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The Effect of Refugia Crops on the Abundance of Insect Pests and Natural Enemies in Fruits Plantations

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Abstract

Background: Refugia plants can provide SNAP (Shelter, Nectar, Alternative food, and Pollen) for insects. Commonly used refugia plants are marigolds (*Tagetes erecta*), zinnia (*Zinnia elegans*), and king's salad (*Cosmos caudatus*). Planting refugia plants is one way to manipulate the habitat of natural enemies so natural enemy populations increase, and pest populations can be controlled. Abiotic factors like temperature, humidity, pH, and rainfall affect insect populations. **Methods:** This research was conducted in March–May 2023. The refugia plants used were king's salad and zinnia flowers with a cropping pattern on the edges of the plots and an insect bank system. Sampling data was collected from both fields twice weekly using observation, sticky yellow traps, sweep nets, and light traps. **Results:** Insect pests and natural enemies from both fields were identified, namely four orders, 11 families, and 13 morphospecies, with 503 insects in the plantations with refugia and 434 without refugia. **Conclusions:** Species diversity values were 2.12 and 2.08 in plantations with and without refugia, indicating moderate diversity. The Bray-Curtis index for planting insect groups with and without refugia was 0.903, indicating the constituents' composition was the same. Based on the linear regression test results, the temperature and humidity factors affect insect pests' Abundance and natural enemies' Abundance.

Keywords: Abundance; Diversity; Natural Enemies; Pests; Refugia.

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Introduction

Refugia plants can provide SNAP (Shelter, Nectar, Alternative food, and Pollen) for insects (Rayl et al., 2018). Insects also utilize the soft tissue of the refugia plant to lay eggs (Zhang et al., 2021). Commonly used refugia plants are marigolds (*Tagetes erecta*), zinnia (*Zinnia elegans*), and king's salad (*Cosmos caudatus*) (Ifanalia et al., 2021). Planting refugia plants is one way to manipulate the habitat of natural enemies so natural enemy populations increase and pest populations can be controlled. Maesyaroh et al. (2018) stated that the population of natural enemies can increase because natural enemies are attracted to colorful refugia flowers.

Natural enemies are divided into predators and parasitoids. Predators are animals that live freely by eating or preying on other animals. Meanwhile, parasitoids are insects that, in their immature phase, parasitize insects or other arthropods (Untung, 2019). Pests are one of the plant-disturbing organisms (OPT) that are detrimental to farmers economically and materially because they damage the cultivated plants. Insects are pests that often damage cultivated plants (Kristiaga et al., 2020). Insects classified as poikilothermic animals can be affected by their activities depending on the ambient temperature (Menendez, 2007; Jaworski & Hilszczański, 2013). Abiotic factors like temperature, humidity, pH, and rainfall affect insect populations.

Habibi & Fuadah's (2021) research regarding refugia plants showed that refugia basil, cabbage, and celery affected the population of natural enemies of leafhoppers in rice plants. Irvin et al. (2021) also conducted a similar study with results, namely the effect of flowering plants (refugia) on hoverfly predator populations. Abidin (2021) analyzed the effectiveness of marigold and long bean refugia plants. As a result, marigold refugia plants can significantly impact natural enemy populations so that pest populations can be controlled. This study was conducted to determine the effect of refugia on the relative abundance of insects, diversity of insect species (H'), community similarity (Bray-Curtis) of insect pests and natural enemies in fruit plantations with refugia and fruit plantations without refugia, and the effect of temperature and humidity on the abundance of these insects in the Miracle Kurnia Farm Agrotourism area.

Method

Location and Time

This research was conducted in March-May 2023 on two types of land, namely fruit planting (red guava, crystal guava, guava, Siem orange, and lemon) with refugia plants and fruit planting without refugia plants in Miracle Kurnia Farm Agrotourism, Sambibulu Village, Taman District, Sidoarjo Regency. The Plant Health Laboratory, Faculty of Agriculture, Universitas Pembangunan Nasional "Veteran" Jawa Timur identified insect pests and natural enemies.

