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Review Articles

# Diversity of Hymenoptera in Indonesian Rice Agroecosystems: A Systematic Review of Species Composition and Ecological Roles

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**ABSTRACT**

Hymenoptera play a crucial role in maintaining ecological balance in rice agroecosystems by providing essential ecosystem services, particularly in biological pest control, which reduces reliance on chemical pesticides. Despite their ecological importance, research on Hymenoptera diversity in Indonesia remains limited, especially regarding the impacts of varied agricultural practices on these insects and their ecological functions in rice fields. This gap necessitates a comprehensive understanding of how different farming methods influence Hymenoptera diversity and pest suppression. This systematic review assesses the diversity and ecological functions of Hymenoptera in Indonesian rice agroecosystems, evaluates their contributions to natural pest control, and examines the effects of management practices, including organic farming and Integrated Pest Management (IPM), on Hymenoptera populations. A thorough search of peer-reviewed studies from scientific article focusing on research reporting Hymenoptera species diversity, ecological roles, and farming practice impacts. Data on species composition, pest suppression rates, and management practices were synthesized and analyzed using statistical methods, including regression and ANOVA. The findings reveal significant regional variation in Hymenoptera diversity, with organic and IPM practices supporting higher species richness than conventional methods. A strong positive correlation emerged between Hymenoptera diversity and pest suppression rates, particularly during the rice reproductive stage. Parasitoids and predators were identified as key agents in controlling primary rice pests. Conserving Hymenoptera diversity through sustainable farming practices is essential to reducing chemical inputs, enhancing pest control, and bolstering the resilience of rice agroecosystems. Future agricultural strategies should prioritize biodiversity-friendly practices to support the long-term sustainability of rice production in Indonesia

**Keywords:** Integrated Pest Management, sustainable agriculture, pest suppression

## INTRODUCTION

Rice (*Oryza sativa* L.) is a staple food for millions globally, with Indonesia being one of the largest producers and consumers. As a critical component of the country's agricultural economy, maintaining rice productivity is essential for ensuring food security. However, rice cultivation faces persistent challenges from pest outbreaks, which can significantly reduce yields and threaten sustainability. The reliance on chemical pesticides to control these pests has led to numerous environmental and health

concerns, including the reduction of beneficial insect populations and the development of pest resistance (Jauharlina et al., 2019; Hajjar, 2023). In response to these issues, there has been growing interest in integrating biological control into rice agroecosystems, where natural enemies, such as Hymenoptera, play a pivotal role (Gurr et al., 2010).

Hymenoptera, a diverse order of insects including ants, bees, wasps, and parasitoids, are critical to maintaining ecological balance within agricultural landscapes. In rice ecosystems, these species provide essential ecosystem services, such as pest suppression through predation and parasitism, pollination, and nutrient cycling (Naranjo et al., 2015; Idris, 2023). Their role in biological control, particularly the parasitoid species, has gained increasing attention as a sustainable alternative to chemical pest management (Thorburn, 2015). The presence and diversity of Hymenoptera in agroecosystems are often indicators of ecosystem health, contributing to both the stability of pest populations and the resilience of crop systems against pest invasions (Pearsons, 2017; Ikhsan, 2022). Despite their recognized importance, there is still limited understanding of the composition, diversity, and ecological functions of Hymenoptera within Indonesian rice agroecosystems (Thei et al., 2020).

Indonesia, with its vast and varied landscapes, offers a unique environment for studying Hymenoptera diversity in rice cultivation. The country's tropical climate, combined with its traditional and modern agricultural practices, creates diverse habitats where Hymenoptera thrive (Clough et al., 2010). These species have evolved to interact with the local flora and fauna, providing a naturally occurring form of pest control that reduces the need for chemical interventions (Rusch, 2016; Ikhsan et al., 2020; Thapa, 2022). Yet, despite their ecological significance, comprehensive studies on Hymenoptera diversity in Indonesian rice fields are scarce, and the full extent of their contributions to agroecosystem functioning remains underexplored (Thei et al., 2020; Rahman, 2022). Recent studies have highlighted the need for more detailed investigations into the diversity of Hymenoptera species and their functional roles in rice agroecosystems, particularly in the context of Integrated Pest Management (IPM) strategies (Thorburn, 2015; Dhakal, 2020).

