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The Increase of Insect Pest Population in Paddy Field Managed with an Ecological Approach using Refugia Plants and Biopesticides

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Abstract

Insect pests can damage plants and act as vectors of diseases such as brown planthoppers which can transmit dwarf virus disease. The presence of insect pests is influenced by the type of variety, planting patterns, and excessive use of chemical pesticides so that insect pests increase and are difficult to control. This research wanted to provide insights into the effectiveness of combining insectary plants and biopesticides as ecological strategies to manage paddy (*Oryza sativa* Linnaeus) insect pests. The study was conducted in February-April 2024 in Sukodadi Village, Sukodadi District, Lamongan Regency. Method of study was conducted using a combination of direct observation, insect traps, and quantitative analysis to evaluate the impact of refugia plants and biopesticides on insect pest populations in paddy fields. The analysis includes the species diversity index (Shannon-Winner), species evenness index, species richness index (Margalef), dominance index (Simpson) and similarity index (Bray-Curtis). The study obtained 2,687 individual insect pests in paddy fields with refugia and fobio and 1,761 individuals in paddy fields without refugia and fobio. Insect pests were more abundant in paddy fields with refugia and fobio compared to fields without refugia and fobio. Refugia provides alternative habitats and additional resources for insect pests, and the use of biopesticides can create temporary ecosystem imbalances, and increase the population of insect pest.

Keywords: Biological agents, insect biodiversity, insect populations, pest management

Introduction

Paddy (*Oryza sativa* Linnaeus) is a staple food for more than half of the world's population, making its cultivation vital for global food security (Sen et al., 2020). However, paddy production is persistently threatened by various insect pests, which can significantly reduce yields and impact farmer livelihoods (Ali et al., 2021). The insects form a large part of the composition of agricultural ecosystems, especially agricultural ecosystems for food crops such as paddy. Herbivorous insects are plant-eating insects that mostly act as crop pests (Windriyanti et al., 2023). Insect pests are destructive to plants, causing imperfections in plant parts that will cause the cultivated plants to grow in the vegetative and generative phases.

A case study in Java from 2009 to 2011 reported brown planthopper (BPH) infestations, which caused a reduction in production by up to 2 million tons (Triwidodo, 2020). Other research indicates that BPH infestations in other paddy-producing regions of Indonesia create a gap between potential and actual production, with average yield losses due to pest attacks reaching 20-25% annually (Susanti et al., 2018). Another pest, the yellow stem borer (YSB), attacks paddy during the vegetative stage and causes "white ear head" during the generative stage, with attack intensities reaching 90% and yield losses up to 125,000 tons per planting season (Adiartayasa and Wijaya, 2016). According to Pradhana et al. (2014), three types of pests were identified in paddy fields using conventional agricultural systems, classified as significant pests: *Leptocorisa acuta*, *Nephotettix* sp., and *Scirpophaga incertulas*.

The presence of insect pests in the paddy ecosystem is influenced by several factors, including paddy varieties susceptible to pest attacks, planting patterns, biotic and abiotic factors that support insect development and behavior, and the application of chemical pesticides, which can reduce populations of natural enemies (Prihandiani et al., 2021). Traditional management strategies of pests, often reliant on synthetic chemical pesticides, pose significant environmental and health risks, causing many non-target organisms to die and reducing the functionality of agricultural land habitats, which is crucial for maintaining natural enemy populations (Jayasiri et al., 2022; Shaki et al., 2020).

An ecological approach, combining insectary plant and biopesticide strategies, emerges as a promising solution to manage paddy pest insects effectively. Insectary plants, also known as banker plant or refugia, are cultivated alongside main crops to attract and sustain beneficial insects, including predators and parasitoids of pest species (Aparicio et al., 2021). This strategy leverages the natural ecological interactions to suppress pest populations, reducing the reliance on chemical inputs. Insectary plants provide nectar, pollen, and habitat, thereby enhancing the biodiversity in paddy fields (Chen et al., 2022). Research has shown that certain flowering plants, such as marigolds (*Tagetes* spp.) and king's salad (*Cosmos caudatus*), can attract natural enemies of paddy pests, including lady beetles, lacewings, and parasitic wasps (Nawir et al., 2021; Hasriyanty et al., 2023). By strategically planting these insectaries, farmers can create a more resilient agroecosystem where pest control is achieved through predation and parasitism. This method not only curtails pest outbreaks but also promotes a healthier environment by maintaining ecological balance (Duff et al., 2024).

