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AGROTECH

ISSN: 2773-4870 **eISSN:** 2821-3106
DOI: https://doi.org/10.53797/agrotech.v5i1.1.2026

The Effect of Different Types of Refugia Plants on Insect Adequacy Based on Ecological Roles in Rice Fields

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Received 3 January 2026; Accepted 10 January 2026; Available online 13 January 2026

Abstract: Refugia plants are an important component of Integrated Pest Management (IPM) because they provide habitats and food sources for beneficial insects. This study aimed to analyze the effect of different types of refugia plants on insect abundance based on their ecological roles, namely pests, predators, parasitoids, and pollinators, in paddy rice fields. The research was conducted in eight rice fields in Kudus Regency, Central Java, from October to December 2024. Insect sampling was conducted using the sweep-net method, with three replicates per site. Collected insects were identified to the family level and classified according to their ecological roles. Data analysis was performed using the Shannon–Wiener diversity index (H') and the evenness index (E'). The results showed that differences in refugia plant species influenced insect abundance in rice fields. Of the total 128 insect individuals recorded, 51.56% functioned as pests and 46.58% as predators, while parasitoids and pollinators each accounted for 0.78%. Predator insects belonged to 15 families and 8 orders, with the family Coccinellidae being the dominant group. The diversity index (H') across all fields was categorized as low, ranging from 0.223 to 0.691, while the evenness index (E') ranged from 0.501 to 0.889. Certain refugia plants demonstrated potential to enhance the presence of natural enemies. Therefore, the use of refugia plants supports natural pest control and the sustainability of rice agroecosystems.

Keywords: Refugia Plants, Rice Fields, Predators

1.0 Introduction

The rice cropping ecosystem is a complex and dynamic agroecosystem in which insects play highly important ecological roles (Edirisinghe, 2009). Insects function not only as pests that can reduce crop yield, but also as predators, parasitoids, and pollinators that help maintain the balance of agricultural ecosystems (Nicholles & Artieri, 2013). Imbalances in insect populations, particularly the dominance of pest species, are often triggered by intensive cultivation practices and excessive use of chemical pesticides, negatively affecting the sustainability of rice production and environmental conservation (Sarwar, 2024). Implementing refugia plants constitutes an environmentally sustainable approach to agroecosystem management (Rossetto & Kooyman, 2021). Refugia plants function as alternative habitats and food sources for non-target insects, especially natural enemies such as predators and parasitoids (Nechols, 2021). The presence of refugia around rice fields is expected to increase the abundance and diversity of beneficial insects, thereby suppressing pest populations naturally and supporting the principles of Integrated Pest Management (IPM) (Nelly et al., 2020).

Various types of refugia plants possess different morphological and phenological characteristics as well as food resources, such as flower color, flower shape, and the availability of nectar and pollen (Filipiak et al., 2022). These differences potentially influence the attractiveness of refugia plants to specific insect groups. However, information on the effects of different refugia plant species on insect abundance, based on their ecological roles (pests, predators, parasitoids, and pollinators), in rice ecosystems remains limited, particularly under local paddy field agroecosystem conditions (Wardana & Erdiansyah, 2017).

Based on the above considerations, this study aimed to analyze the effect of different refugia plant species on insect abundance according to their ecological roles in rice fields. The results of this study are expected to provide scientific contributions to the development of sustainable rice agroecosystem management strategies and to serve as a basis for selecting effective refugia plant species to support natural pest control.

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2.0 Material and Methods

2.1 Time and Location of Study

The rice fields used in this study were located in Kudus Regency, Central Java, Indonesia. A total of eight rice fields were included in the study. Insect trapping was conducted three times at each field. Identification of trapped insects was carried out at the Plant Protection Laboratory, Agrotechnology Study Program, Universitas Muria Kudus. The research was conducted from October to December 2024.

2.2 Materials and Equipment

The tools used in this study included a sweep net, stationery, a stereo microscope, and a digital camera. The materials used consisted of rice fields containing refugia plants, insect containers, cotton, Petri dishes, brushes, chloroform, and 70% alcohol.

2.3 Experimental Design

The rice fields used in this study met the following criteria: (a) a minimum area of 1,000 m^2 and (b) rice field bunds overgrown with refugia plants belonging to weed groups. The study used a purposive sampling method. Insect observations were carried out in three replications with a one-day interval between each observation. Insect collection was conducted by swinging a sweep net ten times along a single linear transect on the rice field bunds. Captured insects were placed into containers and transported to the laboratory for identification. Insects were grouped by experimental field prior to identification. Identification was performed to the family level, and insects were classified according to their ecological roles using insect identification keys.

