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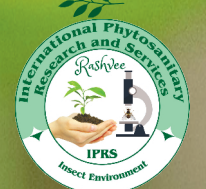
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***Cover Page: *Ischiodon scutellaris* Preyed Upon by a Spider**

Photo by Tamoghno Majumder

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Insect Environment

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Editorial

Insects at the Crossroads of History, Climate, and Conservation

Insects, though often relegated to the margins of human narratives, remain indispensable to the functioning of ecosystems and the resilience of agriculture. Their presence is woven into stories of science, engineering, climate, and culture. As we reflect on milestones from the recent centenary of Sir David Attenborough (100 years) to the engineering vision of Late Sir M. Visvesvaraya, (both Knighted) and from the recent Rajasthan's dust storms to Singapore's Insect Park we see how insects are both beneficiaries and victims of human progress. This editorial seeks to highlight these ecological intersections, urging readers to recognize insects not as peripheral actors but as central to our shared environmental future.



As a student of entomology and ornithology, I grew watching photographs and films by Attenborough, especially in the 80's and 90's. The celebration of Sir David Attenborough's hundredth year is a tribute to a life dedicated to storytelling that dignified the smallest creatures. His documentaries consistently elevated insects from obscurity, portraying them as architects of ecosystems and biodiversity. Attenborough's genius lay not only in scientific communication but in inspiring generations to see nature especially insects as integral to overall conservation. His contribution reminds us that the survival of insects is inseparable from the survival of humanity, and that awareness is the first step towards conservation.

The recent dust storms sweeping Rajasthan in India and heat waves across Asia and Europe were not mere climatic upheavals; they were ecological stressors with profound consequences for insect life. Dust deposition and thermal ups alter habitats, disrupt pollinator foraging, and reshapes microhabitats. Soil insects face shifts in moisture regimes, while aerial species struggle to navigate dust-laden air. These events are a reminder that climate adaptation strategies must account for the smallest yet most essential organisms. Studies on impacts and suitable prediction and protection systems for insects must be in place on priority.

The Krishnarajasagara (KRS) dam, engineered by Sir M. Visvesvaraya, transformed India's South Karnataka's drought-prone terrain into fertile fields. Beyond irrigation, it created wetlands that became sanctuaries for insect diversity dragonflies, aquatic beetles, and countless

species that stabilize food webs. These wetlands illustrate how visionary engineering can inadvertently foster biodiversity. Yet they also highlight the fragility, as reduction in wetlands caused drastic decline in numbers and diversity of Odonata. Perhaps this is also reflected in reduction of dragon flies and damsel files in western ghats region close to the dam. Protecting these wetlands is not merely about sustaining agriculture; it is about ensuring that insects continue to thrive as keystone species in aquatic ecosystems.

I enjoy frequenting the butterfly park at Sentosa, Singapore. Singapore's Insect Park and Museum exemplifies how education and wonder can drive conservation. But what fascinated me is, perhaps the world's only airport-butterfly park in Singapore's Changi airport in Terminal 3, levels 2 & 3. If you have the time, irrespective of terminals the Skytrain will take you there-the ride is free! By curating live exhibits and immersive experiences, it bridges science with public fascination to the insect world. Such parks highlight the aesthetic and ecological value of insects, reminding us that awareness and engagement are powerful tools against global insect decline. In a world where insect populations are shrinking, parks like Sentosa and Changi T3 airport, serve as ento-beacons, demonstrating that conservation begins with public curiosity.

From Attenborough's storytelling to Visvesvaraya's engineering, from Rajasthan's storms to Singapore's insect parks, insects remain woven into the fabric of human-environment interface. Their survival is not guaranteed, but their importance is undeniable. Insect Environment's Editorial voices will continue to champion insect conservation, ensuring that these small yet indispensable creatures thrive in the landscapes of tomorrow. We put this philosophy into practice through our outreach. Our editorial team and AVIAN Trust members spent three days with rural school children, teaching them about insect life, its ecological importance, and how even at a young age they can contribute to environmental conservation through knowledge of entomology! The challenge before us is clear: to build a future where insects are not casualties of neglect but celebrated as partners in resilience.

We are delighted that our early back volumes (hard copies) are in great demand. The editors thank our authors who keep our IE vibrant and engaging for both national and international readers, who now number more than 10,000.

Abraham Verghese
Editor-in-Chief

Research Articles

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New Record of *Procontarinia robusta* (Diptera: Cecidomyiidae) on Mango (*Mangifera indica*) from Uttarakhand, India

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Corresponding author E-mail: duraivasanthakumar@gmail.com*Abstract**

Gall midges (Diptera: Cecidomyiidae) are minute but ecologically important insects associated with diverse host plants, including mango (*Mangifera indica*). Globally, 25 species across 9 genera have been reported on mango, with 18 species recorded from India, 12 of which belong to the genus *Procontarinia*. The present study reports the first record of *Procontarinia robusta* Li, Bu & Zhang, a leaf gall-inducing midge previously known from Tamil Nadu, Andhra Pradesh, and Maharashtra, from northern India, based on leaf galls collected from Dehradun and Mussoorie, Uttarakhand, in February 2026. Identification was based on characteristic gall morphology—epiphyllous, cylindrical to conical, sessile galls with a calyx-like base—as adult rearing was unsuccessful. This record extends the species' known distribution within India and highlights the need for integrated morphological and molecular surveys across agro-climatic zones to better understand the diversity, distribution, and management implications of mango-associated cecidomyiids in Indian agroecosystems.

Keywords: *Procontarinia robusta*, mango, gall midge, Cecidomyiidae, Uttarakhand

Introduction

Gall midges (Diptera: Cecidomyiidae) are minute, delicate flies that often go unnoticed except by specialists. Nevertheless, their remarkable species diversity, wide host range, and important ecological roles make them significant despite their inconspicuous appearance. A total of 25 species of gall midges belonging to 09 genera have been reported in association with mango, *Mangifera indica* (Table 1). Of these, 18 species are

recorded from India, including 12 species under the genus *Procontarinia* (Gagné and Jaschhof, 2025). Members of this genus are known to induce galls on various parts of the mango tree, including leaves, branches, inflorescences, and fruits, which may adversely affect plant growth and yield (Gangaraju *et al* 2020; Jiao *et al* 2018; Kolesik *et al* 2009; 2024).

Procontarinia robusta Li, Bu & Zhang, 2003 which induces leaf galls on mango, was originally described from China in 2003 based on adult males and females (Li *et al.* 2003). Subsequently, the immature stages of this species were described by Cai *et al.* (2013). The species was first reported from India by Vasanthakumar *et al.* (2020). In India, it has been recorded from three states: Tamil Nadu, Andhra Pradesh, and Maharashtra. In the present study, the species is recorded for the first time from northern India based on gall characteristics. Attempts to rear the insects to the adult stage were unsuccessful; therefore, the identification was made based on gall morphology.

Image. 1 Infestation of Mango leaf gall midge, *Procontarinia robusta*



Gall: Leaf gall (Image 1). Epiphyllous, cylindrical to obtusely conical, sessile, glabrous, brown to reddish-brown, shiny and hard, unilocular and indehiscent. Galls measure about 1 mm in diameter at the base and 1–2.5 mm in height. During gall development, the leaf epidermis ruptures, forming a calyx-like structure around the base. On the underside of the leaf, the gall appears as a slightly discoloured blister with a necrotic area at the centre (Mani 2000).

Material examined: Leaf galls collected from Dehradun and Mussoorie, Uttarakhand, India on 07.02.2026.

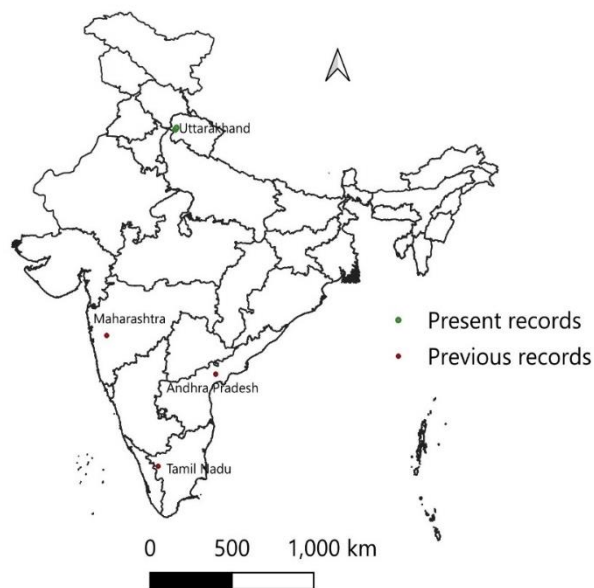


Fig. 1 Distribution of Mango leaf gall midge, *Procontarinia robusta* in India

Distribution in India: Tamil Nadu, Andhra Pradesh, Maharashtra, and Uttarakhand (present record) (Figure 1).

Elsewhere: China, Indonesia, and East Timor.

Table.1 List of gall midges reported to be associated with mango (*Mangifera indica*)

1	<i>Asphondylia mangiferi</i> Kolesik & David, 2024
2	<i>Asynapta mangiferae</i> Felt, 1909
3	<i>Dasineura amaramanjarae</i> Grover, 1964
4	<i>Gephyraulius mangiferae</i> (Felt, 1927)
5	<i>Gephyraulius indica</i> (Grover & Prasad, 1966)
6	<i>Hastatomyia hastiphalla</i> Yang & Luo, 1999
7	<i>Lasioptera mangiflorae</i> (Grover, 1968)
8	<i>Oligotrophus mangiferae</i> Kieffer, 1909
9	<i>Procontarinia allahabadensis</i> (Grover, 1962)
10	<i>Procontarinia amraeomyia</i> (Rao, 1950)
11	<i>Procontarinia biharana</i> Gagné, 2004
12	<i>Procontarinia brunneigallicola</i> (Rao, 1950)
13	<i>Procontarinia echinogalliperda</i> (Mani, 1947)
14	<i>Procontarinia fructiculi</i> Jiao, Wang, Bu & Kolesik, 2018
15	<i>Procontarinia frugivora</i> Gagné, 2004
16	<i>Procontarinia keshopurensis</i> (Rao, 1952)
17	<i>Procontarinia mangicola</i> (Shi, 1980)
18	<i>Procontarinia mangiferae</i> (Felt, 1911)
19	<i>Procontarinia mangifoliae</i> (Grover, 1965)
20	<i>Procontarinia matteiana</i> Kieffer & Cecconi, 1906
21	<i>Procontarinia pustulata</i> Kolesik, 2009
22	<i>Procontarinia robusta</i> Li, Bu & Zhang, 2003
23	<i>Procontarinia tenuispatha</i> (Kieffer, 1909)
24	<i>Procontarinia viridigallicola</i> (Rao, 1950)
25	<i>Prodiplosis longifila</i> Gagné, 1986

This note extends the known distribution of *Procontarinia robusta* to northern India, representing the first record of this species from Uttarakhand. The occurrence of characteristic leaf galls in this region suggests a wider distribution of mango-associated cecidomyiids than previously documented. As mango is an economically important crop, the presence of gall-inducing species such as *P. robusta* warrants attention due to their potential impact on plant health and productivity. The inability to rear adults in the present study highlights the need for further detailed investigations integrating both morphological and molecular approaches for accurate species confirmation. Additionally, systematic surveys across different agro-climatic zones, coupled with life history studies, would help reveal the true diversity, distribution patterns, and ecological significance of mango gall midges in India. Such information is essential for developing a comprehensive understanding of their role in agroecosystems and for formulating appropriate management strategies, if required.

Acknowledgements

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**First confirmed locality report of *Xenerianthus affinis* (Westwood, 1843)
(Insecta: Orthoptera: Chorotypidae) from Assam**

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Abstract

Xenerianthus affinis (Westwood, 1843) was originally described from “Assam,” however, the absence of a precise locality, coupled with subsequent geopolitical changes, has rendered its occurrence in present-day Assam uncertain. The present study provides the first confirmed, voucher-based record of the species from Assam based on specimens collected in 2025 from Garbhanga Reserve Forest, Kamrup (Metropolitan) district. A total of three specimens (two males and one female) were collected, preserved, and identified through detailed morphological examination using standard taxonomic keys and literature. Diagnostic characters and morphometric analyses confirmed the identity of the species. Earlier reports from Assam, particularly those linked to Sylhet during the British colonial period, are biogeographically ambiguous and therefore cannot be regarded as reliable evidence of its presence within the current administrative boundaries of the state. This record resolves a long-standing distributional uncertainty and confirms the presence of *X. affinis* in Assam, contributing to a clearer understanding of its range in northeastern India.

Keywords: *Xenerianthus affinis*, Assam, Garbhanga Reserve Forest, taxonomy

Introduction

Grasshoppers of the family Chorotypidae (superfamily: Eumasticoidea), commonly referred to as monkey grasshoppers, are sub-aerial herbivores of angiosperms and are morphologically distinct from members of Acridoidea. They are characterized by a head elevated above the level of the thorax, very short antennae, absence of abdominal tympana, wings (when present) broadened distally, and a laterally

spread posture of the hind legs at rest in most species. Globally, the family comprises six subfamilies, 44 genera, and 163 species (Cigliano *et al.*, 2026), of which 11 species have been reported from India to date (Chand *et al.*, 2025, Swaminathan *et al.*, 2016).

The species *Xenerianthus affinis* (Westwood, 1843), belonging to the subfamily Erianthinae, was originally described as *Mastax affinis* from “Assam” during the British Indian period. Subsequently, Stål

(1875) transferred the species to the genus *Erianthus*. Later, Decamps (1975), in his revision of the group, divided *Erianthus* into multiple genera and established the genus *Xenerianthus*, to which *X. affinis* was assigned. The genus is monotypic, represented solely by *X. affinis*. Globally, the species is known from Bangladesh, Myanmar, and Bhutan (Cigliano *et al.*, 2026), while within India it has been reported from Meghalaya, Mizoram, and Tripura (Swaminathan *et al.*, 2016, Shishodia *et al.*, 2010, Kumar *et al.*, 2024).

Despite its original attribution to Assam, the precise locality of *X. affinis* within the state has remained unclear. Kirby (1914), in *The Fauna of British India*, mentioned its occurrence from “Sylhet: Assam”; however, Sylhet was part of Assam only during the British period and became part of East Pakistan (now Bangladesh) following geopolitical reorganization in 1947. Consequently, historical records of its distribution referring to Assam are ambiguous in the context of present-day political boundaries. No subsequent literature has provided a confirmed, locality-specific record of the species from Assam, and recent faunal checklists, including Das *et al.* (2023) in Fauna of Assam, do not include this species within the state.

Although unverified photographic observations available on online platforms such as iNaturalist suggest the possible occurrence of *X. affinis* in Assam, these

records lack voucher specimens and diagnostic confirmation. During recent field surveys in the Garbhanga Reserve Forest, Assam, several specimens of *X. affinis* were collected and examined. The present study provides the first confirmed, voucher-based record of the species from a precise locality within the current political boundaries of Assam, thereby clarifying its distributional status in northeastern India.

Materials and Methods: Surveys were conducted in the year 2025 in Garbhanga Reserve Forest, Assam (**Figure 1**); specimens were collected using an insect net by sweeping vegetation and through hand-picking method. To euthanize the specimens, killing jars containing ethyl acetate were used. For temporary field storage, the specimens were placed in insect collection envelopes. Subsequently, they were transported to the laboratory, where they were pinned, labelled, and preserved for further identification. The geographic coordinates of the collection site were recorded using a Garmin Oregon 550 GPS device. The dried specimens were examined under a stereo zoom binocular microscope (Leica EZ4E) and identified based on descriptions provided in Kirby (1914) and Swaminathan *et al.* (2016). Measurements were taken using a Vernier caliper. All identified specimens were deposited in the National Zoological Collections at the North Eastern Regional Centre, Zoological Survey of India (ZSI), Shillong.

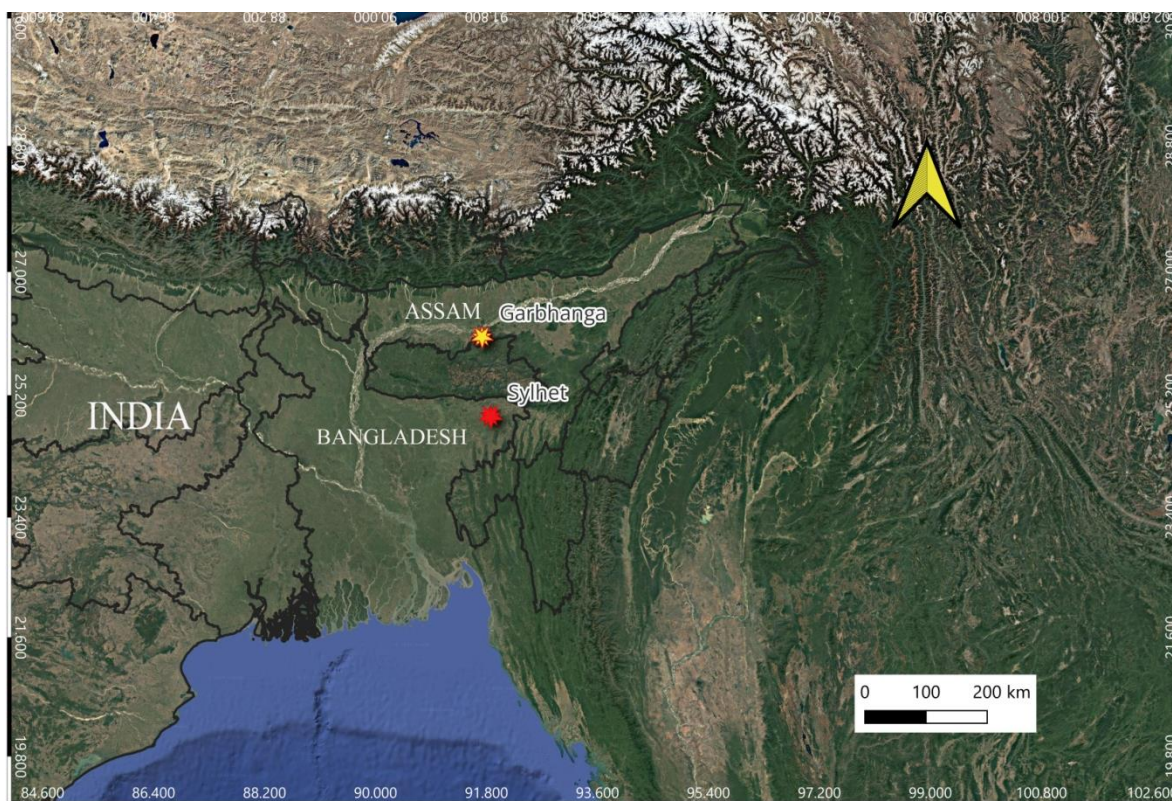


Figure 1: Map showing the earlier record of *X. affinis* from Sylhet (now in Bangladesh) in Red Asterisk and new locality report from Assam in Garbhanga Reserve Forest in Yellow Asterisk.

Result

Materials examined: 2 M, 1 F, Garbhanga Reserve Forest, Kamrup (Metropolitan) District, Assam, 26.0565 N, 91.727492 E, 103 m, 13.6.2025, Collector: Rumi Kalita, IV/ORTH/ERS/564.

Diagnosis: *Xenerianthus affinis* (**Figure- 2**) is characterized by a generally brown coloration with a slight rufous tinge in females and green colouration in males. The fastigium of the vertex is upright, notably broad, and usually appears weakly to distinctly bifid at its apex. The pronotum is distinctly rugose and bears a prominent, uneven median carina. The tegmina

show a ferruginous reticulation, while the intervening areas are partly subhyaline, particularly above the main vein; a pale oblique whitish streak is present near the apical one-fifth of the inner margin and extends toward the apex. The wings are fulvous-hyaline with ferruginous venation and possess a narrow brown posterior border. The abdomen is ferruginous brown, becoming deeper toward the terminal region. In the female, the upper valvular appendages are delicately serrulate, whereas the lower appendages bear three small teeth before the tip. The male can be recognized by the presence of a small whitish spot near the apex of the tegmina. The femora

are blackish, strongly compressed, and furnished with lamellate carinae above and below; the hind femora further exhibit three white transverse bands, and the upper carina ends in a sharp triangular tooth.

Measurements

Linear measurements (mm)	Female	Male
Antennae	4.95	3.07
Tegmina length	26.72	16.58
Tegmina width	3.27	2.03
Wing length	29.44	18.27
Body up to genitalia tip	29.00	18.00
Body up to wing tip	47.74	29.52
Pronotum	4.99	3.10
I Femur	5.54	3.44
II Femur	5.95	3.70
III Femur	19.28	11.97
I Leg	15.47	9.61
II Leg	16.47	10.23
III Leg	45.31	28.15

Discussion

The present study resolves a long-standing ambiguity regarding the type locality of *Xenerianthus affinis* in Assam. Although the species was originally described from “Assam” (Westwood, 1843), the absence of a precise locality in the original description has historically limited the reliability of this record. Kirby’s (1914) subsequent mention of “Sylhet: Assam” further complicates the

interpretation, as Sylhet no longer falls within the political boundaries of India following its transfer to East Pakistan (now Bangladesh) after independence. Therefore, earlier references to Assam do not necessarily correspond to the present-day state. In subsequent literature, the distribution of *X. affinis* within India has been restricted to Tripura (Shishodia *et al.*, 2010) and later extended to Meghalaya and Mizoram (Swaminathan *et al.*, 2016 and Kumar *et al.*, 2024). The absence of confirmed records from Assam in recent taxonomic works and faunal checklists create a gap in the documented distribution of the species within the region.

Recent photographic observations on platforms such as iNaturalist have indicated the possible presence of the species in Assam; however, such records remain unverified due to the lack of voucher specimens and detailed morphological examination. In taxonomic studies, especially within groups where species identification may require examination of fine morphological characters, including genitalia, such photographic evidence cannot be considered conclusive.

The collection and examination of multiple specimens from Garbhanga Reserve Forest in the present study provide the first reliable, voucher-based confirmation of *X. affinis* from a precisely defined locality in Assam. This finding not only validates the occurrence of the species within the current political boundaries of the state but also

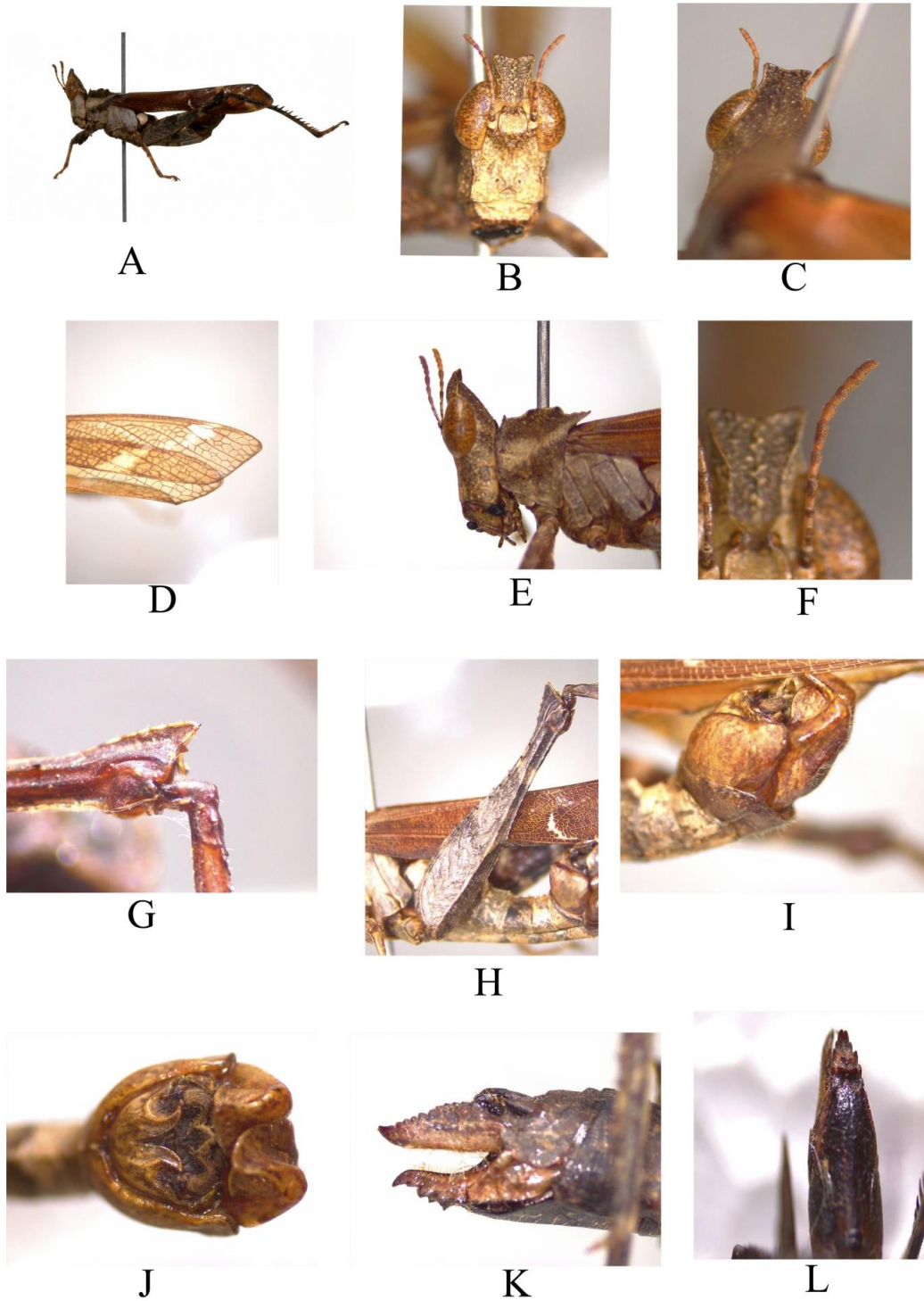


Figure 2: A- Male habitus (lateral view), B- Head frontal view, C- Head rear view, D- Apical part of Wings Male, E- Head and Pronotum (lateral view), F- Antennae, G- Hind knee, H- Hind femur, I- Male genitalia (lateral view), J- Male Genitalia (dorsal view), K- Female genitalia (lateral view), L- Female genitalia (ventral view).

bridges the gap between historical records and modern distribution data. The present record, therefore, represents the first precise locality-based confirmation of the species from Assam and contributes to a more accurate understanding of its distribution in northeastern India.

Acknowledgment: We would like to thank the Assam Forest Department and Assam State Biodiversity Board for the permission to carry out the study. We are thankful to the Head of the Department of Zoology, Girijananda Chowdhury University for supporting us. We would also like to thank the local residents of Garbhanga Reserve Forest for helping us during the survey and collection of specimens. The corresponding author would like to thank the Director, Zoological Survey of India and the Officer-in-Charge of Northeastern Regional Centre, Zoological Survey of India for providing necessary facilities to carry out this work.

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[Orthoptera: Eumastacoidea:
Chorotypidae] from Meghalaya, India.
Entomon **41(1)**: 39-46.

Westwood, J. O. 1843. Plate LXIII.
Descriptions of some orthopterous
insects belonging to the section
Saltatoria. *Arcana Entomologica or
Illustrations of New, Rare and
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First Report of *Aphid*, *Rhopalosiphum* Spp. (Hemiptera: Aphididae) Infesting Isabgol (*Plantago Ovata* Forskel) in Gujarat, India

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Abstract

A study was conducted to identify the aphid species infesting isabgol (*Plantago ovata* Forskel) at Medical and Aromatic Plant Research Station, Anand Agricultural University, Anand, Gujarat. A field survey in January, 2026 isabgol plants were found infested by aphid. Both nymphs and adults were found colonizing the plant stems and tender shoots, particularly during the flowering stage. Heavy infestation resulted in weakening of plants and a noticeable reduction in seed setting. The aphids were found forming dense colonies on the upper portions of the plants, especially on young growing shoots. Specimens (nymphs & adults) were collected and brought to the laboratory of the Department of Entomology, B. A. College of Agriculture, AAU, Anand for detailed identification and further studies. Based on morphological characterization, the pest was identified as aphid with genus *Rhopalosiphum* Spp. This study represents the first report of *Rhopalosiphum* spp. infesting isabgol in Gujarat, India, highlighting a potential emerging pest concern for this economically important medicinal crop.

