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The Ecological Roles of Diurnal Flying Insects in Agriculture and Their Potential for Collaboration in Biology Education

Hery Fajeriadi[1*], Bimo Aji Nugroho[2], Fahmi[3], Riza Arisandi[1]

[1] Department of Biology Education, Faculty of Teacher Training and Education, Universitas Lambung Mangkurat, Banjarmasin, Indonesia
[2] Department of Biology Education, Faculty of Teacher Training and Education, Universitas Borneo, Tarakan, Indonesia
[3] Department of Natural Science Education, Faculty of Teacher Training and Education, Universitas Lambung Mangkurat, Banjarmasin, Indonesia

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Corresponding Author:
Hery Fajeriadi
heryfaje@gmail.com

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Abstract: The quality of agriculture is affected by insects in agricultural areas. Both insects that have a negative impact such as pests, positive such as predators against pests, and those that are neutral or have no effect on agriculture, but can be an indicator of the ecosystem. Control of plant pest organisms (PPO) is often done by spraying pesticides, but also results in a decrease in the population of insect predators of pests. The diversity of flying insects in Haturak farm, Kupang Village, Tapin Regency has not been documented. This study aims to identify the types of flying insects on Haturak farm and analyze their ecological role. The research method used was a descriptive and observational approach. Data were collected through total roaming and direct documentation using macro photography in the insects' natural habitat. Analysis was done descriptively and reinforced with literature studies. The results of the study found 18 species of flying insects from six orders. Eight species played a positive role, while ten species had a negative impact on agriculture. Among them, two species played both positive and negative roles, and two others had a neutral role. This condition is less favorable for agriculture because there are fewer predatory insect species than pests. For the sake of biological pest control, enriching pest predator species is recommended to reduce land damage due to high or frequent chemical use. Further studies on diversity and abundance indices are recommended to understand the territorial dominance of each species, as well as to evaluate the effectiveness of biological control. Collaboration between Biology Education and farmers through ecological education builds synergy between science and sustainable farming. The five initiatives enhance ecological literacy and apply local wisdom. To maximize impact, it is recommended to integrate these programs into regular academic and community service activities, ensuring long-term engagement and measurable outcomes.

Keywords: Biology education; Macro photography; Potential collaboration; Reduce pesticides; Rice pests.

Introduction

Insects represent the most species-rich class within the phylum Arthropoda (Mayhew, 2007; Thorp, 2009; Stork, 2018), and they are widely distributed across various ecosystems, including agricultural lands (Eggleton, 2020). Insect diversity not only reflects the health of an ecosystem but also plays a critical role in maintaining agroecosystem balance through ecological functions such as pollination, decomposition, pest predation, and supporting the food web (Thorp, 2009; Wardhaugh, 2015). However, the quality of agricultural environments and climate change have emerged as major threats to the survival of these organisms (Raven & Wagner, 2021), especially in tropical regions such as South Kalimantan. A decline in the number of farming enterprises in this province—from 507,964 units in 2013 to 488,487 units in 2023, particularly in the food crop and agricultural services subsectors (BPS South Kalimantan, 2023)—serves as an indicator of both structural and

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ecological pressures that affect food production sustainability.

One of the real challenges faced by farmers is crop damage caused by pest infestations, such as brown planthoppers and mealybugs, as reported in the agricultural area of Haturak, Kupang Village, North Tapin District. These recurring pest outbreaks, such as those recorded in 2015–2016 and again in 2023–2024, are not solely caused by the pests themselves but are also exacerbated by rising temperatures due to climate change. In response, farmers typically apply pesticides and insecticides regularly. Although these practices can effectively control major pests, they also cause harm to other flying insects—such as dragonflies, grasshoppers, and butterflies—that play important ecological roles. This highlights the challenges of pest management, which not only impact biodiversity but also threaten the resilience of agricultural production systems.

The use of pesticides, particularly neonicotinoid insecticides, has raised serious concerns due to their harmful effects on beneficial insect populations (Eggleton, 2020). Additionally, public perception often narrowly views insects solely as pests, overlooking the fact that many species serve as natural enemies, pollinators, or decomposers of organic matter (Thorp, 2009; Wardhaugh, 2015). Nevertheless, there is also a prevailing perception that insects can act as vectors of human diseases (Auerswald & Lopata, 2005), adding complexity to decision-making in insect management on agricultural land.

