar accessed by Coccinellidae as source feed additional (Sun et al., 2025; Durak et al., 2025).

Another factor is the striking color of *Z. elegans* flowers, such as red, purple, pink, orange, yellow, and white, which play a role in attracting visual insects such as Coccinellidae (Pramaishella & Haryadi, 2023) because predatory arthropods use visual sensors such as color, contrast, and shape as well as chemical sensors during foraging activities (Lim & Ben-Yakir, 2020). Visual characteristics of flowers, including color, have been shown to be one of the main factors influencing the abundance of predators such as Coccinellidae in various insectary plant planting experiments (Hatt et al., 2018). In accordance with the findings that flower characteristics including color, shape, visual contrast, and nectar availability are strongly correlated with the presence of natural enemies, so that color becomes an important variable in attracting predators to plant habitats (Fiedler & Landis, 2007).

Temporal observations also revealed a clear increasing trend in Coccinellidae populations from 15 to 60 days after planting (DAP), followed by a slight decline at 75 DAP. The peak abundance occurred at 60 DAP (115 individuals), indicating that insectary plants were most effective in attracting Coccinellidae during the mid-growth stage of rice. This pattern suggests that the availability of floral resources and prey during this period plays a key role in enhancing predator presence.

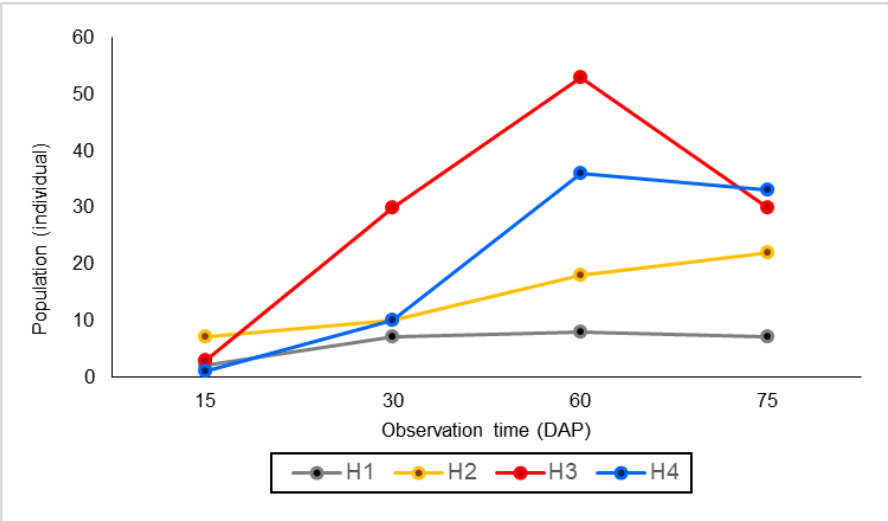

Figure 2. Coccinellidae population graph for each observation period in *insectary plants* block. H1. Control block, H2.*Cosmos sulphureus*, H3. *Zinnia elegans*, H4. *Turnera subulata*

Peak Presence of Coccinellidae in Insectary Plants

Temporal observations also revealed a clear increasing trend in Coccinellidae populations from 15 to 60 days after planting (DAP), followed by a slight decline at 75 DAP. The peak abundance occurred at 60 DAP (115 individuals), indicating that insectary plants were most effective in attracting Coccinellidae during the mid-growth stage of rice. This pattern suggests that the availability of floral resources and prey during this period plays a key role in enhancing predator presence (Figure 2).

At the age of the rice plants 60 days after planting, conditions in the insectary plants block have entered the peak flowering phase along with the rice plants that also begin to produce flowers. The availability of abundant food sources in the form of nectar and pollen during this phase is the main attraction factor, thus increasing the activity of Coccinellidae visits (Gurr et al., 2017).

The high presence of Coccinellidae in *insectary plant* blocks at 60 days after planting is due to the synergy between prey population dynamics, the phenological phase of the rice plant, and the availability of alternative food sources from insectary plants. Syatrawati et al., (2020) stated that adult Coccinellidae can be found in high numbers in fields when plants enter the flowering phase.