Biopesticides, derived from natural materials like microorganisms, plants, and certain minerals, offer an environmentally friendly alternative to chemical pesticides. These biological agents include bacteria, fungi, viruses, and botanical extracts, minimizing non-target effects and resistance development (Khursheed et al., 2022). Incorporating biopesticides into pest management programs not only enhances the specificity and efficacy of pest control but also supports the sustainability of agricultural practices. These biological agents degrade more rapidly in the environment compared to chemical pesticides, reducing pollution and the risk of residues in food products (Fenibo et al., 2021). This research wanted to provide insights into the effectiveness of combining insectary plants and biopesticides as ecological strategies to manage paddy (*Oryza sativa* Linnaeus) insect pests.

Methods

The study was experimental research that carried out from February to May 2024. The planting of refugia flowers and collecting insect samples were carried out in the paddy field in Sukodadi Village, Lamongan Regency, East Java Province, Indonesia. Lamongan Regency is located at 0-7 meters above sea level, latitude 7º06' LS (South latitude), and relative humidity usually ranges from 70 to 90%. Insect identification was performed at the Plant Health Laboratory, Faculty of Agriculture, Universitas Pembangunan Nasional "Veteran" Jawa Timur, Indonesia.

Refugia Cultivation

This study utilized two different paddy fields: With refugia plants and fobio, and without refugia plants and fobio. Fobio is classified as a biopesticide which contains microorganisms from the rhizosphere of the roots of coconut, siwalan, sugar cane, fire mangrove, and supporting root mangrove (Wiyatiningsih et al., 2020). Microorganisms contained in fobio have roles as biological agents, decomposers and PGPR (Hasyidan et al., 2021). The dosage used ranged from 5-10 ml per liter of water (Ramada and Syah, 2023).

The 3 species of refugia plants used in this study include zinnia (*Zinnia* sp), king's salad (*Cosmos caudatus*), and marigold (*Tagetes erecta)*. The planting pattern employed was a perimeter refuge, where the three refugia were planted in a continuous row along one side of the paddy field bund. The distance between flower seedlings was 30 cm according to the method described by Sulistiyono et al. (2022). Additionally, traps such as yellow traps and light traps were placed. Different traps were installed in both paddy fields, with a distance of 30 meters between traps.

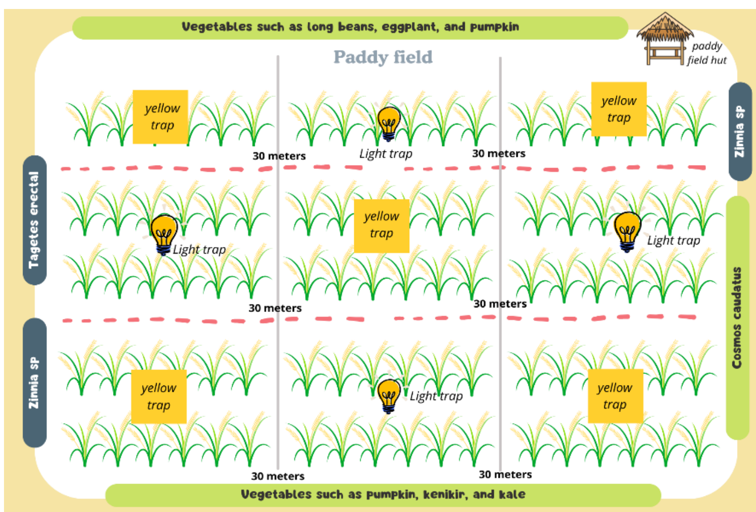

Figure 1. Research design for refugia cultivations and insect traps in paddy fields

Insect Sampling

The insect sampling methods were adapted from Jannah et al. (2023), using direct collection, sweep nets, yellow traps, and light traps. Sampling was conducted during the generative phase of the paddy plants. Observations were made three times a week, with the total observation period lasting for eight weeks.