2.4 Experimental Procedure

The rice fields used in this study met the following criteria: (a) a minimum area of 1,000 m^2 and (b) rice field bunds overgrown with refugia plants belonging to weed groups. The study used a purposive sampling method. Insect observations were carried out in three replications with a one-day interval between each observation. Insect collection was conducted by swinging a sweep net ten times along a single linear transect on the rice field bunds. Captured insects were placed into containers and transported to the laboratory for identification. Insects were grouped by experimental field prior to identification. Identification was performed to the family level, and insects were classified according to their ecological roles using insect identification keys.

Data obtained from insect identification were processed in Microsoft Excel by insect type and population. Data analysis was conducted by calculating the Shannon–Wiener diversity index using the following formula:

$$H = -\Sigma pi * \ln(pi), \quad Pi = n/N$$

H' = Shannon-Wiener diversity index
Pi = Proportion of individuals of the i-th species
ln = Natural logarithm
n = Abundance of individuals of the i-th species
N = Total number of individuals of all species

The insect diversity index was classified into five criteria, namely: (a) very good ($H \geq 2.41$), (b) good (H between 1.80 and 2.41), (c) moderate (H between 1.21 and 1.80), (d) poor (H between 0.61 and 1.20), and (e) very poor ($H < 0.60$) (Krebs, 1999).

Meanwhile, the evenness index (E') was calculated using the following formula:

$$E' = H'/\ln S$$

The insect evenness index based on Simpson's index was also classified into five criteria, namely: (a) very good ($E \geq 0.81$), (b) good (E between 0.61 and 0.80), (c) moderate (E between 0.41 and 0.60), (d) poor (E between 0.21 and 0.40), and (e) very poor ($E < 0.20$) (Krebs, 1999).

3.0 Results

Table 1: Abundance of pest, predator, and parasitoid insects associated with different types of refugia plants in rice fields

Location	Refugia	Insect		
		Pest	Predator	Parasitoid
	Lindernia antipoda (L.) *Ludwigia peruviana* (L.)	3	13	1
Land 2	*Imperata cylindrica* *Panicum repens*	10	3	0
Land 3	*Imperata cylindrica* singkong	11	6	0
Land 4	*Bidens pilosa L.*	16	1	0
Land 5	*Neonotonia wightii* *Cyperus rotundus*	5	17	0
Land 6	*Lantana camara* *Imperata cylindrica* *Amarantus spinosus*	9	8	0
Land 7	*Cosmos caudatus* K. *Catharanthus roseus* *Tagetes* sp. *Amaranthus* sp.	3	6	0
Land 8	*Ipomoea triloba* *Borreria repens* *Cynodon dactylon* *Pluchea indica*	9	3	0

Refugia plants are plants that are deliberately cultivated or naturally grow within agricultural areas. Certain refugia plant species can provide shelter and food resources for insect natural enemies. Refugia plants may originate from weed groups, vegetables, ornamental plants, and wild vegetation. Based on the results of this study, refugia plants in rice fields comprised various weed species (Table 1). Lands 1, 2, 3, and 5 were composed of two refugia plant species, whereas Lands 6, 7, and 8 contained a greater diversity of refugia plant species.

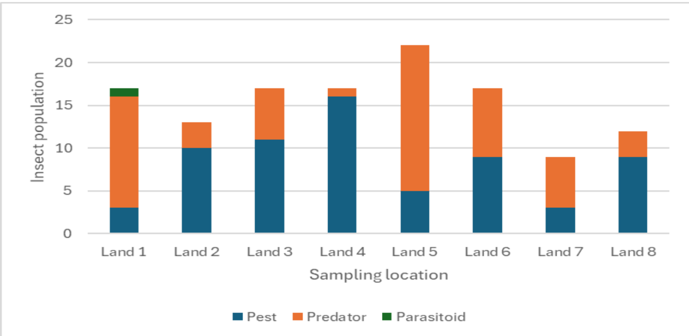

Figure 1: Abundance of pest, predator, and parasitoid insect populations in rice paddy Fields

Based on observations, differences in insect abundance among ecological roles were found across the different refugia plant treatments in rice fields. These differences indicate that the composition and types of refugia plants influence insect community structure, particularly the balance between pest and predator groups. In Lands 1 and 5, the population of predator insects was higher than in the other lands (Figure 1).