At 60 days after planting, rice plants enter the flowering and panicle formation phase, a crucial phase in the dynamics of the rice paddy ecosystem. Research Sholahuddin et al., (2023) on the legowo row planting system showed that predator populations, including those of the Coccinellidae genus, increased as rice entered the early generative phase, from panicle emergence to flowering. In another study, the reproductive phase and grain formation period were dominated by Hemipteran and Heteropteran insect pests, which became prey for predators, including Coccinellidae (Rattanapun, 2012).

During this phase, pest populations typically experience a significant increase, representing the primary prey for Coccinellidae. With increased prey availability, predator activity increases, playing a crucial role in natural biological control. Concurrently, *Zinnia elegans*, *Turnera subulata*, and *Cosmos sulphureus* in the *insectary plants* block have also entered their peak flowering phase, providing additional food sources in the form of nectar and pollen, essential for Coccinellidae (Yulifada et al., 2024), particularly for adult individuals, to maintain metabolic activity and support reproduction.

The combination of abundant prey and the availability of additional food sources on insectary plants creates a microhabitat that supports the life of Coccinellidae. Furthermore, the denser structure of rice plants during the generative phase also provides ideal shelter and increases the retention and reproduction rates of these predators in the surrounding fields (Ali et al., 2023).

Identification of Coccinellidae species

Based on results observation and capture Coccinellidae insects in the *insectary plants* blocks, five types were obtained Coccinellidae with character morphology different associated with *insectary plants*. The five species were then identified morphologically by identification key Gordon (1985); Ślipiński (2007) and with visual references from *the Global Biodiversity Information Facility (GBIF) website , Insect Images: The Source for Entomology Photos* and *iNaturalist*. This identification was carried out by matching key morphological characters such as body shape, body size, color pattern, antennae, and elytra characters to allow for more accurate species determination. The results obtained consisted of *Micraspis lineata, Micraspis discolor, Cheilomenes sexmaculata, Coccinella transversalis,* and *Coelophora inaequalis.*

The five identified species are members of the Coccinellidae family, subfamily Coccinellinae, and tribe Coccinellini. All are insect predators and play a crucial role as natural biological control agents, particularly against herbivorous pests such as aphids and planthoppers. These results demonstrate the role of *insectary plants* in attracting and maintaining natural predator populations in agricultural ecosystems and serve as a basis for developing ecologically based integrated pest management (IPM) strategies.