Four light traps were installed in each field from 6 pm to 6 am. (GMT+7). The light traps were designed to attract and trap insects using containers filled with water and detergent to prevent insects from climbing back up to the surface. Insects attracted to the light would gather around the lamp and fall into the container below (Faradila et al., 2019). Yellow traps attracted insects located on the upper surface of paddy plants or insects actively flying around the paddy plantation. These traps were made of adhesive-coated paper measuring 20 cm x 30 cm and supported by plywood of the same size and wooden supports on the ground surface.

The traps were placed in each paddy field plot layout in the morning at 6:30 am and left in place for seven days (Faradila et al., 2019). These trap applications aim to capture and monitor insect populations in the paddy fields, providing valuable data for pest management strategies. The light traps attract insects during the night, while the yellow traps target insects active during the day, enhancing the overall effectiveness of pest monitoring and control measures.

Observation

Observations were conducted in the same manner between the two paddy fields. Visual observations were performed by observing the refugia blocks in the IPM paddy field at eight observation points in a straight vertical line from the refugia block. Observations were conducted every 5 days, from 30 days after transplanting (DAT) until nearing harvest. The observation time was conducted from 6 am. to 9 am. Four paddy clumps were selected as samples at each observation point in the IPM paddy fields. Insects at the observation points were observed directly (Faradila et al., 2019). Insect sampling was carried out using a sweep net to capture insects active during the day. This involved randomly swinging the net 50 times in each sub-plot of the research area (Jannah et al., 2023).

Insect Preservation

When collected, insects are placed in a vial film with alcohol. Smaller insects, such as *Thrips parvispinus* and *Aphis gossypii*, are prepared for identification using the whole mount method (Kurniawan and Soesilohadi, 2020). Larger insects are observed using a light microscope to examine their characteristics. Labeling is done to keep track of each specimen. The label includes information about where the insect was found, the coordinates, the date, and the name of the collector or person who found the insect. This labeling helps organize and identify the insects in the collection.

Morphology Identification

Insect identification up to morpho-species level. Identification is done by observing the morphological characteristics of insects with a microscope. The identification process uses the *naturalist* application. Photos of insects to be identified were uploaded to the application (Argiyanti et al., 2022), matching insect morphological traits and Inaturalist results (Unger et al., 2021) search on the Bugguide.net website (Yunus et al., 2022) according to research Reksiana et al. (2023), matched with Triplehorn and Johnson (2005), Kalshoven (1981), Gullan and Cranston (2014).

The next step was labeling to provide information about the insect found. The labeling section consists of ordo, species, and author according to the identifying mark, name, and year.

Data Analysis

Analysis of species diversity index, species evenness index and dominance index were analyzed manually using Microsoft Excel and diagrammatic data presentation using graphpad prism 9.5.1.

The following are the formulas used in this study:

$$H' = -\Sigma(\frac{\mathrm{ni}}{\mathrm{N}} In \frac{ni}{N}) \quad \text{......................................(1)}$$

Notes: H' = Species diversity index, ni= individuals of each species, ln = natural logarithm, N = Total individuals

The Evenness Index used the calculation equation from (Krebs, 1989 *in* Reksiana et al., 2023), as following:

$$E = \frac{H'}{In\ S} \quad \text{.. (2)}$$

Notes: E= Evenness index (value between 0 - 10), H' = Species diversity, ln = Natural logarithm, S = Number of species

The Margalef species richness index is calculated using the following equation (Anjani et al., 2022)

$$R = \frac{S-1}{In\ (N)} \quad \text{.. (3)}$$

Notes: R= Species richness index, S = Total number of species observed, ln = Natural logarithm, N = Total individuals observed

The Dominance Index using the Simpson index equation (Mardiyanti et al., 2013):

$$C = \Sigma(\frac{ni}{N})^2 \quad \text{... (4)}$$

Notes: C = Dominance index, ni = Important value of each species, N = Total importance of all species