Given this context, the present study is both important and urgent. It aims to identify species of flying insects found in agricultural fields and to comprehensively analyze their ecological roles. The findings are expected to provide a scientific foundation for developing more environmentally friendly, ecosystem-based pest management strategies that support sustainable agriculture in the era of climate change.

Amid the urgency and sustainability challenges facing the agricultural sector, research on flying insect identification and their ecological roles opens strategic opportunities for the field of education—particularly in Biology Education—to actively contribute to building ecological awareness among the public. Biology Education is not only responsible for mastering scientific concepts such as ecology and entomology, but also serves as an agent of change that bridges scientific knowledge with real-world needs, especially in the context of sustainable agriculture. Collaboration among students, lecturers, and farming communities through field-based educational activities offers a relevant and visionary approach to reinforcing contextual understanding of ecosystem concepts.

In this context, field practices, community service initiatives, and collaborative research can focus on the direct observation of insect diversity, identification of local species, and education on the ecological functions of insects within the food chain and natural pest control. Such collaborations will not only improve ecological literacy among farmers but also enrich student learning experiences through active engagement with real-world issues. This approach is vital in shaping biology graduates who are not only academically competent but also adaptive and contributive to environmental challenges and regional development.

Furthermore, higher education institutions, as centers of research and innovation, have the capacity to promote environmentally friendly, evidence-based agricultural advocacy developed from field data. This study, for instance, can be integrated into programs such as *Merdeka Belajar–Kampus Merdeka* (MBKM), thematic community service (*KKN*), or community-engaged research initiatives. Thus, collaborative efforts involving the academic community in Biology Education should not be seen merely as an alternative but as a strategic necessity in supporting the transformation of agriculture into a system that is not only productive but also ecological and sustainable—an area that warrants further analysis.

Thus, the presence of flying insects in agricultural areas not only reflects the health of the ecosystem, but also serves as a crucial indicator in facing the challenges of agricultural sustainability amid climate change. Pest management, which has been dependent on the use of pesticides, must be combined with ecological methods that are more prudent and sustainable. In this context, Biology Education plays an important role as a link between science and real needs in the field through conceptualized learning methods, collaborative research, and community service. This method not only increases ecological literacy among the community, especially farmers, but also creates graduates who are responsive and able to make a real contribution to productive and sustainable agricultural development. So, this study aims to identify the types of flying insects on Haturak farm and analyze their ecological role.

Method

This research is a descriptive study aimed at identifying the types of flying insects, their ecological roles, and the potential for educational collaboration within the Biology Education Study Program. Observations were conducted during the fruiting stage of rice plants, in the morning between 07:00 and 10:00 Central Indonesia Time (WITA), at the Haturak agricultural area, Kupang Village, Tapin Regency. The observed population consisted of macroscopic flying insects found within a rice field plot measuring 17 × 85 meters, using a total range exploration technique.

Sample collection was carried out through direct documentation using a macro photography camera, namely the Canon EOS Kiss X7/EOS 100D kit 18–55mm IS STM, equipped with an APS-C CMOS sensor of 18 megapixels and other supporting features. Macro photography techniques were used to capture detailed visual documentation of the insects. This technique is used to see how many insects can be observed directly without catching them. Catching insects in agricultural areas has the potential to damage rice crops planted by farmers, and is considered to affect farmers' interest in collaboration.

Species identification analysis referred to the insect identification guide by Borror et al. (1992), along with supplementary references from scientific journals and books. The analysis of ecological roles was conducted through literature studies sourced from relevant national and international references. The ecological roles of insects were categorized into three types based on Gamage et al. (2023): Type A (positive impact on agriculture), Type B (negative impact), and Type C (no direct or specific impact).

Furthermore, the analysis of potential educational collaboration was carried out descriptively through a literature review. The analyzed literature was required to meet the following criteria: published within the last ten years (2015–2024), open access, and published in nationally accredited journals or reputable international journals. The selected literature also had to be relevant to the research topic.

Result and Discussion

A total of 18 species of flying insects were found in Haturak farmlands. The ecological role of each flying insect species was analyzed based on its influence on agricultural activities. The roles were grouped into several categories, namely: positive impact on agriculture, negative impact, act as an indicator of the condition of agricultural land, and have no direct influence. The results of species identification and grouping based on their ecological roles are shown in Table 1. A comparison chart of ecological roles for each order is presented in Figure 1.

