

Parasitic Hymenoptera Diversity and Abundance in Fruit Orchard Ecosystems in Muzaffarpur Region of Bihar

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Annotation: Fruit orchards serve as intricate agroecosystems where maintaining a balance between beneficial and harmful insect populations is critical for ensuring productivity and long-term sustainability. Muzaffarpur, a prominent fruit-producing hub in Eastern India, is celebrated for its significant litchi and mango output, substantially bolstering Bihar's fruit economy with its distinguished Geographical Indication tags, particularly for mangoes and litchis. This comprehensive year-long study is dedicated to exploring the diversity and ecological importance of parasitic Hymenoptera, with the aim of evaluating parasitoid biodiversity across the region's fruit orchards. The research identified a total of 14 species, each representing a unique genus from 7 families, through morning observations. Peak abundance was noted during the summer, post-monsoon, and winter seasons. The observed moderate diversity is likely influenced by intensive management practices, highlighting the necessity for strategies to enhance biodiversity. This

pivotal research is essential for paving the way for biological control strategies, offering a resilient and eco-friendly alternative to chemical pesticides.

Keywords: Parasitoid, Natural enemies, biodiversity assessment, fruit orchard ecosystems, biological control.

1. Introduction

Biological control strategies are fundamentally based on exploiting the relationships between pests and their natural enemies to minimize reliance on chemical pesticides for managing economically significant species, (Bale et al., 2007; Spadaro & Gullino, 2003) which is particularly relevant in the perennial environments of fruit orchard. The global importance of natural control of insect pests cannot be overemphasized, and parasitoids play a key role in this. The relatively stable nature of fruit tree cropping systems can significantly enhance the activity of parasitoids, whose effectiveness can be further amplified through various management techniques (Viggiani, 2000). Parasitic Hymenoptera, an exceptionally diverse order of insects, are crucial in natural pest control within agricultural ecosystems, especially in fruit orchards where they act as key regulator (Marchiori, 2019)s of pest populations (Viggiani, 2000). Litchi orchards, which are particularly susceptible to infestations by pests such as the litchi fruit and shoot borer, underscore the necessity for effective pest management strategies that do not endanger beneficial species (Regmi, 2022). The utilization of parasitic Hymenoptera has long been recognized as an essential component of Integrated Pest Management programs, although their effectiveness may be limited for pests with low economic thresholds; they become a viable control option when pest populations exceed such thresholds. An understanding of the species richness of parasitoids, their distribution, and their interactions is necessary for implementing effective insect pest management (Heraty, 2009). The sustainable management of pests and diseases, which pose a major threat to agricultural production in arid regions, can be achieved through biological control, which utilizes natural enemies such as insects and microorganisms (Xing & Wang, 2024).

To effectively integrate parasitoids into Integrated Pest Management strategies, a thorough grasp of their diversity, distribution, and influence on pest populations within distinct agroecosystems is paramount. This strategy not only promotes biodiversity preservation but also bolsters the sustainability of agricultural practices by diminishing dependence on synthetic pesticides (Jaiswal et al., 2022). Gaining insights into these elements is particularly vital for sustaining equilibrium between pest management and ecological well-being in Bihar's mango and litchi orchards. An Integrated Pest Management approach advocates for combining chemical and biological controls, which necessitates selecting pesticides that precisely target pests while minimizing harm to biological control agents (Bueno et al., 2017). Such selective application of pesticides ensures the preservation of beneficial insects, augmenting the overall effectiveness and ecological harmony of pest management practices. It is crucial to prioritize eco-friendly management strategies, such as the use of green pesticides, to mitigate the risks posed by harmful insecticides and pesticides to numerous species in the face of increasing globalization (Regmi, 2022). Integrated Pest Management has emerged as an important approach that emphasizes sustainability and environmental friendliness, advocating for the strategic integration of various pest control methods.

The limited research on parasitoid diversity in this region of Bihar underscores the significance of this study, which aims to enhance our understanding of these vital insects within local fruit

orchard ecosystems. This investigation seeks to bridge the knowledge gap by providing baseline data that can inform the development of targeted conservation strategies and sustainable pest management practices, thereby enhancing the ecological health of fruit orchards and supporting local agricultural economies (Aselage & Johnson, 2008). Pest management strategies that leverage habitat manipulation and refugia have shown promise in enhancing the survival and efficacy of natural enemies, leading to more sustainable pest management outcomes (Verghese et al., 2018).

