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***Cover Page:**
***Rhopalosiphum maidis* on Sweet Corn**
Photo by Dr. M. A. Rashmi

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IE Blog Contents

EDITORIAL

As the year 2024 comes to an end, we look back with gratitude to God Almighty for another year of success at *Insect Environment* (IE). Our authors and photographers deserve special recognition for their excellent technical contributions, which have greatly supported us in the editorial team and in the upkeep of excellence which is our hallmark. Their efforts have resulted in over 60 research articles and nearly 100 beautiful insect pictures, documenting the very pulse of Indian entomology. We have received several articles from the USA, Southeast Asia, Sri Lanka, Africa, the West Indies, and other regions. We are thrilled to receive reprint requests for our early hardcopy versions of *Insect Environment*. Thanks to the ICAR-NBAIR library, these back volumes are now available to researchers.

As our subscription and downloads are free, many international libraries include our journal in their digital collections.

In my earlier editorials too, I mentioned the impact of unpredictable and erratic climate spikes, which have dominated this quarter. The most affected are undoubtedly the weathermen! The flooding in Valencia, Spain—a place I have enjoyed visiting for its charming people and rich entomology—saw significant social opposition as people took to the streets, likely feeling inadequate administrative support following the flood damage. Valencia is also home to excellent olive orchards and a significant facility for sterile insect release programs targeting fruit flies, which I enjoyed visiting. *Insect Environment* hopes and wishes the citizens of Valencia safety from future climate aberrations.

In 2024, we marked the 40th anniversary of the disastrous Bhopal tragedy, which killed and maimed many. *IE* remembered this tragic event on its 25th anniversary and continues to pray for the next generation of affected families to be adequately compensated. We also hope that safety protocols are enforced in pesticide manufacturing plants to prevent such incidents in the future.

We signed off this year with an award ceremony (21st December 2024) recognizing nearly 73 awardees in three categories, Junior Environmentalist Award, Rising Star Environmentalist Award and Outstanding Environmentalist Award. This was a great celebration of our AVIAN

Trust, the publisher of *Insect Environment* and Rashvee International Phytosanitary Research and Services and Shreenidhi Plant Health Clinic, supporters of *Insect Environment*.

Insect Environment remains the only research and blog journal of India and is well-managed with the latest digital publication technologies. This facilitates speedy refereeing, correspondence, DOI coordination, and many other functions. I am especially grateful for the overall supervision and coordination by *Co-Editor-In-Chief,* Dr. M.A. Rashmi (Bengaluru), *Editor* Dr. S. Deepak (Delhi), and *Assistant Copy Editor* Ms. Salome (Muscat, Oman), along with the National and International editorial board who are connected to the office via advanced networking systems.

We at the editorial office wish all of you an exciting year in 2025!

Dr Abraham Verghese
Editor In Chief
Insect Environment

Research articles

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Report of a new polyphagous leaf roller pest, *Archips machlopis* (Meyrick, 1912) (Lepidoptera, Tortricidae) from Nandurbar, Maharashtra, India

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Abstract

The present study focuses on reporting a new pest, *Archips machlopis* (Meyrick, 1912) from Nandurbar, Maharashtra, India. The detailed morphological and female genitalia description of *A. machlopis* is provided in this paper.

Keywords: Moth, Tortricidae, *Archips,* Maharashtra, Garlic leaf roller, pest.

Introduction

Archips machlopis (Meyrick, 1912) is a tortricid moth predominantly found in India (Razowski, 1999). The family Tortricidae, commonly known as leaf-roller moths, encompasses a large and diverse group of insects with a global distribution (Pathania *et al*., 2020). Within this family, the genus *Archips* stands out as one of the largest, known for its economic importance and taxonomically challenging groups. It is reported as a serious pest to several important crops and generally rolls or ties the leaves of host plants (Soumia *et al*., 2019). Larvae of *A. machlopis* are reported as voracious feeders causing severe foliage damage in citrus in Bangladesh (Rashid *et al*., 2023). It is commonly found infesting various important plants such as toon tree, flame lily, stylo, babul, garlic, citrus, salix, litchi, tea plant, avocado, mango, jamun, and sweet orange (Fletcher, 1932; Tuck, 1990; Bhumannavar*et al*., 1991; Gilligan *et al*., 2011; Soumia *et al*., 2019; Rashid *et al*., 2023).

Although *A. machlopis* has been reported from various parts of India, its genitalia morphology remains inadequately described, leading to potential misidentifications and taxonomic confusion. Morphological characteristics, such as genitalia features, can be crucial for species-level identification within this genus (Horak & Brown, 2009). Thus, an attempt has been made to describe and document the morphological and female genitalia features of *A. machlopis*. Earlier, this pest was reported from Rajgurunagar, Pune, on garlic by Soumia *et al*. (2019). The present study reports its infestation in Dudhale Shivar, Kokani hills, Nandurbar, Maharashtra.

Material and methods

A single specimen of *A.machlopis* was collected from the light trap installed in the field at Kokani Hill located in Nandurbar district, Maharashtra, India. The adult morphology was observed under the Leica S9i stereomicroscope. The genitalia of the female was dissected following the standard methods in lepidopterology and observed under a Leica S9i stereomicroscope. The species identification was done using available literature (Tuck, 1990). The series of images taken through the microscope was stacked using the CombineZP software (Hadley, 2010) to create a single focused image and were edited using Adobe Photoshop software. The map of collection locality was generated using the open-source GIS software QGIS version 3.22.7. The identified specimen was labelled, duly registered and deposited in the collection of Zoological Survey of India, Western Regional Centre, Pune, Maharashtra, India (ZSI-WRC-L-3329).

Results and Discussion

Taxonomy

Order: Lepidoptera Linnaeus, 1758

Superfamily: Tortricoidea Latreille, 1802

Family: Tortricidae Latreille, 1802

Subfamily: Tortricinae Latreille, 1803

Tribe: Archipini Pierce & Metcalfe, 1922

Genus: *Archips* Hübner, 1822

Type species: *Phalaenapiceana* Linnaeus, 1758

***Archips machlopis*(Meyrick, 1912)**

Cacoeciamachlopis Meyrick, 1912; *Exotic Microlepid.* **1**: 4.

Type Locality: India, Assam, Khasi Hills [now in Meghalaya].

Material examined. 01 ex., India, Maharashtra, Nandurbar, Dudhale Shivar, Kokani Hill (21.3469 N 74.2498 E); 20.viii.2021, S.N. Pawara (ZSI-WRC-L-3329).

Description: Adult female **(Fig. 1: a & b)**. 17mm wingspan. Thorax is brownish; antennae filiform, dorsally pale yellow, light brown with alternate yellow & black lustrous bands; compound eyes near marginal area covered with alternate black markings. Forewings sinuate, light brown, falcate at the apex, below coastal margin & at the postdiscal area black spots & curved dark brown patches are present; hindwing at apical area to the one third area of coastal margin is black in color, dorsal area to CuA1 covered with blackish color & other parts with pale yellowish color; abdomen is light brown in color. Legs are light yellow & brownish in color, hind legs with two pairs of tibial spurs.

Female genitalia description (**Fig. 1: c, d**):Papilla analis is broad anteriorly & tapered at the posterior end; ostium bursae covered with hairs; apophyses slender, long & blunt at the end; ductus bursae membranous with long internal sclerite; corpus bursae oval, large, weak sclerite at the entrance of corpus bursae; signum blade long with circular basal plate.

The current study provided a new pest record for Dudhale Shivar, Nandurbar. The major crops grown in the district are: Jowar, wheat, rice, pigeon pea, groundnuts, chilli, sugarcane, cotton, mango, banana, papaya, sitaphal, onion, etc. The surrounding area where the light trap was installed has agricultural field of onion, vegetables, cotton, etc.

The morphological features described in this paper provide valuable insight into the taxonomic aspects of *A. machlopis*. Further study is recommended to assess the morphological diversity within *A. machlopis* populations across India and to compare and contrast genitalia traits with other related species. This study is based on a limited sample size. Further investigation using specimens from different geographical locations and population studies are necessary to confirm the consistency and variability of the genitalia across the species distribution range.

Conclusion: The present study is the first report of *A. machlopis* from the Nandurbar region of Maharashtra. This research provides a comprehensive and detailed description of the adult female of *A. machlopis* from Maharashtra, India. The detailed descriptions and illustrations presented here will serve as valuable resources for future taxonomic studies. Further research, especially involving both male and female specimens along with other species from this genus, is warranted to study the taxonomic aspects in greater detail.

Acknowledgement

The authors are thankful to the Director, Zoological Survey of India, Kolkata and the Officer-in-Charge, WRC, ZSI, Pune for facilities and encouragement. Authors are also indebted to late Smt. Shital N. Pawara for her dedication to lepidoptera studies and collection of samples.

Fig. 1. *Archips machlopis* female, Adult:a, dorsal view, b, ventral view, female genitalia:c, singum blade at corpus bursae, d, dorsal view.

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Studies on succession of arthropods on tomato (*Lycopersicum esculentum* L.) in Vindhya plateau region of Madhya Pradesh

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Abstract

A field experiment on the succession of arthropods on tomato (*Solanum lycopersicum*) was conducted during the Rabi season of 2021-2022 at JNKVV, College of Agriculture, Ganj Basoda. The study documented the onset, activity period, and persistence of major insect pests and natural predators throughout crop development stages. The aphid (*Aphis gossypii*) was observed 8 days post-transplantation, persisting densely until April 25. The jassid (*Amrasca biguttula*) appeared 11 days post-transplantation and remained active throughout the season, while whitefly (*Bemisia tabaci*) populations emerged at 17 days, persisting until harvest. The American leaf miner (*Tuta absoluta*) appeared at 31 days and remained until harvest, as did the tomato mirid bug (*Nesidiocoris tenuis*), observed at 26 days. Fruit borer (*Helicoverpa armigera*) emerged at 38 days, active through fruiting and harvest stages. Various beneficial arthropods like the ladybird beetle and syrphid fly were also noted. Their presence highlights their role in natural pest control, offering insights into sustainable tomato crop management.

Keywords: Tomato, Succession of arthropods, Pest complex, growth stages, damage.

Introduction

Tomato (*Lycopersicum esculentum* L.), a member of the Solanaceae family, is one of the most economically valuable vegetables worldwide, cultivated across diverse climatic regions. In India, tomato cultivation spans approximately 880,000 hectares, producing an estimated 19,696 metric tonnes annually, with an average yield of 24.4 tonnes per hectare (NHB, 2017). Madhya Pradesh, one of India's primary tomato-producing states, accounts for 2,588,000 tonnes, contributing 13.91% to national production (NHB, 2020). Other key tomato-producing states include Andhra Pradesh, Karnataka, Gujarat, Odisha, Chhattisgarh, West Bengal, Tamil Nadu, Bihar, Maharashtra, and Uttar Pradesh, responsible for nearly 85% of India's total tomato output.

Tomato crops face significant arthropod pressure, leading to severe yield losses. Over 41 insect species from 21 families are identified as threats to tomato crops in India. Primary pests include the American leaf miner (*Tuta absoluta*), aphid (*Aphis gossypii*), jassid (*Amrasca bigutulla*), whitefly (*Bemisia tabaci*), and fruit borer (*Helicoverpa armigera*) (Reddy & Kumar, 2004). These pests are polyphagous, affecting crops year-round (Sharma et al., 2014). They cause direct damage by feeding on foliage, stems, and fruits, and indirectly by transmitting viral pathogens, leading to economic losses for farmers. Notably, *H. armigera* causes yield losses of 14-45% across various Indian states (Kurl and Kumar, 2010). The whitefly and aphid species also inflict severe crop damage. Additionally, the invasive *T. absoluta*, originating from South America, has become a significant pest globally due to its resistance to many insecticides and rapid dispersal (Biondi *et al*., 2018).

Understanding the seasonal succession and population dynamics of these pests is crucial for developing integrated pest management (IPM) strategies. This study examines the succession of arthropod populations on tomato crops in the Vindhya Plateau, providing insights for sustainable pest management practices.

Materials and Methods

The study was conducted at the College of Agriculture research farm in Ganj Basoda, Madhya Pradesh, during the *Rabi* season of 2021-2022. The study area is located at 23°51'5.3" N latitude and 77°55'34.7" E longitude, characterized by a hot, dry climate except for the monsoon season, with an annual rainfall averaging 1135.5 mm. The soil is primarily montmorillonite, underlain by Deccan Basalt, with mixed red-yellow soil along river courses. Field preparation included pre-tillage, residue removal, and ploughing, followed by the creation of drainage channels. The tomato variety used was TO-1156 (Hybrid). The experimental plot measured 100 m^2, with a plant spacing of 60 × 45 cm. Sowing and transplanting took place on November 24 and December 30, 2021, respectively, with harvesting on May 1, 2022. Standard agricultural practices suggested for the region were adhered to for cultivating the crop. Notably, no plant protection methods were employed throughout the entire crop season. Weekly observations were made on 25 randomly selected plants, documenting the presence of insect pests, natural enemies, and spider mites across different crop stages: vegetative, flowering, maturity, and harvesting. Arthropod incidence was recorded from initial observation until crop maturity.

Results and Discussion

The study identified six major insect pests affecting tomato crops. Detailed observations were documented on their onset, activity period, density, and persistence throughout various crop stages, along with their natural predators. The findings are summarized below.

Insect pest complex on tomato crop: The succession of arthropods on tomato crops began with the aphid *Aphis gossypii* (Glover), which first appeared in early January and persisted until April 28 **(Table 1).** *A. gossypii* established dense populations, thriving across both vegetative and reproductive stages, causing visible damage to foliage and stunting growth **(Figure 1)**. The jassid *Amrasca biguttula* made an early appearance around 11 days post-transplantation and remained active throughout the entire crop season until harvest on May 5 **(Table 1 and Figure 1)**. The consistency of *A. biguttula* populations across all growth phases suggested a continuous and potentially compounding impact on plant health.

Whitefly (*Bemisia tabaci*), another prominent pest, was first detected at around 17 days post-transplantation and exhibited prolonged activity until May 3 **(Table 1)**. The persistent presence of *B. tabaci* throughout the growth period indicated its capability to affect plant health adversely, particularly through transmission of viral pathogens, impacting both crop yield and quality. The American leaf miner *Tuta absoluta* was observed approximately 31 days after transplantation and remained consistently active until the harvest in early May **(Table 1)**. *T. absoluta* larvae caused visible leaf mining damage, compromising photosynthesis, and reducing vigor, which was especially detrimental during the fruiting stage **(Figure 1)**.

The tomato mirid bug, *Nesidiocoris tenuis* appeared around 26 days post-transplantation, establishing a population that lasted until crop harvest **(Table 1)**. Persistent feeding by *N. tenuis* affected foliage and stems, with detrimental effects on plant health and growth throughout the reproductive stages **(Figure 1)**. *Helicoverpa armigera*, commonly known as the tomato fruit borer, emerged roughly 38 days after transplanting (Table 1). Its larval activity persisted into the crop's critical fruiting and harvesting phases, impacting yield and fruit quality due to direct feeding on the developing fruit (Figure 1). The

Table 1: Insect pest and natural enemies population recorded on tomato crop

Common name	Scientific name	Order	Family	Period of activity
Insect pest population				
Aphid	*Aphis gossypii* (Glover)	Hemiptera	Aphididae	1st week Jan to 28th April
Jassid	*Amrasca biguttula* (Ishida)	Hemiptera	Cicadellidae	2nd week Jan to 5th May
Whitefly	*Bemisia tabaci* (Genn.)	Hemiptera	Aleyrodidae	Mid Jan to 3rd May
American leaf miner	*Tuta absulata* (Meyrick)	Lepidoptera	Gelechidae	1st week Feb to 4th May
Tomato mirid bug	*Nesidiocoris tenuis (*Reture)	Hemiptera	Miridae	1st week Feb to 5th May
Tomato fruit borer	*Helicoverpa armigera* (Hubner)	Lepidoptera	Nocutidae	2nd week Feb to 5th May
Natural enemies population				
Weaver ant	*Oecophylla smaragdina*	Hymenoptera	Formicidae	Mid-Jan to 5th May
Lady bird beetle	*Coccinella septempunctata* (Fabricius)	Coleoptera	Coccinellidae	3rd week Jan to 1st week of May
Syrphid fly	*Mesembrius bengalensis* (Wiedemann)	Diptera	Syrphidae	Last Jan to 30th April
Spotted orb-weaver spider	*Neoscona theisi* (Walck)	Araneae	Araneidae	1st week Feb to 5th May
Dragonfly	*Anax guttatus* (Burmeister)	Odonata	Aeshnidae	Mid-Jan to 5th May
Damselfly	*Lestes viridulus* (Rambur)	Odonata	Lestidae	Starting Feb to 5th May
Mason wasp	*Delta esuriens* (Fabricius)	Hymenoptera	Eumenidae	Starting Feb to 30th April

presence of *H. armigera* posed a significant challenge for yield preservation, with its damage extending until the end of the crop cycle.

