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The preference of insect predators on several types of flowering plants as insectary plant in cayenne pepper fields

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Abstract. *Fadhilah K, Rahardjo BT, Hadi MS. 2023. The preference of insect predators on several types of flowering plants as insectary plant in cayenne pepper fields. Biodiversitas 24: 6177-6183.* Cayenne pepper (*Capsicum frutescens* L.) is a popular commodity yet often suffers from reduced yields due to pest attacks. Therefore, growing this plant requires environmentally friendly management. One of the measures is using the baby blue eyes (*Nemophila menziesii*) plant. Baby blue eyes are promising insectary plants since they attract predatory insects. This study, which was conducted in Kasin Village, Karangploso, Malang, from March to June 2023, aimed to explore the predatory insects' diversities and preferences in cayenne pepper fields by comparing baby blue eyes as insectary plants with common zinnias and marigolds. The research comprised four treatments: P1. Control; P2. Cayenne peppers + baby blue eyes; P3. Cayenne peppers + common zinnias (*Zinnia elegans*); and P4. Cayenne peppers + marigolds (*Tagetes erecta*). The study revealed lady beetle *Coccinella transversalis*, *Menochilus sexmaculatus*, and big-eyed bug *Geocoris* sp. as the most abundant predatory insects with increasing populations across the treatments. The highest predator insect diversity was found in the Cayenne pepper + baby blue eyes (P2) treatment. In conclusion, baby blue eyes attract more predatory insects in cayenne pepper fields than other insectary plants, making them valuable alternatives besides common zinnias and marigolds. These findings provide a reference for future studies to promote baby blue eyes as insectary plants for farmers.

Keywords: Biological control, diversity, fluctuation, *Nemophila menziesii*, population

INTRODUCTION

Cayenne pepper (*Capsicum frustescens* L.) is a commodity with a high economic value. However, the cayenne pepper plants face an imbalance between production supply and demand in Indonesia (Indriani et al. 2019). Additionally, there has been a decrease in the yield of cayenne pepper plants, indicating a low supply of cayenne pepper production. The production of cayenne pepper plants in Indonesia decreased by 4.22% in 2021, specifically from January to May (BPPP 2021). One of the leading causes of this low production is the infestation of plant pests, which can significantly reduce the quality and quantity of the harvest and eventually result in suboptimal yields and economic losses. Control efforts are necessary to manage and limit the number of pests with natural predators and to prevent losses due to pest attacks. Insectary plants are one of many strategies to attract the presence of natural predators for suppressing pests.

Insectary plants can attract insects, such as pests, predators, and pollinators. They provide a place to live, a source of food, and even a place for insects to lay eggs. Additionally, insectary plants have flowers with diverse and vibrant colors that attract insects (Sutriono et al. 2019). The vibrant color is one of the factors attracting predatory insects (Lu et al. 2014). The vibrant colors of flowers can affect the spectrum of insects' vision, making them attractive to be approached by insectary plants (Hardiansyah et al. 2021). Based on this phenomenon, one of the flower plants that has the potential to become an insectary plant is the baby blue eyes (*Nemophila menziesii*).

As an insectary plant, baby blue eyes have bright and striking blue flower petals. The striking blue color is produced by metalloanthocyanin, a component of anthocyanin, which contains flavonoid pigments attracting insects (Yoshida et al. 2015). In addition, there are several insect orders frequently visiting baby blue eyes, such as *Apis mellifera* (Hymenoptera: Apidae), *Andrena macrocephala* (Hymenoptera: Andrenidae), *Andrena torulosa* (Hymenoptera: Andrenidae), and *Andrena crudeni* (Hymenoptera: Andrenidae) (Cruden 1971). The plant can also attract several pest insects such as fruit flies (*Bactrocera dorsalis*, *Drosophila melanogaster*) and flea beetle (*Altica* sp.). Baby blue eyes also attract natural predators such as lady beetle (*Menochilus sexmaculatus*) and parasitoid wasp (*Trichogramma japonicum*) (Fadhilah 2022).

Based on these things, baby blue eyes cannot be included in the list of commonly used insectary plants since there is a lack of information on how baby blue eyes can attract insects, particularly for farmers, and a lack of research specifically related to baby blue eyes as insectary plants. One important aspect is the absence of comparative data on the diversity of predatory insect pests attracted to baby blue eyes compared to commonly used insectary plants. Natural predators indicate a flowering plant being identified as an insectary plant. Therefore, it is necessary to research the diversity and preference of predatory insects for different flowering plants, including baby blue eyes, common zinnias, and marigolds. This study aims to determine the diversity and preference of cayenne pepper predatory insect pests towards baby blue eyes, which have the potential as insectary plants, and common zinnias and marigolds, often used as insectary plants. The findings of this research will provide valuable information to the public, especially farmers, regarding the diversity and preferences of predatory insect pests on cayenne pepper with baby blue eyes, common zinnias, and marigolds as insectary plants.