Table 1. Species diversity and ecological role of flying insects to agriculture in Haturak farming area

Classification			Local Name	Ecological Role Type		
Order	Genus	Species		A	B	C
Orthoptera	Phlaeoba	*P. fumosa*	Belalang coklat	-	+	-
	Oxya	*O. servile*	Belalang hijau	-	+	-
	Atractomorpha	*A. crenulata*	Belalang daun	-	+	-
	Sogatella	*S. furcifera*	-	-	+	-
Odonata	Orthetrum	*O. sabina*	Capung Besar	+	-	-
	Ischnura	*I. senegalensis*	Capung Jarum	+	-	-
	Agriocnemis	*A. femina*	Capung Jarum	+	-	-
	Diplacodes	*D. trivialis*	Capung Biru Kecil	+	-	-
Coleoptera	Coccinella	*C. transversalis*	Kepik	+	-	-
	Micraspis	*M. discolor (*)*	Kepik	+	-	-
	Aulacophora	*A. lewisii*	Kumbang kecil	-	+	-
Lepidoptera	Melanitis	*M. leda*	Kupu-kupu sawah	+	+	-
	Ypthima	*Y. pandocus (**)*	Kupu-kupu coklat	+	+	-
	Cnaphalocrocis	*C. medinalis*	Hama putih palsu	-	+	-
	Scirpophaga	*S. nivella*	Hama putih	-	+	-
Diptera	Musca	*M. domestica*	Lalat besar	-	-	+
	Calliphora	*C. vomitoria*	Lalat hitam	-	-	+
Hemiptera	Leptocorisa	*L. oratorius*	Hama Wereng	-	+	-

Remark:
Type A = Positive
Type B = Negative (Pests)
Type C = No effect
\+ = Present
\- = Absent
(*) = Morphologically it is most similar to *Micraspis discolor* found in Central Sri Lanka by Mayadunnage *et al.* (2007) and in Merangin Regency Indonesia by Yudiawati & Pertiwi (2020), although it also has similarities with *Verania discolor* found in Southeast Asia according to Amir (2002).
(**) = Morphologically, it is most similar to *Ypthima pandocus* found in Banten Indonesia by Budiaman *et al.* (2021) and in Peninsular Malaysia by Min (2014), although it also has similarities with *Ypthima nigricans* found at Gunung Ciremai

National Park in Indonesia by Karyaningsih *et al*. (2024). However, *Ypthima pandocus* has several varieties as described by Bhowmik *et al*. (2020).