The findings were aligned with previous report (Singh, 2017), which identified serpentine leaf miner (*Liriomyz atrifolii*), aphids (*Aphis gossypii*), jassids (*Amrasca bigutulla*), tomato mirid bugs, and whiteflies (*Bemisia tabacii*) as significant pests affecting tomato crops. Additionally, during the fruiting phase, another notable pest, the tomato fruit borer (*Helicoverpa armigera*), was detected. These results mirror the observations made by (Jandial & Kumar, 2007), who studied the prevalence of sucking pests such as aphids, whiteflies, jassids, and mites on tomato crops. Previous studies further supported these findings, noting that these insect species are common polyphagous pests with broad host ranges. (Chaudhuri *et al*., 2001; Mahla *et al*., 2017; Mandloi *et al*., 2015; Sachin, 2012; Suresh, 2006) The continuous presence of these pests throughout various growth stages underscores the importance of developing effective pest management strategies tailored to the local conditions of the Vindhya Plateau region.

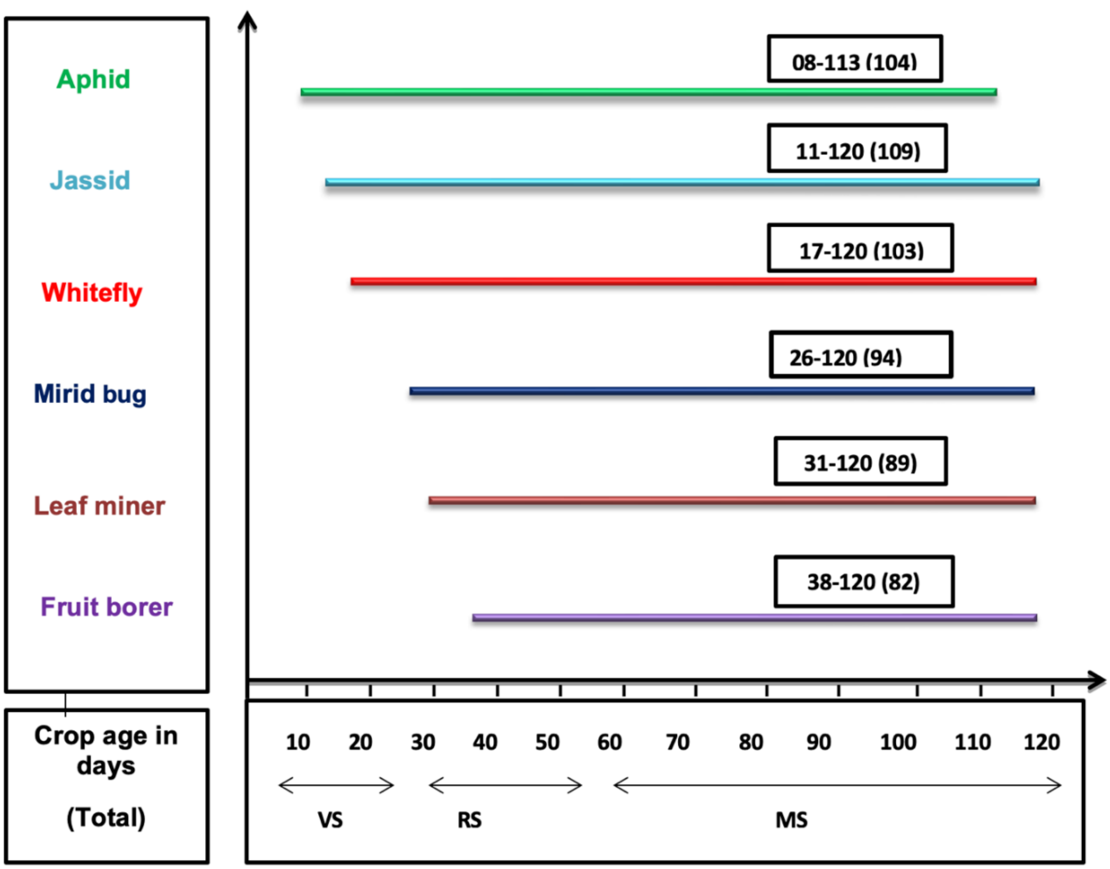

Figure 1: Succession of insect pests on tomato crop

VS: Vegetative stages, RS: Reproductive stages, MS: Maturity stages, (:): Duration of pest's activity in crop in days.

Natural enemy's complex on tomato crop: The presence of natural enemies was documented alongside pest populations, providing insights into the ecological interactions that help manage pest densities in the crop ecosystem. The weaver ant, *Oecophylla smaragdina* (Fabricius) was initially observed 11 days after transplantation **(Table 1)**. *O. smaragdina* established a continuous presence through the fruiting stage **(Figure 2)** and up until the harvest, underscoring its role as a potential biocontrol agent against sap-sucking pests, given its predatory habits.

The ladybird beetle, *Coccinella septempunctata* (Fabricius), a key natural enemy, was detected 19 days post-transplantation and remained active during the fruiting stage until crop harvesting (Table 1 and Figure 2). Known for its predation on aphids, jassids, and other soft-bodied pests, *C. septempunctata* played a critical role in reducing pest populations naturally. The beetle's sustained activity highlights its importance in integrated pest management (IPM) approaches for tomato crops.

Neoscona theisi, a species of spotted orb-weaver spider, made its initial appearance approximately 18 days after transplanting **(Table 1)**. This spider species was consistently present throughout the fruiting phase and remained until the crop's final harvest (Figure 2). Known for its ability to prey on various insect pests, including aphids and whiteflies, *N. theisi* contributes to the natural pest control within tomato ecosystems. Its role in reducing pest density especially arachnids was significant, given the spider's continuous activity through the crop's critical stages.

The syrphid fly *Mesembrius bengalensis* (Wiedemann) was initially sighted 26 days post-transplantation, remaining active in the field until late April **(Table 1 and Figure 2)**. Besides being an effective predator of jassids, syrphid flies are frequent floral visitors, contributing to pollination and supporting the crop's reproductive stages. Their dual role emphasizes their ecological significance within the crop environment, aiding both in pest control and crop health maintenance.

The Mason wasp *Delta esuriens* (Fabricius) was observed beginning on February 5 and continued to remain present until April 30 **(Table 1)**. Known for its nesting behavior and predation on pest larvae, *D. esuriens* contributed to the suppression of pest populations throughout the crop's growth cycle **(Figure 2)**. The consistent presence of these beneficial wasps underscores their potential role in integrated pest management by supporting pest population regulation naturally.

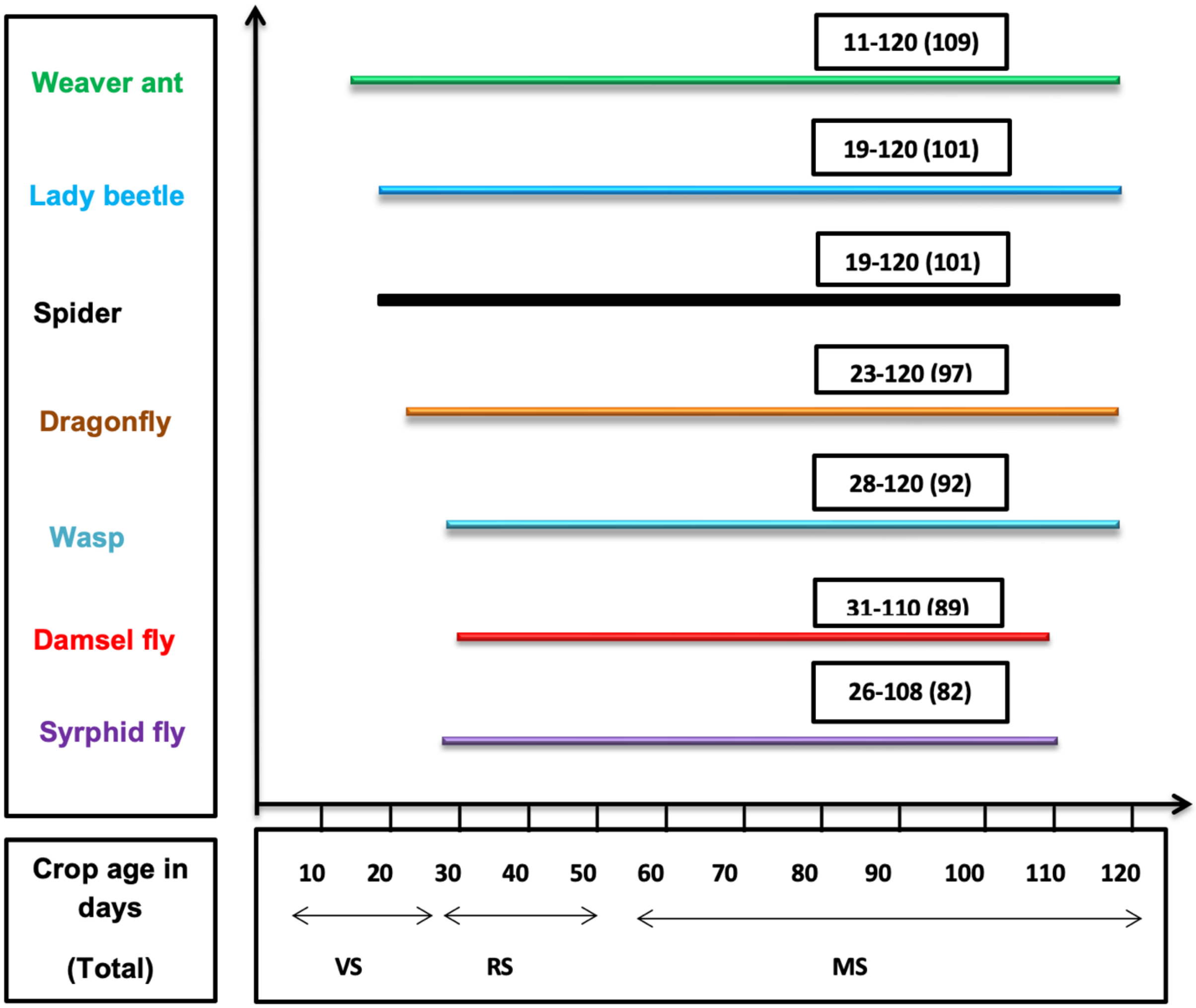

Figure 2: Succession of natural enemies on tomato crop

VS: Vegetative stages, **RS**: Reproductive stages, **MS**: Maturity stages, (:): Duration of pest's activity in crop in days.

The results aligned with previous reports (Armendano and Gonzalez, 2011; Biondi *et al*., 2018; Khokhar & Rolania, 2021; Liu *et al*., 2017; Madhushree, 2019; Marcano and Issa, 2000; Pluess *et al*., 2010; A. Sharma *et al*., 2020; Singh, 2017). These studies also documented the presence of natural predators, such as *O. smaragdina*, *C. septempunctata*, *N. theisi*, *M. bengalensis*, *D. esuriens*, *Anax guttatus* (dragonfly), and *Lestes viridulus* (damselfly), which contribute to pest control in tomato crops. The natural enemies identified in this study highlighted the complexity of biological interactions and the ecological balance necessary for effective crop protection. Their presence and predation activities provide valuable insights into sustainable pest management practices in tomato cultivation. Moreover, the natural enemies can be supported by using modern techniques like Specialized Pheromone and Lure Application Technology (SPLAT) and Sterile Insect Technique (SIT) while effectively managing the pests. SPLAT, a wax-based formulation with sustained-release pheromones, disrupts insect mating, curbing population growth (Kumar et al., 2023). SIT, an eco-friendly method using radiation-induced sterility, targets pest reproduction to achieve a higher incidence of sterile mating within natural populations (Dalal *et al*., 2024). Both these techniques have potential to revolutionize the pest management strategies, support nature and natural enemies' populations.

Conclusion

This study revealed a dynamic arthropod population on tomato crops, encompassing seven orders with both pest and beneficial species recorded. *Coccinella septempunctata* emerged as the dominant predator, preying on soft-bodied pests like aphids, jassids, and whiteflies. Additionally, spiders, notably *Neoscona theisi*, played a vital role in targeting aphid populations. These findings underscore the importance of natural predators in maintaining ecological balance and supporting sustainable pest control in tomato cultivation.

Acknowledgements

Express gratitude to all the authors mentioned, with special thanks to Dr. Yogesh Patel for their valuable and timely support.

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Influence of different colours substrates on oviposition behaviour of silk moths of silkworm *Bombyx mori* L-A new concept

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Abstract

This study evaluated the egg-laying behavior of silkmoths (*Bombyx mori* L.) on different colored substrates. Eight substrate colours—Black, Orange, Pink, Blue, Green, Brown, Red, and Violet—were used to assess the oviposition behavior of moths. A total of 160 moths were allowed to lay eggs on each colored sheet (85cm x 55cm) during the autumn grainage of 2023 at SSPC, Udhampur. The results indicated that the highest number of eggs was laid on black sheets (122 dfls/160 moths) with a seed weight of 36.750g, followed by orange (87 dfls/160 moths) and brown (83 dfls/160 moths) sheets. The findings suggest that black substrates are highly effective for oviposition in grainages.

Key Words: *Bombyx mori*, Colour, Egg laying, Oviposition behaviour, silkworm, substrate.

Introduction

The most successful organisms on earth belong to Arthropods, supported by numerous factors that enhance their adaptability to variable environmental conditions (Khaliq *et al*., 2014). Different insects have varying types of oviposition sites; some lay eggs on the hairy surfaces of plants, others on smooth surfaces, and some even lay eggs in fruits and vegetables (Minkenberg *et al*., 1992). Oviposition is essential in the life history of insects, and oviposition sites vary among species based on factors such as substrate composition, presence of immatures of the same species, attractive odors, humidity, light intensity, and colors (Clements, 1999; Wong *et al*., 2011).

The success of oviposition in silkworms not only depends on the substrate but also involves numerous neural, chemical, physical, environmental, and behavioral factors. For instance, the number of eggs laid and the time the moth spends ovipositing are influenced by environmental conditions such as temperature, light, humidity, and surface texture. Once mating is complete and female moths have found a suitable place, 90% of the eggs are deposited within 24 hours. Research indicates that higher oviposition rates occur at a temperature of about 25 ± 1 °C and 80 ± 5% relative humidity (Singh and Saratchandra, 2004).

There are multiple examples of how larval or oviposition experiences influence later oviposition choices (Jones and Agrawal, 2017). However, evidence regarding associative learning in adult lepidopterans related to oviposition is scarcer. Some studies suggest that female moths learn associations between leaf shapes and the chemical compositions required for oviposition (Papaj, 1986), or between the appearance of oviposition substrates and chemical oviposition stimulants (Traynier, 1986). Lepidopterans and other insects show an innate preference for a given chemical composition of the substrate, making plant odor a valuable cue for choosing their oviposition sites. For example, Traynier (1986) tested the preference of cabbage butterflies for laying eggs on discs of different sizes and colors wetted with either a sinigrin solution or water. Sinigrin, a compound found in plants like cabbage, triggers oviposition behaviour in lepidopteran species such as the cabbage butterfly. The results showed that individuals preferred to lay eggs on discs resembling those containing the sinigrin solution. Studies on adult silk moths have primarily focused on understanding the behavioral aspects of mating and egg laying (Yamaoka and Hirao, 1981; Manjula kumari, 1991). However, no studies have examined the influence of different substrate colours on oviposition under dark conditions. To address this, an experiment was undertaken to evaluate the egg-laying behaviour of moths on substrates of different colours using eight different coloured sheets.

Materials and Methods

Silkworm seed cocoons of foundation bivoltine race FC_1 and FC_2 were procured from SSPC, Bangalore during autumn, 2023. After cutting of seed cocoons, the males and females were segregated at the pupal stage and maintained in separate rooms to avoid copulation. The newly emerged moths were picked at 6 A.M. and allowed to copulate for 3 hours. The females were then transferred on egg sheets by allowing 160 moths on each sheet of a size (85cm x 55 cm) of eight deferent colours substrates black, orange, pink, blue, green, brown, and red printed with flex sheets to examine the egg layings behaviour of moths. A total of three sheets were used for each substrate colour and creamy white colour kraft paper was used as the control to assess the egg laying behaviour. Two important parameters were studied weight of egg (g) and number of Dfls obtained from each sheet. The replicated data of each substrates colour were analyzed by applying analysis of variance (ANOVA) using SPSS software and the results are given in **Table-1**

Different color substrates used for studying the oviposition behaviour of silk moths

Results and discussion

Oviposition behaviour comprises one of the final steps in insect reproduction. It involves the deposition of the mature egg outside the body of the female and includes a series of behavioural and physiological events that begin with the movement of the egg through the oviduct and end with the placement of the egg on a substrate. Among the different substrate colours used in the present study to examine the egg laying behaviour, the findings showed that the black colour substrate was the most preferred by the females moths for laying eggs (122 dfls) followed by orange (87 dfls moths) and brown colour (83 dfls). The eggs laid by the female moths under black colour substrate was more when compared to control creamy white kraft paper (90 dfls) which is generally used for egg laying purpose in commercial grainage. More generally, different sets of plant-derived odours attract female moths for oviposition. Remarkably, the odorants eliciting feeding or oviposition activates different collections of olfactory glomeruli (Bisch-Knaden *et al.,* 2018). These results indicate that moths do not rely on a single odour to locate an oviposition site, but can instead exploit several scents to guide them to a suitable substrate. They also suggest a model in which the various odours indicating oviposition substrates to a female are recognized by different olfactory receptors, expressed in distinct olfactory sensory neurons. Several Lepidoptera species use leaf shape (Rausher, 1978) or leaf colour (Kelber, 1999) to target their favourite oviposition substrates. In general, there is not a clear relation of the substrate colour (natural or artificial) with the insect fecundity. Most studies relate the effects of colours with photo-tactical behaviour (movement in response to light stimuli) (Drew *et al.*, 2003). The little studies of attractiveness with colours were performed with Lepidoptera (Peitsch *et al.*, 1992; Chittka *et al.*, 1992).

