Volume 28 (3) September 2025

ISSN 0975-1963

Insect Environment

Quarterly Journal

Not-for-profit journal promoting
Insect Science

Articles with DOI

NAAS Rating 3.53

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An *AtmaNirbhar* initiative by Indian entomologists for promoting Insect Science

Published by
Abraham Verghese Insect And Nature Trust (AVIAN Trust), Bengaluru, India

Supported by
International Phytosanitary Research & Services (IPRS), Bengaluru
Shree Nidhi Agrochemicals, Vijayapura, Devanahalli
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***Cover Page:**
***Dysdercus* sp.**
Photo by Dr. M. A. Rashmi

Insect Environment
(Quarterly journal to popularize insect study and conservation) ISSN 0975-1963
NAAS Rating 3.53

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Editorial

Insects, Climate Upheavals, and the Pulse of Insect Environment

This quarter has witnessed several cataclysmic weather events across northern India—Dharali (Uttarakhand), Eastern Kishtwar (Kashmir), and several other regions were shaken by cloudbursts, flash floods, and landslides. Orchards, homes, and entire landscapes were swept away, along with wild flora, fauna, and perhaps thousands of unnamed insect species—silent casualties of a rapidly shifting climate.

Climate change? Nay—it's climate upheaval.

From June onwards, southern Europe on the other hand had simmered under unusually high temperatures. Insects, ever adaptive, have probably responded with predictable migrations. These movements, shifts in fecundity and dietary patterns often go unstudied, unnoticed, and undocumented; yet they hold vital clues to ecosystem resilience, if noticed.

Still, Europe remained pleasant through September. In cities like London, Yorkshire, Paris, Brussels, Madrid, Valencia, and Lisbon, the sun shone brightly, allowing for lighter attire, less of thermals, mufflers, and pullovers. It was heartening to see bees and butterflies flitting about, moths drawn to streetlights, and the eerie chirps of crickets in the outskirts where I often find modest, economic stays. But winter looms, and with it, insects retreat to 'tropical' zones, leaving behind a quieter, duller landscape with diminished natural insect life.

IE Blogs: A Buzzing Success

IE blogs are evolving into superhits not just among entomologists, but also farmers, specialists, and curious amateurs. International agencies have praised our crisp, lucid, and fluent insect alerts and alarms. In a world lacking fast disseminating insect stories for professionals, IE has carved out a vital niche-topical, relevant, and timely.

I always say: IE is powered by our distinguished insect authors. They are not swayed by personal promotions, but willingly venture into the wild to document insect natural history and field studies. This spirit breathes life into our journal.

A glance at some articles in this issue confirms this dedication:

- *Empowering Farmers Through Biopesticide Awareness: Strengthening Ecosystem Health for Sustainable Farming*
- *The Silent Siege: Understanding Date Palm Vulnerability to Red Palm Weevil Infestation*
- *Post-Harvest Susceptibility of Pearl Millet Hybrids to the Red Flour Beetle, Tribolium castaneum (Herbst, 1797)*
- *Morphometric Characterization of Tetragonula iridipennis Smith (Hymenoptera: Apidae) from Diverse Nesting Habitats in Karnataka, India*

The editorial dynamic team, as industrious as ever, is led by Dr. M.A. Rashmi, ably supported by Dr. S. Deepak, Salome, Prathika, and others. I commend them all for their tireless efforts and unwavering commitment to insect education and outreach.

Abraham Verghese
Editor-In-Chief
Insect Environment

Research Articles

DOI: 10.55278/CELY4069

The Silent Siege: Understanding date palm vulnerability to red palm weevil infestation

Hamadttu Abdel Farag El-Shafie[1*] and Jose Romeno Faleiro[2]
[1]*International Center for Agricultural Research in the Dry Areas (ICARDA), Dubai, UAE*
[2]*Arlem-Raia, Salcette, Goa, India*
****Corresponding author:*** **h.elshafie@cgiar.org**

Abstract

Following the widespread invasion of the red palm weevil (RPW) across the Middle East and North Africa, initial infestations in date palms were predominantly observed on the lower trunk and basal offshoots. However, recent field observations in Saudi Arabia indicate a rise in apical infestations, which are harder to detect due to limited access to the palm canopy, especially in taller palms. These apical infestations pose a greater threat as they can serve as sources for adult weevils that spread to neighbouring healthy palms. In addition to these two types of infestation, RPW can infest the trunk just below the crown where aerial offshoots are attached. Consequently, three main types of RPW infestations on date palms are observed: lower trunk, apical, and below-crown infestations. The study investigates the role of both basal and aerial offshoots in the development of RPW injuries as well as the measures to be undertaken to mitigate the impact of such infestations.

Keywords: offshoots, apical infestation, date palm, red palm weevil, management

Introduction

The red palm weevil (RPW) *Rhynchophorus ferrugineus* (Olivier) originally from Southeast Asia, has invaded many countries in the world, where date palm is cultivated, during the last four decades causing economic damage and negatively affecting the livelihood of rural communities and the environment (Faleiro & El-Shafie, 2024). There are several reasons that contribute to the aggressiveness of RPW in date palm, the most important being the method of flood irrigation which increases in-grove humidity, wounds created on date palm trunk through cultural practices of pruning, cutting of fruit bunch stalks, and detachment of young offshoots from the mother palm without proper treatment of the resulting injuries on the mother palm (Sallam *et al.,* 2012). During the years following RPW invasion in the Middle East and North Africa, most infestation were reported on the trunk usually a metre from the ground and on the basal offshoots (Faleiro, 2006). However, in recent years, apical infestations have been reported in different regions of Saudi Arabia. These apical infestations are even more difficult to detect because inspectors, in most cases, have no access to the palms canopy, particularly in tall palms. This type of infestation aggravates the problem of RPW by acting as foci for releasing adult weevils that initiate new infestation on neighbouring healthy palms (El-Shafie *et al.,* 2024; Nasraoui *et al*., 2024). RPW infestation cam also occur on the trunk just below the crown in the sites where aerial offshoots are attached to the parent palm. Thus, we can categorize three main types of RPW infestations on date palm namely, lower trunk, apical, and below-crown infestations (Fig. 1).

Fig. 1. Sites of red palm weevil infestation on date palm trunk, ground infestation on one meter from the ground (left), below-crown infestation (middle), and apical infestation at the top of the crown

Basal and aerial offshoots on the date palm trunk represent the main points of RPW entry in the trunk for initiation of infestation and they are considered the Achilles heel or weaknesses of date palms in relation to the threat posed by the red palm weevil. This article emphasizes the importance of addressing these vulnerabilities for effective pest management.

Date palm offshoots

The date palm offshoots (pups, offset, suckers, palm clump) arise from the auxiliary buds between the leaf base and the trunk. They develop during the juvenile vegetative phase of the palm (10-15 years old) and these young palms are true-to-type of the mother tree. The offshoot takes about 7 years from the initiation of the auxiliary bud until ready for detachment from the mother. Growers can sell offshoots to generate additional income during the vegetative phase of the date palm before the palm yields dates. The term seedlings is used to describe offshoots produced from seeds which are not true to type to mother. Additionally, seedlings have roots all around their base with no connecting point to the palm, while an offshoot does not have any roots on the side where it was connected to the mother plant (Nixon & Carpenter, 1978). The date palm offshoots are called either basal (ground) or aerial based on their position on the trunk. Demand for offshoots is high and, depending on the variety, they can cost as much as US$100 to $300 each (Hodel & Pittenger, 2003).

The role date palm offshoots in the infestation by RPW

The detachment of offshoots from the mother palm is typically performed using a sledgehammer and a broad-bladed chisel, which is driven between the offshoot and the trunk to sever their connection (Hodel & Pittenger, 2003). Improper removal of aerial offshoots without subsequent treatment of the exposed tissue is a major contributor to infestations occurring just below the crown, where these offshoots are attached.

Field investigations have revealed that in some plantations, up to 85% of red palm weevil (*Rhynchophorus ferrugineus*) infestations are concentrated in this below-crown region. This vulnerability is largely attributed to routine farm practices, where aerial offshoots are removed without sealing or treating the resulting wounds. These untreated injuries release volatile organic compounds (kairomones), which act as attractants for red palm weevils, facilitating colonization and oviposition (Fig. 2).

Usually, the date palm offshoot is separated from the mother palm after 3 to 5 years depending on the date palm cultivar (Nixon, 1966; Nixon & Carpenter, 1978) and during this period the date palm remains susceptible to infestation by RPW because the point of attachment between the offshoot and the trunk of the mother palm is the weakest point for oviposition and development of newly hatched larvae. In some countries, where date palm is produced, offshoots are left to continue growing outwards from the original mother palm, producing large clumps consisting of many offshoots, none of which produces a trunk and of course with no significant yield (Dowson, 1982).

Fig. 2. Development of below-crown RPW infestation: an aerial offshoot (left), pruning of the offshoot without proper treatment (middle), RPW infestation developed at the site of cut offshoot (right)

In young date palm the offshoots are at the base of palm and these offshoots are the primary sites for RPW infestation and external symptoms are characterized by the drying out of these offshoots (Fig. 3). The hearts of dead offshoots and young date palms can be easily pulled revealing the internal damage due to the larval activities.

Fig. 3. Initiation of RPW infestation at the junction between the offshoot and mother palm (left), mortality of the offshoot due to larval feeding on the inner meristematic tissues

Spread of RPW through infested offshoots

The RPW spread through infested date palm planting materials, particularly the offshoots. Trading of infested offshoots has tremendously increased the distribution and dispersal of RPW into new uninfested areas. Prohibition of offshoots trading is not a solution for the problem and negatively affects the income of farmers who are involved in commercialization of these offshoots. The offshoots as well as the mother palm are very susceptible to infestation by red palm weevil. When the offshoots are crowded around the mother palm, the visual inspection for RPW infestation becomes more difficult and this is one way that the offshoots harm the mother palm by hindering the inspection operations.

Date palm offshoots management for controlling RPW infestation

Globally, many growers rely heavily on offshoots for the propagation of date palms. Although the production of offshoots is a labor-intensive, costly, and time-consuming process, it remains the most reliable method for ensuring that new palms are true-to-type and genetically identical to the mother plant or desired cultivar.

However, red palm weevil (*Rhynchophorus ferrugineus*) infestations are closely associated with these offshoots, and the risk of inadvertently transferring the pest from infested to uninfested areas is high if proper phytosanitary precautions are not observed during the movement of planting material. Alarmingly, the optimal period for detaching and planting offshoots typically September to October coincides with peak weevil activity in several regions, further elevating the risk.

The offshoot industry has expanded significantly in recent years due to rising demand for elite cultivars. This propagation process involves a five-phase production value chain: (1) development of offshoots on the mother palm, (2) initiation of root systems on the suckers, (3) detachment from the parent palm, (4) transportation to planting sites, and (5) transplantation.

To ensure the production and distribution of high-quality, RPW-free offshoots, a comprehensive management program must be implemented. Below are recommended measures to mitigate infestation risks and enhance biosecurity during offshoot propagation and movement:

- Inspection and monitoring of developing offshoots while they are attached to the parent palm to detect any RPW infestation at an early stage of development.
- Selection of healthy offshoots that are at least 3-4 years old and have a good number of roots.
- Detachment of the offshoots should be carried by skilled workers to avoid damaging the mother palm.

- Smearing the site of detachment of offshoot from the mother palm with fungicides and effective contact insecticides help to prevent fungal infection and infestation by RPW.
- Inspection of both the mother palm and the offshoots for signs of RPW infestation before and after detachment to prevent the spread of the weevil.
- Prior to movement, detached offshoots must be dipped in recommended insecticides or treated with Eco2Fume as phytosanitary and quarantine measure to prevent the dispersal of the weevil through infested planting material
- Accreditation of certified nurseries, by the national authorities, as the sole suppliers of weevil-free offshoots for palm growers.
- Enforcements of quarantine regulations to ensure the movement of pest free offshoots from one place to another.

Conclusion

The red palm weevil (*Rhynchophorus ferrugineus*) is a highly adaptive invasive pest that has successfully expanded across a wide geographical range beyond its native habitat. Its adaptability is evident in its broad host range and its ability to exploit multiple entry points on date palms, including the crown region when the lower trunk becomes less accessible.

Historically, infestations in susceptible date palms (aged 5–20 years) were primarily restricted to the lower trunk, within the first meter above ground level. However, recent field observations indicate a shift toward apical infestations, targeting the crown and meristematic tissues—sites that are more difficult to monitor and manage. These apical infestations are particularly lethal, often leading to irreversible damage and rapid decline of the host palm.

Additionally, a third infestation type has emerged, occurring just below the crown in association with aerial offshoots. The presence of these three distinct colonization pathways—lower trunk, apical, and below-crown—underscore the strategic versatility of RPW in subduing its host.

This evolving infestation behavior necessitates a re-evaluation of current management practices. Integrated pest management strategies must be adapted to address these new vulnerabilities, emphasizing early detection, canopy-level surveillance, and targeted interventions to contain and control this destructive pest more effectively.

Acknowledgment

The logistical and financial support provided by the International Center for Agricultural Research in the Dry Areas (ICARDA) is appreciated and sincerely acknowledged.

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MS Received on 01st June, 2025
MS Accepted on 30th August, 2025

DOI: 10.55278/FBHZ4006

Morphometric characterization of *Tetragonula iridipennis* Smith (Hymenoptera: Apidae) from diverse nesting habitats in Karnataka, India

Nithinkumar H. L*[1]., Chetan V. M[1]., Brunda B. S[2]., Sahana A[2] Rakshitha, T. N[1]., and Nayimabanu Taredahalli [1] and Vijayakumar, K. T[1]

[1]*AICRP on Honey bees and Pollinators, University of Agricultural Sciences, GKVK, Bangalore, India*

[2]*Nrupathunga University, Bangalore 560001*

Corresponding author: nithinkumarhl@gmail.com

Abstract

This study explores the nesting habitat characteristics and morphometric variations of the stingless bee *Tetragonula iridipennis* Smith across four distinct locations in Karnataka, India. Ten feral colonies were examined for nesting traits, while morphometric analysis was conducted on specimens from Nrupathunga University (Bangalore), UAS-GKVK (Bangalore), Honnadevipur, and Harohalli. Nesting observations revealed a preference for varied substrates including stone structures and residential buildings primarily situated within educational and urban areas. Entrance tubes displayed notable variability, with lengths ranging from 0.5 to 1.5 cm and widths from 0.3 to 1.0 cm. Analysis of 29 morphometric parameters highlighted statistically significant differences among populations, with mean body length ranging from 3.87 mm to 4.07 mm. These findings underscore the ecological adaptability and morphological diversity of *T. iridipennis*, reinforcing its role as a vital indigenous pollinator in diverse environments.

Keywords: Stingless bees, *Tetragonula iridipennis*, morphometry, nesting behavior, Karnataka, pollinators

Introduction

Stingless bees (Hymenoptera: Apidae: Meliponini) constitute one of the most diverse and ecologically pivotal groups of social bees in tropical and subtropical regions worldwide (Engel and Rasmussen, 2023). As integral members of the pantropical melitto-fauna, stingless bees possess significant cultural and economic importance. Among the approximately 605 described extant species distributed across 45 genera, the genus *Tetragonula* stands out as one of the most widespread and economically significant groups in the Indo-Pacific region.

Tetragonula iridipennis Smith, commonly known as the Indian stingless bee or 'dammer bee', is a key native species that serves as an important pollinator for a wide variety of horticultural crops in India. This diminutive tropical stingless bee is common throughout South Asia and plays a crucial role in maintaining ecosystem balance and agricultural productivity.

The species exhibits remarkable ecological adaptability, nesting in diverse microhabitats ranging from tree hollows to human-made structures. Previous studies have documented their preference for nesting in old mud and stone walls, with entrance characteristics varying significantly across different geographical regions (Devanesan *et al*., 2021; Choudhary *et al*., 2021). Understanding these nesting habitat preferences is critical for developing informed conservation strategies and promoting sustainable pollinator management. Morphometric analysis has emerged as a powerful tool for understanding intraspecific variation, population structure, and adaptive responses to environmental conditions in stingless bees. Miniaturisation can influence the foraging behaviour of flower visitors by shaping their sensory systems, flight capabilities, and their compatibility with floral shapes and structures. Regional differences in body size of *T. iridipennis* have been reported from different geographical regions, with implications for their foraging efficiency, pollination effectiveness, and ecological niche partitioning.

Global threats such as climate change and habitat fragmentation increasingly imperil stingless bee populations. Predictive modelling studies have underscored the vulnerability of *T. iridipennis* to shifting climatic conditions, reinforcing the urgency of ecological investigations to inform conservation priorities.

The present study aims to characterize nesting habitat preferences and morphometric variations of *T. iridipennis* across selected locations in Karnataka, India contributing baseline data essential for conservation planning and integrated pollinator management.

Materials and methods

Study area and sample collection

The study was conducted across four locations in Karnataka, India *viz*., Nrupathunga University Bangalore (12.9734; 775861), University of Agricultural Sciences (UAS), GKVK Bangalore (13.0770, 77.5771), Honnadevipur, Doddaballapura, Bangalore (13.2423,77.4159), and Harohalli, Devanahalli, Bangalore (13.3153,77.7478). These locations represent diverse ecological conditions and urbanization gradients, providing an opportunity to assess habitat plasticity and morphological variation across different environments.

Nest characteristics analysis

A total of 10 feral colonies were randomly selected and studied for nest characteristics. Parameters recorded included nest site preferences, orientation, shape, color, height from ground, and entrance tube dimensions. Nest orientation was determined using a compass, and measurements were taken using digital callipers with 0.01 mm precision.

Morphometric analysis

Specimens were collected from active colonies at each location and preserved in 70% ethanol. Morphometric measurements were taken using a stereoscopic microscope equipped with an ocular micrometer. A total of 29 morphometric parameters were recorded in accordance with standardized entomological protocols. These included measurements of body length; head capsule dimensions; antennal characteristics; thoracic features; wing structure; leg segment lengths; and abdominal proportions.

Statistical Analysis

Morphometric data was analyzed using descriptive statistical methods. Mean values and standard deviations were calculated for all measured parameters to summarize central tendencies and variation. Comparative analysis across locations was conducted to evaluate morphological plasticity among populations of *Tetragonula iridipennis* across the study region.

Results and discussion

Nest characteristics of feral colonies

Observations from ten feral colonies of *T. iridipennis* revealed substantial diversity in nesting habitat preferences and architectural features (Table 1). Colonies exhibited notable adaptability in nest site selection, utilizing a wide range of substrates including stone buildings, residential structures, and institutional facilities. This broad substrate utilization reflects the species' ecological plasticity and ability to exploit anthropogenic environments for nesting, consistent with observations by Devanesan *et al*. (2021) who documented nesting in varied human-made substrates.

Nest orientation showed considerable variation with colonies facing all cardinal and intermediate directions (North, South, East, West, Northeast, Northwest, Southeast, Southwest). This omnidirectional nesting pattern suggests that *T. iridipennis* does not exhibit strong directional preferences, contrasting with some studies that report eastern orientation preferences in certain populations (Choudhary *et al*., 2021). which reported an eastern-facing tendency in certain populations. The absence of a consistent directional bias may confer adaptive advantages in urban landscapes, where architectural constraints often limit optimal nest placement. Nest shape exhibited three distinct categories namely circular, oval and irregular. The predominant nest colors observed black, greenish-black, grey and brown likely reflect the materials employed in construction, potentially offering camouflage benefits. Color variation may be attributed to the incorporation of diverse plant resins and waxes sourced locally, as stingless bees are known to utilize a wide array of natural materials during nest formation (Roubik, 2006; Wille, 1983) (Fig.2 a).

The nest height from ground ranged from 31.75 to 95 cm, indicating flexibility in vertical habitat utilization (Table 1). This height range suggests that the bees select sites that balance accessibility for foraging flights with protection from ground-based predators and environmental disturbances. The relatively low nesting heights compared to some other stingless bee species may reflect the urban and semi-urban nature of the study sites, as reported in similar urban studies (Slaa *et al*., 2006).

Entrance tube characteristics showed notable variation with tube lengths ranging from 0.6 to 1.5 cm and entrance tube lengths from 0.5 to 1.5 cm. Entrance tube width varied from 0.3 to 1.0 cm. These dimensions are consistent with previous studies on *T. iridipennis* nest architecture (Devanesan *et al*., 2021), though the range of variation observed suggests local adaptations to specific environmental conditions. Choudhary *et al*. (2021) reported that the length and width of the entrance tube ranged between 9-13 and 3-9 mm, respectively on different sites, indicating some geographical variation in entrance tube dimensions across different study regions (Fig. 2b).

The entrance tube plays multiple critical roles, including regulation of airflow, deterrence of intruders, and stabilization of the colony's internal microclimate (Roubik, 2006). The observed variability in entrance tube dimensions may reflect local environmental pressures such as ambient temperature, humidity, predator activity, or resource availability. For instance, longer tubes may offer enhanced protection from external threats, while wider openings might facilitate greater forager throughput during peak activity periods (Inoue *et al.,* 1984).

Morphometric characteristics

The morphometric analysis of *T. iridipennis* specimens from four locations revealed significant variation across measured parameters, indicating considerable phenotypic plasticity within the species (Francoy *et al*., 2009). The pooled data analysis of 29 morphometric parameters provides comprehensive insights into the body size and structural variations of this important pollinator species.

Body size and general morphology

The mean body length across all locations was 3.95±0.07 mm, with individual location means ranging from 3.87 mm (Harohalli) to 4.07 mm (Nrupathunga University, Bangalore) (Fig.1 a). This body size range is consistent with the characterization of *T. iridipennis* as a miniature stingless bee species (Michener, 2007). Previous studies have reported the mean value of head length (HL) (1.43 mm), head width

(HW) (1.68 mm), antennal length (AL) (1.98 mm), hind leg length (HLL) (3.54 mm) and forewing length (FL) (3.84 mm) in *T. iridipennis*, showing some variation from our findings, possibly due to geographical and environmental differences (Pedro, 2014).

The relatively small body size of *T. iridipennis* has important ecological implications. As noted in recent studies, the tremendous variation in body size makes them an excellent group to study how miniaturization affects vision and visual behaviours (Engel and Rasmussen, 2023). Small body size may limit flight range and carrying capacity but allows access to smaller floral resources and reduces energy requirements for flight (Heard, 1999).

Head region morphometry

Head morphometry showed considerable variation across locations (Table 2). Head length (HL) ranged from 0.99 mm (Nrupathunga University) to 1.33 mm (Harohalli), with a mean of 1.16±0.15 mm. Head width (HW) varied from 1.39 mm to 1.63 mm across locations, with an overall mean of 1.52±0.10 mm. The head width to head length ratio provides insights into head shape variations that may be related to feeding ecology and sensory capabilities (Francoy *et al.*, 2009). Compound eye measurements revealed significant variation in eye length (CEL) from 0.83 to 1.05 mm and relatively stable eye width (CEW) from 0.38 to 0.43 mm across locations. Eye size is crucial for visual navigation and flower recognition in stingless bees (Wille, 1983). The observed variation in compound eye dimensions may reflect adaptations to different light environments or foraging strategies across study locations, as suggested by recent research on miniature bee vision systems (Engel and Rasmussen, 2023).

Wing morphometry

Wing measurements are critical indicators of flight capability and foraging range in stingless bees (Heard, 1999). Forewing length (FWL) showed moderate variation from 3.27 to 3.54 mm across locations (Fig.1 b), with a mean of 3.38±0.10 mm (Table 2). Forewing width (FWW) was relatively stable ranging from 1.07 to 1.20 mm. The forewing length to body length ratio averaged approximately 0.85, indicating well-developed flight capabilities relative to body size. Hind wing dimensions showed greater variation, with hindwing length (HWL) ranging from 1.78 to 2.29 mm and hindwing width (HWW) from 0.60 to 0.69 mm. The variation in wing morphometry may reflect adaptations to local environmental conditions, including wind patterns, vegetation structure, and foraging distances required in different habitats (Slaa *et al.*, 2006). Wing morphometry has been successfully used for taxonomic identification and population studies in stingless bees (Francoy *et al.*, 2009).

Leg morphometry

Leg measurements provide insights into foraging behavior, pollen collection efficiency, and locomotory capabilities (Michener, 2007). Significant variation was observed across all leg segments and between different leg pairs.

Fore leg measurements showed considerable variation, with fore coxa length (FCL) ranging from 0.31 to 0.54 mm across locations (Table 2). Fore femur dimensions were relatively stable, while fore tibia measurements showed moderate variation. The fore legs are important for manipulating small floral structures and may show adaptations to the predominant flower types available in different locations (Yamamoto *et al.*, 2012).

Mid leg morphometry revealed substantial variation in coxa length (MCL) from 0.24 to 0.60 mm, suggesting possible functional adaptations. Mid legs play crucial roles in locomotion and stability during flower visits (Wille, 1983). The observed variation may reflect different behavioral requirements across study locations.

Hind leg measurements, particularly important for pollen collection and transport, showed moderate variation. Hind tibia length (HTL) ranged from 1.25 to 1.46 mm, with corresponding width variations. This structural difference may influence the morphometric patterns observed in our study (Fig.1 c).

Abdomen morphometry

Abdomen measurements showed relatively low variation compared to other body regions. Abdomen length (AL) ranged from 1.45 to 1.65 mm, while abdomen width (AW) varied minimally from 1.21 to 1.26 mm across locations (Table 2). The relatively stable abdomen dimensions may reflect functional constraints related to internal organ arrangement and reproductive biology (Sakagami, 1982).

Geographical variation and ecological implications

The morphometric variation observed across the four study locations suggests local adaptation or phenotypic plasticity in response to environmental conditions (Francoy *et al.*, 2009). Similar patterns of geographical variation have been documented in other stingless bee species and may result from differences in resource availability, climate conditions, or selective pressures (Pedro, 2014).

The largest specimens were generally observed from Harohalli and Honnadevipur locations, while those from Nrupathunga University showed smaller dimensions in several parameters. This pattern may reflect environmental quality differences, with more favourable conditions supporting larger body sizes, or may represent population-specific genetic differences (Rasmussen, 2008).

Body size variation in social insects can have cascading effects on colony productivity, foraging efficiency, and ecological interactions (Imperatriz-Fonseca *et al*., 2006). Larger workers may have greater flight range and carrying capacity but require more resources for development and maintenance (Heard, 1999). The optimal body size likely represents a balance between these competing factors under local environmental conditions.

The documented nesting habitat diversity and morphometric variation of *T. iridipennis* have important implications for conservation and management strategies. The species' ability to utilize diverse nesting substrates, including anthropogenic structures, suggests potential for coexistence with human activities if appropriate management practices are implemented (Slaa *et al*., 2006).

The maintenance of morphometric diversity across populations is crucial for long-term species viability and adaptive potential (Nunes *et al*., 2008). Conservation strategies should focus on preserving habitat heterogeneity and connectivity between populations to maintain gene flow and prevent local extinctions (Venturieri *et al*., 2003).

Urban and semi-urban environments, as represented by the study locations, can serve as important refugia for stingless bee populations if designed to provide appropriate nesting sites and floral resources (Imperatriz-Fonseca *et al*., 2006). The integration of stingless bee conservation considerations into urban planning and building design could significantly benefit pollinator communities, as demonstrated by successful meliponiculture programs in other regions (Venturieri *et al*., 2003).

Discussion and Conclusion

This study presents comprehensive baseline data on the nesting habitat characteristics and morphometric variation of *T. iridipennis* from Karnataka, India. The species exhibits notable ecological plasticity in nesting site selection, reflecting its ability to adapt to a range of substrates—including anthropogenic structures—and to adopt omnidirectional nesting orientations. Such versatility suggests strong potential for persistence in modified and urbanized landscapes.

Morphometric analyses revealed substantial variation across all measured parameters, indicative of phenotypic plasticity that may underlie adaptive responses to diverse environmental conditions. The observed geographical differences in body size and structural features highlight potential local adaptation and warrant further investigation into genetic and environmental determinants of these variations.