Keywords: First report, Aphid, *Rhopalosiphum* Spp., *Plantago ovata*, Gujarat

Introduction

Export-oriented Medicinal crops plays a vital role in the agricultural economy of India. Among them, *Plantago ovata* Forskel, known as isabgol, is one of the most important commercial medicinal crops cultivated in the country. It is also locally known as isabgul, issabgol, ispaghol, isakol, and isphagol. The

name “Isabgol” is derived from the Persian words *Isap* and *Ghol*, meaning “horse’s ear,” which refers to the characteristic shape of its seeds. The crop originated in the mediterranean region. It belongs to the family Plantaginaceae and is a short-stemmed, highly cross-pollinated *rabi* crop bearing alternate leaves and small white flowers. The seeds are ovate, brownish-grey in colour and enclosed in

a translucent mucilaginous husk, which constitutes its principal economic product (Tyagi *et al.*, 2016). India dominates the global psyllium husk market, contributing nearly 80 per cent of the world's total supply and accounting 90-95 per cent of its production. The crop is cultivated over approximately 4.5 lakh hectares with a production of about 4.32 lakh metric tonnes (Das and Trivedi, 2023). In India, the major isabgol growing states are Gujarat, Rajasthan and Madhya Pradesh. Owing to its high export potential, isabgol is popularly regarded as a “dollar-earner” crop. In Gujarat, it the crop occupied 13,303 hectares with a production of 12,952 metric tonnes and it accounts for nearly 90 per cent of the country's processing capacity during 2022-23. Banaskantha district contributes the highest share of production, followed by Kachchh, Mehsana and Junagadh (Anonymous, 2023). Isabgol is primarily cultivated for its mucilaginous seed husk, which is widely used as a natural laxative in indigenous and traditional systems of medicine worldwide (Lal *et al.*, 1999). The seeds are nutritionally rich, containing appreciable amounts of crude fibre, protein and carbohydrates (Pendse *et al.*, 1976). However, the yield and productivity of isabgol are affected by several biotic and abiotic stresses. Among the biotic constraints, insect-pests reported on the crop include aphid (*Aphis gossypii* Glover), cigarette beetle (*Lasioderma serricornis* Fabricius), termite (*Odontotermes obesus* Rambur) and white grub (*Holotrichia consanguinea* Blanchard) are important. Recently, infestation of aphid,

Rhopalosiphum spp. was observed on isabgol crop in Anand, Gujarat causing significant damage. Since there are no earlier published reports of this pest infesting isabgol in Gujarat state the present study was conducted to identify the aphid infesting isabgol.

MATERIALS AND METHODS

A field survey was conducted during January, 2026 to identify the aphid infesting isabgol at Medicinal and Aromatic Plants Research Station, Anand Agricultural University, Anand, Gujarat. Aphid specimens were collected from the spikes of isabgol plants using a fine camel hair brush in 5 ml glass vials containing 70 per cent ethyl alcohol for identification based on morphological character.

The preserved specimens were also sent to the ICAR–National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru, for taxonomic identification. The species of aphid has been identified as *Rhopalosiphum* spp. and is the first of its kind reported from isabgol in Gujarat. Earlier, aphid species *Aphis gossypii* Glover was reported in isabgol crop at Anand Agricultural University, Anand (Patel, 2014).

Further, the aphid population was recorded to estimate the average population level. For this purpose, ten plants were selected randomly from each plot area. Each plant was carefully examined using the standard zero-to-four index method as described by Banks

(1954). Based on these observations, the aphid population was assessed and mean aphid index was calculated accordingly.

Aphid Index

Aphid Index	Criteria
0	Plant free from aphid infestation
1	Aphid present, but colonies did not build up. No injury due to pest apparent on the plant
2	Small colonies of aphid are present
3	Large colonies of aphid are present on tender parts. Counts of aphids in colonies are possible and tender plant part show damage symptoms due to aphids
4	Aphids cover the entire plant. Counts of aphids in colonies are impossible and plant show severe damage symptoms like curling and drying of spike due to aphids

Following aphid index was fixed for estimating the population of aphid and the average

Aphid index was worked out by adopting following formula.

$$\text{Average aphid index} = \frac{0N+1N+2N+3N+4N}{\text{Total number of plants observed}}$$

Where,

0, 1, 2, 3 and 4 are aphid index

N = Number of plants showing respective aphid index

RESULTS AND DISCUSSION

The survey was carried out during January, 2026 on isabgol at the Medicinal and Aromatic Plants Research Station, Anand Agricultural University, Anand, Gujarat. During the study, taxonomic identification was

performed based on morphological characteristics. The identification was further confirmed by a taxonomist at ICAR–NBAIR, Bengaluru, and aphid infestation was systematically recorded to assess the extent of pest occurrence in the crop.

Morphological characteristics

Aphids of the genus *Rhopalosiphum* are small to medium-sized insects with a broadly oval to moderately elongate body shape. Marginal tubercles are typically present on the pronotum and on abdominal segments I and VII. The siphunculi are variable in shape, being cylindrical, tapering, or slightly swollen, but are consistently characterized by an apical expansion with a well-developed flange. The cauda is shorter than the siphunculi and is bluntly tapering or tongue-shaped. These

diagnostic characters are consistent with earlier descriptions (Kamal and Ali, 2022).



Apterae



Alatae

Fig. 1: Different forms of aphid, *Rhopalosiphum* Spp.

Distribution of *Rhopalosiphum* Spp. in India

The genus *Rhopalosiphum* (Hemiptera: Aphididae) is notable for its wide geographical distribution and broad host plant range. According to Favret (2024), the genus *Rhopalosiphum* comprises 16 species distributed worldwide. Among them, several species are recognized as major pests of economically important agricultural and horticultural crops (Blackman & Eastop, 2000). In India, five species of *Rhopalosiphum* spp. have been reported, of which four are considered highly destructive. These four species include the corn aphid (*Rhopalosiphum maidis* Fitch), waterlily aphid (*Rhopalosiphum nymphaeae* L.), bird cherry-oat aphid (*Rhopalosiphum padi* L.) and rice root aphid

(*Rhopalosiphum rufiabdominale* Sasaki) (Singh *et al.*, 2023).

Incidence and nature of damage

At the Medical and Aromatic Plant Research Station, Anand, the aphid, *Rhopalosiphum* spp. was recorded as a major sap-sucking pest of isabgol. It showed considerable incidence, with an average aphid index of 2.3 aphids per plant during January, 2026. The pest causes severe damage, particularly at 80–90 days after sowing. During this stage, both nymphs and adults colonize tender shoots in large numbers and feed by extracting plant sap. While feeding, they excrete honeydew, a sugary and sticky substance that promotes the development of black sooty mould on plant surfaces, thereby reducing photosynthetic activity. Heavy

infestation ultimately results in stunted plant growth, reduced spike formation, and poor seed filling.

Table 1. Host range of different major species of genus *Rhopalosiphum* in India

Species	Hosts	References
Corn aphid (<i>R. maidis</i>)	<i>Avena sativa</i> L.	Behura (1963)
	<i>Cynodon dactylon</i> L.	Agarwala (1979)
	<i>Hordeum vulgare</i> L.	Raychaudhuri (1973)
	<i>Oryza sativa</i> L.	Raha (1979)
	<i>Pennisetum glaucum</i> L.	Ghosh (1970)
	<i>Sorghum bicolor</i> L.	Kar <i>et al.</i> (1990)
	<i>Triticum aestivum</i> L.	Verma <i>et al.</i> (1975)
	<i>Zea mays</i> L.	Chakrabarti (1972); Chaudhari (2016)
	<i>Cajanus cajan</i> L.	Sathe and Jadhav (2008)
Waterlily aphid (<i>R. nymphaeae</i>)	<i>Nuphar lutea</i> (L.) Sm.	Ganganalli <i>et al.</i> (2024)
	<i>Hydrilla</i> spp.	Basu and Raychaudhuri (1967)
Bird cherry-oat aphid (<i>R. padi</i>)	<i>Avena sativa</i> L.	Raychaudhuri (1980); Chaudhari (2016)
	<i>Hordeum vulgare</i> L.	Agarwala (1979)
	<i>Oryza sativa</i> L.	Raha <i>et al.</i> (1977)
	<i>Zea mays</i> L.	Agarwala (1979)
	<i>Triticum aestivum</i> L.	Chaudhari (2016)
Rice root aphid (<i>R. rufiabdominale</i>)	<i>Oryza sativa</i> L.	Behura (1963)
	<i>Hordeum vulgare</i> L.	Chakrabarti (1972)
	<i>Cynodon dactylon</i> L.	Behura (1963)
	<i>Avena sativa</i> L.	Rao and Kulkarni (1975)
	<i>Triticum aestivum</i> L.	Verma <i>et al.</i> (1975)
	<i>Zea mays</i> L.	Chakrabarti (1972)

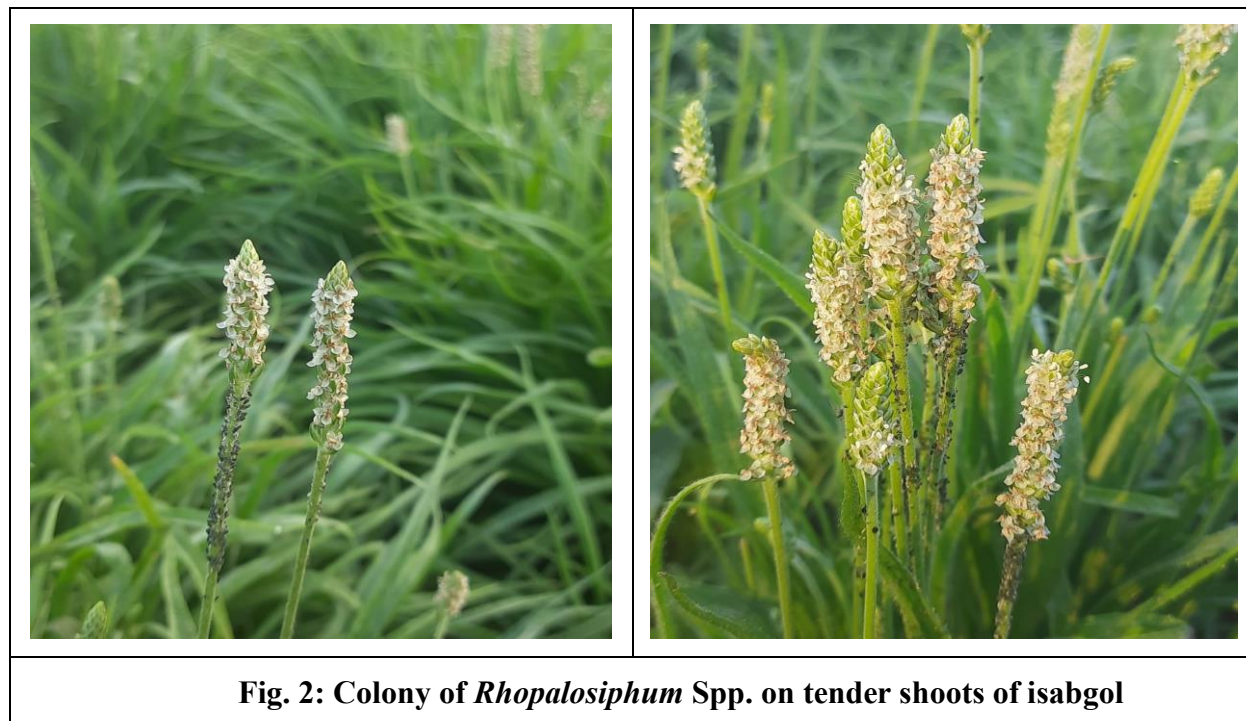


Fig. 2: Colony of *Rhopalosiphum* Spp. on tender shoots of isabgol

Conclusion

Rhopalosiphum spp. has invaded several isabgol-growing regions and is steadily increasing its pest status on isabgol as well as on other crops. The pest was recorded with an aphid index of 2.3 during January, 2026, indicating noticeable infestation and crop damage at this critical growth stage.

Therefore, systematic surveys and regular surveillance of the pest are essential to document its geographical spread, host range, and extent of damage in isabgol-growing areas. Such monitoring is crucial for designing timely and effective management strategies to minimize yield losses. Otherwise, it may become a serious threat to isabgol growers, who are already challenged by multiple pest problems during the crop season.

Acknowledgement

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Making India Book of Records for Massive White Grub Beetle Collection: A Success Story of Large Community Mobilization in Majuli River Island of Assam, India

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Abstract

Large community mobilization or social engineering approach transforms insect pest management programmes into a coordinated, sustainable, ecosystem-based strategy, ensuring long-term crop protection, environmental safety, and economic stability, especially for agriculture-based communities. Considering the importance of community mobilization, the All India Network Project on Soil Arthropod Pests, Assam Agricultural University, Jorhat Centre has embraced "Group Approach of Extension Management" to tackle white grub menace in Majuli river island of Assam during 2010-2023. As a part of the mass campaigning and awareness programme the project team planned and executed a "National Record" achievement of "Most Beetles Collected in 3 Hours", by collecting 73,700 white grub beetles in collaboration with 100 farmers at Maharichuk Village, Majuli, on 9th April 2018. The impact analysis of this record revealed that this mass campaigning programme based on group approach of extension mostly targeting the flood and erosion affected farmers in Majuli had a tremendous impact in terms of protecting the crops, disseminating ecofriendly technologies, enhancing crop productivity as well as improving both livelihood and nutritional security.

Keywords: Scarabaeidae, *Lepidiota mansueta*, Farmers Participatory Approach, Impact assessment

Introduction

The large community mobilization or social engineering is a data-driven and participatory framework used to design

sustainable systems for the efficient management of resources and human capital, with the aim of achieving greater socio-economic stability and well-being. A

participatory approach tends to focus initially on small numbers of clients which are location specific in nature. Rather than “passive participation,” it is aimed to inspire “self-mobilization”, where communities organize and take initiatives independently to solve their own problems/issues. Community mobilization involves engaging stakeholders to identify priorities, resources, and solutions collectively, thereby promoting inclusive participation, accountability, good governance, and sustainable outcomes. Being a group approach, this concept profoundly relies on all the members coming together to achieve a common goal, finding technical solutions and building capacities in the extension system and bridges the gaps in knowledge and technology dissemination. An underlying purpose of participatory approaches is the 'empowerment' of disadvantaged groups (Farrington and Martin, 1988; Tavernier, 2006) where large community mobilization can effectively and intelligently be explored in solving some crucial constraints related to agriculture and allied sciences. Such type of approaches not only improves crop productivity and livelihood but also tremendously improve overall knowledge content and capacity building of the farming community (Deka *et al*, 2018). Most of such approaches are ecofriendly, economical and sustainable. One major benefit of working through farmers' group is that farmers support each other to learn and adapt (Akinagbe and Ajayi, 2010)

and it also reduces the cost of public extension services (Conroy, 2003).

Parallel efforts were made to integrate basic research with community-based action programmes, focusing on the mass collection of adult white grub beetles during their short emergence period (6:00-9:00 PM during April-May) as a practical and cost-effective management strategy. These extension activities were initiated from 2010 onwards in collaboration with different stakeholders under the theme “Mass campaigning against *Lepidiota mansueta* in Majuli river island through social engineering” prioritized group-based mass collection and destruction of adult beetles.

Outbreak of white grub, *Lepidiota mansueta* in Majuli river island of Assam

The white grub, *L. mansueta* (Coleoptera: Scarabaeidae) was first detected in October 2005 in the farmers' field of Majuli (26°57'0"N 94°10'0"E), Assam. Majuli island is a biodiversity hotspot due to its rich ecology with rare breeds of flora, fauna and many migratory bird species (Borkataki, et al, 2021, Saikia and Ahmed, 2017; Saikia, 2025). This species has emerged as a serious pest of several field crops in Majuli (Bhattacharyya et al, 2015; 2021; Dumala et al, 2023). It has a biennial life cycle, which is unique in North-East India, with the duration of egg, grub, and pupal stages ranging from 12-17 days, 635-671 days, and 28-35 days, respectively. Third instar grubs cause extensive damage to many

economically important crops and have a prolonged developmental period ranging from 545 to 563 days. Field surveys conducted during 2005-2009 revealed the most severely affected crops were potato, sugarcane, Colocasia and green gram and the extent of damage varied from 42-48, 15-20, 35-40 and 30-35%, respectively (Bhattacharyya *et al*, 2013).

L. mansueta can be regarded as a rare species, because it spends its entire life cycle under the ground except for a short period during which adults emerge from the ground for mating (Bhattacharyya *et al*, 2013; 2015; 2023a; Das *et al*, 2026). There is no evidence that the adults fed on plants either in the field or in the laboratory and hence this species has the unique distinction of being the first Indian phytophagous white grub species with nonfeeding adults (Bhattacharyya *et al*, 2011; 2026). The species showed the highest level of endemism occurring only in the Majuli river island and adjacent areas which is considered to be one of the most important organic hubs of Assam. Moreover, this island is also making constant efforts to get the tag of “World Heritage Site” from UNESCO. Therefore, searching for a novel management strategy without applying synthetic insecticides became inevitable. The peculiar emergence behavior of the beetles during dusk (18.00-21.00 hours) for a very short period of time (2-3 weeks during April) was explored for the massive collection of beetles by light trapping and scouting through large community

mobilization programme (Bhattacharyya *et al*, 2017; Deka *et al*, 2018; Sreedevi *et al*, 2019; Das *et al*, 2016; 2021; Bhattacharyya *et al*, 2023b).

A mass campaign based on social engineering principles was organized involving approximately 400 farmers from 40 endemic villages, focusing on coordinated collection and destruction of adult beetles. This group-based approach received an overwhelming response and proved highly effective in reducing beetle populations.

As a part of this initiative, a record attempt was conducted at Maharichuk village on 9th April 2018, involving 100 farmers, with the following objectives:

1. To destroy the huge breeding ground/reservoir of white grub beetle
2. To create awareness among farmers and stakeholders about the pest problem
3. To demonstrate the effectiveness of social engineering/community mobilization in pest management

Genesis of the record attempt

The All India Network Project on Soil Arthropod Pests, Assam Agricultural University, Jorhat Centre has made “National Record” of “Most Beetles collected in 3 hours” by collecting 73,700 numbers of white grub beetle (*L. mansueta*), in collaboration with 100 farmers of Majuli at Maharichuk Village on 9th April, 2018. This record was made under the

project headed by Dr. Badal Bhattacharyya, then Principal Scientist and Principal Investigator. This record attempt was made under the ongoing mass campaigning programme against white grub beetles to collect and destroy the beetles by exploring the “Large community mobilization/ Social Engineering” concept. This innovative approach really helped in reducing beetle menace in Majuli river island, thereby ensuring livelihood security of the farmers.

How the record attempt was executed

A highly white grub endemic area was selected at Maharichuk Village, Majuli where heavy emergence of beetles was expected during the 2nd week of April, 2018. Accordingly based on weather forecast, 3 day (9-11th April, 2018) were fixed for the date of execution. This record attempt was done under the “Mass Attempt” theme of India Book of Records (IBR). Seven members from Assam Agricultural University (AAU), Jorhat and 100 well trained skilled farmers (above 18 years) having excellent knowledge on beetle behaviour were selected for executing the national record attempt. There were 10 groups of farmers (1 Leader, 1 Vice Leader and 8 members) and the groups were named after some renowned personalities of Assam. After registration, groups were lined up and the detail rules were explained to them at 5 PM and both National and State Anthem were sung. Later on, the farmers marched to the execution site (10 ha area demarcated by putting coloured flags) and positioned at already specified 10

spots. Farmers were signalled to start the collection through siren exactly at 6 PM. Hand collection was continued up to 6.30 PM and after that both hand collection and light trapping were done. The collection was continued up to 9 PM with 5 minutes break after every hour of attempt. The whole programme was video-graphed and both print and electronic media personnel were present at the execution site. Safety measures like arrangement of ambulance and other medical facilities like fast aid and snake anti venom were kept ready as per the guidelines of IBR. The counting of the beetles was done in front of the Judges, district administration, print and electronic media and local people. Finally, the adjudicator declared that all total 73,700 numbers of beetles were caught in 3 hours by the project team and 100 farmers, awarded the certificates and medal to the whole team (Fig. 1 (A-F)).

Outcome of the effort

The whole programme was planned as a part of “Social Engineering for the adult management of *L. mansueta*” in Majuli as per the mandate of the project. Such type of “Large community mobilization programme” helps splendidly in awareness programme and the major advantages of such approaches are - (i) the gravid females are killed before egg laying, (ii) capacity building of the farmers in white grub endemic areas and (iii) the management approach is ecofriendly and cost effective since without applying a single drop of insecticide, the beetles were caught and killed.

Collecting and killing such a large number of beetles at their breeding site definitely helped the flood and erosion-affected farmers in protecting their crops from white grub menace. It has been observed that this endeavour led to a great help to potato growers in subsequent years at the operational area since the area was almost free from beetle menace due to massive collection through community participation. The widespread diffusion of light traps and scouting techniques as an eco-friendly non-chemical approach of managing white grub beetles have also been embraced by the farming community.

Hypothetical model on impact of massive destruction of beetles

A hypothetical model on the impact of massive beetle collection leading to a possible grub reduction in the operational area is presented below:

- Total number of beetles collected within 3 hours = 73,700
- Numbers of gravid females considering sex ratio 1: 3 (Female: Male) = 24,567
- Say Numbers of gravid females after deducting 20 % natural mortality = 19,654
- Total egg load considering fecundity @ 27 eggs = 5,30,658
- Total 1st instar grubs after deducing 20% mortality in egg stage/Say fail to hatch = 4,24,527

- Let there be 50% mortality of 1st instar due to various factors like predation, parasitization, natural mortality etc. = 2,12,264
- Probable reduction in grub load: 4,24,527- 2,12,264= 2,12,263 numbers

Success story highlighted

The success story of setting a national record was highlighted by most of the print and electronic media of Assam. The story was also featured in the editorial column of one of the premier English daily newspaper (The Assam Tribune), where the editor has commented as cited below.

- In a remarkable show of community participation, farmers of Maharichuk village of Majuli took upon themselves the task of getting rid of pests and ended up collecting a whopping 73,700 white grub beetles in a mere three hours' time.
- The 'catch' has yielded another dividend as well to the farmers as the beetle with its high nutrient contents is being added to the local cuisine. The Assam Agricultural University also deserves credit for the exercise which had been undertaken under the guidance of its scientists.
- This has been a refreshing development on several counts, not the least because the pest menace was contained without the use of harmful insecticides- a normal practice these days which is emerging as a health

hazard. Secondly, the initiative goes to show that community participation can do wonders when it comes to securing common interests. Endeavours such as this also allow a strong sense involvement and bonding among the communities and make people take active part in the development process.

- This kind of community initiative can hasten the development process and also be an effective deterrent to corruption because people are in a position to keep strict vigil on the implementation of a project that involves their direct participation. Indeed, there is an urgent need to replicate successful instances of community participation across the State and in diverse spheres. Afforestation and building of rural infrastructure and community assets hold a lot of potential for harnessing community participation.

From pest to cuisine, the Majuli beetle: an opportunity

The project has made an innovative approach to convert the “Pest into Cuisine” by floating up the concept of “Beetle Fry” (Fig. 2. A-C) & “Roasted beetles” prepared from *L. mansueta* beetles. Local tribal communities traditionally consumed the cooked or fried adult beetles as a protein-rich food source, which opened new avenues for research into their nutritional and nutraceutical potential. The processing, refinement, and value addition of these food products have led to their

increasing popularity not only among indigenous tribes but also among other communities of Majuli (Bhattacharyya et al, 2021). The beetles were also used in bulk quantities as feed for pig, dog and poultry. Biochemical studies indicated that the beetles contained carbohydrate (9.18 %), fat (4.10 %), protein (76.42 %), fibre (5.16 %), ash (2.98 %) and seven dietary elements (Bhattacharyya et al, 2018). The total phenolic content, flavonoid content, and antioxidant activity of *L. mansueta* were 4.00 mg catechol equivalent/g, 1.59 mg quercetin equivalent/g, and 22.60% DPPH activity, respectively. Fatty acid profiling revealed the presence of 4 fatty acids viz. lauric acid, stearic acid, linoleic acid and palmitoleate. All together 17 amino acids have also been recorded, of which 8 amino acids viz. histidine, threonine, valine, methionine, isoleucine, leucine, phenylalanine and lysine were found to be essential. Water soluble vitamins viz., thiamine hydrochloride, ascorbic acid, nicotinic acid, pyridoxal phosphate, pyridoxine hydrochloride, folic acid and riboflavin were also recorded in considerable amount through HPLC analysis. Toxicological evaluation through acute oral toxicity tests in rats demonstrated that beetle powder is safe for consumption up to a dose of 5 g/kg body weight, indicating its potential as a safe alternative protein source.

Overall impact of the mass campaigning against white grub beetles during 2010-23

White grub is a dangerous destructive insect which can cause major havoc in the

agricultural sector. Hence destruction of both the beetle and grub is extremely important during its availability in the sunny days of April, immediately after the first pre monsoon shower. Awareness creation is one of the main requisites to manage this insect, not only in Majuli, but also in other parts of the state. Social engineering/ Farmers Participatory Approach started from 2010 onwards involving 400 farmers in 40 endemic villages of Majuli received overwhelming responses and was exceedingly successful leading to massive collection and killing of approx. 13.51 lakh of beetles during 2010-23. Apart from targeting the management of adult white grub beetles through community mobilization, the technologies tested and applied to manage the grubs of this pest also found effective in suppressing the pest menace in the endemic pockets (Bhattacharyya and Pujari, 2014; Pujari and Bhattacharyya, 2016).

The other impacts are also mentioned below:

- a) There was less emergence of beetles from soil and low population of grubs in both cultivated and non-cultivated fields in areas where the mass collection and destruction of adults by light traps and scouting were undertaken in the previous years.
- b) The crop productivity had also increased in different crops after formation of groups and group-based activities.
- c) Farmers re-adopted the crops that were discontinued due to white grub infestation.
- d) Farmers who had the capacity to increase their area under cultivation had started to expand the crops due to reduction of white grub infestation.
- e) Farm income was increased after being involved in group activity.
- f) The re-adoption of Colocasia cultivation by the affected farmers has restored the nutritional security of farmers.
- g) Some tribes relished the cooked/fried adults of *L. mansueta* as protein rich food which opens an avenue of further research on its nutritive/nutraceutical value. Since, the traditional method of preparation of the beetles was somewhat crude, attempts were made to float up a concept of “Beetle Fry” and “Roasted Beetles” dish. Beetles were also used in bulk quantities as feed for pig, dog and poultry. Besides, the farmers were also encouraged to explore the grubs of *L. mansueta* as bait for fishing purposes.
- h) Even, the famers who were not included in groups showed their eagerness to form groups for the task due to spreading effect of group approach in a passive way.
- i) The mass collection and destruction of beetles were carried out during the evening hours (6-9 pm) during the month of heavy emergence of beetles i.e. April. Therefore, the farmers virtually did not lose any effective working hours/man-days.
- j) Majuli river island is organic by default. Therefore, the farmers have shown preference as well as adopted the

technology because without applying insecticides this dreaded pest could be managed. Farmers were convinced and specially delighted when they could kill the gravid females before egg laying in their field.

- k) Other stakeholders associated with this mass campaigning have also endorsed this technology because a non-chemical approach of management strategy which was primarily based on the concept of beetle population regulation was successfully implemented.

This exemplary, non-chemical and innovative approach, aimed at farmers in the flood and erosion prone areas of Majuli island, has significantly reduced crop losses and safeguarded farmers' incomes amounting to approximately Rs. 2.0 crores from the devastating impact of this rare white grub. Though the selected beneficiaries of the project have been performing extremely well in reducing the effects of white grub under the guidance of AAU experts, better results are

still awaited, which is mainly due to the hindrances like availability of vast sand banks and ability of the beetle to move from one place to the other within short period of time. It is expected that involvement of more manpower, continuous guidance by AAU, Jorhat and other line departments, and support of the government will surely help to reduce the effects of the insect to a satisfactory level in the days to come. The impact analysis reveals that this mass campaigning programme explored the group approach of extension mostly targeting the flood and erosion affected farmers in Majuli had tremendous impact in terms of protecting the crops, disseminating ecofriendly technologies, enhancing crop productivity as well as improving both livelihood and nutritional security. Such type of approach can also be explored for the management of some of the notorious and highly polyphagous crop pests like swarming caterpillars in rice, paddy ear cutting caterpillars, locusts, cutworms, fall army worm, giant African snails, squirrels, rodents etc.



A. Farmers marching to the execution site



B. Collection of beetles



C. Counting of beetles

D. Beetle heap during the record



E. Award distribution ceremony

F. Certificates and medals received

Fig. 1 (A-F). Glimpses of activities of IBR National Record of “Most Beetles collected in 3 hours” by collecting 73700 numbers of white grub beetles in collaboration with 100 farmers of Majuli River Island on 9th April, 2018



A. Edible portion of adult beetles



B. Beetle fry dish



C. Beetle fry dish served in feast

Fig. 2 (A-C). Beetle fry dish

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Declaration

All the authors hereby declare that the submitted article is original, has been written by us, and contributes to the advancement of knowledge in entomology.