Tools and Materials

The tools used included polybags measuring 15 x 15 cm, light traps, sweep nets, yellow sticky traps measuring 20 x 25 cm, writing tools, mobile phone cameras with 12-megapixel resolution, microscopes, petri dishes, HTC-1 digital thermohygrometers, book Donald J. Borror and Delong's Introduction to the Insect (Triplehorn & Jhonson, 2005). Materials needed include insects found in fruit plantations and around refugia plants, planting media, and 70% alcohol.

Refugia Planting

King's salad (*C. caudatus*) and zinnia (*Z. elegans*) are the refugia plants used. The refugia planting pattern was modified from a study by Musarofa et al. (2023), using a planting pattern on the perimeter refuge, which is planted alternately with a row width of 50 cm and a spacing of 15 cm x 15 cm and an insect bank system planting with a size of 1 m x 1 m.

Data Collection Method

Collecting sample data on land with and without refugia using observation, sticky yellow traps, sweep nets, and light traps. The sampling technique using this trap is placed in a zigzag manner to distribute and spread over each field evenly. The observation time of this research was carried out in the generative phase of fruit plants and the generative phase of refugia plants with an observation time interval of 1 week 2 times for two months. Sampling modified from the study of (Musarofa et al., 2023), namely the direct observation method, was carried out along the refugia row, seven samples of guava trees and seven samples of citrus trees, both fruit plantations with and without refugia for 10 minutes each in 3 periods (06.00 - 08.00 WIB, 11.00 - 13.00 WIB and 15.00 – 17.00 WIB). Sampling using a sweep net was also carried out in 3 periods (08.00 – 09.00 WIB, 13.00 – 14.00 WIB, and 16.30 – 17.00 WIB), temperature and humidity measurements using the HTC-1 digital thermohygrometer.

Insects obtained were preserved using the wet preservation method (soaking the sample in 70% alcohol solution) and dry (pinning) (Barantan, 2015). Then, identification was carried out from the family level to the morphospecies based on the book Donald J. Borror and Delong's Introduction to the Insect (Triplehorn & Jhonson, 2005).

Data analysis

Identification results were tabulated and analyzed relative abundance, species diversity index (H'), and community similarity index (Bray-Curtis). Relative abundance shows the number of insects that often come to the field and can describe the distribution pattern of these insects (Prabhulinga & Kumar, 2019).

$$Di = \frac{ni}{N} \times 100\%$$

Di : Relative Abundance
ni : Total of individuals of the i types
N : Total of all individuals

The diversity index or species diversity index shows how many different types of species are in a community or ecosystem (Bosco et al., 2023).

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

H' : Diversity index
ni : The number of individuals of each type
ln : Natural logarithm
N : The total number of all individuals

The community similarity index shows the level of similarity of species from two locations. The Bray-Curtis Index (IBC) compares species composition and variation at two locations (Sidabukke et al., 2022).

$$IBC = 1 - (\sum (Xij - Xik)/ \sum (Xij + Xik))$$

IBC : Coefficient of composition similarity
Xij : Total of individuals in species i in habitat 1
Xik : Total of individuals in species i in habitat 2

A linear regression test was carried out using IBM SPSS Statistics 26 to determine the effect of temperature and humidity on insect abundance. All data was presented using GraphPad Prism 9.5.1.

Result and Discussion

Types, Role, and Abundance of Insect Pests and Natural Enemies in Fruit Plantations with and Without Refugia Plants

Table 1. Types, Role, and Abundance of Insects

Classification	Population			Relative abundance (%)	
Order / **Family** / **Morfospecies**	**Refugia Land**	**Land Without Refugia**	**Roles**	**Refugia Land**	**Land Without Refugia**
***Coleoptera**					
**Buprestidae					
****Agrilus*	13	15	Pest	2.58	3.46
**Coocinellidae					
****Menochilus*	30	22	Predator	5.96	5.07
****Micraspis*	22	15	Predator	4.37	3.46
**Curculionidae					
****Xyleborus*	5	9	Pest	0.99	2.07
**Staphylinidae					
****Paederus*	17	11	Predator	3.38	2.53
***Diptera**					
**Dolichopodidae					
****Condylostylus*	80	57	Predator	15.90	13.13
**Syrphidae					