These findings enhance our understanding of the ecology and biology of *T. iridipennis*, a vital native pollinator, and serve as foundational data for conservation and habitat management initiatives. Future research should explore the genetic basis of morphometric variability and examine how environmental change particularly urbanization and habitat fragmentation impacts population dynamics and distribution patterns.

Acknowledgments

The authors acknowledge Indian Council of Agricultural Research- All India Coordinated Research Project on honey bees and pollinators, New Delhi for funding and Department of Apiculture, University of Agricultural Sciences, Bangalore for facilities to conduct this study.

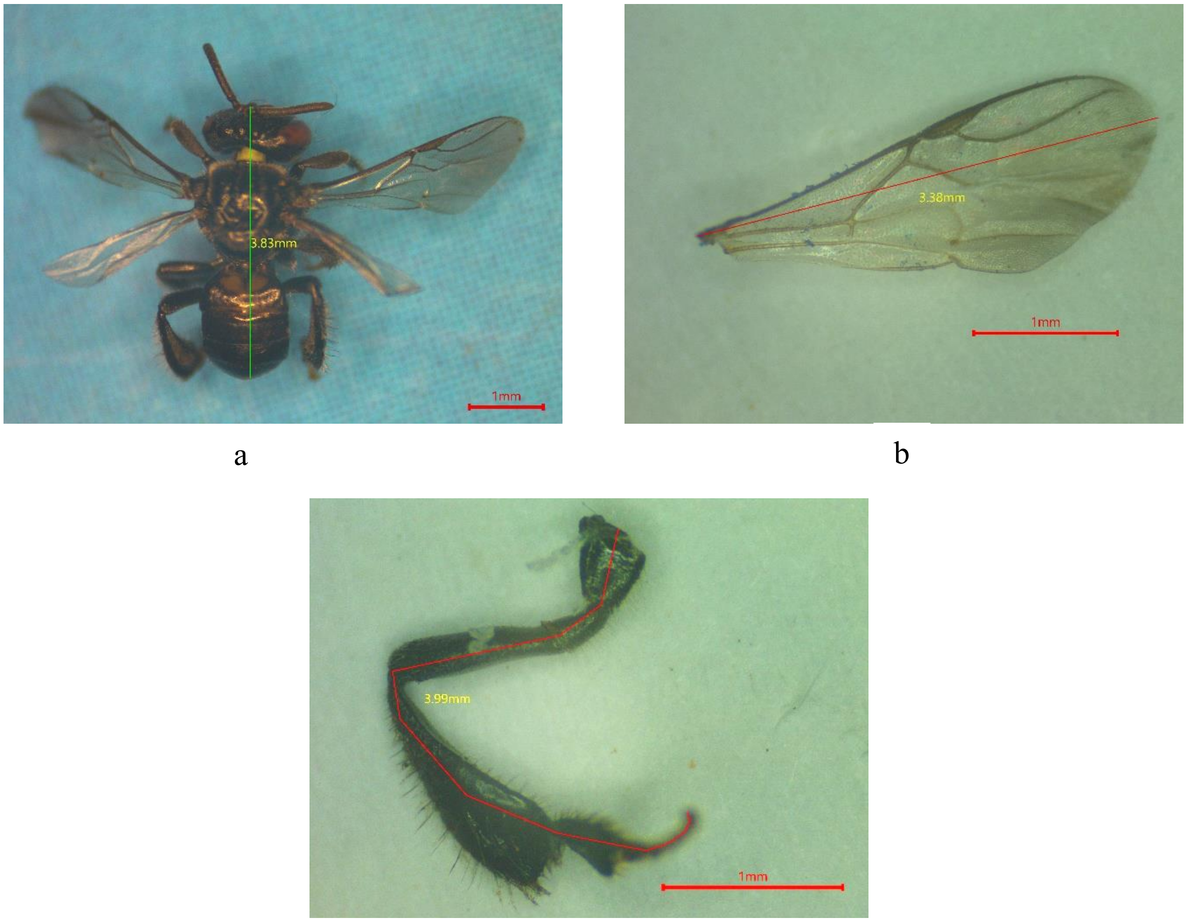
Table 1. Nest characteristics of feral colonies of stingless bee, *T. iridipennis*

Parameters (n=10)	Observation
Nest site	Stone building, house building, residential, education building
Nest orientation	North, South, East, West, North east, North West, South east, South west.
Nest shape	Circular, Oval, Irregular
Nest colour	Black, greenish black, grey, brown
Nest height from ground (cm)	31.75-95
Tube length(cm)	0.6-1.5
Entrance tube length (cm)	0.5-1.5
Entrance tube width (cm)	0.3-1.0

Table 2. Morphometric characteristics of stingless bee, *T. iridipennis* from different locations of Karnataka

Sl. No.	Morphometric characteristics	Nrupathunga University, Bangalore (n=30)	UAS, GKVK Bangalore (n=30)	Honnadevipura (n=30)	Harohalli (n=30)	MEAN± SD (mm)
1	BL	4.07	3.95	3.92	3.87	3.95±0.07
	HEAD PART					
2	HL	0.99	1.03	1.29	1.33	1.16±0.15
3	HW	1.39	1.45	1.60	1.63	1.52±0.10
4	CEL	0.83	0.97	1.05	0.97	0.95±0.08
5	CEW	0.38	0.43	0.40	0.41	0.40±0.02
	WING PART					
6	FWL	3.54	3.27	3.33	3.38	3.38±0.10
7	FWW	1.19	1.20	1.15	1.07	1.15±0.05
8	HWL	2.29	2.12	1.78	2.16	2.09±0.19
9	HWW	0.60	0.65	0.69	0.65	0.65±0.03
	FORE LEG					
10	FCL	0.31	0.36	0.48	0.54	0.42±0.09
11	FCW	0.27	0.21	0.34	0.37	0.30±0.06
12	FFL	0.67	0.69	0.67	0.72	0.68±0.02
13	FFW	0.20	0.19	0.19	0.20	0.20±0.01
14	FLT	0.56	0.64	0.68	0.67	0.64±0.05
15	FLTW	0.21	0.19	0.21	0.21	0.21±0.01
	MID LEG					
16	MCL	0.60	0.24	0.51	0.52	0.47±0.14
17	MCW	0.26	0.19	0.33	0.28	0.26±0.05
18	MFL	0.83	0.75	0.81	0.83	0.81±0.03
19	MFW	0.20	0.23	0.26	0.26	0.24±0.02
20	MTL	0.87	0.79	0.90	0.78	0.84±0.05
21	MTW	0.24	0.20	0.30	0.30	0.26±0.04
	HIND LEG					
22	HCL	0.41	0.48	0.49	0.53	0.48±0.04
23	HCW	0.38	0.35	0.30	0.30	0.33±0.03
24	HFL	0.96	0.93	0.97	0.98	0.96±0.02
25	HFW	0.25	0.23	0.25	0.27	0.25±0.01
26	HTL	1.25	1.28	1.43	1.46	1.36±0.09
27	HTW	0.48	0.47	0.55	0.64	0.54±0.07
	ABDOMEN					
28	AL	1.53	1.65	1.47	1.45	1.52±0.08
29	AW	1.22	1.24	1.26	1.21	1.23±0.02

Note: BL: Length of the body, HL: Head length, HW: Head width, CEL: Compound eye length, CEW: Compound eye width, SL: Scape length, SW: Scape width, PL: Pedicel length, AL: Antenna length, 1stFL: First flagellomere length, 1stFW: First flagellomere width, FL: Flagellum length, NF: Number of flagella, TL: Thorax length, TW: Thorax width, FWL: Fore wing length, FWW: Fore wing width, HWL: Hind wing length, HWW: Hind wing width, FCL: Fore coxa length, FCW: Fore coxa width, FFL: Fore femur length, FW: Fore femur width, FLT: Fore tibia length, FTW: Fore tibia width, MCL: Mid coxa length, MCW: Mid coxa width, MFL: Mid femur length, MFW: Mid femur width, MTL: Mid tibia length, MTW: Mid tibia width, HCL: Hind coxa length, HCW: Hind coxa width, HFL: Hind femur length, HFW: Hind femur width, HTL: Hind tibia length, HTW: Hind tibia width, AL: Abdomen length, AW: Abdomen width.



a b

c

Fig. 1: Morphometric characteristics of stingless bee, *T. iridipennis* a) Body length, b) Wing length, c) Hind leg length

d e

Fig.2: d) Nest characteristics of feral colony of stingless bee, e) colony entrance

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MS Received on 10th May, 2025
MS Accepted on 25th August, 2025

DOI: 10.55278/NWDL6998

Evaluation of Garlic (*Allium sativum*) derivatives for suppressing oviposition of *Callosobruchus chinensis* (L.) in stored chickpea seeds

Arulraj and Ram Singh*
Department of Entomology, CCS Haryana Agricultural University, Hisar 125004, Haryana, India
***Corresponding author: ramjood2@gmail.com**
(ORCID ID: 0000-0002-9616-6042)

Abstract

Chickpea*, Cicer arietinum* L., is a major pulse crop in India. During storage, the pulse beetle *Callosobruchus chinensis* L. inflicts significant quantitative and qualitative seed losses. With rising safety concerns over synthetic insecticides, botanical alternatives have gained prominence. This study evaluated the efficacy of various garlic (*Allium sativum* L.) products against *C. chinensis* oviposition on stored chickpea seeds at CCS Haryana Agricultural University, Hisar. Garlic oil (1.5%) completely inhibited egg laying for up to 6 months. Methanol extract (3%) and oil (0.5%) significantly reduced egg laying for 45 days, though not completely whereas garlic powders and other extracts hexane, chloroform and acetone failed to prevent oviposition beyond initial days. It may be concluded that garlic oil (especially at 1.5%) is a potent, long-lasting, and eco-friendly alternative to synthetic insecticides for protecting stored chickpea seeds from egg laying of *C. chinensis*. It showed strong anti-oviposition properties, making it a promising biopesticide for storage pest management.

Keywords: Garlic, *Callosobruchus chinensis,* Oviposition, Oil, Chickpea, methanol extract

Introduction

In India, major insect infesting chickpea, *Cicer arietinum* L. during storage is *Callosobruchus chinensis* (L.) (Sharma *et al.,* 2013). It is essential to protect stored grains from insect-pests during storage using safer and ecofriendly chemicals (Reena and Singh, 1993). Several plant materials, vegetable oils and essential oils have been tested for the management of pests of stored grains (Jood *et al.,* 1996; Reena and Singh, 2003; Yadav *et al*., 2025). Various spices have been suggested traditionally for protecting food stuff from insects (Rahman *et al.,* 2013; Kale *et al.,* 2023). Among these spices, garlic *Allium sativum* (L.) has been discovered to act as a promising insecticide (Shaaya *et al*., 1997; Reena and Singh, 2003; Ofuya *et al*., 2010). Reena and Singh (2003) reviewed insecticidal properties of garlic extensively and reported wider use and acceptability of garlic products as protectants against storage pests in several cereal and pulse crops in India. The information on the ovicidal properties of garlic products is scanty (Pandey *et al.,* 1976; Ho *et al.,*1996; Denloye, 2010). Keeping in view, garlic products such as oil, powder and extracts were evaluated for their effects on oviposition of *Callosobruchus chinensis* (L.) in chickpea.

Material and methods

Mass rearing of test insects and preparation of garlic products

The culture of *Callosobruchus chinensis* was maintained in the Laboratory, Department of Entomology in a BOD incubator at 29 ± 1^{0}C and 80 ± 5 percent relative humidity (RH) as recommended by Strong *et al*. (1968). The certified seed of chickpea variety 'HC-5' was procured from the Directorate of Farms, CCS Haryana Agricultural University, Hisar for use in different experiments. The bulbs of garlic were procured from Department of Vegetable Science of the University. These were crushed using pestle and mortar. The crushed bulbs (one kg) were taken in a round bottom flask (5-liter capacity) and the methanol was added to it in a volume of 2.5 liter. Refluxing was done by fitting the flask with a water condenser and boiling the set using a heating mantle for 6 h. The extract was then filtered out of the flask and was concentrated by distillation process. This refluxing and distillation procedure was repeated thrice. Likewise, 20 Kg (5 Kg each) of garlic was extracted using solvents *viz*, methanol, hexane, chloroform, acetone to obtain 20g of methanol, hexane, chloroform and acetone extracts, respectively. The garlic oil and garlic powder were procured from local market of Hisar.

Mixing of chickpea seeds with garlic products

Garlic products including garlic oil, various solvent extracts, and garlic powder—were uniformly applied to chickpea seeds using a standardized mixing procedure. A 2-liter round-bottom flask was used to combine 250 g of chickpea seeds with the respective doses of garlic products (as detailed in Table 1). The flask was sealed with butter paper and manually shaken for five minutes to ensure even coating of the seeds. Treated seeds were then transferred into clean glass jars for subsequent experimental trials. Each treatment was replicated three times. For control, three sets of 250 g seeds were treated with acetone alone and processed similarly.

Impact on oviposition

From each garlic-treated batch, 100 chickpea seeds were placed into a plastic tube (10 cm height × 4 cm diameter). Five pairs of newly emerged *Callosobruchus chinensis* adults (0–1 day old) were introduced into each tube. The open ends of the tubes were sealed using cotton swabs wrapped in muslin cloth to allow ventilation while preventing insect escape. Tubes were maintained in a biological oxygen demand (BOD) incubator at a constant temperature of 29 ± 1 °C and relative humidity of 80 ± 5%.

Egg laying was recorded at intervals of 1-, 3-, 5-, and 7-days post-release. To assess the residual efficacy of treatments, fresh beetles were introduced at 45-day intervals up to six months, and oviposition was recorded following the same schedule. Control treatments, using seeds treated with acetone alone, were run concurrently under identical conditions.

Statistical analysis

The experimental data were analyzed using analysis of variance (ANOVA) under a completely randomized design (CRD) to determine the critical difference (CD) among treatments. Treatment effects were evaluated at the 5% level of significance. Where appropriate, data were subjected to angular or square root transformation to normalize variance, following the methodology outlined by Snedecor and Cochran (1996).

Results and Discussion

The number of eggs laid by *C. chinensis* after one, three, five and seven days of beetle release was significantly reduced (Table 1). First day after release there was no egg laying in garlic oil 0.5% and 1.5%, methanol extract 2% and 3% treated seeds. Reduced number of eggs (8.3) was recorded in hexane extract 3%, followed by chloroform extract 3% (11.3). Maximum number of eggs 18.3 was laid in garlic powder 2% treated seeds as compared to other treatments but in control (acetone treated) there were 39.3 eggs. Similar to first day, there was no egg laying in garlic oil 0.5% and 1.5%, methanol extract 2% and 3% treated seeds after three, five and seven days but in other products after seven days, minimum number of eggs (42.0) was observed in hexane extract 3% and maximum 196.3 eggs were recorded in garlic powder 2% treated seeds which were significantly less as compared to control (436.6).

The number of eggs laid at 45 days of insect release on treated seeds was similar to first one (Table 2). There was no egg laying in garlic oil 1.5% treated seeds up to seven days but after one day, minimum number of eggs (11.2) was recorded in methanol extract 3% treated seeds and maximum 30.0 eggs were observed in garlic powder 2% treated seeds, this trend continued up to seven days.

The data on number of eggs laid on 90 days treated seeds (Table 3) showed reduced impact. There was no egg laying in garlic oil 1.5% treated seeds up to seven days. After one day, minimum number of eggs (40.0) was recorded in methanol extract 3% and maximum 74.0 eggs were observed in garlic powder 2% treated seeds, this trend continued up to seven days Similarly, there was no egg laying in garlic oil 1.5% treated seeds up to seven days in fourth observation recorded after 135 days of seed treatments (Table 4). The final observation was recorded after 6 months (Table 5). There was no egg laying in garlic oil 1.5% treated seeds up to seven days after release of the beetles. After one day, minimum number of eggs (58.0) was recorded in methanol extract 3% and garlic oil 0.5% treated seeds. Maximum number of eggs (82.0) was observed in garlic powder 2% treated seeds; this trend continued up to seven days. The studies clearly indicate anti-oviposition properties of garlic derivatives overtime (Fig 1).

Insecticidal efficacy of garlic oil has been reported in several investigations against beetles in stored cereals and pulses (Shaaya *et al.*,1997; Rahman *et al.*, 2013; Onu *et al.,* 2015). In present studies, garlic oil (1.5%) completely inhibited egg laying for up to 6 months. Methanol extract (3%) and garlic oil (0.5%) significantly reduced egg laying till 45 days, though not completely whereas garlic powders and other extracts hexane, chloroform and acetone failed to prevent oviposition beyond initial days. The results on anti-ovipositional effect of garlic products against beetle and weevils in stored pulses and cereals (Sharma and Rathore, 2006; Ho *et al.*,1996; Denloye, 2010) corroborates the present findings.

Summary

Comprehensive evaluation of garlic-based products on chickpea seeds revealed significant inhibition of *Callosobruchus chinensis* oviposition. Garlic oil (1.5 %) completely prevented egg deposition across all assessment intervals, including up to six months post-treatment. At a lower concentration (0.5 %), garlic oil and methanol extract (3 %) markedly decreased egg laying for 45 days, achieving reductions of over 70 % relative to untreated controls. In first-week assessments, nonpolar extracts (hexane, chloroform, acetone) and garlic powder (2 %) only transiently reduced oviposition, with egg counts rebounding after seven days. These findings underscore garlic oil’s superior, long-lasting anti-oviposition properties and support its application as an eco-friendly strategy for bruchid management.

Table 1. Effect of garlic oil, extracts and garlic powder on oviposition of *Callosobruchus chinensis* (Linnaeus) released on chickpea seeds at first day after treatment.

Treatment	Conc (%) v/w	Mean number of eggs laid by pulse beetles days after release				
		1	3	5	7	Mean
Garlic oil	0.5	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)
Garlic oil	1.5	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)
Methanol extract	2	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)
Methanol extract	3	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)
Hexane extract	2	13.3 (3.7)	41.3 (6.4)	46.0 (6.8)	46.0 (6.8)	36.6 (5.9)
Hexane extract	3	8.3 (3.0)	40.3 (6.4)	42.0 (6.5)	42.0 (6.5)	33.1 (5.6)
Chloroform extract	2	13.3 (3.7)	41.6 (6.8)	62.3 (7.9)	62.3 (7.9)	44.8 (6.5)
Chloroform extract	3	11.3 (3.4)	40.3 (6.4)	55.6 (7.5)	55.6 (7.5)	40.7 (6.2)
Acetone extract	2	16.6 (4.1)	44.0 (6.7)	68.3 (8.3)	68.3 (8.3)	49.3 (6.8)
Acetone extract	3	14.3 (3.9)	45.6 (6.8)	73.6 (8.6)	73.6 (8.6)	51.7 (6.9)
Garlic powder	2	18.3 (4.3)	66.6 (8.2)	122.0 (11.0)	196.3 (14.0)	100.8 (9.4)
Garlic powder	4	16.3 (4.1)	55.6 (7.5)	86.0 (9.3)	125.3 (11.2)	70.8 (8.0)
Control (acetone treated)	2	39.3 (6.3)	194.3 (13.9)	313.6 (17.7)	436.6 (20.9)	245.9 (14.7)
Mean		11.6 (3.1)	43.8 (5.6)	66.8 (6.7)	85.0 (7.8)	
SE(m) ±		(0.10)	(0.13)	(0.16)	(0.16)	
C.D. at 5%		(0.30)	(0.39)	(0.48)	(0.49)	
Factors	DF	SE(m) ±	C.D. at 5%			
Period (days)	3	(0.04)	(0.11)			
Treatment	12	(0.07)	(0.20)			
Period (days) x Treatment	36	(0.14)	(0.40)			

Figures in the parentheses are square root transformation values

Table 2. Effect of garlic oil, extracts and garlic powder on oviposition of *Callosobruchus chinensis* (Linnaeus) released on chickpea seeds at 45 days after treatment

Treatment	Conc (%) v/w	Mean number of eggs laid by pulse beetles days after release				
		1	3	5	7	Mean
Garlic oil	0.5	19.0 (4.5)	61.0 (7.8)	87.3 (9.3)	116.7 (10.8)	71.8 (8.2)
Garlic oil	1.5	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)
Methanol extract	2	19.6 (4.5)	47.6 (6.9)	84.6 (9.2)	125.3 (11.2)	69.2 (8.0)
Methanol extract	3	11.3 (3.5)	40.0 (6.3)	74.0 (8.6)	98.0 (9.9)	55.8 (7.1)
Hexane extract	2	22.6 (4.6)	59.6 (7.7)	91.3 (9.6)	123.6 (11.1)	74.2 (8.4)
Hexane extract	3	19.6 (4.5)	53.0 (7.3)	90.6 (9.5)	120 (10.9)	69.9 (8.0)
Chloroform extract	2	24.3 (5.0)	84.3 (9.2)	125.3 (11.2)	156.3 (12.5)	97.5 (9.5)
Chloroform extract	3	23.0 (4.8)	60.6 (7.8)	94.6 (9.7)	136 (11.7)	78.5 (8.5)
Acetone extract	2	27.0 (5.2)	83.6 (9.1)	135.0 (11.6)	207 (14.2)	113.5 (10.1)
Acetone extract	3	24.6 (5.0)	76.6 (8.8)	117.6 (10.80	173.3 (13.2)	97.9 (9.5)
Garlic powder	2	30.6 (5.6)	118.6 (10.9)	208.3 (14.4)	313.6 (17.7)	167.7 (12.0)
Garlic powder	4	22.0 (4.7)	86.6 (9.3)	174.6 (13.2)	266.3 (16.3)	137.3 (10.9)
Control (acetone treated)	2	48.6 (7.0)	185.6 (13.6)	296.0 (17.2)	413 (20.3)	235.8 (14.3)
Mean		22.4 (4.6)	73.6 (8.1)	121.4 (10.4)	173.0 (12.4)	
SE(m) ±		(0.14)	(0.22)	(0.20)	(0.29)	
C.D. at 5%		(0.42)	(0.65)	(0.58)	(0.87)	
Factors	DF	SE(m) ±	C.D. at 5%			
Period (days)	3	(0.06)	(0.17)			
Treatment	12	(0.11)	(0.31)			
Period (days) x Treatment	36	(0.22)	(0.63)			

Figures in the parentheses are square root transformation values

Table 3. Effect of garlic oil, extracts and garlic powder on oviposition of *Callosobruchus chinensis* (Linnaeus) released on chickpea seeds at 90 days after treatment.

Treatment	**Conc (%) v/w**	**Mean number of eggs laid by pulse beetles days after release**				
		1	**3**	**5**	**7**	**Mean**
Garlic oil	0.5	57.0 (7.6)	130.3 (11.4)	265.0 (16.3)	314 (17.7)	196.4 (13.4)
Garlic oil	1.5	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)
Methanol extract	2	48.3 (7.0)	137.6 (11.7)	239.0 (15.4)	294.0 (17.1)	179.7 (12.8)
Methanol extract	3	40.0 (6.4)	122.0 (11.7)	224.6 (15.0)	253.6 (15.9)	160.0 (12.2)
Hexane extract	2	65.6 (8.1)	161.3 (12.7)	236.3 (15.3)	341.3 (18.5)	201.1 (13.5)
Hexane extract	3	61.3 (7.8)	123.6 (11.1)	244 (15.6)	333.6 (18.3)	185.7 (13.1)
Chloroform extract	2	67.3 (8.2)	149.6 (12.2)	252.6 (15.9)	350 (18.7)	204.8 (13.7)
Chloroform extract	3	66.3 (8.1)	142.2 (11.9)	247.3 (15.7)	316.3 (17.8)	193.0 (13.4)
Acetone extract	2	71.6 (8.5)	178 (13.3)	281.6 (16.7)	376.3 (19.4)	226.8 (14.4)
Acetone extract	3	67.0 (8.2)	165 (12.2)	275.6 (16.6)	330.3 (18.1)	209.4 (13.8)
Garlic powder	2	74.0 (8.6)	166.6 (12.8)	296.3 (17.2)	382.3 (19.5)	229.8 (14.6)
Garlic powder	4	70.0 (8.4)	145.6 (12.1)	261.3 (16.1)	358.3 (18.9)	208.8 (13.2)
Control (acetone treated)	2	78.0 (8.8)	191.6 (13.8)	314 (17.7)	459.3 (21.4)	260.7 (15.1)
Mean		58.9 (7.2)	139.4 (11.4)	241.3 (15.0)	316.1 (17.1)	
SE(m) ±		(0.22)	(0.38)	(0.42)	(0.24)	
C.D. at 5%		(0.64)	(1.13)	(1.23)	(0.70)	
Factors	DF	SE(m) ±	C.D. at 5%			
Period (days)	3	(0.09)	(0.25)			
Treatment	12	(0.16)	(0.46)			
Period (days) x Treatment	36	(0.33)	(0.92)			

Figures in the parentheses are square root transformation values.

Table 4. Effect of garlic oil, extracts and garlic powder on oviposition of *Callosobruchus chinensis* (Linnaeus) released on chickpea seeds at 135 days after treatment.

Treatment	**Conc (%) v/w**	**Mean number of eggs laid by pulse beetles days after release**				
		1	**3**	**5**	**7**	**Mean**
Garlic oil	0.5	59 (7.7)	148 (12.2)	273 (16.5)	351.6 (18.7)	207.9 (13.7)
Garlic oil	1.5	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)
Methanol extract	2	52 (7.2)	122.3 (11.1)	240 (15.5)	341 (18.4)	188.8 (13.1)
Methanol extract	3	50.6 (7.1)	122.3 (11.1)	236.6 (15.4)	342.3 (18.5)	187.9 (13.0)
Hexane extract	2	69.6 (8.4)	161.3 (12.7)	272 (16.5)	358 (18.9)	215.2 (14.1)
Hexane extract	3	67.6 (8.2)	140.6 (11.8)	264.3 (16.2)	359 (18.9)	207.8 (13.7)
Chloroform extract	2	73 (8.5)	176.6 (13.3)	284.6 (16.8)	395.3 (19.9)	232.3 (14.6)
Chloroform extract	3	70.3 (8.4)	158.3 (12.6)	277.6 (16.6)	373.3 (19.3)	230.5 (14.2)
Acetone extract	2	76.6 (8.8)	185.3 (13.6)	281.6 (16.8)	378.6 (19.4)	230.5 (14.6)
Acetone extract	3	76.3 (8.7)	176.6 (13.3)	285.6 (16.9)	363.3 (19.0)	225.4 (14.4)
Garlic powder	2	74.0 (8.6)	188.3 (13.6)	384.3 (16.8)	381 (19.5)	256.9 (14.6)
Garlic powder	4	70.6 (8.4)	158.6 (12.6)	279.6 (16.7)	376.6 (19.4)	221.3 (14.2)
Control (acetone treated)	2	77.3 (8.8)	180.6 (13.4)	285.8 (16.9)	416 (20.4)	239.9 (14.8)
Mean		62.8 (7.7)	147.6 (11.7)	258.8 (15.3)	341.2 (17.8)	
SE(m) ±		(0.18)	(0.26)	(0.18)	(0.31)	
C.D. at 5%		(0.54)	(0.77)	(0.54)	(0.91)	
Factors	DF	SE(m) ±	C.D. at 5%			
Period (days)	3	(0.06)	(0.19)			
Treatment	12	(0.12)	(0.34)			
Period (days) x Treatment	36	(0.24)	(0.68)			

Figures in the parentheses are square root transformation values

Table 5. Effect of garlic oil, extracts and garlic powder on oviposition of *Callosobruchus chinensis* (Linnaeus) released on chickpea seeds at 180 days after treatment.