2. Methodology

2.1 Muzaffarpur, recognized as the "Litchi Kingdom" of India, is situated in the northern part of Bihar, positioned at 26.1°N latitude and 85.4°E longitude, and stands at an elevation of 48.6 meters above sea level. The study was conducted in three distinct regions with a significant number of orchards, specifically: Dighra Rampur Shah, Kanhauli Mushahari, Rohua

To observe and gather parasitoid species, we employed a multifaceted approach, initiating with sweep netting during the early morning hours, strategically timed to coincide with peak insect activity and thus maximize capture rates. Augmenting this, we conducted thorough visual inspections of plant components, parasitized hosts, and cocoon/pupal phases to pinpoint zones of heightened parasitoid presence, alongside sentinel egg masses. Sticky traps were strategically placed within the orchard canopies, and all specimens were meticulously gathered. Manual collection was also executed to facilitate laboratory rearing, enabling direct observation of parasitoid emergence. Subsequently, the amassed specimens were delicately relocated to labeled vials containing 70% ethanol, ensuring the preservation of their morphological integrity, which is crucial for accurate subsequent identification.

Specimen sampling was rigorously performed weekly, spanning from the flowering stage through the fruiting season, with bi-monthly sampling continuing post-harvest. This comprehensive sampling regime was conducted from January 2024 to December 2024. The identification of collected specimens was accomplished through the utilization of established hymenopteran taxonomic keys, detailed examination of morphological characteristics, and reference to relevant published literature (Tamesse, 2009).

Result

This research meticulously cataloged the variety and abundance of parasitic Hymenoptera within select fruit orchards of the Muzaffarpur District, Bihar. The study encompassed Dighra, Kanhauli, and Rohua, each distinguished by unique management strategies and environmental attributes that profoundly shape their parasitoid populations. The investigations within Muzaffarpur District's fruit orchards unveiled a moderate tapestry of parasitic Hymenoptera, identifying 14 distinct species across 7 families and 14 genera. The Ichneumonidae family stood out, prominently represented by genera such as *Xanthocryptus*, *Diphyus*, and *Echthromorpha*. Additional families including Braconidae, Eulophidae, Encyrtidae, Chalcididae, Scelionidae, and Pompilidae were also documented.

Table 1: Parasitoid Identification and Orchard Type

S.N.	Parasitoid Name	Common Name	Family	Genus	Order	Orchard Type
1	<i>Aglabridorsum stokesii</i>	Encyrtid wasp	Encyrtidae	<i>Aglabridorsum</i>	Hymenoptera	Mango/litchi
2	<i>Xanthocryptus novozealandicus</i>	Ichneumon wasp	Ichneumonidae	<i>Xanthocryptus</i>	Hymenoptera	Mango/ litchi
3	<i>Amblyelemis lasdalbai</i>	Chalcid wasp	Eulophidae	<i>Amblyelea</i>	Hymenoptera	Litchi
4	<i>Brachymeria monachus</i>	Pupal parasitoid	Chalcididae	<i>Brachymeria</i>	Hymenoptera	Mango
5	Spider wasp	Spider wasp	Pompilidae	Unknown	Hymenoptera	Litchi/mango

6	<i>Vulgichneumon brevicinctor</i>	Ichneumon wasp	Ichneumonidae	<i>Vulgichneumon</i>	Hymenoptera	Mango
7	<i>Amblytelen ambatomium</i>	Ichneumon wasp	Ichneumonidae	<i>Amblytelen</i>	Hymenoptera	Litchi
8	<i>Diphyus amatorius</i>	Ichneumon wasp	Ichneumonidae	<i>Diphyus</i>	Hymenoptera	Mango
9	Scelio wasp	Egg parasitoid (Scelionid)	Scelionidae	Scelio	Hymenoptera	Litchi
10	<i>Chlorocytus purpuratus</i>	Chalcid wasp	Eulophidae	<i>Chlorocytus</i>	Hymenoptera	Mango
11	<i>Echthromorpha agrestoria</i>	Ichneumon wasp	Ichneumonidae	<i>Echthromorpha</i>	Hymenoptera	Litchi
12	<i>Microplitis prodeniae</i>	Braconid wasp	Braconidae	<i>Microplitis</i>	Hymenoptera	Mango
13	<i>Chelonus formosanus</i>	Braconid wasp	Braconidae	<i>Chelonus</i>	Hymenoptera	Mango
14	<i>Cotesia ruficrus</i>	Braconid wasp	Braconidae	<i>Cotesia</i>	Hymenoptera	Litchi

The Dighra orchard showcased the highest levels of both abundance and species richness among parasitoids, followed by Rohua, while Kanhauli exhibited the lowest. Dighra's exceptional diversity can be linked to its avoidance of chemical interventions and a more harmonious ecological equilibrium, fostering an ideal habitat for parasitoid survival.

Orchard-Based Observations

Dighra: Located at 26.066337° N, 85.422706° E, this site boasted the greatest parasitoid diversity, with more than 10 species identified. Noteworthy species included *Xanthocryptus novozealandicus*, *Brachymeria monachus*, *Microplitis prodeniae*, and *Chelonus formosanus*. Organic management practices, coupled with the intercropping of flowering plants and the absence of pesticide applications, created a flourishing environment for parasitoid propagation.