****Mesembrius*	20	8	Predator	3.98	1.84
**Tephritidae					
****Bactrocera*	17	12	Pest	3.38	2.76
***Hemiptera**					
**Cicadellidae					
****Empoasca*	11	13	Pest	2.19	3.00
**Pseudococciae					
****Pseudococcus*	25	28	Pest	4.97	6.45
***Hymenoptera**					
**Formicidae					
****Monomorium*	127	120	Predator	25.25	27.65
****Oecophylla*	121	113	Predator	24.06	26.04
**Sphecidae					
****Sceliphron*	15	11	Predator	2.98	2.53

The types, roles, populations, and relative abundance of insects found in fruit plantations with and without refugia can be seen in Table 1. Insect pests and natural enemies were found in 937 individuals, of which there were four orders: Coleoptera, Diptera, Hemiptera, and Hymenoptera. These insects act as insect pests and natural enemies from 11 families: Buprestidae, Coccinellidae, Curculionidae, Staphylinidae, Dolichopodidae, Syrphidae, Tephritidae, Cicadellidae, Pseudococciae, Formicidae, Sphecidae and 13 morphospecies. The insect pest morphospecies found include *Agrilus, Xyleborus, Bactrocera, Empoasca,* and *Pseudococcus*. Natural enemy insect morphospecies include *Menochilus, Micraspis, Paederus, Condylostylus, Mesembrius, Monomorium, Oecephylla,* and *Sceliphron.*

The results of the significance analysis (2-way) of insect pests in fruit plantations with refugia and without refugia using IBM SPSS, namely sig. 0.453, meaning that insect pests found in plantations with refugia were not significantly different from insect pests in plantations without refugia (sig 0.453 > 0.05) because the number of pests found was not much different, namely 71 individuals in plantations with refugia and 77 individuals in plantations without refugia. The most common insect pests found in both fields were the order Hemiptera, the Pseudococciae family, and the *Pseudococcus* morphospecies. *Pseudococcus* pests, commonly called mealybugs, are the primary pests on vegetable and fruit plants. The characteristics of the mealybug are its oval body covered with white flour wax extending along the midline of the back. The legs are yellowish brown with 18 short filaments and a slightly longer anal pair (Moghaddam, 2013). Mealybugs can live on the undersides of leaves, stems, and shoots and then attack plants by sucking the sap from shoots and leaves. Symptoms caused by this mealybug attack are the shoots of the plants are wrinkled, and when the high population reaches 200-1000 insects per shoot, it can cause the leaves on the shoots to fall off (Huddin et al., 2021). Several trees in the land without refugia were also found to have wrinkled shoots due to attacks by mealybugs.

The results of the significance analysis (2-way) of insect natural enemies in fruit plantations with refugia and without refugia, namely sig 0.008, means that the natural enemy insects found in the two fields were significantly different (sig. 0.008 < 0.05). It can be seen that the number of insects found between the two plantations was quite different, namely 432 individuals in plantations with refugia plants and 357 insects found in plantations without natural enemy insects. More insects were found in plantations with refugia than in plantations without refugia because of the diversity of vegetation (Sari & Fitrianti, 2021). In addition, the presence of refugia plants can also increase the presence of insects because these plants are a source of food and a place to lay insect eggs (Musarofa et al., 2023). Hymenoptera order, Formicidae family, and *Monomorium* morphospecies are predatory insects that are commonly found in fruit plantations both on land with and without refugia. This insect can be found in every plantation because it lives in colonies and is easy to adapt. Latumahina et al. (2013) stated that Formicidae is easy to find in every agroecosystem and is the most dominant group in the tropics. Villani et al. (2008); Putra et al. (2021) stated that *Monomorium* was dominant because this insect is an insect that likes food scraps, animal carcasses, and insects, so it is called an omnivorous insect.