MATERIALS AND METHODS

Study area

The research was conducted from March to June 2022 in Ampeldento Village, Karangploso Sub-District, Malang District (7°54'38"S; 112°36'20"E). The research location was chosen because the general condition of the area met the growth requirements for cayenne peppers, peanuts (*Arachis hypogaea*), baby blue eyes, common zinnias (*Zinnia elegans*), and marigolds (*Tagetes erecta*) with an average temperature of 23-24°C, an average rainfall of 224 mm, an altitude of 525 masl (meter above sea level), and air humidity around 21-100%.

Plant cultivation activities

The plant cultivation activities involved the main crop (cayenne peppers), intercrop (peanuts), and three insectary plants (baby blue eyes, common zinnias, and marigolds) in seven plots of land with an area of 63 m^2 per plot and a distance of 4 m per plot, resulting in a total research area of 693 m^2 (Figure 1). While chemicals were not utilized in the cultivation process, the cayenne pepper plants, peanut plants, and flowers were planted from seeds. This study used four treatments. i.e., control cayenne peppers (P1), cayenne peppers + baby blue eyes (P2), cayenne peppers + common zinnias (P3), and cayenne peppers + marigolds (P4). The total plants planted were 680 cayenne pepper plants, 480 insectary plants, and 832 peanut plants. The spacing of cayenne pepper plants was 60×60 cm, and the peanut plants was 40×15 cm. Insectary plants were planted between cayenne pepper plants in all treatments except in the control group.

Determination and sampling of plants

Plant determination and sampling were conducted using the diagonal sampling method on five observation plots, each measuring 2.4×1.8 m. Within each observation plot, there were 16 insectary plants sampled for the treatment involving cayenne peppers with insectary plants (Figure 2). For the control treatment, 20 cayenne pepper plants were sampled in one observation plot (Figure 3). These plant samples were used to observe the predatory insects of cayenne pepper pests in the field, which were observed using the visual method and farmcop. Observations were conducted from April to June 2023. The observation data were collected when the cayenne pepper plants were three Weeks After Planting (WAP) at intervals of once a week and until harvested, resulting in 12 data collections. Farmcop suction sampler is a tool for insect sampling by suction (Buchori et al. 2020). Samples were taken and then were put into collection bottles containing ethanol 70% and labeled for identification in the laboratory using the Olympus SZX7 stereo microscope, Borror and Delong's Introduction to the Study of Insects (Triplehorn et al. 2005), Entomophagous Insects (Curtis 1940), and other supporting kinds of literature.

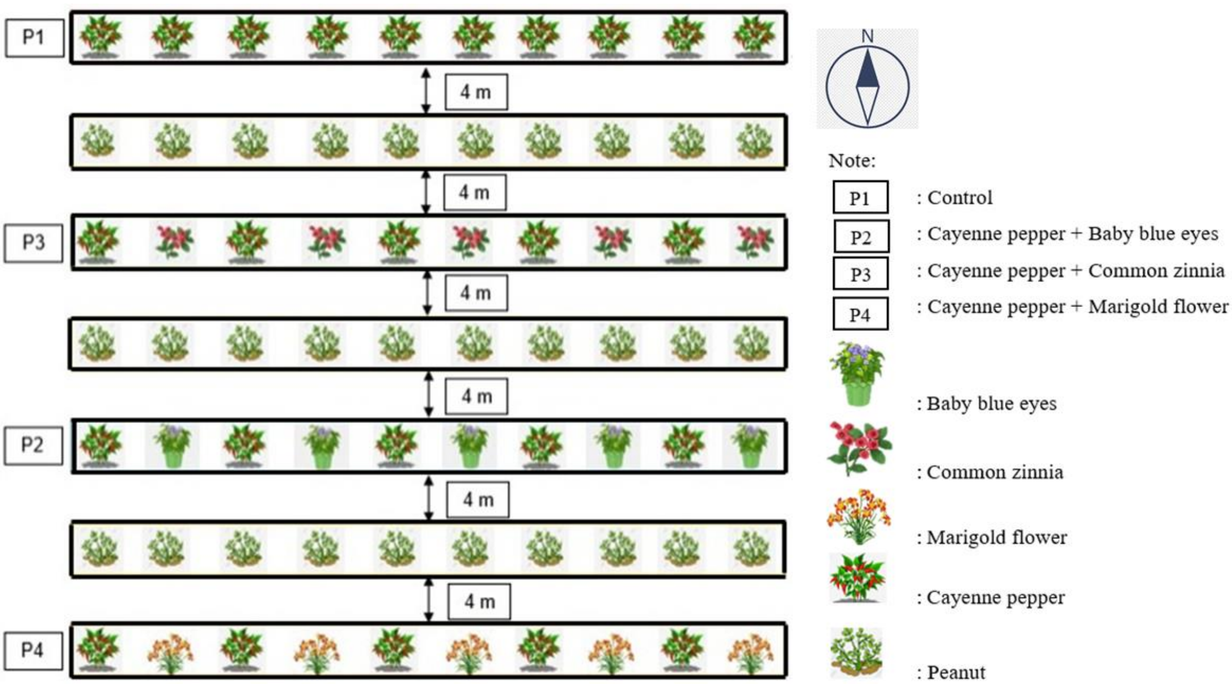

Figure 1. The experimental field design contained 7 plots of field for 4 treatments: P1. Control; P2. Cayenne pepper + baby blue eyes; P3. Cayenne pepper + common zinnia; and P4. Cayenne pepper + marigold flowers