Table 2: Composition and abundance of predator insects based on order and family

Ordo	Family	Population	Ecological service
Coleoptera	Coccinellidae	19	Predator
Coleoptera	Sciaridae	1	Predator

Hymenoptera	Vespidae	2	Predator
Orthoptera	Gyllidae	10	Predator
Mantodea	Mantidae	2	Predator
Hemiptera	Miridae	1	Predator
Hemiptera	Reduviidae	3	Predator
Hemiptera	Pentatomidae	5	Predator
Hemiptera	Pyrrhocoridae	1	Predator
Hemiptera	Coreidae	4	Predator
Araneae	Oxyopidae	5	Predator
Araneae	Thomicidae	2	Predator
Aranae	Aracidae	3	Predator
Diptera	Muscidae	1	Predator
Hymenoptera	Formicidae	1	Predator

Refugia plants surrounding rice crops can attract insects with different functional roles. In this study, a total of 128 insect individuals were recorded, of which 51.56% were pests, 46.58% were predators, 0.78% were parasitoids, and 0.78% were pollinators. The predator insects identified belonged to 15 families and 8 orders, including Coleoptera, Hemiptera, Hymenoptera, Orthoptera, Mantodea, Diptera, and Araneae (Table 2). The diversity of predatory insects observed indicates that the rice agroecosystem studied has the potential to maintain a healthy ecological balance, particularly in supporting biological control of pest populations.

Table 3: Diversity Index (H') and Evenness Index (E') in Rice Paddy Fields Planted with Refugia

Location	Population	H'	Category	E'	Category
Land 1	17	0,678	Poor	0,619	Good
Land 2	13	0,540	Very poor	0,644	Good
Land 3	17	0,649	Poor	0,543	Moderate
Land 4	17	0,223	Very poor	0,889	Very good
Land 5	22	0,535	Very poor	0,648	Good
Land 6	17	0,691	Poor	0,501	Moderate
Land 7	9	0,636	Poor	0,556	Moderate
Land 8	12	0,562	Very poor	0,625	Good

Based on Table 3, the Shannon–Wiener diversity index (H') in the eight rice paddy lands ranged from 0.223 to 0.691. The H' values were classified as poor to very poor. Land 6 had the highest H' value (0.691), followed by Land 1 (0.678) and Land 3 (0.649). In contrast, Land 4 showed the lowest H' value. The evenness index (E') in the eight rice paddy fields ranged from 0.501 to 0.889. Even though there are several lands that showed good to very good category, overall, all lands had the same range in E' values, indicating that the distribution of individuals among species was uneven and that dominant species were still present within the community.

4.0 Discussion

Refugia plants belonging to Lindernia antipoda, Ludwigia peruviana, Cyperus rotundus, and kenikir (Cosmos caudatus) play an important role in attracting natural enemies of insects in rice fields. This is because kenikir has pink and white flower colors that are attractive to insects such as butterflies, ants, beetles, and spiders (Pribadi et al., 2020). The abundance of natural enemies can increase due to the diversity of flower colors in refugia plants (Hatt et al., 2017). Insects from the family Coccinellidae (Coleoptera) were the most abundant predators, with a population of 19 individuals. Coccinellidae play an important role in controlling aphid pests (Pratiwi & Apriyadi, 2023). The high abundance of Coccinellidae indicates the availability of sufficient food resources and favorable habitat conditions, including the presence of alternative host plants that serve as refugia.

In addition, predators from the order Hemiptera were found in relatively high abundance and diversity, particularly from the families Reduviidae, Pentatomidae, Coreidae, Miridae, and Pyrrhocoridae. Reduviidae are generalist predators that actively prey on various insect pests at both nymphal and adult stages. The presence of predatory Pentatomidae and Coreidae underscores the importance of Hemiptera in maintaining the stability of herbivorous insect populations in agroecosystems. According to Schoonhoven et al. (2005), Hemipteran predators have a high capacity to adapt to changes in agricultural environments, leading to higher field populations. Predatory insects from the order Araneae, particularly the families Oxyopidae, Thomisidae, and Araneidae, were also found in relatively significant numbers. Spiders act as generalist predators that effectively suppress populations of both flying and crawling insects. Their presence reflects a relatively complex habitat structure, as spiders are highly sensitive to environmental disturbances and the use of synthetic pesticides. Nyffeler and Sunderland (2003) stated that spiders can make a substantial contribution to natural pest control in agricultural ecosystems.

The number of individual insects recorded ranged from 9 to 22, with the highest abundance in Land 5 (22). However, high insect abundance was not always accompanied by high diversity values. This was evident in Land 5, which had an H' value of 0.535 (low category), indicating dominance by certain species. The evenness index (E') across the eight rice fields was categorized as low. Land 4 showed the lowest H' value but the highest E' value, indicating that although species richness was very limited, individuals were relatively evenly distributed among species. This condition reflects a simple community with a homogeneous structure but limited species richness. In ecosystems, the proportions of pest, predator, and parasitoid populations are crucial in influencing ecological balance and stability. A smaller difference between pest and predator or parasitoid populations indicates greater ecosystem balance and stability, in which pest populations can be effectively controlled by predators and parasitoids (Kurniawan & Setiawan, 2024).

Acknowledgement

We would like to acknowledgeall project members who helped to carry out this research activity.

Conflict of Interest

The authors declare no conflicts of interest.

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