Table 1: Ovipositional preference of moths on different substrate colours

Treatment (Substrate Colours)	**Weight of egg (g)**	**Dfls Obtained (No's)**
Black	36.75*	123.00
Orange	26.2	87.00
Pink	19.4	64.00
Blue	20.15	67.00
Green	22.7	74.00
Brown	25.1	83.00
Red	18.7	62.00
violet	21.4	71.00
Creamy white (Control)	27.13	90.00
Sem±	**0.11**	**1.80**
CD @ 5%	**0.34**	**5.33**
CV (%)	**1.40**	**3.88**

*The result is significant at $p < .05$

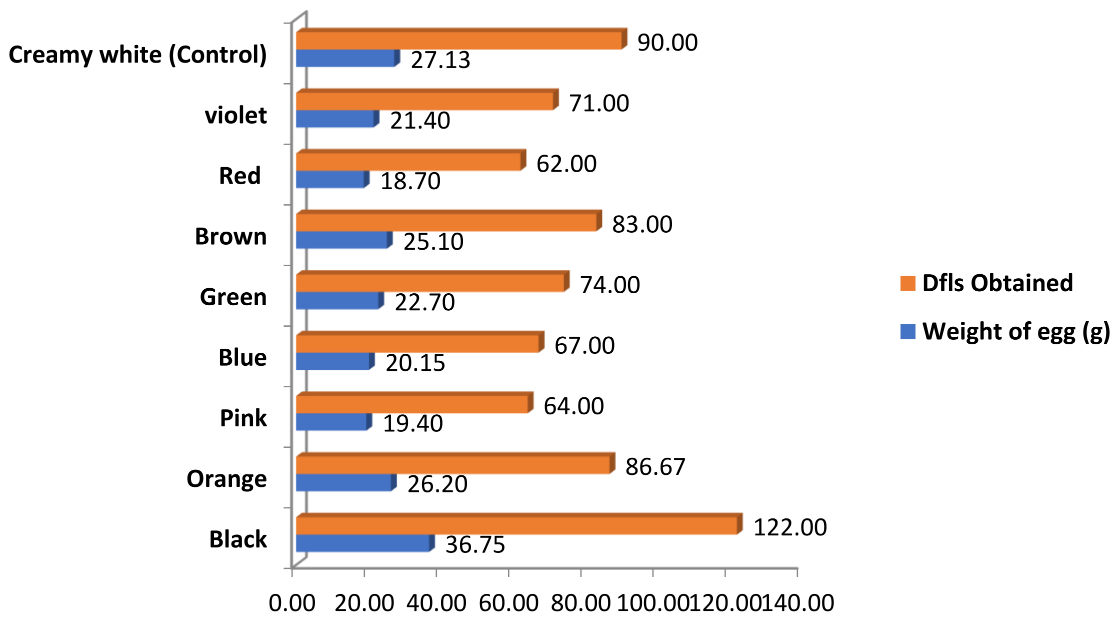

Fig. 2: Ovipositional preference of moths on different substrate colours.

Conclusion

The findings of this study demonstrate that the ovipositional behaviour of moths is influenced by the colour of the substrate. This insight suggests that utilizing specific coloured substrates could be highly beneficial in commercial F1 seed production in grainages. If these results prove encouraging, this small but significant initiative has the potential to greatly enhance seed production efficiency across India. By optimizing substrate colour for oviposition, it is possible to improve both the quantity and quality of silkworm seed production, thereby supporting the growth and sustainability of the sericulture industry.

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Exploring the potential of tasar silkworm rearing in national highway plantations

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Introduction

Tasar culture is an age-old practice in which tribal forest dwellers collect tasar cocoons from the forest (Vishaka et. al., 2019). Over time, the establishment of systematic plantations of tasar food plants and the development of an egg production chain by Basic Seed Multiplication and Training Centres (BSM&TCs) in various states have led to increased tasar production. However, India still struggles to meet its raw silk production target. With a vision of producing 6000 MT of raw silk by 2030, (Rathore et., al., 2022) India needs to adopt diverse rearing practices.

Currently, most tasar silkworm rearing occurs in forest plantations and, to some extent, in block plantations. The National Highways Authority of India (NHAI), in collaboration with the forest department, undertakes roadside avenue plantations to trap dust, control pollution, enhance beauty, provide food and shade, act as windbreaks, and generate economic opportunities. Typically, they plant trees such as Jacaranda, Nandi flame, flame tree, Neem, Yellow cassia, Bustard almond, Prosopis, golden shower tree, sacred fig, Eucalyptus, Casuarina, Arjun, Mahua, Bael (wood apple), gular, and bamboo, based on local needs (Anon., 2023).

It has been observed that the NH-30 from Parchanpal to Bastar is planted with a significant number of Arjun trees (*Terminalia arjuna*) (Fig. 1), which serve as host plants for tasar silkworms. This provides an opportunity for income generation and the economic upliftment of landless local tribes by practicing tasar silkworm rearing on avenue plantations. To this end, BSM&TC, Bastar, initiated a project to engage local tribes in tasar silkworm rearing on roadside plantations. The outcomes of this initiative and its future perspectives are discussed in this article.

Venturing into Innovative Silkworm Rearing

The concept of rearing tasar silkworms in roadside avenue plantations emerged due to the pressing issues of unemployment among local tribes, the increasing pressure to meet raw silk production targets, and the lack of sufficient tasar host plants for silkworm rearing. Recognizing these challenges, the Basic Seed Multiplication and Training Centre (BSM&TC), Bastar, approached the forest department, specifically the Divisional Forest Officer (DFO) of Bastar, to seek approval for tasar silkworm rearing in the roadside plantations along NH-30 from Parchanpal to Bastar. The forest department welcomed this innovative idea and granted their approval to proceed with the project. This collaborative effort aims to provide a sustainable livelihood for local tribes and contribute to the overall raw silk production goals of the country.

Tasar silkworm rearing

The Basic Seed Multiplication and Training Centre (BSM&TC) in Bastar conducted trials with Daba bi-voltine and tri-voltine tasar silkworms. They distributed quality disease-free layings (dfls) to farm workers and meticulously monitored the rearing activities through officers and technical officials (Fig. 5). The Daba bi-voltine yielded 33 cocoons per dfl, while the Daba tri-voltine yielded 36 cocoons per dfl (Fig. 3).

As a token of appreciation and to showcase the improved quality of the cocoons, subsequent harvests were presented to the district forest officials (Fig. 4). This gesture acknowledged the supportive role of the forest department in promoting sustainable silkworm rearing practices. The successful outcomes of these trials have further piqued the interest of the forest department in tasar silkworm rearing on roadside avenue plantations, highlighting its potential for economic upliftment and sustainable development.

Challenges and techniques to overcome the challenges in road

Rearing tasar silkworms on 15-year-old trees, towering at 30-40 feet, posed significant challenges. Initially, the tree height made it difficult to manage the worms, which were brushed onto lower branches, requiring frequent transfers. As the worms matured, a novel method was employed, using bamboo and a two-person team to release them onto the upper canopy, a risky but necessary task.

The worms' voracious appetite led to complete defoliation, taking advantage of the high-quality leaves. To address this, the worms were transferred to trees with full foliage, enabling them to progress through further stages.

In subsequent harvests, we refined our technique by brushing Disease-Free Layings (DFLs) onto the upper canopy, where young foliage was concentrated. As the worms fed, they gradually descended, reducing the need for frequent transfers and promoting overall worm and plant health. This approach improved upon the previous method by avoiding branch pruning, showcasing a significant enhancement in our rearing technique.

Biodiversity Boost:

Tasar silkworm rearing boost the diversity of wildlife, especially birds and insect species in national high way food plants. Moreover, the presence of silkworms in avenue plants attracts natural predators of agricultural pests, leading to a surge in beneficial organisms. This innovative idea has a positive impact on the ecosystem, potentially benefiting surrounding agricultural crops.

Advantages of Silkworm Rearing on National Highway Avenues

Economic Empowerment: Silkworm rearing on national highway avenues provides income to local communities through silk production and related activities, contributing to rural development and poverty alleviation.

Environmental Benefits: Integrating silkworm rearing with food plants on national highways positively impact the environment. Silkworm act as natural bio-converters, efficiently utilizing the plant resources and promoting sustainable waste management.

Sustainable Agriculture: This approach exemplifies sustainable agriculture principles by integrating silkworm rearing with food plants. Farmers can benefit from dual-cropping systems, combining traditional crop cultivation with sericulture, leading to increased productivity and income stability.

Government Support and Policy Advocacy: Widespread adoption of Tasar silkworm rearing on national highway avenues requires government support. Policies that incentivize and promote this integrated approach, along with financial assistance and technical support, will encourage farmers and communities to embrace sericulture.

Conclusion

The integration of silkworm rearing and food plant cultivation along national highway avenues presents a groundbreaking model for sustainable economic development and environmental stewardship. By merging the practices of sericulture and agriculture, this approach achieves a harmonious balance between economic prosperity and ecological well-being. Ultimately, it contributes to the comprehensive prosperity of communities along national highways, fostering both economic growth and environmental sustainability.

Fig. 1: Roadside avenue *Terminalia arjuna* plantations in NH-30

Fig. 2: Tasar silkworm rearing under progress at NH-30 roadside avenue plantation

Fig. 3: Cocoon harvest under progress at NH-30 roadside avenue plantation

Fig. 4: Cocoons harvested from NH-30 roadside avenue plantation offered to officials of forest department Bastar, Chhattisgarh.

Fig. 5: A&B Avenue tree, *Terminalia arjuna* on either sides of NH-30, C-F Silkworm Rearing and H. Cocoon harvestings.

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Host plant resistance to insects in pearl millet hybrids and its role in integrated pest management

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Abstract

The experiment was conducted during the kharif season of 2018 at the Instructional Farm, College of Agriculture, JAU, Junagadh. Ten hybrids of pearl millet were screened against shoot fly (*Atherigona approximata*) and stem borer (*Chilo partellus*). Among these, the hybrids GHB-732 and GHB-1231 were found to be resistant to shoot fly at both stages of the crop. In contrast, the hybrids MSH-339 and MH-2024 were found to be susceptible to shoot fly. Regarding stem borer, the minimum attack was recorded in GHB-1231 at both stages of the crop. Additionally, the hybrids GHB-1231 and GHB-905 were found to be tolerant to stem borer during the vegetative stage of the crop.

Key words: shoot fly, stem borer, pearl millet and host plant resistance

Introduction

Pearl millet (*Pennisetum glaucum*) is a staple food for the majority of poor and small landholders, as well as a source of feed and fodder for livestock in the rain-fed regions of the country. In India, pearl millet occupies an area of 6.70 million hectares with an average production of 9.62 million tonnes and a productivity of 1,436 kg/ha (Anon., 2022). The major pearl millet-growing states are Rajasthan, Maharashtra, Gujarat, Uttar Pradesh, and Haryana, which account for more than 90% of the pearl millet acreage in the country. Being a climate-resilient crop, it plays a crucial role in mitigating the adverse effects of climate change, facilitating income and food security among farming communities in arid regions. The United Nations General Assembly declared 2023 as the "International Year of Millets" to bring millets into the mainstream, exploiting their nutritional properties and promoting their cultivation and use.

Pearl millet is cultivated in various agro-ecosystems, and its grain yield is influenced by both biotic and abiotic factors. Among the biotic factors, arthropods constitute a major constraint to increasing pearl millet production. About 26 insect species have been reported to damage pearl millet in different agro-ecosystems (Balikai, 2010). Investigations were carried out by Juneja *et al.* (2022) at Main Pearl Millet Research Station, Jamnagar (Gujarat) during *kharif* 2021 revealed that shoot fly, *Atherigona approximata*, stem borer, *Chilo partellus*, and ear head worm, *Helicoverpa armigera* were the major insect-pests in pearl millet. Apart from shoot fly, stem borer and *H.armigera*, fall army worm emerged as a new pest in pearl millet (Juneja and Parmar, 2022).Grain losses due to shoot fly range from 23.3% to 36.5% (Prem Kishore, 1996) in pearl millet. Stem borer incidence is 4.47% at 15 days after germination, gradually increasing to its peak of 15.1% at 77 days after germination (Raghavani *et al*., 2008). Parmar *et al.* (2022) calculated economic threshold levels (ETL) for stem borer in pearl millet to be 5%.

The use of resistant varieties is a cost-effective way to protect against pests as part of Integrated Pest Management (IPM) in pearl millet. However, host-plant resistance needs to be supplemented with other pest control methods. Thus, the present study aimed to evaluate pearl millet varieties for resistance against shoot fly and stem borer.

Materials and Methods

The experiment was conducted during the kharif season of 2018 at the Instructional Farm, College of Agriculture, JAU, Junagadh. A total of 10 pearl millet hybrids were tested against shoot fly (*Atherigona approximata*) and stem borer (*Chilo partellus*) infestations in the pearl millet crop. Each variety was planted in a single row of 5 meters in length, with a spacing of 50 x 10 cm, and replicated four times. The maintenance of the experiment followed standard agronomic practices, except that no plant protection measures were applied.

During the vegetative stage, observations were recorded on 5 plants from each plot by counting the dead hearts, and the percentage of shoot fly dead hearts was calculated. At the ear head stage, the number of ear heads showing empty or white ear head damage was recorded separately, and the percentage of ear head damage was calculated from the ear heads of 5 plants in each plot.

For stem borer assessment, plants displaying parallel holes in the leaves, caused by stem borer larvae, were considered damaged at the vegetative stage, and the percentage of damaged plants was calculated. At the ear head stage, the number of ear heads showing stem borer damage was recorded separately from 5 randomly selected ear heads in each plot, and the percentage of ear head damage was calculated.

Results and Discussion

Shoot fly

During the vegetative stage, the mean percentage of plant infestation due to shoot fly ranged from 0.0% to 8.12%. The minimum infestation was recorded in hybrids GHB-744 and GHB-1231, both showing 0.0% infestation, while the maximum infestation was observed in GHB-558 at 8.12%. Based on the percentage of infestation, two hybrids, GHB-744 and GHB-1231, were found to be resistant to shoot fly. Four hybrids, namely GHB-732, GHB-1231, GHB-905, MSH-346, and 86M64, were found to be tolerant. Meanwhile, four hybrids, MSH-339, MH-2024, GHB-538, and GHB-558, were found to be susceptible to shoot fly.

At the ear head stage, the mean shoot fly infestation varied from 0.0% to 7.54%. The least infestation was recorded in GHB-1231 (0.0%), while the maximum infestation was observed in MSH-339 (7.54%). Based on the percentage of infestation, only GHB-1231 was found to be resistant to shoot fly at the ear head stage. Five hybrids, GHB-905, GHB-732, GHB-538, GHB-744, and GHB-558, were found to be tolerant. Four hybrids, 86M64, MSH-346, MH-2024, and MSH-339, were found to be susceptible to shoot fly in the pearl millet crop.

Stem borer

During the vegetative stage, infestation ranged from 3.95% to 44.59%. None of the hybrids were free from stem borer infestation at either stage of the crop. The lowest damage was recorded in GHB-1231 (3.95%), which was on par with GHB-905 (4.21%), both showing resistance against stem borer. Infestation between 5% and 10% was recorded only in GHB-744 (8.78%), indicating tolerance to this pest. Over 20% infestation was recorded in seven varieties: GHB-558, GHB-538, GHB-732, MSH-339, MSH-346, 86M64, and MH-2024, indicating high susceptibility to stem borer.

At the ear head stage, the least infestation was observed in GHB-1231 (1.41%). Infestation between 5% and 10% was noted in six varieties: GHB-1231, GHB-558, 86M64, GHB-905, MH-2024, and GHB-538, indicating tolerance to this pest. More than 20% infestation was recorded in four varieties: GHB-732, MSH-339, GHB-744, and MSH-346, indicating susceptibility to stem borer at the ear head stage.

Table-1: Incidence of shoot fly and stem bore in different pearl millet hybrids during *Kharif*-2018

No.	Name of variety	Shoot fly incidence (%)		Stem borer incidence (%)	
		At vegetative stage	At ear head stage	At vegetative stage	At ear head stage
1	GHB-558	8.12	4.02	29.08	6.28
2	GHB-538	7.11	2.57	23.71	9.05
3	GHB-732	2.36	1.34	17.87	10.61
4	GHB-744	0.0	3.27	8.78	12.62
5	GHB-905	3.06	1.38	4.21	7.45
6	GHB-1231	0.0	0.0	3.95	1.41
7	MSH-339	5.18	7.65	25.50	11.05
8	MSH-346	3.63	6.42	20.88	14.32
9	86M64	4.20	5.83	44.59	7.06
10	MH-2024	6.20	7.54	22.03	8.53
	SEm±	0.25	0.25	0.98	0.46
	CD at 5%	0.73	0.74	2.85	1.33
	CV %	12.80	12.84	9.78	10.43

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Diagnosis and prevention of Thai sac brood viral disease in Indian honey bee (*Apis cerana* F.)