The calculation of the community similarity index (Bray-Curtis) uses the formula (Reksiana et al., 2023):

$$IBC = 1 - (\frac{\Sigma(\mathrm{Xij} - \mathrm{Xik})}{\Sigma(\mathrm{Xij} + \mathrm{Xik})}) \quad \text{......................... (5)}$$

Notes: IBC = Composition similarity coefficient, Xik= Number of individuals of i-th species in habitat 2, Xij = Number of individuals of the i-th species in habitat 1.

Results

The insect pests were found in 2,687 individuals in paddy fields with refugia and fobio and 1,761 individuals in without refugia and fobio. Insect pests came from 5 orders, including Hemiptera, Coleoptera, Lepidoptera, Orthoptera, and Diptera; the two dominants were Lepidoptera and Coleoptera. The highest population found was the species *Chilo suppressalis* 2,072 individuals in paddy fields with refugia and 1,268 individuals in without refugia. Meanwhile, Coleoptera was dominated by the *Aulacophora indica*, with 558 individuals on paddy fields with refugia and 482 without refugia (Table 1, Figure 2).

Table 1. Population of insect pests in paddy field treated by different refugia (with and without refugia)

Orders	Family	Species	Populations	
			With Refugia	Without Refugia
Coleoptera	Scarabaeidae	*Adoretus compressus*	1	0
Coleoptera	Chrysomelidae	*Altica cyanea*	1	3
Coleoptera	Chrysomelidae	*Aulacophora indica*	558	482
Coleoptera	Chrysomelidae	*Aspidimorpha deusta*	1	0
Hemiptera	Pentatomidae	*Halyomorpha halys*	1	0
Hemiptera	Alydidae	*Riptortus linearis*	5	3
Hemiptera	Cicadellidae	*Empoasca fabae*	17	0
Hemiptera	Cicadellidae	*Recilia dorsalis*	23	0
Lepidoptera	Erebidae	*Creatonotos gangis*	1	0

Orders	Family	Species	Populations	
			With Refugia	Without Refugia
Lepidoptera	Erebidae	*Lymantria dispar*	1	0
Lepidoptera	Crambidae	*Cnaphalocrocis medinalis*	1	0
Lepidoptera	Crambidae	*Chilo supperssalis*	2,072	1,268
Lepidoptera	Hylaeidae	*Hyblaea puera*	1	2
Lepidoptera	Noctuidae	*Noctua pronuba*	2	0
Orthoptera	Gryllidae	*Acheta domesticus*	1	0
Orthoptera	Acrididae	*Oxya japonica*	1	2
Diptera	Tephritidae	*Zeugodacus tau*	1	0
Grand Total			2,687	1,761