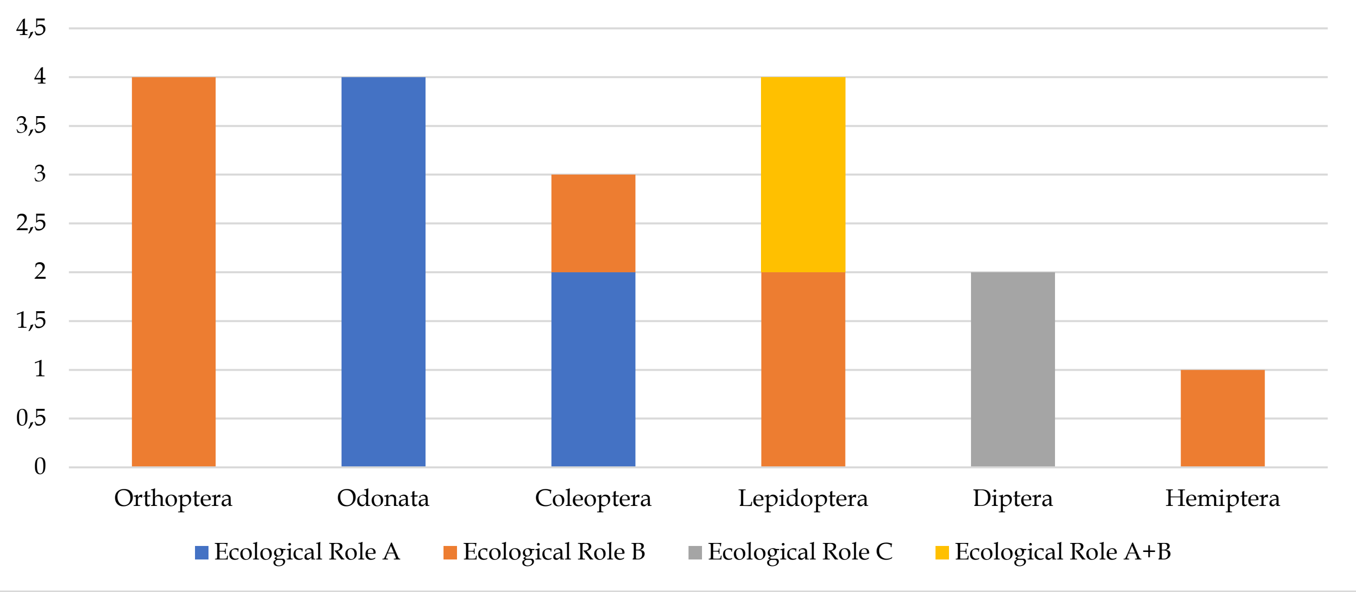

Figure 1. Comparison chart of ecological roles per Order

Ecological Role of Flying Insects

Based on literature analysis, the flying insect species found in this study fill each type according to their ecological roles. Type A in this study contains species that benefit agriculture or help plant development, namely acting as pest predators and as pollinators. Type B is filled with species that act as pests or harm agriculture. Finally, Type C is filled with species that have no direct effect on agriculture, but the species found for this type act as disease vectors.

Type A begins with dragonfly species found in the study area, including *Ischnura senegalensis, Agriocnemis femina, Diplacodes trivialis,* and *Orthetrum sabina*, which are natural predators of several species of crop pests in agriculture, especially suppressing the population of leaf borers and rice stem borers. The use of pesticides or insecticides affects the presence of these dragonfly species because the dragonfly's life cycle is mostly spent in the water. According to Wardhani (2007); Purnomo (2010); Zulhafandi (2020), residues of pest control pesticides that mix into waters cause pollution which at certain levels affects the growth and development of dragonfly species.

Besides dragonflies, *Coccinella transversalis* and *Micraspis discolor* are predatory ladybird species of aphids. According to Efendi *et al*. (2016), the ability of *Coccinella transversalis* in predation increases with the density of aphids on plants, so it is classified as an effective plant pest control species. The prey species of aphids are *Aphis gossypii, Aphis craccivora,* and *Myzus persicae* with approximately the same level of predation. This is consistent with our observations at the study site, where *C. transversalis* was found more frequently in rice paddy plots that also showed high aphid populations. *Verania discolor* which in the caption of Table 1 is described as having similarities with *Micraspis discolor* according to (Nelly *et al*., 2015) also acts as a predator for *Aphididae* spp., or several aphid species.

Type B is populated by *Phlaeoba fumosa* and *Oxya servile* species which are leaf attacking pests. It usually leaves large tears in the leaf starting from the edge. The tears are caused by the mandibular mouthparts. Symptoms of damage caused by these mouthparts include tearing of the leaves. Generally, this species lays eggs at the beginning of the dry season and will hatch at the beginning of the rainy season. Nymphs emerge from soil holes and climb up the plant. The nymphs eat the leaves until they are just skeletons. Once winged, the nymphs fly away and look for food elsewhere. Once mature, this species will mate on the plant. After that, it flies to the ground to find a place to lay eggs and gather in the open to seek sunlight.

However, the symptoms of *Atractomorpha crenulata* attack are small holes (perforations) in the form of slightly round, angular, millimeter-sized holes in the leaves. It also causes yellowish spots on the leaves, giving the leaves a bad appearance. Heavy infestations result in perforated or yellow-spotted leaves and subsequent drying. *Sogatella furcifera* attacks rice plants in the early generative phase when rice starts to bear fruit. According to Sianipar *et al*. (2015), when rice enters the late stage of the generative phase, the population of these insects tends to decrease because the morphology of rice both plant tissue resistance, size and shape are no longer suitable for insect pests.

Aulacophora lewisii, a species categorized as a small beetle, also acts as a plant pest. At the study site, no plants such as eggplant or spinach were found around the field, supporting the finding that the dominant species is *A. lewisii* as also described by Dou et al. (2023). According to Dou *et al*. (2023), the presence of species of the genus *Aulacophora* is influenced by the presence of plants around cultivated land. If eggplant, mustard greens, spinach, or kale are found around the cultivated land, the species *Aulacophora similis* will be found to dominate compared to *Aulacophora lewisii*. However, it is suspected that the absence of these plants around the farm causes the species found to be *Aulacophora lewisii* because it is not dominated by the other species.