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Introduction

Bees, as pollinators, play a crucial role in ecosystem and biodiversity conservation. Their pollination services are essential for the reproduction of numerous plant species, including many crops that form the backbone of the agricultural economy. Beekeeping offers a source of income that is relatively low-cost to initiate and maintain, making it accessible to small-scale farmers and marginalized communities. The sale of honey and hive products not only provides direct revenue but also stimulates local economies through value chain development and market linkages. Beekeeping creates employment opportunities along the entire value chain, from hive construction and maintenance to honey extraction, processing, packaging and marketing. In this context, apiculture, or beekeeping, emerges as a promising tool for promoting sustainability in rural communities (Radivoj Prodanovi *et al*., 2024).

Similar to all living organisms, honeybees also experience various pests (KT Vijayakumar and Nayimabanu Taredahalli) and diseases caused by bacteria, protozoa and viral pathogens due to social interactions, among them Thai sacbrood virus disease (TSBV) has caused serious problems to beekeepers.

Despite extensive study on Sac brood virus, we continue to confront obstacles in its control due to lack of comprehensive information on disease frequency and severity of TSBV in honeybees. There is a major lack of quick, accurate and sensitive diagnostic tests for the early and precise identification of TSBV. Additionally, there is insufficient information on the morphometric and genetic features of indigenous TSBV isolates.

Prevalence

The disease TSBV, caused by *Morator aetatulus*, first appeared in Thailand in 1976, causing 100% mortality before spreading to other parts of the world. In India, it was first detected in Nagaland in 1978 and subsequently spread to Meghalaya (1979), Sikkim (1980), Bihar (1981), Uttar Pradesh (1982), and Himachal Pradesh (1984), eventually reaching South India in 1991.

Infection rates are notably higher during the brood-rearing season and under changing weather conditions. A recent study conducted in Karnataka from September 2022 to August 2023 revealed the following infection rates: Chikkamattigatta (Hassan): 100%, Gokarna (Uttara Kannada): 42.06%, Uruvalu (Dakshina Kannada): 36.19%, Savanoor (Dakshina Kannada): 5.26%.

The high prevalence of this disease has significantly affected beekeepers' interest and enthusiasm in continuing this profession (Chetan, 2023)

Relation with weather parameters

There is no definitive relationship between the incidence of the disease and meteorological conditions. However, studies have shown that no disease was detected in the absence of rain (Negi et al., 2018; Devi et al., 2021). The infection tends to occur when brood raising is high and when rainfall is present, with relative humidity ranging from 40-95% and temperatures between 20-35°C (Chetan, 2023).

Epidemiology and Symptoms of TSBV

Thai sacbrood virus (TSBV) can infect both brood and adult honeybees, with two-day-old larvae being particularly vulnerable. The virus multiplies and accumulates in the ecdysial fluid, creating fluid-filled sacs that hinder normal molting and result in a high death rate among capped brood. As the disease progresses, the color of the larvae changes from white to pale yellow, then tan, and finally to brittle, dark scales that can be easily removed from cells (Wei et al., 2022).

The diseased comb exhibits partially perforated brood with prepupae turned upwards, resembling a tiny sac when lifted with tweezers (Hitchcock, 1996). In the later stages of infection, the queen stops laying eggs, leading to a decline in population and inevitably weakening the colony. As the disease advances, bees become aggressive and may eventually abandon their hive to seek new habitats.

Transmission of TSBV

Horizontal Transmission

Worker bees spread the virus within the colony through direct contact or via contaminated food sources such as pollen and nectar. The spread is exacerbated when infected bees interact with other bees or colonies, including through vectors such as mites.

Vertical Transmission

The virus can be transmitted from queens or drones to their offspring, either directly through sperm or indirectly through the queen's previous venereal infection (Yenez *et al.*, 2020).

Characterisation of TSBV

Taxonomic classification proposed by Baker and Schroeder (2008)

Kingdom : Virus

Phylum : Pisuviricota

Class : Pisoniviricetes

Order : Picornavirales

Family : Iflaviridae

Genus : Iflavirus

Species : *Morator aetatulas*

Morphological Characterization

Thai sacbrood virus (TSBV) belongs to the Iflavirus genus and possesses icosahedral symmetry. It is a non-enveloped, spherical virus with a diameter of 30-32 nm (Aruna *et al.*, 2016).

Molecular Characterization

The TSBV genome consists of approximately 8800 nucleotides with a single-stranded RNA of 2.8 x 10^6 Daltons molecular weight (Bailey et al., 1982). It contains a single open reading frame encoding a polyprotein of about 2800 amino acids. The genome includes structural polyproteins such as VP2, VP4, VP3, and VP1 organized at the N-terminal, and non-structural polyproteins such as helicase, protease and RNA-dependent RNA polymerase at the C-terminal. VP1 influences the infection process, VP3 inhibits the dicer enzyme and, along with VP2, exhibits significant immunogenic qualities. VP4's function is uncertain but it contributes to the capsid shape. The non-structural polyproteins aid in the replication and synthesis of new RNA strands (Prochazkova *et al.*, 2018).

Impact on Larval Cuticle

Healthy larvae exhibit uniform pigmentation, smooth texture, sturdiness, regular contours, and even growth, indicating proper cuticle development and health. In contrast, TSBV-infected larvae display wrinkles, folds, and irregular bulges, indicating disrupted development (Chetan, 2023).

Strains of Sacbrood Virus (SBV)

There are several strains of the single-stranded RNA virus known as sacbrood virus (SBV), which infect honeybee larvae. The strain affecting *Apis cerana* includes Thai Sacbrood Virus (TSBV), Chinese Sacbrood Virus (CSBV), and Korean Sacbrood Virus (KSBV), which have few genetic differences from the strain affecting *Apis mellifera* (Bailey *et al.*, 1964; Rana *et al.*, 2007; Choi *et al.*, 2010). Due to its physicochemical and serological characteristics, TSBV was initially identified as a separate strain after being isolated from *A. cerana* larvae in Thailand (Bailey *et al.*, 1982).

According to Zhang *et al.* (2001), CSBV was discovered in China in 1972 and is categorized as a member of the Picornaviridae family. Its antigenic differences prevent it from infecting other strains of SBV. KSBV, identified in Korea in 2008, triggered a major epidemic in 2010 that impacted 75% of *A. cerana* colonies and showed close genetic links to other Asian strains of SBV (Choi et al., 2010; Yoo *et al.*, 2012). A Brazilian variant of SBV known as "Brazilian sacbrood-like disease" was the first to be identified outside of Asia (Freiberg *et al.*, 2012). These strains demonstrate the catastrophic effects of SBV on honeybee populations and its geographical heterogeneity.

Diagnosis

Apart from visual detection, other diagnostic procedures for TSBV include electron microscopy, RT-PCR, and enzyme-linked immunosorbent assay (ELISA). While these traditional methods are accurate, they are also costly and require sophisticated equipment. Recently developed technologies, such as Recombinase Polymerase Amplification (RPA) and Loop-Mediated Isothermal Amplification (LAMP), can detect the virus under minimal laboratory conditions and are accurate, sensitive, and enable early and swift detection. Although early detection helps restrict and prevent disease transmission, further research is needed to develop viable and proven procedures for field-level detection (Chetan, 2023).

Prevention and Control

Colony Management

1. **Boosting Population**: Minimize disease attacks by stimulative feeding and regularly monitoring and cleaning the colony.

2. **Reducing Horizontal Transmission**: Sterilize honeycombs and hives and remove combs with infected brood.

3. **Preventing Vertical Transmission**: Replace the queen with a young, healthy one or cage her to stop laying eggs for a few days, which significantly improves colony recovery.

4. **Feeding Plant-Based Supplements**: Use supplements like *Phyllanthus niruri*, turmeric, tulsi, and citric acid rich in B-complex vitamins and anti-viral compounds to minimize TSBV infection.

5. **Medication**: Administer 100 ml of sugar syrup mixed with 1 ml of ribavirin or 200 mg of acyclovir two to three times a week until the colony appears healthy.

6. **Severe Cases**: If the condition worsens and becomes unmanageable, burn and eliminate infected colonies.

A study on holistic management strategies for TSBV disease was conducted with different non-chemical treatments at various locations in Karnataka for two years.

The experiment included plant extracts such as turmeric, ganoderma, tulsi, kalonji, P. niruri, and their combinations (P. niruri + tulsi + turmeric) compared with the antiviral drug acyclovir (200 mg). The results revealed that, after four days of the second treatment, the highest decrease in TSBV infection among non-chemical methods was recorded in the bee colony fed with P. niruri + tulsi + turmeric extract (41.74%), followed by *P. niruri* extract (40.22%). Although chemical treatment with acyclovir was found to be the best, the combination of P. niruri (2 g) + tulsi (0.5 g) + turmeric (0.5 g) was effective against TSBV infection among non-chemical methods. The active phytochemicals, including flavonoids, alkaloids, terpenoids, lignans, polyphenols, tannins, coumarins, and saponins, identified from various parts of P. niruri and its extracts, have been proven to have therapeutic effects in many clinical studies.

Conclusion

The current investigation was carried out at various locations in Karnataka to monitor the incidence of TSBV disease in *Apis cerana* colonies. The infection rate per colony varied widely, ranging from zero percent to one hundred percent across different locations. Transmission electron microscopy (TEM) images of *A. cerana* showed round virus particles with a diameter of 31-32 nm. Among non-chemical control methods, Phyllanthus niruri was found to be effective against TSBV infection.

Fig. 1: Comb containing infected brood with perforated cells

Figure 2: Infected larva looking like a sac

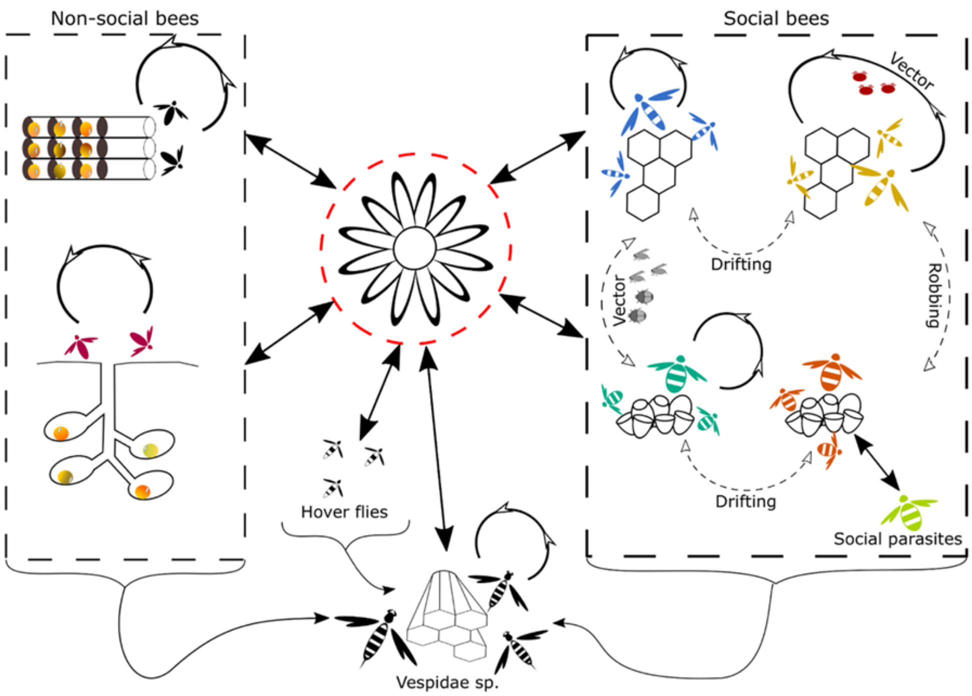

Fig. 3: The natural paths of virus transmission in Hymenoptera are graphically represented. Inter-species transmission through the use of shared flowers is in the centre, with solid arrows indicating the most likely routes and dotted arrows indicating less common ones.

(Non-social bees with inter- and intra-species transmission on the left, whereas social bees with intra-species transmission on the right (Yanez et al., 2020).

Fig. 4: Survey of TSBV and interaction with beekeeper

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Review articles & Short notes

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Major predatory bugs of tobacco based agro ecosystem in Gujarat - A short review

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Abstract

Biological control is a vital component of integrated pest management, using predators and parasitoids to efficiently and safely reduce pest populations. This review highlights key predatory bug families, Pentatomidae, Geocoridae, Miridae, and Reduviidae found in agro-ecosystems of Gujarat and their role in pest control. By identifying and conserving these predators of insect pests, we can significantly reduce our reliance on chemical insecticides. This sustainable approach can lead to a less harmful and more environmentally friendly pest management system.

Key words: Predatory bugs, Pentatomidae, Geocoridae, Miridae, Reduviidae

Introduction

Predatory insects, including bugs, ladybugs, and lacewings, are vital for biological pest management and ecological balance in agriculture. They prey on harmful pests like whiteflies, thrips, caterpillars, and leaf miners, providing an environmentally friendly and sustainable pest control solution. Insect predators and parasitoids, natural enemies of crop pests, regulate pest populations through natural biological control in agro-ecosystems (Metcalf and Flint, 1962).

Typically, insect predators are characterised by attributes that distinguish them from parasitoids, the other major group of entomophagous insects. (Doutt, 1964; Hagen *et al.*, 1976). However, predators are found in approximately 20 insect orders, with some variations depending on the definitions of scavenging and fortuitous predation. The orders of insects not known to contain predatory species are Isoptera, Phasmatodea, Phthiraptera, Strepsiptera and Siphonaptera (Hagen, 1987).

Predatory insects play an important role in biological pest control. Here we reviewed some major predatory bugs (Plate 1) belonging to various families found in bidi tobacco-based agroecosystem in Gujarat. The aim is to educate farmers on the eco-friendly management of insect-pests in their fields.

Family: Pentatomidae

Shield bugs are medium-sized, stout, flattened insects with a shield-shaped body, a prominent scutellum, and hemelytra covering most or all of the abdomen. While some are predatory, most are plant-feeders (Eger *et al*., 2015). Shield bugs lay barrel-shaped eggs in clusters, with females often guarding them until they hatch. First instar nymphs rely on plant sap or moisture for survival, turning carnivorous in the second instar. They undergo five nymphal stages, developing visible wing buds by the fifth. Nymphs are typically colorful and may look strikingly different from earlier stages or the more subdued adult forms, usually brown or green (Powel, 2020). Most species of shield bugs are phytophagous, but a few are predaceous in nature. Truly predaceous shield bugs (Asopinae) differ from other groups in possessing flexible mouthparts that are capable of being directed horizontally forward when impaling their prey (De Clercq, 2000). Some predaceous shield bugs are known to target phytophagous insects, which accumulate plant derived defence chemicals in their bodies, and may even be preferred as prey due to the sequestration of such chemicals. Known examples preyed upon by shield bugs include burnet moths (*Zygaena* spp.) and marsh fritillary butterflies (*Eurodrya saurinia* Rott.) (Hamilton and Heath, 1976; Tremewan, 1985; Konvicka *et al*., 2005). The activity of various natural enemies like spider, coccinellids, *Nesidiocoris tenuis* Reuter, *G. ochropterus* and *Rhynocoris* sp., were found on different crops raised for entomophage park under middle Gujarat tobacco based agroclimatic zone (Bhatt *et al*.,2019).

Family: Geocoridae

***Geocoris ochropterus* (Fieber)**

The big-eyed bug is widespread from Myanmar to Pakistan, across North Indian plains and foothills, and into Tamil Nadu's Coimbatore district and Peninsular India.

This species is 3.5–4.0 mm long with a brownish-yellow head, black pronotum, scutellum, and body, and transparent wing membranes. The abdomen, corium, coxae, legs, lateral sternum margins, pronotum, and rostrum are yellow with a slight brownish tinge, and the rostrum's first joint is slightly longer than the second (Bal and Biswas, 2013). *G. ochropterus* preys on sedentary pests like jassids, flies, thrips, and small caterpillars, hunting by chasing or ambushing. Its incubation period is 8 days, with a 25.4-day nymphal stage and 33.6-day total development. Adult males live 48 days, females 64.4, laying an average of 176 eggs each. Key metrics include a net reproductive rate of 28.6, generation time of 51.9–56.77 days, a finite rate of increase of 1.06, hypothetical F2s of 817.96, and a weekly multiplication rate of 1.5 when reared on *Sitotroga cerealella* (Varshney and Ballal 2017).

The dual feeding habit *i.e.,* partial phytophagic and necrophagic gives this species a special characteristic to survive at the time of extreme shortage of live prey. *G. ochropterus* is predaceous on weevil, *Myllocerus viridanus* Fabricius; the mired bugs, *Calocoris angustatus* Lethiery and *Ragmus importunitas* Distant; pentatomid bugs, *Coptosoma cribraria* Fabricius; the apids, *Aphis gossypii* Glover and *Aphis nerii* Boyer de Fonscolombe, and the coccids, *Pseudococcus* sp. and *Dactylopius nipae* Maskell (Bal and Biswas, 2013).

Geocoris jucundus (Fieber)

G. jucundus is abundant and widely distributed in various agroclimatic regions of India (Bihar and West Bengal) and Myanmar.