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First discovery of inter-specific roosts of tribe Dacini (Tephritidae: Diptera) fruit flies from Asia: Maneuvering toward the efficient bio-rational management of true fruit fly pests

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Abstract

Fruit flies of the tribe Dacini (Tephritidae: Diptera) are major pests of global horticulture, causing significant economic losses despite extensive management efforts. Current biorational control relies largely on male-specific paraperomones, limiting effectiveness against females. Here, we report the first evidence of interspecific communal roosting in Asian Dacini, involving six *Bactrocera* species (*B. cucurbitae*, *B. zahadi*, *B. diversa*, *B. scutellaris*, *B. caudata*, and *B. yoshimotoi*) observed in bamboo plantations of Himachal Pradesh, India. Large mixed-sex aggregations formed during winter, with flies repeatedly returning to roost sites after disturbance and exhibiting proctodeal tropholaxis. All species belonged to the *Zeugodacus* subgenus group, suggesting phylogenetic constraints. We hypothesize that interspecific aggregation is mediated by unidentified allelochemicals, herein termed “requiemones,” facilitating communication among ecologically similar species. This discovery provides new insights into fruit fly behavioral ecology and offers potential for developing novel, more inclusive biorational pest management strategies targeting both sexes.

Keywords : Inter-specific roosts, Allelochemicals, Fruit flies, Dacini, *Bactrocera* and bio-rational Pest management.

Fruit flies of tribe Dacini (Tephritidae: Diptera) are notorious pests of global importance. Enormous management and quarantine efforts are undertaken every year to reduce their populations. Many insect pests attack fruits and vegetables but none have garnered greater notoriety than Tephritids. They are recognised worldwide as the most

important threat to the horticultural industry. Among the well established fruit fly pests, *Bactrocera dorsalis* (Hendel), *B. cucurbitae* (Coquillett), *B. tau* (Walker), *B. zonata* (Saunders), *B. zahadi* Mahmood, *B. invadens* Drew, Tsururta & White, *B. diversa* (Coquillett) and *B. scutellaris* (Bezzi) are major species infesting fruits and vegetables.

The crop loss estimated due fruit fly damage has been reported to be of approximately US\$353.2 million (Mumford, 2001, values converted).

Among the various management strategies, semiochemicals are considered eco-friendly and effective tools. However, for pest fruit flies, the only available semiochemicals are male-specific parapheromones, such as methyl eugenol and cue-lure, which limit management effectiveness because females are not attracted to them.

In this context, we report the first discovery of interspecific roosting behavior in the tribe Dacini, involving six pest fruit fly species.

Roosting fruit flies were collected using a sweep net and identified according to keys provided by Drew and Romig (2013, 2016). We follow Hancock and Drew (2018) in treating *Zeugodacus* Hendel as a subgenus of *Bactrocera* and Drew and Hancock (2022) in treating *B. invadens* Drew, Tsuruta & White as a distinct species.

Earlier communal roosts in subfamily Dacinae (genus *Dacus* Fabricius) were recorded by Munro (1925) from South Africa and discussed by Hancock (1989) from Zimbabwe but no such communal roosts were recorded from the Asian region. We found 6 different species congregating in mass between two adjacent leaves of bamboo (Figure 1) and three such roosts were recorded from 3

different bamboo plantations in Solan district of Himachal Pradesh (India). There were 324, 204 and 185 male and female fruit flies in these roosts, comprising *B. cucurbitae*, *B. zahadi*, *B. diversa*, *B. scutellaris*, *B. caudata* and *B. yoshimotoi* (Hardy) (Table 1).

We concur with Hancock (1989), who concluded that roosting may occur due to low food availability and environmental stresses. During winter, Himachal Pradesh remain too cold (0°-7° C) without any horticultural crops, leading to formation of such roosts in fruit flies. However, our major focus was on communication among the fruit flies in the roost and it is also noteworthy that all these species occur in cucurbitaceous ecosystems. All the recorded species in the Indian roosts belong in the *Zeugodacus* group of subgenera of genus *Bactrocera* Macquart (Hancock and Drew, 2018) and this activity indicated their subgeneric relationship. Since no other species apart from those in the *Zeugodacus* group of subgenera roosted among them we hypothesize that they may release certain inter-specific aggregation semiochemicals to communicate for roosting in mass.

Apart from the roosting we observed *proctodeal tropholaxis*, i.e. there was lot of excreta on leaves and fruit flies were feeding on each other's droppings. As described by Hancock (1989), after disturbance flies flew away and returned to the roosting leaves after 10-35 minutes, even if disturbed multiple times. Returning to the same roosting leaves

indicates the presence of an inter-specific allelochemical, the isolation and identification of which could be an important future research topic for the management of fruit fly pests and to sort out their subgeneric relationships. There appear to be no other reasons for all these species roosting together than an inter-specific allelochemical communication.

Among the Indian roosts, males of all species respond to the parapheromone cuelure except *B. diversa*, which responds to isoeugenol, and that is used as an important character in classifying the genus *Bactrocera*. However, there are other prominent species present in the area responding to cuelure such as *B. (Bactrocera) divenderi* Maneesh, Hancock & Prabhakar, which infests peaches and nectarines (Maneesh *et al.*, 2022) but did not occur in the roosts. Females also responded and therefore we can rule out the involvement of lures in roosting. Similarly, African *Dacus* species associated with roosts showed either no lure response or responded to vertlure (Hancock, 1989), with females and teneral also responding. We think it is the host plant that is the only constant among many variables in the Indian roosts and feeding on common crops may have led to development of specific allelochemical-like metabolites, since it is evident that many insects get their chemical composition from their hosts. All these roosting species are well known pests and feed

on cucurbits: *B. zahadi* and *B. cucurbitae* infest the fruits while *B. diversa*, *B. scutellaris* and *B. caudata* infest the flowers and tendrils of cucurbitaceous crops. African *Dacus* species associated with roosting all breed in either cucurbits or asclepiads.

Volatiles involved in inter-specific communication are known as allelochemicals (Kalaisekar *et al.* 2017) and classified into further types based on their action. However, specificity of these allelochemicals is still unknown in relation to roosts of separate species; we would like to call this “*Requiemone*”, allelochemicals involved in inter-specific communication among the organisms of similar ecological guild belonging to similar genera but may or may not belong to similar subgenera. The term *Requiemone* is derived from Latin word *requiem* and *mone* which means warn to rest. We hope this short communication will open the door for new research into the management of these notorious crop pests and help in isolation of an inter-specific aggregation allelochemical. Such an allelochemical might also help in establishing the subgeneric placement of certain species. This particular observation supports the views of Hancock and Drew (2018) in treating *Zeugodacus* Hendel and *Javadacus* Hardy are closely related subgenera within the *Zeugodacus* group of subgenera.



Figure 1. Roosts of Genus *Bactrocera* Macquart (Dacini:Dacinae: Tephritidae)

Table 1. Number of individuals of fruit flies in three different roosts on bamboo leaves (Locality, Nauni, H.P. India, 30°51'32"N 77°9'58")

Species	Number of flies in Roost 1		Number of flies in Roost 2		Number of flies in Roost 3	
	Females	Males	Females	Males	Females	Males
<i>B. zahadi</i>	80	44	27	65	45	30
<i>B. scutellaris</i>	55	72	12	20	28	30
<i>B. diversa</i>	15	22	10	3	10	8
<i>B. cucurbitae</i>	2	18	10	25	0	5
<i>B. caudata</i>	0	4	5	5	0	0
<i>B. yoshimotoi</i>	1	11	2	20	3	26

Summary

This study reports the first discovery of interspecific communal roosting in Dacini fruit flies from Asia, involving six *Bactrocera* species. Behavioral observations, including site fidelity and tropholaxis, suggest the presence of interspecific chemical communication mediated by unknown allelochemicals. The authors propose a new term, “requiemone,” for such compounds facilitating aggregation among ecologically similar species. These findings provide new insights into fruit fly ecology and open avenues for developing improved biorational pest management strategies.

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Impact of Weather Factors (Temperature and Relative Humidity) on the Relative Abundance of two Honey bees (*Apis*) Species on *Sesamum orientale* and *Ricinus communis*

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Abstract

Sesamum orientale (sesame) and *Ricinus communis* (castor) are two economically important oilseed crops cultivated in the northern region of Bihar, including the Tirhut division, where Muzaffarpur district is located. These crops provide substantial economic returns to farmers. Both crops are entomophilic, with honey bees serving as the primary pollinators. Two species, *Apis mellifera* and *Apis florea*, are commonly found in this region, and their foraging activities contribute significantly to pollination.

Environmental factors such as temperature, relative humidity, and photoperiod influence the relative abundance of these honey bee species and, consequently, crop yield. The present study revealed that the relative abundance of these bees exhibits a clear diurnal pattern, increasing during the morning hours, peaking around noon, and declining thereafter. Furthermore, the abundance of both species showed a highly significant positive correlation with temperature, whereas a non-significant negative correlation was observed between the population of *Apis florea* and relative humidity.

Key words: relative abundance, relative humidity, entomophilic, diurnal variation, honey bees

Introduction

Honey bees are one of the most efficient entomophilic agents collecting and transferring pollen grains among different flowers during their foraging activity. In farmed areas bees are needed for the

pollination of the cultivated crops and also for maintaining biodiversity among intervening non cultivated areas. The efficiency of honey bee as a pollinator depends upon their high numerosity and the behaviour of visiting same species of flower again and again. i.e. their

foraging consistency. Two species of honey bees *Apis mellifera* and *Apis florea* subjected to the current study are commonly distributed in and around Muzaffarpur, while *Apis mellifera* is readily dominated species, *Apis florea* domestication in comparatively difficult.

Among different crops pollinated by these species *Sesamun orientale* and *Ricinus communis* are common. The productivity of these crops to a greater extent depends upon the efficiency of pollination carried mainly by the bees. The later in its turn is influenced by the bees foraging activities. Many environmental factors such as temperature and relative humidity tend to affect foraging activity of these bees and thereby their efficiency as an agent of pollination. Since the weather parameters are changing due to anthropogenic activities, their impact on the relative abundance of the bees must be

ascertained and that's why this research work has been undertaken. Although not much works has been done on castor, it has been reported as a good source of pollen to honey bees (Suryanarayanan, 1992).

Materials and Methods

Experiments concerning current research work were mainly carried out at University Department of Zoology (B. R. A. Bihar University) Muzaffarpur. The fields chosen were located at Mushari block of Muzaffarpur district (Bihar). The study was carried out during two consecutive years 2023 and 2024.

The crops of *Sesamum orientale* and *Ricinus communis* were grown by farmers following locally suited procedures. The crops were grown in the year 2023 and 2024. The details of crops grown are as follows:

Crops	Cultivers	Date of Sowing	Seed rate	Spacing (in cm)
<i>S. orientale</i>	Kanke safed	7 th Aug	5kg / ha.	30×5
<i>R. communis</i>	Aruna	8 th July	15kg / ha	60×30

The experiments were conducted in a factorial randomized block design (RBD) with three replications. When crops came into bloom, the number of foragers *Apis mellifera* and *Apis florea* collecting nectar, pollen, or both was recorded for 10 minutes within a randomly marked area of one square meter in the experimental plots. Numbers of foragers were recorded at 900h, 1100h, 1300h and

1500h of the day at weekly intervals. On different dates and at different times, the temperature and relative humidity were recorded. The abundance of *Apis mellifera* and *Apis florea* was correlated with mean temperature and mean relative humidity. Statistical analyses, including correlation and regression, were performed following the methods of Panse and Sukhatme (1967). The

data were analyzed under a factorial RBD framework, and all values represent mean observations. The level of significance was set at $P < 0.05$. The different dates of observation of crops are given below:

Crop	Date of Observation	
	2023	2024
<i>Sesamum orientale</i>	29.09.23	29. 09. 24
	06.10.23	06. 10. 24
	13.10.23	13. 10. 24
	20.10.23	20. 10. 24
	25.11. 23	25.11. 24
<i>Ricinus communis</i>	02.12. 23	02. 12. 24
	08. 12. 23	08. 12. 24
	15. 12. 23	15. 12. 24

Result and discussion

Observations on *Sesamum orientale*

The data presented in Table 1 reveal the relative abundance (number of bees per 10 minutes per m^2) of *Apis mellifera* and *Apis florea* at different hours of the day on different dates in the year 2023 and 2024. On different dates, at different hours of the day the population of *Apis melifera* was consistently higher *Apis florea*. The mean population of Apis species were maximum (12.96 and 13.73) in the second week of October and minimum (7.11 and 8.24) in the fourth week of October in the year 2023 and 2024 respectively.

The grand mean population was at its peak at 1100h followed by 1300h and 900h and the lowest at 1500h during both the years. The populations of honey bees were low in the morning hours which increased till noon and again declined in the afternoon. The peak activity of Apis species were recorded during mid day.

Furthermore, the grand mean population of *Apis* species was low during the early flowering stage, reached its peak during mid-flowering, and then declined in successive weeks, becoming lowest at crop maturity.

On the population of *Apis mellifera* the effects of year, hour, dates and interaction effects of year \times date, year \times hour, hour \times date and year \times hour \times date were statistically significant ($P=0.05$). Table2. In the case of *Apis florea*, the effects of hour, date and year \times date were significant ($P=0.05$), whereas those of year, year \times hour, hour \times date and year \times hour \times date were non-significant (Table 2).

The dominance of *A. mellifera* may be attributed to its domestication potential, whereas *A. florea* is a wild species with a tendency to migrate between locations. Rao (1997) and Panda (1998) also observed high attraction of *Apis mellifera* to Sesamum flowers. Similar findings were suggested by Virakamath, Patil, Murasing and Guruprasad (2002). Shein, Sargent, and Miko (1980) reported that the corolla tube length influences the availability of floral rewards, thereby affecting pollinator activity.

Table 1. Relative abundance (No. of bees/10 minute/m²) of *Apis mellifera* and *Apis florea* on *Sesamum orientale* at different hours of the day during two constitutive years 2023 and 2024.

Month	Week	Species	*Mean population at different hours of the day (h)					Avg. temp (°C)	Avg.RH (%)
			900h	1100h	1300h	1500h	Mean		
Year: 2023									
September	V	<i>Apis mellifera</i>	9.32	15.25	12.15	7.35	11.02		
		<i>Apis florea</i>	5.15	7.12	6.75	5.15	6.04	26.1	73.0
		Mean	7.24	11.20	9.45	6.25	8.53		
October	II	<i>Apis mellifera</i>	16.15	19.12	16.75	13.35	16.34		
		<i>Apis florea</i>	9.23	11.75	10.15	7.15	9.57	29.2	67.5
		Mean	12.69	15.44	13.45	10.25	12.96		
	III	<i>Apis mellifera</i>	13.15	17.35	14.02	11.35	13.97		
		<i>Apis florea</i>	8.57	10.30	9.15	5.75	8.44	28.1	69.0
		Mean	10.86	13.83	11.59	8.55	11.20		
	IV	<i>Apis mellifera</i>	7.15	12.35	8.12	7.15	8.69		
		<i>Apis florea</i>	5.15	7.37	6.35	3.25	5.53	27.1	69.5
		Mean	6.15	9.86	7.24	5.20	7.11		
		Grand Mean	9.23	12.58	10.43	7.56	9.95		
Year 2024									
September	V	<i>Apis mellifera</i>	12.15	15.82	14.35	9.50	12.95		
		<i>Apis florea</i>	5.25	9.35	7.15	4.35	6.53	27.1	72
		Mean	8.70	12.59	10.75	6.93	9.74		
October	II	<i>Apis mellifera</i>	16.35	22.15	18.75	14.25	17.88		
		<i>Apis florea</i>	8.15	13.30	10.75	6.15	9.59	29.5	66.8
		Mean	12.25	17.73	14.75	10.20	13.73		
	III	<i>Apis mellifera</i>	12.25	17.57	16.15	11.25	14.31		
		<i>Apis florea</i>	7.25	11.23	8.55	4.37	7.85	27.9	70.0
		Mean	9.75	14.40	12.35	7.81	11.08		
	IV	<i>Apis mellifera</i>	10.15	15.25	13.15	7.75	11.58		
		<i>Apis florea</i>	3.47	7.12	5.57	3.47	4.91	26.0	75.0
		Mean	6.81	11.19	9.36	5.61	8.24		
		Grand Mean	9.38	13.97	11.80	7.64	10.70		

Table 2 * Means of three replications

Factors	<i>Apis mellifera</i>		<i>Apis florea</i>	
	SEM (\pm)	CD (P=0.05)	SEM (\pm)	CD (P=0.05)
Year	0.06	0.17	NS	NS
Hour	0.09	0.24	0.23	0.65
Date	0.09	0.24	0.23	0.65
Year \times hour	0.12	0.34	NS	NS
Year \times date	0.12	0.34	0.33	0.91
Hour \times date	0.18	0.49	NS	NS
Year \times Hour \times date	0.25	0.68	NS	NS
CV (%)	3.23		15.60	

The data presented in table 3 reveal that the population of *A. mellifera* and *A. florea* are positively and highly significantly correlated with temperature (0.983** and 0.999**) and

negatively and highly significantly correlated with relative humidity (- 0.895** and - 0.996**) respectively.

Table 3. Correlation coefficients and multiple regression equations between mean population (*A. meliifera* and *A.florea*) and weather parameters on *Sesamum orientale*.

Independent variable (X)	Dependent variable (Y)	
	<i>Apis mellifera</i> (Y ₁)	<i>Apis florea</i> (Y ₂)
Temperature ((°C) (X ₁))	0.983**	0.999**
Relative humidity (X ₂)	-0.859**	-0.996**

Multiple regression equation:

$$Y_1 = -5.497 + 1.726 X_1 - 0.391 X_2$$

$$(R^2 = 0.974^{**} \quad \text{Adj. } R^2 = 0.963^{**})$$

$$Y_2 = -14.688 + 0.949 X_1 - 0.056 X_2$$

$$(R^2 = 0.998^{**} \quad \text{Adj. } R^2 = 0.997^{**})$$

**Significant at 1% probability level

*Significant at 5% probability level

The multiple regression models show that the standard regression coefficients of temperature are significantly positive, where those of relative humidity are significantly

negative for both the species. This indicates that the temperature plays a significant role in the activity of honey bees. Raj and Rana (1993) observed highest activity of honey bees at

noon. Rajagopal, Urs and Eswarappa (2003) observed the highest activity of *Apis* species at 1300h and 1500h on Sesamum. Ortiz- Sanchez and Tinaut (1994) also observed positive and significant correlation of honey bee populations with temperature. Abrol (1998) reported that the populations of *A. mellifera* and *A. cerana* showed positive correlation with temperature and negative correlation with relative humidity.

The R^2 value of *Apis mellifera* and *Apis florea* in statistical regression equations were 0.974** and 0.998** respectively. The combined contribution of temperature and relative humidity in fluctuating the populations of *A. mellifera* and *A. florea* are 97.4% and 99.8% respectively.

Observations on *Ricinus communis*

Apis mellifera was the dominant visitor of castor flowers, whereas *Apis florea* had the lowest population. In the years 2023 and 2024, the highest mean populations (11.14 and 9.70) of *Apis* species were recorded in the fourth week of November, while the lowest populations (5.29 and 4.95) were observed in the third week of December, respectively (Table 4). The lower population recorded in the third week of December may be attributed to a decline in the number of flowers and the attainment of crop maturity by castor.

The effects of year, hour, and date, as well as the interaction effects of hour \times date and year

\times hour, on the population of *A. mellifera* were significant ($P < 0.05$). In contrast, for *Apis florea*, the effects of year, hour, date, and interactions (year \times hour and year \times date) were significant, whereas the interaction effects of hour \times date and year \times hour \times date were non-significant. Similarly, the interaction effects of year \times date and year \times hour \times date on *A. mellifera* were non-significant (Table 5). The population of *A. mellifera* was consistently higher than that of *A. florea* in both years. The highest populations of *Apis* species were observed in the week having higher temperature and lower relative humidity, where as the lower populations of *Apis* species was recorded in the week having relatively lower temperature and higher relative humidity.

The grand mean populations of *Apis mellifera* and *Apis florea* were the highest (10.75 and 9.49) at 900h, followed by 1100h (9.26 and 7.88) and 1300h (7.34 and 6.20) while the lowest populations (5.54 and 4.42) were recorded at 1500h during the year 2023 and 2024, respectively (Table 4). The two species exhibited their highest populations in the morning hours, reduced continuously in the later hours of the day, becoming the lowest in the afternoon. This peak abundance in the morning may be attributed to the availability of abundant pollen during full bloom of castor. Similar findings have been reported by earlier workers (Rana, Raj, and Kaushik, 1997; Bhowmik et al., 2003).

Table 4. Relative abundance (No. of bees/10 minute/m²) of *Apis mellifera* and *Apis florea* on *Ricinus communis* at different hours of the day during two constitutive years 2023 and 2024.

Month	Week	Species	*Mean population at different hours of the day (h)					Avg. temp (°C)	Avg.RH (%)
			900h	1100h	1300h	1500h	Mean		
Year: 2023									
November	IV	<i>Apis mellifera</i>	19.25	16.12	13.35	11.32	15.01		
		<i>Apis florea</i>	9.35	8.35	7.25	4.12	7.27	20.7	61.0
		Mean	14.30	12.24	10.30	7.72	11.14		
December	I	<i>Apis mellifera</i>	17.25	15.23	11.15	9.12	13.19		
		<i>Apis florea</i>	7.15	7.02	5.32	3.12	5.65	20.7	70.0
		Mean	12.20	11.13	8.24	6.12	9.42		
	II	<i>Apis mellifera</i>	13.35	10.75	8.25	7.12	9.87		
		<i>Apis florea</i>	5.32	4.34	4.15	3.15	4.24	18.5	81.0
		Mean	9.34	7.55	6.20	5.14	7.46		
	III	<i>Apis mellifera</i>	9.57	8.15	6.12	4.14	7.00		
		<i>Apis florea</i>	4.75	4.15	3.15	2.22	3.57	17.1	89.0
		Mean	7.16	6.15	4.64	3.18	5.29		
		Grand Mean	10.75	9.26	7.34	5.54	8.22		
Year 2024									
November	IV	<i>Apis mellifera</i>	17.15	14.35	11.35	9.35	13.05		
		<i>Apis florea</i>	8.32	7.35	6.32	3.36	6.34	19.85	78.0
		Mean	12.74	10.85	8.84	6.36	9.70		
December	I	<i>Apis mellifera</i>	14.12	12.68	8.15	6.25	10.30		
		<i>Apis florea</i>	5.35	5.15	3.34	2.16	4.00	18.55	82.0
		Mean	9.74	8.92	5.75	4.21	7.15		
	II	<i>Apis mellifera</i>	12.35	9.75	7.79	5.35	8.81		
		<i>Apis florea</i>	5.36	3.38	3.46	2.16	3.59	17.80	85.5
		Mean	8.86	6.57	5.62	3.75	6.20		
	III	<i>Apis mellifera</i>	9.15	7.65	7.05	5.35	7.30		
		<i>Apis florea</i>	4.16	2.75	2.12	1.36	2.60	17.55	92.0
		Mean	6.66	5.20	4.59	3.36	4.95		
		Grand Mean	9.49	7.88	6.20	4.42	7.00		

Table 5 * Means of three replications

Factors	<i>Apis mellifera</i>		<i>Apis florea</i>	
	SEM(±)	CD(P=0.05)	SEM(±)	CD(P=0.05)
Year	0.17	0.47	0.16	0.45
Hour	0.24	0.67	0.23	0.64
Date	0.24	0.67	0.23	0.64
Year × hour	0.34	0.94	0.32	0.90
Year × date	NS	NS	0.32	0.90
Hour × date	0.48	1.33	NS	NS
Year × Hour × date	NS	NS	NS	NS
CV (%)	11.16		18.16	

The abundance of both species was correlated with weather parameters and is presented in Table 6. The results indicate a highly significant positive correlation between temperature and population density (*A. mellifera*: 0.949 and *A. florea*: 0.913), whereas

there was a non-significant negative correlation between population and relative humidity for *A. mellifera* (−0.690). In contrast, a significant negative correlation was observed between the population of *A. florea* and relative humidity (−0.998).

Table 6. Correlation coefficients and multiple regression equations between mean population (*A. mellifera* and *A. florea*) and weather parameters on *Ricinus communis*.

Independent variable (X)	Dependent variable (Y)	
	<i>Apis mellifera</i> (Y ₁)	<i>Apis florea</i> (Y ₂)
Temperature ((°C) (X ₁))	0.949**	0.913**
Relative humidity (X ₂)	-0.690 NS	-0.998**

Multiple regression equation:

$$Y_1 = -14.505 + 1.575 X_1 - 0.060 X_2 \quad (R^2 = 0.925^{**} \quad \text{Adj. } R^2 = 0.895^{**})$$

$$Y_2 = 15.365 - 0.046 X_1 - 0.125 X_2 \quad (R^2 = 0.997^{**} \quad \text{Adj. } R^2 = 0.995^{**})$$

**Significant at 1% probability level

*Significant at 5% probability level

The multiple regression model indicates that the temperature is the major factor influencing the abundance of *Apis* species as the regression coefficient of variables X₁ is observed positive. The combined contributions of temperature and relative humidity to the populations of *Apis*

mellifera and *Apis florea* are 92.5% and 99.7%, respectively. Sihag and Khatkar (1999) also reported that the populations of *A. mellifera*, *A. florea* and *A. dorsata* were positively and significantly correlated with temp; and negatively and significantly correlated with relative humidity.

Conclusion

The population of *Apis mellifera* was consistently higher than that of *Apis florea* on both *Sesamum orientale* and *Ricinus communis*. On *Sesamum orientale*, the mean population of *Apis* species was highest during the second week of October and lowest during the fourth week of October. In contrast, on *Ricinus communis*, the highest and lowest mean populations were recorded in November and December, respectively.

The peak activity of both *Apis mellifera* and *Apis florea* on *Sesamum orientale* occurred at midday, with lower activity in the morning that gradually increased until noon and declined thereafter. However, on *Ricinus communis*, the peak activity of both species was observed during the morning hours, followed by a steady decline toward the afternoon.

A highly significant positive correlation was observed between temperature and the population of *Apis* species on both crops, indicating the strong influence of temperature on their foraging activity.

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New Records and Novel DNA Barcodes of Scelionidae (Hymenoptera: Platygastroidea) from Arunachal Pradesh, India

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Abstract

Taxonomic investigations of Scelionidae (Hymenoptera: Platygastroidea) collected from the Dihang-Dibang Biosphere Reserve, Arunachal Pradesh, India, revealed the presence of eight species. Among these, *Trissolcus semistriatus* (Nees von Esenbeck) reported for the first time from India. Of the remaining species, six represent new records for Arunachal Pradesh, while one species is documented with an extended distributional range within the state. Molecular characterization was conducted using the mitochondrial cytochrome c oxidase subunit I (mt COI) gene, resulting in the generation of novel DNA barcode sequences for three species. Molecular data also revealed the first records of *Psilanteris coriacea* Rajmohana and *Dvivarnus agamades* (Kozlov & Lê) from Bangladesh. Additionally, an updated checklist of the Scelionidae recorded from Arunachal Pradesh is provided.

Keywords: checklist, DNA barcode, Telenominae, Scelioninae, Teleasinae

Introduction

Platygastroidea is the third-largest superfamily of parasitoid Hymenoptera after Ichneumonoidea and Chalcidoidea (Austin *et al.*, 2005). Currently, more than 6,000 described species are recognized worldwide, with Scelionidae representing the most species-rich family within the superfamily (Chen *et al.* 2021). Members of Scelionidae are exclusively egg parasitoids and play a crucial ecological role in regulating populations of a wide range of arthropods. They are known to

parasitize the eggs of hosts belonging to at least ten arthropod orders, including insects and spiders (Chen *et al.* 2021). Owing to their host specificity and ecological significance, scelionids have attracted considerable attention in biodiversity, evolutionary, and biological control research.

India harbours a rich diversity of Scelionidae, with approximately 520 species reported to date (Rameshkumar *et al.* 2025). However, knowledge of their distribution remains uneven across different regions of the

country. Arunachal Pradesh, situated within the Indo-Burma biodiversity hotspot (Myers *et al.* 2000), is characterized by exceptional habitat heterogeneity. Despite its recognized biological importance, the scelionid fauna of the state remains poorly documented, with

only 14 species reported so far (Table 1). The paucity of taxonomic and faunistic investigations has resulted in significant gaps in our understanding of the diversity and distribution of these ecologically important parasitoids in the region.