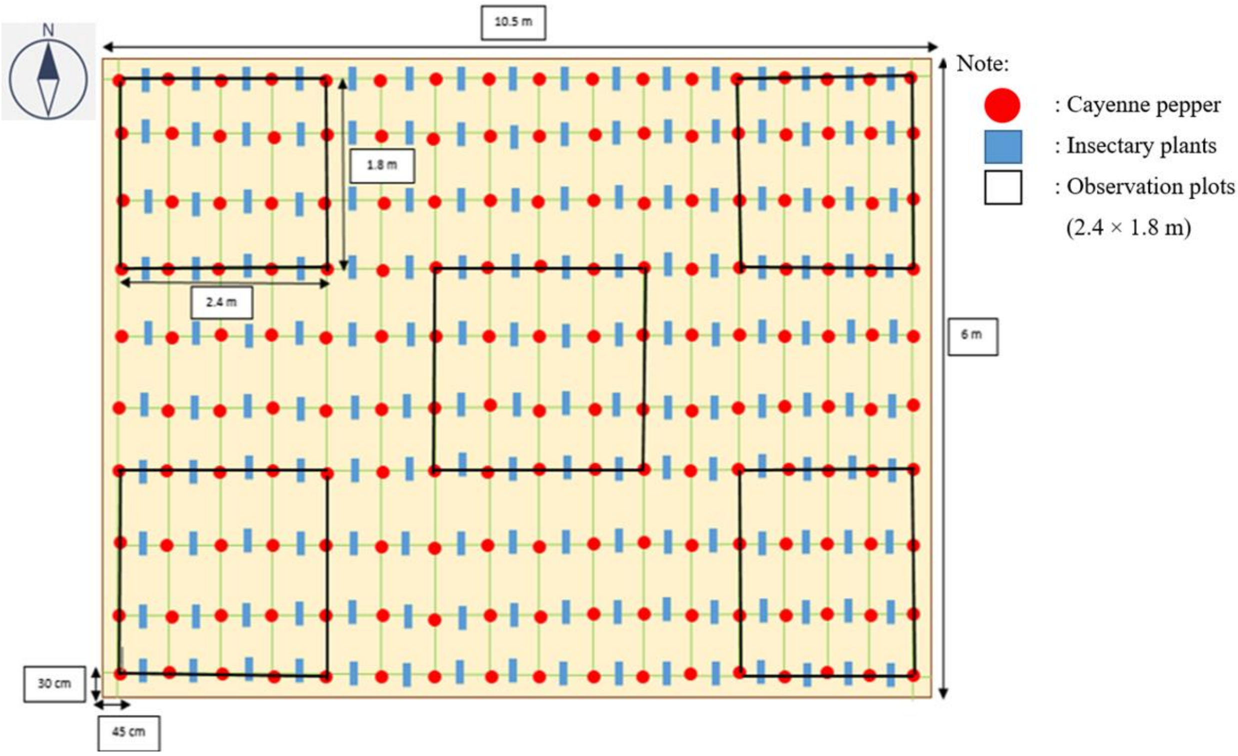

Figure 2. Plot design for harvesting predatory insect pests from treating cayenne pepper with insectary plant: P2. Cayenne pepper + baby blue eyes; P3. Cayenne pepper + common zinnia; and P4. Cayenne pepper + marigold flowers. Each treatment consisted of five observation plots with the size of each plot being 2.4×1.8 m. The observation plots were selected using the diagonal sampling method