Treatment	Conc (%) v/w	Mean number of eggs laid by pulse beetles days after release				
		1	3	5	7	Mean
Garlic oil	0.5	58.0 (7.6)	141.0 (11.9)	257.0 (16.0)	346.0 (18.6)	200.5 (13.5)
Garlic oil	1.5	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)	0.0 (1.0)
Methanol extract	2	61.0 (7.8)	153.0 (12.3)	264.0 (16.2)	360.0 (19.0)	209.5 (13.8)
Methanol extract	3	58.0 (7.7)	138.0 (11.7)	255.0 (15.6)	328.0 (18.1)	194.7 (13.2)
Hexane extract	2	63.0 (7.9)	143.0 (11.9)	273.0 (16.5)	359.0 (18.9)	209.5 (13.8)
Hexane extract	3	61.0 (7.8)	144 (12.0)	257.0 (16.0)	355.0 (18.8)	204.2 (13.6)
Chloroform extract	2	65.0 (8.1)	159.0 (12.6)	285.0 (16.9)	366.0 (19.1)	218.7 (14.1)
Chloroform extract	3	63.0 (7.9)	149.0 (12.2)	273.0 (16.5)	375.0 (19.3)	215.0 (14.3)
Acetone extract	2	74.0 (8.6)	156.0 (12.5)	278.0 (16.6)	383.0 (19.6)	222.7 (14.1)
Acetone extract	3	74.0 (8.6)	154.0 (12.4)	272.0 (16.4)	372.0 (19.3)	218.0 (14.4)
Garlic powder	2	74.0 (8.6)	157.0 (12.5)	282.0 (16.8)	393.0 (19.8)	226.5 (14.6)
Garlic powder	4	74.0 (8.6)	183.0 (13.5)	282.0 (16.8)	375.0 (19.3)	228.5 (14.5)
Control (acetone treated)	2	82.0 (8.8)	189.0 (13.8)	287.0 (16.9)	410.0 (20.2)	295.3 (15.3)
Mean		60.4 (7.6)	143.5 (11.6)	251.1 (15.3)	340.1 (17.8)	
SE(m) ±		(0.15)	(0.17)	(0.14)	(0.16)	
C.D. at 5%		(0.44)	(0.49)	(0.42)	(0.46)	
Factors	DF	SE(m) ±	C.D. at 5%			
Period (days)	3	(0.04)	(0.12)			
Treatment	12	(0.07)	(0.22)			
Period (days) x Treatment	36	(0.15)	(0.44)			

Figures in the parentheses are square root transformation values.

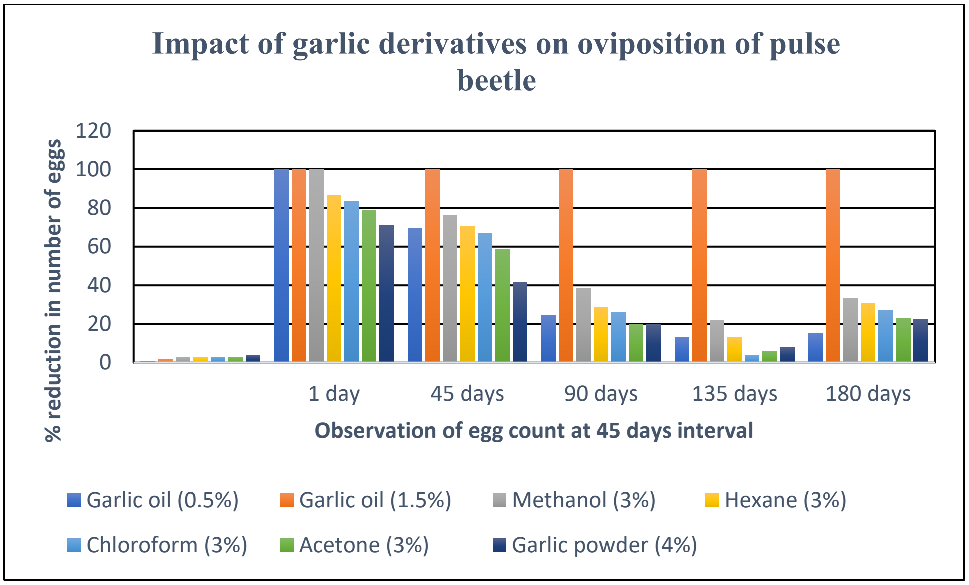

Fig. 1. Impact of garlic derivatives on egg deposition of *C. chinensis* on chickpea seeds.

Acknowledgement: The senior author gratefully acknowledges the Research facilities at CCS Haryana Agricultural University, Hisar, for the generous provision of laboratory and field resources.

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MS Received on 15th June, 2025
MS Accepted on 12th September, 2025

DOI: 10.55278/IFXM2042

Post-Harvest susceptibility of pearl millet hybrids to the red flour beetle, *Tribolium castaneum* (Herbst, 1797)

G. M. Parmar, P. R. Patel, R. J. Chaudhari and K. D. Mungra
Pearl Millet Research Station, Junagadh Agricultural University,
Jamnagar-361006,Gujarat, India
Corresponding author: gmparmar@jau.in

Abstract

An evaluation was conducted at the Main Pearl Millet Research Station, Junagadh Agricultural University, Jamnagar (Gujarat) in 2024 to compare the storage-pest resistance of nine pearl millet hybrids against the rust red flour beetle, *Tribolium castaneum*. Seeds of APHB 126, PB 1939, MP 7173, MP 7179, NBH 5992, US 7773, JKBH 1870, GHB 1305 and 86M01 were stored under ambient conditions and assessed after three and six months for grain damage, adult emergence, weight loss and seed germination. After three months, GHB 1305, APHB 126, MP 7214, NBH 5992, JKBH 1870, GHB 1337, HHB 67 Imp. and 86 M01 suffered minimal damage (0.25 %) and low emergence (2.5 adults/100 g), whereas HHB 344 exhibited the highest damage (2.13 %) and emergence (23.5 adults/100 g). At six months, NBH 5992 maintained the lowest grain damage (3.25 %), least weight loss (2.5 %) and highest germination (97 %), while HHB 344 recorded 23.13 % damage, 21 % weight loss and 77.5 % germination. NBH 5992, JKBH 1870, 86M01 and APHB 126 emerge as promising genotypes for enhanced post-harvest resilience against *T. castaneum.*

Key Words: Pearl millet, *Tribolium castaneum*, adult emergence, storage, seed germination.

Introduction

Pearl millet is renowned for its climate resilience, owing to its ability to withstand environmental stresses and resist insect pests while maintaining high productivity under low-input management. It serves as a rich source of dietary fibre, minerals, vitamins, and other essential nutrients, and contains several health-promoting phytochemicals (Rao *et al.,* 2011). In response to growing consumer awareness of these nutritional and functional benefits, pearl millet cultivation and trade have gained considerable momentum in recent years.

Despite these advantages, insect infestation of stored seeds in high-yielding pearl millet hybrids and varieties is becoming increasingly serious (Prem Kishore and Sharma, 1984). The red flour beetle, *Tribolium castaneum* Herbst, is a cosmopolitan pest that attacks sound, dry cereal grains as a secondary invader (Akshay *et al*., 2025). Both adults and larvae feed on exposed grain surfaces, and severe infestations render the produce unfit for human consumption. Under storage conditions, pearl millet often suffers significant damage from this pest, leading to reduced seed viability and poor germination. Detailed insights into *T. castaneum's* host preference and population dynamics in pearl millet are therefore essential for developing effective preventive measures to ensure safe grain preservation.

Methods and Materials

To identify resistance sources to *Tribolium castaneum*, recently released pearl millet varieties were screened under laboratory conditions. The experiment was conducted in 2024 using a completely randomized design with two replications.

For each variety and replication, 100 g of seed was placed in a 250 ml glass jar. Ten pairs of adult *T. castaneum* were introduced into each jar for a 10-day oviposition period, after which they were removed. Jars were covered with muslin cloth to allow ventilation.

Observations on the number of adults emerged per 100 g seed, percentage seed damage (based on a 400-grain sample), and percentage weight loss (on a 100 g basis) were recorded at three and six months after insect release. Seed germination percentage was determined at the end of six months of storage.

Results and discussion

The results revealed that (Table-1) per cent grain damage after three months storage period was observed significantly lower (0.25%) in GHB 1305, APHB-126, MP7214, NBH 5992, JKBH 1870, GHB 1337, HHB 67 Imp. and 86M01 and found statistically at par with PB 1939, MP 7173, US 7773 and Pratap. The highest grain damage was recorded in HHB 344 (2.13%). After six months storage period, least per cent grain damage (3.25%) was observed in NBH 5992 and it was statistically at par with JKBH 1870, 86M01, MP 7173, MP 7179, APHB 126, PB 1939, US 7773 and GHB 1337. The highest damage was recorded in Kaveri Super Boss (23.13%).In case of adult emergence, after three months storage period significantly lower adults emerged from varieties (2.50 adults/100g seeds) in NBH 5992 and was found statistically at par with APHB 126, MP 7173, JKBH 1870, 86M01, GHB 1305, MP 7214, PB 1939, MP 7179, US 7773 and GHB 1337. Maximum adult emergence was observed in (23.50 adults/100g seeds) HHB 344. At 6 months storage period the least adult emergence was recorded in JKBH 1870 (35.50 adults/100g seeds) and it was statistically at par with NBH 5992, 86M01, MP7173, APHB 126, GHB 1305, PB 1939, US 7773, MP 7214, MP 7179 and GHB 1337. The highest number of adults was recorded in HHB 344 (222.50 adults/100g seeds).

Table 1: Relative susceptibility of pearl millet advanced entries to *T.castaneum*

No.	Hybrids	Adult *Tribolum* population/100g		Per cent grain damage		Per cent weight loss		Ger %
		3 months	6 months	3 months	6 months	3 months	6 months	
1	CZH 267	3.94# (14.50)	11.77# (137.50)	6.72* (1.38)	22.07* (14.13)	9.33* (3.00)	21.07* (13.00)	85.50
2	RHB-273	4.18 (16.50)	12.98 (167.50)	7.86 (1.88)	23.27 (15.63)	13.54 (5.50)	23.17 (15.50)	83.50
3	GHB 1305	2.34 (4.50)	6.40 (40.00)	2.87 (0.25)	11.89 (4.25)	5.74 (1.00)	13.54 (5.50)	95.50
4	HHB 344	4.95 (23.50)	14.94 (222.50)	8.38 (2.13)	27.00 (20.63)	19.34(11.00)	27.26 (21.00)	79.50
5	APHB 126	2.12 (3.50)	6.39 (40.00)	2.87 (0.25)	11.35 (3.88)	4.90 (0.75)	10.75 (3.50)	95.50
6	IIMRPH2	4.36 (18.00)	13.54 (182.50)	7.86 (1.88)	24.71 (17.50)	15.18 (7.00)	24.30 (17.00)	82.50
7	MP7214	2.34 (4.50)	6.44 (40.50)	2.87 (0.25)	11.71 (4.13)	5.74 (1.00)	11.44 (4.00)	96.00
8	PB1939	2.34 (4.50)	6.40 (40.00)	3.46 (0.38)	11.35 (3.88)	5.74 (1.00)	10.75 (3.50)	95.50
9	MP7173	2.12 (3.50)	6.29 (38.50)	3.46 (0.38)	10.97 (3.63)	5.74 (1.00)	9.83 (3.00)	96.00
10	MP7179	2.34 (4.50)	6.44 (40.50)	4.05 (0.50)	11.16 (3.75)	5.74 (1.00)	11.15 (4.00)	96.00
11	DHBH 21003	3.60 (12.00)	10.88 (117.50)	6.08 (1.13)	19.01 (10.63)	6.93 (1.50)	18.90 (10.50)	88.50
12	VNR 106	4.12 (16.00)	12.59 (157.50)	6.72 (1.38)	23.27 (15.63)	12.22 (4.50)	22.37 (14.50)	84.50
13	VNR 107	4.35 (18.00)	13.45 (180.00)	7.86 (1.88)	24.24 (16.88)	15.30 (7.00)	24.33 (17.00)	80.50
14	NBH 5992	1.87 (2.50)	6.20 (37.50)	2.87 (0.25)	10.37 (3.25)	4.90 (0.75)	9.05 (2.50)	97.00
15	US7773	2.34 (4.50)	6.40 (40.00)	3.46 (0.38)	11.35 (3.88)	5.74 (1.00)	10.75 (3.50)	95.50
16	BLPMH 112	4.06 (15.50)	12.29 (150.00)	7.86 (1.88)	23.27 (15.63)	12.22 (4.50)	22.37 (14.50)	84.50
17	KPH6277	3.60 (12.00)	10.88 (117.50)	6.08 (1.13)	19.48 (11.13)	6.93 (1.50)	19.34 (11.00)	86.50
18	JKBH1870	2.12 (3.50)	6.04 (35.50)	2.87 (0.25)	10.57 (3.38)	6.38 (1.25)	10.52 (3.50)	96.50
19	GHB 1337	2.34 (4.50)	6.48 (41.00)	2.87 (0.25)	11.35 (3.88)	6.93 (1.50)	11.44 (4.00)	96.00
20	HHB 67 Imp.	3.07 (8.50)	9.41 (87.50)	2.87 (0.25)	16.81 (8.38)	9.05 (2.50)	16.39 (8.00)	91.50
21	PB 1756	3.79 (13.50)	11.34 (127.50)	7.01 (1.50)	20.69 (12.50)	7.85 (2.00)	20.24 (12.00)	86.50
22	MPMH 21	4.35 (18.00)	13.36 (177.50)	7.83 (1.88)	26.10 (19.38)	15.30 (7.00)	24.33 (17.00)	80.50
23	RHB 223	3.99 (15.00)	12.29 (150.00)	7.01 (1.50)	23.27 (15.63)	9.96 (3.50)	21.47 (13.50)	84.50
24	Pratap	3.15 (9.00)	9.41 (87.50)	3.46 (0.38)	16.81 (8.38)	9.05 (2.50)	16.94 (8.50)	91.00
25	AHB 1269	4.06 (15.50)	12.48 (155.00)	6.08 (1.13)	22.27 (14.38)	12.85 (5.00)	22.77 (15.00)	85.50
26	86M01	2.23 (4.00)	6.24 (38.00)	2.87 (0.25)	10.57 (3.38)	6.09 (1.25)	10.52 (3.50)	96.50
27	KBH 108	3.79 (13.50)	11.66 (135.00)	5.35 (0.88)	21.44 (13.38)	7.85 (2.00)	20.24 (12.00)	87.50
28	86M86	4.41 (18.50)	13.64 (185.00)	7.86 (1.88)	25.37 (18.38)	15.30 (7.00)	24.33 (17.00)	82.50
29	MP 7878	4.12 (16.00)	12.59 (157.50)	6.08 (1.13)	23.27 (15.63)	11.44 (4.00)	21.95 (14.00)	84.50
30	Kaveri SuperBoss	4.74 (21.50)	14.78 (217.50)	8.11 (2.00)	28.73 (23.13)	17.94 (9.50)	26.19 (19.50)	77.50
31	NBH 4903	4.00 (15.00)	12.49 (155.00)	6.72 (1.38)	23.27 (15.63)	12.22 (4.50)	22.37 (14.50)	84.50
32	AHB 1200	3.99 (15.00)	12.48 (155.00)	6.72 (1.38)	23.27 (15.63)	12.22 (4.50)	22.37 (14.50)	84.50
	SE.m +/-	0.19	0.22	0.37	0.43	1.46	1.24	2.17
	C.D. 5%	0.56	0.63	1.07	1.25	4.21	3.59	6.28
	C.V. %	7.98	3.00	9.60	3.26	10.88	9.62	3.47

(*) arcsine transformed values, (#) Square root √ X+0.5 values, .Figure in parenthesis are original values.

The least per cent weight loss *i.e.* 0.75% after three months storage period, was recorded in NBH 5980 and APHB 126 and it was statistically at par with GHB 1305, MP 7214, PB 1939, MP 7173, MP 7179, US 7773, 86M01, JKBH 1870, DHBH 21003, KPH 6277, GHB 1337, PB 1756, KBH 10, HHB 67 Imp., Pratap, CZH 267 and RHB 223. The highest per cent weight loss was observed in HHB 344 (11.00%). After six months storage period least per cent weight loss (2.50%) was recorded in NBH 5992. However, it was at par with MP 7173, JKBH 1870, 86M01, APHB-126, PB 1939, US 7773, MP 7179, MP 7214 and GHB 1337. The highest per cent weight loss was recorded in HHB 344 (21.00%). After the six month storage period, the highest germination *i.e.* 97.00 % was recorded in NBH 5992. However, it was at par with JKBH 1870, 86M01, MP 7214, MP 7173, MP 7179, GHB 1337, GHB 1305, APHB 126, PB 1939, US 7773, HHB 67 Imp and Pratap. The least germination was recorded in Kaveri Super Boss (77.50%). Raghavani *et al,* (*2*008) reported that the hybrids GHB 538 and GHB 558 were found the most promising against *T. castaneum*on the basis of lowest per cent grain damage and adult emergence. Hybrid, GHB-1305 released at National level during *kharif* season in scanty rainfall areas of Rajasthan, Gujarat and Haryana state (zone A_1) as early maturity hybrid for general cultivation (Anon., 2025).

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MS Received on 20th June, 2025
MS Accepted on 18th September, 2025

DOI: 10.55278/NOAP2215

Evaluating bagging as a non-chemical screening method to manage grasshoppers in cowpea (*Vigna unguiculata* L. Walp)

Pallavi Nair K[1]* and Manuel Alex[2]
Regional Agricultural Research Station, Kumarakom, Kottayam,
686563, Kerala, India
Krishi Vigyan Kendra, Kottayam, 686563, Kerala, India
****Corresponding author: pallavi.k@kau.in***

Abstract

This study evaluated the effectiveness of bagging as a physical exclusion technique for managing grasshopper infestation in cowpea (*Vigna unguiculata* L. Walp), in comparison with chemical and botanical treatments. Five management strategies were assessed: chemical control (Malathion 50 EC), traditional practices, azadirachtin application, physical bagging, and an untreated control. Percent damage was recorded at 2, 5, 7, 10, and 14 days after transplanting (DAT). Among all treatments, the physical bagging method consistently maintained zero damage throughout the 14-day observation period, demonstrating significantly superior efficacy. Chemical and traditional methods showed moderate initial effectiveness but declined over time, while azadirachtin was the least effective. These findings highlight bagging as a promising, eco-friendly alternative to chemical control, particularly suited for smallholder farmers seeking sustainable and affordable pest management solutions.

Key words: Bagging, grass hopper, cowpea, management

Cowpea (*Vigna unguiculata* L. Walp) represents a vital leguminous crop across tropical and subtropical regions, providing an essential source of protein for millions of people worldwide (Singh *et al*., 2003). However, production faces significant constraints due to insect pest attacks, with grasshoppers being particularly destructive herbivores capable of causing substantial crop losses (Tiroesele *et al*., 2015). Even though these orthopteran pests are reported as a minor pest category (D. Kumar and P. Narain, 2005) they feed on shoot apices, growing tips (Fig a, b) and leaves, resulting in dead terminals, arrested growth, bushy appearance and defoliation. Traditional pest management strategies in cowpea production rely heavily on synthetic chemical insecticides, which present numerous concerns including environmental contamination, non-target organism effects, resistance development and health risks to farmers and consumers (Sharma *et al*., 2017). The search for alternative, sustainable pest management approaches has intensified in recent years, focusing on methods that are economically viable for smallholder farmers while minimizing environmental impact. Physical exclusion strategies represent a promising direction in integrated pest management, offering mechanical barriers against insect pests without chemical inputs. Bagging techniques, where protective covers are placed over plants or plant parts have shown success in fruit crops but remain underexplored for field crops like cowpea (Aziz *et al.*, 2013). This research aimed to evaluate the efficacy of bagging as an exclusion method compared to conventional chemical control, traditional farmer methods and botanical alternatives for managing grasshopper attack in cowpea.

Materials and methods

The experiment was conducted during the kharif season of 2024 at the Regional Agricultural Research Station, Kumarakom, Kottayam, using a randomized complete block design (RCBD) with five treatments and four replications. Each experimental plot measured 10 m × 4 m, with a 1 m buffer zone between plots to minimize treatment interference.

Cowpea seeds (*Vigna unguiculata* L. Walp; Variety: Vellayani Jyothika) were raised in a nursery and transplanted at a spacing of 2 m × 2 m between plants. Standard agronomic practices—including fertilization, irrigation, and weed management—were uniformly applied across all plots, except for pest management, which varied according to the treatment.

Treatments were imposed immediately after transplanting and included:

- T1: Chemical control using Malathion 50 EC @ 500–750 g *a.i.*/ha
- T2: Traditional method (Fig. C) — staking-based exclusion barrier using small bamboo pieces around individual plants
- T3: Botanical treatment with Azadirachtin 0.03% EC
- T4: Physical exclusion method (Fig. D) — bagging/covering of plants using polypropylene covers with aeration holes
- T5: Untreated control

For the physical exclusion treatment (T4), polypropylene covers (open at both ends) were used to fully enclose the plants after seedling establishment. These covers were supported by stakes to prevent direct contact with foliage while ensuring adequate ventilation, irrigation access, and sunlight penetration.

Grasshopper damage was assessed visually by examining five randomly selected plants per plot. Percent damage was calculated as the proportion of plants showing feeding injury relative to the total number of plants. Observations were recorded at 2, 5, 7, 10, and 14 days after transplanting (DAT).

To normalize the data distribution, percentage damage values were subjected to arcsine transformation prior to statistical analysis. The transformed data were analyzed using analysis of variance (ANOVA) in GRAPES 1.1.0 software. Treatment means were separated using the least significant difference (LSD) test at a 5% probability level ($p = 0.05$).

Fig. a & b: Damage symptoms of grasshopper on cowpea

Fig c: Traditional method

Fig d: Physical method (bagging/covering of plants with polypropylene covers with holes for aeration)

Results

The analysis of data on percent damage caused by grasshoppers across different treatments and observation intervals revealed significant differences in treatment efficacy (Table 1).

The physical method demonstrated complete protection (0% damage), which was maintained throughout the observation period. The chemical treatment (T1) provided moderate protection initially with 12% damage at 2 DAT, but its efficacy deteriorated over time, reaching 96% damage by 14 DAT. Similarly, the traditional method (T2) showed promising early protection (6% damage at 2 and 5 DAT) but declined to 92% damage by the end of the observation period. The botanical treatment using azadirachtin (T3) performed poorly throughout the experiment, with damage increasing from 10% at 2 DAT to 100% by 14 DAT, showing no statistical difference from the untreated control by the end of the observation period. The untreated control (T5) exhibited consistently high levels of damage, increasing from 50% at 2 DAT to 100% by 14 DAT, demonstrating the severe threat posed by grasshoppers to unprotected cowpea plants.

Table 1: Percent damage by grasshoppers in cowpea under different management strategies

Treatments	**Percent damage (%)**				
	2DAT	**5DAT**	**7DAT**	**10 DAT**	**14 DAT**
T1: Chemical treatment (Malathion 50 EC @ 500-750 g *a.i.*/ha)	12.00 (0.023) ^{b}	26.00 (0.040) ^{ab}	26.00 (0.040) ^{abc}	52.00 (0.071) ^{b}	96.00 (0.098) ^{a}
T2: Traditional method	6.00 (0.002) ^{b}	6.00 (0.012) ^{b}	26.00 (0.032) ^{bc}	74.00 (0.085) ^{ab}	92.00 (0.098) ^{a}
T3: Azadirachtin 0.03%EC	10.00 (0.015) ^{b}	46.00 (0.053) ^{a}	52.00 (0.063) ^{ab}	90.00 (0.094) ^{a}	100.00 (0.1) ^{a}
T4: Physical method (cover)	0.00 (0.002) ^{b}	0.00 (0.002) ^{b}	0.00 (0.002) ^{b}	0.00 (0.002) ^{b}	0.00 (0.002) ^{b}
T5: Untreated control	50.00 (0.071) ^{a}	60.00 (0.077) ^{a}	70.00 (0.083) ^{a}	80.00 (0.088) ^{ab}	100.00 (0.1) ^{a}
CD	0.027	0.038	0.045	0.019	0.004
SE (m)	0.009	0.013	0.015	0.006	0.001

Values in parentheses are transformed values. Means followed by the same letter in a column are not significantly different at p=0.05. DAT: Days after transplanting

Discussion

This study demonstrates the remarkable efficacy of physical exclusion through bagging as a method for protecting cowpea from grasshopper damage. This finding aligns with Aziz *et al.* (2013) and Sharma *et al*. (2014), who reported similar success with physical barriers against insect pests in other crops. The chemical treatment using Malathion, despite being a conventional approach, showed only temporary effectiveness, with protection diminishing significantly after 7 days. This reduction in efficacy could be attributed to the degradation of the active ingredient, development of pest resistance, or new infestations of grasshoppers migrating from surrounding areas (Roditakis *et al*., 2017). The traditional method performed comparably to chemical control initially but also failed to provide long-term protection. The poor performance of azadirachtin was unexpected, considering previous studies documenting its effectiveness against certain insect pests (Schmutterer, 1990). The limited efficacy observed in this study might be related to the specific grasshopper species involved, application methodology, or environmental conditions affecting the stability of the azadirachtin. The consistent protection provided by the physical bagging method throughout the observation period highlights its potential as a sustainable alternative to chemical control. This approach offers several advantages like long lasting protection, environmental sustainability, resistance management etc.

Conclusion

This study conclusively demonstrates that bagging as a physical exclusion method offers superior protection against grasshopper damage in cowpea compared to chemical, traditional, and botanical alternatives. Once properly implemented, the bagging technique provided near-complete protection and sustained its efficacy throughout the 14-day observation period.

In contrast, all other treatments exhibited a marked decline in effectiveness over time. These findings carry significant implications for sustainable pest management, particularly for smallholder farmers seeking viable alternatives to synthetic pesticides. The physical exclusion strategy offers an environmentally friendly, low-cost solution that aligns with the principles of agroecology and promotes resilient, pesticide-free cowpea cultivation.

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MS Received on 05th June 2025
MS Accepted on 12th September 2025

DOI: 10.55278/VHZK2850

Influence of panchagavya foliar nutrition on silk protein synthesis in multivoltine silkworms (*Bombyx mori* Linn.)

Sanjai Kumar Gupta[1] and Awadhesh Singh Yadav[2]
Department of Zoology, Silkworm/Entomology Laboratory, Veer Bahadur Singh Post Graduate Government Degree College, Campierganj, Gorakhpur-273158, India
Department of Zoology, Government Post Graduate College, Chunar Mirzapur-231304. U.P , India
Corresponding author: drsanjaigupta1976@gmail.com

Abstract

The silk gland of *Bombyx mori* is a specialized tubular organ comprising three regions: the posterior silk gland (producing fibroin), the middle silk gland (producing sericin), and the anterior silk gland (forming the excretory duct). Fibroin forms the structural core of silk, while sericin acts as a natural adhesive. Sericulture is a labor-intensive, remunerative, and rural welfare-oriented agro-enterprise in India, offering significant employment and economic benefits to agrarian communities. This study investigates the impact of panchagavya foliar spray on mulberry (*Morus alba*) and its influence on cocoon yield, silk gland weight, and post-cocoon traits specifically fibroin and sericin contentin multivoltine Nistari and PM races. Panchagavya application significantly enhanced mulberry leaf quality, leading to increased silk gland weight in fifth instar larvae and improved fibroin and sericin content. These improvements translated into higher cocoon productivity and filament quality. Sericin, often discarded in textile processing, holds substantial biomedical and commercial value, and its recovery contributes to environmental sustainability. The findings suggest that panchagavya foliar spray is a viable, eco-friendly strategy for boosting silk yield and quality, with practical benefits for silkworm grainage and reeling operations. This approach aligns with sustainable sericulture practices and supports agroecological development.

Keywords: Nistari race, Pure Mysore race, Salivary gland, Moriculture.

Introduction

The silkworm (*Bombyx mori*) produces silk through a specialized tubular organ known as the silk gland, which synthesizes and secretes silk proteins expelled via the spinneret to form a cocoon. The gland is anatomically divided into three regions: the posterior silk gland (PSG), which secretes fibroin—a robust, fibrous structural protein forming the core of silk; the middle silk gland (MSG), which produces sericin—a gelatinous protein acting as a natural adhesive; and the anterior silk gland (ASG), which forms the excretory duct facilitating the transformation of silk dope into solid fiber through dehydration and stretching.

The silk gland comprises heavy (H) chains, light (L) chains, and glycoproteins linked by disulfide bonds.