Table 1: Checklist of Scelionidae from Arunachal Pradesh, India.

Sl.	Species	Subfamily	Reference
1	<i>Aneuroscelio parashurama</i> Veenakumari, 2020	Scelioninae	Kamalanathan <i>et al.</i> 2020
2	<i>Aneuroscelio triangularis</i> Veenakumari, 2020	Scelioninae	Kamalanathan <i>et al.</i> 2020; This study
3	<i>Baeus acuminatus</i> Veenakumari, 2020	Scelioninae	Kamalanathan <i>et al.</i> 2020
4	<i>Baeus chakora</i> Veenakumari, 2020	Scelioninae	Kamalanathan <i>et al.</i> 2020
5	<i>Baeus krishnareddy</i> Veenakumari, 2020	Scelioninae	Kamalanathan <i>et al.</i> 2020
6	<i>Baeus mahanetra</i> Veenakumari, 2020	Scelioninae	Kamalanathan <i>et al.</i> 2020
7	<i>Cremastobaeus cornutus</i> Veenakumari, 2017	Scelioninae	Kamalanathan and Mohanraj 2017
8	<i>Duta coriata</i> Debnath & Rajmohana, 2026	Scelioninae	Debnath <i>et al.</i> 2026
9	<i>Duta indica</i> Mukerjee, 1994	Scelioninae	This study
10	<i>Duta protuberata</i> Debnath & Rajmohana, 2026	Scelioninae	Debnath <i>et al.</i> 2026
11	<i>Embidobia barbarika</i> Veenakumari, 2024	Scelioninae	Veenakumari <i>et al.</i> 2024
12	<i>Habroteleia flavipes</i> Kieffer, 1905	Scelioninae	This study
13	<i>Idris deergakombus</i> Veenakumari, 2015	Scelioninae	Kamalanathan <i>et al.</i> 2015
14	<i>Idris samueli</i> Veenakumari and Austin, 2021	Scelioninae	Kamalanathan and Austin 2021
15	<i>Psilanteris coriacea</i> Rajmohana, 2007	Scelioninae	This study
16	<i>Dvivarnus agamedes</i> (Kozlov & Lê, 1986)	Teleasinae	This study
17	<i>Trimorus anamalaianus</i> Mukerjee, 1981	Teleasinae	This study
18	<i>Paratelenomus anu</i> Rajmohana, Sachin & Talamas, 2019	Telenominae	This study
19	<i>Phlebiaporus supattra</i> Veenakumari, 2018	Telenominae	Kamalanathan and Mohanraj 2018
20	<i>Trissolcus areolatus</i> (Rajmohana, 2013)	Telenominae	Rajmohana 2013, Yan <i>et al.</i> 2022
21	<i>Trissolcus semistriatus</i> (Nees von Esenbeck, 1834)	Telenominae	This study

As part of our ongoing investigations on the taxonomy and diversity of scelionids from India (Debnath *et al.* 2026a, 2026b; Debnath & Rajmohana 2026), the present study examines recently collected scelionid material from Arunachal Pradesh using an integrative taxonomic approach combining morphology and molecular data. Eight species are documented herein, with seven recorded from Arunachal Pradesh for the first time and one constituting a new record for India. In addition, novel DNA barcode sequences are generated for three species, providing valuable molecular resources for future taxonomic, phylogenetic, and biodiversity studies of Scelionidae. An updated checklist of scelionids from the state is also provided.

Material and Methods

Faunistic surveys were conducted in the Dihang-Dibang Biosphere Reserve, Arunachal Pradesh, India, during February 2024 to February 2026. Scelionid specimens were primarily collected using yellow pan traps. The collected specimens were immediately transferred to molecular-grade absolute ethanol and preserved for subsequent morphological and molecular analyses. Representative specimens were card-mounted for taxonomic examination, while the remaining specimens were retained in ethanol for DNA-based studies.

Taxonomic identification was carried out following the keys and diagnostic characters provided by Masner (1976),

Rajmohana (2014), and Talamas *et al.* (2017). Morphological observations and photomicrography were performed using a Leica M205A stereomicroscope equipped with a Leica DFC500 digital camera and a 1× objective lens. Image acquisition and processing were carried out using Leica Application Suite (LAS) software. Voucher specimens examined in the present study have been deposited in the National Zoological Collections (NZC), Zoological Survey of India, Kolkata, India.

For molecular analyses, genomic DNA was extracted from individual adult female specimens using the Dneasy Blood & Tissue Kit (QIAGEN, Inc.), following the manufacturer's protocol. The quality and concentration of the extracted DNA were assessed using Qubit 2.0 fluorometer. Amplification of the mitochondrial cytochrome c oxidase subunit I (mt COI) barcode region was performed using the universal primer pair LCO1490 and HCO2198 (Folmer *et al.* 1994). Polymerase chain reaction (PCR) conditions and thermal cycling parameters followed Debnath *et al.* (2025). Successful amplification was confirmed by agarose gel electrophoresis. PCR products showing clear amplification were purified and subjected to bidirectional Sanger sequencing using an ABI 377 automated sequencer (Applied Biosystems). The resulting chromatograms were manually inspected, edited, and assembled to obtain high-quality consensus sequences. The curated sequences

were subsequently submitted to the Barcode of Life Data System (BOLD) database, and sequence similarity searches were performed on 5 June 2026 using the National Center for Biotechnology Information (NCBI) Basic Local Alignment Search Tool (BLAST) and the BOLD Identification Engine.

Results

Taxonomy

Family: Scelionidae

Subfamily: Scelioninae

1. *Aneuroscelio triangularis* Veenakumari, 2020

Aneuroscelio triangularis Veenakumari, 2020 in Kamalanathan and Mohanraj (2020): 577, 593. Original description, keyed. (Figure 1A)

Material examined: 1♂, INDIA: Arunachal Pradesh: Upper Siang: Dumling area; 28.6292°N, 95.0353°E; alt. ~500 m a.s.l.; YPT, 28.x.2025; Coll: Rajmohana & party.

Distribution in India: Andaman and Nicobar Islands, Arunachal Pradesh, Assam, Himachal Pradesh, Karnataka, Kerala, Odisha, Sikkim, Tamil Nadu, Tripura, West Bengal.

2. *Duta indica* Mukerjee, 1994

Duta indica Mukerjee, 1994: 19. Original description. (Figure 1B)

Material examined: 1♀, INDIA: Arunachal Pradesh: Upper Siang: Dumling area;

28.6292°N, 95.0353°E; alt. ~500 m a.s.l.; YPT, 28.x.2025; Coll: Rajmohana & party.

Distribution in India: Uttarakhand (Mukerjee 1994), Karnataka (Rajmohana 2013), Kerala (Rajmohana 2014), Assam, West Bengal (Debnath et al. 2026b), Arunachal Pradesh (this study).

3. *Habroteleia flavipes* Kieffer, 1905

Habroteleia flavipes Kieffer, 1905: 15. Original description, keyed. (Figure 1C)

Material examined: 1♀, INDIA: Arunachal Pradesh: Upper Siang: Dumling area, Yingkiong; 28.6292°N, 95.0353°E; alt. ~500 m a.s.l.; YPT, 28.x.2025; Coll: Rajmohana & party. 1♂, INDIA: Arunachal Pradesh: Upper Siang: Simong, Yingkiong; 28.5818°N, 95.0688°E; alt. ~310 m a.s.l.; YPT, 29.x.2025; Coll: Rajmohana & party. 1♀, 1♂, INDIA: Arunachal Pradesh: West Siang: Aalo; 28.1859°N, 94.7954°E, alt. ~251 m a.s.l.; YPT, 31.x.2025; Coll: Rajmohana & party.

Distribution in India: West Bengal, Kerala (Saraswat and Sharma 1978, Sharma 1980, Chen et al. 2018), Arunachal Pradesh (this study).

Molecular characterization: A NCBI BLAST search of the *H. flavipes* mt COI sequence (BOLD ID: ARPSC001-26) yielded an 86.6% identity match with an unidentified Platygastriidae from Canada (GenBank accession no. KM556191). The BOLD Identification Engine revealed a 99.8%

similarity match with an unidentified scelionid specimen from Bangladesh (BOLD ID: GMBDC2935-23).

Comment: Given the previous records of this species from Bangladesh (Chen et al. 2018), the molecular data generated herein further support its distribution in that country. The generated sequence represents the first reference DNA barcode for the species, and facilitates its reliable identification at the species level.

4. *Psilanteris coriacea* Rajmohana, 2007

Psilanteris coriacea Rajmohana, 2007: 57, 64. Original description, keyed. (Figure 1D)

Material examined: 1♀, INDIA: Arunachal Pradesh: Upper Siang: Yingkiong; 28.6325°N, 95.0275°E; alt. ~450 m a.s.l.; YPT, 24.ii.2024; Coll: Dilip Mondal. 2♀♀, INDIA: Arunachal Pradesh: Dibang valley: Etalin; 28.5391°N, 95.7131°E; alt. ~996 m a.s.l.; YPT, 27.ii.2024; Coll: R. Kushwaha. 1♀, 1♂, INDIA: Arunachal Pradesh: Upper Siang: Tuting; 28.1033°N, 94.9507°E, alt. ~400 m a.s.l.; YPT, 26.x.2025; Coll: Rajmohana & party. 1♀, INDIA: Arunachal Pradesh: Upper Siang: Tuting; 29.1357°N, 94.9767°E; alt. ~1170 m a.s.l.; YPT, 21.ii.2026; Coll: Dilip Mondal.

Distribution in India: Karnataka, Kerala (Rajmohana 2007, 2014), West Bengal

(Debnath and Rajmohana 2026), Arunachal Pradesh (this study).

Molecular characterization: BLAST analysis of the mitochondrial COI sequence of *P. coriacea* (BOLD ID: ARPSC002-26) showed 91.7% sequence similarity with an unidentified platygastriid species from Pakistan (GenBank accession no. KY841660). A search using the BOLD Identification Engine revealed 99.5% similarity with an unidentified Scelionidae specimen from Bangladesh (BOLD ID: GMBCE2462-15). This high level of sequence similarity suggests that the specimen from Bangladesh is conspecific with *P. coriacea*, representing the first record of the species from Bangladesh. The generated sequence provides a novel DNA barcode for the species, supporting its identification at the species level.

Subfamily: Teleasinae

5. *Dvivarnus agamades* (Kozlov & Lê, 1986)

Dvivarnus agamades (Kozlov & Lê, 1986): 100. Original description. (Figure 2A)

Material examined: 1♀, 3♂, INDIA: Arunachal Pradesh: Upper Siang: Dumling area; 28.6292°N, 95.0353°E; alt. ~500 m a.s.l.; YPT, 28.x.2025; Coll: Rajmohana & party.

Distribution in India: Karnataka, Andhra Pradesh (Veenakumari et al. 2011, Talamas et al. 2016), Delhi, Tamil Nadu (Talamas et al. 2016), Arunachal Pradesh (this study).

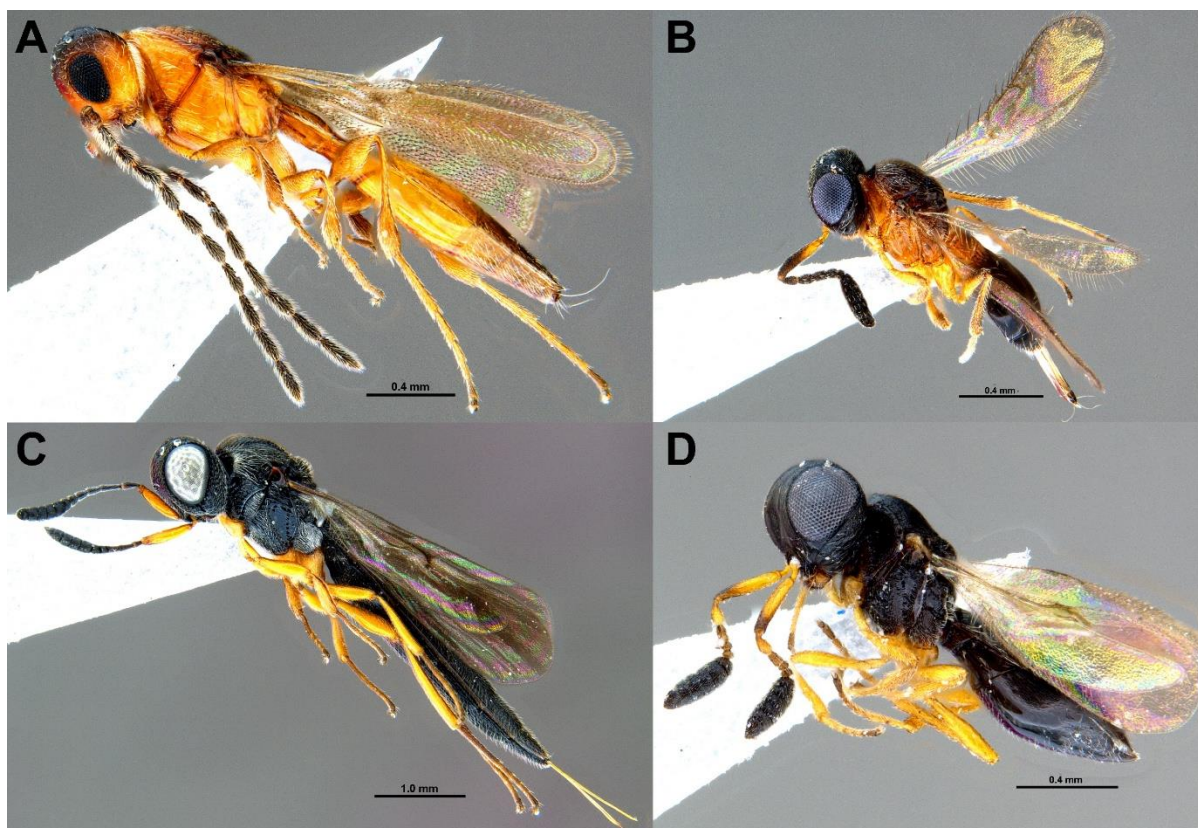


Figure 1: A. *Aneuroscelio triangularis* Veenakumari, 2020, ♂; B. *Duta indica* Mukerjee, 1994, ♀; C. *Habroteleia flavipes* Kieffer, 1905, ♀; D. *Psilanteris coriacea* Rajmohana, 2007, ♀.

Molecular characterization: A BLAST search of the *D. agamades* mtCOI sequence (BOLD ID: ARPSC003-26) yielded an 87.2% identity match with an unidentified platygastriid from Canada (GenBank accession no. KM567888). The BOLD Identification Engine revealed a 99.0% similarity match with an unidentified scelionid specimen from Bangladesh (BOLD ID: GMBDE961-23) and marking the first record of this species from Bangladesh. This barcode constitutes the first reference DNA barcode for the species and facilitates accurate species-level identification.

6. *Trimorus anamalaianus* Mukerjee, 1981

Trimorus anamalaianus Mukerjee, 1981: 5. Original description, keyed. (Figure 2B)

Material examined: 1♀, INDIA: Arunachal Pradesh: Dibang valley: Etalin; 28.6048°N, 95.8703°E; alt. ~800 m a.s.l.; YPT, 26.ii.2024; Coll: Rahul Mondal. 1♂, INDIA: Arunachal Pradesh: Dibang valley: Etalin; 28.5391°N, 95.7131°E; alt. ~996 m a.s.l.; YPT, 27.ii.2024; Coll: R. Kushwaha.

Distribution in India: Kerala (Mani 1981, Rajmohana 2014), Karnataka, Tamil Nadu

(Rajmohana 2013), Arunachal Pradesh (this study).

Subfamily: Telenominae

7. *Paratelenomus anu* Rajmohana, Sachin & Talamas, 2019

Paratelenomus anu Rajmohana, Sachin & Talamas, 2019: 107. Original description. (Figure 2C)

Material examined: 1♀, INDIA: Arunachal Pradesh: Upper Siang: Yingkiong; 28.6325°N,

95.0275°E; alt. ~450 m a.s.l.; YPT, 24.ii.2024; Coll: Dilip Mondal.

Distribution in India: Kerala, Karnataka, Tamil Nadu (Rajmohana et al. 2019), Bihar (Patra et al. 2026), Arunachal Pradesh (this study).

8. *Trissolcus semistriatus* (Nees von Esenbeck, 1834)

Teleas semistriatus Nees von Esenbeck, 1834: 290. Original description. (Figure 2D)

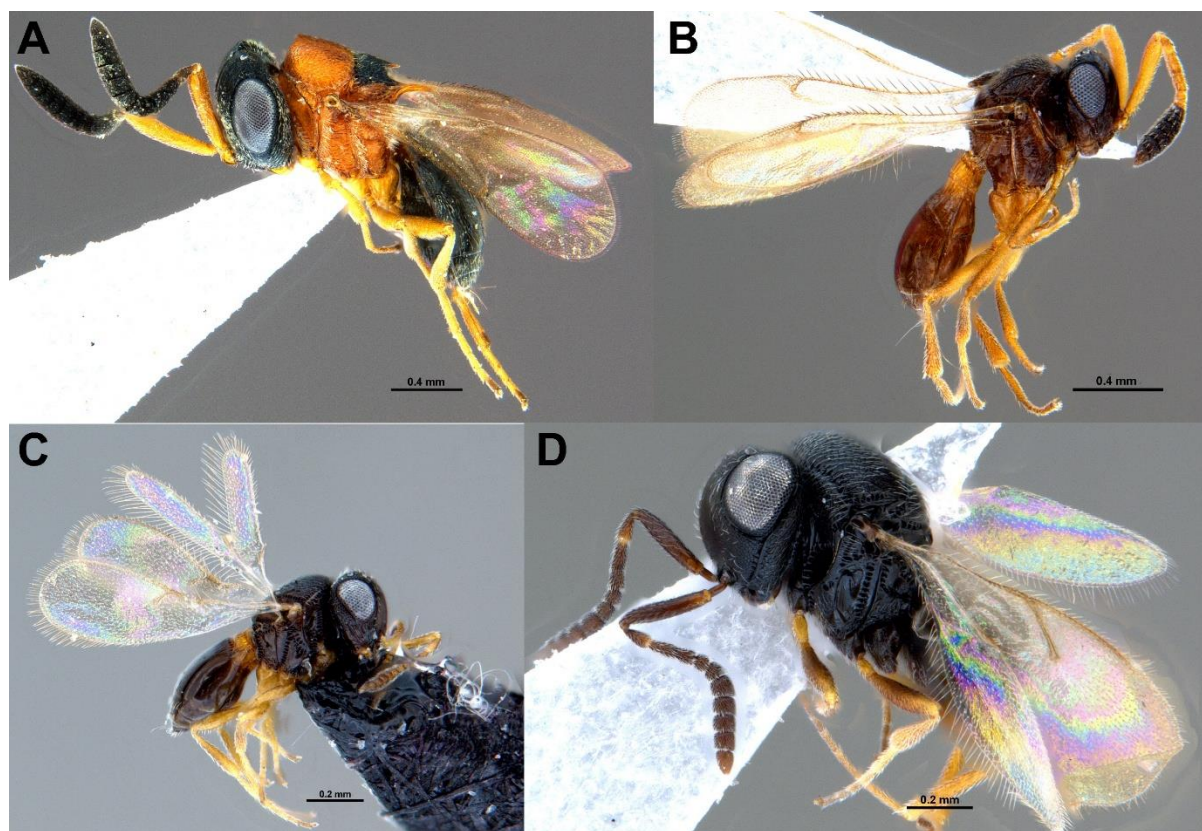


Figure 2: A. *Trimorus agamades* (Kozlov & Lê, 1986), ♀; B. *Trimorus anamalaianus* Mukerjee, 1981, ♀; C. *Paratelenomus anu* Rajmohana, Sachin & Talamas, 2019, ♀; D. *Trissolcus semistriatus* (Nees von Esenbeck, 1834), ♀.

Material examined: 1♀, INDIA: Arunachal Pradesh: Dibang Valley, Anini; 28.7933N, 95.8970E; alt. ~1656 m a.s.l.; YPT, 24.ii.2024; Coll: P. C. Saha. 4♀♀, INDIA: Arunachal Pradesh: Upper Siang: Yingkiong; 28.6325°N, 95.0275°E; alt. ~450 m a.s.l.; YPT, 24.ii.2024; Coll: Dilip Mondal.

Distribution in India: Arunachal Pradesh (this study).

Comment: This species is reported from India for the first time. Identification was based on Talamas et al. (2017). It has a wide distribution across multiple countries and is primarily known from high-altitude regions (Talamas et al. 2017). No host records are currently available.

Discussion

The present study provides new insights into the diversity and distribution of Scelionidae in Arunachal Pradesh, a region that remains inadequately explored. A total of eight species were identified from the material examined. Among these, *Trissolcus semistriatus* is recorded for the first time from India, significantly extending the known distribution of the species. Of the remaining species, six are newly recorded from Arunachal Pradesh, while *Aneuroscelio triangularis* represents an additional distributional record within the state. With the inclusion of these new records, the known scelionid fauna of Arunachal Pradesh now comprises 21 species (Table 1). Considering

the vast geographical extent, habitat heterogeneity, and rich arthropod diversity of the state, the currently known scelionid diversity is likely an underestimate and underscores the need for more intensive and systematic surveys to better document the scelionid fauna of the region.

The novel mt COI barcode sequences generated in this study enrich the currently available molecular database for Indian Scelionidae. Molecular analyses also revealed the occurrence of *Psilanteris coriacea* and *Dvivarnus agamades* in Bangladesh, representing the first records of both species from the country. These barcode data will facilitate future species identification, taxonomic revisions, phylogenetic studies, and biodiversity assessments of scelionid wasps. Overall, the present study contributes to a better understanding of the scelionid fauna of the Eastern Himalaya and highlights the importance of integrating morphological and molecular approaches in documenting parasitoid diversity from understudied regions.

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Review articles

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Sachet-based bio-agents release system vis-à-vis conventional method of bio-agents release under green-house conditions**Rutvik Patel¹; D. B. Sisodiya¹; D. H. Patel¹; A. N. Patel²; P. N. Chaudhary¹**¹Anand Agricultural University, Department of Entomology, Anand, Gujarat 388 110, India²Navsari Agricultural University, Department of Entomology, Navsari, Gujarat, 396 450, India**Corresponding author email: rutvikpatel680@gmail.com****Abstract**

Sachet-based release systems represent an innovative approach to integrated pest management (IPM) that has gained significant adoption in greenhouse and protected cultivation systems worldwide. These systems utilise specialised packages to deliver biocontrol agents, particularly predatory mites, in a controlled and sustained manner for managing key agricultural pests, including thrips, whiteflies and spider mites. This review synthesises evidence from 30 peer-reviewed publications examining sachet technologies, their mechanisms, efficacy and applications in both international and Indian contexts. Sachet systems offer distinct advantages over conventional pest management methods, including prolonged predator establishment, protection from intra-guild predation, reduced labour requirements and compatibility with integrated pest management strategies. Multiple sachet types have been developed, including slow-release, breeding, sheltered and moisturised sachets, each optimised for specific environmental conditions and target pests. Key biocontrol agents deployed through sachets include *Neoseiulus cucumeris*, *Amblyseius swirskii*, *Neoseiulus californicus* and *Typhlodromips swirskii*, which effectively suppress populations of *Frankliniella occidentalis* (western flower thrips), *Tetranychus urticae* (two-spotted spider mite), *Bemisia tabaci* (whitefly) and related pest species. Despite demonstrated efficacy in controlled environments, challenges remain regarding environmental sensitivity, cost-effectiveness for small stakeholder farmers and adaptation to diverse cropping systems. In India, the adoption of sachet-based systems is gradually increasing in protected cultivation; however, research development and commercial availability still lag behind global standards. Overall, sachet-based bioagent delivery systems show strong potential as sustainable alternatives to conventional pest management approaches.

Keywords: *Neoseiulus cucumeris*, *Amblyseius swirskii*, *Neoseiulus californicus*, Bio control, Management

Introduction

Pest management in protected cultivation systems faces increasing challenges from pesticide resistance, environmental regulations, consumer demand for residue-free produce and the need for sustainable agricultural practices. Among the most economically damaging pests in greenhouse and polytunnel systems are thrips (*Frankliniella* spp., *Thrips* spp., *Scirtothrips* spp.), spider mites (*Tetranychus* spp.) and whiteflies (*Bemisia* spp., *Trialeurodes* spp.), which cause direct feeding damage, transmit plant viruses and rapidly develop resistance to chemical pesticides (Arthurs et al. 2009; Mebius, 2025; Saito et al. 2018). Biological control using natural enemies has emerged as a cornerstone of integrated pest management (IPM) strategies, offering environmentally friendly and sustainable alternatives to synthetic pesticides (Gulati, 2012; Kumar et al. 2020; Liburd et al. 2019). However, traditional methods of releasing biocontrol agents, such as bulk applications or open rearing systems, face significant limitations, including high labour costs, vulnerability to adverse environmental conditions, intra-guild predation and inconsistent establishment rates (Buitenhuis et al. 2014; Pochubay et al. 2015).

Sachet-based release systems represent a technological innovation designed to overcome these limitations by providing controlled, sustained delivery of biocontrol agents directly within the crop canopy (Buitenhuis et al. 2014; Pochubay et al. 2015;

Shimoda et al. 2017, 2023). These systems typically consist of small, permeable containers housing predatory mites or other beneficial organisms along with a food source (factitious prey or pollen), enabling continuous reproduction and gradual dispersal over extended periods (Gállego et al. 2022; Midthassel et al. 2014; Solano-Rojas et al. 2022). The development of sachet technology has been driven by the need for "prophylactic" or preventive biocontrol strategies that establish natural enemy populations before pest populations reach damaging levels (Jacobson et al. 2001; Kumar et al. 2020). This approach contrasts with reactive pest management and aligns with the ecological principle of maintaining predator-prey balance throughout the growing season. This review synthesises current knowledge of sachet-based release systems, examining their design principles, mechanisms of action, efficacy against major insects-pest groups, advantages and limitations and applications across diverse geographical and cropping contexts. Particular attention is given to comparing sachet systems with conventional biocontrol methods and exploring their potential for wider adoption in both developed and developing agricultural systems, including the Indian context.

Background and Theoretical Foundations

Evolution of Biological Control in IPM

Biological control has evolved from simple augmentative releases of natural enemies to more advanced, technology-driven

delivery systems. Early biocontrol approaches relied on inundative releases, where large numbers of predators or parasitoids were introduced to achieve immediate pest suppression (Liburd *et al.*, 2019). However, these methods often failed to establish persistent populations, resulting in repeated applications and higher costs.

The concept of inoculative biological control, involving the release of smaller populations of natural enemies with the expectation of their establishment and reproduction, offered a more sustainable alternative (Jacobson *et al.*, 2001; Kumar *et al.*, 2020). Sachet-based systems operationalize this concept by creating microhabitats that support continuous predator reproduction and gradual colonization within crops (Gállego *et al.*, 2022; Solano-Rojas *et al.*, 2022).

Principles of Controlled Release Systems

Controlled release technology, widely used in pharmaceuticals and agriculture for pesticide formulations, has been adapted for biological control agents. The fundamental principle involves regulating the rate at which active agents (in this case, living organisms) are delivered to the target environment (Shimoda *et al.* 2017, 2019, 2023). Sachet systems achieve controlled release through several mechanisms, as given below.

1. Physical barriers: Permeable membranes or mesh materials that allow predators to find a way out while retaining factitious prey and

providing protection from external threats (Pochubay *et al.* 2015; Shimoda *et al.* 2017, 2019).

2. Population dynamics: Breeding sachets maintain internal predator-prey dynamics, with predators reproducing on factitious prey and gradually dispersing as populations increase (Gállego *et al.* 2022; Midthassel *et al.* 2014; Solano-Rojas *et al.* 2022).

3. Environmental modulation: Sachet design can buffer against temperature and humidity fluctuations, creating stable micro-environments that support predator survival and reproduction (Shimoda *et al.* 2017, 2019, 2023).

4. Behavioural regulation: Predator dispersal is influenced by food availability within sachets, with emigration increasing as factitious prey is depleted (Gállego *et al.* 2022; Solano-Rojas *et al.* 2022).

Target Pest Biology and Economic Importance

Thrips

Thrips, particularly *Frankliniella occidentalis* (Pergande), are among the most economically significant greenhouse pests worldwide (Arthurs *et al.*, 2009; Jacobson *et al.*, 2001; Saito *et al.*, 2018; Sullivan *et al.*, 2023). These small insects (1–2 mm) damage crops by feeding on plant tissues, causing silvering, scarring, and deformation of leaves, flowers, and fruits. Additionally, they act as

vectors of tospoviruses such as tomato spotted wilt virus (TSWV), leading to severe crop losses (Arthurs *et al.*, 2009; Saito *et al.*, 2018).