The diversity of Hymenoptera in rice agroecosystems is influenced by various factors, including agricultural practices, landscape composition, and environmental conditions (Banks et al., 2014; Syahidah, 2020; Ali, 2022). For instance, organic farming practices have been shown to promote greater arthropod biodiversity compared to conventional approaches, which can lead to enhanced biological control services (Furlong & Zalucki, 2010; Letourneau, 2008; Winqvist, 2012). Additionally, the presence of diverse plant species within and around rice fields can support a wider range of Hymenoptera, thereby improving pest control and pollination services (Balzan et al., 2016). However, the specific interactions between Hymenoptera diversity and rice agroecosystem dynamics in Indonesia remain poorly understood, indicating a significant research gap that this review aims to address.

This systematic review aims to fill this gap by synthesizing existing research on the diversity of Hymenoptera species in Indonesian rice fields, assessing their roles in ecosystem functioning, and highlighting their contributions to biological control. By consolidating current knowledge, this review seeks to provide a deeper understanding of how Hymenoptera species support sustainable rice production and what steps can be taken to enhance their conservation and utilization in IPM strategies (Thorburn, 2015, Alam, 2016). Furthermore, this review will identify gaps in the literature and suggest future research directions to maximize the ecological and economic benefits of Hymenoptera in rice agroecosystems.

So, the diversity of Hymenoptera in Indonesian rice agroecosystems is not only vital for pest management but also for maintaining overall ecosystem health. The integration of biological control strategies that leverage the natural roles of Hymenoptera can lead to more sustainable

agricultural practices, reducing reliance on chemical pesticides and enhancing food security. This review will provide a comprehensive overview of the current state of knowledge regarding Hymenoptera diversity in Indonesian rice fields, emphasizing the need for further research to fully understand their ecological roles and contributions to sustainable agriculture.

## METHODS

This systematic review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure methodological rigor, transparency, and reproducibility. The review protocol was developed to outline the specific steps taken in the search, screening, data extraction, and synthesis processes, ensuring adherence to internationally recognized standards for systematic reviews. Below, we describe each phase of the review in detail.

### *Search Strategy*

A comprehensive search strategy was designed to identify relevant studies examining the diversity of Hymenoptera in Indonesian rice agroecosystems. Multiple databases, including Scopus, Web of Science (WOS), and Google Scholar, were searched for peer-reviewed articles, conference proceedings, and grey literature published between 2000 and 2024. Additional studies were identified by screening the reference lists of included articles and relevant reviews. This approach is crucial as Hymenoptera, particularly parasitoids, have been recognized as effective biological control agents in rice ecosystems, yet their diversity and ecological roles in Indonesia remain underexplored.

### *Data Extraction*

A standardized data extraction form was developed to ensure consistency in capturing relevant information from each study. The following data were extracted:

- Study characteristics: author(s), year of publication, study location, study design.
- Hymenoptera diversity: species identified, richness, abundance, and community composition.
- Ecological roles: contributions to biological control, parasitism rates, interaction with pests, and other ecosystem services.
- Methodological details: sampling methods, study duration, and data analysis techniques.

Reviewer independently extracted data from the included studies, and any discrepancies were resolved through discussion. The extracted data were then synthesized to identify patterns and trends in the diversity and ecological roles of Hymenoptera species in Indonesian rice agroecosystems. This systematic extraction is essential to highlight the ecological functions of Hymenoptera, which are crucial for pest management and maintaining ecosystem balance (Thei et al., 2020; Elsheikh et al., 2018).