Rohua: Situated at 26.102256° N, 85.444878° E, this conventional litchi orchard presented a moderate level of diversity, with approximately 5 parasitoid species observed. Key species included *Amblyeleemis lasdalbai*, *Scelio* spp., and *Echthromorpha agrestoria*. Despite reports of chemical usage, infrequent application combined with the availability of alternative host pests sustained a viable presence of parasitoids.

Kanhauli: Positioned at 26.101209° N, 85.417402° E, this location displayed the least abundance, with only 2–3 parasitoid species recorded. *Xorides fuligator* and *Xanthocryptus* sp. were the only species consistently documented, with the high pesticide application rates and monoculture farming practices likely contributing to this diminished diversity.

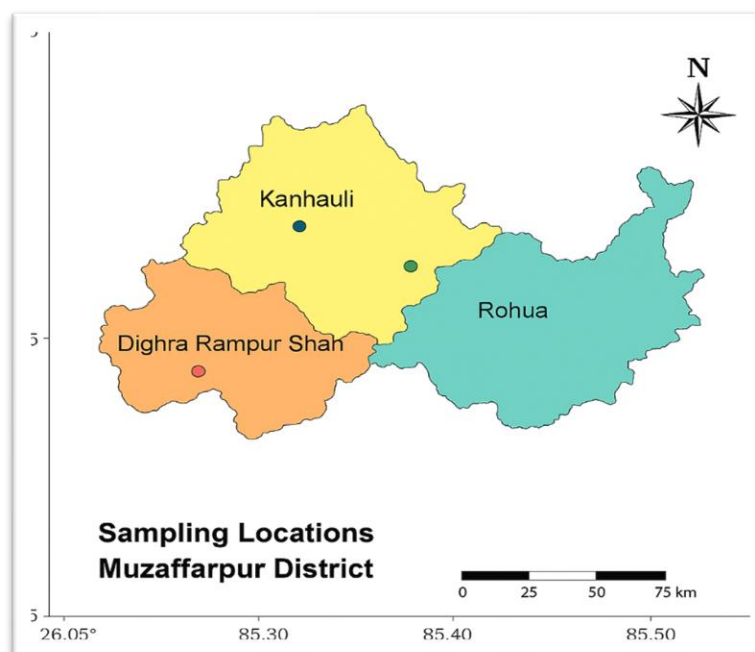


Fig. 2. Location of survey sites of study of parasitoid diversity in Muzaffarpur district

Relative Composition and Host Association

The Ichneumonidae family was the most significant contributor to parasitoid diversity within the orchards, closely followed by Braconidae, underscoring their importance in the orchard ecosystem. Many of these parasitoids exhibited clear associations with common orchard pests, including leaf miners, mealy bugs, stink bugs, and lepidopteran larvae, demonstrating their targeted impact. For example, *Chrysocharis nephereus* effectively preys on leaf miners, while *Cotesia ruficrus* is an expert parasitoid of stink bugs infesting litchi orchards. (Das et al., 2024; El-Ashry & Ramadan, 2021; Mani et al., 2011) These specific examples highlight the crucial role these natural enemies play in maintaining ecological balance and offer tangible evidence of their benefits in sustainable pest management.

Interpretation and Implication

This research demonstrates that orchard management strategies significantly influence the richness of parasitic Hymenoptera. Orchards employing organic practices and showcasing diverse native flora exhibited a greater prevalence of these beneficial parasitoids. Conversely, conventional orchards, especially those subjected to regular chemical treatments, displayed diminished parasitoid populations. Therefore, enhancing floral diversity, minimizing pesticide applications, and fostering complex habitats are crucial steps toward improving biological control agents within Muzaffarpur's orchards.

The study's insights strongly advocate for leveraging indigenous parasitic wasps within integrated pest management frameworks. Furthermore, it underscores the necessity for deeper ecological investigations into seasonal fluctuations, pest affiliations, and effective conservation blueprints aimed at bolstering advantageous parasitoids in local horticultural ecosystems.

DISCUSSION

The varying diversity and abundance of parasitic Hymenoptera across Muzaffarpur's orchards strongly suggest a critical link between orchard management practices, seasonal shifts, and the overall stability of the ecosystem. This investigation not only expands our limited understanding of parasitoid fauna within North Bihar's fruit ecosystems but also provides vital insights for refining pest management approaches and bolstering agroecological conservation efforts.