Their rapid life cycle (2–3 weeks), cryptic behavior, and high dispersal ability complicate management (Jacobson *et al.*, 2001; Mebius, 2025). Furthermore, resistance to multiple insecticide classes increases the importance of biological control (Saito *et al.*, 2018).

Spider Mites

The two-spotted spider mite, *Tetranychus urticae* Koch (1836), and related species are highly polyphagous, affecting more than 1,100 plant species (Liburd *et al.*, 2019; Mikawa *et al.*, 2020). They damage plants by piercing cells and extracting contents, leading to stippling, chlorosis, and premature leaf drop.

Under favorable warm and dry conditions, populations rapidly increase, with generation times as short as 7–10 days (Mikawa *et al.*, 2020). Their ability to develop resistance to over 90 active ingredients makes them difficult to control (Liburd *et al.*, 2019), thereby highlighting the importance of predatory mites in biological control programs (Mikawa *et al.*, 2022).

Whiteflies

Whiteflies, particularly *Bemisia tabaci* (Gennadius) and *Trialeurodes vaporariorum* (Westwood), are major pests in greenhouse crops. They cause direct feeding damage and

act as vectors of plant viruses, including begomoviruses affecting tomato, pepper, and cucurbits (Abdallah, 2020).

Management is challenging due to their rapid reproduction, high fecundity (100–300 eggs per female), and multiple life stages—eggs, nymphs, pupae, and adults—with varying susceptibility to control measures (Abdallah, 2020; Arthurs *et al.*, 2009).

Types of Sachet Systems and Release Mechanisms

Slow-Release Sachets

Slow-release sachets are designed to provide gradual, sustained dispersal of predatory mites over extended periods, typically 4–8 weeks (Buitenhuis *et al.* 2014; Pochubay *et al.* 2015; Shimoda *et al.* 2023). These systems are particularly valuable for establishing baseline predator populations before pest pressure develops.

Design and Mechanism: Slow-release sachets typically consist of a permeable paper or fabric pouch containing predatory mites, a carrier substrate (often bran or vermiculite) and factitious prey such as *Carpoglyphus lactis* or *Tyrophagus putrescentiae* (Pochubay *et al.* 2015; Solano-Rojas *et al.* 2022). The sachet material allows predators to exit while retaining the factitious prey population, creating a continuous source of emerging predators. Slow-release sachets of *Neoseiulus cucumeris* provided sustained dispersal for up to seven weeks, with increasing dispersal rates

in later weeks as internal predator populations grew. This contrasts with "breeder piles" (open rearing material), which showed higher initial

dispersal but shorter duration (Pochubay *et al.* 2015).

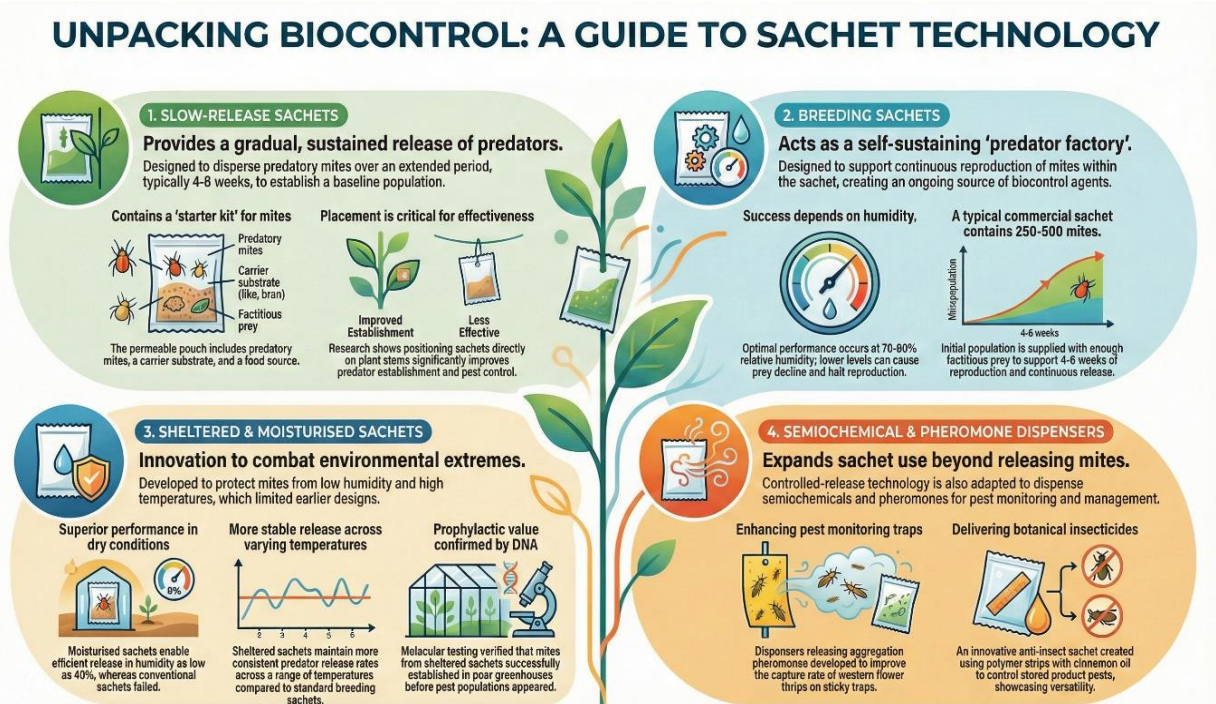


Fig 1. Types of Sachet Systems and Release Mechanisms

Placement and Optimisation: Extensive research on optimising sachet placement in greenhouse crops happened. Their work demonstrated that practical placement strategies, such as positioning sachets on plant stems rather than hanging them from wires, significantly improved predator establishment and pest control efficacy (Buitenhuis *et al.* 2014). Proper placement ensures that emerging predators quickly encounter pest populations and suitable microhabitats for establishment.

Breeding Sachets

Breeding sachets, also referred to as 'open rearing system', are designed to support the continuous reproduction of predatory mites within the sachet, thereby creating a self-sustaining source of biocontrol agents (Gállego *et al.* 2022; Midthassel *et al.* 2014; Saito *et al.* 2018; Solano-Rojas *et al.* 2022).

The effectiveness of breeding sachets depends on maintaining stable predator–factitious prey interactions within the confined sachet environment. Midthassel *et al.* (2014) examined the functional and numerical

responses of *Typhlodromips swirskii* (now *Amblyseius swirskii* Athias-Henriot, 1962) to the factitious prey *Suidasia medanensis*, demonstrating that predator populations can be sustained for extended periods when prey availability is sufficient.

Similarly, studies on *Amblyseius swirskii* and its prey *Carpoglyphus lactis* in slow-release sachets showed that relative humidity significantly influences both predator and prey populations, with optimal performance at 70–80% RH. Lower humidity reduced prey populations, thereby limiting predator reproduction capacity (Solano-Rojas et al., 2022).

Gállego *et al.* (2022) developed improved methodologies to study mite population dynamics within sachets, enabling precise estimation of how internal conditions affect predator production and dispersal. Their findings highlight the importance of monitoring both predator and prey populations to optimise sachet formulations.

Commercial Formulations

Commercial breeding sachets typically contain 250–500 predatory mites along with sufficient factitious prey to support 4–6 weeks of reproduction (Abdallah, 2020). These sachets are placed within the crop canopy, where they function as continuous “predator factories,” steadily releasing natural enemies over time (Abdallah, 2020; Adesso *et al.*, 2018).

Sheltered and Moisturised Sachets

Early sachet systems were limited by sensitivity to environmental extremes, particularly low humidity and high temperatures. To address this, Shimoda et al. (2017, 2019) developed sheltered and moisturised sachets that enhance predator survival while maintaining effective release rates.

Sheltered sachets incorporate protective materials that shield predatory mites from environmental stress without restricting dispersal. These designs improved predator survival and establishment compared to conventional sachets, especially under suboptimal conditions (Shimoda et al., 2017).

Moisturised sachets further enhance this concept by maintaining higher internal humidity. Studies showed that moisturised sheltered sachets enabled effective release of *Neoseiulus californicus* and *Amblyseius swirskii* across a wide humidity range (40–80% RH), unlike conventional systems that failed under low humidity (Shimoda *et al.*, 2019). Temperature also affects release rates, with higher temperatures increasing predator emergence; however, sheltered sachets provide more stable release patterns across temperature variations (Shimoda *et al.*, 2023).

Molecular verification using species-specific PCR confirmed successful establishment and persistence of *N. californicus* released from sachets in

greenhouse crops, demonstrating their prophylactic value (Mikawa *et al.*, 2020; Mikawa *et al.*, 2022).

Semiochemical and Pheromone Dispensers

Controlled-release systems are also applied to semiochemicals. Dispenser design significantly influences pheromone release rates and attraction efficiency (Nielsen, 2013). Aggregation pheromone dispensers improve thrips monitoring on sticky traps (Todorov *et al.*, 2022). Additionally, anti-insect sachets using polyvinyl alcohol–cinnamon oil formulations demonstrate effectiveness against stored-product pests (Jo *et al.*, 2013).

Biocontrol Agents Used in Sachet Systems

Predatory Mites: Species and Characteristics

Predatory mites (Acari: Phytoseiidae) are key biocontrol agents used in sachet systems, with several species suitable for this delivery method (Gulati, 2012). *Neoseiulus cucumeris* (formerly *Amblyseius cucumeris*) is widely used for thrips control in greenhouse crops (Buitenhuis *et al.* 2014; Jacobson *et al.* 2001; Pochubay *et al.* 2015; Saito *et al.* 2018). It primarily feeds on first-instar larvae, preventing pest population buildup. *N. cucumeris* performs best at moderate temperatures (20–25 °C) and high humidity (>70% RH), making it well suited for greenhouse conditions (Jacobson *et al.* 2001; Saito *et al.* 2018). Prophylactic releases from sachets effectively suppressed *Frankliniella*

occidentalis in cucumber crops and maintained pest levels below economic thresholds (Jacobson *et al.* 2001).

Amblyseius swirskii (formerly *Typhlodromips swirskii*) is a versatile predator feeding on thrips, whiteflies, spider mites, and pollen (Abdallah, 2020; Adesso *et al.* 2018; Arthurs *et al.* 2009; Midthassel *et al.* 2014; Saito *et al.* 2018; Solano-Rojas *et al.* 2022; Sullivan *et al.* 2023). Its ability to tolerate higher temperatures (up to 35 °C) makes it suitable for warm climates (Abdallah, 2020). It has shown effective pest suppression in nursery and pepper crops (Adesso *et al.* 2018; Arthurs *et al.* 2009).

Neoseiulus californicus is a generalist predator targeting spider mites and tolerating low humidity and high temperatures (Liburd *et al.* 2019; Mikawa *et al.* 2020, 2022). Studies confirm its successful establishment and long-term pest suppression when released from sachets (Mikawa *et al.* 2022).

Species selection depends on pest type, crop, environmental conditions, and IPM compatibility (Gulati, 2012; Liburd *et al.* 2019). Comparative studies show *N. cucumeris* is more effective at high thrips densities, while *A. swirskii* performs better at low pest levels (Saito *et al.* 2018).

Factitious Prey and Banker Plant Systems

The success of breeding sachets depends critically on the factitious prey species

used to support predator reproduction (Gállego et al. 2022). The dried fruit mite, *Carpoglyphus lactis* is the most commonly used factitious prey in commercial sachet systems. This Astigmatid mite reproduces rapidly on bran substrates and provides suitable nutrition for predatory mites. However, *C. lactis* populations are sensitive to humidity, declining rapidly at RH below 60%, which can compromise sachet performance in dry environments (Solano-Rojas et al. 2022). *Tyrophagus putrescentiae* and *Suidasia medanensis* are alternative factitious prey species used in some sachet formulations. Midthassel et al. (2014) demonstrated that *S. medanensis* could effectively support *A. swirskii* populations in breeding sachets, with predator functional and numerical responses suitable for sustained reproduction.

Banker Plant Systems: While not strictly sachet systems, banker plants represent a related approach where predator populations are maintained on non-crop plants infested with non-pest prey species (James et al. 2010). Sullivan et al. (2023) evaluated a "guardian plant system" combining banker plants with sachet releases to suppress *F. occidentalis* in greenhouse ornamentals, demonstrating synergistic effects when multiple predator-supporting strategies are integrated.

Population Dynamics Within Sachets

Understanding population dynamics within sachets is essential for optimising their design and predicting field performance

(Gállego et al. 2022; Solano-Rojas et al. 2022). Even studies also on the relative humidity affects the population dynamics of *A. swirskii* and *C. lactis* in slow-release sachets were conducted. At optimal humidity (70-80%), both predator and prey populations remained stable for 6-8 weeks, supporting continuous predator dispersal. At lower humidity (50%), prey populations crashed within 3-4 weeks, leading to predator starvation and reduced dispersal (Solano-Rojas et al. 2022). Gállego et al. (2022) developed innovative methodologies for monitoring mite populations within sachets without destructive sampling. Their techniques enable real-time assessment of sachet performance and can inform quality control in commercial production. The temporal dynamics of predator release from sachets follow predictable patterns: initial dispersal is relatively low as predators feed on abundant factitious prey; as prey is consumed and predator populations increase, dispersal accelerates; finally, as both populations decline, dispersal tapers off (Pochubay et al. 2015; Gállego et al. 2022; Solano-Rojas et al. 2022). This pattern creates a sustained release profile lasting 4-8 weeks, depending on sachet formulation and environmental conditions.

Mechanisms of Action of Sachet-based Biocontrol Agents

Release Kinetics and Dispersal Patterns

Sachet systems fundamentally differ from conventional biocontrol releases in their

temporal dynamics of predator delivery (Buitenhuis et al. 2014; Pochubay et al. 2015; Shimoda et al. 2023).

Conventional Bulk Releases: Traditional biocontrol applications involve releasing large numbers of predators (typically as mobile stages) directly onto plants. This approach provides immediate predator presence but often results in rapid dispersal, emigration or mortality, requiring frequent reapplications (Buitenhuis et al. 2014; Pochubay et al. 2015).

Sachet Release Kinetics: In contrast, sachets provide gradual, sustained release over weeks

to months (Buitenhuis et al. 2014). Pochubay et al. (2015) quantified dispersal patterns from *N. cucumeris* sachets, showing that while initial dispersal (weeks 1-3) was lower than from breeder piles, sustained dispersal continued through week 7, resulting in higher cumulative predator delivery. Temperature significantly affects release rates from both breeding and sheltered sachets, with higher temperatures accelerating dispersal. However, sheltered sachets maintained more consistent release patterns across temperature ranges, providing more predictable biocontrol outcomes (Shimoda et al. 2023).

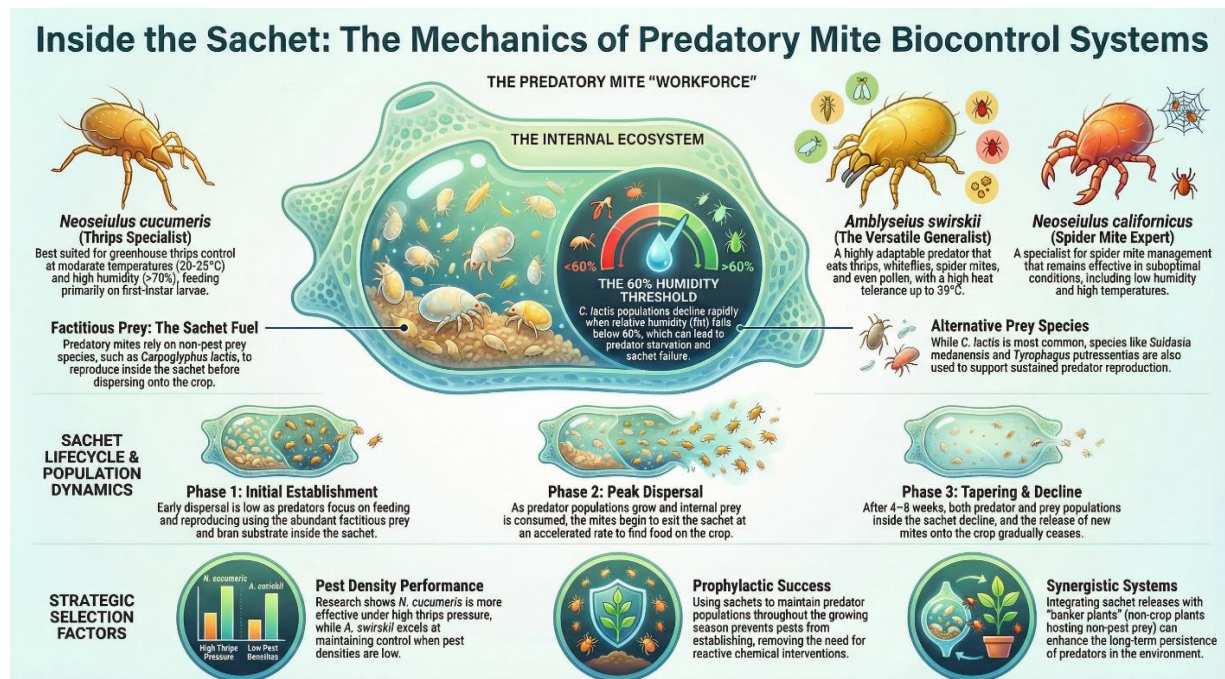


Fig. 2. The mechanics of Predatory Mite Bio control Systems

Spatial Distribution: Buitenhuis et al. (2014) showed that sachet placement critically affects predator distribution within crops. Sachets placed on plant stems resulted in better

predator establishment on nearby leaves compared to sachets hung from overhead wires, as emerging predators preferentially moved onto adjacent plant surfaces.

Environmental Factors Affecting Performance

Environmental conditions, particularly humidity, temperature, and light, strongly influence sachet performance. Relative humidity is the most critical factor, with *A. swirskii* performing optimally at 70–80% RH; performance declines below 60% RH due to collapse of factitious prey populations (Solano-Rojas et al. 2022). To address this, moisturised sheltered sachets maintain internal humidity and enable effective release across 40–80% RH (Shimoda et al. 2019). Temperature affects predator development and dispersal, with higher temperatures increasing release rates and potentially causing premature depletion, while sheltered sachets stabilise release patterns (Shimoda et al. 2023). Sachets also protect predators from environmental stress, improving establishment (Shimoda et al. 2017).

Comparison of Sachet-Based Bio-control Agents with Conventional Biocontrol Deployment

Sachet systems improve labour efficiency by simplifying application; workers hang them at set densities, reducing labour by 50–70% compared to bulk releases (Kumar et al. 2020). They enhance establishment rates by protecting predators from intraguild predation, resulting in 6–8 fold higher populations than open releases (Pochubay et al. 2015). Unlike reactive methods, sachets enable prophylactic control; *N. cucumeris* releases prevented *F.*

occidentalis establishment and maintained pest levels below thresholds (Jacobson et al. 2001), supporting the “Predator-In-First” strategy (Kumar et al. 2020). They also improve compatibility with other natural enemies by reducing predation and competition (Pochubay et al. 2015).

Efficacy of Sachet-based Bio-control Agents against Major Insect-Pests

Thrips

Thrips, particularly *F. occidentalis*, represent the primary target for sachet-based biocontrol systems, with extensive research demonstrating efficacy across diverse cropping systems. Jacobson et al. (2001) demonstrated that prophylactic releases of *N. cucumeris* from sachets effectively suppressed the establishment of *F. occidentalis* in cucumber crops. By maintaining predator populations throughout the growing season, thrips populations were kept below economic thresholds without requiring reactive interventions. Saito et al. (2018) compared slow-release breeding sachets of *N. cucumeris* and *A. swirskii* against western flower thrips under different pest pressure levels. Under high thrips pressure, *N. cucumeris* sachets provided better control than mycoinsecticide sprays (Met52 EC). Under low pest pressure, *A. swirskii* sachets effectively suppressed thrips population growth, with combination treatments (predators + mycoinsecticides) providing complete elimination of thrips. Buitenhuis et al. (2014) demonstrated that

practical placement of *N. cucumeris* slow-release sachets significantly improved thrips control efficacy. Sachets placed on plant stems resulted in better predator establishment and thrips suppression compared to sachets hung from overhead wires, highlighting the importance of deployment strategy. Arthurs et al. (2009) evaluated *N. cucumeris* and *A. swirskii* for biological control of chilli thrips (*Scirtothrips dorsalis*), an invasive pest of increasing importance. Both predator species, deployed via sachets, provided effective suppression of chilli thrips in pepper crops, offering valuable tools for managing this difficult pest. Sullivan et al. (2023) evaluated a guardian plant system combining banker plants with sachet releases to suppress *F. occidentalis* in greenhouse ornamentals. This integrated approach provided enhanced thrips control compared to sachets alone, demonstrating the value of combining multiple predator-supporting strategies. Research on thrips management in strawberry polytunnels has shown that sachet-based biocontrol can be optimised for everbearing production systems. These studies emphasise the importance of timing sachet deployment to coincide with crop establishment and adjusting predator densities based on expected pest pressure (Mebius, 2025; Midthassel et al. 2014).

Spider Mite

Spider mites, particularly *Tetranychus urticae*, are effectively managed using sachet systems deploying predatory mites. Mikawa et al. (2020, 2022) demonstrated successful

spider mite control in Japanese pear greenhouses using sheltered slow-release sachets of *N. californicus*. Molecular monitoring confirmed that commercially released predators established and persisted throughout the growing season, providing prophylactic suppression of spider mite populations. Saito et al. (2018) showed that under mixed infestations of thrips and spider mites, combination treatments of predatory mite sachets and mycoinsecticides provided superior control. Spider mites were effectively suppressed by mycoinsecticide sprays, while predatory mites from sachets controlled thrips, demonstrating compatibility of sachet systems with other IPM components. James et al. (2010) explored how plant volatiles and other semiochemicals can be manipulated to improve conservation biological control of mites. Although not specifically focused on sachets, this study suggests that incorporating plant-based attractants could improve predator retention and enhance the effectiveness of sachet systems.

Whitefly

Whiteflies, particularly *B. tabaci* and *T. vaporariorum*, are effectively controlled by *A. swirskii* deployed through sachet systems (Arthurs et al. 2009). Abdallah (2020) investigated mass production of *A. swirskii* and its efficacy against whiteflies and thrips in Lebanese greenhouse vegetable production. Breeding sachets containing 250 predatory mites with bran and factitious prey provided sustainable biocontrol of both pest groups,

Target Pest Species	Crop Type	Biocontrol Agent (Species)	Sachet Deployment Strategy	Observed Efficacy	Study/Researcher Reference
Western flower thrips (<i>F. occidentalis</i>)	Cucumber	<i>N. cucumeris</i>	Prophylactic release using slow-release breeding sachets	Effectively suppressed establishment and kept populations below economic thresholds	Jacobson et al. (2001)
Whiteflies (<i>B. tabaci</i> and <i>T. vaporariorum</i>) and thrips	Pepper	<i>A. swirskii</i>	Prophylactic release (Predator-In-First strategy)	Season-long suppression; significantly reduced the need for pesticide applications	Kumar et al. (2020)
Whiteflies (<i>B. tabaci</i> and <i>T. vaporariorum</i>) and thrips	Lebanese greenhouse vegetables	<i>A. swirskii</i>	Breeding sachets containing 250 mites, bran, and factitious prey	Provided sustainable biocontrol of both pest groups	Abdallah (2020)
Western flower thrips (<i>F. occidentalis</i>)	Chrysanthemum	<i>N. cucumeris</i> and <i>A. swirskii</i>	Slow-release breeding sachets	<i>N. cucumeris</i> outperformed mycoinsecticides under high pressure; <i>A. swirskii</i> was effective under low pressure	Saito et al. (2018)
Chilli thrips (<i>Scirtothrips dorsalis</i>)	Pepper	<i>N. cucumeris</i> and <i>A. swirskii</i>	Deployed via sachets	Both species provided effective suppression of this invasive pest	Arthurs et al. (2009)
Spider mites (<i>Tetranychus urticae</i>)	Japanese pear greenhouses	<i>N. californicus</i>	Sheltered slow-release sachets	Predators established and persisted throughout the season; provided prophylactic suppression	Mikawa et al. (2022)
Whiteflies	Outdoor nursery (container tree production)	<i>A. swirskii</i>	Controlled-release sachets	Effective suppression; predators persisted on pollen when pest populations were low	Addesso et al. (2018)
Thrips	<i>Gerbera jamesonii</i>	<i>N. cucumeris</i>	Placed on plant stems (compared to overhead wires)	Stem placement resulted in better predator establishment and thrips suppression	Buitenhuis et al. (2014)
Western flower thrips (<i>F. occidentalis</i>)	Greenhouse ornamentals	-	Guardian plant system combining banker plants with sachet releases	Enhanced thrips control compared to sachets alone	Sullivan et al. (2023)
Thrips	Strawberry polytunnels (everbearing)	-	Timed to coincide with crop establishment	Optimization achieved by adjusting predator densities based on expected pest pressure	(Markkanen , 2025; Mebius 2025)

demonstrating the value of generalist predators in sachet systems. Kumar et al. (2020) developed a "Predator-In-First" pre-emptive biological control strategy for sustainable pepper pest management in Florida. Prophylactic releases of *A. swirskii* from sachets provided season-long suppression of whiteflies and thrips, significantly reducing the need for pesticide applications. Adesso et al. (2018) evaluated *A. swirskii* controlled-release sachets for pest management in container tree production, demonstrating effective suppression of whiteflies and other pests in outdoor nursery conditions. The predator's ability to persist on pollen when pest populations are low enhanced its value for prophylactic biocontrol in this challenging environment.

Advantages and Limitations of Sachet based Release System

Advantages

1. **Sustained predator delivery:** Sachet systems provide continuous release of predatory mites for 4–8 weeks, eliminating the need for frequent reapplications associated with conventional bulk releases and maintaining predator populations during critical crop growth stages (Buitenhuis et al. 2014; Shimoda et al. 2023).
2. **Labour efficiency:** Sachet deployment is simple and requires minimal labour, as sachets are hung or placed at fixed locations. This reduces application time by

50–70% and improves the economic feasibility of biological control programs (Buitenhuis et al. 2014).

3. **Protection from intraguild predation:** Sachets protect predatory mites during the vulnerable establishment phase. Pochubay et al. (2015) reported 6–8 fold higher predator populations in sachet systems compared to open breeder piles in the presence of soil-dwelling predators.
4. **Environmental buffering:** Modern sachet designs provide protection against temperature extremes, desiccation and other environmental stresses, thereby improving predator survival and expanding the conditions under which biocontrol can be effectively implemented (Shimoda et al. 2017, 2019).
5. **Prophylactic biocontrol:** Sachets support preventive pest management by establishing predator populations before pest outbreaks occur, reducing crop damage and the need for chemical interventions (Jacobson et al. 2001; Kumar et al. 2020).
6. **Compatibility with IPM:** Sachet systems are compatible with other IPM components, including mycoinsecticides, banker plants and selective pesticides, enabling integrated, multi-tactic pest management strategies (James et al. 2010; Saito et al. 2018; Sullivan et al. 2023).

7. **Reduced pesticide dependence:** Effective biological control through sachet systems lowers reliance on chemical pesticides, thereby reducing production costs, environmental contamination and pesticide residues in harvested produce (Abdallah, 2020; Kumar et al. 2020; Liburd et al. 2019).
8. **Quality control and reliability:** Commercial production of sachets allows standardized quality control of predator species, numbers and viability prior to release, improving consistency and reliability of biocontrol outcomes (Mikawa et al. 2020, 2022).

Limitations and Challenges

1. **Environmental sensitivity:** Despite improved designs, sachet performance remains sensitive to environmental conditions, particularly low humidity, which can limit effectiveness in certain cropping systems (Shimoda et al. 2019; Solano-Rojas et al. 2022).
2. **Cost considerations:** Sachet systems have higher initial costs than conventional pesticides, posing challenges for smallholders. Although labour savings and reduced pesticide use can offset costs, economic feasibility varies with crop value and pest pressure (Abdallah, 2020).
3. **Limited pest spectrum:** Most sachets target specific pests such as thrips, mites, whiteflies and are less effective against aphids, caterpillars, or plant diseases necessitating integration with other control methods (Arthurs et al. 2009; Liburd et al. 2019; Saito et al. 2018).
4. **Delayed action:** Predator populations require time to establish and disperse, making sachets unsuitable for rapid control of existing pest outbreaks and more effective in prophylactic applications (Jacobson et al. 2001; Kumar et al. 2020).
5. **Crop-specific optimization:** Effective use depends on crop-specific optimization of sachet density, placement and timing, requiring technical knowledge and experience (Buitenhuis et al. 2014).
6. **Storage and handling constraints:** Sachets contain living organisms with limited shelf life and require careful storage and handling under controlled conditions (Shimoda et al. 2017, 2023).
7. **Monitoring difficulties:** Evaluating predator establishment and performance is challenging and requires expertise to correctly identify predatory mites and assess population levels (Gállego et al. 2022; Mikawa et al. 2020, 2022).
8. **Factitious prey dependence:** Sachet efficacy depends on maintaining viable factitious prey populations, which are sensitive to environmental conditions; prey

failure can result in premature loss of control (Solano-Rojas et al. 2022).