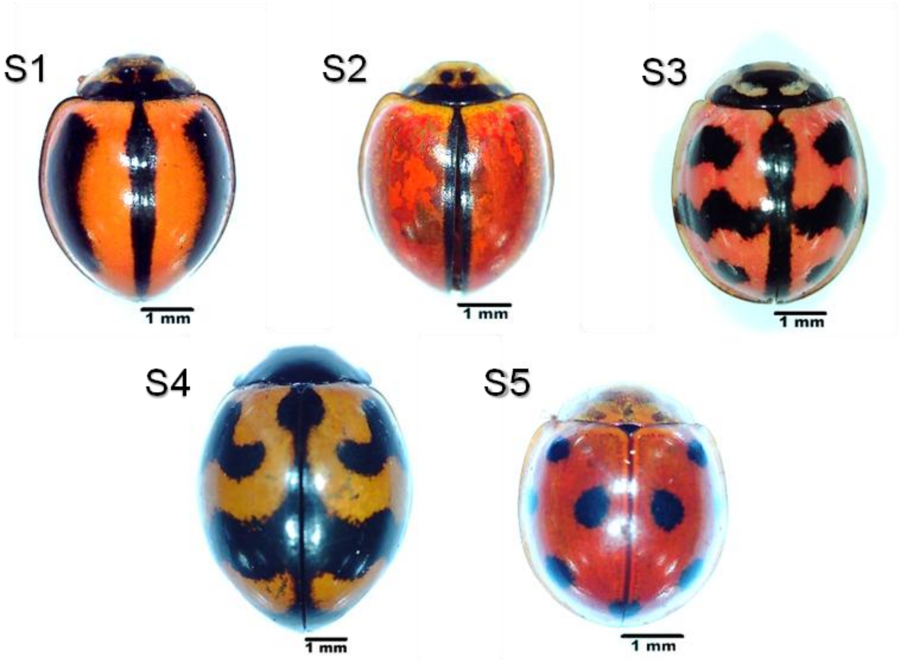

Figure 3. Coccinellidae Species
Description: S1.*Micraspis lineata,* S2.*Micraspis discolor,* S3. *Cheilomenes sexmaculata,* S4.*Coccinella transversalis* and S5.*Coelophora inaequalis*

Diversity of Coccinellidae

The differences amount of populations and species of Coccinellidae present in each *insectary plants* block indicate that Coccinellidae have different preferences for *insectary plants* block habitats. The *Zinnia elegans insectary plants* block is the habitat most visited by Coccinellidae both in terms of population number and number of species present. The *Zinnia elegans insectary plants* block was visited by 116 individuals consisting of 5 species dominated by the *Micraspis lineata* species which reached 92 individuals.

Other *insectary plant* blocks, *Turnera subulata*, *Cosmos sulphureus*, and control, were only visited by three Coccinellidae species with lower population densities than the *Zinnia elegans insectary plants* block. The presence of predatory insects from the Coccinellidae family in the *insectary plants* block was influenced by the brightly colored flowers that attract predatory insects (Li et al., 2020). Characteristics that can influence insect presence on insectary plants include flower color, nectar, and pollen content. Flower color is one of the attractions because the brighter the flower color, the more it is preferred by natural enemies. Nectar and pollen content also attract insects to attend and carry out activities (Allifah et al., 2019).

Zinnia elegans is preferred because period long flowering up to reach 23 days compared to plant *insectary plants* others (Wahocho et al., 2016). Furthermore, flower shape also determines the preference of Coccinelidae for visiting. The rosette-shaped flowers of *Zinnia* sp. are attractive to predators, thus attracting more visitors (Jennings et al., 2017). Coccinellidae are typically found visiting *insectary plants* around 08.00 AM. This is related to the longer blooming period of *Zinnia flowers*, and the blooming of flowers indicates the availability of nectar and pollen.

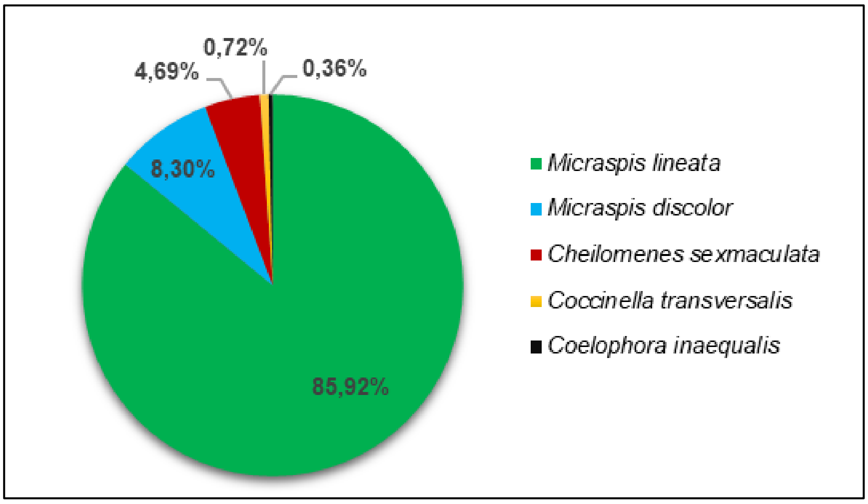

Figure 4. Percentage of Coccinellidae species in the *insectary plants block*

The most dominant species present in the *insectary plants* block is *Micraspis lineat*a with a percentage reaching 85.92%. Meanwhile, other species such as *Micraspis discolor* 8.3%, *Cheilomenes sexmaculata* 4.69%, and *Coccinella transversalis* and *Coelophora inaequalis* less than 1%. *Micraspis lineata* is the most commonly found species because it is a species that has high reproductive activity and supported by suitable environmental conditions and food sources, especially in tropical areas. Shanker et al., (2018); Yudha et al., (2022) reported *Micraspis lineata* is dominant species in rice field ecosystems because is the main predator of brown planthoppers, which are a major pest of rice plants.