The Effect of Refugia Plants on the Diversity and Similarity of Insect Habitats in Fruit Planting in the Miracle Kurnia Farm Agrotourism Area

Table 2. Species Diversity Index and Bray-Curtis Index

	Refugia	Without Refugia
Species Diversity Index (H')	2.12	2.08
Index Bray-Curtis	0.903	

The results of calculating the diversity index on land with and without refugia, namely 2.12 and 2.08 (Table 2). Based on the indicators of Odum (1993), the index values for the diversity of types of the two lands belong to the medium category. The index value of species diversity is moderate because both lands contain the same insect species. Communities have high species diversity if they are composed of many different species with high complexity, so they are not easily affected by environmental changes. Conversely, a community with low species diversity comprises the same or a few species (Irni et al., 2021).

The results of calculating the Bray-Curtis index based on insect groups on refugia and without refugia were 0.903 or 90.3%, indicating that insects on refugia and without refugia had the exact composition of community types. This 90.3% value is close to 100%, indicating high similarity (Zhang et al., 2011). Krebs (2008) states that if an index value is close to or equal to 1, the variation and composition between the first and second habitats are the same. The similarity in the composition of this type of arrangement is because the two research fields are in the same area, the method of land management is the same and the environmental factors are the same. The closer the research location will have the same relative community structure, the farther the distance will have a relatively different structure, so the distance affects the community structure (Purwanti & Nizar, 2019).

Correlation of Abiotic Factors with Insect Abundance in Fruit Planting

Abiotic environmental factors are important because they affect insect populations, including temperature, humidity, wind, and soil (Wood et al., 2005; Rasib et al., 2021). Data analysis was used with a linear regression test to determine the correlation between abiotic factors and insect abundance. The results of the linear regression test show the regression equation, $R^{2,}$ and its significance (Table 3).

Table 3. Linear Regression Test Results for Abiotic Factors with Insect Abundance

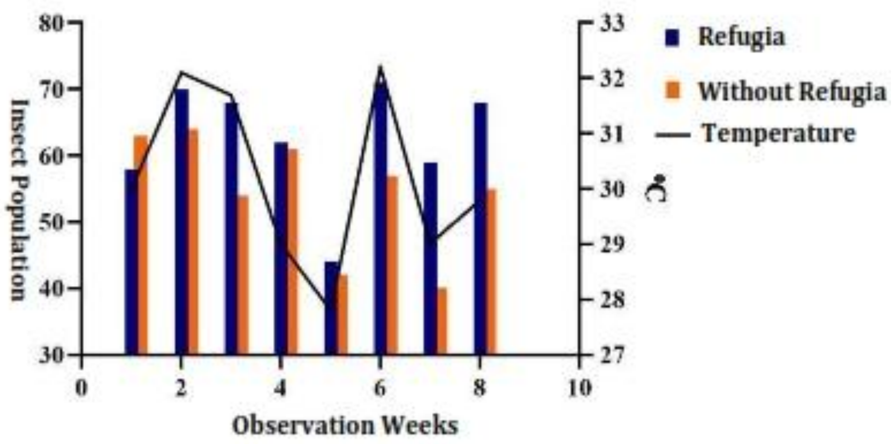

Figure 1. Graph of Correlation of Temperature with Insect Abundance

The results of the linear regression test for temperature and insect abundance showed a significance of 0.017 (sig value <0.05) (Table 3), so it can be concluded that temperature affects insect abundance. The R2 value of 0.643 indicates a relatively strong effect of temperature on insect abundance (0.25 < R^2 value < 0.75) (Hair et al., 2009). The results of the linear regression test also show that temperature has a positive correlation with insect abundance. A positive correlation can be seen in the regression equation (Table 3); when the temperature increases by 1^0C, the population increases by 7,882 or 8 individuals. This positive correlation can also be seen in Figure 1 of the 2 and 6 weeks of observation, which shows that the abundance of insects increases when the temperature is high. This is because the temperature recorded during the observations is in the optimum range, namely 27-32^0C. Generally, the effective temperature for insect survival is a minimum temperature of 15^0C, an optimum temperature of 25^0C, and a maximum temperature of 45^0C. At the optimum temperature, the ability of insects to produce more offspring, less mortality (mortality) before the age limit, and faster insect metabolism affects the susceptibility of insect pests to attacks by natural enemies and higher survivability (Jumar, 2000; Wijayanto et al., 2022). Research Musarofa et al. (2023) regarding the interest of arthropods in refugia blocks (*C. caudatus, Helianthus annus* L., *Zinnia acceraso*) in the mango-avocado field of Oro-Oro Ombo Kulon village, Rembang, Pasuruan, it was also carried out at temperatures in the range of 25-32^0C and the results obtained were many insect pests, natural enemies and pollinators on refugia blocks.