International and Indian Scenarios

Global Adoption and Commercial Applications

Sachet-based biocontrol has achieved widespread commercial adoption in greenhouse and protected cultivation systems across North America, Europe and parts of Asia (Abdallah, 2020; Adesso et al. 2018; Buitenhuis et al. 2014; Kumar et al. 2020).

North America: In the United States and Canada, sachet systems are standard practice in greenhouse vegetable and ornamental production (Buitenhuis et al. 2014). Major biocontrol companies (Koppert, Biobest, Applied Bio-nomics) offer multiple sachet products targeting different pest-predator combinations. Kumar et al. (2020) documented successful implementation of "Predator-In-First" strategies using *A. swirskii* sachets in Florida pepper production, demonstrating economic viability and sustainability. Adesso et al. (2018) extended sachet applications beyond greenhouses to outdoor container tree production in Tennessee, showing that controlled-release systems can function in more variable environments when properly managed.

Europe: European greenhouse industries, particularly in the Netherlands, Belgium and Spain, have been early adopters of sachet technology. Buitenhuis et al. (2014) conducted

extensive research in Canadian and European greenhouses, developing best practices for sachet placement and deployment that have been widely adopted by commercial growers.

Asia: Japan has been at the forefront of developing advanced sachet technologies, particularly sheltered and moisturized sachets (Buitenhuis et al. 2014). Shimoda et al. (2017, 2019, 2023) pioneered innovations in sachet design that improve performance under challenging environmental conditions. Mikawa et al. (2020, 2022) demonstrated successful implementation in Japanese pear greenhouses, using molecular monitoring to verify predator establishment.

Middle East: Abdallah (2020) documented efforts to establish sustainable biocontrol programs in Lebanese greenhouse vegetable production, including mass production of *A. swirskii* and deployment through breeding sachets. This work demonstrates the potential for sachet technology in regions with limited biocontrol infrastructure.

Indian Context and Opportunities

The Indian scenario for sachet-based biocontrol presents both significant opportunities and challenges. India's rapidly expanding protected cultivation sector, driven by demand for high-value vegetables, flowers and fruits, creates ideal conditions for biocontrol adoption. However, several factors have limited widespread implementation to date.

Current Status: While comprehensive India-specific research on sachet systems is limited in the reviewed literature, the broader context of Indian protected cultivation suggests growing interest in biological control. India's greenhouse and polyhouse area has expanded dramatically in recent years, particularly in states like Karnataka, Maharashtra, Tamil Nadu and Himachal Pradesh.

Opportunities:

- 1. Protected Cultivation Growth:** India's protected cultivation area is expanding rapidly, creating demand for sustainable pest management solutions. Sachet systems are particularly well-suited to greenhouse and polyhouse environments where environmental conditions can be partially controlled.
- 2. Pesticide Resistance:** Indian farmers face increasing problems with pesticide resistance in thrips, whiteflies and mites, making biological control increasingly attractive (Gulati, 2012; Liburd et al. 2019).
- 3. Export Markets:** Growers producing for export markets (particularly Europe and Middle East) face stringent pesticide residue limits, creating strong incentives to adopt biocontrol methods, including sachets.
- 4. Government Support:** Indian government programs promoting organic

farming and sustainable agriculture provide potential support mechanisms for biocontrol adoption.

Challenges:

- 1. Limited Commercial Availability:** Few Indian companies currently produce or distribute sachet-based biocontrol products, limiting accessibility for farmers.
- 2. Cost Sensitivity:** Indian agriculture is highly cost-sensitive and the upfront costs of sachet systems may be prohibitive for many smallholder farmers, even in protected cultivation.
- 3. Technical Knowledge:** Successful implementation of sachet-based biocontrol requires technical knowledge that may not be readily available to Indian farmers without extension support.
- 4. Climate Variability:** Many Indian growing regions experience high temperatures and variable humidity that can challenge sachet performance, though advanced designs (moisturised, sheltered sachets) may address these limitations (Shimoda et al. 2017, 2023).
- 5. Supply Chain:** Biocontrol agents are living organisms requiring cold chain logistics and rapid delivery, infrastructure that is underdeveloped in many Indian agricultural regions.

Integration with Other IPM Components

Sachet-based biocontrol is most effective when integrated with other IPM components rather than used as a standalone tactic (Sullivan et al. 2023).

Compatibility with Mycoinsecticides: Saito et al. (2018) demonstrated that predatory mite sachets are compatible with mycoinsecticide sprays (*Metarhizium brunneum*, *Beauveria bassiana*). In mixed thrips-spider mite infestations, combination treatments provided superior control, with mycoinsecticides suppressing spider mites while predatory mites-controlled thrips. This compatibility allows growers to address multiple pest groups simultaneously.

Cultural Practices: Proper crop management including sanitation, optimal nutrition and environmental control creates conditions favourable for biocontrol success (Liburd et al. 2019; Santiago et al. 2019; Vila and Cabello, 2014). Sachets perform best in well-managed greenhouses where environmental conditions support predator activity and pest populations are monitored regularly.

Selective Pesticides: When pesticide applications are necessary, selecting products with minimal impact on predatory mites preserves biocontrol capacity (Liburd et al. 2019; Saito et al. 2018). Compatibility testing ensures that sachet-based biocontrol can be integrated with chemical control when needed.

Monitoring and Decision-Making: Effective IPM requires regular monitoring of both pest and predator populations to guide management decisions (Liburd et al. 2019; Santiago et al. 2019). Molecular techniques developed by Mikawa et al. (2022) enable precise monitoring of predator establishment, improving decision-making in sachet-based programs.

Future Directions and Research Needs

Despite advances in sachet technology, key research gaps remain. Development of improved sachet designs capable of performing across extreme environmental conditions is needed, including innovations inspired by controlled-release systems (Shimoda et al. 2017, 2019). Multi-species sachets combining predators or parasitoids could address complex pest systems, though compatibility and optimal ratios require further study (Arthurs et al. 2009; Saito et al. 2018). Precision deployment using sensor-based monitoring and automation may improve efficiency and reduce costs (Vila and Cabello, 2014).

Economic analyses across crops and regions are essential to evaluate labour savings, pesticide reduction, and profitability (Abdallah, 2020; Adesso et al. 2018; Kumar et al. 2020). Climate change adaptation, including development of resilient designs for variable temperature and humidity, remains critical (Shimoda et al. 2019, 2023; Solano-Rojas et al. 2022). Expanding applications in

developing countries such as India requires affordable solutions and improved local capacity (Abdallah, 2020).

Further priorities include molecular monitoring for quality control (Mikawa et al. 2020, 2022), optimisation of factitious prey (Midthassel et al. 2014; Solano-Rojas et al. 2022), integration of semiochemicals (James et al. 2010; Nielsen, 2013; Todorov et al. 2022), and extending sachet use to open-field systems (Arthurs et al. 2009).

Conclusion

Sachet-based release systems are a reliable and efficient method for delivering natural enemies in protected cultivation, shifting biological control from reactive to preventive management. They ensure continuous predator availability, improve establishment, reduce labour, and protect agents from environmental and biological stresses. Predatory mites such as *N. cucumeris*, *A. swirskii*, and *N. californicus* effectively suppress thrips, spider mites, and whiteflies, maintaining pest populations below economic thresholds when applied prophylactically. Advances in sachet designs, including slow-release, breeding, sheltered, and moisturised formats, have improved performance across diverse climatic conditions and enhanced compatibility with integrated pest management components.

However, adoption is limited by environmental sensitivity, costs, technical

complexity, and constraints in developing regions. In India, growing protected cultivation and pesticide resistance create strong potential, but challenges such as limited production, climate variability, and knowledge gaps persist. Future innovations in design, precision deployment, and climate resilience will strengthen their role in sustainable pest management.

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Microbial volatile organic compounds for insect-pest suppression

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Abstract

Naphthalene produced by *M. vitigenus* was found to be behaviorally active and acts as a repellent against *Cephus cinctus* (wheat stem sawfly). Volatiles from *M. albus* caused high mortality in adults of the potato tuber moth and reduced larval development. The volatile compound, 1-octen-3-ol was lethal to male *Drosophila* flies which reduced survival and locomotor performance in both male and female while exhibiting strong repellency against adults of red flour beetle. Volatiles such as 2-methyl-1-butanol, 3-methyl-1-butanol and 2-phenylethanol produced by *A. pullulans* were found to attract beneficial predators (hoverflies) and pollinators (sweat bees). Additionally, 2-cyclohepten-1-one and 1, 3-dimethoxy-benzene were identified as effective repellents against adults of banana black weevil. The bacterial mVOCs (produced by *M. morgani* and *C. freundii*) attracted *Cyclocephala* species while ethenyl benzene and benzothiazole from *B. bassiana* were effective repellents of female red palm weevil. Sucking pests of cotton are effectively managed by the attractant formulations, which increase the attraction efficiency rather than the use of yellow sticky trap. Furthermore, the mVOCs produced by *S. vini* were the most effective in attracting female *D. suzukii* followed by those from *H. uvarum*.

Key words: mVOCs, fungal mVOCs, bacterial mVOCs, yeast mVOCs, *C. cinctus*, wheat stem sawfly, *Drosophila* flies, red flour beetle, hoverflies and sweat bees, banana black weevil, *M. morgani* and *C. freundii*, *B. bassiana*, red palm weevil, attractant formulations, yellow sticky trap, *S. vini*, *D. suzukii*, *H. uvarum*

Introduction

Agriculture has always been a cornerstone of human civilization, providing the food and raw materials essential for our survival and economic prosperity. However, one of the most persistent challenges faced by agriculture is the management of insect-pests. Conventional methods of pest management have relied heavily on chemical pesticides.

These chemicals pose several problems, including the development of insecticide resistance in pests, harm to non-insect pests, pest resurgence and environmental contamination. Thus, there is a need to find safer alternatives, such as the use of microbial volatiles for insect pest management.

Microbial volatile organic compounds (mVOCs) are a type of volatile organic

compounds produced by microorganisms, especially bacteria and fungi, during their primary and secondary metabolism. They are designated as lipophilic compounds with a low

boiling point, low molecular mass (less than 300 Da) and high vapour pressure (0.01 kPa) (Chandrasekaran *et al.*, 2023).

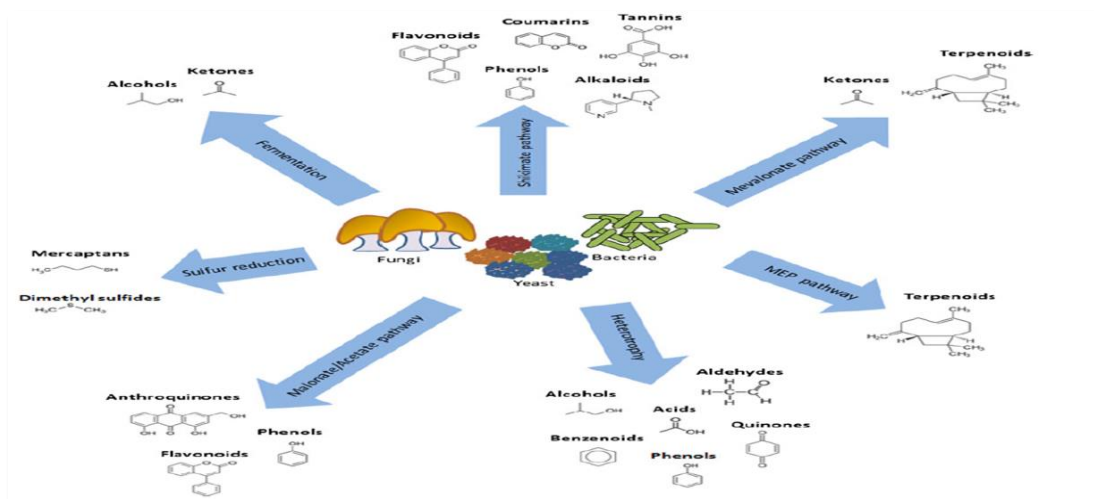


Figure 1: Metabolic pathways used by bacteria and fungi for producing different volatiles Davis et al. (2013)

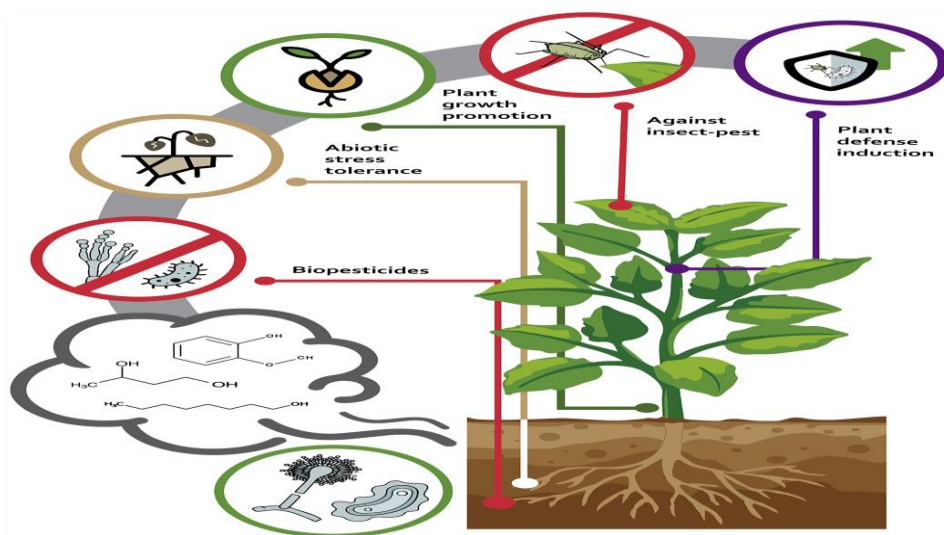


Fig. 2: Beneficial effects of mVOCs in plants

Impacts of mVOCs on strawberries

The mVOCs (2-hydroxypropanal) produced by endophytic bacteria (methylobacteria) serve as precursors for

flavouring agents 2,5-dimethyl-4-hydroxy-2 H-furanone and 2,5-dimethyl-4-methoxy-2 H-furanone, which promote the distinct flavour and aroma and reduce the invasion of insect

pests and diseases in strawberries (Srikamwang *et al.*, 2023).

2. Method of microencapsulation of mVOCs for field application:

- a. **Emulsification:** Volatiles are mixed with a polymer (e.g., alginate, gelatin, or starch) and an emulsifier to create a stable emulsion.
- b. **Processing:** Volatiles are coated using spray drying (heat evaporation), coacervation (polymer precipitation with solvents like ethanol), or extrusion with cross-linking agents (solidification using CaCl₂).
- c. **Microencapsulation:** The microcapsules are separated, dried and prepared for field use, ensuring controlled release, stability and prolonged effectiveness in pest control and plant growth promotion (Sharifi and Ryu, 2018).

3. Method of application of mVOCs:

Microcapsule and Sol-gel formulations can be applied for post-harvest storage application, greenhouse application, pest control, open field application and seed priming (Sharifi and Ryu, 2018).

4. Effect of mVOCs on insect-pests suppression:

1) Fungal mVOCs:

High mortality of adult potato tuber moth (*Phthorimaea operculella* Zeller) was

observed upon exposure to 15 and 30 g of fungal formulations in fumigation chambers, while neonate larvae were significantly affected by volatiles from *Muscodor albus*, though they showed lower susceptibility than adults (Lacey and Neven, 2006).

Complete (100%) mortality was recorded in male fruit flies (*Drosophila melanogaster*) after 7 days of exposure to 1-octen-3-ol, while compounds such as 1-octen-3-ol, 2-octenone, 3-octanol, and trans-2-octenal induced locomotory defects within 24 hours (Inamdar *et al.*, 2010).

Volatiles 2-methyl-1-butanol, 3-methyl-1-butanol, and 2-phenylethanol, isolated from *Aureobasidium pullulans*, can be used as lures to attract beneficial insects, including hoverflies and sweat bees (Davis and Landolt, 2013).

Among fungal mVOCs, 2-cyclohepten-1-one was identified as the most effective repellent against banana black weevil (*Cosmopolites sordidus*), followed by 1,3-dimethoxybenzene. Additionally, styrene and benzothiazole were found to inhibit the attraction of banana weevil adults to host and pheromone cues (Lozano-Soria *et al.*, 2020).

Exposure to 1-octen-3-ol (5 µL/L) significantly reduced survival and locomotor performance in both male and female *D. melanogaster* (Macedo *et al.*, 2020), and at 100 nL/cm², it showed strong repellency against

adults of red flour beetle (*Tribolium castaneum*) (Cui et al., 2021).

Furthermore, ethenyl benzene and benzothiazole produced by *Beauveria bassiana* (Bb203) were found to repel female red palm weevil (*Rhynchophorus ferrugineus*), thereby reducing infestation (Jalinas et al., 2022).

2) Bacterial mVOCs:

The mVOCs from bacteria *Morganella morganii* attracts both (males, females) of masked chafer, *Cyclocephala lunulata* and from bacteria *Citrobacter freundii* attracted males of masked chafer, *Cyclocephala barrerae* and both (male, female) of *C. lunulata* (Sanchez-Cruz et al., 2020). ICAR-Central Institute for Cotton Research (CICR) has developed an eco-friendly, cost-effective, sustainable bacterial-based synthetic volatile attractant formulations viz., ICAR-CICR-BVW, ICAR-CICR-BVJ, ICAR-CICR-BVA and ICAR-CICR-BVT, which on three-year large-scale field studies at ICAR-CICR and 2-year multi-location evaluations in 15 AICRP (Cotton) centres, proved to effectively manage cotton sucking pests through their attraction to the yellow sticky trap (Anonymous, 2025).

3) Yeast mVOCs:

The mVOCs produced by *Saccharomycopsis vini* 1.33 were the most effective in attracting female *Drosophila suzukii* followed by those from *Hanseniaspora uvarum* 2.2. (Castellan et al., 2024).

Advantages of mVOCs

- ✓ Eco-friendly in nature, biodegradable and harmless to non-target organisms
- ✓ Specific to insect-pests, minimizing harm to other species
- ✓ Reduces toxicity and safer for the ecosystem
- ✓ Reduces pest resistance due to multiple mode of action viz., repellent, attractant and behavioural impact

Challenges and Limitations of mVOCs

- ✓ The mVOCs identification and characterization of insecticidal compounds are difficult
- ✓ The mVOCs extraction and purification processes are costly
- ✓ Stable formulations are not available that remain effective under field conditions and during storage

Conclusion

Microbial volatile organic compounds (mVOCs) have emerged as promising eco-friendly alternatives to conventional chemical pesticides for insect-pest suppression. They operate through diverse mechanisms, including repelling pests, attracting beneficial insects, disrupting insect behaviour, and inducing systemic resistance in plants, while ensuring minimal risk to non-target organisms and the environment. Their multifunctional nature also reduces the risk of resistance development in pest populations. However,

despite their potential, challenges remain in the identification and characterization of bioactive compounds, high costs of extraction and purification and the lack of stable formulations suitable for large-scale field applications. With continued advancements biotechnology, formulation technology and field validation, mVOCs hold great promise as a sustainable and effective component of Integrated Pest Management (IPM) strategies.

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Insect diversity studies in Indian educational institute campuses

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Educational campuses (universities, colleges, and research institutes) in India serve as important urban and semi-natural biodiversity refuges. These green spaces often contain heterogeneous habitats including gardens, plantations, water bodies, and remnant vegetation, making them ideal for studying insect diversity.

This review adopts a systematic approach to identify relevant literature (the last two decades) on the studies documenting insect diversity in educational campuses across India. Methodologically, most campus-based insect diversity studies mentioned rely on standardized sampling tools and techniques including pitfall traps, sweep nets, beating sheets, Berlese funnels, hand collection, quadrats, light traps, transect counts and visual encounter surveys. Data recording typically includes photographic documentation and the use of smartphone-based applications for identification and data management.

Tiple *et al.* (2007) in a campus-based survey in Nagpur recorded 145 species of butterflies of which 62 were new records for the city demonstrating that species richness and composition vary significantly with

habitat modification and establishing butterflies as reliable bioindicators of environmental quality. At the Christian College campus in Kattakada, Thiruvananthapuram, Kerala, a checklist of insect biodiversity of 599 individuals from 14 different orders was documented (Bindulekha and Amalnath, 2017). Between February and April 2017, a study at Maharani's Science College campus in Mysuru identified 41 insect species from 22 families and nine orders. The most prevalent order among them was Hymenoptera (24.3%), followed by Coleoptera (21.9%) and Lepidoptera (14.6%). The Shannon-Weaver diversity index (2.97), indicated a reasonably high degree of diversity (Priyadarshini *et al.* 2018). Sahu and Rai, (2019) at Pt. Ravishankar Shukla University Campus, Chhattisgarh documented 28 odonate species. Kaur *et al.* (2019) documented insect fauna belonging to 9 orders and 26 families, in the Mehr Chand Mahajan D.A.V. College for Women campus.

A study conducted in 2019 to evaluate moth diversity on the campus of Banaras Hindu University, Varanasi, recorded 99 morphospecies belonging to 84 genera under 11 families. Among these, Erebidae was the

most species-rich (35 species across 30 genera; 34.85%), while Crambidae showed the highest abundance (33 species across 28 genera; 38.70%), followed by Geometridae and Noctuidae (Nayak and Ghosh, 2020).

Ant diversity studies conducted in the University of Kerala campus, Thiruvananthapuram revealed a rich assemblage of species dominated by the subfamily Myrmicinae, with diversity patterns strongly influenced by habitat disturbance and resource availability (Antony *et al.*, 2021). Lochana *et al.*, (2021) reported the incidence of two grass moth species, *Herpetogramma licarsisalis* and *H. bipunctalis* (family Crambidae) in the St. Joseph's College campus, Bengaluru, during December 2020. Since the larvae of these moths feed on grasses and are considered turf pests, the study suggested further investigation into larval abundance and potential damage to campus lawns. In a different study from the same campus, observations on 67 nests of stingless bees (*Tetragonula iridipennis*) were made between 2019 and 2020 (Murthy and Jayashankar, 2022).

During a survey from July 2021-June 2022 to document butterfly fauna in Kurukshetra University Campus, Haryana, 39 species under 32 genera, and five families were recorded. This included the Common Baron (*Euthalia aconthea*), a Schedule II species under the Wildlife (Protection) Amendment Act, 2022 (Gupta and Kumar, 2024).

In a study aimed to investigate the seasonal variation, relative abundance, and biodiversity of odonates within the diverse habitats of the West Bengal State University campus, from January to December 2022, 42 odonate species were documented, with the highest number of species being recorded from the family Libellulidae (62%) (Mallick and Ghorai, 2022).

A total of 92 insect species belonging to nine orders and 24 families were identified during a survey conducted at Sarah Tucker College campus, Tirunelveli, from January to July 2022. Lepidoptera was the most dominant order (58 species), followed by Hymenoptera, Orthoptera, and Odonata. A clear seasonal pattern was observed, with January and February showing the highest diversity, while June recorded the lowest (Jeyaprabha *et al.*, 2023).

Hussein and Suhara (2023) recorded 965 insects belonging to 9 orders under 35 families in the Kariavattom campus of the University of Kerala, Hymenoptera and Orthoptera were the dominant insect groups observed. The study also revealed the less-disturbed South Campus supporting higher species richness and diversity compared to other areas, emphasizing the importance of minimally disturbed habitats in conserving campus insect biodiversity. In Cotton University, Guwahati, Assam experiencing a change in land use pattern, Saikia and Naorem, (2024) recorded 163 bugs of 20 different

species under 10 families of Heteroptera from July 2018 - July 2019. Pentatomidae emerged as the most dominant family, with eight recorded species.

Charan *et al.*, (2025) reported over 100 species in University of Rajasthan, Jaipur with arthropods comprising the majority of recorded taxa. Transect-based surveys conducted at the ICAR-National Dairy Research Institute campus, Karnal, Haryana, during June 2023–May 2024 to evaluate butterfly diversity revealed 38 species under 29 genera belonging to 5 families. With 11 species, Nymphalidae was the most species-rich family, while Pieridae had the maximum abundance (587 individuals), significant seasonal change in diversity was also found in the study, highlighting the campus's importance as habitat for urban insect biodiversity (Neha, 2025). A three-month survey carried out in and around the Mula Education Society's Arts, Commerce, and Science College campus in Sonai, Maharashtra during June–August 2024, 40 species under 36 families, and 11 orders were recorded. Coleoptera had the greatest family-level diversity, whereas Hymenoptera was the most prevalent order (46.76%), followed by Diptera (Mohiuddin, 2025). Using a visual sampling technique, a butterfly diversity study was conducted at St. Joseph's University in Bengaluru, Karnataka, from April 2017 to April 2018 throughout the campus and surrounding green areas. Nymphalidae (37.20%), Lycaenidae (25.58%), Papilionidae

(16.28%), Pieridae (11.63%), and Hesperidae (9.30%) were the most common families among the 43 butterfly species observed including *Castalius rosimon* and *Acytolepis puspa* (Schedule I) and *Pachliopta hector*, *Euthalia aconthea*, and *Mycalesis mineus* (Schedule II) (Desai *et al.* 2025). In a study undertaken from November 2023-January 2024 in DKV Arts & Science College Botanical Garden, Jamnagar, Gujarat, 88 species (insects + spiders), dominated by Formicidae was observed (Pandya and Patel, 2025). In Danya College campus, Almora, Uttarakhand 24 species of 18 families and 6 orders *viz.*, Lepidoptera, Coleoptera, Diptera, Hemiptera, Orthoptera, and Hymenoptera were documented (Pandey & Tamta, 2025). A total of 53 species, including 27 species of moths and 26 species of butterflies were identified during the survey from January to December, 2024 in Govt. Serchhip College, Mizoram (Vanlalnghaka and Solo, 2025). Kaur *et al.* (2025) conducted an entomofaunal diversity assessment at Maitreyi College, University of Delhi between February and August 2024 documenting 198 insect species of which 164 species were identified under 13 orders. Lepidoptera was the most dominant order, accounting for 20.2% of the recorded insect diversity.

Using the Visual Encounter Survey (VES) approach, the study conducted at S.T. Hindu College in Kanyakumari District from September to December 2024, 54 species under Lepidoptera (14 species), Coleoptera (6

species), Orthoptera (5 species), Hemiptera (5 species), Hymenoptera (5 species), Odonata (4), Diptera (4), Mantodea (3), Blattodea (1) and Zgentoma (1) were recorded (Selvi *et al.* 2026). Moth diversity in three suburban areas of Bengaluru Urban District, Karnataka, including St. Joseph's University campus, documented 42 genera belonging to 7 families. Erebiidae was the dominant family followed by Crambidae and Geometridae. The findings highlight the ecological importance of urban green spaces in supporting moth diversity and represent the first documented moth survey from these selected regions (Lochana *et al.*, 2026). A total of 94 species from 59 genera and 6 families *viz.*, Riodinidae, Nymphalidae, Pieridae, Papilionidae, Lycaenidae, and Hesperidae were found during the survey on the campus of Dr. Y. S. Parmar University of Horticulture and Forestry in Nauni, Solan, Himachal Pradesh from October 2018-September 2020. Riodinidae had the least representation among these, while Nymphalidae was the most prevalent family (Mahajan *et al.*, 2026).

The present review, while representative, encompasses institutions across different regions of the country, highlighting the role of urban educational campuses in supporting considerable insect diversity despite increasing urbanization clearly demonstrating that educational campuses in India are valuable microhabitats for insect biodiversity research and conservation. These ecosystems offer unique opportunities for

conducting ecological studies, promoting environmental awareness, and engaging students in citizen science initiatives.

Future research should adopt multidisciplinary approaches, integrating taxonomy, ecology, and conservation biology, to better understand, manage, and protect biodiversity within campus environments.

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Short Notes

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Recent Observations on the Status of the House Sparrow (*Passer domesticus*) in Bangalore, India

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The House Sparrow (*Passer domesticus*) has historically been among the most familiar and abundant avian species across the Indian subcontinent, thriving in close association with human habitation (Ali & Ripley, 1987). In Bangalore (12.9699°N, 77.5752°E), the first author has been observing birds for over five decades and recalls *P. domesticus* as the most commonly encountered species well into the early 1990s. Its cheerful chirping has been a defining feature of residential neighbourhoods, markets, and railway platforms alike. Maybe pertinent to mention that the new international airport at Bangalore used to be frequented by house sparrows until about 2020.