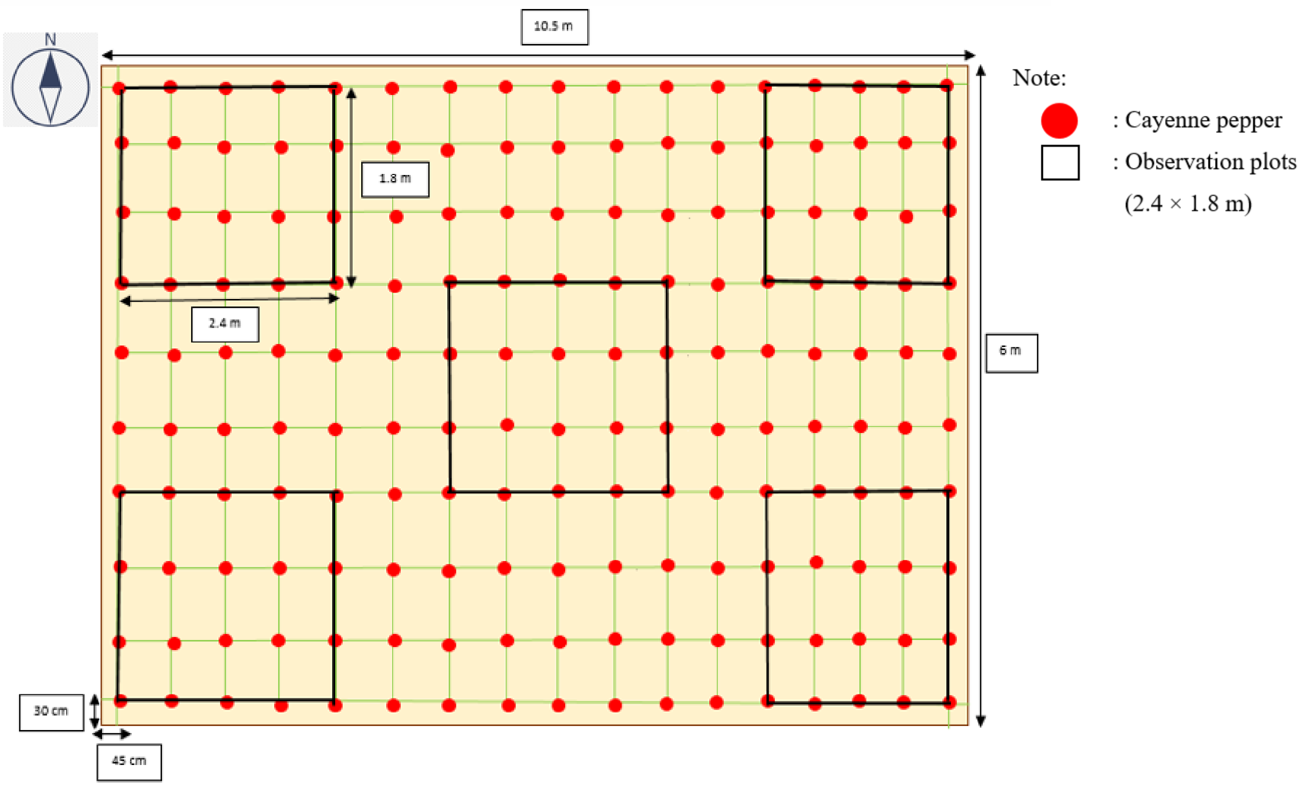

Figure 3. P1. Plot design for taking predatory insect pests on the control, each consisting of five observation plots with a size of 2.4×1.8 m. The observation plots were selected using the diagonal sampling method

Data analysis

The diversity of predators was measured using several indices. Shannon-Wiener Diversity Index (H') for measuring diversity, Simpson's Dominance Index (D) for measuring dominance, Evenness Index (E) for measuring evenness, and Species Richness Index (R) for measuring the species richness (Magurran 2004). The data tabulation and calculation of those indices were processed using Microsoft Excel software version 15.0.4420.1017. The diversity and abundance of predators were analyzed using the Analysis of Variance (ANOVA). The significantly different results were tested using Duncan's Multiple Range Test (DMRT) with a level of 5%. Additionally, the normality test was carried out before the analysis of variance. The abnormal data were transformed by log(x+1) and analyzed by the R-Studio version 4.3.1.

RESULTS AND DISCUSSION

Population and fluctuation of predatory insects in cayenne pepper field

Observing predatory insects in cayenne pepper resulted in the identification of three orders, 6 families, and 13 species in four treatments (Table 1). The results show that P2 (cayenne peppers + baby blue eyes) had the highest population of predatory insects compared to other treatments. Several factors caused the high population of predatory insects. The first factor was planting baby blue eyes, which are bright and striking blue colors that attract predatory insects. This result is supported by Li et al. (2021), who stated that plants with brightly colored flowers can attract predatory insects such as hemipteran predatory bugs. Mulligan and Kevan (1973) also explained that blue is one of the primary colors in insects' vision, while other primary colors are ultraviolet and yellow.

The next factor is the flower structure. Flowers are classified into two groups: perfect and imperfect flowers. The characteristics of perfect flowers are the stamens and stigmas in one flower, while imperfect flowers have the stamens and stigmas not in one flower (Armbruster et al. 2017). Baby blue eyes are classified as perfect flowers, characterized by a large and dense petal attracting predatory insects. This characterization is in line with the statement of Oliveira et al. (2021) that the large and dense flower petals make the flowers look spacious and comfortable in insect's eyes so that predatory insects are attracted to come. In addition, Cruden (1972) stated that the perfect flower contains stamens and stigmas that attract insects, especially *Hymenoptera*. Based on the study's results, it can be seen that in P2, there were many hymenopteran predatory insects (Table 1).

The last factor is that the baby blue eyes function as insectary plants and ground cover plants, so wingless insects can easily come to the plant. McCall (2011) stated that these procumbent plants typically grow 15-30 cm in size and spread across the ground, making them suitable as ground cover plants.