Adult bugs average 3.0 mm in length with a black head marked by spots near the eyes. The pronotum is black with yellowish-brown lateral angles, while the scutellum and corium are pale yellowish-brown with a brown anal spot. The yellowish-brown rostrum has black markings at the base, third joint, and apex. This species is an effective predator of crop pests like the tomato aphid, *A. gossypii* and lucerne aphid, *Acyrthosiphon pisum* (Pal, 1974).

Family: Miridae

Mirid bugs, a key heteropteran group, are small to medium-sized with three-segmented tarsi, four-segmented antennae and rostrum, and no ocelli. Adults are typically macropterous, with hemelytra featuring a distinct cuneus and a membrane with two cells. They may be brachypterous and uniquely possess sensory setae (trichobothria) on the meso- and metafemora (Schuh, 1975). Some mirids are facultative or obligate predators and play a key role in biological control or integrated pest management, often outnumbering harmful pests in apple orchards and protected cultivations.

Nesidiocoris tenuis (Reuter)

N. tenuis, a multivoltine Mediterranean species, breeds year-round without entering diapause. It develops rapidly, completing up to six summer and two winter generations annually in favorable areas. It is a voracious predator of whiteflies, *Bemisia tabaci* Gennadius (Sridhar *et al*., 2012). It also feeds on thrips and has proved to be an effective biocontrol agent for combating tomato borer infestations on both open field as well as protected conditions (Shaltiel-Harpaz *et al*., 2016). It also preys on eggs and neonate larvae of fruit borer, leaf eating caterpillar, stem borer, tomato pin worm, and aphids as well as mites (Bhatt and Patel, 2018). Although considered a zoophytophage and an important biocontrol agent, *N. tenuis* can also cause direct damage to crops, primarily when suitable prey is in short supply or absent (Perdikis *et al*., 2009; Arno *et al*., 2010). The tomato bug, *N. tenuis,* is a predator of major pests, feeding on the eggs and neonate larvae of fruit borers, leaf-eating caterpillars, stem borers, and tomato pinworms (Bhatt *et al.*, 2019).

Family: Reduviidae

Reduviids are polyphagous predatory insects and global biocontrol agents. Most are predatory, with a few blood-sucking species that can act as human disease vectors (Sahayaraj and Balasubramanian, 2016).

Reduviidae includes *Rhynocoris fuscipes*, *R. kumarii*, *R. longifrons*, *R. marginatus*, *Ectomocoris tibialis* and *Acanthaspis pedestris*. These species have been studied for their controlling trait of insect pests on crops like cotton, vegetables, castor, groundnut, and cereals in India (Ambrose and Kumar 2016). Padamshali and Ganguli (2020) found four species of Reduviid bugs as predators from Chhattisgarh. The entomopathogenic fungus *Isaria fumosorosea* can be used alongside a reduviid predator to enhance biological control of *S. litura* in commercial crops (Muhammad, I U *et al.*, 2019). Conservation and augmentation of reduviid predators in the field can be helpful to protect the crop from pests for a long time (Rahate and Wankhede, 2024).

***Rhynocoris marginatus* (Fabricius)**

R. marginatus targets pests on crops like sugarcane, pigeonpea, cardamom, cotton, tea, and groundnut in India. It is useful in biocontrol due to its higher pesticide tolerance compared to the pests it preys on (Sahayaraj, 2014b). The extra-oral digestion and three-segmented rostrum, equipped with hair-like sensors, help it detect prey and deliver venomous saliva to paralyze them. (Kumar and Sahayaraj, 2012). The accessory salivary glands that recapture water, ensuring a continuous flow of saliva to flush out predigested food from its prey (Sahayaraj, 2014b; Sahayaraj *et al.*, 2010). *R. marginatus* feeds on over 20 crop pests, with a preference for the tobacco cutworm, *Spodoptera litura*, followed by *Helicoverpa armigera*, *Aproaerema modicella*, and *Amsacta albistriga*. It is widespread in Indian agriculture, attracted by kairomones from its prey, including moth scales (Sahayaraj, 1999). *R. marginatus* prefers moth larvae over pests like the red cotton bug and Mylabris beetles. Feeding on moth larvae accelerates its growth, suggesting its potential in biocontrol of cotton moth larvae (Sahayaraj, 2014a).

***Rhynocoris fuscipes* (Fabricius)**

R. fuscipes is a generalist predator of cotton pests and is commonly found inhabiting cotton-growing regions in Assam, Maharashtra, southern India and Sri Lanka (Tomson *et al.*, 2017). *R. fuscipes* is 14–16 mm long, coral red with black markings on the rostrum, antennae, scutellum, postocular area, legs, and pronotum. Shanker *et al.* (2016) reported that the egg, nymph, and adult of *R. fuscipes* last 7-12, 72.37 ± 6.87, and 57.20 ± 16.16 days, respectively, when reared on *Cnaphalocrocis medinalis*. The pronotum has a sculptured anterior lobe and a pale fuliginous posterior margin. These bugs inhabit vegetation, bark, litter, and boulders, preying on larvae of *H. armigera*, *S. litura*, *Semiothisa pervolgata*, *Eurema hecabae*, *Catopsilia pyranthe,* and beetles like *Henosepilachna vigintioctopunctata* and *Raphidopalpa foveicollis*.

Predatory potential

Grundy and Maelzer (2000) revealed that the 5th instar of the assassin bug, *Pristhesancus plagipennis* Walker has higher predatory rate on the early instars of *H. armigera*. Ghelani (2000) reported higher predatory potential of *R. fuscipes*on *S. litura* than *Corcyra cephalonica* Stainton. Additionally, the rate of predation was higher in 5th instar of the *Rhynocoris* sp. Sahayaraj *et al*. (2016) reported that *R. marginatus* preferred *S. litura*. Shanker *et al*. (2016) reported 3rd instar of *R. fuscipes* had higher predatory potential on *C. medinalis*. Sahid *et al*. (2018) observed 5th instar and female adults of *Sycanus annulicornis* Dohrn. had higher consumption rate against *Crocidolomia pavonana* Fabricius. *S. collaris* showed varying predatory efficiency on *Hyposidra talaca*; under free-choice feeding, nymphal consumption ranged from 3.2 ± 1.3 (3rd instar) to 2.2 ± 0.8 (5th instar), while no-choice feeding increased with instar advancement (Sarkar *et al*., 2019). Reduviids also exhibit cannibalistic behaviour confirmed by Padamshali and Ganguli (2020) wherein, the 1st nymphal instar showed the maximum rate of cannibalism followed by the 2nd and 5th instars.

	
Predatory pentatomid preying on *Carea angulata* Fabricius in jamun	***Nesidiocoris tenuis* Reuter preying on aphids in tobacco**
	
Eggs of *Rhynocoris* sp. on Tobacco	***Rhynocoris* sp. preying on *S. litura***
	
***Rhynocoris* sp. and its different preys in tobacco ecosystem**	**Adult of *Rhynocoris* sp.**

Plate 1: Major predatory bugs recorded from middle Gujarat agro ecosystems

Conclusion

Predatory bugs from families like Pentatomidae, Geocoridae, Miridae, and Reduviidae play a key role in Gujarat's agricultural pest management. Species such as *Nesidiocoris tenuis*, *Geocoris ochropterus*, and *Rhynocoris* sp. prey on pests like jassids, thrips, and caterpillar larvae in tobacco crops. Conserving these predators reduces dependence on chemical insecticides, promoting sustainable agriculture.

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Unveiling insect olfaction: advances and applications of electroantennography and single sensillum recording

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Abstract

Electroantennography (EAG) and single sensillum recording (SSR) are two fundamental electrophysiological techniques used to study the olfactory responses of insects. These methods have significantly contributed to our understanding of insect olfaction, from the initial identification of pheromones to the detailed analysis of olfactory receptor function. This review discusses the principles, methodologies and applications of EAG and SSR, highlighting their respective advantages and limitations. It also explores advancements in these techniques, such as multidimensional EAG, which offers an advanced approach to analysing complex odour mixtures. Emphasis is placed on the equipment, insect preparation, and technical considerations essential for effective electrophysiological studies.

Keywords: Electroantennography (EAG), Single Sensillum Recording (SSR), Insect Olfaction, Olfactory Receptor Function, Multidimensional EAG.

Introduction

Insects possess highly sophisticated chemical senses critical for their survival, including locating food, mates and avoiding predators. The antennae of insects are primary sensory organs for detecting volatile chemical signals, such as pheromones, which play vital roles in various behavioural processes. The use of electrophysiological techniques, specifically electroantennography (EAG) and single sensillum recording (SSR), has been pivotal in advancing our understanding of insect olfaction. These techniques allow researchers to measure the electrical responses of olfactory sensory neurons (OSNs) to specific odorants, providing insights into how insects perceive and process chemical information.

Electroantennography, developed by Schneider in the 1950s, measures the electrical potential difference between the distal and proximal ends of the antennal flagellum in response to odour stimuli (Schneider, 1957). Single sensillum recording, introduced shortly after, focuses on the activity within individual sensilla, offering a more detailed view of olfactory neuron responses (Schneider *et al*., 1962; Boeckh, 1962). Despite their longstanding use, these techniques have undergone significant refinements and applications, including the integration of gas chromatography and the development of multidimensional EAG for complex odorant analysis.

Electroantennography (EAG): Principles and Methodology

Electroantennography (EAG) involves placing electrodes on the antennal flagellum of an insect to measure changes in electrical potential caused by odour stimulation. The basic setup includes two electrodes: one at the distal end and the other at the proximal end of the antenna or on the insect's head (Schneider, 1957). The EAG signal reflects the summed activity of multiple OSNs within the antenna, representing the collective response to the odorant.

The EAG technique is advantageous for its simplicity and speed, allowing researchers to assess the olfactory sensitivity of an insect to a broad range of odorants. However, it primarily provides qualitative data, as the amplitude of the EAG response can be influenced by various factors, including electrode placement, insect health, and the strength of the odour stimulus (Roelofs, 1984; Nagai, 1981). The EAG response typically consists of a slow potential change that persists for several seconds following a short (less than 0.5 seconds) odour pulse.

Applications and Limitations

EAG is frequently used in combination with gas chromatography (GC) to analyse natural odour mixtures. This integration, known as electroantennographic detection (EAD), enhances the detection of specific compounds within complex mixtures (Roelofs *et al*., 1984). Despite its utility, EAG has limitations in providing quantitative data on individual OSN responses due to the summation of signals from multiple neurons and the influence of electrotonic spread within the antenna (Nagai, 1981; Ochieng *et al*., 1998).

Single Sensillum Recording (SSR): Principles and Methodology

Single sensillum recording (SSR) offers a more detailed analysis of olfactory responses by measuring the electrical activity within individual sensilla on the insect antenna. This technique involves inserting a fine electrode into a sensillum to record the action potentials of the OSNs present within it (Schneider *et al*., 1962; Boeckh, 1962). The action potentials are characterized by their amplitude, which is related to the size of the nerve cell and can be used to differentiate between different types of OSNs.

SSR provides a quantitative measure of the sensitivity and specificity of individual OSNs to various odorants. This technique is particularly valuable for mapping the receptive range of specific olfactory receptors and understanding the neural coding of odour information (Hansson *et al*., 1994; Vosshall *et al*., 2000). Additionally, SSR can be used to investigate the effects of pharmacological agents on OSN response kinetics through techniques like microinjection (Olsson *et al*., 2011).

Applications and Limitations

SSR is ideal for studying the precise responses of individual OSNs and their role in odour detection and discrimination. It allows for detailed characterization of receptor types and their convergence onto specific brain regions (Gao *et al*., 2000). However, SSR requires more intricate preparation and is generally more time-consuming compared to EAG. Maintaining the health and stability of the preparation is crucial for obtaining reliable data (Kaissling *et al*., 1991; Pophof, 2004).

Multidimensional Electroantennography (EAG): Principles and Methodology

Multidimensional EAG is a novel extension of the traditional EAG method, designed to analyse complex mixtures of odorants. This technique leverages the presence of various populations of group-specific olfactory receptor molecules within a single antenna. By representing different odours as orthogonal vectors in a multidimensional "odour space," this method enables the analysis of odour mixtures based on their vector sums (Struble *et al*., 1984).

The multidimensional EAG approach is useful for studying how insects differentiate between and respond to complex odorant mixtures. It has been applied using antennae from the Colorado potato beetle and specialized biosensor systems to examine the possibilities and limitations of this method in odour qualification and quantification (Hallem *et al*., 2004; Hallem *et al*., 2006).

Applications and Limitations

Multidimensional EAG offers a powerful tool for understanding how insects perceive and process complex odour mixtures. It can provide insights into the combinatorial coding of odorants and the interactions between different olfactory receptors. However, the method's complexity and the need for precise calibration and interpretation of multidimensional data can pose challenges (Laughlin *et al*., 2008; Flecke *et al*., 2006).

Insect Preparation and Equipment's

Insect Preparation

For both EAG and SSR, the choice of insect and its preparation are critical for obtaining accurate and reliable data. Healthy, young insects with undamaged antennae are preferred, as they generally produce the best electrophysiological signals. Insect preparations can involve excised antennae or whole animals, with each method requiring specific mounting and maintenance techniques (Kaissling, 1995).

Equipment

The essential equipment for electrophysiological recording includes conductive metal electrodes, high-impedance amplifiers, anti-vibration tables, microscopes, and Faraday cages. The choice of electrodes and their preparation (e.g., sharpening or etching) is crucial for effective recording (Roelofs, 1984). For odour stimulation, equipment like filtered air sources, humidifiers, and directional-control valves are used to deliver precise odorant pulses to the antennae (Laughlin *et al*., 2008).

Conclusion

Electroantennography (EAG) and single sensillum recording (SSR) have been instrumental in advancing our understanding of insect olfaction. EAG provides a broad overview of antennal responses, making it particularly useful for assessing the general olfactory sensitivity of insects. In contrast, SSR offers a more detailed and quantitative analysis of individual olfactory sensory neurons (OSNs), allowing for precise mapping of olfactory receptor functions.

Recent advancements, such as multidimensional EAG, have further enhanced our ability to analyze complex odour mixtures and refine our understanding of olfactory coding. These techniques have not only deepened our knowledge of how insects perceive and process chemical information but have also highlighted the intricate mechanisms underlying insect olfaction.

While both EAG and SSR have their respective advantages and limitations, their continued development and application are expected to lead to even deeper insights into the mechanisms of insect olfaction and its ecological and behavioural implications. As we refine these methods and integrate new technologies, we will continue to uncover the complexities of insect sensory systems and their roles in survival and adaptation.

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Integrating insect dynamics in agricultural ecosystems: the role of predators, prey, and sustainable practices in enhancing biodiversity and ecosystem resilience

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Abstract

Insects play a pivotal role in food webs, influencing ecosystem stability through their interactions as herbivores, predators, and prey. This review explores the impact of agricultural practices on insect dynamics, focusing on how no-till farming, mulching, crop residues, and diverse farming systems like intercropping and crop rotation can shape predator-prey interactions. No-till systems, by reducing soil disturbance, enhance the survival of natural enemies such as ants, spiders, and beetles, indirectly regulating pest populations. Practices like mulching and maintaining crop residues hinder pests' ability to locate host plants, boosting the abundance of natural predators. Additionally, crop rotation and intercropping create varied habitats, supporting a higher diversity of predators and improving biological pest control. These integrated approaches not only reduce reliance on chemical pesticides but also foster ecological balance and enhance agricultural sustainability. The review highlights the importance of sustainable land-use practices in preserving insect biodiversity and improving ecosystem resilience.

Keywords: Biodiversity, food web and predator-prey interactions.

Introduction

Insects represent the most diverse group of animals on our planet, encompassing a wide range of taxonomic varieties and ecological roles, making up 75% of all known animal species (Sankarganesh, 2017). Insects play a vital role at various trophic levels within food webs, serving as an essential food source for many organisms and contributing significantly to the maintenance of balance and energy flow. They function as primary consumers and herbivores, as well as prey for higher-level consumers such as birds, reptiles, amphibians, and mammals (Price *et al.*, 2011a). Insectivorous animals depend heavily on insects for their diet, and the presence of these insects also aids in regulating their populations. Furthermore, predatory insects like dragonflies and ladybugs help manage the numbers of herbivorous insects, preventing outbreaks and maintaining ecological balance. The diversity and abundance of insects are crucial for ensuring the stability and resilience of food webs, which in turn supports the survival of countless species. At the base of the insect food web are phytophagous insects, commonly referred to as herbivores. These insects feed directly on plants, consuming leaves, stems and other parts, thereby playing a significant role in shaping plant communities and influencing plant species composition based on their feeding habits and preferences. Herbivorous insects may be generalists, eating a wide variety of plant species, or specialists, focusing on specific plants. Their feeding behaviours can impact plant growth, reproduction, and even the plants' defensive mechanisms against herbivory. In addition to their roles as herbivores, insects can also function as both predators and prey, contributing to complex food webs and predator-prey dynamics that influence ecosystem balance, species interactions, and population control.

Insects as Predators

Predatory insects play a crucial role in the insect food web, feeding on other insects, including herbivores and small invertebrates, thus preventing herbivore populations from becoming overly destructive (Finke and Snyder, 2008). For example, lady beetles (Coccinellidae) control aphid populations, promoting crop health and increasing agricultural yields. Other beneficial predatory insects include mantises, dragonflies, and ground beetles. The diversity and effectiveness of predatory insects are essential for maintaining ecological balance and supporting sustainable agriculture. By regulating pest populations, these predators reduce the need for chemical pesticides, promoting healthier crops and environments.