However, the rapid urbanization and concretization of Bangalore over the past three decades appear to have taken a significant toll on sparrow populations. Despite its strongly commensal nature with humans, *Passer domesticus* has become increasingly conspicuous by its absence in urban and peri-urban zones. Analogous declines have been

documented across European and Asian cities, attributed to changes in food availability, nesting architecture, and urban green cover (Summers-Smith, 2003; Shaw *et al.*, 2008).

Quarterly surveys were conducted between January 2024 and June 2026 across Bangalore city and its peri-urban northern corridor, extending from Nelamangala to Kolar, including the Melur area of Chikkaballapura district. Observations were recorded using standard point count methodology (Bibby *et al.*, 2000), supplemented by opportunistic field notes. Emphasis was placed on recording presence or absence of *P. domesticus* along transects covering residential localities, agricultural fringes, and semi-rural settlements. Farmers and local residents were interviewed informally regarding perceived changes in sparrow populations and associated land-use patterns.

Across eight quarterly survey cycles spanning in 2026, *P. domesticus* was not

recorded in Bangalore city or its peri-urban extensions. Small flocks were infrequently observed by our team in the following villages: Melur (13.4350°N, 77.7286°E), Chikkaballapura district, Varadenahalli Village (13.2189°N, 77.8031°E) (Devanahalli Taluk) Fig.1, Naganayakanahalli (13.2242°N, 77.7869°E), Channarayapatna (13.14505°N 77.4745°E), Thalahalli (13.3688°N, 77.7625°E), Sonnahallipura (13.1362°N, 77.7892°E), Bandappanahalli (13.3604°N, 77.7983°E) and Patalammanahalli (13.3481°N, 77.8172°E).

Farmers in this locality reported that the conversion of paddy fields into horticultural plots and expansion of residential concrete construction had progressively discouraged sparrow presence. Additional factors cited by respondents included the proliferation of mobile phone towers, reduced availability of traditional food grains, the disappearance of tiled-roof houses, and the replacement of wooden electric poles, erstwhile nesting and roosting supports with smooth concrete and steel structures.



Fig. 1 *P. domesticus* at Varadenahalli Village, Devanahalli Taluk PC: Authors

The findings from the present study are consistent with broader reports of House Sparrow decline across urban India and other rapidly developing cities globally (Summers-Smith, 2003; Shaw et al., 2008). The twin pressures of food scarcity particularly the decline of traditional grain crops and open grain storage and the near-total loss of nesting substrates through architectural modernization emerge as the most significant proximate drivers in Bangalore's context.

The speculative role of electromagnetic radiation from mobile phone towers in sparrow population decline, cited by local communities, has been the subject of limited published investigation (Balmori & Hallberg, 2007) and warrants more rigorous study. Additionally, feral cats in urban areas constitute significant predation pressure on nests and eggs, a factor rarely quantified in Indian urban bird surveys.

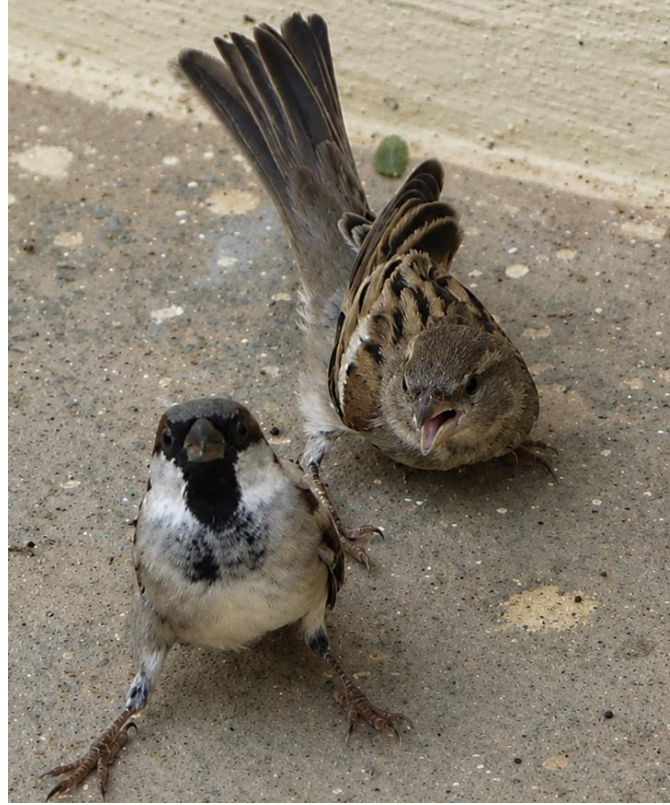


Fig. 2. Pair of House Sparrows PC: Authors

Notably, sparrows persist in rural settlements (Fig 2) where traditional tiled-roof houses, cattle sheds, and granaries continue to exist. This habitat specificity underscores that structural continuity of traditional built environments is as critical as food availability for *P. domesticus* persistence. Importantly, the species is insectivorous during breeding and chick-rearing stages (Ali & Ripley, 1987), imparting significant ecological value as a biological regulator of insect populations in agricultural landscapes.

Several farmers expressed the traditional belief that the presence of House Sparrows around homesteads is an auspicious sign an ethno-ornithological sentiment that,

while culturally significant, also reflects a deeper community-level awareness of the sparrow's association with human wellbeing. Such local ecological knowledge can be leveraged effectively in community-based conservation outreach.

Conclusion

The conspicuous absence of the House Sparrow from Bangalore's urban and peri-urban landscape, juxtaposed with their persistence in rural habitats, signals an urgent need for targeted conservation action. Practical interventions may include installation of nest boxes in residential and institutional premises, promotion of native grain-bearing plants in urban gardens, and civic awareness campaigns.

Their documented role as insectivorous birds during breeding makes their rural conservation ecologically imperative. Systematic, long-term monitoring of *P. domesticus* across Karnataka's urban–rural gradient is strongly recommended.

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Note on *Liriomyza* spp Leaf Miner Incidence on *Amaranthus* in Peri-urban Bangalore

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Regular horticultural surveys in south Karnataka are conducted by Rashvee IPRS and Shreenidhi Plant Health Clinic to issue blog alerts on pests and diseases, and to provide suitable advisories and inputs to farmers. During a recent survey of Bangalore rural and peri-urban belts, *Liriomyza* leaf miner infestation was recorded on edible *Amaranthus* at a damage level of 18–20% mined leaves. Leaf miners of the genus *Liriomyza* (Diptera: Agromyzidae), commonly referred to as serpentine leaf miners, are polyphagous pests of global significance (Spencer, 1973; Parrella, 1987). The two major species affecting leafy vegetables in South India are *Liriomyza trifolii* (Burgess) and *Liriomyza sativae* Blanchard (Weintraub & Horowitz, 1995).

Adults are small (1.5–2.5 mm), black flies with a distinctive yellow scutellum and bright yellow facial markings. Females puncture the leaf surface with their ovipositor for feeding and oviposition, laying 50–300 eggs singly within leaf tissue. Eggs hatch in 2–4 days under Bangalore's prevailing temperatures of 25–30°C. Larvae are pale

yellow maggots that tunnel between the upper and lower leaf epidermis, creating the characteristic silvery, serpentine mines (Fig. 1). A single larva produces one mine; heavy infestations result in coalesced mines causing premature leaf desiccation. Larval development is completed in 4–7 days, after which mature larvae cut an exit slit and drop to the soil for pupation. The brown, barrel-shaped puparium is formed at 2–3 cm depth in soil or in leaf litter. Pupal development takes 7–12 days (Parrella, 1987). Total life cycle is completed in 15–25 days, enabling 10–12 generations per year under Bangalore's agroclimatic conditions.

Liriomyza spp. are highly polyphagous, attacking over 40 host plants including tomato, French bean, cucumber, and *Amaranthus*. Warm, dry weather favours rapid population buildup, whereas heavy rains reduce adult populations and drown pupae (Weintraub & Horowitz, 1995). Natural enemies, particularly ectoparasitoids such as *Diglyphus* spp., *Chrysocharis* spp., and *Neochrysocharis* spp. (Hymenoptera: Eulophidae), play an important

role in regulating leaf miner populations in unsprayed crops (Hanafi, 1999; Minkenberg & van Lenteren, 1986). Excessive use of broad-spectrum insecticides decimates these parasitoids, frequently triggering resurgent leaf miner outbreaks, as documented particularly in tomato in the surveyed areas.

In Bangalore rural tracts, *Amaranthus* is a short-duration leafy crop harvested within 25–30 days after sowing. At the recorded damage level of 18–20% mined leaves, photosynthetic loss remains within tolerable limits and marketable yield is not significantly affected. As the crop was at or near the harvest stage, and because *Liriomyza* larvae are internal feeders, insecticidal sprays would have poor contact efficacy and risk leaving unacceptable residues on edible leaf tissue. Furthermore, natural parasitism is typically highest at this crop stage. Accordingly, farmers were advised to harvest the crop immediately without insecticide application. For post-harvest sanitation, destruction of crop residues by burying or composting was recommended to eliminate pupae. Further staggered sowing, which provides a continuous green-bridge host for leaf miners, has also been discouraged (Parrella, 1987).

For the following season, the following preventive and low-residue IPM measures were recommended: (i) deployment of yellow sticky traps for early monitoring and mass trapping of adults; (ii) foliar spray wash at three leaf stage with Veraxaa (Rashvee herbal

liquid soap) at 0.5ml/ liter concentration as a deterrent to adult feeding and oviposition; and (iii) conservation of native parasitoids by avoiding broad-spectrum insecticide sprays, in and around the growing belts. These recommendations align with integrated pest management (IPM) principles for vegetable crops in peri-urban settings (Verghese et al., 2001).

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An Integrated, Climate-Resilient Approach for Management of Fruit Flies *Bactrocera* spp. in Fruit Crops (Mango, Pomegranate, Guava, Dragon Fruit, Sapota)

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Fruit fly infestation continues to be among the most economically damaging constraints in fruit crops, Mango (*Mangifera indica*), Pomegranate (*Punica granatum*), Guava (*Psidium guajava*), Dragon Fruit (*Hylocereus undatus*) Sapota (*Manilkara zapota*) cultivation. Oviposition by gravid females within developing fruit leads to internal maggot development, premature fruit drop, and a sharp decline in market value. Unpredictable climate changes and shifting phenological windows associated with climate change have further complicated fruit fly management across fruit growing tracts, underscoring the need for climate-resilient management approaches that are effective, affordable, and ecologically sound (Verghese & Rashmi, 2026).

Rashvee International Phytosanitary Research & Services Pvt. Ltd. (R-IPRS) recognized by the Ministry of Commerce as a government-promoted startup. The startup has developed an Integrated Climate Resilient Fruit Fly Management protocol comprising

three complementary, non-insecticidal, and zero-toxicity components, intended for adoption by horticulture growers, including those adopting organic orchards. The programs were funded by the Biotechnology Industry Research Assistance Council, Department of Biotechnology (BIRAC–DBT), Government of India (GoI). The products were screened and tested at the Indian Council of Agricultural Research–National Bureau of Agricultural Insect Resources (ICAR–NBAIR) and State Agricultural Universities (SAUs), and were approved by BIRAC–DBT, GoI for commercialization and marketing. The products, PhalRakshak™ and Veraxaa™, have also received patents from the Government of India. (Rashmi *et al.*, 2025b).

1. PhalRakshak™ – Climate-Resilient Liquid Lure for Fruit Flies

PhalRakshak™ is a patented, 100% insecticide-free liquid lure that retains efficacy under high ambient temperatures for over 65 days. Disposable water bottles may be used as trap, eliminating the need for perforation, and

are fitted with a low-cost climate-resistant yellow cap designed to withstand wind and rain. A trap is prepared by adding 5 ml of PhalRakshak™ in 200–250 ml of water in a 500 ml used water bottle. The trap odour affects the female fruit flies reproductive and Ten traps per acre are recommended for mango, increasing to 15 traps per acre for guava, pomegranate, custard apple, sapota and dragon fruit; traps are suspended inside the canopy at approximately six feet height. Once filled, the spent solution can be filtered, dead flies removed, and the lure replenished (1–2 ml fresh lure in water) for repeated use (Fig 1).

2. Veraxaa™ Herbal Liquid Soap adjuvant with Neem/Azadirachtin Spray

Veraxaa™, a patented (mainly volatile oils) herbal liquid soap adjuvant, functions as an adjuvant and plant host odour-masking and that interferes with host-fruit volatile recognition by gravid female fruit flies. At flowering, 0.5 ml Veraxaa™ with 1 ml azadirachtin (10,000 ppm) per litre of water is recommended, increasing to 1 ml Veraxaa™ with 1 ml azadirachtin per litre after fruit set. Sprays are applied at 15-day intervals during vegetative growth and at 10–15-day intervals through fruit development, covering foliage, new flush, flowers, and developing fruit for whole-tree protection. This is proved safe for bees, natural enemies, and other beneficial insects. This also protects the fruits from sucking and other pests both at vegetative and fruiting phases (Rashmi et al., 2025a).

3. Rashvee Phytofer™ Protein Bait Application

Rashvee Phytofer™ Protein bait (1 kg) is soaked overnight in 20 litres of water; on the following day, 40 ml deltamethrin (Decis 2.8 EC) is added and the mixture is brush-applied to the tree trunk. Application is initiated approximately two weeks before harvest and repeated once after a 7-day interval, targeting adult flies. In organic orchards where growers prefer not to use pesticides, the pit method of baiting can be effectively adopted. This method involves digging 4 pits per acre (placed at the four corners or in evenly spaced quadrants) and filling them with fallen or infested fruits along with a Phytofer bait solution to attract and trap fruit flies; for 4 pits, mix 2 kg of Phytofer in 40 liters of water and pour 10 liters into each pit. By the end of the season, these pits can be closed as they turn into natural manure, and within this rotting mass, no maggots can pupate or emerge as adults; this approach naturally reduces pest populations without chemicals, supporting eco-friendly, organic, and residue-free fruit production while improving orchard hygiene (Rashmi et al., 2025b).

Reported Benefits

- More than 99 percent reduction in fruit-fly-damage.
- Lower incidence of anthracnose, attributed to reduced fruit puncture wounds

- Improved fruit quality and market price realisation
- Approximately 70% lower cost compared with commercial trap systems
- Reported yield gains of 30–40% when the protocol is followed as part of a complete IPM programme

Amid intensifying pest pressure under changing climatic conditions, horticulture growers require fruit fly management options that are simultaneously effective, low-cost, and environmentally compatible. The integrated protocol described here – combining a climate-resilient liquid lure trap, Climate resilient cap, a herbal liquid soap odour mask adjuvant spray, and a targeted protein bait application – offers a practical, organic-orchard-compatible

pathway toward improved fruit quality, reduced losses, and better farm-gate returns and residue free exportable returns.

Acknowledgments

The authors express their sincere gratitude to BIRAC (Biotechnology Industry Research Assistance Council), Department of Biotechnology (DBT), GoI, for providing financial support, which was instrumental in the development of these products. Special appreciation is extended to Dr. S. N. Sushil for his valuable assistance in the evaluation of Veraxaa for sucking insect pests and PhalRakshak liquid lure for fruit flies at ICAR-NBAIR. The authors also thank Federation of Indian Chambers of Commerce and Industry (FICCI) and Confederation of Indian Industry (CII) for recognizing the startup and its eco-friendly products.



RASHVEE
PhalRakshak

RASHVEE FRUIT FLY LIQUID LURE FOR FRUIT CROPS

SAFE • EFFECTIVE • ECO-FRIENDLY

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
- Synergistic odour affects the female fruit fly reproductive and orientation behavior
- Ideal for quarantine and invasive species monitoring

Pack Sizes:
100 ml, 250 ml

Shelf Life:
24 months

Contact: Dr. M A Rashmi, 9036608527



TARGET FRUIT FLY SPECIES

- Bactrocera dorsalis, Bactrocera carveae,
- Bactrocera correcta, Bactrocera zonata,
- Bactrocera versicolor, Bactrocera affinis,
- Bactrocera diversa.










Fig. 1 PhalRakshak™ -Climate-Resilient Liquid Lure for Fruit Flies



VERAXAA
HERBAL LIQUID SOAP ADJUVANT/SPRAY
WASH/SPREADER

A POWERFUL, ECO-FRIENDLY SOLUTION FOR HEALTHIER CROPS

ECO-FRIENDLY
Safe for environment and natural enemies

IMPROVES SPRAY ADHESION
Better coverage, better results

ENHANCES PESTICIDE EFFECTIVENESS
Works well with pesticides & botanicals

SUPPORTS HEALTHY CROP GROWTH
Stronger plants, better yield



KEY FEATURES & BENEFITS

- Eco-Friendly:** Safe non-target organisms and natural enemies, ensuring environmental safety.
- Synergistic Properties:** Works well with entomopathogens, botanicals and insecticides, boosting their efficiency.
- Natural Odour-Masking Technology:** Odour-masking effect disrupts insect host-finding and reduces plant infestation.
- Excellent Adjuvant:** Enhances the effectiveness of pesticides, demonstrating a synergistic effect.
- Resistance Management:** Preventing the development of resistance in insects to insecticides, thereby increasing their effective lifespan.

USE AS

ADJUVANT
at 1 ml/litre spray solution

STICKER & SPREADER
on leaf surfaces

WASHING OFF
sucking insect eggs, nymphs & spores

HELPS CLEAN
fungal spores, bacterial residues & dust

PACK SIZES:

- ✓ 250 ml
- ✓ 500 ml
- ✓ 1000 ml
- ✓ 5000 ml

HOW TO USE

Use as adjuvant at 1 ml/litre spray solution

For delicate plants, reduce to 0.5 ml/litre

Can be used as a stand-alone spray (1 ml/litre) for washing off

HERBAL & SILICON-FREE SPRAY ADJUVANT

A natural choice for sustainable and effective farming.

BETTER ADHESION. BETTER COVERAGE. BETTER RESULTS. | **HEALTHY CROPS. HEALTHY FUTURE.**

Fig 2. Veraxaa™ Herbal Liquid Soap adjuvant with Neem/Azadirachtin Spray

Rashvee
PHYTOFER BAIT-SPLASH FOR FRUIT FLIES IN FRUITS
For fruits: Mango, Guava, Custard Apple, Dragon Fruit, Sapota, Pomegranate & Others

Preparation & Application Method

- 1 Take 1 kg Rashvee Phytofer Bait and soak in 20 liters of water overnight.
- 2 Next day, add 40 ml Deltamethrin (Desis 2.8 EC) to the solution.
- 3 Splash the bait solution on the base of tree trunks.
- 4 20 liters of prepared solution is sufficient for 25 trees.
- 5 Recommended dosage: 2 kg Rashvee Phytofer Bait per acre.

Effective Fruit Fly Management

- 1. Trap-Based Management**
 - Rashvee Liquid Lure Traps: Install 10 traps per acre to attract and capture adult fruit flies.
- 2. Preventive Spray for Oviposition Deterrence**
 - Rashvee Herbal Liquid Soap (1 ml) + Azadirachtin 10,000 ppm (1 ml):
 - Acts as an excellent ovipositional deterrent.
 - Spray 40 days prior to harvest at 10-day intervals.
 - Prevents egg laying and ensures best results.
- 3. Bait Application (Phytofer Bait)**
 - Rashvee Phytofer Bait: Apply as a bait-splash on tree trunks.
 - Begin 2 weeks prior to harvest.
 - Repeat two applications for effective control.

A Natural Approach for Healthier Fruits & Higher Yields

Fig. 3. Rashvee Phytofer™ Protein Bait Application

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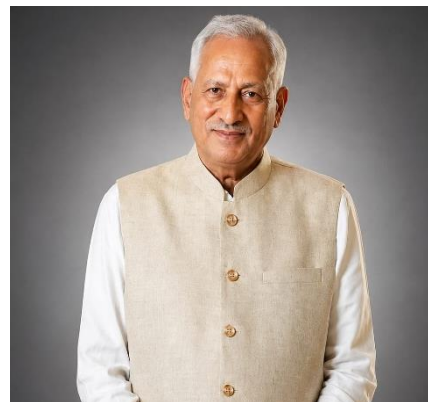
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MS Received on 22th March, 2026
MS Accepted on 26th June, 2026

Obituary

Dr. Gavi Gowda

Former Professor & Head, Department of Apiculture, UAS, Bangalore



Dr. Gavi Gowda, a distinguished entomologist and highly respected academician of the University of Agricultural Sciences (UAS), Bangalore, passed away on 24th May 2026, leaving behind an extraordinary legacy in the fields of Entomology and Apiculture.

Born on January 2, 1947, in Dummasandra, Kanakapura, Bengaluru, Dr. Gavi Gowda dedicated his life to agricultural research, education, and service to the farming community. He was an alumnus of UAS, Bangalore, and earned his Ph.D. from Tamil Nadu Agricultural University in 1996.

Dr. Gavi Gowda began his professional career at the Regional Research Station, Mudigere, Chikkamagaluru (1979–1984), followed by the Zonal Agricultural Research Station, Mandya (1984–1986). During this period, he made significant contributions to the management of field crop pests in the hill zone (Malnad region) of Karnataka. His research and extension efforts greatly benefited the farming community and enhanced sustainable agricultural practices.

Over a remarkable career spanning more than three decades, he guided 20 postgraduate and Ph.D. students in the disciplines of Entomology and Apiculture. His mentorship, academic excellence, and unwavering dedication profoundly influenced generations of students and researchers.

Dr. Gavi Gowda authored and co-authored over 100 research publications and books, particularly in crop pest management and apiculture. His work has been of immense value to researchers, students, and farmers alike, with several publications having significant practical applications in the field of beekeeping.

He also played a pivotal role in establishing and strengthening the Department of Apiculture at UAS, Bangalore. He served with distinction as Professor and Head of the Department from November 18, 1998, to March 19, 2007, demonstrating exemplary leadership and commitment.

During the 1990s, Dr. Gavigowda and his team made significant contributions to apiculture research by developing effective management strategies to control Thai sacbrood viral disease in honey bee colonies. He played a pivotal role in popularizing beekeeping across the state through hands-on workshops, extension publications, radio broadcasts and television programmes, reaching a wide audience of farmers and aspiring beekeepers. His hands-on beekeeping training programs, conducted across various parts of the state, gained immense popularity among farmers and beekeeping enthusiasts.

Even after his retirement, Dr. Gavi Gowda remained actively engaged in advancing the field of apiculture through his guidance, expertise, and continued association with academic and research activities.

Dr. Gavi Gowda will always be remembered for his scholarly contributions, humility, dedication to education, and tireless service to agricultural science. His passing is an irreparable loss to the scientific community, his students, colleagues, and the farming fraternity.

May his soul rest in eternal peace.

Dr. Jagadish K.S.,

Professor and Scientific Officer,

Directorate of Education, UAS, GKVK Bengaluru

Dr. K.T. Vijayakumar

Assistant Professor,

Department of Apiculture, UAS, GKVK Bengaluru

Obituary

Frieda Fernandes (1950–2026)

Frieda and Fruit Flies

Mrs. **Frieda Fernandes**, born on 24 May 1950 in Tanzania, passed away peacefully in June 2026, in Goa, shortly after celebrating her 75th birthday. Her life was a remarkable journey of courage, integrity, and trailblazing achievements that left an indelible mark on agricultural science in India, especially in Goa.



Frieda was the **first woman student** in the Bachelor of Agricultural Sciences program at the University of Agricultural Sciences, Bangalore, where she studied from 1971 to 1975. In a class of boys, she was the **ONLY** girl student and the **FIRST** girl to be admitted for B Sc (Agri), at UAS, Bangalore, India. She stood out not only for her pioneering presence but also for her dignity, friendliness, broad-mindedness and above all scholarly approach to her studies. She scored well in entomological subjects. We her classmates fondly ascribed her as the “darling of the batch,”!

Frieda’s journey was extraordinary. As the **first woman student** in the Bachelor of Agriculture program at the University of Agricultural Sciences, Bangalore (1971–1975), she stood tall in a class of 179 boys. She accompanied her classmates on every study tour, winning their admiration and affection

After graduation, Frieda returned to Goa, where she served with distinction in the **Agriculture Department**, rising through the ranks with promotions earned by sheer efficiency and honesty. Her career was a testament to perseverance and excellence, and she became a role model for generations of agricultural officers.

Her classmates recall with pride her presence at the **Golden Jubilee Reunion in 2025** in Bangalore, where, despite frailty and bound to a wheelchair, she traveled from Goa to Bangalore to celebrate with her peers. Her courage and determination touched everyone present, including Dr. G. Parameshwara, our classmate and now Deputy Chief Minister of Karnataka.

Frieda’s contributions extended beyond administration. In 2003, during the India–UK International Programme, which I coordinated, she provided invaluable field support for fruit fly

research in mango orchards, as only her department farm, which she headed, had a contiguous mango grove of *Mancurad* variety in Goa's coast. Her cooperation enabled groundbreaking studies, resulting in published papers and even a PhD on fruit flies for a young scholar from Goa. During this period, I used to visit this Goa at least once in two months to guide and supervise the fruit fly management research. Dr Romeno Faleiro of ICAR also coordinated with me and Frieda. Frieda showed all interest in plant protection and gave me all logistic support. The outcome of the fruit fly control developed here is still the recommendation for fruit fly management in Goa, and truly a testimonial to Frieda's commitment to agricultural entomology.

Her personal life was marked by resilience. After losing her husband in 2009, she bravely raised her family, traveled abroad, and continued to live with grace. Even in her final years, confined to her home in Goa, she radiated cheerfulness and kindness. Friends remember her thoughtful gestures—like gifting cashews and wine during visits—and her ever-present smile.

Mrs. Frieda Fernandes leaves behind not only her family (two daughters, sons-in-law and grand children) but also countless friends, colleagues, and students who were touched by her life. She was a pioneer, a leader, and above all, a compassionate soul. Today, as we mourn her passing, we also celebrate her remarkable journey. She continues to smile with the Lord in Eternity, and her memory will remain a source of inspiration for all who knew her.