Based on the observation results, it was found that the three species of predatory insects with the highest population on cayenne pepper plants were *Coccinella transversalis*, *Geocoris* sp., and *Menochilus sexmaculatus*. Additionally, several pests, such as aphids (*Myzus persicae* and *Aphis* sp.) and whiteflies (*Bemisia tabaci*), were found on the fields. These pests serve as the primary prey for the predatory insects. This finding aligns with DeLong and Uiterwaal (2022), who reported that the main predators of flea pests are *Coccinella transversalis*, *Menochilus sexmaculatus*, and *Geocoris* spp.

As shown in Figure 4, the weekly increase in pest populations on the field is directly proportional to the increase in predatory insect populations. The increase in predatory insect populations occurred in all treatments and was significant in the generative phase due to the presence of pests. This result aligns with Varshney and Budhlakoti (2022), who stated that the presence of natural predators will be affected by pests.

Table 1. The overall population of predatory insects in cayenne pepper fields with different insectary plants

Order	Family	Species	Treatment (Individual)			
			P1	P2	P3	P4
Coleoptera	Coccinellidae	*Coccinella transversalis*	15	94	85	78
		Menochilus sexmaculatus	13	83	44	59
		Micraspis frenata	0	7	4	4
		Hyperaspis maindroni	0	10	6	4
	Carabidae	*Ophionea nigrofasciata*	5	1	2	0
	Staphylinidae	*Paederus* sp.	6	1	2	0
Hemiptera	Geocoridae	*Geocoris* sp.	10	66	61	57
Hymenoptera	Formicidae	*Odontoponera* sp.	1	14	6	4
		Polyrhachis armata	3	26	11	17
	Vespidae	Vespidae sp.1	0	6	9	6
		Vespidae sp.2	0	28	19	20
		Vespidae sp.3	0	8	6	11
		Vespidae sp.4	0	4	7	5
Total			53	348	284	265

Note: P1. Control; P2. Cayenne pepper + baby blue eyes; P3. Cayenne pepper + common zinnia; and P4. Cayenne pepper + marigold flowers

The causative factor for the existence of predatory insects in cayenne pepper fields is the insectary plant. Figure 4 shows that the population of predatory insects in treating insectary plants (P2, P3, and P4) is higher than the control treatment (P1) due to striking-colored plants. This finding aligns with Snyder (2019), who stated that the planting system of striking-colored insectary plants is classified as an engineering system of agricultural ecosystem functioning as a habitat for natural predators and pest control.

Baby blue eyes, common zinnias, and marigolds contain nectar, which can attract predatory insects. Nectar and pollen on flowering plants serve as complementary food resources for predatory insects (Snyder 2019; Li et al. 2021). Silberbauer et al. (2010) also stated that several species of predatory insects forage on nectar and pollen. Lenaerts et al. (2015) mentioned that the presence of nectar in flowering plants also attracts predatory insects. More nectars in flowers means more predatory insects are around.

The factors triggering the presence of predatory insects in the cayenne pepper plant are also supported by environmental factors, i.e., temperature and humidity. The average temperature and humidity in the cayenne pepper fields are 25°C and 80%. The average temperature and humidity indicate that the temperature and humidity in the chili field are optimal for attracting predatory insects. According to Pradhan et al. (2020), the average temperature for living insects is 12-28°C, with the humidity ranging from 60-95%. In this case, the insectary plants positively impacted the population of predatory insects, and the environmental factors in cayenne pepper fields also support the presence of pests.

Diversity and abundance of predatory insects in cayenne pepper field

The different treatments in cayenne pepper fields affected species diversity ($F_{3.20}$: 9.88; $P<0.01$) (Figure 5A) and the species abundance ($F_{3.20}$: 4.95; $P=0.013$) (Figure 5B). Species diversity and abundance at P1 (control) showed significant differences compared to P2 (cayenne peppers + baby blue eyes), P3 (cayenne peppers + common zinnias), and P4 (cayenne peppers + marigolds). These differences were due to insectary plants in the P2, P3, and P4 treatments affecting the food abundance factor. Similarly, Forister et al. (2019) stated that the more abundant the food provided in a habitat, the higher the diversity and abundance of the species. This study used the baby blue eyes plant (P2), a new insectary plant. Table 1 shows that P2 is superior to P3 (common zinnias) and P4 (marigolds) since baby blue eyes' flowers are structurally more proportional than those of common zinnias and marigolds.