Diversity of Insect Predators

The global distribution of insect predators and parasitoids is influenced by unique environmental factors present in different ecosystems. From a taxonomic perspective, insect predators are highly diverse, spanning numerous orders such as Coleoptera, Diptera, Hemiptera, Heteroptera, Mantodea, Neuroptera, Odonata, and Thysanoptera. Sometimes, these predators maybe attacking its prey in both larval and adult stages. For instance, Odonatans are predators on mosquitoes, flies and other aquatic invertebrates in larval and adult stages (Vashishth *et al.*, 2002; Aleena *et al.*, 2024). In contrast, parasitoids have a more limited taxonomic range, predominantly found within the wasp subgroup Parasitica of Hymenoptera and specific families of Diptera, particularly Tachinidae. This specialization underscores the important roles that wasps and certain fly families play in parasitoidism. Gaining a deeper understanding of the taxonomy of entomophagous insects is essential for revealing insights into their evolutionary adaptations, which improve their morphological, physiological, and behavioral characteristics, enabling them to successfully target hosts or prey (Quicke, 2015).

Trophic Cascades

A trophic cascade is an ecological phenomenon triggered by the addition or removal of top predators, which leads to reciprocal changes in the populations of predators and prey throughout a food chain. This often results in dramatic changes in ecosystem structure and nutrient cycling. In a three-level food chain, an increase (or decrease) in carnivores leads to a decrease (or increase) in herbivores, and subsequently, an increase (or decrease) in primary producers such as plants and phytoplankton (Carpenter, 2023).For instance, a study examined the impact of manipulating the presence of damselfly larvae (strictly aquatic predators) and spiders (predators from both habitats) in tank bromeliads on detritivore survival, detrital decomposition, nitrogen flux, and host plant growth. Piecewise structural equation models were employed to analyze the direct and indirect effects on multiple detritivore groups. The results showed that each predator reduced detritivore survival and negatively influenced ecosystem processes. However, when both predators co-occurred, spiders diminished the damselfly's top-down effects, highlighting that detritivore traits and detritus quality modulated these interactions. This study emphasizes the importance of biodiversity for ecosystem function (Piccoli *et al.*, 2024).

Insects as Prey and their Nutritional Role

The food web interactions among animals are increasingly analyzed based on the nutritional quality of their food, specifically focusing on the concentrations of essential elements or nutrients. This perspective emphasizes that the nutrient composition of food can influence how animals interact within an ecosystem (Mayntz and Toft, 2001; Müller-Navarra, 2008).The nutritional makeup of the predators' bodies was closely linked to the nutritional content of the prey they consumed (Hawley *et al*., 2014). Most predators select its prey based on its nutritional composition which ultimately influences the predator longevity. For instance, the eggs of the corn earworm, *Helicoverpa zea* (Lepidoptera: Noctuidae), provide better nutrition compared to pea aphids, *Acyrthosiphon pisum* (Homoptera: Aphididae), for big-eyed bugs, *Geocoris punctipes* (Heteroptera: Geocoridae). Big-eyed bugs fed on corn earworm eggs lived four times longer than those given pea aphids. Additionally, only big-eyed bugs that consumed corn earworm eggs successfully developed and reached adulthood (Eubanks and Denno, 2000).

Moreover, prey consumption and the reproductive success of predators are greatly influenced by the nutrient composition of their prey. For example, Omkar and Bind (2004) found that the prey consumption and reproductive success of *Cheilomenes sexmaculata* F. (Coleoptera: Coccinellidae) were greatest when feeding on aphid species with the highest nutritional value. Fertilization of host plants also impacts the predatory behaviour of beetles. Previous research indicated that the degree of nitrogen fertilization influenced the foraging efficiency of *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae) on cereal aphids (Aqueel and Leather, 2012) as well as on *Aphis nerii* Boyer de Fonscolombe (Couture *et al.,* 2010).

Influence of Prey Diversity on Predator Foraging

The diversity of available insect prey can enhance predator foraging efficiency and overall ecosystem resilience. Greater diversity among prey types can stabilize predator populations against fluctuations in specific prey availability. Predators adapt their behaviour to maximize energy gains and minimize costs, influenced by the variety and availability of prey species. Diverse prey options led to flexible foraging tactics, allowing predators to switch between different prey based on encounter rates and handling times. Prey diversity significantly impacts predator foraging behaviour. Socolar and Washburne (2015) found that predators often switch to more abundant prey when their preferred prey is scarce. This behaviour helps maintain prey diversity by preventing any single species from becoming dominant. High prey diversity also ensures a stable food supply for predators, enhancing overall ecosystem stability. (Fox and Fairbairn, 2001).

Interactions Between Predator and Prey Insects

Insect predator-prey interactions are fundamental to food web dynamics and ecosystem stability. Predators, such as lady beetles and lacewings, regulate prey populations, including herbivorous insects like aphids and caterpillars. These interactions influence population dynamics, with predators reducing prey abundance and prey availability affecting predator survival. Predation can drive evolutionary adaptations, leading to an "arms race" where prey develop defences like camouflage or chemical deterrents, and predators evolve more effective hunting strategies. These complex interactions contribute to the stability and resilience of ecosystems by maintaining balance and preventing overpopulation of any single species (Price *et al*., 2011b).

Competition and Coexistence

Competition among insect predators can regulate their populations and influence food web dynamics. Understanding these interactions is crucial for comprehending community structure within ecosystems. Klauschies and Gaedke (2020) found that nutrient retention in predator biomass hampers the coexistence of two predators on one prey because it stabilizes the dynamics. In contrast, a non-linear resource uptake rate of the prey slightly promotes predator coexistence. Bi *et al.* (2024) explored the ecological niches of *Hylurgus ligniperda* and its co-occurring stem-boring insect species in Shandong Province, China. Their findings revealed that these species coexist by partitioning spatial and temporal resources within the same habitat. Specifically, *H. ligniperda* primarily exploits tree roots, while *Cryphalus* sp. utilizes the entire trunk. In contrast, *Arhopalus rusticus* and *Shirahoshizo* sp. concentrate their activities in the lower to middle trunk and root sections. This distinct resource allocation minimizes direct competition, facilitating coexistence among the species. Such niche differentiation underscores the role of resource partitioning in promoting biodiversity within shared ecological systems.

Habitat Complexity and biodiversity

Habitat complexity plays a crucial role in influencing biodiversity by affecting predation pressure, which in turn shapes species richness and abundance (Loke and Todd, 2016; Hall-Spencer and Harvey, 2019; Feit *et al*., 2021). Complex habitats, characterized by diverse physical structures such as varying spatial arrangements and densities, provide resources and refuges for prey species, facilitating niche differentiation while reducing competition (Loke *et al*., 2015). This can lead to a greater diversity of species coexisting within these environments (Chesson, 2000). Furthermore, predation pressure is generally negatively associated with prey diversity; as complex habitats can lower predation rates, they may enhance prey abundance and variety. In contrast, simpler habitats often result in heightened predation, which can force prey into competitive scenarios within predator-free spaces, disrupting stable coexistence. While evidence suggests that predator-prey interactions are essential in determining biodiversity, the dynamics vary depending on the hunting strategies of predators. Active predators may benefit from the cover offered by complex structures (Ryer *et al*., 2004), while ambush predators can utilize these environments to their advantage (Flynn *et al*., 1999). Overall, understanding the relationship between habitat complexity, predation pressure, and biodiversity remains vital for effective restoration strategies aimed at enhancing ecological resilience and species conservation.

Environmental Influences on Insect Dynamics

Impact of Climate Change

Changes in climate can alter the distribution and abundance of insect species, affecting their roles in food webs. For example, temperature changes can influence predator-prey interactions and species distribution. Climate change disrupts seasonal rhythms and developmental rates of insects, leading to phenological mismatches between predators and prey. These mismatches can alter the strength of their interactions and affect ecosystem services like biological control

(Damien and Tougeron, 2019). Model prediction shows that increased temperatures lead to higher predation rates due to the metabolic needs of predators, resulting in more significant fluctuations in prey and predator populations (Sekerci, 2020). Predation efficacy of *O. similis* in controlling *B. tabaci* nymphs followed the sequence: 28°C > 25°C > 31°C > 22°C > 19°C. Increased predator density reduced predation rates, and *O. similis* preferred low-instar nymphs. The study suggests releasing *O. similis* at 25–28°C for effective management of *B. tabaci*. (Zhang *et al*., 2024)

Land Use Changes

Agricultural intensification and habitat destruction can disrupt insect populations, leading to declines in predator or prey species and destabilizing food webs. A study by Madeira *et al*. (2022) examined the effects of changing land use and crop management on insect abundance in alfalfa fields. The researchers found that field size and alfalfa growth stage influenced insect abundance. Similarly, Ohler *et al.* (2023) observed that agricultural sites had higher insect biomass and abundance compared to forested sites, with significant differences in the phenology of major insect orders. Land-use-related drivers, landscape and field management strategies can be used to improve pest control.

Conservation Implications

Recognizing the critical roles that insects play in food webs underscores the importance of conservation efforts aimed at preserving insect diversity. Sustainable land-use practices and habitat restoration can enhance insect populations, thereby promoting ecosystem resilience and stability. Rabary *et al*. (2008) found that no-till systems increased the density of white grubs due to less soil disturbance, which conserves their natural enemies. practices like mulching and maintaining crop residues on the soil surface can influence predator-prey dynamics by impairing pests' ability to locate host plants and enhancing the abundance of natural enemies such as ants, spiders, and beetles (Ghosh *et al*., 2010; Bhan and Behera, 2014). Crop rotation and intercropping can provide diverse habitats and food sources for predators, enhancing biological control. For instance, intercropping can act as a barrier to pests locating their host plants, thereby reducing pest populations and increasing predator efficiency (Dumanski *et al*., 2006; Kassam *et al*., 2009).

Summary

Insects are crucial to maintaining ecosystem stability and resilience through their diverse roles as herbivores, predators, and prey. Their interactions regulate food webs, enhance biodiversity, and influence essential ecosystem processes. The complexity of these relationships, combined with environmental factors like habitat structure and climate change, underscores the importance of understanding insect dynamics for effective conservation and ecosystem management. Sustainable land-use practices and habitat restoration are vital to preserving insect populations, promoting biodiversity, and ensuring ecological balance for future generations.

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Embracing entomophagy: Nutritional benefits and sustainable potential

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Abstract

This review delves into the emerging role of entomophagy, or insect consumption, in contemporary diets, highlighting its benefits, challenges, and potential for widespread acceptance. Insects are an abundant source of protein and nutrients, presenting a sustainable alternative to conventional animal proteins with a considerably lower environmental impact. Traditionally, insects have been an integral part of diets in numerous Asian, African, and Latin American cultures. However, acceptance in Western markets remains limited due to cultural norms and psychological barriers. This review explores strategies to enhance consumer acceptance, including educational initiatives, innovative product development, and advanced processing technologies. By addressing these challenges, entomophagy holds the promise of significantly contributing to food security and sustainability in the future.

Keywords: Entomophagy, Sustainability, Consumer Acceptance, Nutritional Benefits, Cultural Integration

Introduction

Insects are the most diverse and abundant organisms on Earth, serving as the foundation of terrestrial ecosystems. Their indispensable role in ecological processes highlights their importance, with life itself intricately linked to their functions (Pongen, 2020). Entomophagy, derived from the Greek words *entomos* (insect) and *phagein* (to eat), refers to the practice of consuming insects as food. This practice includes both the deliberate and incidental ingestion of insects and their by-products, such as honey. For centuries, many cultures worldwide have incorporated insects into their diets as a natural part of their cuisine. In ancient Greece, philosopher Aristotle documented the consumption of cicadas, noting that young cicadas were considered more tender and preferred over adults. The Old Testament of the Bible mentions locusts as a permissible food for the Israelites (Leviticus 11:22). Traditional cultures across Africa, Asia, and Latin America have long relied on insects as a significant source of protein. In Africa, insects like termites, caterpillars, and locusts are traditionally eaten and play a crucial role in local diets. Indigenous peoples in Australia, such as the Aborigines, have a history of consuming insects like witchetty grubs. In Mexico, chapulines (grasshoppers) are commonly consumed and are a staple in many traditional dishes (Ramos-Elorduy, 2009; Huis*et al*., 2013).

Today, over 2 billion people worldwide consume insects as part of their regular diet, particularly in regions like Asia, Africa, and Latin America (DeFoliart, 1999). Beyond human consumption, insects have garnered recognition as a sustainable protein source for animal feed, particularly in poultry and aquaculture. Studies highlight black soldier flies (*Hermetia illucens*) and house flies (*Musca domestica*) as efficient feed options for poultry and aquaculture, offering essential proteins and lipids that support growth and sustainability (Mishra, 2020; Dörper *et al*., 2021). This review examines the nutritional benefits, environmental impact, market potential, and consumer acceptance of insect-based foods, emphasizing their growing importance in modern diets.

Nutritional Benefits

Insects are a highly nutritious food source, offering abundant protein and essential nutrients. Many edible insects contain protein levels comparable to or even higher than traditional livestock. For example, crickets offer around 60-70% protein by dry weight, surpassing beef and chicken (FAO, 2021). Mealworms, another commonly consumed insect, contain about 50% protein, along with healthy fats and fiber (Rumpold and Schluter, 2013). In addition to protein, insects are rich in essential amino acids, vitamins, and minerals, such as vitamins B12, B2 (riboflavin), vitamin A, and key minerals like iron, zinc, and magnesium. This high nutrient density makes them an excellent food source, particularly in developing countries where nutritional deficiencies are prevalent (Mancini *et al*., 2019). For instance, iron from insects is more bioavailable than from plant sources, which is crucial in regions impacted by iron deficiency (Gahukar, 2016).

Moreover, insects are low in fat, with most of their fat content being unsaturated and beneficial for health. The fiber in insects, primarily in the form of chitin, also contributes to their nutritional value. Chitin, found in insect exoskeletons, is linked to various health benefits, including improved gut health and immune function (Muzzarelli *et al*., 2012). Incorporating insects into the diet not only provides high-quality nutrition but also supports sustainable food production, as insect farming requires far fewer resources than traditional livestock, thus reducing environmental impact (Huis *et al*., 2013) **(Fig. 1)**.

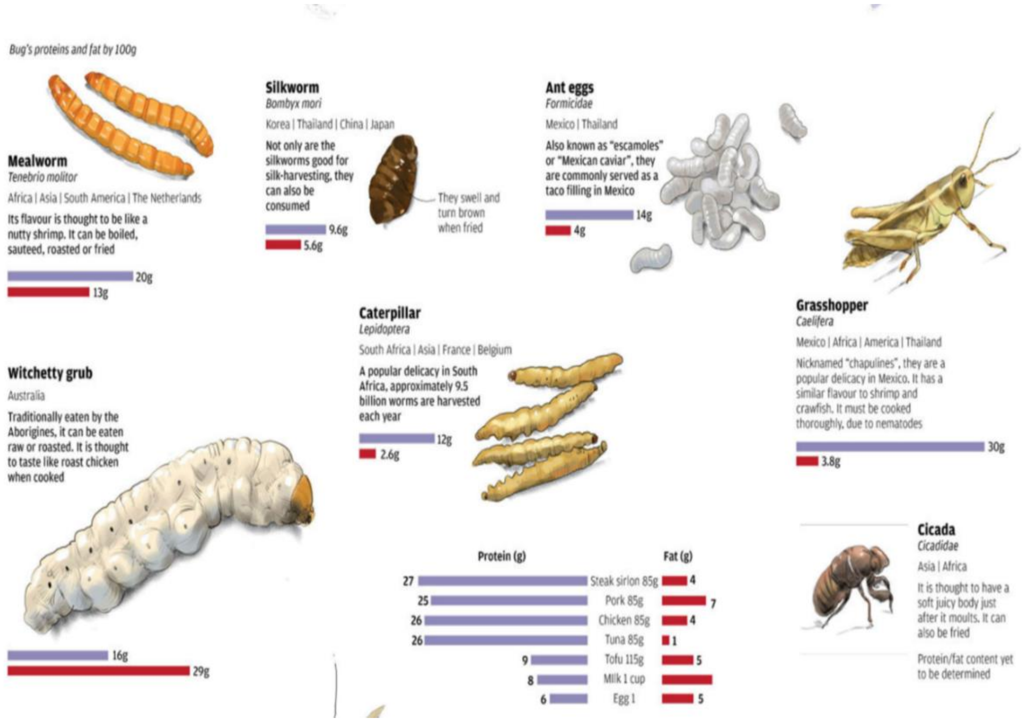

Figure 1. Nutritional benefits of Insects across the world (blog.drunkphotography.com)

Environmental Impact

The environmental impact of insect farming is notably positive compared to traditional livestock production. Insects are highly efficient in converting feed into edible biomass; for example, crickets need just 1.7 kg of feed to produce 1 kg of biomass, whereas cattle require 8 kg of feed for the same amount (Oonincx *et al*., 2015). This efficiency significantly reduces feed requirements in animal production. In addition, insect farming uses far less water and land. Producing 1 kg of cricket protein requires only 0.6 liters of water, compared to the 15,000 liters needed for beef production. Insects also produce minimal greenhouse gases such as methane and ammonia, which are major pollutants in traditional livestock farming. For instance, crickets emit about 10 times less greenhouse gas than cattle (Huis *et al*., 2013), contributing to lower environmental pollution and a smaller carbon footprint.