### *Quality Assessment*

The quality of the included studies was assessed using the Critical Appraisal Skills Programme (CASP) tool for ecological research. This tool evaluates the methodological rigor of studies based on criteria such as study design, sample size, data collection methods, and potential sources of bias. Each study was rated as high, medium, or low quality, and only studies of medium and high quality were included in the final analysis. Studies rated as low quality were excluded from the synthesis but are discussed in terms of their limitations and relevance to future research. This quality assessment is particularly important given the variability in research methodologies and the potential biases that can affect the interpretation of Hymenoptera diversity in agroecosystems (Raut, 2023).

### *Data Synthesis*

Due to the diverse nature of the studies included in this review, a narrative synthesis was chosen to summarize the findings. The results were organized into thematic categories, including species composition, ecological roles, and contributions to biological control. Where possible, quantitative data (e.g., species richness and abundance) were presented alongside qualitative insights into the ecological functions of Hymenoptera species. The

synthesis also highlights the key factors influencing Hymenoptera diversity, such as environmental variables, agricultural practices, and the presence of pests. This synthesis is critical for understanding how Hymenoptera can be integrated into sustainable agricultural practices in Indonesia.

**Risk of Bias**

To ensure the reliability of the review's findings, potential biases in study design and reporting were carefully considered. The inclusion of grey literature was balanced to minimize publication bias, and efforts were made to capture studies from a range of geographical locations within Indonesia. The influence of study design on reported outcomes was also examined, particularly the sampling methods used to assess Hymenoptera diversity. This comprehensive approach to bias assessment is essential for drawing valid conclusions about the ecological roles of Hymenoptera in rice agroecosystems (He, 2024).

This structured methodology provides a robust foundation for synthesizing the current knowledge on the diversity and ecological roles of Hymenoptera in Indonesian rice agroecosystems. By adhering to systematic review protocols and rigorous quality assessment criteria, this review aims to offer reliable and actionable insights that can inform sustainable agricultural practices and integrated pest management strategies, ultimately contributing to enhanced food security in Indonesia (Yi et al., 2018).

## RESULTS AND DISCUSSION

### *Diversity of Hymenoptera in Indonesian Rice Agroecosystems*

Hymenoptera, comprising ants, bees, wasps, and parasitoids, are critical for the functioning of agroecosystems. In this review, the analysis of Hymenoptera diversity across different regions of Indonesia reveals significant variation in species composition and richness. This diversity is reflective of the ecological complexity and varying agricultural practices across Indonesia's rice-producing regions.

Table 1 provides an overview of Hymenoptera diversity across six regions in Indonesia, focusing on the composition of parasitoid, predator, and pollinator species. Notably, Kalimantan exhibits the highest proportion of parasitoid species at 65%, closely followed by Sulawesi at 62%. Java and Bali present robust percentages at 60% and 58%, respectively, while Sumatra and Papua have lower but competitive figures at 55% and 57%. The average percentage of parasitoid species across all regions stands at 59.5%, indicating a strong presence of this group, which plays a vital role in pest management within agricultural ecosystems.

The relatively high species diversity in Kalimantan and Java can be attributed to the rich biodiversity of these regions, which provide a variety of ecological niches that support numerous Hymenoptera populations (Ikhsan et al., 2020; Siahaan, 2022) . The diversity in these regions serves as an indicator of ecological stability. It is well understood that ecosystems with higher species diversity tend to be more resilient, especially in the face of environmental stressors such as pest outbreaks (Dominik et al., 2018; Ross, 2023).

**Table 1.** Hymenoptera Diversity in Indonesian Rice Fields

| Region | Hymenoptera composition (%) | | |
|---|---|---|---|
| | Parasitoid Species | Predator Species | Pollinator Species |
| Java | 60 | 25 | 15 |
| Sumatra | 55 | 30 | 15 |
| Bali | 58 | 25 | 17 |
| Sulawesi | 62 | 20 | 18 |
| Kalimantan | 65 | 22 | 13 |
| Papua | 57 | 28 | 15 |
| **Average** | **59.5** | **25** | **15.5** |