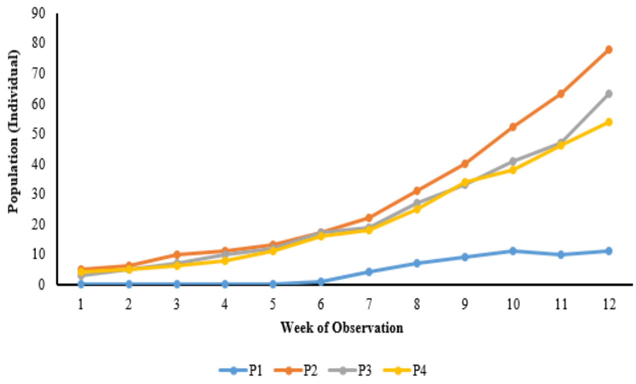

Figure 4. The overall population fluctuations of predatory insects per week observation in cayenne pepper field with different treatment: P1. Control; P2. Cayenne pepper + baby blue eyes; P3. Cayenne pepper + common zinnia; and P4. Cayenne pepper + marigold flowers

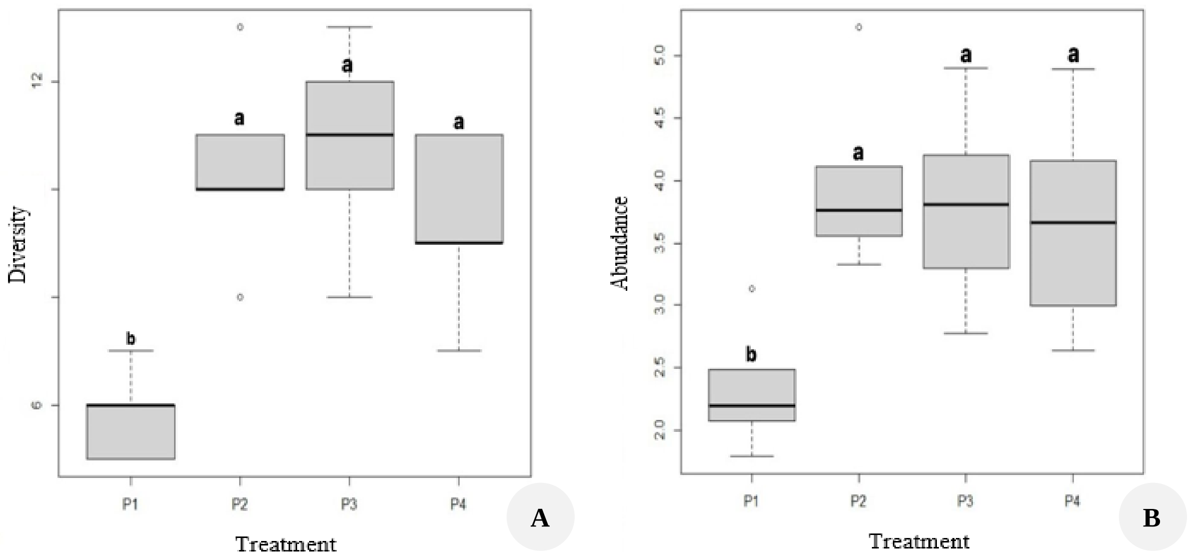

Figure 5. A. Diversity and B. Abundance of predatory insects in cayenne pepper field treatment: P1. Control; P2. Cayenne pepper + baby blue eyes; P3. Cayenne pepper + Common zinnia; and P4. Cayenne pepper + Marigold flowers. Boxplots with different letters are significantly different at P<0.05 according to Tukey Test

Table 2. Indices of diversity, dominance, evenness, and species richness of predatory insects in cayenne pepper field

Biodiversity indicators	Control (P1)	Cayenne pepper + Baby blue eyes (P2)	Cayenne pepper + Common zinnia (P3)	Cayenne pepper + Marigold flowers (P4)
Biodiversity index (H')	1.72	1.96	1.91	1.88
Dominance index (D)	0.80	0.82	0.80	0.80
Evenness index (E)	0.76	0.85	0.83	0.82
Species richness index (R)	1.51	2.10	2.10	1.79

While baby blue eyes are classified as perfect plants with stamens and pistils in their single flower, common zinnia has flowers with three different types: single, double, and pom-pom. The pom-pom type is imperfect since it lacks stamens (unfertilized male), while the single and double types have different stamens (Pallavi et al. 2017). Based on the observation in the fields, the types of common zinnia flowers were the double and pom-pom ones, with a higher number of pom-poms. It indicated sterile males were the most common zinnia flowers on the cayenne pepper fields. The perfect flowers will attract more insects than the imperfect ones, as supported by Bell et al. (1984), who mentioned that flowers with stamens contain about 50% more nectar, and predatory Hymenoptera prefer the perfect male flowers to others.

The most prominent feature of baby blue eyes is the size of its petals, affecting the diversity and abundance of predatory insects. The large petals and small flower size are factors attracting the insects. Accordingly, van Rijn and Wäckers (2016) stated that most insects prefer small flowers and tend to an open (large) petal. Baby blue eyes' flower petals are larger than those of common zinnias and marigolds.

The analyses of the diversity index, dominance index, evenness index, and species richness of predatory insects on cayenne peppers showed various results. Table 2 shows that the treatment of cayenne pepper plants with baby blue eyes (P2) has the highest diversity index (1.96); the treatment of cayenne pepper plants with baby blue eyes (P2) has the highest dominance index (0.82); the treatment of cayenne pepper plants with baby blue eyes (P2) has the highest evenness index (0.85); and the treatment of cayenne pepper plants with baby blue eyes (P2) and cayenne pepper plants with common zinnia flowers (P3) have the highest species richness index (2.10).