Sericin, synthesized in the labial gland, surrounds fibroin filaments and forms the compact cocoon structure. It possesses biomedical properties such as enhancing cell adhesion, proliferation, and moisture retention (Kundu, S.C., 2008; Wu, J.H., 2007). During cocoon processing, sericin is removed via degumming, while fibroin is converted into raw silk for textile production (Mondal, M., 2007; Padol, A.R., 2012). Sericulture is one of the oldest agricultural practices, originating in North China over 5000 years ago (Nagaraju, J., 2002; Joseph, B., 2012), and has since expanded globally (Altman, G.H., 2003; Wang, W.H., 2021).

In Bombyx mori, silk gland development is rudimentary from the 1st to 4th instars, producing minimal silk for tegument repair. At the 5th instar, hypertrophy occurs, increasing cellular volume and silk biosynthesis, with gland weight comprising 20–40% of the insect's total weight (Gulrajani, M.L., 2005; Fabiani, C., 1996). The PSG, approximately 15 cm long with ~500 secreting cells, is a typical exocrine gland (Aramwit, P., 2009; Kato, N., 1998). The MSG can be subdivided into four zones—each synthesizing distinct sericin types (Freddi, G., 2003). Sericin forms three concentric layers around fibroin filaments (Zhu, L.J., 1998; Ki, C.S., 2009).

Fibroin is secreted in solution (~15% protein), surrounded by sericin, and gradually concentrated into a gel (~30% protein), exhibiting nematic liquid crystal properties (Cho, OK.Y., 2003; Arami, M., 2007). During spinning, water and ions are absorbed in the ASG, solidifying the silk thread. Head movement of Bombyx mori aids protein orientation, increasing hydrophobicity and water loss (Aramwit, P., 2012; Takasu, Y., 2002). Cocoon formation takes ~3 days, using a continuous silk thread (900–1500 m), offering protection during metamorphosis. Cocoon composition includes fibroin and sericin (98%), p25 protein, fats and waxes (0.4–0.8%), inorganic salts (0.7%), and pigments (0.2%) (Padamwar, M.N., 2004; Khan, M.R., 2010).

Organic inputs like green manures, biofertilizers, and certified organic formulations enhance mulberry (*Morus alba*) yield and silk quality. Mulberry, revered as "Kalpvriksha" or "Kamdhenu," thrives in tropical and subtropical regions. Panchagavya foliar spray—a nutrient-rich organic formulation—improves leaf quality, nutrient uptake, and silkworm performance. Foliar feeding bypasses soil limitations, enhancing absorption through stomata and epidermis. It boosts larval development, silk gland growth, and fibroin/sericin content in multivoltine races like Nistari and Pure Mysore. India's sericulture, dominated by tropical crossbreeds (multivoltine × bivoltine), relies on high-yielding mulberry varieties and optimized nutrition for superior silk production.

Materials and Method

Panchagavya, a well-known organic formulation, was prepared to enhance mulberry growth and yield. It contains five cow-derived products; cow dung (7 kg), cow urine (10 L), milk (3 L), curd (2 L), and ghee (1 kg)along with jaggery (3 kg), ripe bananas (1 dozen), tender coconut water (3 L), and plain water (10 L). Initially, cow dung and ghee were mixed thoroughly and stirred twice daily for three days. Cow urine and water were then added and fermented for 15 days with regular stirring (Venkataramana *et al*., 2009). Afterward, milk, curd, coconut water, jaggery, and banana were incorporated, and the mixture was allowed to ferment for a total of 30 days. Panchagavya is rich in macro- and micronutrients and growth-promoting hormones beneficial for mulberry leaf quality.

Disease-free layings of two pure multivoltine silkworm races Nistari and PM were procured from the Sericultural Station, Baharaich, and Uttar Pradesh. Larvae were reared on fresh mulberry leaves under controlled conditions: temperature (26±1°C), relative humidity (80±5%), and photoperiod (12±1 hours). After the fourth moult, larvae were divided into three groups with three replications each. For each treatment, 25 silk glands were dissected from fifth instar larvae.

Panchagavya foliar spray was diluted in distilled water and applied to mulberry leaves at concentrations of 10 µg/larva and 15 µg/larva, fed to larvae on day 1 and day 2 of the fifth instar. Control larvae received leaves sprayed with distilled water only. Post-cocoon parameters including filament length, filament weight, non-breakable filament length, denier, reelability, and size deviation were recorded for both control and treated groups of Nistari and PM races of *Bombyx mori* Linn.

Result

The results presented in Table-1 reveal the extent of changes in the fifth instar larval, weight of silk gland, fibroin and sericin content of control and experimental multivoltine Nistari and Pure Mysore races of silk worm, Bombyx mori Linn.

Weight of silk gland

A significant effect ($P<0.001$) in the weight of silk gland showing percent increase of 36.71 and 22.40 in race Nistari and 31.21 and 18.87 in Pure Mysore were noticed when treated with panchagavya foliar spray of 10µg/larva and 15µg/larva over control parameter of experiment.

Fibroin: The fibroin content recorded was 78.10%, 86.70% and 84.80% in control experiment and when treated with panchagavya foliar spray of 10µg/larva and 15µg/larva respectively in pure Nistari race 77.20%, 84.75% and 82.25% were observed in Pure Mysore.

Sericin: The sericin content recorded was 23.90%, 15.30% and 17.20% in control and when treated with panchagavya foliar spray of 10µg/larva and 15µg/larva respectively in pure race Nistari and 24.80%, 17.25% and 19.75 were observed in Pure Mysore race.

Table 1. Effect of experimental panchagavya foliar spray nutrition of 10µg/larva and 15µg/larva silkworm multivoltine Nistari & PM races of *Bombyx mori* Linn fed on mulberry leaf. Values are the mean of the 25 individual observations. Mean ±S.D; and '+' indicate (%) increase and '-'decrease over control respectively.

S. No.	**Parameters**	**Multivoltine Nistari races**			**Multivoltine PM (Pure Mysore races)**		
		Control	**Experimental (Panchagavya foliar spray)**		**Control**	**Experimental (Panchagavya foliar spray)**	
			Panchagavya 10µg/larva	**Panchagavya 15µg/larva**		**Panchagavya 10µg/larva**	**Panchagavya 15µg/larva**
1-	Weight of silk gland (gm)	0.560 ± 0.051	0.760±0.075 +36.71	0.680±0.059 +22.40	0.470 ±0.038	0.612±0.0054 +31.21	0.554±0.051 +18.87
2-	Fibroin content (%)	78.10 ±7.23	86.70±8.12 +11.15	84.80±7.89 +8.69	77.20 ±5.98	83.75±6.53 +9.91	82.25±7.32 +6.63
3-	Sericin (%)	23.90 ±1.88	15.30±1.36 -37.55	17.20±1.57 -29.26	24.80 ±2.10	17.25±1.41 -31.72	18.75±1.64 -21.22

"P"- Statistical Significant $P<0.001$ SD- Standard Deviation/ Standard Error

Discussion

The application of panchagavya foliar spray significantly enhanced economic traits in multivoltine silkworm races, particularly Nistari and Pure Mysore. The observed improvements in pre- and post-cocoon parameters—including cocoon weight, shell weight, and shell ratio can be attributed to increased biosynthesis of proteins and nucleic acids in the silkworm, stimulated by nutrient-enriched mulberry leaves. Notably, fibroin content showed marked improvement, contributing to superior silk quality with greater export potential. Among the tested concentrations, 10 µg/larva proved more effective than 15 µg/larva, indicating an optimal threshold for nutrient uptake and metabolic stimulation.

Panchagavya's impact reflects the metabolic flexibility and adaptability of Bombyx mori, where basal metabolism was enhanced, indirectly influencing lifespan and silk gland activity. Physiological and molecular changes likely promoted active biosynthesis of silk proteins, reinforcing the need for large-scale trials to validate its utility in sericulture. As a plant growth promoter, panchagavya holds promise for improving silk yield and quality, with significant implications for grainage and reeling industries.

The mulberry silkworm (Bombyx mori) is a cornerstone of the silk industry due to its silk-secreting capacity. Its nutritional requirements are exclusively met by mulberry (Morus alba), and leaf quality directly affects larval growth and silk production (Genç *et al*., 2009; Padamwar, M.N., 2005).

Approximately 70% of silk proteins are derived from mulberry leaves, underscoring the importance of nutrient-rich foliage (Khire, T.S., 2010; Yamada, H., 2001).

Sericin, a “glue-like” protein surrounding fibroin filaments, plays a vital role in cocoon integrity (Aramwit, P., 2010; Vaithanomsat, P., 2008). Its presence imparts toughness to silk fibers, while its absence yields smoother, lustrous silk (Srinivas, N., 2015). Structurally, sericin is a globular protein composed of random coils and β-sheets, which transition under mechanical stress, moisture, and temperature. At 50–60°C, sericin becomes soluble; at lower temperatures, it forms β-sheets and gels (Zhang, Y.Q., 2002; Kundu, S.C., 2008). Sericin comprises 18 amino acids with polar groups hydroxyl, carboxyl, and amino—enabling cross-linking and polymer interactions (Yun, H., 2013; Sasaki, M., 2000). Its elemental composition includes 46.5% carbon, 31% oxygen, 16.5% nitrogen, and 6% hydrogen (Ki, C.S., 2009; Gulrajani, M.L., 1993). These biochemical traits confer sericin with biocompatibility, antibacterial, antioxidant, and moisturizing properties (Yang, Y., 2013; Rajkhowa, R., 2011).

Sericin is classified into three fractions—A, B, and C—based on water solubility (Gulrajani, M.L., 2001; Subrata Devi, D., 2012). Fraction A, the most soluble, is found in the outer cocoon layer and contains 17.2% nitrogen. Fraction B, in the intermediate layer, includes tryptophan and 16.8% nitrogen. Fraction C, adjacent to fibroin, is least soluble and contains 16.6% nitrogen along with proline (Capar, G., 2008; Castrillon, D.C., 2018).

Thus, foliar application of panchagavya enhances mulberry leaf quality, directly benefiting silkworm development, silk gland growth, and fibroin/sericin synthesis—ultimately improving cocoon productivity and silk quality.

Conclusion:

The effective utilization of panchagavya foliar spray significantly enhances mulberry leaf quality, providing nutrient-rich, pest-free foliage essential for silkworm rearing. Its application improves the biochemical composition of mulberry, leading to increased fibroin and sericin protein levels in the silk glands of fifth instar larvae and improved cocoon and post-cocoon parameters in multivoltine silkworm races such as Nistari and Pure Mysore.

The study confirms that mulberry leaves were not adversely affected even with partial or complete replacement of chemical fertilizers by organic supplements. Panchagavya foliar spray demonstrated a positive impact on silk gland development, cocoon productivity, and silk quality, with 10 µg/larva showing greater efficacy than 15 µg/larva. This organic approach supports ecological farming by enhancing soil fertility, microbial activity, and nutrient uptake, thereby improving silk yield and quality.

Given the economic importance of Bombyx mori in the grainage and reeling industry, the findings hold substantial value for sericulture farmers seeking sustainable alternatives. Physiological and molecular changes induced by panchagavya may stimulate active biosynthesis of silk proteins, warranting further investigation.

Large-scale trials are recommended to validate its effectiveness across diverse agro-climatic zones and soil types. Establishing optimal application protocols will help farmers achieve higher leaf yield and nutritive value, promoting healthy larval development and superior cocoon quality. Panchagavya foliar spray thus emerges as a cost-effective, eco-friendly strategy for enhancing silk production and quality, with significant implications for the sericulture sector.

Acknowledgements

I would like to express our sincere gratitude and extremely thankful to the principal and head to Zoology Department of Veer Bahadur Singh Government Post Graduate College, Campierganj, Gorakhpur U.P (India) for providing necessary facilities and for field studies.

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MS Received on 05th June, 2025
MS Accepted on 12th September 2025

DOI:10.55278/LOJX6269

Effect of *Apis florea* pollination on seed yield and quality traits in Niger (*Guizotia abyssinica*)

Nithinkumar H. L[*]. Vijayakumar, K. T. Nayimabanu Taredahalli, Rakshitha, T. N. and Chetan V. M.

AICRP on Honey bees and Pollinators, University of Agricultural Sciences, Bangalore-560065, India

Corresponding author: nithinkumarhl@gmail.com

Abstract

Niger (*Guizotia abyssinica*) is a commercially valuable oilseed crop that depends on efficient pollination to achieve optimal seed yield and quality. Among tropical and subtropical regions, the dwarf honey bee, *Apis florea*, plays a notable role as a natural pollinator. This study evaluated the impact of *A. florea* on Niger seed production through a randomized field experiment comprising three treatments: open pollination (OP), *Apis florea*-mediated pollination, and pollinator exclusion (control). Measurements included heads per plant, head weight, seeds per head, seed weight, and seed morphometric traits. Plants pollinated by *A. florea* showed an 84.3% increase in head weight (1.53 g vs. 0.83 g), a 2,490% increase in seeds per head (33.67 vs. 1.30), and complete seed viability compared to the control group. Open pollination yielded the highest number of heads per plant (15.00) and seeds per head (43.33), while *A. florea* pollination resulted in intermediate but significantly improved performance. The findings affirm *Apis florea* as an effective pollinator that substantially enhances seed productivity and quality in Niger, advocating for its conservation and ecological management in regions where it occurs naturally to support sustainable cultivation practices.

Keywords: *Apis florea*, Niger seed, pollination efficiency, seed yield, oilseed crops, bee pollination

Introduction

Niger (*Guizotia abyssinica* (L.f.) Cass.) is a commercially important oilseed crop grown primarily in Ethiopia, India, and various regions of Africa and Asia (Geleta *et al*., 2007; Wubetu *et al*., 2018). The crop is valued for its high-quality edible oil containing 35-50% oil content and excellent nutritional seed properties (Ramadan *et al*., 2003; Chakraborty *et al*., 2009). Like many members of the Asteraceae family, Niger exhibits protandrous flowers with temporal separation of male and female phases, making it highly dependent on cross-pollination by insects, particularly bees (Free, 1993; Abrol, 2012).

Apis florea Fabricius, commonly referred to as the dwarf honey bee, is a significant pollinator species distributed across tropical and subtropical regions of Asia and parts of Africa (Ruttner, 1988; Hepburn *et al*., 2001). This small-bodied bee species (8-10mm) is known for its effective foraging behaviour, high flower constancy, and ability to visit a diverse range of flowering plants including important agricultural crops (Wongsiri *et al*., 1997; Radloff *et al*., 2010). Understanding the pollination efficiency of *A. florea* on economically important crops like Niger is crucial for developing sustainable agricultural practices and evidence-based pollinator conservation strategies (Klein *et al*., 2007).

Previous studies have demonstrated the critical importance of bee pollination in various oilseed crops, with yield increases ranging from 18-95% in different species (Delaplane and Mayer, 2000; Garibaldi *et al*., 2013). However, limited research exists specifically examining the role of *A. florea* in Niger pollination, despite this species being prevalent in many Niger-growing regions (Oldroyd and Wongsiri, 2006). This study aims to quantify the impact of *A. florea* pollination on Niger seed yield and quality parameters compared to open pollination and pollinator exclusion treatments.

Materials and Methods

Experimental Design

A field experiment was conducted in 2021-22 at University of Agricultural Sciences, GKVK, Bangalore using a randomized complete block design with three treatments: Open Pollination (OP) - natural pollination by all available pollinators; *Apis florea* Pollination - controlled exposure to *A. florea* colonies; Control - pollinator exclusion using fine mesh cages

At harvest, a comprehensive set of yield and seed quality parameters was recorded, including the number of heads per plant, head weight per plant (g), number of seeds per head, seed weight per head (g), number of chaffy (non-viable) seeds, number of sound (viable) seeds, single seed weight (g), and seed length (mm). In addition, a visitation frequency experiment was conducted to determine the optimum number of *Apis florea* visits required for effective pollination in *Niger*. Individual flower heads were subjected to controlled visitation treatments ranging from 1 to 10 visits per head, and pollination metrics were evaluated corresponding to each visitation level.

Statistical Analysis

Experimental data were subjected to analysis of variance (ANOVA) to determine the significance of treatment effects. Treatment means were compared using appropriate post-hoc tests to account for multiple comparisons. All statistical procedures were performed using standard analytical software.

Results and discussion

Plant Productivity Parameters

The number of heads per plant varied across treatments, with open pollination producing the highest mean count (15.00), followed by *Apis florea* pollination (14.33), and the control (13.00). In contrast, head weight per plant exhibited more pronounced differences. Plants exposed to *A. florea* pollination produced heads that were 84% heavier than those in the control group (1.53 g vs. 0.83 g), demonstrating substantial improvement in biomass. Open pollination yielded the greatest head weight overall (1.73 g), suggesting additive contributions from multiple pollinator species.

Seed Production and Viability

Seed production showed the most striking differences between treatments, with highly significant treatment effects (F = 156.89, P < 0.001). Open pollination resulted in 43.33 seeds per head, while *A. florea* pollination produced 33.67 seeds per head, both significantly higher than the control treatment which yielded only 1.30 seeds per head, representing a 97% reduction compared to open pollination (Table 1).

The dramatic increase in seed production (2,490% increase compared to control) aligns with studies by Delaplane and Mayer (2000) who reported similar magnitude increases in bee-pollinated oilseeds. The intermediate performance of *A. florea* treatment compared to open pollination is consistent with findings by Garibaldi *et al.* (2013), who demonstrated that pollinator diversity often enhances crop yields beyond single-species pollination services.

Seed viability was completely absent in control treatments, with no sound seeds produced. Both pollination treatments produced significantly different numbers of viable seeds (F = 201.56, P < 0.001), with *A. florea* pollination resulting in 31.67 sound seeds per head and open pollination producing 38.83 sound seeds per head. The number of chaffy seeds showed significant treatment effects (F = 12.34, P < 0.01), with minimal numbers in pollination treatments (2.00-4.50) and complete absence in controls.

The number of chaffy seeds was minimal in pollination treatments (2.00-4.50) and absent in controls. The complete failure of seed production in control treatments supports the classification of Niger as an obligate outcrossing species, as suggested by Abrol (2012) in his comprehensive review of oilseed pollination. This finding is particularly significant given that Geleta *et al.* (2007) identified protandry as the primary mechanism preventing self-fertilization in Niger, making external pollinators essential for reproductive success.

Seed Quality Parameters

Individual seed weight showed significant treatment differences (F = 8.91, P <

0.01), remaining consistent between open pollination and *A. florea* pollination treatments (0.0023g each), while control seeds were significantly lighter (0.0017g). Seed length followed a similar pattern (F = 15.67, P < 0.001), with pollinated treatments producing significantly longer seeds (4.33-4.67mm) compared to control (3.67mm). No significant differences were observed between the two pollination treatments for either seed weight or length parameters.

Beyond quantity, *A. florea* pollination significantly improved seed quality parameters, with increased seed weight and length indicating enhanced seed development. This aligns with research by Klein *et al*. (2007) who found that adequate pollination not only increases seed set but also improves seed quality in various crops. The 35% increase in seed length observed in *A. florea*-pollinated plants compared to controls suggests better embryo development, potentially translating to higher oil content as reported by Ramadan *et al*. (2003) in well-pollinated Niger seeds.

The uniform single seed weight between *A. florea* and open pollination treatments (0.0023g) indicates that *A. florea* achieves pollination quality comparable to diverse pollinator assemblages, supporting findings by Wongsiri *et al*. (1997) regarding the high foraging efficiency of this species.

These findings have important implications for Niger cultivation in regions where *A. florea* is prevalent, particularly in South and Southeast Asia where this species is native (Ruttner, 1988). Following recommendations by Delaplane and Mayer (2000) for pollinator-dependent crops, farmers should consider: Maintaining *A. florea* nesting habitat within 500m of Niger fields, as suggested by Radloff *et al*. (2010) based on this species' foraging range. Avoiding broad-spectrum pesticide applications during Niger flowering period, following integrated pest management principles outlined by Abrol (2012). Implementing pollinator-friendly practices such as maintaining flowering hedgerows, as recommended by Garibaldi *et al*. (2013) for enhancing wild bee populations. The economic implications are substantial, given that proper pollination management could increase Niger yields by over 2,000% compared to pollinator-limited conditions, potentially transforming farm profitability in regions dependent on this crop (Chakraborty *et al*., 2009).

The high pollination efficiency of *A. florea* demonstrated in this study underscores the importance of conserving this species and its habitat, as emphasized by Oldroyd and Wongsiri (2006) in their assessment of Asian honey bee conservation status. Declining bee populations, as documented globally by various authors, could significantly impact Niger yields in regions dependent on this pollinator (Hepburn *et al*., 2001). The intermediate position of *A. florea* between control and open pollination treatments suggests that while this species provides substantial pollination services, maintaining pollinator diversity remains important for optimal crop production, supporting the pollinator portfolio approach advocated by Wubetu *et al*. (2018).

Visitation frequency requirements

The visitation frequency study revealed a strong positive correlation between the number of *A. florea* visits and pollination success (Table 2). Head weight increased dramatically from 0.08g with single visits to 1.00g with 10 visits, representing a 1,150% increase. Similarly, seed production per head increased from 5.00 seeds with one visit to 36.33 seeds with 10 visits.

Table 1. Effect of different pollination treatments on Niger seed production parameters

Parameter	Open Pollination	*Apis florea* Pollination	Control	F-value	P-value
Heads/Plant	15.00^a	14.33^a	13.00^a	2.45	0.156
Head Weight/Plant (g)	1.73^a	1.53^a	0.83^b	18.72	<0.001
Seeds/ Head	43.33^a	33.67^b	1.30^c	156.89	<0.001
Seed Weight/Head (g)	0.14^a	0.13^a	0.00^b	89.43	<0.001
Sound Seeds/Head	38.83^a	31.67^b	0.00^c	201.56	<0.001
Chaffy Seeds/Head	4.50^a	2.00^b	0.00^c	12.34	<0.01
Single Seed Weight (g)	0.0023^a	0.0023^a	0.0017^b	8.91	<0.01
Seed Length (mm)	4.67^a	4.33^a	3.67^b	15.67	<0.001

*Means within rows followed by different letters are significantly different (P < 0.05, Tukey's HSD test)

Sound seed production showed the most pronounced response to visitation frequency, increasing from 3.33 seeds per head with single visits to 35.00 seeds per head with 10 visits. The proportion of chaffy seeds remained relatively low across all visitation levels (0.67-9.67 seeds), indicating consistent fertilization quality regardless of visitation intensity.

Notably, substantial improvements in pollination parameters were observed between 6-9 visits, with head weight increasing from 0.22g to 0.67g, and seed production stabilizing around 30-35 seeds per head beyond 6 visits. Single seed weight remained consistent across visitation levels (0.003-0.005g), while seed length showed optimal development (5.00mm) at intermediate visitation frequencies (2-5 visits).

The visitation frequency study provides crucial insights into the relationship between *A. florea* foraging behaviour and pollination success. The strong positive correlation between visitation number and seed production ($r^2 > 0.85$) demonstrates that Niger flowers benefit from multiple visits, consistent with findings by Delaplane and Mayer (2000) for other protandrous crops requiring pollen transfer over extended periods.

Table 2. Effect of *Apis florea* visitation frequency on Niger pollination parameters

No. of visitation	Head weight/Plant (n=10)	No. of seeds /head (n=10)	Seed weight/ head	No. of sound seeds	No. of chaffy seeds	Single seed weight	Length of seed (mm)
1	0.08	5.00	0.01	3.33	1.67	0.003	4.67
2	0.04	3.67	0.02	3.00	0.67	0.005	5.00
3	0.09	9.33	0.03	7.00	2.33	0.004	5.00
4	0.15	16.67	0.09	21.33	2.00	0.004	5.00
5	0.12	11.00	0.03	7.67	3.00	0.004	5.00
6	0.22	30.67	0.06	21.00	9.67	0.003	4.00
9	0.67	34.33	0.18	28.00	6.33	0.004	4.00
10	1.00	36.33	0.11	35.00	1.00	0.004	4.00

The threshold effect observed between 6-9 visits, where substantial improvements plateau, suggests an optimal visitation range for maximizing pollination efficiency. This finding aligns with research by Garibaldi *et al.* (2013) who documented similar threshold effects in bee-pollinated crops. The 1,150% increase in head weight from single to multiple visits emphasizes the importance of adequate pollinator abundance and flower constancy in Niger production systems.

The relatively stable seed quality parameters (single seed weight and length) across visitation levels indicate that *A. florea* maintains consistent pollen transfer quality regardless of visitation intensity, supporting the species' reputation for effective pollination services documented by Wongsiri *et al.* (1997).

Regression analysis of visitation effects

Linear regression was employed to quantify the relationship between *Apis florea* visitation frequency and key pollination parameters (Table 3). Strong positive correlations were observed for most yield-related traits, with head weight exhibiting the most robust association ($R^2 = 0.889$), followed by sound seed production ($R^2 = 0.784$). The regression coefficients suggest that each additional *A. florea* visit increases head weight by approximately 0.098 g and enhances sound seed production by 3.31 seeds per head. In contrast, single seed weight and seed length showed no significant correlation with visitation frequency, indicating that once fertilization has occurred, seed quality parameters remain largely unaffected by additional visits. Nevertheless, treated plants produced longer seeds (4.33–4.67 mm) compared to control plants (3.67 mm), suggesting indirect benefits from insect-mediated pollination.

Table 3. Regression analysis of *Apis florea* visitation frequency effects on Niger pollination parameters

Parameter	Regression Equation	R²	P-value	Slope	Intercept
Head Weight (g)	y = 0.098x - 0.085	0.889	<0.001	0.098	-0.085
Total Seeds/Head	y = 3.21x - 1.85	0.743	<0.01	3.21	-1.85
Sound Seeds/Head	y = 3.31x - 1.58	0.784	<0.01	3.31	-1.58
Seed Weight/Head (g)	y = 0.013x - 0.002	0.652	<0.05	0.013	-0.002
Single Seed Weight (g)	y = 0.00003x + 0.0037	0.045	>0.05	0.00003	0.0037
Seed Length (mm)	y = -0.094x + 5.13	0.301	>0.05	-0.094	5.13

The visitation frequency study offers vital insights into the pollination ecology of *Niger*, highlighting the value of repeated bee visits. The strong positive relationships for head weight ($R^2 = 0.889$, *P* $R^2 = 0.784$, *P Niger* inflorescences gain significantly from multiple *A. florea* visits. These findings align with observations by Delaplane and Mayer (2000), who reported similar patterns in other protandrous crops requiring successive pollen transfers over time.

The regression analysis reveals that each additional *A. florea* visit contributes approximately 0.098g to head weight and resulted 3.31 more sound seeds per head, providing quantitative metrics of pollination efficiency. This linear relationship supports the threshold effect observed between 6-9 visits, where substantial improvements plateau, suggesting an optimal visitation range for maximizing pollination efficiency. This finding aligns with research by Garibaldi *et al.*

(2013) who documented similar threshold effects in bee-pollinated crops.

Notably, single seed weight and seed length showed no significant correlation with visitation frequency ($R^2 = 0.045$ and 0.301 respectively, $P > 0.05$), indicating that *A. florea* maintains consistent pollen transfer quality regardless of visitation intensity. This supports the species' reputation for effective pollination services documented by Wongsiri *et al.* (1997) and suggests that seed quality parameters are determined by successful fertilization events rather than visitation intensity.

Conclusions

Apis florea proves to be a highly effective pollinator for Niger, dramatically improving seed yield and quality compared to pollinator exclusion. While open pollination (involving multiple pollinator species) produced the highest yields, *A. florea* alone contributed substantially to Niger reproductive success. These results support the development of management practices that conserve and promote *A. florea* populations in Niger-growing regions.

The study establishes critical baseline data for understanding crop–pollinator dynamics and advancing ecologically sustainable agricultural practices. Future research should focus on determining the optimal colony density of *A. florea* required to maximize pollination efficiency, as well as evaluating the agronomic and economic viability of managed *A. florea* pollination systems under varying agroclimatic conditions.

Acknowledgments

The authors acknowledge Indian Council of Agricultural Research- All India Coordinated Research Project on honey bees and pollinators, New Delhi for funding and Department of Apiculture, University of Agricultural Sciences, Bangalore for facilities to conduct this study.