Waste management in insect farming is another advantage, as insects can process organic waste, like agricultural residues and food scraps, into high-quality protein. This helps reduce the burden on waste management systems, lowers landfill waste, and diminishes associated greenhouse gas emissions. Overall, the resource efficiency of insect farming, including its lower water, land, and feed use, coupled with its reduced greenhouse gas emissions and ability to process organic waste, makes insects a sustainable and viable alternative to traditional animal protein sources, supporting future food security.

Market Overview

The market for insect-based foods is expanding rapidly, driven by increasing awareness of their nutritional and environmental benefits. As of recent estimates, the global edible insect market was valued at approximately USD 1.5 billion in 2023 and is projected to grow significantly in the coming years (Grand View Research, 2024). This growth is fuelled by rising consumer interest in sustainable and alternative protein sources.

A wide range of insect-based products are now available on the market, including protein bars, snacks, and flours. Leading companies like Exo and Eat Grub are pioneering the development of innovative products that incorporate cricket flour and other insect ingredients into familiar food formats. In parallel, insect farming start-ups are emerging worldwide, aiming to scale production to meet the growing consumer demand. Insect-based foods are also gaining traction in Western markets, where there is increasing recognition of their sustainability and nutritional benefits. However, challenges such as cultural resistance and regulatory obstacles remain. Companies are working to address these barriers by educating consumers and improving product acceptance. Overall, the insect-based food market is set for significant growth as more consumers and industries embrace these sustainable protein sources, driven by environmental concerns and the search for alternative nutrition solutions **(Fig. 2)**.

Figure 2. Insect-based food products (blog.drunkphotography.com)

Consumer acceptance and Cultural barriers

Consumer acceptance of insect-based foods varies widely, primarily due to cultural norms and psychological factors. In Western countries, resistance is often driven by established food traditions and the "yuck" factor (Kosonen, 2022). However, as interest in sustainable protein sources grows, acceptance is expected to increase (Sogari *et al*., 2019). Key factors influencing acceptance include risk perceptions, knowledge, and food neophobia. While insects are commonly accepted as animal feed, their acceptance as human food is hindered by disgust and safety concerns (Pakseresht *et al*., 2023). Research also shows that visual cues play a significant role; realistic images of insects can increase disgust, while less realistic ones may reduce it and enhance taste expectations, influencing purchase intent (Hémar-Nicolas *et al*., 2024).

Additionally, the legal status and consumer acceptance of edible insects vary across countries, influenced by geographical locations, cultural backgrounds, and safety concerns (Siddiqui *et al*., 2023). Processing technologies are being explored to enhance safety, shelf life, and sensory properties of insect-based products to overcome these barriers (Baigts-Allende and Stathopoulos, 2023).

Conclusion

Entomophagy, the practice of consuming insects, presents a sustainable and nutritious alternative to conventional animal proteins. While it has been a staple in the diets of many cultures for centuries, its acceptance in Western markets is hindered by cultural norms and psychological barriers. However, growing awareness of the environmental and health benefits of edible insects is gradually shifting perceptions. Overcoming resistance requires enhancing consumer education, developing appealing insect-based products, and addressing safety concerns. As these efforts progress, insects have the potential to significantly contribute to a more sustainable and secure global food system.

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Infestation index and damage rating scale for bondar's nesting whitefly (*Paraleyrodes bondari* Peracchi) infestation in coconut plantations in southern Tamil Nadu

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Abstract

Surveys were conducted at fortnightly intervals in major coconut gardens across the southern districts of Tamil Nadu, including Thoothukudi, Tenkasi, Tirunelveli, and Kanyakumari, from December 2020 to October 2021, to assess the intensity of damage caused by the whitefly complex in coconut. *Paraleyrodes bondari* Peracchi, commonly known as Bondar's Nesting Whitefly, poses a significant threat to coconut crops, affecting both yield and overall plant health. During the study a comprehensive Damage Rating Scale was tailored for the assessment of Bondar's Nesting Whitefly infestation in coconut crops. In Thoothukudi district, *P. bondari* infestation was generally low, except during early December 2020 and March 2021, when the infestation index ranged from 1.01 to 2.00. Tenkasi district saw the infestation index peak at 1.06 in early August 2021, with a low of 0.54 recorded in late July 2021. In Tirunelveli district, the infestation index varied from 1.38 in early December 2020 to 0.14 in late October 2021, while Kanyakumari district reported the highest infestation index of 1.54, categorizing it as medium. This scale aims to provide a standardized and practical tool for growers, researchers, and agricultural practitioners to quantify the extent of damage caused by this particular pest.

Keywords: Bondar's nesting whitefly, damage rating scale, Woolly wax nests, Sooty mold

Introduction

The initial description of Bondar's nesting whitefly, *Paraleyrodes bondari*, stemmed from a male holotype specimen discovered on a citrus plant in Brazil by Peracchi in 1971 (*Peracchi, 1971*). For several years, it remained documented exclusively within the Neotropics.

Recently, however, it has expanded its range beyond the Neotropics, causing damage to crops such as cotton (*Gossypium sp*.), custard apple (*Annona reticulata*), citrus (*Citrus limon*), coconut (*Cocos nucifera*), and banana (*Musa paradisiaca*), leading to decreased yields. Unlike most other genera of whiteflies, the taxonomic classification of the genus *Paraleyrodes* primarily relies on the anatomical features of adult male reproductive organs (Stocks, 2012).

The adult *P. bondari* measures approximately 0.95 mm in length, displaying a powdery white hue and featuring a distinctive "X" pattern on its forewing, covered thinly in powdery substance across its wings and body. Females of *P. bondari* possess four articulated antennal segments, while males have three, as documented by Stocks and Hodges (2012). *P. bondari* was first discovered in India in 2018, identified on coconut trees (*Cocos nucifera* L.) in Kerala and the Andaman Islands (Joseph Rajkumar *et al*., 2019; Vidya *et al*., 2019). Subsequently, it was found on 25 host plants across 19 families, including plantation crops, fruits, vegetables, spices, tubers, tree species, ornamental plants, and weeds (Suriya *et al*., 2024). It was also observed feeding on cotton in Tamil Nadu (Sadhana *et al*., 2021). Currently, *P. bondari* has proliferated significantly in the Indian states of Kerala, Tamil Nadu, Karnataka, and West Bengal (Chandrika *et al*., 2019; Vidya *et al*., 2019; Suriya *et al*., 2023; Sankarganesh and Kusal, 2021).

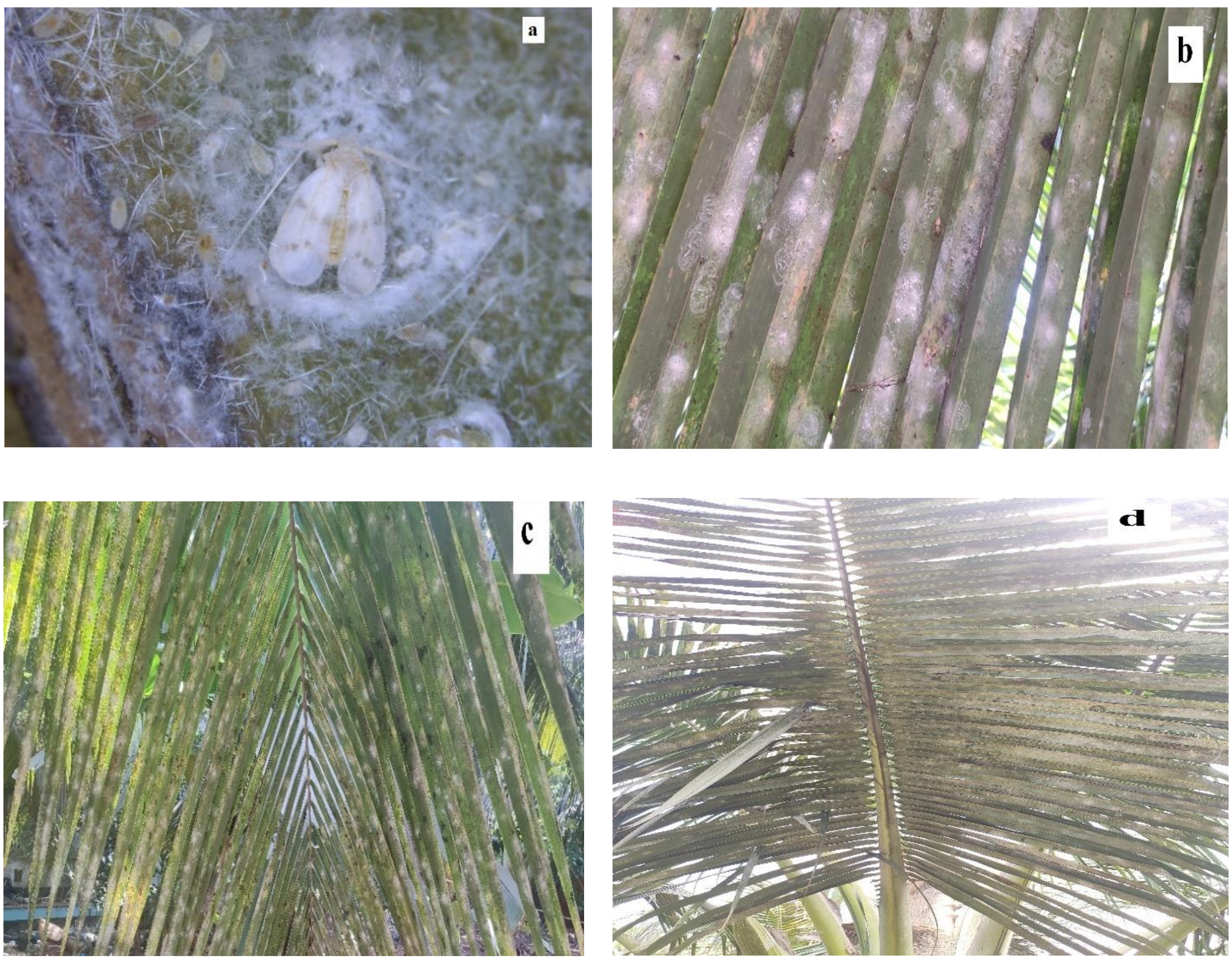
Coconut is an important plantation crop in India. Recently, the Bondar's nesting whitefly has emerged as an invasive pest, severely affecting coconut plants and reducing yield. Until now, no damage rating scale has been developed for Bondar's nesting whitefly. Only Raguteja et al. (2022) have proposed a scale, but it focused solely on adult insects. In this study, we have included woolly wax nests and sooty mold encrustation to create a more accurate damage rating scale for Bondar's nesting whitefly. This scale will be crucial for implementing effective management practices, which is the primary objective of this study

Materials and Methods

The Damage Rating Scale was developed through extensive field surveys conducted at fortnightly intervals across various coconut plantations in the southern districts of Tamil Nadu, including Thoothukudi, Tenkasi, Tirunelveli, and Kanyakumari, from December 2020 to October 2021. These surveys encompassed various stages of infestation severity and were validated through controlled experiments. Various parameters, including woolly wax nests and sooty mold, were considered to establish a comprehensive and nuanced grading system.

In this study, the scale was developed by modifying the damage rating scale by *Srinivasan et al.* (2016) for the rugose spiraling whitefly (*Aleurodicus rugioperculatus* Martin) in coconut. The infestation index was calculated based on the number of woolly wax nests per leaflet and sooty mold encrustation on the third or fourth frond from the bottom of the tree, focusing on the 5th, 10th, 15th, 25th, 30th, 35th, 40th, 45th, and 50th leaflets. This approach ensures that the population spread within the frond is taken into consideration. A total of 20 coconut trees were randomly observed diagonally in a garden to finalize the grades. The following formula was used for determining the level of infestation in the coconut garden:

$$\text{Infestation Index} = \frac{(\text{No. of palms under scale } 0 \times 0) + (\text{No. of palms under scale } 1 \times 1) + (\text{No. of palms under scale } 3 \times 3)}{\text{Total no. of palms observed}}$$



Srinivasan *et al.* (2016)

Fig. 1. a- adult present inside woolly wax next, b- less than 10 woolly wax nests, c- 10-20 woolly wax nests, d- more than 20 woolly wax nests.

Results and Discussion

Scale Description:

The Damage Rating Scale consists of a range from 0 to 3, with 0 representing no observable damage and 3 indicating severe infestation with detrimental effects on coconut crop health. Each numerical grade corresponds to specific visual and physiological indicators, allowing for a quick and accurate assessment of the pest's impact.

No. of woolly wax nests	Grade	Category	Infestation Index
No. of woolly wax nests/ leaflet and sooty mould encrustation noticed	0	Nil	0.0
Fewer than 10 woolly wax nests/ leaflet; presence of sooty mould encrustation in 5-6 lowermost fronds	1	Low	0.01-1.00
10 to 20 woolly wax nests/ leaflet; presence of sooty mould encrustation in 10-12 fronds	2	Medium	1.01-2.00
More than 20 woolly wax nests/ leaflet; presence of sooty mould encrustation in more than 12 fronds	3	High	2.01-3.00

In Thoothukudi district, *P. bondari* infestation remained low, except for the first half of December 2020 and March 2021, where the infestation index ranged from 1.01 to 2.00 with a damage rating of 2. In Tenkasi district, the infestation index peaked at 1.06 with a damage rating of 2 in early August 2021, while the lowest was 0.54, damage rating 1, in late July 2021. In Tirunelveli district, the infestation index was 1.38 with a damage rating of 2 in early December 2020, dropping to 0.14 and a damage rating of 1 by late October 2021, indicating low to moderate infestation levels. In Kanyakumari district, the highest recorded infestation was 1.54 with a damage rating of 2, falling under the medium infestation category.

The scale is designed to be user-friendly, making it accessible to farmers, extension workers, and researchers alike. Its application will aid in early detection of infestations, guide appropriate intervention strategies and contribute to the overall management of Bondar's Nesting Whitefly in coconut cultivation.

Conclusion:

This study presents the first comprehensive Damage Rating Scale for Bondar's Nesting Whitefly (*Paraleyrodes bondari*) in coconut plantations. By incorporating factors such as woolly wax nests and sooty mold encrustation, this scale provides a more accurate assessment of infestation severity. The results demonstrate varying levels of infestation across different districts, highlighting the need for localized management strategies. The developed scale will serve as a valuable tool for growers, researchers, and agricultural practitioners, facilitating effective pest management and ultimately contributing to the sustainability of coconut cultivation.

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First record of the rhinoceros beetle, *Oryctes rhinoceros* (l.), as a cob feeder in maize (*Zea mays* L.) in Dindigul, Tamil Nadu, India

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Maize (*Zea mays* L.), a globally significant cereal crop belonging to the family Poaceae, is widely cultivated across tropical, subtropical, and temperate regions. It serves as both a staple food and feed crop. India is one of the major producers of maize, with an annual production of 31.65 million tonnes from 9.6 million hectares of cultivation area (Directorate of Economics and Statistics, 2022). Among the Indian states, Karnataka, Madhya Pradesh, Bihar, Andhra Pradesh, and Tamil Nadu contribute significantly to maize production. Tamil Nadu, in particular, is noted for dual-purpose maize cultivation (grain and fodder), with Erode, Salem, Namakkal, and Coimbatore districts being prominent producers (Ganesan *et al*., 2020).

Despite its economic importance, maize production is heavily affected by biotic and abiotic stress factors, with insect pests posing a significant challenge. Globally, over 130 insect pest species infest maize, of which more than 80 have been recorded in India. Major pests include the maize stem borer (*Chilopartellus*), pink stem borer (*Sesamia inferens*), and the invasive fall armyworm (*Spodoptera frugiperda*), which has caused severe foliage damage in recent years (Sharma and Dhillon, 2009; Day *et al*., 2017).

The rhinoceros beetle (*Oryctes rhinoceros* Linnaeus) (Coleoptera: Scarabaeidae) is a well-known pest of palms such as coconut and oil palm in tropical and subtropical regions, causing substantial economic losses. This pest is also reported on sugarcane, banana, and arecanut, where it typically infests tender tissues, seedlings, and stems during critical growth stages (Bedford, 2014).

During a pest survey conducted in maize fields in the Kendaya Goundanur village of Reddiyarchatram block, Dindigul district, Tamil Nadu (Latitude: 10.499967, Longitude: 77.897005), we observed the incidence of *O. rhinoceros* feeding on maize cobs. This is the first documented case of rhinoceros beetle as a pest of maize.

The beetles were found feeding on the inner core (central rachis) of the cob, entering from the base and progressing toward the tip. While they did not directly consume grains extensively, damage to grains occurred as they tunneled through the cob. This infestation was localized, as it was not observed in all surveyed fields.

Given the adaptability of *O. rhinoceros*, there is potential for it to become a minor or major pest of maize under favourable conditions. Manikandan and Rengalakshmi (2023a) similarly reported tropical fire ants (*Solenopsis geminata*) infesting moringa flowers in Dindigul. Such occurrences highlight the potential for alternate hosts to support pest survival. Previous studies have documented alternate host plants aiding the persistence of pests like hadda beetles, sesame leaf webbers, and mango leaf-twisting weevils (Saravanaraman *et al*., 2016; Manikandan *et al*., 2019; Isaianbu and Manikandan, 2020; Manikandan *et al.*, 2022; Manikandan and Rengalakshmi, 2023b; Manikandan *et al*., 2024; Gavas Ragesh *et al*., 2024).