The diversity index values of the four treatments were moderate ($1<H' <3$), and the dominance index values were classified as high ($D>0.6$). In the fourth treatment, predatory insects dominated the cayenne pepper fields. Based on the diversity index calculation (Table 2), the diversity was in the medium category, and the dominance was in the high category. These findings indicate that diversity is not always inversely proportional to dominance. Accordingly, Anggraini et al. (2020) on the diversity of predatory insects in insectary plants stated that the diversity index calculation results in medium category diversity and high category dominance since, in their research, there were only five out of 19 types of predatory insects with high populations. The value of diversity (H') is influenced by the high number of species and populations (Karenina et al. 2019). Additionally, the evenness index of the four treatments was high ($0.75<E<1$), indicating that species diversity of predatory insects was stable and thus did not negatively impact pest control. This finding is supported by Crowder and Jabbour (2014), who stated that the equity of natural predators indicates a stable diversity with no predominance. Finally, the population richness index of the four treatments was classified as low ($R<3.5$), indicating that only 13 species were present in the fields. Correspondingly, Wakhid et al. (2020) stated that the low population richness index is directly proportional to the number of arthropod species.

Based on the discussion about the diversity and abundance of predatory insects on cayenne pepper fields, it can be concluded that the treatment of cayenne pepper plants with baby blue eyes (P2) shows that the plants attract more predatory insects on the fields than other plants did. It can be used as an insectary plant besides the common zinnias and marigolds. Further studies regarding the compounds contained in baby blue eyes need to be carried out to reveal the compounds that can attract predators. The results of this research can be used as a reference for future research that strengthens the reputation of the baby blue eyes plants among farmers.

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REFERENCES

Anggraini E, Pardingotan R, Herlinda S, Irsan C, Harun MU. 2020. Diversity of predatory arthropods in soybean (*Glycine max* L.) refugia. Appl Agric Sci Technol 4 (2): 101-117. DOI: 10.32530/jaast.v4i2.165.

Armbruster WS, Bolstad GH, Hansen TF, Keller B, Conti E, Pélabon C. 2017. The measure and mismeasure of reciprocity in heterostylous flowers. New Phytol 215 (2): 906-917. DOI: 10.1111/nph.14604.

Badan Pengkajian dan Pengembangan Perdagangan (BPPP). 2021. Analisis Perkembangan Harga Bahan Pangan Pokok di Pasar

Domestik dan Internasional. Ministry Trade of Indonesia, Jakarta. [Indonesian]

Bell G, Lefebvre L, Giraldeau LA, Weary D. 1984. Partial preference of insects for the male flowers of an annual herb. Oecologia 64 (3): 287-294. DOI: 10.1007/BF00379123.

Buchori D, Rizali A, Lukvitasari L, Triwidodo H. 2020. Insect communities associated with siam weed: evaluation after three decades of *Cecidochares connexa* release as biocontrol agent. Diversity 12 (9): 1-12. DOI: 10.3390/d12090344.

Crowder DW, Jabbour R. 2014. Relationships between biodiversity and biological control in agroecosystems: current status and future challenges. Biol Control 75: 8-17. DOI: 10.1016/j.biocontrol.2013.10.010.

Cruden RW. 1972. Pollination biology of *Nemophila menziesii* (Hydrophyllaceae) with comments on the evolution of oligolectic bees. Evolution 26 (3): 373-389. DOI: 10.2307/2407013.

Cruden DM. 1971. The form of the creep law for rock under uniaxial compression. Intl J Rock Mech Min Sci 8 (2): 105-126. DOI: 10.1016/0148-9062(71)90003-9.

Curtis PC. 1940. *Entomophagous* insects. Digital Library of India, India.

DeLong JP, Uiterwaal SF. 2022. Predator functional responses and the biocontrol of aphids and mites. BioControl 67 (2): 161-172. DOI: 10.1007/s10526-021-10127-1.

Fadhilah K. 2022. Keanekaragaman Artropoda Hama pada Lahan Cabai Rawit Monokultur dan Polikultur dengan Memanfaatkan Tanaman Bunga Baby Blue *(Nemophila menziesii)* sebagai Tanaman Perangkap. Faculty of Agriculture Universitas Brawijaya, Malang. [Indonesian]

Forister ML, Pelton EM, Black SH. 2019. Declines in insect abundance and diversity: We know enough to act now. Conserv Sci Pract 1 (8): e80. DOI: 10.1111/csp2.80.

Hardiansyah MY, Hartini, Musa Y. 2021. Agrobiodiversity of using refugia plants toward several plant gardens at Tulung Rejo, East Java. IOP Conf Ser: Earth Environ Sci 866: 012066. DOI: 10.1088/1755-1315/886/1/012066.

Indriani R, Darma R, Musa Y, Tenriawaru N, Mahyuddin M. 2019. Supply chain performance of cayenne pepper in Gorontalo, Indonesia. Intl J Sup Chain Manag 8 (5): 112-118. DOI: 10.59160/ijscm.v8i5.2631.