Table 2. Diversity, Evenness, Dominance and Species richness index of Coccinellidae in *insectary plants*

Indicator Diversity	**Insectary plants block**			
	H1	**H2**	**H3**	**H4**
Index diversity (H')	0.3446	0.3563	0.7054	0.3813
Index uniformity (E)	0.3137	0.3243	0.4383	0.3471
Index dominance (D)	0.8438	0.8363	0.6485	0.8163
Index riches type (R)	0.6293	0.4947	0.8415	0.4564

Notes : H1 . Control ; H2. *Cosmos sulphureus* ; H3. *Zinnia elegans* ; H4. *Turnera subulata*

The analysis of diversity indicators showed clear ecological differences in the community structure of Coccinellidae across treatments. The highest diversity index (H') was recorded in H3 (0.7054), while the lowest value was observed in H1 (0.3446). According to Odum & Barrett (2005), higher H' values represent more stable communities with better species distribution. The elevated H' in H3 indicates that *Zinnia elegans* was more effective in attracting a wider range of Coccinellidae species, likely due to its floral structure, continuous nectar supply, and strong visual cues. Gurr et al., (2017) These plant traits are known to enhance natural enemy abundance and diversity.

The evenness index (E) also showed the highest value in H3 (0.4383), reflecting a more balanced distribution of individuals among species. In contrast, H1, H2, and H4 displayed low evenness values (0.3137–0.3471), suggesting a strong dominance of *Micraspis lineata*. Magurran (2004) Low evenness typically indicates community imbalance, where specific species disproportionately dominate the system. This supports the interpretation that *Z. elegans* contributed to a more equitable representation of predator species.

The dominance index (D) further demonstrated that H1 (0.8438), H2 (0.8363), and H4 (0.8163) were highly dominated by a single species, while H3 had a considerably lower dominance value (0.6485). Begon et al., (2006) A lower dominance index reflects a more stable and resilient community structure, where the ecological role is distributed among several species rather than concentrated in one. This again highlights the ecological advantage provided by *Z. elegans* as an *insectary plant*.

Similarly, species richness (R) was highest in H3 (0.8415), indicating that more species were present in this block compared to H1, H2, and H4. Landis et al., (2000) Richness is strongly influenced by floral resources, and flowering plants with open structures and attractive visual characteristics often support higher numbers of natural enemy species. The result reinforces the suitability of *Z. elegans* for supporting predator biodiversity in rice ecosystems.

Overall, all ecological indices consistently demonstrate that H3 (*Zinnia elegans*) supported the highest diversity, evenness, and species richness, with the lowest dominance among the four blocks. Meanwhile, the control (H1), *Cosmos sulphureus* (H2), and *Turnera subulata* (H4) were dominated by *M. lineata*, indicating lower ecological balance. These findings align with Heimpel & Mills (2017) that the principles of conservation biological control, which emphasize that selecting appropriate flowering plants can enhance predator communities and contribute to more effective pest suppression.

CONCLUSION

The results indicate that *Zinnia elegans* is the most effective *insectary plants* for enhancing the diversity and ecological balance of Coccinellidae in rice fields. This species supported higher diversity, evenness, and species richness while reducing dominance compared to *Cosmos sulphureus*, *Turnera subulata*, and the control. These findings suggest that the selection of appropriate *insectary plants* plays a critical role in structuring predator communities by promoting a more balanced and functionally stable assemblage, which is essential for strengthening biological control services in agroecosystems. Thus, the integration of suitable insectary plants such as *Z. elegans* represents a practical ecological strategy to improve habitat quality and support sustainable pest management in rice production systems. Future research should focus on evaluating the long-term effectiveness of *insectary plants* under different agroecological conditions and their direct impact on pest suppression and crop yield.

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