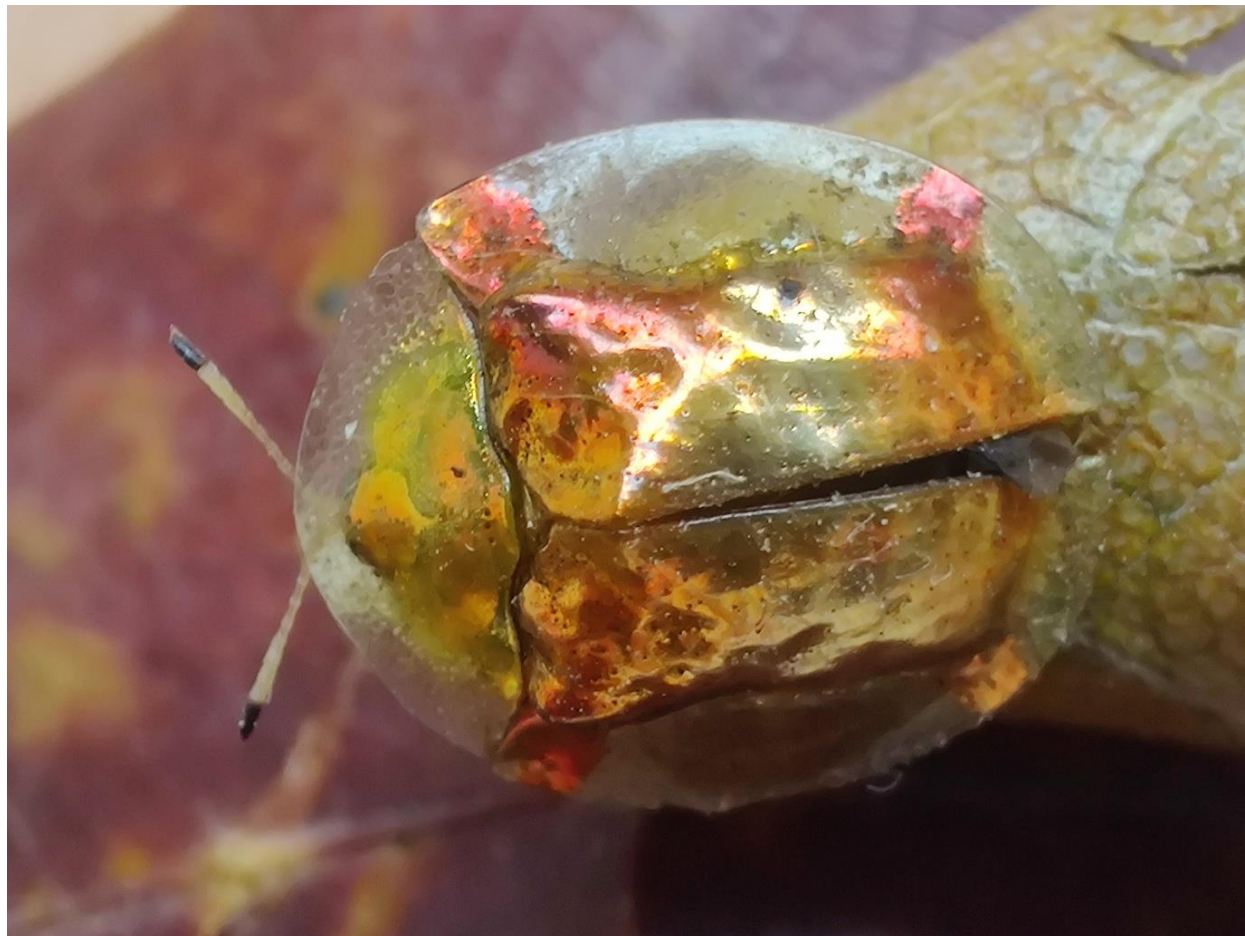
Dr Abraham Verghese

*Editor-in-Chief
Insect Environment*

Errata: The authors wish to issue the following corrections to the article “Monitoring avian ecological health through ectoparasites: A review from India’s diverse habitats” published in Volume 28(3), pages 356–360:

- The year of publication for (Clayton, D. H. and Walther, B. A.) should be corrected to 2001.
 - The reference (Jongejan, F. and Uilenberg, G., 2004) should be replaced with (Tatsunori M. et al., 2017).
 - The reference (McClure, H. E. and Ratanaworabhan, N., 1973) was missing and has now been included.
 - The reference (Sharma, R. et al., 2020) has been deleted along with its associated content.
- Note: This errata has been submitted by the authors for an inadvertent citing in the paper

INSECT LENS



Golden tortoise beetle, Charidotella sexpunctata (Chrysomelidae: Coleoptera)

Author: Mr. Rushikesh Rajendra Sankpal., Assistant Professor, Babasaheb Garware College

Location: Pune, Maharashtra

Email: rushisankpal@gmail.com



Unidentified moth (Noctuidae: Lepidoptera)

Author: Mr. Rushikesh Rajendra Sankpal., Assistant Professor, Babasaheb Garware College

Location: Warananagar, Maharashtra

Email: rushisankpal@gmail.com



Insect multipartite association

Author: Mr. Rushikesh Rajendra Sankpal., Assistant Professor, Babasaheb Garware College

Location: Pune, Maharashtra

Email: rushisankpal@gmail.com



Unidentified Katydid (*Tettigoniidae*: Orthoptera)

Author: Mr. Rushikesh Rajendra Sankpal., Assistant Professor, Babasaheb Garware College

Location: Pune, Maharashtra

Email: rushisankpal@gmail.com



Unidentified fly (*Diptera*)

Author: Mr. Rushikesh Rajendra Sankpal., Assistant Professor, Babasaheb Garware College

Location: Pune, Maharashtra

Email: rushisankpal@gmail.com



Eggs of Giant litchi stink bug, Tessarotoma javanica (Hemiptera: Tessaratomidae)

Author: Mr. Keshav Raj, ICAR-NRC on Litchi, Bihar

Location: Muzaffarpur, Bihar



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



Larvae of Marbled Sallow or Droplet moth, Acontia marmoralis (Noctuidae: Lepidoptera)

Author: Dr. Nagaraj, D.N., Project Head (Entomologist) Ento. Proteins Pvt. Ltd., Mangalore

Location: Bengaluru

Email: nasoteya@yahoo.co.in



The crimson rose/Swallow Tail Butterfly , Pachliopta hector (Papilionidae: Lepidoptera)

Author: Dr. Nagaraj, D.N., Project Head (Entomologist) Ento. Proteins Pvt. Ltd., Mangalore

Location: Bengaluru

Email: nasoteya@yahoo.co.in

Important blogs

Insect Environment Blog

Kheti Bachao Abhiyan (save farm campaign): Migratory Beekeeping

Mitigating Flower Drop and Sustaining Pomegranate Yield through Managed Bee Pollination by Rashvee International Phytosanitary Research and Services

21 June 2026

M.A. Rashmi, Abraham Verghese and V.G. Raghavendra, Rashvee International Phytosanitary Research and Services

Pomegranate (*Punica granatum* L.) is an economically significant fruit crop in Karnataka, Maharashtra, and Andhra Pradesh; however, growers report poor fruit set, excessive flower drop, and reduced marketable yield. While high temperatures and nutritional imbalances contribute to these problems, increasingly pollination deficit is also a key factor, that can be addressed effectively through managed migratory beekeeping.



Apis cerana colony in Rashvee IPRS Pomegranate orchard PC: Authors

Pomegranate produces two flower types: hermaphrodite (bisexual) flowers capable of fruit set and staminate (male) flowers that naturally abscise as part of normal physiology. Although the crop is self-fertile, self-pollination alone is insufficient to fertilise all ovules within a flower. Since each fertilised ovule forms an aril, incomplete pollination directly reduces aril number,

resulting in lighter fruits and inferior commercial grades.

Thus, effective pollen transfer between flowers is essential for optimum yield and fruit quality. In South Karnataka, the Indian honey bee, *Apis cerana* Fabricius (Hymenoptera: Apidae), is particularly well suited for managed pollination and its peak foraging activity between 0700 and 1100 hours coincides precisely with maximum stigma receptivity and pollen viability. In addition, *Apis dorsata* is seen foraging at natural conditions but not amenable to manipulative introduction. This synchrony of pollinators with flowering is critical for enhanced fruit set.

Field observations at Rashvee IPRS Research Farm provided practical evidence of this synergy. In early March, a flowering–pollinator mismatch in the Bhagwa variety, aggravated by heat stress and limited soil moisture, led to severe flower drop at peak bloom. In addition, as the farmers also indicated trash burning and the ensuing smoke caused swarming out of *Apis dorsata* colonies.

To mitigate this, twenty *A. cerana* colonies were introduced across twelve acres, accompanied by supplementary irrigation and placement of shallow water troughs 10/ acre on the ground between trees to support foraging bees. Pesticide applications were

completely avoided during the flowering period.



Honey bee foraging in Pomegranate PC: Authors

Only need-based sprays were undertaken after 6.30 pm, using exclusively green- and blue-label insecticides along with Veraxaa (Rashvee Herbal liquid soap adjuvant), a honey-bee-safe herbal adjuvant, for the management of sucking pests.

The colonies rapidly adapted to pomegranate flowers, fruit drop ceased within 10 days, and by mid-April our data showed that the fruit formation was significantly restored. After flowering period, hives were relocated within the farm to areas rich in bee flora such as cucurbits and *Antigonon*, ensuring continuity of forage and colony health.



Shallow water troughs to support foraging bees during summer PC: Authors

An earlier article on importance of pollinators in pomegranate see below: *Vijayakumar, K. T., Nithin Kumar, H. L., Rakshita, T. N., & Nayimabanu, T. (2024). Impact of Flower Position and Pollinator Diversity on Yield Parameters of Pomegranate (Punica granatum L.). Sociobiology, 71(2), e10368. <https://doi.org/10.13102/sociobiology.v71i2.10368>*

To cite this blog, M.A. Rashmi, Abraham Verghese and V G Raghavendra (2026, June 21) Kheti Bachao Abhiyan (save farm campaign): Migratory Beekeeping (IE Blog No. 311). *Insect Environment*. <https://insectenvironment.com>

Watch Rashvee Video: (Bilingual – Kannada & English, for the benefit of farmers) <https://youtube.com/shorts/TbR1vrh0zew?feature=share>

IE Blog No. 311

All IE blogs are available on website <https://insectenvironment.com>

Insect Environment Blog

Celebrating World Environment Day 2026: the Real Way

Beyond Symbolism: A Purpose-Driven Celebration- Sowing the Seeds of Awareness in young minds

31 May 2026

Prathika, R., Social Media & Outreach Executive, Insect Environment

World Environment Day has been observed every June 5 since 1974, yet in most places it passes as ceremony like tree-planting, a slogan on a banner, or a photograph on poster etc.,

We at AVIAN Trust and IE do not believe in sloganeering, postering, or even symbolic “plant-and-forget” tree-planting. We believe in planting environmental seeds of knowledge in young minds, especially those in rural schools. These seeds, sown in fertile minds, would surely mature into fruit-bearing environmental stewardship.

This year, as usual AVIAN Trust chose the different path. At Government Higher Primary School in Melur village, Sidlaghatta taluk, Chikkaballapura district, Karnataka, India. The celebrations ran from June 3 to June 5 and were designed around a single conviction: that lasting environmental change begins not only in soil and nature, but in young minds too.



Plant environmental values in young minds not just saplings in soil alone

The programme, organised by AVIAN Trust in association with *Insect Environment* quarterly journal, Alumni Association University of Agricultural Science, Bengaluru, Rashvee International Phytosanitary Research and

Services and Shreenidhi Plant Health Clinic and Federal Bank opened with orientation sessions for school teachers, equipping them to guide students meaningfully through the days ahead.



Awarding Prizes to the Winners

Students then took centre stage. Poster making and drawing competitions, oratory contests on environmental conservation gave children a voice on topics that will define their lifetimes. When students themselves stood up to deliver speeches on ecological responsibility, the message had already taken root.

A highlight of the sessions was a focused discussion on insects the quiet workforce sustaining every ecosystem. Pollinators, decomposers, natural pest controllers, and food-chain anchors: without them, agriculture and biodiversity will not survive. By connecting these invisible creatures to visible outcomes, like the mango on a farmer's tree, the soil under their feet the programme made ecology tangible for every child in the room.

The programme also included an engaging and informative session where children were introduced to the different trees within their own school campus, such as Gulmohar, Rain Tree, Silver Oak, and other locally significant species.



By connecting classroom learning with real-life observation, the initiative transformed the school campus into a living laboratory, fostering curiosity, appreciation, and a deeper bond between children and nature.

Our team distributed jute bags and useful books to the students and Federal Bank gifted steel water bottles to students to promote reduced plastic usage.



Furthermore, the Shreenidhi Plant Health Clinic

donated a color printer to the school to support students and teachers in their various academic activities. The event closed with prize distribution for talented students who won in competitions, felicitation of teachers, recognition of progressive farmers, and social forestry trees planting ceremony rooted in the ethic of long-term care.



As the 2026 theme *Inspired by Nature. For Climate. For Our Future* affirms that, nature holds the solutions we need. The real work is ensuring the next generation knows how to listen to it.

The event on June 5th 2026, the finale of our 3 day program was graced by a distinguished gathering of experts, academicians, and community leaders whose presence added immense value and inspiration to the programme.



Dr. Abraham Verghese, Chairman of AVIAN Trust and former Director of ICAR– National Bureau of Agricultural Insect Resources, along with Dr. M.A. Rashmi, Founder & CEO of Rashvee International Phytosanitary Research & Services (IPRS) Pvt. Ltd., Managing Trustee, AVIAN Trust guided the programme with their vision for sustainable environmental stewardship.



Dr. Verghese with School Children during Jute Bag Distribution Drive to Minimize Plastic Usage

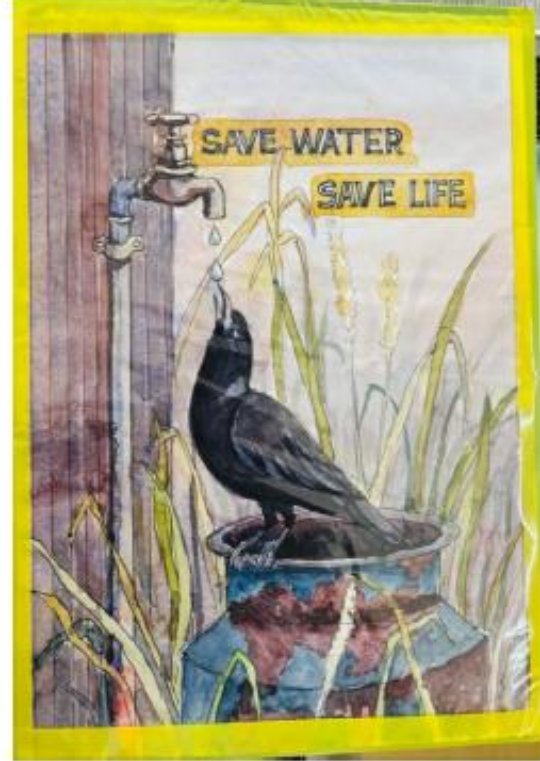
They were joined by Dr. H.L. Harish, President, Dr. B.V. Venkateshaiah, Vice President, Sri. A. Gopal, Co-opted Member, University of Agricultural Sciences Bengaluru Alumni Association and Dr. V.G. Raghavendra, Head of Shreenidhi Plant Health Clinic, Vijayapura, Devanahalli. Representatives from Federal Bank, along with Mr. Prabhakar, Vice President of Bharatiya Kisan Sangh (BKS), and other progressive farmers, actively participated in the celebration.

Through their interactions, speeches, and encouragement, these dignitaries not only enriched the event but also ignited curiosity and environmental consciousness among the children, motivating them to become responsible custodians of nature and champions of sustainable living.

To cite this blog, Prathika, R, 7 June 2026 Celebrating World Environment Day 2026: the Real Way (IE Blog No.308). *Insect Environment*. <https://insectenvironment.com>

IE Blog No. 308

All IE blogs are available on website <https://insectenvironment.com>



Poster by Nagaraj. M, Art Teacher, Govt High School, Melur, Karnataka

ಗಿಡ ನೆಡಲು ಹೊರಡು

ಒಂದು ಎರಡು
ಗಿಡ ನೆಡಲು ಹೊರಡು
ಮೂರು ನಾಕು ಗಿಡಕೆ ನೀರನು ಹಾಕು
ಐದು ಆರು
ಮರ ಬೆಳೆಯಲಿ ಜೋರು
ಏಳು ಎಂಟು
ಆಗಲಿ ಊರಿಗೆ ಮರಗಳ ನಂಟು
ಒಂಭತ್ತು ಹತ್ತು
ಬೆಳೆಯಲಿ ಹೋಪುಗಳತ್ತು
ಆಗ ನೋಡು ಭೂಮಿಗೆ
ಮಳೆರಾಯನ ಮುತ್ತು
ದೂರವಾಗುವುದು ಬರಗಾಲದ ಅವತ್ತು

Poem by V. Narayanaswamy, Assistant Teacher, Govt High School, Melur, Karnataka

Insect Environment Blog

A New Beetle from the Western Himalayas, India

New Beetle Species Discovered in the Western Himalayas: Expanding India's Biodiversity Record

3 May 2026

Irtiza Wani and Devanshu Gupta

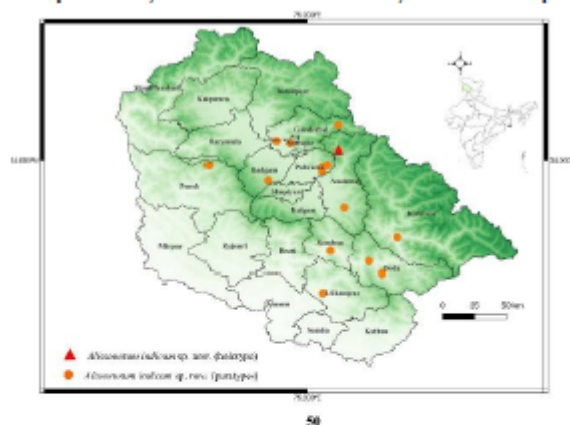
Zoological Survey of India, M-Block, New Alipore, Kolkata-700053, West Bengal, India

Scientists from the Zoological Survey of India have added an important new chapter to India's biodiversity story with the discovery and description of a new species of rhinoceros beetle from the Western Himalayas, along with several significant national distribution records that deepen our understanding of the country's insect fauna.



New Beetle Species Discovered in the Western Himalayas, Dorsal habitus of adult; 1. *Alissonotum indicum* sp. nov. (holotype, ♂); 2. *A. indicum* sp. nov. (paratype, ♀) PC: Authors The study, published in the *Journal of Asia-Pacific Biodiversity* by researchers Irtiza Wani and Devanshu Gupta, documents *Alissonotum indicum*, a previously unknown scarab beetle species belonging to the subfamily Dynastinae, discovered in the high-altitude regions of Jammu and Kashmir. The new species is clearly distinguished from its close relatives by a unique combination of morphological features,

including the structure of the male genitalia (parameres), a deep and well-defined depression on the pronotum, and distinctive punctation patterns on the elytra, all confirmed through detailed microscopic examination and comparative analysis. Specimens were collected from multiple sites across a wide altitudinal range, from about 675 metres to over 2,600 metres above sea level, indicating a broader ecological adaptability within the Himalayan landscape.



Map of Jammu and Kashmir showing type locality and other collection localities of *Alissonotum indicum* sp. nov. PC: Authors In addition to describing a species new to science, the research reports the first Indian records of *Alissonotum pittinoi* and *Alissonotum piceum besucheti*, confirms the presence of *Alissonotum simile* in Jammu and

Kashmir, and provides updated distribution data for several known species, bringing the total number of *Alissonotum* species and subspecies recorded from India to eight.

To support future research and conservation efforts, the authors have also presented an updated identification key for all Indian members of the genus, offering a practical tool for researchers, forest officials, and biodiversity practitioners.

Beetles play critical ecological roles in nutrient cycling, soil formation, and maintaining food-web stability, and discoveries like *Alissonotum indicum* underscore both the rich biological heritage of the Himalayan region and the urgent need for continued taxonomic research at a time when insect diversity faces growing threats from habitat loss and climate change.

The study is based on material collected during field surveys conducted between 2022 and 2023 as well as specimens housed in the National Zoological Collection at ZSI, Kolkata, using a combination of advanced

microscopy, rigorous morphological comparison, and geospatial mapping to ensure robust and reliable species documentation.

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Full article: Wani, I., & Gupta, D. (2026). New species and records of *Alissonotum* Arrow, 1908 from India (Coleoptera: Scarabaeidae: Dynastinae: Pentodontini). *Journal of Asia-Pacific Biodiversity*, 19(1), 226–236.

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IE Blog No. 302

All IE blogs are available on website
<https://insectenvironment.com>



Dr. M. A. Rashmi, Rashvee International Phytosanitary Research and Services, Bengaluru, addressing farmers on integrated pest management in pomegranate



Integrated Disease Management by Dr. Manjunath, Senior Scientist (Plant Pathology) ICAR–National Research Centre on Pomegranate, Solapur, Maharashtra

ಪ್ರತಿನಿಧಿ

PAGE_07
19 Apr 2026

ತಂತ್ರಜ್ಞಾನ ನೆರವಿನಿಂದ ಕೃಷಿಕರಿಗೆ ಅಧಿಕ ಲಾಭ

ಪ್ರತಿನಿಧಿ ವರದಿ ವಿಜಯಪುರ (ದೇವನಹಳ್ಳಿ)
ಇಲ್ಲಿನ ಅನ್ವಯೋಪಯುಕ್ತ ಕೃಷಿ ಹಾಗೂ ಇಂಟರ್‌ನ್ಯಾಷನಲ್ ಫೈಟೋಸ್ಯಾನಿಟರಿ ರಿಸರ್ಚ್ ಆಂಡ್ ಸರ್ವಿಸಸ್, ಜೈನ್ ಇರಿಗೇಶನ್ ಸಿಸ್ಟಮ್ ಲಿಮಿಟೆಡ್ ಹಾಗೂ ಶ್ರೀನಿಧಿ ಆಗ್ರೋ ಕೆಮಿಕಲ್ಸ್ ಸಹಯೋಗದಲ್ಲಿ ದಾಳಿ ರೈತರಿಗೆ ತರಬೇತಿ ಕಾರ್ಯಾಗಾರ ನಡೆಯಿತು.
ದಾಳಿ ಬೆಳೆಯಲ್ಲಿ ವಿಜ್ಞಾನ ಮತ್ತು ಆಧುನಿಕ ತಂತ್ರಜ್ಞಾನವನ್ನು ಅಳವಡಿಸಿಕೊಂಡರೆ ರೈತರು ಅಧಿಕ ಲಾಭ ಸಾಧಿಸಲು ಸಾಧ್ಯವಾಗುತ್ತದೆ. ಇದರಿಂದ ಹೆಚ್ಚಿನ ಲಾಭ ಪಡೆಯುವುದರ ಜೊತೆಗೆ ಗುಣಮಟ್ಟವನ್ನು ಕಾಪಾಡಿಕೊಳ್ಳಬಹುದಾಗಿದೆ ಎಂದು ಬೆಂಗಳೂರಿನ ಇಂಟರ್‌ನ್ಯಾಷನಲ್ ಫೈಟೋಸ್ಯಾನಿಟರಿ ರಿಸರ್ಚ್ ಆಂಡ್ ಸರ್ವಿಸಸ್‌ನ ಸೀನಿಯರ್ ಹಾಗೂ ಕೃಷಿ ವಿಜ್ಞಾನಿ ಡಾ. ಎಂ.ಎ. ರಶ್ಮಿ ಹೇಳಿದರು.
ಭಾರತದಲ್ಲಿ ದಾಳಿ ಇಂದು ಕೇವಲ ಹಣ್ಣಿನ ಬೆಳೆಯಾಗಿಯೇ ಉಳಿಯದೆ ಅಂತಾರಾಷ್ಟ್ರೀಯ ಮಟ್ಟದ ವಾಣಿಜ್ಯ ಬೆಳೆಯಾಗಿ ಬೆಳೆಯುತ್ತಿದೆ. ಅದರಲ್ಲೂ ಭಿನ್ನ ತಳಿಯು ರಫ್ತು ಮಾರುಕಟ್ಟೆಯಲ್ಲಿ ಶೇ. 80ರಷ್ಟು ಪಾಲು ಹೊಂದಿದೆ. ರೈತರು ಸಮರ್ಪಕ ಕೃಷಿ ನಿರ್ವಹಣೆ ಮಾಡಿದರೆ ಎಕರೆಗೆ ವರ್ಷಕ್ಕೆ 4 ರಿಂದ 8 ಲಕ್ಷದವರೆಗೆ ಲಾಭ ಗಳಿಸಬಹುದು



ಎಂದು ತಿಳಿಸಿದರು.
ಭಿನ್ನ ತಳಿಯ ದಾಳಿ ಉತ್ತಮ ಗಾತ್ರ, ರಸ ಹಾಗೂ ಶೇಖರಣಾ ಸಾಮರ್ಥ್ಯ ಹೊಂದಿದ್ದು ದೇಶದ ಹವಾಮಾನಕ್ಕೆ ಹೊಂದಿಕೊಳ್ಳುತ್ತದೆ. ಮಣ್ಣಿನ ಗುಣಧರ್ಮಕ್ಕೆ ಅನುಗುಣವಾಗಿ ತಳಿ ಆಯ್ಕೆ ಮಾಡುವುದರಿಂದ ಇಳುವರಿ ಹೆಚ್ಚಿಸಬಹುದಾಗಿದೆ ಎಂದು ಭಿನ್ನ ತಳಿ ಸಂಶೋಧಕ ಡಾ. ಡಿ.ಪಿ. ವಾಸ್ಕರ್ ಹೇಳಿದರು.
ತಜ್ಞರಾದ ಡಾ. ಜ್ಯೋತ್ಸಾ ಮತ್ತು ಡಾ. ಮಂಜುನಾಥ್ ಅವರು ದಾಳಿ ಬೆಳೆಗಾಗಿ ಸಮಗ್ರ ಕೀಟ ಹಾಗೂ ರೋಗ ನಿರ್ವಹಣೆ ಕುರಿತು ಮಾಹಿತಿ ನೀಡಿದರು. ಅನ್ವರ್ ಚಿಟ್ಟೆ, ಮೀಲಿಬಗ್ ಮತ್ತು ಸಸ್ಯ ರೋಗಗಳ ನಿಯಂತ್ರಣಕ್ಕೆ ಜೈವಿಕ ವಿಧಾನಗಳನ್ನು ಬಳಸುವಂತೆ ರೈತರಿಗೆ ಸಲಹೆ ನೀಡಿದರು.

ಜೈನ್ ಇರಿಗೇಶನ್‌ನ ಶ್ರೀತೋಷಿತ್ ರೈ ಅವರು ದಾಳಿ ಬೆಳೆಯಲ್ಲಿ ಸರಿಯಾದ ಸಮಯದಲ್ಲಿ ಹನಿ ನೀರಾವರಿ ಹಾಗೂ ಆಟೋ ಮೇಶನ್ ಪದ್ಧತಿಯನ್ನು ಬಳಸುವುದರಿಂದ ನೀರಿನ ಉಳಿತಾಯದೊಂದಿಗೆ ಹಣ್ಣಿನ ಗುಣಮಟ್ಟವನ್ನು ಕಾಪಾಡಿಕೊಳ್ಳಬಹುದಾಗಿದೆ ಎಂದು ತಾಂತ್ರಿಕ ಮಾಹಿತಿ ನೀಡಿದರು.
ಕಾರ್ಯಕ್ರಮದಲ್ಲಿ ನೂರಾರು ರೈತರು ಭಾಗವಹಿಸಿ ತಜ್ಞರೊಂದಿಗೆ ನೇರ ಸಂವಾದ ನಡೆಸಿದರು. ಜೈನ್ ಇರಿಗೇಶನ್ ಸಿ.ಎ. ಜೋಶಿ ಹಾಗೂ ಶ್ರೀನಿಧಿ ಆಗ್ರೋ ಕೆಮಿಕಲ್ಸ್‌ನ ರಾಘವೇಂದ್ರ ಉಪಸ್ಥಿತರಿದ್ದರು.
ಕಾರ್ಯಾಗಾರದಲ್ಲಿ ದಾಳಿ ಬೆಳೆ ನಿರ್ವಹಣೆ ಕುರಿತು ಕೃಷಿ ವಿಜ್ಞಾನಿಗಳು ಸಮಗ್ರ ಮಾಹಿತಿ ನೀಡಿದರು.

News coverage of the Pomegranate Farmers Training Program in the vernacular language (Kannada)



Dr. Jyotsna, Dr. D. P. Vaskar, and Dr. Raghavendra V. G. interacting with farmers during field visits



Dr. Abraham Verghese and Dr. M. A. Rashmi interacting with delegates at the Global Agri-Tech Summit 2026, held from April 24 to 26, 2026, at Tripura Vasini, Palace Grounds, Bengaluru, organized by the Federation of Karnataka Chambers of Commerce and Industry (FKCCI)



Ms. Uma Reddy, President of the Federation of Karnataka Chambers of Commerce and Industry and Dr. S. S. Dolli, Principal Investigator & CEO of KRISHIK-ABI, UAS Dharwad



Officials from the Directorate of Plant Protection, Quarantine & Storage (DPPQS), Ministry of Agriculture & Farmers Welfare — Dr. D.K. Nagaraju and Dr. Mohan S.M. with the Rashvee Team



Dr. Verghese and Dr. Rashmi at Grapes field, Mandibele, Devanahalli, Bengaluru rural

Glimpses from the Workshop on “Fine-Tuning Strategic Modules for Adaptive Response and Treatment of IPM (SMART-IPM)”, jointly organised by University of Horticultural Sciences, Bagalkot (Directorate of Research, Division of Entomology) in collaboration with Academy for Indian Horticulture, Bengaluru





Dr. Abraham Verghese, Dr. DK Nagaraju and Dr. N.K. Krishna Kumar chairing the sessions at SMART IPM workshop





Farmers from Navali Village, Koppal district, North Karnataka visiting Shreenidhi Plant Health Clinic (from distant places) for expert advice and quality inputs



Dr. M. A. Rashmi receiving appreciation from FMC India for Shreenidhi Plant Health Clinic's outstanding achievements in delivering quality agricultural inputs to farmers



Meeting and interaction with primary school teachers at Melur, Chikkaballapura District, on Environment Day event briefings



Procurement of plant seedlings from the UHS Bengaluru nursery for Environment Day celebrations



Shreenidhi Plant Health Clinic receiving the prestigious BASF Golden Petal Award

Glimpses of Environment Day Celebration 2026 organized by AVIAN Trust, featuring dignitaries from the AVIAN Trust, University of Agricultural Sciences Bengaluru Alumni Association, Rashvee IPRS, Shreenidhi Plant Health Clinic, Federal Bank, Bharatiya Kisan Sangh (BKS), and progressive farmers











The Rashvee Team with a progressive pomegranate farmer from Melur, Chikkaballapur, Karnataka, India