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MS Received on 30th June, 2025
MS Accepted on 27th August, 2025

DOI: 10.55278/AIZA1729

Empowering farmers through biopesticide awareness: Strengthening ecosystem health for sustainable farming

Nandita Paul Ganguli and Subuhi Nishad
College of Agriculture, IGKV, Raipur, Chhattisgarh, India
Corresponding author: nanditapaul352@gmail.com

Introduction

The present study was undertaken in two villages Aamdi and Parsada-4 in Tehsil Abhanpur, District Raipur, (21.2514° N, 81.6296° E) as part of a research project under the National Service Scheme (NSS). Launched in 1969, commemorating the birth centenary of Mahatma Gandhi, NSS began in 37 universities with the active involvement of over 40,000 students. It was conceived as an extension of the higher education system with the aim of sensitizing and engaging youth in constructive community service during their academic journey.

Through NSS, students are encouraged to interact with local communities, understand ground realities, and contribute meaningfully to social and environmental development. One of the pressing challenges in contemporary agriculture is the overreliance on chemical pesticides, which has resulted in environmental degradation, health risks, the emergence of resistant pest populations, and long-term soil toxicity.

Amidst growing concern, biopesticides have emerged as a sustainable and eco-friendly alternative. Derived from natural sources such as plants, microorganisms, and minerals, biopesticides offer key advantages including biodegradability, target specificity, and minimal risk to non-target organisms, including humans.

The growing concerns over the harmful effects of chemical pesticides on human health, soil fertility, and the environment have led to a significant shift towards sustainable agricultural practices. Among these, the use of biopesticides has emerged as a promising, eco-friendly alternative. In India, various institutions such as the Indian Council of Agricultural Research (ICAR), Krishi Vigyan Kendras (KVKs), and outreach programs under initiatives like the National Service Scheme (NSS) have played a pivotal role in promoting the adoption of biopesticides among farmers (ICAR-NIBSM, 2025; IPFT, 2024).

Scientific reviews and field-based training programs have shown that biopesticides can be effectively integrated into farming systems when combined with proper farmer training, field demonstrations, and timely technical support. For example, ICAR-NIBSM organized the Viksit Krishi Sankalp

Abhiyan in 49 villages of Chhattisgarh, training over 4,100 farmers in sustainable farming techniques including biopesticide use (Times of India, 2025). Similarly, ICAR-NBAIR distributed biological pest control agents such as *Shatpada All-Rounder* in Karnataka, demonstrating their effectiveness against major pests like thrips and mites (Krishak Jagat, 2023).

To promote awareness and adoption of biopesticides, an outreach initiative was conducted under the NSS program. Awareness sessions were organized in the selected villages, where farmers were introduced to various types of biopesticides, their modes of application, comparative advantages over synthetic chemicals, and their role in achieving sustainable agriculture.

Scientists involved in these initiatives observed that farmer confidence increased when they witnessed visible field-level benefits and received direct guidance from agricultural experts (ICAR-NBAIR, 2023). However, despite this growing interest, widespread adoption of biopesticides remains limited due to issues such as high cost, inconsistent availability, perceived lower effectiveness, and limited awareness (Rai *et al*., 2021; FAO, 2023).

Therefore, community-level programs like NSS and government-led campaigns offer valuable platforms to bridge the knowledge and confidence gap by combining science-led innovations with local-level demonstrations and feedback mechanisms. This report highlights key scientific reviews, farmer outreach efforts, and institutional strategies to promote biopesticides, with a focus on their role in sustainable agriculture in India.

This article presents a comprehensive overview of biopesticides—exploring their classification, mechanisms of action, and field-level efficacy. Additionally, it evaluates the impact of NSS-led awareness campaigns in enhancing knowledge and influencing the behavioral shift of rural farming communities toward more environmentally responsible pest management practices.

Farmer-Led Transitions to Safer Pest Control in Chhattisgarh

This study, conducted during 2023–2024 in the agriculturally rich region of Chhattisgarh, explores the gradual transition of local farmers toward safer and more environmentally responsible crop protection practices. Using a combination of surveys, field observations, and participatory awareness programs, research activities were carried out in two villages—Aamdi and Parsada-4.

The project team engaged directly with 70 farmers who expressed interest in understanding or adopting biopesticide-based pest control. Through structured interviews, group discussions, and frequent on-site visits, valuable insights were gathered regarding current pesticide usage, preferred biopesticides, and their practical effectiveness in local farming systems.

This initiative was part of a broader outreach campaign aimed at creating awareness about the harmful consequences of conventional chemical pesticides. Interactive sessions, supported by locally relevant posters, leaflets, and live demonstrations, helped farmers recognize the environmental and health risks associated with chemical inputs—including soil and water contamination, harm to beneficial insects and aquatic fauna, and human health concerns such as dermatological and respiratory issues.

Simultaneously, alternatives like neem-based formulations, *Bacillus thuringiensis* (Bt), pheromone traps, and sticky traps were introduced as part of an integrated pest management strategy. These tools were shown to support crop protection while preserving ecological balance.

Adoption of Biopesticides and Observed Impact on Pest Populations

Data collected from the two villages revealed that approximately 22% of the participating farmers had adopted biopesticides, including neem-based extracts and *Bt.* Reported benefits included:

- Reduced incidence of key insect pests
- Minimal disruption to non-target organisms
- Improved indicators of soil health

A detailed record of pest prevalence, as reported by the farmers, is summarized in the following table

Table 1- Insect pests recorded on various crops at Aamdi and Parsada-4.

Categories	**Name of crops**	**Insect pests recorded in the study area**
Cereals crops	**Paddy**	Stem borer
		Gundhi bug
		Brown plant hopper
		Leaf folder
		Grasshopper
	Maize	Maize stem borer
		Fall army worm
Oilseeds crop	**Mustard**	Aphids
		Painted bug
Pulse crops	**Urd bean and Mung Bean**	Aphid
		Whiteflies

Categories	Name of crops	Insect pests recorded in the study area
		Red hairy caterpillar
		Bihar hairy Caterpillar
	Pigeon pea	Tur pod bug
		Tur pod borer
		Whiteflies
Vegetables Crops	**Brinjal**	Brinjal shoot and Fruit borer
		Hadda beetle
		Aphids
		Whiteflies
		Leafhopper
	Tomato	Tomato fruit borer
		Tobacco caterpillar
		Leaf miner
		Whiteflies
		Leafhopper
	Okra	Okra shoot and fruit borer
		Leafhopper
		Whiteflies
	Cowpea	Aphid
		Red hairy caterpillar
	Chilli	Fruit borer
		Chilli thrips
		Chilli mites
Cucurbita- ceous crops	**Bottle gourd, Cucumber, Bitter gourd, Ridge gourd.**	Red pumpkin Beetles
		Cucurbit fruit flies
		Semi looper
		Whiteflies

Table 2- General survey of farmers regarding knowledge about Biopesticides.

S. No.	Name	Knowledge about biopesticides Yes/No	Mode of insect control (Biopesticides /Chemical Control)	Biocontrol lab visited Yes/No
1	Shri. Surya Thakur	No	Chemical Control	No
2	Shri. Pankaj Yadav	No	Chemical Control	No
3	Smt. Nirmla Sahu	Yes	Bio pesticides Control	Yes
4	Ku. Jyoti Sahu	No	Chemical Control	No
5	Shri. Ramesh Unchal	No	Chemical Control	No
6	Shri. Sonu Mahraj	No	Chemical Control	No
7	Shri. Badu Yadav	Yes	Bio pesticides control	Yes
8	Shri. Rajkumar Tondan	No	Chemical Control	No
9	Shri. Ahok Mahilange	Yes	Chemical Control	Yes
10	Shri. SarojaniSahu	Yes	Bio pesticides Control	Yes
11	Shri. Narottam Yadav	Yes	Bio pesticides Control	Yes
12	Shri. Satish Sinha	No	Chemical Control	No
13	Shri. Raja Nirmalkar	No	Chemical Control	No
14	Shri. Sanju Yadav	Yes	Bio pesticides Control	Yes
15	Shri. BirendSahu	Yes	Bio pesticides Control	Yes

Table 3- Information about Biopesticides and their effectiveness to respondents.

Comparison of Biopesticide Types: Targets, Effectiveness, and Challenges				
Types	**Target pests**	**Effectiveness**	**Environmental impact**	**Challenges**
Bacterial (eg., *Bt*)	Caterpillar, beetles, nematodes	Highly effective, specific	Safe, but some resistance issues	Resistance development, environmental sensitivity
Fungal (eg., *B. basiana*)	Aphids, whiteflies, termites	Effective, needs specific conditions	Environmentally friendly	Requires moisture, slower action
Viral (eg., NPV)	Lepidopteran larvae	Nil	Nil	Nil
Botanical (eg., Neem)	Broad-spectrum: aphids, caterpillars	Effective, broad spectrum	Safe, minimal residue	Frequent application, slower than chemicals
Spinosad	Thrips, caterpillars, leaf miners	Nil	Nil	Nil
IGRs (e.g., Pyriproxyfen)	Whiteflies, fleas, caterpillars	Nil	Nil	Nil

Awareness Among Farmers About the Harmful Effects of Chemical Pesticides

Following the initial data collection, targeted awareness programs were conducted in both Aamdi and Parsada-4 to educate farmers about the adverse health and environmental impacts of chemical pesticide usage. These sessions were designed to be interactive and engaging, incorporating visual aids, group discussions, and the distribution of educational materials in the local language.

The response from the farming community was largely positive. Many participants expressed concern upon learning about the potential health hazards associated with prolonged pesticide exposure—such as skin disorders, respiratory ailments, and contamination of food and water sources. As a result, approximately 35% of the farmers indicated a willingness to reduce or gradually shift from chemical pesticides in favor of eco-friendly alternatives.

The awareness sessions also sparked active interest and conversations around Integrated Pest Management (IPM) practices and organic farming approaches. This attitudinal shift highlights the effectiveness of direct communication and grassroots-level engagement in fostering behavioral change toward more sustainable agricultural practices.

Notably, after sensitizing all 70 participating farmers, a clear change in perception was observed. Many were surprised to learn that long-term exposure to certain synthetic pesticides has been linked to chronic health conditions, including cancer, respiratory disorders, and neurological damage. This newfound awareness underscores the need for continued education and support to guide farmers toward safer, more informed pest management decisions.

Discussion

This study underscores the power of community engagement and education in driving sustainable agricultural transformation. The participatory model—centered around face-to-face interaction, relatable materials, and continuous support—was instrumental in shifting farmer mindsets. The uptake of biopesticides, though modest, reveals a growing openness to alternatives that align with both ecological balance and farmer well-being.

Interestingly, farmers' reactions to learning about the human health implications of pesticides—ranging from skin conditions to chronic diseases—highlighted a knowledge gap that, once addressed, had immediate influence. Furthermore, the study demonstrates how even limited interventions can catalyze broader conversations about sustainability, especially when led by student volunteers through programs like NSS.

Continued efforts are necessary to build on this momentum: strengthening farmer training, improving access to biopesticide inputs, and integrating traditional practices with scientific innovation. The findings advocate for replicating such models across other regions to achieve scalable impact.

Summary

The study, conducted during 2023–2024 under the NSS program, explored the shift of farmers in Chhattisgarh toward safer pest control practices. A total of 70 farmers from Aamdi and Parsada-4 were engaged through surveys, interviews, and field visits to understand pesticide usage patterns and the potential for adopting biopesticides.

Initially, farmers were using chemical pesticides extensively, unaware of their harmful impacts. Through structured awareness sessions using visual aids, local-language materials, and field demonstrations, the farmers were introduced to the risks associated with synthetic pesticides—including soil and water contamination, health hazards, and ecological disruption. Eco-friendly alternatives such as neem-based sprays, Bacillus thuringiensis (Bt), pheromone traps, and sticky traps were promoted under an Integrated Pest Management (IPM) framework.

As a result, approximately 22% of farmers adopted biopesticides and reported reduced pest incidence, better soil health, and minimal effects on non-target organisms. Additionally, 35% of participants expressed interest in phasing out chemical pesticides after the awareness initiatives. The campaign also triggered greater curiosity and discussion around organic farming and sustainable agriculture.

Photographs showing glimpses of field visits and interaction with farmers during the Programme

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MS Received on 05th July, 2025
MS Accepted on 03rd September, 2025

Review articles

DOI: 10.55278/PQRL1144

Aphid establishment in the tropics: mechanisms of dispersal, colonization and adaptive evolution: A critical review

Chandana C R[1,2], Rakesh V[3] and Sushila Nadagouda[2]

[1]*ICAR-National Bureau of Agricultural Insect Resources, Bengaluru, Karnataka – 560068, India*

[2]*Department of Entomology, University of Agricultural Sciences, Raichur, Karnataka – 584104, India*

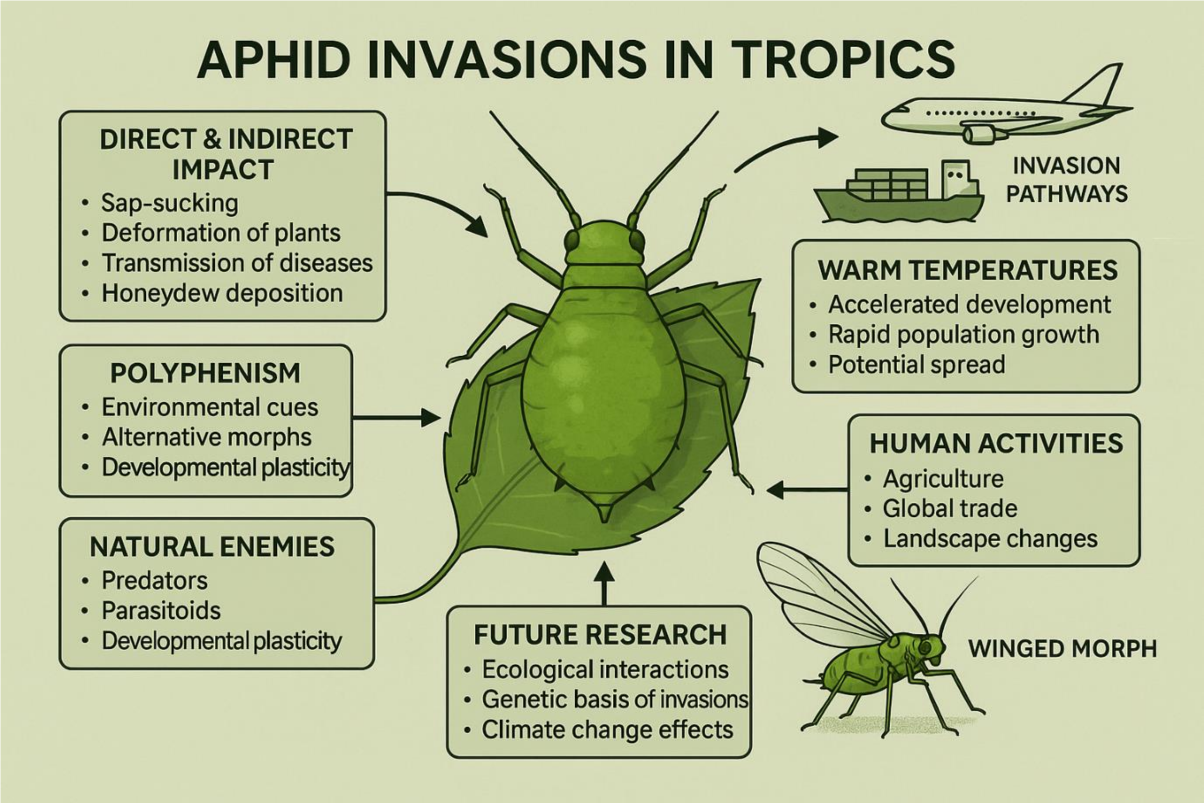
[3]*Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi, 110012, India*

Corresponding author: chandanacr25@gmail.com

Abstract

Aphids are small, oval-shaped phloem-sucking insects that exhibit remarkable polymorphism and complex reproductive strategies, making them highly adaptable and invasive. With over 5,100 known species globally and approximately 1,000 recognized as pests of agricultural crops, aphids inflict both direct and indirect damage to crop plants, including disease transmission and honeydew deposition, which attracts ants. Globalization has accelerated their unintentional spread beyond native ranges via contaminant and hitchhiking pathways, posing serious threats to agroecosystems and agriculture and horticulture production worldwide. Aphids possess unique reproductive strategies such as, parthenogenesis and alternation between wingless and winged forms, facilitating rapid population growth and colonization. Their phenotypic plasticity and polyphenism, shaped by environmental cues such as temperature and population density, are key to morph determination and survival. While low temperatures are commonly reported to induce winged (alate) morphs, studies also suggest that high temperatures can indirectly affect alate induction. Understanding the interplay between abiotic and biotic factors on aphid biology is essential for predicting invasion dynamics, particularly under climate change scenarios. Future investigations at higher levels of biological organization are crucial to elucidate invasion mechanisms and forecast aphid responses to global warming—thereby contributing to more resilient, sustainable pest management strategies.

Aphids are pear-shaped small phloem sap-sucking insects which shows polymorphism within interspecies (Tsuchida, 2016). Currently there are 5100 known aphid species (Alyokhin *et al*., 2022) and about 1000 species are pests of crops (Singh *et al*., 2016). These insects inflict both direct damage—through sap extraction and host plant deformation—and indirect damage by transmitting plant pathogens and secreting honeydew, which facilitates ant colonization and sooty mould fungal growth (Coeur d'Acier *et al*., 2010). The rapid pace of globalization has inadvertently accelerated the spread of invasive insect species, particularly aphids, across natural biogeographic boundaries (Convention on Biological Diversity, 2001). Key invasive pathways include contaminant pathways (traded plants and produce), hitch hiking pathway (luggage, vehicle and cargo) (Gippet *et al*., 2019). Through these routes, invasive insects are able to establish themselves in new areas and surpass the limits of natural dispersal (Pratt *et al*., 2017) and further undermined grain output, agroecosystem-based aphid regulation and current aphid management strategies (Singh *et al*., 2004; Yazdani *et al*., 2018; Zhang *et al*., 2012). Their economic impact, disturbance of agroecosystem function, quick and extensive spread into the new area/crop justify aphid as invasive species and typify aphid invasions into tropics through cereal crops globally and in the future (Brewer *et al*., 2019).


APHID INVASIONS IN TROPICS

DIRECT & INDIRECT IMPACT
- Sap-sucking
- Deformation of plants
- Transmission of diseases
- Honeydew deposition

POLYPHENISM
- Environmental cues
- Alternative morphs
- Developmental plasticity

NATURAL ENEMIES
- Predators
- Parasitoids
- Developmental plasticity

FUTURE RESEARCH
- Ecological interactions
- Genetic basis of invasions
- Climate change effects

INVASION PATHWAYS

WARM TEMPERATURES
- Accelerated development
- Rapid population growth
- Potential spread

HUMAN ACTIVITIES
- Agriculture
- Global trade
- Landscape changes

WINGED MORPH

Figure 1. Aphid Invasions in Tropical Agroecosystems: Pathways, Impacts, and Adaptations

Tropical regions offer both challenges and opportunities for aphid invasions due to their relatively stable climates, high biodiversity, and diverse cropping systems (Vilcinskas, 2016; Brewer *et al*., 2019). In contrast to temperate zones—where seasonal fluctuations significantly regulate aphid life cycles and population dynamics—the tropics present a more consistent environment that compels aphids to modify their reproductive strategies and phenotypic plasticity (Dixon and Hemptinne, 2001; Singh and Singh, 2021). The warmer temperatures and higher humidity typical of tropical environments can accelerate aphid development and reproduction, potentially facilitating rapid population growth and enabling aphids to persist and proliferate year-round across diverse host systems. (Hoffmann *et al*., 2013; Colinet *et al*., 2015). However, tropical ecosystems also harbor a rich community of natural enemies and complex interspecific interactions that may regulate aphid populations (Kunert *et al*., 2005). Human activities such as intensified agriculture, global trade, and landscape modifications further contribute to the introduction and establishment of invasive aphid species in tropical agroecosystems (Gippet *et al*., 2019; Yazdani *et al*., 2018). Understanding how aphids overcome biotic and abiotic constraints in these regions is essential to predict their invasion patterns and to develop effective management strategies tailored to tropical environments (Fig.1).

Aphids are distinctive due to their peculiar mode of reproduction and polymorphism. They may reproduce through parthenogenesis, zygogenesis or paedogenesis (Singh and Singh, 2021). They may be viviparous or oviparous. The parthenogenic mode of reproduction allows quick increase in numbers. Some aphids (Holocyclic species) reproduce both parthenogenically and sexually, while only few (anholocyclic species) reproduce only through parthenogenesis (Dixon and Hemptinne, 2001; Singh and Singh, 2002). Most aphid species are found in northern temperate zones. Aphids are rarely seen on tropical trees, for unknown reasons. The complex life history of aphids characterized by alternating flightless parthenogenetic generations and winged sexual morphs has evolved in response to the seasonal variability of host plant availability in temperate climates. This cyclical reproduction strategy enables aphids to exploit transient food resources efficiently and maintain population resilience across seasons. However, in tropical environments where seasonal cues are less pronounced or absent altogether, aphid life cycle evolution faces distinct challenges. Adaptation to such climatic constancy likely demands modifications in reproductive timing, morph regulation, and dispersal mechanisms to ensure survival and colonization (Vilcinskas, 2016). Unlike most invasive insect species in that sexual reproduction, mostly parthenogenically reproducing aphids do not or very little participate in population dynamics during the establishment and geographic range-expansion phases of invasion. Allee effects associated with limited partner availability are not pertinent, while other allee consequences, like inability to satiate predators and reduced reproductive rate when feeding in low numbers, are unclear (Liebhold and Tobin, 2008). The geographic range expansion is influenced by wind-aided alate migration that establish new colonies of mainly apterous parthenogenic individuals (Parry, 2013). Even when the genetic diversity of invading aphids is minimal, the phenotypic plasticity for effective and successful establishment and spread is apparent (Nibouche *et al*., 2014).

Polyphenism is a form of of developmental plasticity in which organisms respond to environmental signals by developing adaptable, discrete, alternative phenotypes called morphs (Brisson and Davis, 2016). This phenomenon plays a critical role in adaptive evolution and natural selection, enabling organisms to optimize survival and reproductive success in fluctuating environments. Among abiotic factors, ambient temperature stands out as a key regulator influencing developmental pathways and life history traits. In the context of climate change, the effects of extreme high temperatures warrant closer scrutiny not only in terms of direct physiological impacts but also for their role in inducing adult morphs at various developmental stages. Understanding these thermally driven responses is essential for forecasting how species, particularly invasive pests like aphids, may adapt their reproductive and dispersal strategies under global warming scenarios. (Chandana *et al*., 2024). Aphids are polyphonic, that even genetically identical individuals may display distinct phenotypes (Johnson, 1959; Mackay and Wellington, 1975; Simon and Peccoud, 2018). Furthermore, alate forms are more resistant to starvation compared to wingless forms (Hazell *et al*., 2005). The morphological and physiological characters of alate aphids enable them to survive even in harsh situations, have the chance to spread and clone to new environment (Dixon *et al*., 1993).

A significant amount of research has focused on the environmental factors- both biotic (interspecific interactions, crowding, alarm pheromone, nutrition, natural enemies, etc) and abiotic (temperature, precipitation, photoperiod, etc) (Kunert *et al*., 2005; Chandana and Nadagouda, 2023). Crowding is a key factor in production of alate aphids. Furthermore, the stage in the life cycle of aphid at which crowding has the major influence which differs between species (Purandare *et al*., 2014).

Increased temperature has a direct effect on the various life activities of ectotherms, like development, survival, migration and fecundity (Hoffmann *et al*., 2013; Colinet *et al*., 2015; Sentis *et al*., 2017). Likewise, to all the ectotherms, aphids have sensory capability for detecting variations in temperature (Chen and Ma, 2010). There were many opinions in the study related to temperature affecting alate aphid induction. Almost many researchers stated that low temperature would induce alate forms (*Brevvinia brasicae, Myzus persicae, Liriyosoma erysimi*) (Johnson,1965; Lees, 1966; Chen *et al*., 2019) and high temperature would inhibit dimorphism of aphid wings. Another study reported high temperature would increase alate aphids (*Nasonovia ribisnigri*) (Diaz and Fereres, 2005). Further, Muller *et al*. (2001), found that high temperature may expected to impact aphid morph determination indirectly, which results in more alate aphids.

Future research at higher organizational levels such as population, community, and ecosystem scales will be crucial for gaining a comprehensive understanding of the mechanisms driving aphid invasions and their subsequent spread. Investigating these broader ecological interactions will help reveal how aphids respond to complex environmental variables, including climate change, habitat alterations, and interactions with other species such as predators, mutualists, and host plants. Integrating ecological data with molecular and genomic approaches (Chandana and Kalita, 2023) will uncover the genetic basis of aphid adaptability and invasion success.

Additionally, considering anthropogenic factors such as global trade, land-use changes, and pesticide regimes is essential to fully understand invasion pathways. To comprehensively understand invasion pathways, it is equally important to assess anthropogenic pressures such as international trade, land-use transformations and changing pesticide regimes. Moreover, climate-induced shifts in mutualistic networks particularly ant aphid associations may exert cascading effects on aphid population dynamics, demanding closer scrutiny. By merging insights across ecological, genetic and socio-environmental domains, researchers can more accurately model changes in aphid diversity, reproductive strategies and invasion potential under climate change scenarios.

This integrative approach is vital for designing predictive tools and implementing sustainable, region-specific pest management strategies to mitigate the threats posed by invasive aphids in tropical agroecosystems.

Acknowledgements

The authors are grateful to the Director, ICAR-National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru, India. The authors are profusely thankful to University of Agricultural Sciences, Raichur.

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MS Received on 10th July, 2025
MS Accepted on 07th September, 2025

DOI: 10.55278/JMRV6336

Beyond mortality: An overview of sublethal impacts of insecticides on insect health and population dynamics

Chaudhary K V[1]*, Sisodiya D B[1], Thumar R K[2] and Parmar R G[3]

[1]*Department of Entomology, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat 388 110, India*

[2]*AINP on VPM: Agricultural Ornithology, ICAR Unit-9, Anand Agricultural University, Anand, Gujarat 388 110, India*

[3]*Department of Plant Pathology, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat 388 110, India*

Corresponding author: chaudharykirpalv@gmail.com

Abstract

Insecticides display biphasic dose-response characteristics, with high concentrations inhibiting insect activity and low concentrations eliciting stimulatory responses across diverse species. Although research has predominantly addressed lethal and acute toxicity, the sublethal impacts on both pest and beneficial insects often go unexamined. Exposure to sublethal doses can induce profound changes in insect physiology, development, population dynamics and behaviour, thereby facilitating environmental adaptation and complicating management strategies. This review synthesizes current knowledge on sublethal insecticide effects in crop-associated insects and discusses their implications for sustainable pest control and ecological risk assessment.

Keywords: Insecticides, sublethal doses, insect physiology, development, demography, behaviour, crop-associated insects.

Insecticides are indispensable for crop-pest control, but their extensive use has led to resistance development, pest resurgence, residue accumulation, chronic toxicity, environmental pollution, and biodiversity decline (Lalouette *et al.,* 2015). Biotic and abiotic degradation of lethal doses yields sublethal exposures (Bartling *et al.,* 2024). Despite frequent low-dose contact, research overwhelmingly targets acute toxicity, leaving sublethal impacts on insect physiology, population dynamics, and community interactions poorly understood (Tosi *et al.,* 2022).

Most market formulations contact, vapor, and stomach agents are available individually or as mixtures, producing lethal, sublethal, and combined toxicities. Tosi *et al.,* (2022) revealed that 71 percent of 377 individual pesticides and 99 percent of their combinations lack data on lethal, sublethal, and synergistic effects in key bee genera (Bombus, Osmia, Megachile, Melipona, Partamona, Scaptotrigona). Rising concerns over non-target harm especially to pollinators, and growing insecticide resistance have spurred the search for environmentally safe molecules effective at low doses. A PubMed database search for "sublethal effects of insecticides on insects" (PubMed [nih.gov]) retrieved nearly two thousand responses (Fig. 1), with studies on Hymenoptera and Diptera comprising 59 percent of the total. This highlights the urgent need to investigate sublethal impacts across other insect orders.