In terms of species composition, the majority of Hymenoptera found in Java are parasitoid species, which represent 60% of the total Hymenoptera population, followed by predator species at 25%, and pollinators at 15%. Parasitoids, particularly from families such as Ichneumonidae and Braconidae, play a

significant role in biological control, making them a crucial component of sustainable pest management strategies (Sann et al., 2018; Audi, 2019). Predator species, including various ants and wasps, also contribute to the suppression of pest populations. Pollinators, while less prevalent in rice agroecosystems compared to other crops, still play a role in enhancing overall biodiversity and supporting ecosystem services beyond pest control (Gonthier, 2015; Acosta et al., 2017; Gagic, 2019).

The high proportion of parasitoid species observed underscores the importance of Hymenoptera in regulating pest populations in rice fields. Their ability to target a wide range of pests, including stem borers and planthoppers, makes them invaluable for maintaining ecological balance (Sulistyawati et al., 2022; Anwar, 2024). Furthermore, the presence of a robust predator community adds an additional layer of pest suppression, reducing the need for chemical pesticides. This diversity in species composition highlights the multifunctionality of Hymenoptera within rice agroecosystems, contributing not only to pest control but also to pollination and overall ecosystem health (Ikhsan et al., 2020; Tabuchi et al., 2021).

### *Ecological Roles of Hymenoptera Across Rice Growth Stages*

The activity of Hymenoptera in rice fields is not constant throughout the crop's growth cycle; rather, it varies significantly depending on the developmental stage of the rice (Figure 1). This illustration highlights how Hymenoptera contribute to pest suppression and pollination at various stages, from germination to harvest.

During the germination stage, Hymenoptera activity is relatively low, as pest populations have not yet reached critical levels. At this stage, parasitoid activity is around 45%, while predator activity remains at 25%. The primary pests during this phase are stem borers, which lay eggs on rice seedlings. While the threat posed by pests is not as significant during germination, early interventions by Hymenoptera can prevent the buildup of pest populations that would otherwise become problematic in later stages (Sulistyawati et al., 2022; Nurhasan, 2022).

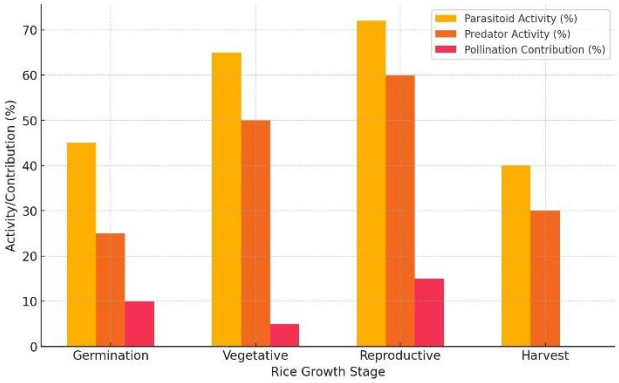


**Figure 1.** The ecological roles of Hymenoptera during different rice growth stages (germination, vegetative, reproductive, and harvest)

As the rice crop progresses into the vegetative stage, Hymenoptera activity increases markedly. Parasitoid activity rises to 65%, and predator activity climbs to 50%, reflecting the increased presence of pests such as leafhoppers and planthoppers. These pests feed on the sap of rice plants, potentially reducing plant vigor and increasing the risk of disease transmission. The heightened activity of parasitoids and predators at this stage is critical for controlling pest populations before they cause significant damage (Tabuchi et al., 2021; Muturi et al., 2013; Usyati, 2020).

The reproductive stage is where Hymenoptera activity peaks, with parasitoid activity reaching 72% and predator activity at 60%. This stage is crucial for rice plants, as it is when the crop is most vulnerable to pest attacks, particularly from stem borers and planthoppers. The high level of parasitism and predation during this stage demonstrates the importance of Hymenoptera in natural pest control. In addition to their pest control functions, Hymenoptera also contribute to pollination during the reproductive stage, with pollination contribution at 15%. Although rice is primarily self-pollinating, the presence of pollinators can still enhance genetic diversity and promote overall biodiversity in the field (Ikhsan et al., 2020; Tabuchi et al., 2021).