Flying insect species that are interesting because of their beauty are butterflies, which are found to include *Melanitis leda* and *Ypthima pandocus* that play a positive role as pollinators (helping 40% of crop pollination). However, despite their beauty, the larvae of these species are leaf-attacking pests. The attack pattern of the larvae of this species is to eat from the edge of the leaf until the leaf bone remains, then move to the next leaf. Based on research by Sianipar *et al*. (2015); Lestari and Rahardjo (2022), the presence of *Melanitis leda* is relatively small in agriculture and is classified as a pest. This is in line with field data, where populations of *M. leda* and *Y. pandocus* were also found in limited numbers and were more often seen at the edges of agricultural fields bordering wild vegetation. Karyaningsih *et al*. (2024) and Herlin *et al.* (2024) added that this species and species from *Ypthima* are also relatively few in agriculture, but these species are classified as pollinators. Even the results of research by Oqtafiana *et al*. (2013) showed that species of *Ypthima* are not found in agriculture, but are found in secondary forests and according to Min (2014) have high densities in wet forests.

Cnaphalocrocis medinalis, Scirpophaga nivella, and *Leptocorisa oratorius* are the most popular pest species in agricultural areas. Several studies on plant pest species also found these species or at least with the same genus, including Sari *et al*. (2017); Heviyanti & Syahril (2018). Even the abundance of these agricultural pest species does not dominate each other because they act as herbivores whose food source is rice plants (Ahmad, 2020). *Scirpophaga* is known as a borer pest and experiences high abundance in environments with low temperature and high rainfall (Ali *et al*., 2020). The weather, although not recorded in detail during the observation, showed high rainfall and relatively low temperatures, thus explaining the high presence of *Scirpophaga* in the farmlands we studied. Borers are a major enemy of agriculture because the larvae of these pests damage the stems of rice plants from the inside, making early detection difficult (January *et al*., 2020).

Finally, *Calliphora vomitoria* and *Musca domestica* fill Type C because they have no direct effect on agriculture. However, the presence of this species becomes a disease vector or can transmit various diseases. According to Saputri (2017); Pertiwi (2019); Irma *et al*. (2023); Maksum *et al*. (2023), several species of houseflies have been known to act as carriers of eggs of *Ascaris lumbericoides, Trichuris trichiura, Enterobious vermicularis, Toxocara canis,* and *Strongyloides stercoralis* cysts.

Implications

The presence of pest attacks in paddy rice fields encourages farmers to control pests using synthetic chemical pesticides. Generally, the rate of pesticide use is in accordance with the experience of farmers, also influenced by the level of pest attack. To control these pests, if pesticides are used carelessly, without considering the right dose, time, method and target, it can cause the death of non-target organisms, such as natural enemies of plant pests including parasitoids, predators, and disease vector insects commonly found on agricultural land. The death of these natural enemies of pests can lead to resistance, resurgence, and secondary pest outbreaks.

Based on the results of this study, it was found that natural predator species such as *O. sabina* only dominated 5% of the total insect population, while pest species such as *S. furcifera* reached 35%. This imbalance shows the weak function of natural biological control in the rice field ecosystem studied. The dominance of pests over their natural enemies in the study sites supports the need to implement a policy of prohibiting the use of synthetic pesticides when natural predator populations are high, or a campaign to strengthen biological pesticides based on local natural enemies.

Farmers know that insecticides threaten the natural enemies of insect pests, yet they continue to use them. Different understandings of the health impacts of spraying are also polemic (Heong & Escalada, 1999), even today. Chemical control still ranks first (based on relative advantage, trialability, observability, farmer efficacy, farm characteristics, and control effectiveness), higher than biological control which ranks second (which excels in technical support, compatibility, and social utility) in controlling agricultural pests. Flexible policies are needed for decision-making in determining pest control strategies to be effective in extension and implementation (Abdollahzadeh *et al*., 2016).

There are several recommendations in dealing with this problem, including ecosystem engineering by spreading predatory insects to suppress insect pest populations. For example, given the abundance of *C. transversalis* in the wetlands studied, the potential use of this species in a planned natural predator release program should be prioritized as part of ecosystem engineering. But before that, further studies need to be done. Not only about the type and ecological role, but also the biodiversity index, abundance, and percentage of success of biological control of insect pests, so that it can be applied more widely. In addition, similar studies are also needed on other species besides flying insects.

Biology Education Collaboration Potential

The discovery of 18 flying insect species in the Haturak agricultural area, classified based on their ecological roles, presents a significant opportunity to foster collaboration between institutions—particularly the Biology Education Study Program—and the farming community through ecological education. These strategic collaboration opportunities are presented in Table 2.