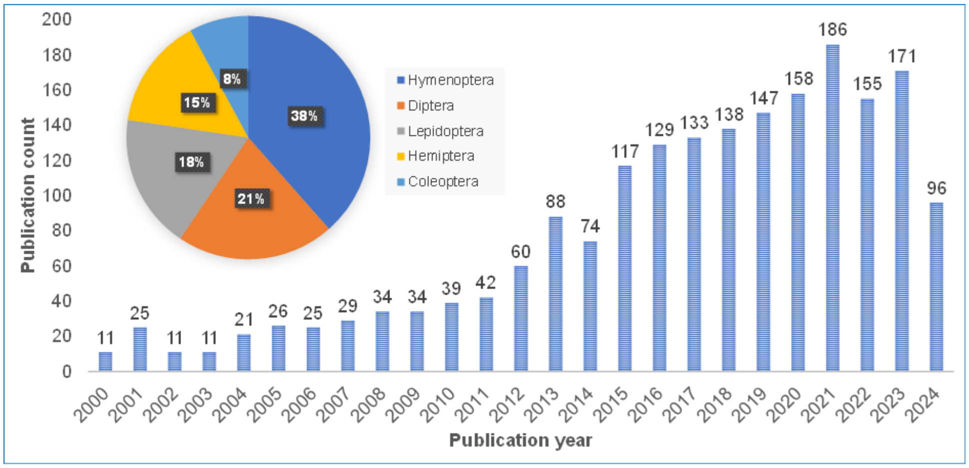

Fig. 1: Annual publication counts (histogram) and research subjects of publications (pie graph) on sublethal effects of insecticides in the past 25 years (2000-2024) [PubMed (nih.gov)]

What is a sublethal effect?

According to Desneux *et al.* (2007), it is defined as the one that does not cause the death of the individual, rather it produces a physiological, biological, demographical or behavioural change in an individual or population that survives upon the exposure to a substance at a lethal or sublethal dose.

Factors affecting sublethal effects

The precise sublethal effects depend on insect species, age and sex; spatial and temporal environmental context; type and dose of active ingredients; application methods of insecticides as well as insect exposure route (Bartling *et al.* 2024), which are briefly described here under.

1) Insect: The characteristics of the insect itself can affect how it responds to sublethal insecticide exposure.
    a) Species: Different insect species have varying susceptibilities to insecticides which can influence their survival, behaviour and reproduction after exposure to a sublethal dose.

   b) Age: Younger or older insects may have different tolerance levels to insecticides e.g. Juvenile stages of insects are more vulnerable than adult stages.

   c) Sex: Male and female insects could respond differently to insecticides due to biological and physiological differences among both the sexes.

2) Environmental context: The specific conditions of the insect's environment that can modify the effects of sublethal exposure.

   a) Spatial: It is nothing but the geographical location or habitat where the insect lives. Factors such as temperature, humidity or vegetation type existing in that location could alter the impact of insecticides.

   b) Temporal: It is a time-related factors such as the season or time of day when exposure occurs. e.g. Insects may be more active during certain periods, making them vulnerable to insecticide exposure.

3) Insecticides: The properties and application of the insecticides themselves play a crucial role in determining sublethal effects.

   a) Type of insecticides and its dose: Different insecticides have different chemical properties and dose. e.g. Higher doses might cause acute toxicity, while lower doses may lead to sublethal effects.

   b) Application methods: Whether the insecticide is applied as a spray, bait, powder or granules affects how insects meet it and resulting sublethal impacts.

4) Exposure route: It refers to how the insect comes into the contact with insecticide.

   a) Oral: Insects may ingest the insecticide through feeding. This route could affect internal organs and behaviours such as feeding and digestion. Feeding and collecting nectar and pollen from insecticide-treated plants can expose bee and their colony to insecticides.

   b) Contact: Insects may absorb the insecticide through their body surface after meeting a treated surface. This route could impact mobility, reproduction or development. The contact with thiamethoxam-contaminated honeydew significantly increased mortality of parasitic wasps, *Anagyrus pseudococci* (64%) and hover fly, *Sphaerophoria rueppellii* (73%) [Agudo, 2021].

Types of sublethal effects

There are four types of sublethal effects of insecticides to insects (Fig. 2) which include physiological, biological, demographical and behavioural effects (Bantz *et al.* 2018; Bartling *et al.* 2024).

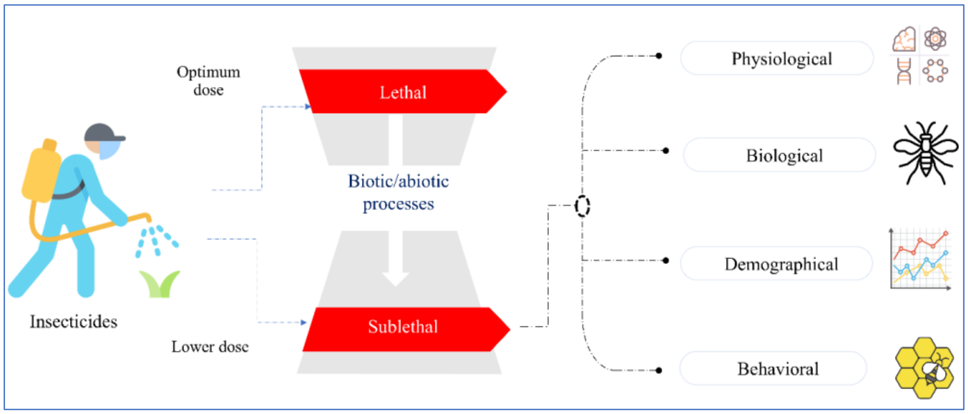

Fig. 2: Sublethal effects of insecticides on insects

1. Physiological sublethal effects

Sublethal insecticide exposure alters insect biochemistry (enzyme activity, cold-stress responses, oxidative metabolism), immunity (haemocyte counts, encapsulation, H_2O_2 production) and cellular integrity (necrosis, vacuolization, ROS buildup, detox-enzyme induction). At the molecular level, it drives microRNA-mediated transcriptional shifts, alternative mRNA splicing and epigenetic modifications (DNA methylation, histone changes), which modify insecticide targets, lower efficacy and can be inherited across generations. These changes also affect growth and development such as wing morphogenesis and body mass (Table 1) (Bantz *et al.* 2018).

Changes in enzymatic activity and immune system

Insects can detoxify insecticides through various enzymatic activities. The key enzymes such as cytochrome P450 monooxygenases (detoxify xenobiotics, source of ROS), esterase (hydrolyze ester bonds), glutathione S-transferases (conjugate toxic substances with glutathione, making the toxins more water-soluble and easier to excrete) and phosphatases (dephosphorylation) work together to break down insecticides, enhancing the insect's metabolism to counteract the toxins. As a result, insects may develop target site insensitivity, reduced penetration of insecticides and nerve insensitivity, which makes them less vulnerable to the chemicals. This enzymatic defence allows insects to adapt and survive sublethal doses of insecticides, which reflects their ability to resist toxic substances.

Potato plants treated with imidacloprid @ 0.25 µg/L resulted in 36-44% increased *P450-CYP6CY3* gene expression in 7 days old green peach aphids, *Myzus persicae* (Sulzer) and 54% increased expression of *E4-esterase* gene and 96% increased expression of *Hsp60* gene in 21 days old *M. persicae* (Rix *et al.* 2016). So, it could be predicted that the exposure of *M. persicae* to a low-imidacloprid dose (0.25 µg/L) will increase the expression of detoxification enzymes. LC_{40} of imidacloprid (6.31 mg/L) significantly increased (28.57%) acetylcholinesterase (AChE) activity in kudzu bug, *Megacopta cribraria* (Fabricius) nymphs developing on soybean plants whereas, the AchE activity of *M. cribraria* significantly decreased by 34.19% and 55.48% when exposed to the LC_{10} (32.36 mg/L) and LC_{40} (89.13 mg/L) of acephate, respectively as compared with the control. The difference in AChE activity is due to different modes of action of insecticides (Miao *et al.* 2016). The negative impact of various organophosphates and neonicotinoids insecticides on insect immunity leads to increased vulnerability to various biotic and abiotic stressors (Table 1).

Changes in cellular activity

In insects at the cellular level in the brain, Kenyon cells of the mushroom bodies are involved in functions like learning, memory and sensory integration; in the gut, epithelial cells which play a critical role in digestion and protein kinases, precursors and receptors are mostly affected by sublethal doses of insecticides (Table 1). The modifications in these organs can significantly affect the physiological processes *viz*. neural, digestive and cellular signaling in insects. Imidacloprid @ 14.651 ppb ($LC_{50}^{1/100}$) caused nuclear and mitochondrial damage and vacuolization in the midgut cells, increased spacing among the Kenyon cells in the mushroom bodies and increased the expression of proteins like vascular endothelial growth factor receptor, amyloid protein precursor and protein kinase C, whereas decreased the expression of the nicotinic acetylcholine receptor alpha 1 in European honeybee, *Apis mellifera* Linnaeus (Catae *et al.* 2018). These alterations demonstrated that extremely lower dose of imidacloprid could compromise the viability of the midgut epithelium, as well as inhibiting important cognitive processes in individuals and it cause the loss of the bee colony.

Growth and development

Insecticides can also interfere with insects' growth and development (Table 1). The sublethal effects have serious consequences on the duration of insect life cycle even if the insecticides do not cause immediate death. These impacts are particularly concerning when considering beneficial insects like pollinators (bees) or natural enemies (stink bugs, lacewings and parasitic wasps) of insect-pests. The sublethal doses (LD_{20}) of imidacloprid (0.09 ng/insect) and dinotefuran (0.15 ng/insect) showed significant induction of macropterous adults in both macropterous and brachypterous families of brown plant hopper (BPH), *Nilaparvata lugens* (Stål). However, dinotefuran produced higher rates of macropterous adults than imidacloprid. These results indicated that insecticides at the sublethal doses could affect wing polymorphism in BPH (Bao *et al.* 2009). After being treated with fluxametamide at LD_{10} (0.09 mg/kg) and LD_{30} (0.25 mg/kg) some pupae of rice striped stem borer, *Chilo suppressalis* Walker could not be generated, and the pupal tail was crumpled and darker in color while some adults failed to be eclosed from pupae, manifested as pupal shells that cannot be detached, or the wings were curled (Li *et al.* 2022). The application of a botanical insecticide, Anisom 2.71 mg/L (LC_{30}) recorded lowest larval (309.0±7.5 mg) and pupal weights (133.2±3.9 mg) and highest malformation in adults (75%) of fall armyworm, *Spodoptera frugiperda* (JE Smith) [Pavana *et al.* 2023]. The hind tibia and wings of egg parasitoid, *Trichogramma brassicae* Bezdenko that developed and emerged from cabbage looper, *Trichoplusia ni* (Hübner) eggs treated with sublethal spinosyn (100 ng/mL) were 11.6% and 26.9% larger compared to control, respectively (Smith *et al.* 2024).

2. Biological sublethal effects

The sublethal doses of insecticides can affect an organism's biological traits. It includes the efficiency of parasitism, the number of individuals that successfully emerge from developmental stages and how traits are passed on generations to generations.

The tebufenozide (0.12 g a.i./L) caused the greatest reduction in parasitism capacity of ectoparasitoid, *Tamarixia radiata* (Waterston) in the F_0 (79%) and F_1 (48%) generations. Moreover, azadirachtin (0.03 g a.i./L) and tebufenozide (0.12 g a.i./L) increased longevity with means of 10.2 and 9.6 days, respectively in F_2 generation (Beloti *et al.* 2015). The key life table parameters such as intrinsic and finite rate of increase of progeny (F_1) diamondback moth, *Plutella xylostella* (L.) were significantly decreased whereas mean generation time was significantly prolonged when parents (F_0) treated with LC_{10} (0.06 mg/L) and LC_{30} (0.11 mg/L) of fluxametamide (Gope *et al.* 2022). Chlorantraniliprole 0.11 mg/L (LC_{10}) significantly increased emergence of parasitoid wasp, *Trichogramma japonicum* Ashmead and showed higher parasitism of *C. suppressalis* under field conditions. Results highlighted a positive sublethal effect, a hormesis (a biphasic dose-response, characterized by high-dose inhibition and low-dose stimulation during or following exposure to a toxicant) effect of chlorantraniliprole on parasitism (Wang *et al.* 2022).

Table 1: Physiological sublethal effects of insecticides to insects

Insecticides	Insects	Effects	References
Changes in immune system			
Chlorpyrifos	Endo-larval parasitoid, *Leptopilina boulardi*	Enhanced encapsulation reaction	Delpuech *et al.* (1996)
Monocrotophos, Methyl parathion and Endosulfan	Reduviid bug, *Rhynocoris kumarii*	Reduced plasma cells in the hemolymph and converted plasmocytes into granular hemocytes	George and Ambrose (2004)
Organophosphates	European honeybee, *Apis mellifera*	Inhibited hemocyte proliferation and suppressed phagocytosis	James and Xu (2012)
Thiacloprid, Thiamethoxam and Clothianidin	*A. mellifera*	Reduced hemocytes, inhibited encapsulation and reduced antimicrobial activity	Brandt *et al.* (2016)
Imidacloprid	Fruit fly, *Drosophila melanogaster*	Reduced hydrogen peroxide (H_2O_2) production	Chmiel *et al.* (2019)
Thiacloprid	Solitary bee, *Osmia bicornis*	Reduced hemocytes in males	Brandt *et al.* (2020)
Changes in cellular activity			
Deltamethrin	*A. mellifera*	Hyperthermia and heart arrhythmia (increased metabolic rate)	Vandame and Belzunces (1998), Desneux *et al.* (2007)
Imidacloprid	*A. mellifera*	Affected olfactory memory (brain) and stimulated oxidative metabolism	Decourtye *et al.* (2004)
Indoxacarb, Emamectin benzoate, Imidacloprid and Lambda-cyhalothrin	Lacewing, *Chrysoperla sinica*	Impacted the activities of protective enzymes and induced DNA damage	Shan *et al.* (2020)
Spiromesifen and Lambda-cyhalothrin	*A. mellifera*	Cell fragments in gut lumen	Arthidoro deCastro *et al.* (2020), Serra *et al.* (2021)

Insecticides	Insects	Effects	References
Chlorantraniliprole	Velvetbean larva, *Anticarsia gemmatalis*	Disorganized microvilli, apoptosis and necrosis of digestive system	Castro *et al.* (2021)
Fipronil	Stingless bee, *Partamona helleri*	Induced oxidative stress, apoptosis and impaired epithelial homeostasis in midgut	Farder-Gomes *et al.* (2021)
Sulfoxaflor	*A. mellifera*	Over expressed Amelα9 & Amelβ2 subunits and down-regulated Amelα1, Amelα3 & Amelα7 subunits of nAChR in brain	Cartereau *et al.* (2022)
Growth and development			
Permethrin	Stink bug, *Supputius cincticeps*	Accelerated female development and delayed male development	Zanuncio *et al.* (2003)
Spinosad and Fenoxycarb	Endo-larval parasitoid wasp, *Hyposoter didymator* and Lacewing, *Chrysoperla carnea*	Inhibited cocoon spinning and lost silk production	Schneider *et al.* (2004), Bortolotti *et al.* (2005)
Bifenthrin and Deltamethrin	*A. mellifera*	Promoted immature periods	Dai *et al.* (2010)
Imidacloprid with lambda-cyhalothrin	*A. mellifera*	Inhibited worker development	Gill *et al.* (2012)
Vairimorpha bombi, Sulfoxaflor and Thiamethoxam	Buff-tailed bumblebee, *Bombus terrestris;* Green lacewing*, Chrysoperla externa* and Asian lady beetle, *Harmonia axyridi*	Inhibited larval growth and pupal survival	Sâmia *et al.* (2019), Siviter *et al.* (2020)
Chlorantraniliprole, Dinotefuran and Beta-Cypermethrin	Fall armyworm, *Spodoptera frugiperda*	Reduced pupation rate	Wu *et al.* (2022)

3. Demographical sublethal effects

Demographical traits like intrinsic rate of increase (r), finite rate of increase (λ), mean generation time (T) and population size are modified by sublethal doses of insecticides. These modifications result in altered population dynamics and population growth parameters.

Higher instantaneous rate of increase (24%) and total reproductive output (almost twice) of aphids, *M. persicae* developing on potato plants was observed when treated with lower dose (0.25 µg/L) of imidacloprid than control plants (Rix *et al.* 2016). It supports the hypothesis that hormesis is likely a manifestation of an adaptive response to a sublethal dose of a stressor. The key demographic parameters such as intrinsic and finite rate of increase of progeny of greenbugs, *Schizaphis graminum* (Rondani) (F_1) were significantly increased when parents (F_0) treated with LC_5 (2.259 mg/L) of thiamethoxam. In addition, it also recorded the highest total population size which was projected to surpass 9.0×10^8 individuals after 50 days of development. Overall, it showed that exposure to thiamethoxam at sublethal dose caused inter-generational hormetic effects on the demographic traits of *S. graminum* (Gul *et al.* 2024). The increased developmental rate might cause pest outbreaks under field and increase the crop damage.

4. Behavioural sublethal effects

It includes modifications in insect mobility, mating, feeding, navigation, orientation and learning behaviour (Table 2).

Insect mobility

Insect mobility refers to the ability of insects to move, which is essential for various survival functions such as foraging, mating and oviposition. It can be influenced by exposure to sublethal doses of insecticides which affect insect populations and ecosystems. Walking activity of adult workers of Italian honeybee, *A. mellifera* reduced when treated with various botanicals *viz*. garlic extract (0.3 mL/L of water), neem oil (2.0 mL/L), eucalyptus oil (10.0 mL/L) and rotenone (5.0 mL/L). The reduction in walking activities might result in greater contact with pesticide residues and increase their toxic effects (Xavier *et al.* 2015). Several botanical insecticides, which are often touted as safe and environmentally friendly, might generate sublethal effects on honeybees. Therefore, the use of botanicals for managing insect-pests on crops should be exercised with caution.

Mating behaviour

The insect experiences changes in sexual behaviour and reproductive patterns as a result of the exposure to sublethal doses of insecticides, which may affect population dynamics. Cotton leafworm, *Spodoptera littoralis* (Boisd.) males treated with deltamethrin at $LD_{50}^{1/10}$ were much more responsive compared to control and $LD_{50}^{1/100}$ treated males. This faster courtship behaviour could putatively lead to higher reproductive success in treated males. Therefore, the *S. littoralis* males treated with $LD_{50}^{1/10}$ (0.76 ng/insect) of deltamethrin were more (60.5±0.04%) successful for mating than control males (39.5±0.04%) when in a competition with a single female, whereas the LD_{30} treated males showed a lower mating success (30.9 ±0.04%) [Lalouette *et al.* 2015]. Sublethal dose (LD_{30}) of fluxametamide (0.25 mg/kg) inhibited the length and weight (5.47±1.33 mm and 8.81±3.16 mg, respectively) of ovarian tube of adult females of *C. suppressalis* as compared to control (8.74±0.93 mm and 15.50±4.00 mg, respectively). The most direct response of the ovarian development of *C. suppressalis* to fluxametamide was the changes in the size of the ovarian tubes (Li *et al.* 2022). The intergenerational impact of LC_5 (2.259 mg/L) and LC_{10} (3.057 mg/L) of thiamethoxam on the F_1 generation of *S. graminum* showed that the net reproductive rate of F_1 aphids at LC_5 was 1.2 times higher than that of the control. Moreover, the fecundity of F_1 aphids was substantially enhanced only at the LC_5 of thiamethoxam, while the reproductive days were dramatically increased at both concentrations as compared to control (Gul *et al.* 2024). This increased reproduction might cause pest outbreaks under field and thereby increase the crop damage.

Feeding behaviour

The feeding is crucial for their survival and ecological functions, including pollination, nutrient requirement and survival. Exposure to sublethal doses of insecticides can alter feeding behaviours, it impacts their efficiency and roles in ecosystems. *A. mellifera* exposed to agarose cubes incorporated with pyrifluquinazon (PQZ) @ 84 ppm spent significantly less time in the feeding zone as compared to the control. Moreover, after 24 h of exposure to PQZ in honeybees' food, they began avoiding it and by day 4, no bees fed on PQZ-treated food as compared to the control. Hence, this avoiding behaviour of bees exhibited to PQZ in their food could potentially limit the risk of this insecticide in the field (Wilson *et al.* 2019). Total duration of non-probing (Np), intercellular stylet pathway and salivary secretion into sieve element of directly exposed aphids, *S. graminum* (F_0) at LC_5 (2.259 mg/L) and LC_{10} (3.057 mg/L) of thiamethoxam were significantly longer than the control. Interestingly, the total duration of Np was significantly decreased, while the total duration of phloem sap ingestion and concurrent salivation was significantly increased in the progeny generation following exposure of the parental aphids to the LC_5 of thiamethoxam. It showed that the sublethal doses of thiamethoxam affect the feeding behaviour of the directly exposed aphids, while significantly increasing the feeding behaviour of the progeny generation, this validates the hormetic effects of insecticides (Gul *et al.* 2024).

Table 2: Behavioural sublethal effects of insecticides on insects

Insecticides	Insects	Effects	References
Insect mobility			
Deltamethrin	Seven-spotted ladybird, *Coccinella septempunctata* and aphid parasitoid, *Aphidius rhopalosiphi*	Higher grooming, lower resting, shorter retention times and shorter visit times at feeding places	Wiles and Jepson (1994), Longley and Jepson (1996)
Imidacloprid	Ground beetle, *Harpalus pennsylvanicus*	Increased grooming	Kunkel *et al.* (2001)
Imidacloprid	*A. mellifera*	Hyperactivity and initially trembling followed by sluggish activity	Suchail *et al.* (2001)
Chlorantraniliprole	Rice weevil, *Sitophilus oryzae*	Reduced number of food approaches and altered locomotion patterns	Kavallieratos *et al.* (2024)
Mating behaviour			
Azadirachtin	*R. kumarii*	Ovarian atrophy and crumbled follicular epithelium	George and Ambrose (2004)
Imidacloprid (with/without lambda-cyhalothrin)	*A. mellifera*	Reduced brood number	Gill *et al.* (2012)
Vairimorpha bombi, Sulfoxaflor and Thiamethoxam	Buff-tailed bumblebee, *Bombus terrestris;* Green lacewing, *Chrysoperla externa* and Asian lady beetle, *Harmonia axyridi*	Reduced fecundity	Sâmia *et al.* (2019), Siviter *et al.* (2020)
Thiamethoxam and Clothianidin	*A. mellifera*	Delayed drone flight by three days and reduced sperm counts by 28%	Staub *et al.* (2021)
Imidacloprid	Predatory bug, *Cyrtorhinus lividipennis*	Prolonged the duration of courtship, pre-mating and adjusting posture of treated males and increased fecundity of females	Hu *et al.* (2024)

Insecticides	Insects	Effects	References
Feeding behaviour			
Deltamethrin	Carabid beetle, *Nebria brevicollis*	Regurgitation of 53-80% treated aphids	Wiles and Jepson (1993)
	A. mellifera and Bumble bees	Reduced syrup uptake	Haynes (1988), Kjaer and Jepson (1995)
Cypermethrin	Assassin bug, *Acanthaspis pedestri*	Impaired ability to paralyze prey, random movement and lacked precision	Claver *et al.* (2003)
Fipronil	*A. mellifera*	Reduced syrup intake, less sensitive antennae and increased thirst (hydration)	El Hassani *et al.* (2005)
Thiamethoxam	Bumble bees and Carabid beetles	Longer foraging bouts and reduced food intake in predators	Stanley *et al.* (2016)
Permethrin and Tebufenozide	Predatory bug, *Podisus nigrispinus*	Repellent effect and decreased attack rate	Silva *et al.* (2020)
Amitraz in combination with thiacloprid	*A. mellifera*	Reduced sugar responsiveness	Begna and Jung (2021)
Navigation and orientation behaviour			
Fipronil, Clothianidin, Thiacloprid and Imidacloprid	Honeybees	Decline in orientation, impaired landmark use, neonicotinoids inhibited homing ability and sometimes fatal	Vandame *et al.* (1995), Fischer *et al.* (2014)
Deltamethrin + Honeydew	Aphid parasitoid, *Aphidius rhopalosiphi*	Departed from patches much earlier than controls not exposed to the insecticide	Longley and Jepson (1996)
Deltamethrin	Egg parasitoid, *Trichogramma brassicae*	Males showed more interest in female pheromones, but treated females' scent was less attractive	Delpuech *et al.* (1999)
Lambda-cyhalothrin and Chlorpyrifos	Aphid parasitoid, *Aphidius* spp.	Reduced attraction and orientation towards host plant odors by up to 71%	Stapel *et al.* (2000), Desneux *et al.* (2004)

Insecticides	Insects	Effects	References
Thiamethoxam	Bumble bee	Improved ability to find the nest 1 km away after exposure, possibly due to longer orientation flights	Stanley *et al.* (2016)
Dimethoate	Parasitic wasp, *Nasonia vitripennis*	Females avoided host odor	Schöfer *et al.* (2023)
Learning behaviour			
Permethrin	*A. mellifera*	Inhibited learning, interfered with medium-term olfactory memory and induced proboscis extension response (PER) habituation	Mamood and Waller (1990), Decourtye *et al.* (2004)
Imidacloprid metabolites (5-OH-imidacloprid)	*A. mellifera*	More potent negative effects on learning and memory than the parent compound	Decourtye *et al.* (2003)
Deltamethrin, Endosulfan and Fipronil	*A. mellifera*	Reduced responses during PER assays, indicating reduced olfactory learning	Decourtye *et al.* (2005)
Flupyradifurone	*A. mellifera*	Memory impaired by 22% in adults and 48% in larvae of *A. mellifera*	Hesselbach and Scheiner (2018)

Navigation and orientation behaviour

Insects rely on orientation and navigation to locate food resources, mates and suitable habitats through olfactory and gustatory signals. Also, the time spent for host searching is an important behavioural trait that should be considered when parasitoids are exposed to pesticide residues. The adult female of egg parasitoid, *T. japonicum* after being exposed to LC_{10} of chlorantraniliprole (0.11 mg/L) significantly increased their creeping speed (faster locomotion), showed more frequent changes in the orientation behaviour, significantly fewer interval rest times and spent shorter time for contacting host eggs (Wang *et al.* 2022). It indicated a positive sublethal hormesis effect of chlorantraniliprole on the orientation. After exposure to spirotetramat at LC_{10} (72.79 mg/L), 94.59% of the *Encarsia formosa* Gahan wasps were attracted to the host plant (Common bean: *Phaseolus vulgaris*) volatiles and they crawled the fastest. It indicated that the *E. formosa* exposed to sublethal spirotetramat at LC_{10} were more eager to locate the hosts for their parasitism, which could have been a consequence of the hormesis induced by spirotetramat at a lower concentration (Yang *et al.* 2022).

Learning behaviour

Insects exhibit learning through experience and adapt to their environment by associating stimuli with rewards or dangers. This ability plays an important role in behaviours like foraging, memory, caste determination, predator/parasitoid avoidance and communication. Flupyradifurone (FLU) 0.03 µg/bee/day decreased average olfactory learning by 74% (larval treatment) and 48% (adult treatment) and average memory by 48% (larval treatment) and 22% (adult treatment) in Indian honeybee, *A. cerana* as compared to controls. FLU was thus 1.3 to 2.5-fold more harmful to the olfactory learning and memory of bees exposed as larvae as compared to foragers exposed as adults. These results suggested that larvae were more susceptible to FLU than adults (Tan *et al.* 2017). Therefore, further research should be conducted on the effects of insecticides, expanding beyond its basic effects on honeybee survival and colony strength to consider its impact on their cognition and memory.