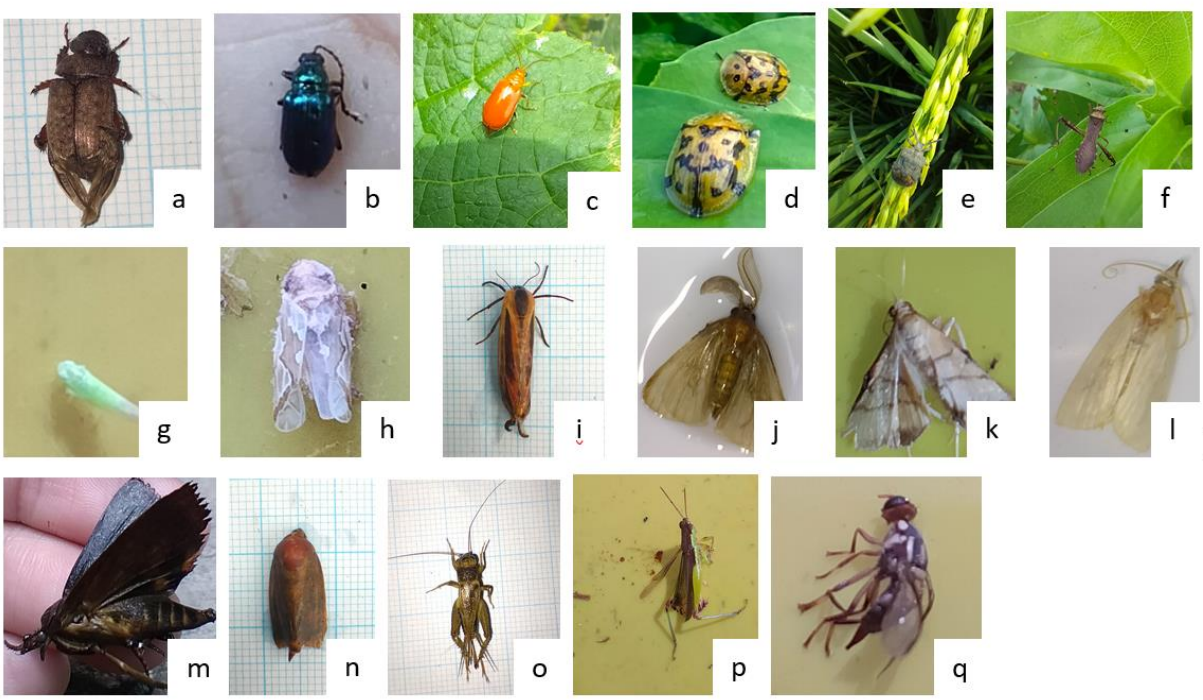

Figure 2. Insect pests found in the fields: *a) Adoretus compressus; b) Altica compressus; c) Aulacophora indica; d) Aspidimorpha deusta; e) Halyomorpha halys; f) Riptortus linearis; g) Empoasca fabae; h) Recilia dorsalis; i) Creatonotos gangis; j) Lymantria dispar*; *k) Cnaphalocrocis medinalis; l) Chilo supperssalis; m) Hyblaea puera; n) Noctua pronuba; o) Acheta domesticus; p) Oxya japonica; q) Zeugodacus tau*

The number of orders, families and species found in paddy fields with refugia and fobio was higher than without refugia and fobio. All diversity indicators were generally in the low category (Table 2).

There were 6 species of the same insect found on each paddy field, and 10 species that only found in paddy field with refugia and fobio. Meanwhile *N. pronuba* was only found in without refugia and fobio (Figure 3).

Table 2. Diversity Index in paddy field based on species diversity index (H'), species evenness index (E'), species richness index (R'), and dominance index (C').

Diversity	Treatment	
	with refugia and fobio	without refugia and fobio
Order number	5	4
Family number	12	6
Species number	16	7
Diversity (H’)	0.65	0.63
Eveness (E’)	0.04	0.11
Richness species (R’)	1.90	0.80
Dominance (C’)	0.15	0.18

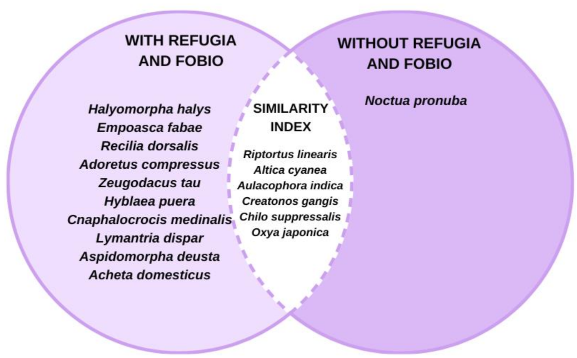

Figure 3. Insect pest found the paddy field treated by different refugia and biopesticides (with and without refugia + fobio)

Discussion

The number of insect pests was higher in paddy fields with refugia and fobio than without refugia and fobio (Tabel 1). Refugia plants provide alternative habitats and additional resources for insect pests. This can be caused by adapting insect pests to new conditions before natural predators or parasitoid populations can adjust and control pest populations; biopesticides such as folio can suppress specific pest populations but may not be effective against all pests. Using fobio as biopesticides in these fields can create temporary ecosystem imbalances, reducing competition among insect pests and increasing their numbers.