Table 2. Strategic Opportunities for Biology and Farmer Education Collaboration

Collaboration Opportunity	Description	Benefits
Strengthening Agricultural Ecological Literacy through Field Schools	Students and lecturers act as facilitators in field-based education by explaining the roles of insects based on field data.	Farmers are able to distinguish between beneficial insects and those that need to be controlled, supporting environmentally friendly farming practices.
Integration of Student Research with Farmers' Needs	Student research is directed to study insect populations in local ecosystems based on field identification results.	Generates locally relevant data and strengthens the university's role as an agent of change.
Education on Biocontrol and Pesticide Impact	Development of interactive educational modules and insect data visualizations for outreach activities.	Increases farmers' awareness of pesticide hazards and the importance of maintaining agricultural ecosystem balance.
Formation of Environmentally-Conscious Farmer Groups (KTPL)	Mentoring farmer groups through nature school-based programs with ecological and local approaches.	Bridges science and local wisdom in sustainable farming practices.
Production of Locally-Contextual Learning Media	Utilization of local insect discoveries as contextual teaching materials in the Merdeka Curriculum.	Helps students understand ecosystems concretely and promotes local biodiversity conservation.

Table 2 illustrates various strategic opportunities that biology education institutions can pursue to collaborate with farmers in enhancing their understanding and application of ecological principles in agriculture. The first opportunity is the strengthening of agricultural ecological literacy through field school programs, where students and lecturers act as facilitators in introducing the ecological roles of various insect species (P1). This activity is highly beneficial in helping farmers distinguish between beneficial and harmful insects, enabling them to adopt more environmentally friendly farming practices.

The second opportunity involves integrating student field research with farmers' needs (P2), which allows students to use real-world agricultural issues as the basis for academic research, particularly for theses or final projects. The research results not only serve academic purposes but also provide relevant data for farmers and village governments to support informed decision-making. Next, the third opportunity is education on biocontrol and raising awareness of the impact of pesticides (P3), emphasizing the importance of data-driven educational media, such as infographics, that are easy for farmers to understand. Through community service initiatives, this educational effort is expected to shift farmers' paradigms regarding chemical pesticide use and introduce them to biological control alternatives.

The fourth opportunity is the formation of Environmentally-Conscious Farmer Groups (Kelompok Tani Peduli Lingkungan – KTPL) based on nature school models (P4), promoting the development of farmer communities with environmental awareness, supported directly by lecturers and students. This approach combines scientific knowledge with local wisdom and fosters biodiversity-based sustainable agricultural practices. Finally, the fifth opportunity is the development of locally contextual learning media (P5), utilizing local findings—such as the presence of Micraspis discolor and Ypthima pandocus insects—as relevant learning materials for elementary to high school students. This integration supports the implementation of the Merdeka Curriculum, which promotes context-based learning grounded in local realities.

Overall, these five opportunities demonstrate how biology education can play an active and strategic role in raising ecological awareness among farmers and fostering a synergistic relationship between academia and local communities. This approach aligns with sustainable development goals, particularly in maintaining agricultural ecosystem balance and supporting local food security.

Conclusion

The study identified 8 species as pest predators, 10 as pests—with 2 acting as both pests (larval stage) and predators (adult stage)—and 2 species with no impact on crops. While farmers commonly use chemical pest control based on attack severity, this practice can degrade soil quality and reduce predator insect populations. Although limited to identifying flying insect species and their ecological roles, the findings suggest potential for ecosystem-based pest control by utilizing natural predators. Further research should explore broader insect biodiversity, species abundance, and the effectiveness of predator-based biocontrol, including nocturnal and non-flying species. Additionally, integrating these findings into Biology Education curricula—through modules on agroecology, biodiversity, and sustainable pest management—can foster practical ecological literacy. Collaboration between Biology Education and farmers through ecological education strengthens the synergy between science and sustainable agricultural practices. The five proposed initiatives promote ecological understanding and the application of local wisdom. Students and lecturers act as facilitators and agents of change, supporting biodiversity conservation, environmental awareness, and locally based food security.

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Author Contributions
For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, H.F.; methodology, H.F. and B.A.N.; software, R.A.; validation, H.F., B.A.N. and F.F.; formal analysis, R.A.; investigation, H.FX.; resources, F.F.; data curation, H.F.; writing—original draft preparation, R.A.; writing—review and editing, B.A.N; visualization, F.F.; supervision, H.F.; project administration, R.A.; funding acquisition, H.F.

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The authors declare no conflict of interest.

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