Conclusions

Insecticides are lethal to insects-pests but improper doses can cause sublethal effects. The sublethal dose of insecticides produces physiological (modifications in expressions of detoxification enzymes, damaged midgut and brain cells of the honeybee, modified wing development in BPH), biological (altered biocontrol activity), demographical (increased intrinsic and finite rate of increase of *S. graminum*) or behavioural (mobility reduction, higher rate of mating success in *S. littoralis*, increased fecundity in *S. graminum*, reduced feeding in *A. mellifera*, hormetic effects on feeding behaviour of *S. graminum*, impaired navigation, orientation and learning behaviour in *T. japonicum, E. formosa* and *A. cerana*) sublethal effects on various insect-pests. Therefore, information on sublethal effects is crucial for all insecticidal efficacy trials in the field of agriculture.

Future thrusts

Future research must prioritize sustainable insect-pest management by elucidating sublethal effects of insecticides.

- Epigenetic investigations should reveal how cellular-level modifications shape pest populations across generations, guiding strategies to avoid unintended, long-term consequences of insecticide use.
- Assessing sublethal impacts on nutritional physiology will uncover species-specific vulnerabilities and enable optimization of dose and timing.
- Risk-assessment frameworks must evolve beyond acute toxicity to include sublethal endpoints—physiological biomarkers, neurobehavioral changes (learning, memory) in non-target organisms, and population-level dynamics.

Integrating these insights will support the development of more effective, eco-friendly, and durable insect-pest management strategies.

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MS Received on 15th July, 2025
MS Accepted on 13th September, 2025

DOI: 10.55278/VIYO6494

Monitoring avian ecological health through ectoparasites: A review from India's diverse habitats

Yashwanth. N.M Gowda and M. Jayashankar*

Department of Zoology, School of Life Sciences,
St Joseph's University, Bengaluru-560027
Corresponding author: jayashankar.m@sju.edu.in

Abstract

Ectoparasites serve as vital indicators of avian health and ecosystem dynamics, offering insights into environmental quality and ecological shifts. This review synthesizes methodologies employed in the study of ectoparasites across wild and captive bird populations, with a particular emphasis on India's diverse ecological landscapes. It explores conventional collection techniques, advanced molecular diagnostics, and emerging non-invasive approaches, underscoring their respective strengths and limitations. A comparative analysis of ectoparasite prevalence across varied Indian habitats reveals patterns that are crucial for understanding host–parasite interactions and environmental stressors. The findings highlight the significance of integrating avian ectoparasite research into broader conservation strategies and biodiversity monitoring frameworks, especially in the context of India's rapidly changing ecosystems.

Keywords: Avian parasite, Ectoparasites, Conservation, Biodiversity, Birds

Introduction

Ectoparasites are among the critical factors influencing the health and ecological balance of organisms and their environments. They play a pivotal role as bioindicators, reflecting environmental health, habitat quality, and biodiversity status. In the Indian context characterized by a rich mosaic of landscapes including deserts, wetlands, grasslands, and forests studying avian ectoparasites offers valuable insights into ecosystem dynamics and emerging threats.

Ectoparasites are confined to the exterior of an organism; they are one of the main vectors that transfer and carry pathogens. Birds may harbor a great variety and number of ectoparasites, viz., biting lice (Mallophaga), fleas (Siphonaptera), Diptera (Hippohoscidae), mosquitoes (Culicidae), and black flies (Simuliidae). Birds' nests may harbor bugs of the hemipterous family Cimicidae, and parasitic dipterous larvae that attack nestlings. Arachnida infesting birds comprise the hard ticks (Ixodidae), soft ticks (Argasidae), and certain mites.

They affect bird behavior, health, reproductive success, and, in extreme cases, lead to mortality (Boyd, 1951; Clayton & Walther, 1997).

Therefore, monitoring ectoparasite load and diversity is essential for assessing environmental health and guiding conservation strategies.

Given their ecological importance, ectoparasite research must integrate behavioral studies, comparative ecology, and advanced diagnostic methodologies. This review aims to explore the diverse techniques employed in studying avian ectoparasites, with a special focus on research conducted across India's varied habitats.

Sampling ectoparasites in avian species involves various methods, each with its own advantages and applications. Some of the primary techniques used are described as follows

Chemical and Physical Methods

- **Potassium Hydroxide and Zinc Sulfate Technique:** In this method, the host's feather is dissolved using potassium hydroxide, and zinc sulfate helps in concentrating the ectoparasite population. This was effectively done for small birds and can be adapted for large birds (Hilton, 1970).
- **Dust-Ruffling:** In this method, the bird is dusted with pyrethrin and dislodged by ruffling. The irritated ectoparasites will fall off and are collected over the collecting surface. It's an effective and simple method to sample ectoparasites like lice (Walther & Clayton, 1997). This method has been used extensively in arid regions where ground-nesting birds are examined for feather mites and lice.

Visual and Non-Invasive Methods

- **Handpicking and Visual inspection:** it's a traditional method where birds are visually inspected and ectoparasites are handpicked using forceps. This method is less accurate compared to destructive sampling methods (Walther & Clayton, 1997).

Molecular and Microscopic Techniques

- **Microscopic Identification:** The samples that are collected can be stored in alcohol, and stereo or light microscopes can be used for detailed taxonomic studies, which helps in documenting the ectoparasite diversity in the ecosystem (Girişgin *et al.*, 2022).
- **Molecular Characterization:** Molecular techniques, including DNA barcoding, provide precise identification of cryptic ectoparasite species (Hebert *et al.*, 2003). Polymerase chain reaction (PCR) is frequently used to detect ectoparasites and the pathogens they may carry (Jongejan &

Uilenberg, 2004). Recent developments in 16s rRNA gene metabarcoding help us in characterizing the microbiota of ectoparasites, which provides insights into microbial communities and potential pathogenic interactions (Cerutti *et al.*, 2018; McCabe *et al.*, 2020).

- **Metagenomics:** With Genomic sequencing, we can characterize the entire ectoparasite communities present on the host and gain information on co-infection and parasite-host dynamics, which is critical knowledge to understand ecosystem health

Environmental Sampling

Nest-based Sampling: Collecting nest material and examining it for ectoparasites is another widely used method, particularly for parasites like mites, fleas, and lice that live in nests when not on the host bird (Sofía *et al.*, 2025). A study conducted by Sharma *et al.* (2020) in Kaziranga National Park examined the nesting site for mite infestation in open-billed storks. It was found that individuals are affected by the Dermanyssidae family.

Case studies

India's rich avian diversity supports a wide range of ectoparasites, with major groups including Acari (mites), Mallophaga/ Phthiraptera (lice), Siphonaptera (fleas) and Hippoboscidae (louse-flies), as documented by Moudgil & Singla (2021) and Salam et al. (2009). A comprehensive survey by McClure et al. (1994) across Southeast Asia, including India, recorded 238 genera and 564 species of arthropods from 743 avian hosts, with lice comprising 53% of the ectoparasite load, followed by mites at 34.3%, and louse-flies at 9.5%. Regional studies further highlight the prevalence and diversity of these parasites. In Assam, Saikia et al. (2017) found that 39.78% of 324 pigeons were infected, with Pseudolynchia canariensis (15.12%) and Columbicola columbae (12.03%) being the most common. In Gujarat, Budgerigars were reported to host Knemidocoptes spp. (burrowing mites), Sideroferus lunula (feather mites), and Heteromenopon spp. (lice) (Patel et al., 2022). In Kashmir, Lipeurus caponis emerged as the most prevalent lice species in free-range chickens, with nearly 100% infestation rates and multiple lice species often co-occurring on a single bird (Salam et al., 2009). Notably, a new host record was established for Afrimenopon waar on pigeons, expanding the known host–parasite associations in Indian avifauna (Moudgil & Singla, 2021). These findings underscore the ecological significance of ectoparasite monitoring across varied habitats and its relevance to avian health and biodiversity assessment.

Conclusion

Ectoparasite research plays a crucial role in assessing avian ecological health, especially within India's diverse and dynamic ecosystems. These parasites not only impact bird populations through direct health effects but also serve as sensitive indicators of environmental change and habitat quality. Integrating advanced molecular diagnostics with traditional field-based methods offers a more comprehensive understanding of host–parasite interactions and their ecological implications. To strengthen conservation and biodiversity monitoring efforts, future research should prioritize underexplored regions and incorporate ectoparasite data into broader avian management frameworks. Such interdisciplinary approaches will be instrumental in shaping responsive strategies for wildlife health, ecosystem resilience, and sustainable conservation planning.

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MS Received on 20th July, 2025
MS Accepted on 15th September, 2025

DOI: 10.55278/XLFN8944

First record of an invasive nectar source for *Prioneris thestylis* (Doubleday, 1842) (Lepidoptera: Pieridae) in Namdapha tiger reserve, Changlang district, Arunachal Pradesh, India

Srinjoy Das[1]
Zoological Survey of India, M-Block, New Alipore, Kolkata-700053, West Bengal, India.
Corresponding author Email: srinjoydas1998@gmail.com
ORCID iD: https://orcid.org/0000-0002-1924-0499

Abstract

Chromolaena odorata, an invasive shrub bearing pale pink flowers, typically blooms from December to April. This study presents the first documented observation of *Prioneris thestylis* (Doubleday, 1842) utilizing *C. odorata* as a nectar source within Namdapha Tiger Reserve (27°23′30″ N to 27°39′40″ N and 96°15′2″ E to 96°58′33″ E), a 1,985 km² protected area in Changlang District, Arunachal Pradesh, India, bordering northern Myanmar. Fieldwork was conducted from September 2024 to March 2025 as part of an ongoing, White-bellied Heron conservation project. Repeated observations confirmed *P. thestylis* feeding on *C. odorata* with photographic documentation and spatial mapping performed. These findings contribute to the ecological understanding of *P. thestylis* and highlight the potential influence of invasive flora on native butterfly foraging behavior. The study underscores the need to monitor *C. odorata's* spread and its implications for pollinator dynamics in Namdapha Tiger Reserve.

Introduction

Chromolaena odorata is a shrub and its flowering period is December-April (Ashraf et al., 2018). Siam Weed (also called Jack-in-the-bush in its native America), *Chromolaena odorata* (L.) King and Robinson, formerly Eupatorium odoratum L., is a perennial plant in the *Asteraceae* family and is one of the worst invasive weeds in the world. It significantly reduces biodiversity and agricultural productivity in the tropics and subtropics of the Old World (Sáfián, 2021). *Chromolaena odorata* (L.) King & Robinson (Asteraceae), a severe weed native to tropical America, is rapidly spreading throughout Asia, Africa, and Europe, encroaching on a range of natural vegetation. It had spread to South Asia (India, Nepal, and Sri Lanka) and South East Asia (Myanmar, Thailand, Vietnam, and Laos) by the early 20th century (Thapa *et al.*, 2016).

According to Shihan & Kabir (2015), 55 butterfly species used *Chromolaena odorata* as a nectar plant in Kaptai National Park (KNP) and Jahangirnagar University Campus. The butterfly species that feed on this plant include *Acraea violae, Anthene lycaenina,* *Appias albina, Appias indra, Appias lyncida, Arthopala amantes, Athyma perius, Badamina exclamationis, Caleta decidia, Castalius rosimon, Catopsilia pomona, Cepora nerissa, Cethosia cyane, Cupha erymanthis, Danaus genutia, Danaus genutia, Delias eucharis, Delias hyparete, Delias pasithoe, Deudorix epijarbas, Euploea core, Euploea mulciber, Eurema blanda, Eurema hecabe, Gerosis bhagava, Graphium agamemnon, Hypolycaena erylus, Iambrix salsala, Jamides bochus, Junonia almanac, Junonia atlites, Junonia iphitia, Junonia lemonias, Leptosia nina, Leptotes plinius, Megisba malaya, Moduza procris, Odontoptilum angulata, Pachliopta aristolochiae, Papilio demoleus, Papilio memnon, Parantica aglea, Parthenos sylvia, Pelopidas agna, Peroronia hippia, Phalanta phalanta, Prosotas nora, Rapala dieneces, Rapala manea, Rapala pheretima, Remelana jangala, Tagiades japetus, Tarucus ananda, Vagrans sinha, Zemeros flegyas* (Shihan & Kabir, 2015). *Chromolaena odorata* (L.) is one of the previously documented nectar plants for *Zizina otis* (Variya & Trivedi, 2024). According to Vara Lakshmi & Solomon Raju (2011), butterflies feed nectar of *Chromolaena odorata.* The butterfly species that feed on this plant include *Pachliopta hector, Papilio polytes, Papilio demoleus, Catopsilia pyranthe, Anaphaeis aurota, Delias eucharis, Ariadne ariadne, Junonia lemonias, Junonia hierta, Precis iphita, Acraea violae, Euploea core, Phalanta phalantha, Danaus genutia, Danaus chrysippus, Ypthima asterope, Melanitis leda, Tirumala limniace, Parantica aglea, Neptis hylas, Everes lacturnus, Tarucus nara, Borbo cinnara, Cephonodes hylas* (Vara Lakshmi & Solomon Raju, 2011).

Furthermore, Layek *et al*., (2022), have documented that Lepidopteran floral visitors of *Chromolaena odorata* include *Suastus gremius, Telicota colon, Anthene lycaenina, Catochrysops strato, Rapala manea, Rapala varuna, Danaus chrysippus, Danaus genutia, Elymnias hypermnestra, Euploea core, Junonia almana, Junonia atlites, Junonia iphita, Mycalesis perseus, Neptis hylas, Phalanta phalantha, Tirumala limniace, Pachliopta hector, Papilio polytes, Appias libythea, Catopsilia pomona, Eurema blanda, Eurema hecabe, Leptosia nina, Pareronia hippia, Cephonodes hylas, Macroglossum gyrans* (Layek et al., 2022). According to Sáfián (2021) & Fernández-Hernández (2007), Butterflies observed feeding on nectar of C. odorata are many and the full list can be found in the article (Sáfián, 2021)(Fernández-Hernández, 2007).

Here, I report for the first time that the invasive species *Chromolaena odorata* is also acts as a nectar food plant of *Prioneris thestylis* (Figure 2).

Study area and methodology:

Namdapha Tiger Reserve (27°23′30″ N to 27°39′40″ N and 96°15′2″ E to 96°58′33″ E) spans approximately 1,985 km² in the Changlang District of Arunachal Pradesh, India, adjoining the northern border of

Myanmar. The reserve encompasses a diverse range of habitats, from tropical evergreen forests to alpine meadows, supporting rich biodiversity including several endemic and threatened species.

Field observations were conducted between September 2024 and March 2025 as part of an ongoing conservation project focused on the White-bellied Heron (Ardea insignis). Butterfly activity was recorded opportunistically during this period. Photographic documentation of *Prioneris thestylis* feeding behavior was captured using a Nikon D7000 DSLR camera equipped with an 80–400 mm telephoto lens. Spatial data were processed and visualized using QGIS version 3.34.3 to generate distribution maps and document observation sites.

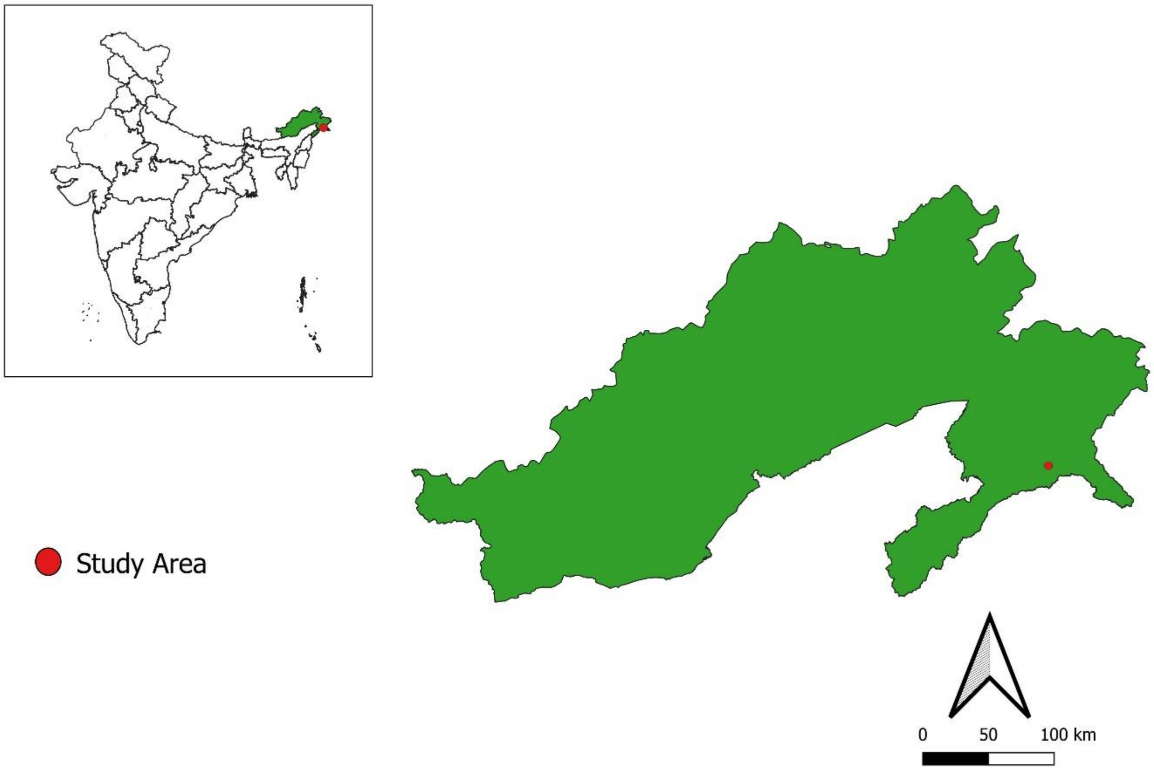

Figure 1. Study Location Namdapha Tiger Reserve (27°23′30″ N to 27°39′40″ N and 96°15′2″ E to 96°58′33″ E).

Result and Discussion

Between September 2024 and March 2025, fieldwork was conducted within Namdapha Tiger Reserve, Arunachal Pradesh, India, as part of an ongoing conservation initiative focused on the critically endangered White-bellied Heron (*Ardea insignis*). During this period, repeated observations were made of *Prioneris thestylis* butterflies actively feeding on the nectar of *Chromolaena odorata*, an invasive plant species (Figure 2).

This interaction highlights a noteworthy ecological dynamic: while *C. odorata* is widely recognized for its negative impact on native flora and habitat structure, its role as a nectar source may influence butterfly foraging behavior and distribution. The documentation of *P. thestylis* utilizing *C. odorata* suggests potential adaptive responses or resource dependencies that merit further investigation. These findings contribute to the conservation of *P. thestylis* by identifying key nectar sources within its habitat, while also informing management strategies for invasive species in Namdapha. Understanding such interactions is essential for balancing species conservation with ecosystem integrity, especially in biodiversity-rich and ecologically sensitive landscapes.

Figure 2: *Prioneris thestylis* fed on the nectar of *Chromolaena odorata*.

Acknowledgements

I express my sincere gratitude to Dr. Gopinathan Maheswaran, Principal Investigator of the DST project on the White-bellied Heron at the Zoological Survey of India, and to the Director, Zoological Survey of India, Kolkata, for their unwavering encouragement and institutional support. I am thankful to Mr. Roshan Upadhaya of the Arunachal Pradesh Police, Basar, Leparada District, for his assistance in identifying the butterfly species. I also extend my appreciation to Dr. Ishita Biswas, Assistant Professor, Department of Botany, S.B.S. Government College, Hili, Dakshin Dinajpur, West Bengal, for confirming the identity of the plant species *Chromolaena odorata*. I gratefully acknowledge the support of the Arunachal Pradesh Forest Department for facilitating fieldwork within Namdapha Tiger Reserve.

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MS Received on 01st June, 2025
MS Accepted on 28th August, 2025

DOI: 10.55278/WJXC9539

Expanding the range of bombardier beetles: New records of *Pheropsophus bimaculatus* and *P. catoirei* in Uttarakhand's Shiwalik region, India

Vasanthakumar D, Purbita Roy Sharma and Gaurav Sharma

Zoological Survey of India, Northern Regional Centre, 218, Kaulagarh road, Dehradun – 248195, Uttarakhand, India.

Corresponding author: duraivasanthakumar@gmail.com

Bombardier beetles (Carabidae: Brachininae) are renowned for their remarkable defense mechanism, ejecting a hot, noxious spray of benzoquinones at would-be attackers. Globally, 657 species have been described, of which 67 (≈10%) occur in India (Venugopal & Thomas 2018, 2019). Their chemical deterrent renders them virtually free from natural predators (Sugiura & Sato 2018), and they serve as effective biocontrol agents by preying on mole cricket larvae, rhinoceros beetles, aphids and other crop and forest pests (Rao & Manjunath 1964; Frank *et al.* 2009). Despite their ecological importance, detailed studies on the taxonomy, diversity and distribution of Indian bombardier beetles remain scarce.

While analysing the backlog collections of bombardier beetles in the Northern Regional Centre of Zoological Survey of India, we came across two species of *Pheropsophus* which were identified as *Pheropsophus bimaculatus* (Linnaeus, 1771) and *Pheropsophus catoirei* (Dejean, 1825) collected from Jim Corbett National Park, Uttarakhand, India. Perusal of published works on bombardier beetles of India (Arrow, 1901; Andrewes, 1924; 1930; Bates, 1886; Dejean, 1825; Hrdlička, 2017; Kushwaha and Hegde, 2015; Lorenz, 2021; Saha and Halder, 2000; Venugopal & Thomas, 2019; Ullah *et al.*, 2017) revealed that this species have never been reported from the state of Uttarakhand, India. Thus, these new records from the Shiwalik region of Uttarakhand represent the first specimen-based reports from the state. The specimens were labelled and assigned registration numbers. The photographs were taken with DSLR camera (Nikon D300). The specimens were deposited in the National Zoological Collection of Zoological Survey of India, Northern Regional Centre, Dehradun, India.

Pheropsophus bimaculatus (Linnaeus, 1771)

Material examined: 1 ex, Registration No. A-19230, 03.iii.1970, Jim Corbett National Park, Paterpani, Nainital district, Uttarakhand (29.57389° N, 78.91083° E), Coll. A. Singh & Party.

Identification characters:

Head yellow, with a dark spot somewhat elongated towards the apex extending to the pronotum; pronotum disc and lateral margin brownish black, with a yellowish spot, oblong, placed on each side along the lateral margin; apical and basal margins straight; hind angles right angled, not protruding; median furrow distinct; elytra black with yellow spots (Fig.1); nearly twice as wide as pronotum; enlarged towards apex, straight truncated at apex; striations wide, rounded, intervals flat; humeral spot rounded; transverse band rounded with weakly serrated edges; apical yellow band narrow, extends anteriorly along each striation as described by Venugopal & Thomas (2019).

Distribution: India (Tamil Nadu, Kerala, Karnataka, Maharashtra and Uttarakhand (New Record)

Elsewhere: Sri Lanka, Nepal and Laos (Andrewes, 1930; Bates 1886; Venugopal & Thomas, 2019; Lorenz, 2021)

Pheropsophus catoirei (Dejean, 1825)

Material examined: 12 ex, Registration No. A-19231, 03.iii.1970, Jim Corbett National Park, Paterpani, Nainital district Uttarakhand) (29.57944° N, 78.90916°E), Coll. A. Singh & Party.

Identification characters:

Head, pronotum, reddish brown without spots; elytra black; elongated, narrow; subparallel; median transverse bands narrow, with few serrations along edges (Fig. 2); apex wider with narrow yellow apical band extending anteriorly along the striations as described by Venugopal & Thomas (2019).

Distribution: India (Bengal, Arunachal Pradesh; Sikkim; Meghalaya: Assam; Himachal Pradesh; Uttar Pradesh; Kashmir; Andaman Islands and Uttarakhand (New Record) [Andrewes, 1924; 1930; Dejean, 1825; Hrdlička, 2017; Kushwaha and Hegde, 2015; Saha and Halder, 2000; Venugopal & Thomas, 2019]

Elsewhere: Bangladesh; Iran; Afghanistan; Pakistan; Sri Lanka; Myanmar; Nepal; Bhutan (Arrow, 1901; Hrdlička, 2017; Ullah *et al.,* 2017).

Summary

In a review of backlog specimens at the Northern Regional Centre, Zoological Survey of India, two *Pheropsophus* species *P. bimaculatus* and *P. catoirei* were identified among collections from Jim Corbett National Park, Uttarakhand. *P. bimaculatus* was represented by a single specimen collected at Paterpani, exhibiting a yellow head with an elongate dark spot, a brownish-black pronotum bearing oblong lateral spots, and black elytra with yellow humeral spots and narrow, serrated transverse bands. *P. catoirei* comprised 12 specimens from the same locality, characterized by a reddish-brown head and pronotum, and elongated black elytra displaying narrow median bands and a yellow apical band. These records constitute the first confirmed occurrences of both species in

Uttarakhand, extending their known Indian distributions.

Acknowledgements

Authors are grateful to the director, Zoological Survey of India, Kolkata for encouragement and research facilities.

Fig. 1. ***Pheropsophus bimaculatus* (Linnaeus, 1771)**

Fig. 2. ***Pheropsophus catoirei*** **(Dejean, 1825)**

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MS Received on 12th June, 2025
MS Accepted on 10th September, 2025

Zeugodacus cucurbitae

RASHVEE FRUIT FLY LIQUID LURE FOR CUCURBITS, TOMATO, TEMPERATE FRUIT CROPS

For Vegetable Crops: Ridge Gourd, Cucumber, Snake Gourd, Bitter Gourd, Bottle Gourd, Coccinia, Gherkins, Watermelon, Pumpkin, Tomato

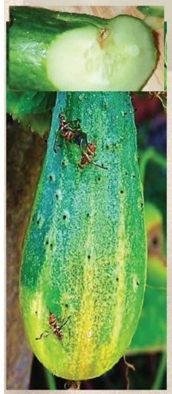
Temperate Fruits: Peach, Plum, Apple etc.,

Key Features

- Climate resilient
- Added anti-evaporants – effective even in high temperatures
- ⊘ 100% Herbal, No insecticides required, safe for residue-free farming
- ⧗ >65 days field efficacy
- ♻ Use recycled water bottles as traps
- Design-patented caps for windy and rainy areas
- Attracts >12 fruit fly species
- ■ Synergestic odour affects the female fruit fly reproductive and orientation behavior
- ● Ideal for quarantine and invasive species monitoring Compatible with other Rashvee technologies (Herbal Liquid soap, Azadirachtin, Protein bait).

⬢ Pack Sizes: 100 ml, 250 ml, 500 ml, 1000 ml

● Shelf Life: 24 months



Target Fruit Fly Species

Zeugodacus cucurbitae, Bactrocera albistrigata, Bactrocera caudate, Bactrocera digressa, Bactrocera tau, Bactrocera scutellaris, Bactrocera neonigrotibialis, Bactrocera trillineata, B. nigrofemoralis, Bactrocera divenderi, (Bactrocera tryoni)

Contact: Dr. M A Rashmi, 9036608527

Selected Insect Environment Blogs

Contarinia icardiflores: A New Blossom Midge Threatening Jasmine in India

Integrative Taxonomy an Important Tool in Pest Surveillance

31 August 2025

D. M. Firake and K. V. Prasad

ICAR-Directorate of Floricultural Research, Pune, Maharashtra, India

Blossom midges (Diptera: Cecidomyiidae) are notorious pests of ornamental and food crops worldwide. Among them, *Contarinia maculipennis* has caused significant damage to jasmine, orchids, and tuberose across South India. These pests lay eggs inside flower buds, and their larvae feed on internal tissues, leading to gall formation, bud distortion, and premature drop drastically reducing marketable yield.

Adult Blossom midge on jasmine flower buds PC: Firake e*t al*., 2025

While studying jasmine (*Jasminum sambac*) at ICAR–Directorate of Floricultural Research (ICAR-DFR), Pune, scientists observed midges resembling *C. maculipennis* but exhibiting host specificity to jasmine. Unlike *C. maculipennis*, these midges did not infest tuberose even under no-choice conditions.

To resolve this anomaly, Dr. D. M. Firake and team conducted molecular characterization using *mt-DNA COI* gene sequencing. DNA barcoding and detailed morphological analysis confirmed the discovery of a new species: *Contarinia icardiflores*. Named in honor of ICAR-DFR, this species mimics *C. maculipennis* in appearance and symptoms but is genetically and biologically distinct.