Karenina T, Herlinda S, Irsan C, Pujiastuti Y. 2019. Abundance and species diversity of predatory arthropods inhabiting rice of refuge habitats and synthetic insecticide application in freshwater swamps in South Sumatra, Indonesia. Biodiversitas 20 (8): 2375-2387. DOI: 10.13057/biodiv/d200836.

Lenaerts M, Pozo MI, Wäckers F, van den Ende W, Jacquemyn H, Lievens B. 2015. Impact of microbial communities on floral nectar chemistry: Potential implications for biological control of pest insects. Basic Appl Ecol 17 (3): 189-198. DOI: 10.1016/j.baae.2015.10.001.

Li S, Jaworski CC, Hatt S, Zhang F, Desneux N, Wang S. 2021. Flower strips adjacent to greenhouses help reduce pest populations and insecticide applications inside organic commercial greenhouses. J Pest Sci 94: 679-689. DOI: 10.1007/s10340-020-01285-9.

Lu Z-X, Zhu P-Y, Gurr GM, Zheng X-S, Read DMY, Heong K-L, Yang Y-J, Xu H-X. 2014. Mechanisms for flowering plants to benefit arthropod natural enemies of insect pest: Prospects for enhanced use in agriculture. Insect Sci 21 (1): 1-12. DOI: 10.1111/1744-7917.12000.

Magurran AE. 2004. Measuring Biological Diversity. Blackwell Publishing Company, Oxford.

McCall AC. 2011. Leaf damage and gender but not flower damage affect female fitness in *Nemophila menziesii* (Hydrophyllaceae). Am J Bot 94 (3): 445-450. DOI: 10.3732/ajb.94.3.445.

Mulligan GA, Kevan PG. 1973. Color, brightness, and other floral characteristics attracting insects to the blossoms of some Canadian weeds. Can J Bot 51: 1939-1952. DOI: 10.1139/b73-248.

Oliveira ACS, Souza JT, de Brito VLG, Almeida NM. 2021. Attraction of florivores and larcenists and interaction between antagonists in *Senna rugosa* (Fabaceae). Arthropod Plant Interact 15: 535-544. DOI: 10.1007/s11829-021-09843-3.

Pallavi B, Nivas SK, D'Souza L, Ganapathi TR, Hegde S. 2017. Gamma rays induced variations in seed germination, growth and phenotypic characteristics of *Zinnia elegans* var. Dreamland. Adv Hortic Sci 31 (4): 267-273. DOI: 10.13128/ahs-20289.

Pradhan PP, Borkakati RN, Saikia DK. 2020. Seasonal incidence of insect pests and natural enemies of mustard in relation to meteorological parameters. J Entomol Zool Stud 8 (1): 1538-1542. DOI: 10.9734/ijecc/2023/v13i113162.

Silberbauer L, Yee M, Socorro AD, Wratten S, Gregg P, Bowie M. 2010. Pollen grains as markers to track the movements of generalist predatory insects in agroecosystems. Intl J Pest Manag 50 (3): 165-171. DOI: 10.1080/09670870410001731880.

Snyder WE. 2019. Give predators a complement: Conserving natural enemy biodiversity to improve biocontrol. Biol Control 135: 73-82. DOI: 10.1016/j.biocontrol.2019.04.017.

Sutriono, Purba E, Marheni. 2019. Insect management with refugia plant in upland rice (*Oryza sativa* L.). IOP Conf Ser: Earth Environ Sci 260: 012138. DOI: 10.1088/1755-1315/260/1/012138.

Triplehorn CA, Johnson NF, Boror DJ. 2005. Boror and DeLong's Introduction to the Study of Insect. Thompson Brooks, Cole, Oklahoma.

van Rijn PCJ, Wäckers FL. 2016. Nectar accessibility determines fitness, flower choice and abundance of hoverflies that provide natural pest control. J Appl Ecol 53 (3): 925-933. DOI: 10.1111/1365-2664.12605.

Varshney R, Budhlakoti N. 2022. Biology and functional response of the predator, *Dortus primarius* (Distant) (Hemiptera Miridae) Preying on *Frankliniella schultzei* (Trybom) (Thysanoptera: Thripidae). Egypt J Biol Pest Control 32: 31. DOI: 10.1186/S41938-022-00531-9.

Wakhid, Rauf A, Krisanti M, Sumertajaya IM, Maryana N. 2020. Species richness and diversity of aquatic insect inhabiting rice fields in Bogor, West Java, Indonesia. Biodiversitas 21 (1): 34-42. DOI: 10.13057/biodiv/d210106.

Yoshida K, Tojo K, Mori M, Yamashita K, Kitahara S, Noda M, Uchiyama S. 2015. Chemical mechanism of petal color development of *Nemophila menziesii* by a metalloanthocyanin, Nemophilin. Tetrahedron 71 (48): 9123-9130. DOI: 10.1016/j.tet.2015.10.007.