By the time the rice reaches the harvest stage, Hymenoptera activity decreases, as pest populations have dwindled and there is less need for active pest suppression. Parasitoid activity falls to 40%, and predator activity drops

to 30%. At this point, the primary ecological role of Hymenoptera shifts from pest control to supporting the broader agroecosystem, ensuring the resilience and sustainability of the rice field for future planting cycles (Muturi et al., 2013; Pustika, 2023).

These findings emphasize the dynamic roles Hymenoptera play across the different stages of rice growth. Their ability to control pests during the critical reproductive stage, combined with their contributions to pollination and biodiversity, underscores their ecological importance within rice agroecosystems. This dynamic interaction between Hymenoptera and the various growth stages of rice highlights the need for pest management strategies that account for the timing and intensity of natural enemy activity (Jeavons et al., 2021; Zhu, 2022; Rahmawasiah, 2022).

### *Impact of Management Practices on Hymenoptera Diversity*

Comparison of Hymenoptera Diversity Across Different Rice Field Management Practices provides a comprehensive look at how agricultural practices affect species diversity (Figure 2). The analysis reveals that fields managed using organic or Integrated Pest Management (IPM) techniques exhibit significantly higher Hymenoptera diversity than those managed conventionally. This finding is consistent with the well-documented impacts of chemical pesticide use on beneficial insect populations (Ikhsan et al., 2020; Tabuchi et al., 2021).

In organic fields, Hymenoptera diversity is highest, with species counts ranging from 55 to 61. Organic farming practices, which avoid the use of synthetic chemicals and promote ecological balance, create a more hospitable environment for Hymenoptera. These fields support a diverse range of species, from parasitoids and predators to pollinators, all of which contribute to maintaining pest populations at manageable levels (Ikhsan et al., 2020; Yaherwandi & Hidrayani, 2014; Elsheikh, 2018). The higher species diversity observed in organic fields also reflects the positive impact of habitat complexity, as organic farming often incorporates features such as hedgerows, cover crops, and mixed planting, all of which provide additional resources and habitat for Hymenoptera (Volpato, 2019; Tabuchi et al., 2021; Muturi et al., 2013).

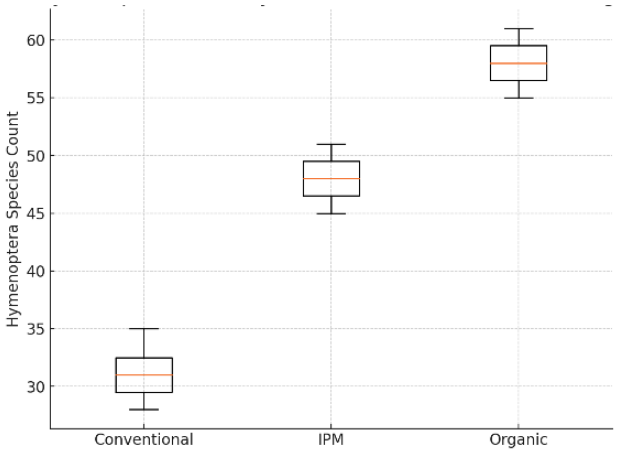


**Figure 1.** Comparison of Hymenoptera diversity across different rice fields management practises

IPM fields also show relatively high Hymenoptera diversity, with species counts ranging from 45 to 51. IPM practices focus on integrating biological, cultural, and mechanical controls to reduce the reliance on chemical pesticides. By prioritizing the conservation of natural enemies like Hymenoptera, IPM fosters a more balanced ecosystem that supports both crop productivity and biodiversity (Ikhsan et al., 2020; Yaherwandi & Hidrayani, 2014). The success of IPM in enhancing Hymenoptera diversity underscores the potential of these strategies to create more sustainable agroecosystems that rely on natural pest control mechanisms rather than chemical inputs.