Blossom midge damage to jasmine flower buds_PC: Firake e*t al*., 2025

C. icardiflores completes its life cycle in 16–21 days and poses a serious threat to jasmine cultivation, especially in some parts of Maharashtra, Tamil Nadu, Andhra Pradesh, and Karnataka. It can be identified by unique traits in female flagellomeres and cerci, and male aedeagus.

This discovery highlights the importance of integrative taxonomy in pest surveillance and lays the groundwork for targeted, eco-friendly management strategies. Early detection and host-specific control measures are essential to protect jasmine a crop of high cultural and economic value in India.

Read full article: *In Phytoparasitica* https://link.springer.com/article/10.1007/s12600-025-01307-1

For more information contact
Dr. D. M. Firake
Email: *dfirake@gmail.com*
IE Blog No. 268
All IE blogs are available on website
https://insectenvironment.com

RASHVEE FRUIT FLY LIQUID LURE FOR FRUIT CROPS

For fruits: Mango, Guava, Custard Apple, Dragon Fruit, Sapota, Pomegranate & Others

Key Features

🌍 Climate resilient

Added anti-evaporants – effective even in high temperatures

⊘ 100% Herbal, No insecticides required, safe for residue-free farming

⧗ >65 days field efficacy

♻ Use recycled water bottles as traps

☁ Design-patented caps for windy and rainy areas

🐞 Attracts >12 fruit fly species

■ Synergestic odour affects the female fruit fly reproductive and orientation behavior

● Ideal for quarantine and invasive species monitoring

⬢ Pack Sizes: 100 ml, 250 ml, 500 ml, 1000 ml

● Shelf Life: 24 months

Contact: Dr. M A Rashmi, 9036608527

🐞 **Target Fruit Fly Species**

Bactrocera dorsalis, Bactrocera caryeae, Bactrocera correcta, Bactrocera zonata, Bactrocera versicolor, Bactrocera affinis, Bactrocera diversa.

Alarming Leafhopper Population in North Indian Cotton: A Weather-driven Surge

Beyond Thresholds Leafhopper Infestation may Redefine IPM Priorities in Cotton

24 August 2025

Rishi Kumar, Babasaheb B. Fand, Satpal Singh and V.N.Waghmare

The cotton leafhopper (*Amrasca biguttula biguttula*) has emerged as the dominant sucking pest in North India's cotton, passing whitefly due to highly favorable weather conditions in 2025. Regions like Haryana, Punjab, and Rajasthan (north India) have reported widespread infestations, with severity peaking earlier and lasting longer than in previous years.

Cotton leafhopper (*Amrasca biguttula biguttula)*

Population dynamics under unprotected conditions at experimental farm of Indian Council of Agricultural Research – Central Institute for Cotton Research (ICAR-CICR), Regional Station Sirsa, revealed that in 2023 and 2024, leafhopper populations crossed the economic threshold level (ETL: 6 nymphs/3 leaves) by the 27th Standard Meteorological Week (SMW), peaking at 9.5 and 11.2 nymphs/3 leaves respectively. In 2025, infestation began earlier (22nd SMW), crossed ETL by 24th SMW, and peaked at a record 18.93 nymphs/3 leaves in the 30th SMW remaining above ETL for over nine weeks.

Survey in farmer's field corroborate this trend: 18.43 % of surveyed fields till 33rd SMW in 2025 exceeded ETL, compared to 10.4% in 2023 and 4.52% in 2024. The infestation pattern in 2025 showed both advancement and prolongation, with peak populations appearing earlier.

Leaf hopper burns on cotton

Weather played a decisive role. According to observatory data of the station, moderate temperature (32.56°C), high humidity (72.29%), and abundant rainfall (240 mm across 32 SMWs) created ideal conditions for leafhopper proliferation. In contrast, hotter and drier conditions in 2024 suppressed the populations.

This scenario underscores the urgency of early monitoring from the 21st SMW, especially in early-sown cotton. Integrated pest management should include timely use of botanicals and selective insecticides post-ETL, avoidance of excessive nitrogen fertilization and management of alternate hosts.

Proactive surveillance particularly in late sown crop and ecological pest management are vital to mitigate future outbreaks and safeguard cotton productivity.

Insect Environment Editors add: Similar studies will be useful if done in vegetables, especially okra where *Amrasca biguttula biguttula* is a serious pest.

For more information contact
Dr. Rishi Kumar
Email:*rishipareek70@yahoo.co.in*

IE Blog No. 267
All IE blogs are available on website
https://insectenvironment.com

INSECT LENS

Species: Red Pierrot (Butterfly)

Author: Mr. Rushikesh Rajendra Sankpal
Location: *Pune, Maharashtra*
Email: *rushisankpal@gmail.com*

A caterpillar

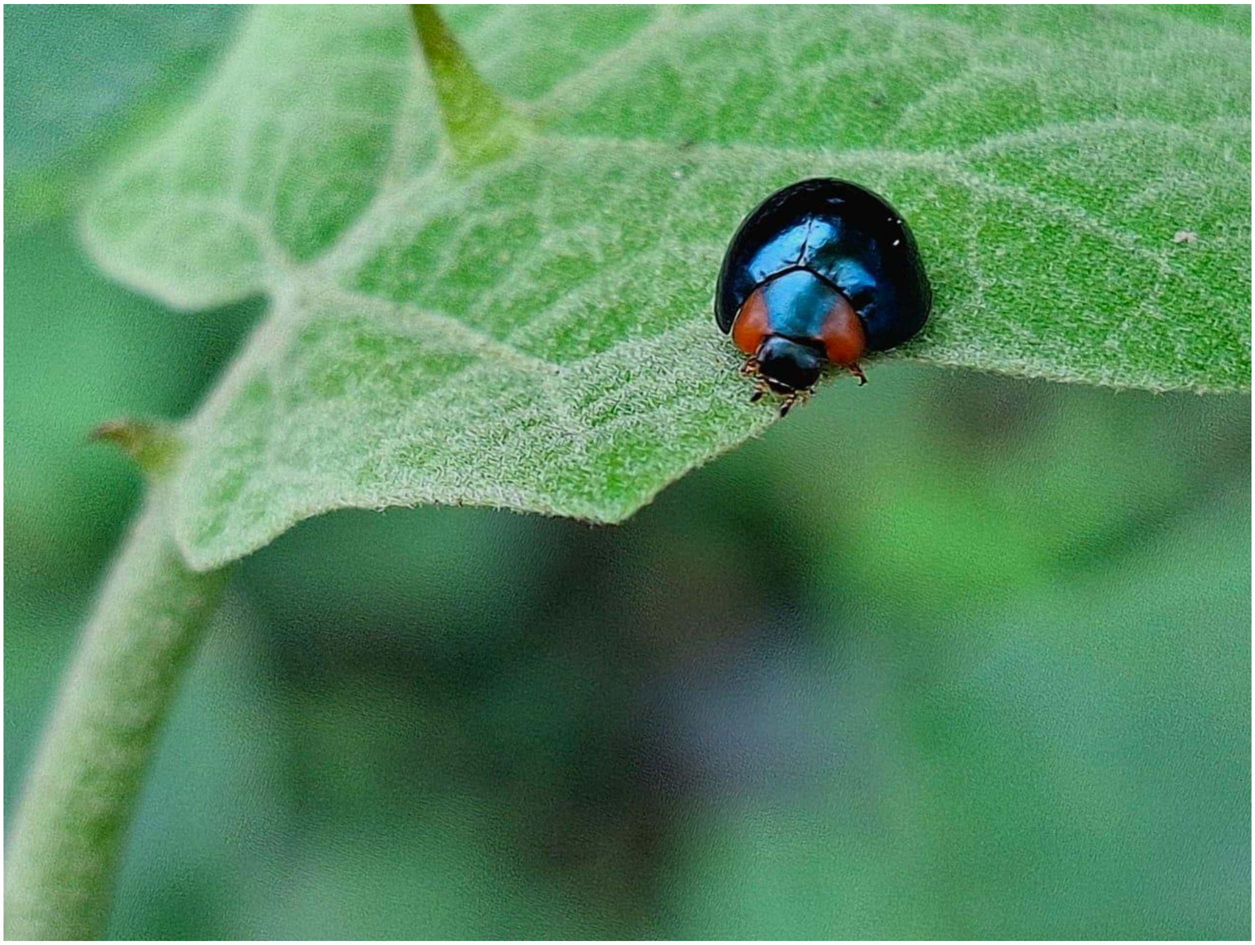
Author: Mr. Rushikesh Rajendra Sankpal
Location: *Pune, Maharashtra*
Email: *rushisankpal@gmail.com*

Fungus Weevil, Apolecta sp. (Anthribidae: Cleoptera)

Author: *Dr. Nagaraj, D. N., Project Head (Entomologist) Ento. Proteins Pvt. Ltd., Mangalore*
Location: *Bengaluru*
Email: *nasoteya@yahoo.co.in*

Tortoise beetle, Aspidimorpha sp. (Chrysomelidae: Coleoptera)

Author: *Dr. Nagaraj, D. N., Project Head (Entomologist) Ento. Proteins Pvt. Ltd., Mangalore*
Location: *Bengaluru*
Email: *nasoteya@yahoo.co.in*



Blue Metallic ladybird beetle, Curinus coeruleus (Coccinellidae: Cleoptera)

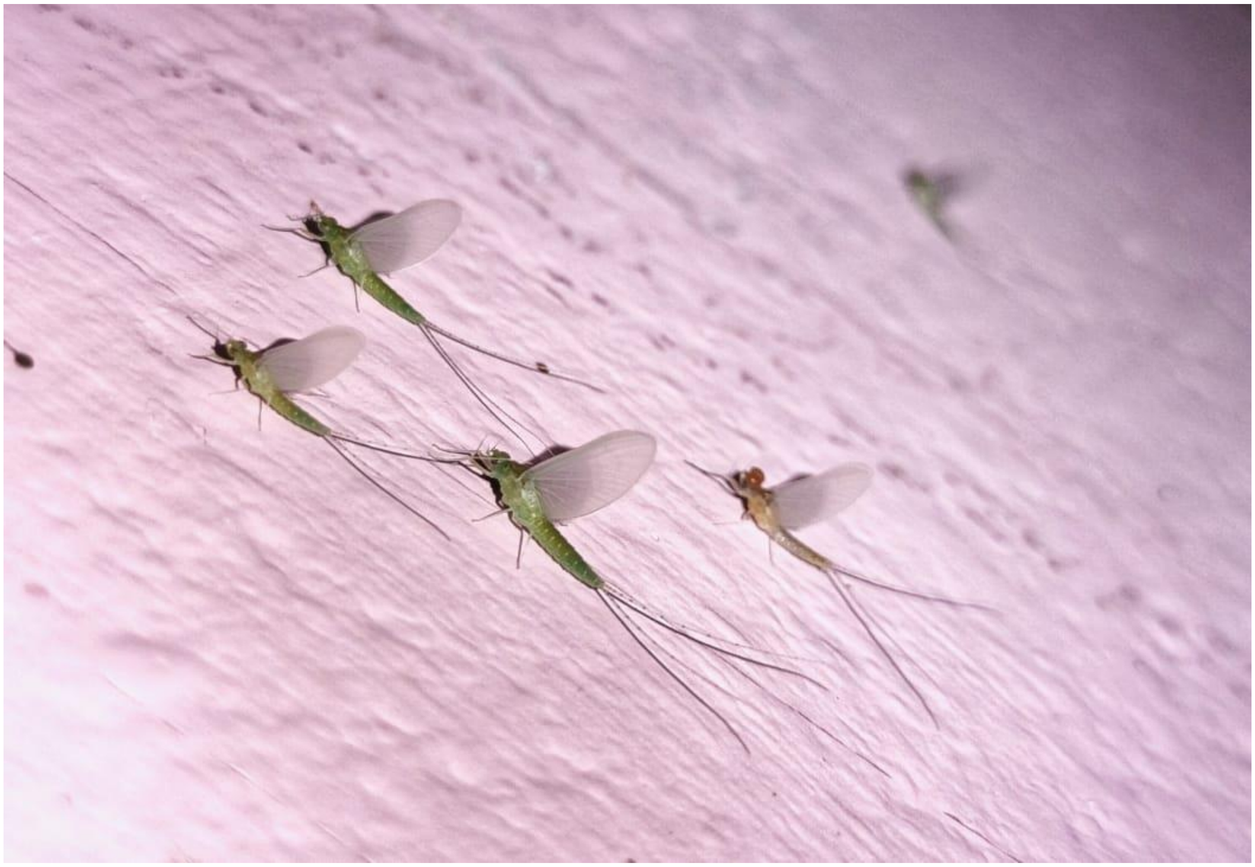
Author: *Dr. Nagaraj, D. N., Project Head (Entomologist) Ento. Proteins Pvt. Ltd., Mangalore*
Location: *Bengaluru*
Email: *nasoteya@yahoo.co.in*

Robber Fly (Asilidae: Diptera)

Author: *Dr. Nagaraj, D.N., Project Head (Entomologist) Ento. Proteins Pvt. Ltd., Mangalore*
Location: *Bengaluru*
Email: *nasoteya@yahoo.co.in*

Flesh fly, Sarcophaga sp. (Sarcophagidae: Diptera)

Author: *Dr. Nagaraj, D.N., Project Head (Entomologist) Ento. Proteins Pvt. Ltd., Mangalore*
Location: *Bengaluru*
Email: *nasoteya@yahoo.co.in*



Mayflies (Ephemeroptera)

Author: *Dr Raja Ramesh*
Location: *Thanjavur*

Assassin bug, Acanthaspis siva (Reduviidae: Hemiptera) common in beehives

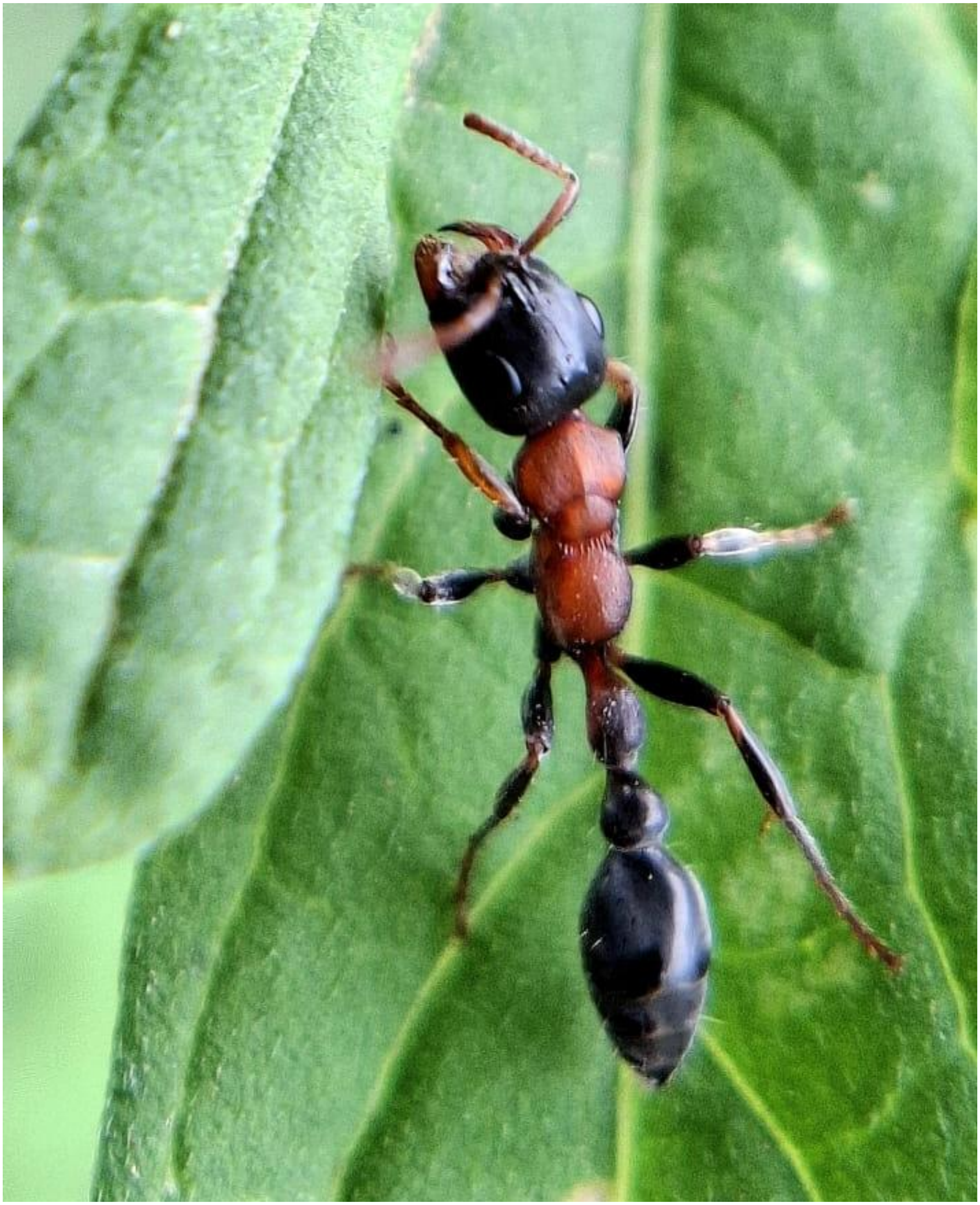
Author: *Dr. Sevgan Subramanian*

Location: *ICIPE - International Centre of Insect Physiology and Ecology, Kasarani, Nairobi, Kenya*

Email: *ssubramania@icipe.org*

Spined Assassin Bug, Sinea spp. (Reduviidae: Hemiptera)

Author: *Dr. Nagaraj, D. N., Project Head (Entomologist) Ento. Proteins Pvt. Ltd., Mangalore*
Location: *Bengaluru*
Email: *nasoteya@yahoo.co.in*



Arboreal Bicolored Slender Ant, Tetraponera rufonigra (Formicidae: Hymenoptera)

Author: *Dr. Nagaraj, D.N., Project Head (Entomologist) Ento. Proteins Pvt. Ltd., Mangalore*
Location: *Bengaluru*
Email: *nasoteya@yahoo.co.in*

Assassin bug, Acanthaspis siva (Reduviidae: Hemiptera) common in beehives

Author: *Dr. Sevgan Subramanian*
Location: *ICIPE - International Centre of Insect Physiology and Ecology, Kasarani, Nairobi, Kenya*
Email: *ssubramania@icipe.org*

Giant Red eyed Butterfly larvae, Gangara thrysis (Hesperiidae: Lepidoptera)

Author: *Dr. Nagaraj, D.N., Project Head (Entomologist) Ento. Proteins Pvt. Ltd., Mangalore*
Location: *Bengaluru*
Email: *nasoteya@yahoo.co.in*

Bag worm (Psychidae: Lepidoptera)

Author: *Dr. Nagaraj, D.N., Project Head (Entomologist) Ento. Proteins Pvt. Ltd., Mangalore*
Location: *Bengaluru*
Email: *nasoteya@yahoo.co.in*

Indian Boxer Mantid, Hestiasula brunneriana (Hymenopodidae: Mantodea)

Author: *Dr. Nagaraj, D.N., Project Head (Entomologist) Ento. Proteins Pvt. Ltd., Mangalore*
Location: *Bengaluru*
Email: *nasoteya@yahoo.co.in*

Dragonfly, Anax sp. (Aeshnidae: Odonata)

Author: *Dr Chitra Shankar*
Location: *Hyderabad*
Email:

Ant Mimic Bush Cricket, Macroxiphus spp. (Macroxiphus: Orthoptera)

Author: *Dr. Nagaraj, D.N., Project Head (Entomologist) Ento. Proteins Pvt. Ltd., Mangalore*
Location: *Bengaluru*
Email: *nasoteya@yahoo.co.in*

Green Lynx Spider, Peucetia viridans (Oxyopidae: Araneae)

Author: *Dr. Nagaraj, D.N., Project Head (Entomologist) Ento. Proteins Pvt. Ltd., Mangalore*
Location: *Bengaluru*
Email: *nasoteya@yahoo.co.in*

Megalurothrips sjostedti - aggregation of males on Sesbania. Location: Eggs of Green lace wing, Chrysoperla carnea (Chrysopidae: Neuroptera)

Author: *Dr. Sevgan Subramanian*
Location: *ILRI Campus, Addis Ababa, Ethiopia*
Email: *ssubramania@icipe.org*

A leaf-mimic katydid

Author: Mr. Rushikesh Rajendra Sankpal
Location: *Pune, Maharashtra*
Email: [*rushisankpal@gmail.com*](mailto:rushisankpal@gmail.com)

IE Extension

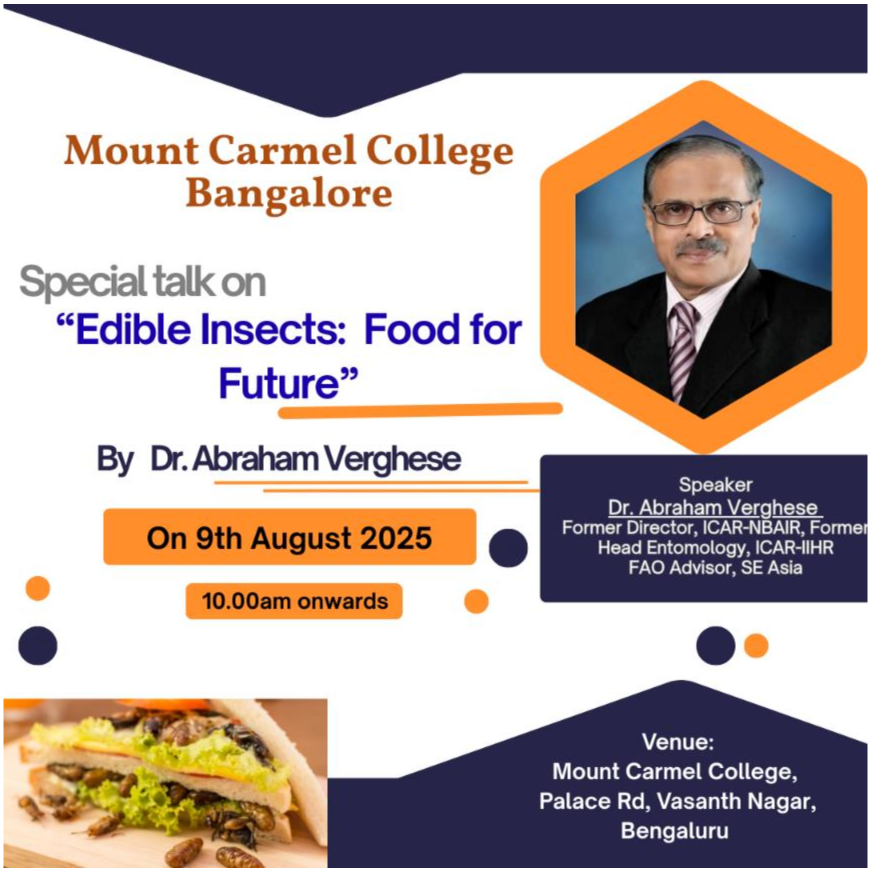
Insect Environment team at the 4th Dr VG Prasad memorial AAPMHE Lecture 2025 at ICAR –IIHR, Bengaluru on 28th July 2025

IE Team with Dr. K. Sreedevi and Students at the Insect Biodiversity & Systematics Laboratory, ICAR–NBAIR

Rashvee team with Mr. Bhimsen Vadvadgi, Founder Venkateshwara Farm Supply and his team and BASF Staff

Interacting with Farmers at Shreenidhi Plant Health Clinic

Dr. Rashmi M.A. with School Students at Jain Heritage School, Bengaluru Science Expo - Showcasing Sericulture Project



Mount Carmel College
Bangalore

Special talk on
"Edible Insects: Food for Future"

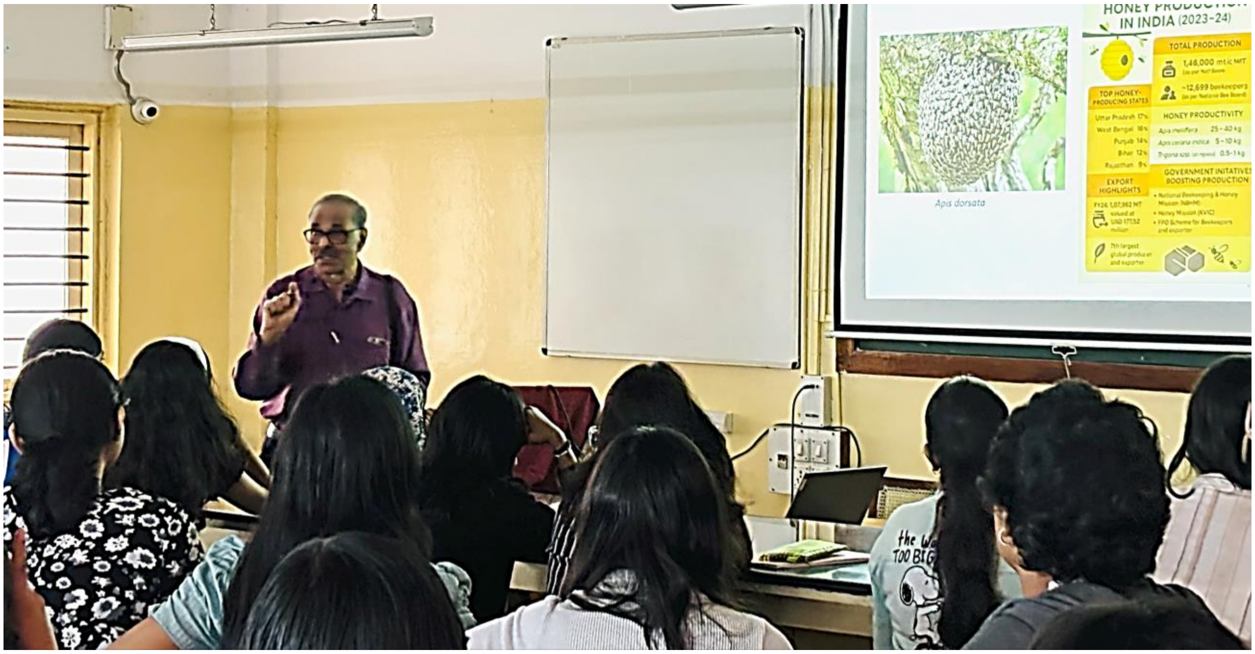
By Dr. Abraham Verghese

On 9th August 2025

10.00am onwards

Speaker
Dr. Abraham Verghese
Former Director, ICAR-NBAIR, Former
Head Entomology, ICAR-IIHR
FAO Advisor, SE Asia

Venue:
Mount Carmel College,
Palace Rd, Vasanth Nagar,
Bengaluru



Dr. Abraham Verghese Delivering a Scientific Talk on "Edible Insects: Food for the Future" at Mount Carmel College, Bengaluru, on 9th August 2025.

AVIAN Trust Inspires Insect Awareness at Mount Carmel College, Bengaluru

AVIAN Trust Team with Life Science Department Staff and Students at Mount Carmel College, Bengaluru

Dr. Rashmi M.A. delivering a special talk on "Science to Startup: Turning Academic Research into Agri-entrepreneurship" at Jyoti Nivas College Autonomous, Bengaluru, on 19th August 2025.

Dr. Rashmi M.A. with the Staff and Students of the Life Sciences Department at Jyoti Nivas College Autonomous, Bengaluru

Dr. Rashmi Inspecting Rose Blooms for International Export — Krishnagiri Greenhouse, Tamil Nadu

Field Surveillance by Rashvee Team - Broccoli Cultivation, Kolar District, India

Rashvee Team Conducting Field Survey on Termite Infestation

Sustainable Pest Management in Action – Rashvee Herbal Liquid Soap Trials at Mango Orchard, Kolar District, Karnataka

Dr. Rashmi M.A. delivering a special talk on Plant quarantine and phytosanitary certification in India: Safeguarding agri-trade and crop biosecurity at GPS Institute of Agricultural Management, Bengaluru on 29th July 2025

Field Insights and Farmer Engagement by Rashvee Team