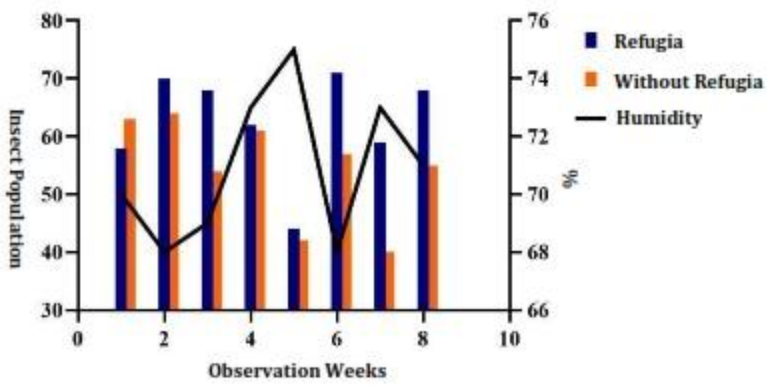

Figure 2. Graph of Correlation of Humidity with Insect Abundance

The results of the linear humidity regression test with insect abundance showed a significance of 0.008 (sig value <0.05) (Table 3), so it can be concluded that humidity also affects insect abundance. The R2 value of 0.714 indicates a relatively strong effect of temperature on insect abundance (0.25 <R^2 value <0.75) (Hair et al., 2009). The negative correlation between humidity and the abundance of these insects can also be seen in Figure 2 of the 5 weeks of observation, which shows that when humidity is at a high point, the abundance of insects is slightly higher and vice versa. In the regression equation (Table 3) Y = 488,952 + (-5,248) X, when the humidity increases by 1%, the abundance of insects decreases by 5,248 or 5 individuals. The humidity recorded in this study is still in the optimal humidity range for insects, namely 68-75%. The optimal humidity for insects is 70-72% (Haneda et al., 2013). At the same time, insects' optimum moisture tolerance range lies at a maximum of 73-100% (Wardani, 2015). Temperatures in the optimal range can stimulate the development of natural enemies and increase their activity (Netherer & Schopf, 2010; Jaworski & Hilszczański, 2013).

The two abiotic factors, namely temperature and humidity, affect the abundance of insects found in fruit plantations with and without refugia plants. However, these two factors cannot be used as a reference for factors that have a strong influence. Many factors still influence insect abundance, namely other environmental conditions, such as the presence or absence of weeds in the land area that can host insects and land management. The level of insect populations cannot be estimated only by temperature and humidity alone, but there are many combinations of other influencing factors (Pribadi & Anggraeni, 2011).

Conclusions

Insect pests and natural enemies in the Agrowisata Miracle Kurnia Farm Sidoarjo field found in fruit plantations with and without refugia consisted of 4 orders, 11 families, and 13 morphospecies. Refugia plants affected the value of species diversity (H'); fruit planting with refugia was higher than fruit planting without refugia, namely 2.12 and 2.08, which belonged to the moderate diversity category. The composition of the community arrangement based on the Bray-Curtis index of insect groups for fruit planting with refugia and fruit planting without refugia was 0.903, which means that the arrangement of insect pests and natural enemies was the same. Abiotic factors of temperature and humidity affect the abundance of insects in fruit plantations with and without refugia based on the results of linear regression tests.

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Declaration statement

The authors report no potential conflict of interest.

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