Figure 1. Rhinocerous beetle infesting maize cob

Figure 2. Tunneling in the maize cob due to Rhinocerous beetle infestation

Summary

Maize, a crucial global cereal crop, is facing emerging threats from insect pests like *Oryctes rhinoceros*, traditionally known to infest palms. Recent surveys in Tamil Nadu have revealed this beetle infesting maize cobs, marking its first documented case as a maize pest. To understand the impact and manage this new threat, year-round surveys are planned in the affected regions. These efforts aim to develop sustainable management practices to safeguard maize cultivation and ensure the crop's resilience against such pest infestations.

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First report of a hitherto unknown larval food plant for the Nilgiri Tiger, *Parantica nilgiriensis* (Moore, 1877) (Lepidoptera: Nymphalidae) from the Western Ghats part of Kerala, India

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On March 19, 2023, during a survey of Mathikettanshola National Park in the Idukki district of Kerala, we observed a substantial number of Nilgiri Tiger butterflies (*Parantica nilgiriensis* (Moore, 1877)) fluttering through the shola forests. One female butterfly was notably seen congregating around a climber, laying eggs on its tender leaves. Upon closer inspection, we identified at least three yellowish-green eggs attached to the leaves.

Identification of the Larval Food Plant

This climber is widely distributed in the shola forests, which support a healthy population of these butterflies; we counted more than eight Nilgiri Tigers in the surveyed area. With the assistance of plant taxonomists, we identified the plant as *Ceropegia bulbosa*, commonly known as Bulbous Ceropegia, which belongs to the Apocynaceae family. The plant is widely distributed in the Western Ghats, particularly in the southern and central parts.

Nilgiri Tiger Butterfly

The Nilgiri Tiger (*Parantica nilgiriensis* (Moore, 1877)) is a rare and endemic butterfly species in the Nymphalidae family. It is predominantly found in the higher elevations of the Western Ghats, extending from Kudremukh in Karnataka to the Agasthyamalai hills in Tamil Nadu, typically above 900 meters (Gaonkar, 1996; Kunte et al., 2024). This butterfly primarily feeds on plants such as *Tylophora indica* and *Tylophora flexuosa*, which are both part of the Apocynaceae family (Nitin et al., 2018).

New Addition to Larval Food Plant List

The current observation represents a new addition to the larval food plant list for the Nilgiri Tiger butterfly within the Western Ghats.

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Thomas College, Pala, for his assistance in identifying the plant species.

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INSECT LENS

Fiery emperor (Family: Aeshnidae)

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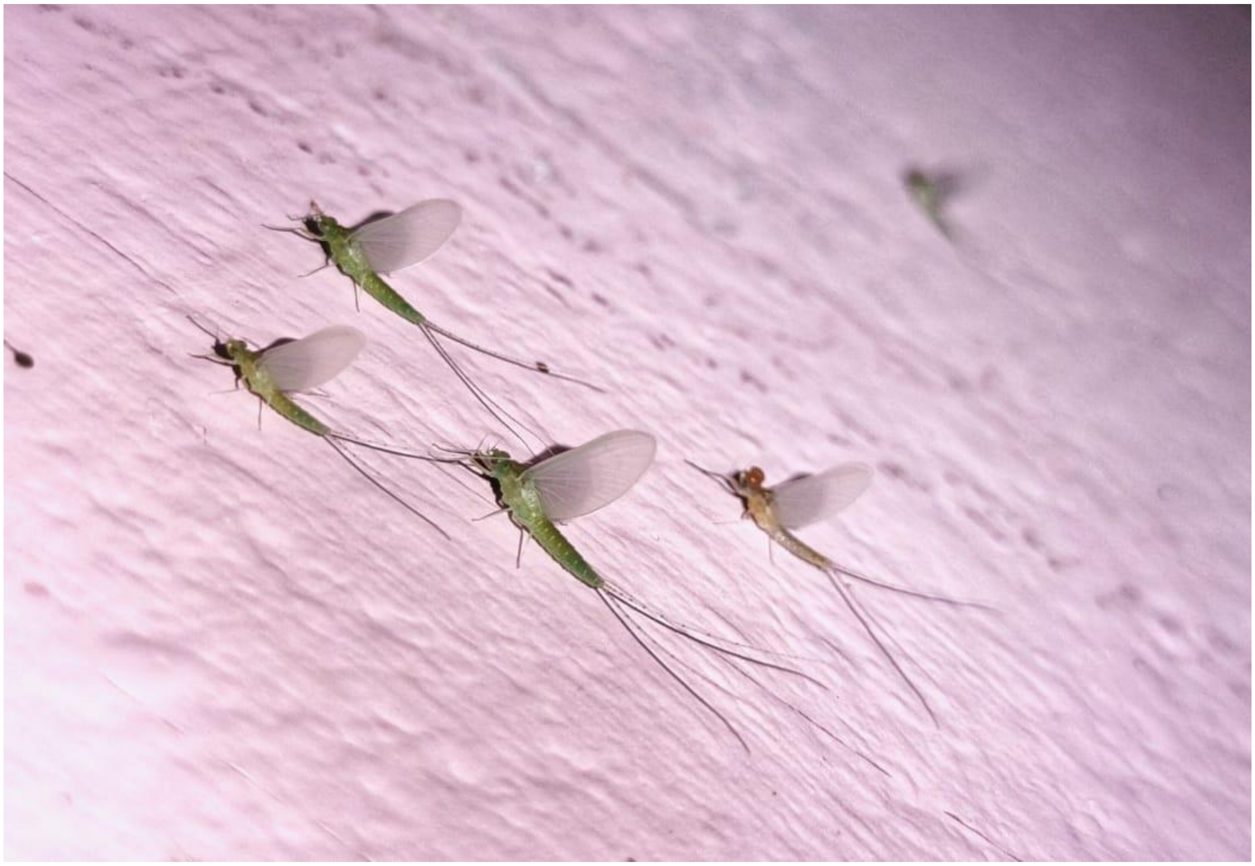

Mayflies (Order Ephemeroptera)

Author: *Dr Raja Ramesh*

Location: *Thanjavur, Tamil Nadu, India*

Tussock hairy caterpillar, Euproctis spp. on ber
Author: *Dr. Sandeep*

Location: *Ludhiana, India*

Genus: Nephele *(Host Karonda)*

Author: *Dr. Rani A.T.*

Location: *Central Horticultural Experiment Station, Chethalli, Karnataka, India*

Cantao ocellatus

Author: *Francis MVI*

Location: *Nedumkandam, Idukki (Dist), Kerala, India*

Dragon fly laying eggs

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

Asian Citrus Psyllid, Diaphorina citri (Hemiptera: Liviidae)

Author: *Dr. Sevgan Subramanian*

Location: *Singampunari, Tamil Nadu, India (September 2024)*

Email: *ssubramania@icipe.org*

Oriental Long headed Grasshopper - Acrida cinerea (Acrididae: Orthoptera)

Authors: *Gopika, K and Dharani Priya, N*

Location: *PGP College of Agricultural Sciences, Namakkal.*

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Blister beetle - Hycleus pustulatus (*Meloidae:Coleoptera)*

Authors: *Gopika, K and Dharani Priya, N.*
Location: *PGP College of Agricultural Sciences, Namakkal.*
Email: *kaliyappangopika@gmail.com / dharanipriya1123@gmail.com.*

Red paper wasp–Ropalidia marginata (Vespidae: Hymenoptera)

Authors: *Gopika, K and Dharani Priya, N.*
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Preying mantis: Mantis religiosa

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AVIAN TRUST AWARDS 2024

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Dr. K.C. Narayanaswamy, Registrar at UAS, GKVK Bengaluru, honored with the Outstanding Sericulture Researcher Award for his distinguished career in sericulture

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పురుగుపట్టని పంట కోసం...

ఇంట్లో ఏడాదికి సరిపోయే పప్పులు గతంలో నిల్వ చేసుకునేవాళ్లం. ప్రస్తుతం నెలకోసారి తెచ్చుకున్నా... రోజుల్లోపే పురుగుపడుతున్నాయి. ఈ సమస్యకు మూలాల్ని పసిగట్టిందీ పరిశోధకురాలు. సాగు నుంచే పరిష్కారం ఇచ్చేలా పరిశోధనలతో రసాయన ఎరువుల వినియోగం నుంచి పెస్ట్ మేనేజ్‌మెంట్ పద్ధతుల వైపు రైతును నడిపిస్తోందీమె. సురక్షితమైన, విష అవశేషాలు లేని దిగుబడి వచ్చేలా కృషి చేస్తున్న డాక్టర్ రష్మి స్ఫూర్తి కథనమిది.

'వాతావరణాన్ని తట్టుకొని, పర్యావరణానికి అనుకూలంగా ఉండేలా పంటకు అవసరమయ్యే చికిత్సనివ్వాలనేదే లక్ష్యం' అని చెప్పే డాక్టర్ రష్మిది బెంగళూరు. వ్యవసాయ కుటుంబం నుంచి వచ్చిన ఈమెకు రైతులకెదురయ్యే సవాళ్లు తెలుసు. ఇదే వ్యవసాయరంగంపై ఆసక్తిని పెంచింది. బెంగళూరు అగ్రికల్చరల్ యూనివర్సిటీలో ఎమ్మెస్సీ, పీహెచ్‌డీ చేసింది. మొక్కల సంరక్షణ, కీటకాల శాస్త్రానికి సంబంధించి పరిశోధనలెన్నో చేపట్టింది. 'మినిస్ట్రీ ఆఫ్ ప్లాంట్ ప్రొటెక్షన్'తో కలిసి పనిచేసి నైపుణ్యాలను మెరుగుపరుచుకుంది.

విష అవశేషాలు...

'పంట ఉత్పత్తిలో కీటకాల తెగుళ్లవల్ల రైతులకెన్నో సవాళ్లు ఎదురవుతుంటాయి. పంట పండేలోపే తెగుళ్లబారిన పడి దిగుబడిలేక, పెట్టుబడి కూడా నష్టపోతుంటారు. రసాయన ఎరువులతో తెగుళ్లను నివారించాలనే పద్ధతి హానికరమైన ఫలితాన్నిస్తోంది. ఇలా పండించిన ఉత్పత్తులూ... విషపూరితమవుతున్నాయి. వీటిని వినియోగించేవారికే కాకుండా, పర్యావరణ వ్యవస్థకూ ఇవి హాని కలిగిస్తున్నాయి. అలాకాకుండా పర్యావరణంపై చెడు ప్రభావం చూపని, అవశేషాలు లేని పరిష్కారాన్ని అందించాలని 2022లో 'ఇంటర్నేషనల్ ఫైటోశానిటరీ రీసెర్చ్ అండ్ సర్వీసెస్ (ఐపీఆర్ఎస్)' స్టార్టప్ స్థాపించా. దీనిద్వారా వాతావరణాన్ని తట్టుకోగలిగేలా, అలాగే పర్యావరణానికి అనుకూలమైన అత్యాధునిక మొక్కల రక్షణ సాంకేతికతలను అందించడమే లక్ష్యంగా పెట్టుకున్నా. పప్పు ధాన్యాలలో నిల్వ ఉండే తెగుళ్లకు అవశేషాలు లేని, పర్యావరణానికి అనుకూలంగా ఉండే పరిష్కారాలను కూడా అందించాలనుకున్నా' అని చెబుతుంది రష్మి.

ఆహార భద్రత...

నిల్వచేసిన కొద్ది రోజులకే పప్పు ధాన్యాలకు పురుగు పడుతుంటుంది. దీనికి కారణమైన తెగుళ్ల అవశేషాలను నియంత్రించే పరిష్కారాన్ని అందిస్తోంది రష్మి. బఠాణీ, నల్ల శనగలు వంటివి పండించేటప్పుడు వచ్చే తెగుళ్లను ప్రాథమిక దశలోనే రసాయనరహిత స్ప్రేల ద్వారా దూరం చేస్తోందీమె. 'దీంతో పంటలో ఎటువంటి విషపూరిత అవశేషాలూ ఉండవు. కాలక్రమేణా పురుగు కూడా పట్టదు. అలాగే ఈ స్ప్రేలు వాడుకలో ఉన్న పురుగుల మందుల్లా పర్యావరణంపై చెడు ప్రభావాన్నీ కలిగించవు. ఆహార భద్రతనూ మెరుగుపరుస్తాయి. అలాగే ద్రవరూప క్రిమిసంహారక మందులనూ అభివృద్ధి చేశాం. తెగుళ్ల సంబంధిత సవాళ్లను ఎదుర్కోవడానికి రైతులకు సమర్థవంతమైన సాధనాల్లా వీటిని అందిస్తున్నాం. మామిడి, జామ, దానిమ్మ, ద్రాక్ష తదితరపంటల్లోనూ తెగుళ్ల నివారణ, మంచి దిగుబడిపై రైతులకు అవగాహన కలిగిస్తున్నాం. ఈ పరిశోధనలన్నింటికీ ఆర్థికంగా ప్రభుత్వ సంస్థలు, ఐఐటీ ముంబయివంటివి నిధులు అందిస్తున్నాయి' అంటోంది రష్మి. 'ప్లాంట్ హెల్త్ క్లినిక్' పేరుతో వేలమంది రైతుల సమస్యలను పరిష్కరించడంలో పరిశోధకులు, శాస్త్రవేత్తలూ ఈమెతో కలిసి పనిచేస్తున్నారు. పంట తెగుళ్లను పరిశీలించి, క్రిమిసంహారక మందుల సూచనతోపాటు రైతులకు విద్యాకార్యక్రమాలు, వినూత్న మార్కెటింగ్ విధానాల పేరిట శిక్షణ వంటివన్నీ ఈమె అందిస్తున్నారు.

రష్మి

Date : 10/12/2024 EditionName : ANDHRA PRADESH PageNo :

Dr. Rashmi's remarkable contributions to non-toxic crop production and eco-friendly pest management were highlighted, in an inspiring article published on 10th December 2024 in Eenadu newspaper (Page 9).

Krishi Mela, 14th to 17th November 2024 (Agriculture Fair) at University of Agricultural Sciences, GKVK, Bangalore. Siddaganga Incubation Foundation provided market access support to its incubatees, enabling them to showcase and promote their products to farmers and potential customers. Rashvee IPRS displayed our products at the Siddaganga Incubation Foundation stall, where we are currently incubated.


SIDDAGANGA
INCUBATION FOUNDATION
A PLACE TO NURTURE YOUR IDEA INTO MARKET READY PRODUCT
Portfolio support

Agriculture Future Forward: Agri Startup Conclave 2024 held at the University of Agricultural Sciences (UAS), GKVK Bengaluru. Rashvee International Phytosanitary Research Services (R-IPRS) had the honor of participating in this prestigious event.


MICROBIOLOGY (UASB)
ENLIGHT AGROTECH INDIA PVT LTD
Non-insecticidal, Climate Resilient Multi Fruit Fly (Bactrocera sp.) Species Liquid Lure
Developed under BIRAC, DBT, GoI


Rashvee Herbal Liquid Soap Adjuvant/Spray wash/Spreader
Developed under BIRAC, DBT, GoI
AGRICULTURAL MICROBIOLOGY (UASB)

Rashvee International Phytosanitary Research Services (R-IPRS) featured in an interview by Doordarshan Chandana at the Agriculture Future Forward: Agri Startup Conclave 2024 held at University of Agricultural Sciences (UAS), GKVK.

Rashvee IPRS was featured in an interview by Doordarshan Chandana, which was telecasted on Krishi Darshana on December 6, 2024. You can click on the link to view the interview: Krishi Darshana - Doordarshan Chandana.
https://youtu.be/cmBHQwcPFZA?si=mUH-Cj9lxpooYINg

Collaboration for Innovation: Wide Mobility Team and Rashvee IPRS

Rashvee IPRS team participated in the Exporters Conclave and Buyer-Seller Meet at the KAPPEC Integrated Cold Chain Facility, Poojenahalli Horticulture Farm, near Kempegowda International Airport, Bengaluru.

It was an honor to engage with KAPPEC Karnataka MD Dr. Shivakumar, RPQS, Joint Director Dr. D. K. Nagaraju, and Dr. Dharma Rao, Regional Head, APEDA while visiting the hot water treatment facilities, developed by Dr. Abraham Verghese and his team at ICAR-IIHR

Rashvee team participated in awareness session on Karnataka Biotechnology Policy 4.0 (2024-2029), organized by Siddaganga TBI Siddaganga Incubation Foundation at Siddaganga Institute of Technology Dr. M A Rashmi with Ms. Parnika Pavanram, KAS, General Manager (Biotechnology & ESDM Policy), Karnataka Innovation and Technology Society (KITS), Govt of Karnataka.

Rashvee team participated in National Agri Startup Expo (NASE) 2024 at UAS, Dharwad on 28th December 2024

Rashvee team participated in National Agri Startup Expo (NASE) 2024 at UAS, Dharwad on 28th December 2024

Dr Rashmi explaining about Rashvee products to Dr. PL Patil, Vice-Chancellor, UAS, Dharwad at NASE 2024