In paddy cultivation, many insects are associated with parts of food plants found in every growth phase, including vegetative and generative phases, developmental phases, and harvest to post-harvest phases (Prihatin et al., 2023). In fields without refugia and fobio, there may be more competition among insect pests for limited resources. Adding refugia and fobio reduced this competition, so insect pest populations may increase.

The two highest populations found in both fields were *Chilo suppressalis* (Lepidoptera: Crambidae) and *Aulacophora indica* (Coleoptera: Chrysomelidae), but with a tendency to be more numerous in with refugia and fobio fields (Table 1). *Chilo supresalis* is known as the paddy stem borer. The larvae nest in paddy stalks, causing severe damage, and the adults lay eggs in paddy plants to ensure a continuous cycle of attack (Xiang et al., 2023).

Zenita et al. (2020) reported that *C. supresalis* larvae attack all stages of paddy, including seedlings, tillers and flowering. According to Siddikah et al. (2020), the high population of insects from the order Coleoptera is due to the group's ability to easily adapt to all habitats. Paddy fields with refugia and fobio were assumed to provide a favorable environment with sufficient food sources and shelter, thereby facilitating the survival and reproduction of these pests. Although biopesticides are used to control pest populations, they may cause temporary imbalances in the ecosystem.

Aulacophora indica is a leaf beetle. However, this pest is not the primary pest of paddy but a pest for Cucurbitaceae (Nguyen et al., 2022). Its population was very high because farmers cultivated yellow pumpkin *(Cucurbita moschata)* from Cucurbitaceae around the field with refugia and fobio. Meanwhile, there were eggplants *(Solanum melongena)* around the field without refugia and fobio. Akbario et al. (2023) reported that *A. indica* attacks water gourd leaves *(Lagenaria siceraria)* and causes holes in the leaves, drying out and even dying.

All diversity index criteria in both fields were in the low category (Table 2). Kurniawan et al. (2018) stated that the evenness of insect types in a habitat is characterized by the number of insects that dominate the local habitat. The low or uneven distribution of species is caused by competition in utilizing available resources. This is influenced by the availability of food in the habitat they occupy.

The similarity of the habitats in the two paddy fields showed that there were significant differences (Figure 3). Species differences between two different fields are influenced by different food availability. Paddy fields with refugia have a diversity of plants, creating a more complex habitat that can support a larger population of insect pests due to the availability of more varied food. In line with Mudjiono (2013), adding refugia creates a more diverse and complex environment that will influence the spread and presence of insect pests. This results in more concentrated pest populations but fewer individuals due to differences in habitat. This causes insect pests on land without refugia to have smaller populations. According to Rizki et al. (2020), the presence of flowering plants does not always increase pest control shortly but rather through technical control with natural enemies.

Noctua pronuba was only found in rice fields without refugia and fobio (Figure 3). Their existence there has yet to be discovered and needs further study. According to Kovtun and Klymchuk (2020), *N. pronuba* is a polyphagous insect with a broad host range, including beets, cabbage, carrots, grapes, lettuce, potatoes, strawberries, tomatoes, various horticultural crops, and weed species. *N. pronuba*, a nocturnal moth, is the most common nocturnal visitor (Ribas-Marquès et al., 2022). Its habitat is in wetlands. Difonzo and Russell (2010) state that rice fields in the lowlands face a higher risk of migration of *N. pronuba* from the lowlands to rice fields in search of food.

Conclusion

Based on the study, 2,687 insect pests were found in paddy fields with refugia and fobio, and 1,761 individuals were found in paddy fields without refugia. Insect pests are more abundant in refugia and fobio than those without refugia. The insect species were higher in paddy fields with refugia and fobio (16 species) than without refugia and fobio (7 species). Flowering plants not only provide alternative food for predators, but they also attract pests.

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Declaration

Author contribution

Arieska Wahyu Alprilia is the main contributor of this paper, Ramadhani Mahendra Kusuma is the corresponding author, and Wiwin Windriyanti is co-author. All authors read and approved the final paper.

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Competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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