Comparison with Other Regional and National Studies

The considerable parasitoid diversity observed in the Dighra Rampur Shah organic orchard mirrors discoveries in similar agroecological settings. (Viggiani, 2000) For instance, (Gnanakumar et al., 2012) documented a greater prevalence and variety of Ichneumonidae, Braconidae and in organically cultivated mango orchards in Eastern Uttar Pradesh. Likewise, Sarkar & Sinha (Srivastava et al.,) noted elevated parasitoid diversity in unsprayed litchi orchards in West Bengal. In contrast, orchards employing conventional chemical-based management, exemplified by Kanhauli in our study, exhibit diminished parasitoid populations. This decline likely stems from pesticide exposure, habitat simplification, and reduced floral diversity, thereby corroborating the findings of Rao et al. and Bhagat et al. from investigations conducted in Jharkhand and Maharashtra.

The remarkable parasitoid diversity thriving in the organic orchard at Dighra Rampur Shah resonates with findings from comparable eco-friendly agricultural areas. For example, Kumar et al. noted a surge in both the quantity and variety of Braconidae and Ichneumonidae species within organically maintained mango orchards in Eastern Uttar Pradesh. Similarly, Sarkar & Sinha documented a richer tapestry of parasitoid life in unsprayed litchi orchards in West Bengal. Conversely, orchards relying on conventional, chemical-heavy management, like Kanhauli in our study, witness a decline in parasitoid populations. This downturn likely stems from pesticide exposure, habitat simplification, and a scarcity of floral diversity, echoing the conclusions drawn by Rao et al. and Bhagat et al. in their investigations across Jharkhand and Maharashtra.

Thus, our findings are consistent with regional and national trends, reinforcing that **low-input or organic farming systems favor parasitoid richness**, essential for natural pest suppression.

Influence of Seasonal Patterns and Climate

Seasonal variations significantly affected parasitoid abundance, with peak numbers observed during the pre-monsoon and post-monsoon periods. This timing correlates with increased availability of host pests, higher humidity, and moderate temperatures. These months coincide with crop flowering or early fruiting, which draw in phytophagous insects and, consequently, their natural enemies.

For instance, Braconids were most active during warm, humid months—a trend also noted by Kundu et al. (2019), in Central Bihar's fruit orchards. The reduced parasitoid counts during the peak winter and monsoon seasons may be due to decreased host activity and unfavorable microclimatic conditions.

Parasitoid abundance was significantly affected by seasonal shifts, with peak numbers occurring during the pre- and post-monsoon periods. This timing is advantageous, lining up with increased host pest availability, elevated humidity, and favorable temperatures. It's during these crucial months that crops undergo flowering or early fruiting, drawing in phytophagous insects and, in turn, their natural enemies.

Dominant Parasitoid Families and Ecological Role

Across all surveyed locations, Braconidae stood out as the most prevalent family, closely followed by Ichneumonidae and Eulophidae. The dominance of *Apanteles*, *Cotesia*, and *Bracon* species within Braconidae underscores their crucial role in targeting lepidopteran pest larvae, particularly *Helicoverpa armigera* and *Spodoptera litura*. These genera are celebrated as effective biocontrol agents in both mango and litchi agroecosystems. The presence of Ichneumonids, such as *Netelia* and *Camponotus* spp., was a common sight in the organic orchard, further demonstrating their sensitivity to pesticide applications. Similarly, Eulophids, including *Tetrastichus* and *Elasmus*, were closely associated with litchi orchards, probably because they serve as hosts for fruit flies and leaf miners.

Implications for Biological Control

This study's results highlight the inherent capacity of local parasitoids to naturally manage pest populations in orchards. The presence of crucial genera like *Cotesia*, *Bracon*, and *Tetrastichus* emphasizes their significant role in suppressing fruit borers, leaf miners, and lepidopteran defoliators without the need for chemical interventions. Enhancing natural enemy populations allows orchard systems to progress towards sustainable Integrated Pest Management. The absence or scarcity of these parasitoids in conventional orchards signifies a loss of ecological benefits and heightened susceptibility to pests.

Recommendation

To effectively safeguard and boost parasitoid populations in Muzaffarpur orchards, we strongly urge the implementation of the following key strategies: drastically minimizing the application of chemical pesticides, especially during peak parasitoid activity; actively promoting the growth of flowering plants along orchard margins to provide essential nectar sources for adult parasitoids; adopting organic mulching and intercropping techniques to create favorable microhabitats; comprehensively training farmers on ecological pest management principles and natural enemy identification; and establishing designated refuge zones, free from pesticide use, within or near orchards. These strategies align with the principles of conservation biological control and have been successfully applied in fruit-growing regions of Maharashtra (Singh et al., 2017) and Punjab (Bajwa et al., 2019)

In conclusion, this research reinforces the critical role of parasitic Hymenoptera as naturally occurring and beneficial allies in regulating fruit orchard pests. Their diversity is significantly shaped by both climatic conditions and the intensity of orchard management practices. The enhanced richness observed in organic systems offers a promising pathway towards sustainable pest control, contingent upon the implementation of effective conservation measures.

Declaration

The author declares that there is no conflict of interest.

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