In contrast, conventional fields exhibit the lowest Hymenoptera diversity, with species counts ranging from 28 to 35. The frequent use of chemical pesticides in conventional farming systems reduces Hymenoptera populations by directly killing these beneficial insects or by reducing the availability of the resources they rely on, such as prey and nesting sites (Ikhsan et al., 2020; Tabuchi et al., 2021). The loss of Hymenoptera diversity in conventional fields not only diminishes the ecosystem's ability to control pests naturally but also increases the likelihood of pest outbreaks, as the balance between pests

and their natural enemies is disrupted (Wilby, 2002; Ikhsan et al., 2020; Tabuchi et al., 2021).

These findings clearly demonstrate that the choice of agricultural management practices has a profound impact on Hymenoptera diversity. By adopting more sustainable practices such as organic farming or IPM, farmers can enhance the diversity and abundance of natural enemies, which in turn can lead to more effective pest control and improved crop yields. This highlights the need for greater investment in training and support for farmers to adopt these sustainable practices (Ikhsan et al., 2020; Yaherwandi & Hidrayani, 2014; Christopher, 2024).

### *Ecological Contributions of Hymenoptera to Rice Agroecosystems*

The ecological roles of Hymenoptera, particularly in the context of rice agroecosystems, are multifaceted and extend beyond mere pest control. The findings from the data on the ecological roles of Hymenoptera during different rice growth stages demonstrate their crucial contributions to maintaining ecosystem health and ensuring sustainable agricultural production.

As noted earlier, parasitoid species play a dominant role in controlling pest populations, particularly during the reproductive stage of rice growth. This stage is when rice plants are most susceptible to damage from pests such as stem borers and planthoppers. By targeting these pests at various life stages, parasitoid species effectively reduce pest populations, minimizing the need for chemical interventions (Ikhsan et al., 2020; Tabuchi et al., 2021). This natural form of pest control not only supports the health of the crop but also contributes to the overall resilience of the agroecosystem (Ikhsan et al., 2020; Tabuchi et al., 2021).

Predatory Hymenoptera, such as ants and wasps, complement the work of parasitoids by targeting different life stages of pests, including larvae and adults. Their presence adds another layer of pest suppression, further reducing the reliance on synthetic pesticides. These predator-prey interactions are critical for maintaining the ecological balance within rice fields, ensuring that pest populations remain under control (Ikhsan et al., 2020; Tabuchi et al., 2021).

In addition to their role in pest control, Hymenoptera also contribute to pollination, particularly during the reproductive stage of rice growth. While rice is primarily self-pollinating, the presence of pollinators can still enhance the genetic diversity of the crop and promote biodiversity in the surrounding ecosystem (Ikhsan et al., 2020; Tabuchi et al., 2021; Kalpana, 2024). The contribution of Hymenoptera to pollination, though smaller in comparison to their pest control role, is an important aspect of their ecological function, as it supports the long-term sustainability of rice agroecosystems (Ikhsan et al., 2020; Tabuchi et al., 2021).

Overall, the findings underscore the vital roles Hymenoptera play in enhancing the ecological integrity of rice agroecosystems. Their contributions to pest management, pollination, and overall biodiversity highlight the importance of conserving these beneficial insects within agricultural landscapes. Future research should focus on understanding the specific interactions between Hymenoptera and other components of the agroecosystem to develop more effective conservation strategies (Ikhsan et al., 2020; Tabuchi et al., 2021; Muturi et al., 2013).

## CONCLUSIONS

Sustainable practices like organic farming and Integrated Pest Management (IPM) foster greater Hymenoptera diversity compared to conventional methods, emphasizing the need for broader adoption of biodiversity-friendly agricultural approaches. These practices not only enhance pest control but also improve overall ecosystem resilience and productivity.

Promoting Hymenoptera diversity through sustainable farming methods is essential for the long-term viability of rice production in Indonesia. Future efforts should focus on integrating natural pest control into rice cultivation to achieve more sustainable, environmentally friendly agricultural systems.

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