Volume 27 (3) September 2024

ISSN 0975-1963

# Insect Environment

*Quarterly Journal*

**Not-for-profit journal promoting Insect Science**

Articles with DOI

NAAS Rating 3.53

*Abstract/ Full text uploaded in*

CABI Google Scholar Crossref ResearchGate ZooBank

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

**Published by**

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

**Supported by**

**International Phytosanitary Research & Services (IPRS), Bengaluru**

**Shree Nidhi Agrochemicals, Vijayapura, Devanahalli Bengaluru Rural**

***Cover Page:**
**Blue Tiger, *Tirumala sp.***
**Photo by Dr. M. A. Rashmi**

# Insect Environment

**(Quarterly journal to popularize insect study and conservation) ISSN 0975-1963**

**NAAS Rating 3.53**


**The first issue of Insect Environment was published in 1996. The sole objective of Insect Environment is to popularize insect study through popular, semi-technical and technical research notes, extension notes for managing insect pests, photographs, short blogs and essays on all aspects of insects. The journal is published quarterly, in March, June, September, and December.**

**Insect Environment subscription is free**; articles can be downloaded from the website https://insectenvironment.com/ For regular updates, blogs and the journal, upload your mail ID on our website. THERE IS NO SUBSCRIPTION FEE.

Those who wish to promote insect science and conservation are welcome to send a sponsorship fee to AVIAN Trust

Bank details are as follows:

Bank Name: Federal Bank

Bank A/C: 11040100351959 Bank IFSC: FDRL0001104

Swift code: FDRLINBBIBD

**Author guidelines**

**Short popular insect notes, review essays, new records, profiles, tributes, and views are acceptable. There are no page charges; each article should preferably not exceed 500 words. Authors can refer to back volumes available on the website for writing style. Good photographs are encouraged. A special insect photo gallery "Insect Lens" is to encourage professional and amateur photographs of insects. These will be published in the quarterly *Insect Environment*. The blogs are for quick dissemination of insect "news". These will be uploaded within a month of submission and will be on the website. Blogs should be about a hundred words with one photograph, in simple English.**

**This journal is unique in that it encourages articles from students to amateurs to professionals! It is hosted in CABI (as full text) and ZooBank, Indian Abstracts, Research Gate, Google Scholar etc. ensuring global coverage. Scientific articles are assigned DOI.**

Mail your papers/notes/queries/photos related to *Insect Environment* to *einsectenvironment@gmail.com*

## Contents

### Volume 27 (3) September 2024

# IE Blog Contents

# EDITORIAL

## *Insect Environment is "BECAUSE OF INSECTS"!*

As I write this editorial now, central Europe is highly flooded. I am reminded of the mountains and valleys of Serbia where we hiked and enjoyed the landscape which are all under waters. Hope Serbia and the adjoining countries soon come out of this.

In the last quarter, climate change has made significant headlines around the globe. For the first time, climate change led to the execution of 30 officials in North Korea, where thousands of people died due to floods, and officials were made scapegoats. The fury of the floods has been widespread in India, with Wayanad in Kerala bearing the maximum brunt. It is time to regulate tourism and plantation expansion in the Western Ghats. As an important biodiversity hotspot, the balance among fauna and flora is indeed delicate. The maximum impact will certainly be on diverse insect species. Natural history and ecological studies in these geographical areas should be heightened, focusing on insect diversity and survival.

As a team, we gathered information that many species, especially the rock bee (*Apis dorsata*), were destroyed in Wayanad, Kerala, not to mention of myriads of flying and ground-dwelling insects. *Apis dorsata*, commonly known as the giant honey bee, plays a crucial role in pollination and maintaining ecological balance. The destruction of their colonies can have significant repercussions on local biodiversity and agriculture. The floods seemed to revive some insect populations, with swarms of dragonflies being reported, in flood-hit Andhra Pradesh and a team of entomologists is investigating this phenomenon. Dragonflies are known bioindicators, meaning their presence and population dynamics can provide insights into the health of the ecosystem. The sudden increase in dragonfly populations could be attributed to the abundance of stagnant water bodies created by the floods, which serve as ideal breeding grounds for their larvae.

We are pleased to report that some of our blogs on plant health interventions, especially on whitefly in tomato, fruit and shoot borer in brinjal, and mite on mulberry, have caught the attention of many policymakers. The ***Insect Environment*** website therefore, has been experiencing millions of hits globally.

I am happy to state that Dr. S.N. Sushil and the Association for Advancement of Pest Management in Horticultural Ecosystems have released my fourth book titled "***Because of Insects***." This book is both autobiographical and a collection of editorials that I have written over the last three decades in ***Insect Environment***. The stimulus to write and compile this book came from my co-editor, Dr. M.A. Rashmi, and my editorial team, including Dr. S. Deepak, Ms. Salome, and Ms. Pratika, provided valuable support to Dr. Rashmi and Mahi Publications. The book is available on Amazon, and in this issue, we are including reviews of the book. I am grateful to the reviewers. ***Insect Environment*** and AVIAN Trust was invited to participate and present lectures, both offline and online, by several universities and institutions. In the last week of September 2024, we presented two papers on new paradigms in fruit fly management and on export protocols for fresh horticultural products for pests and diseases at International Conference on Plant Protection in Horticulture (ICPPH-2024) - Advances and Challenges.

In this issue, we have included very interesting research notes from Indonesia, Sri Lanka, Senegal, and other countries. We are grateful to CABI for uploading full texts and further disseminating our authors' research findings. In fact, ***Insect Environment*** is technically run because of its highly competent authors.

During this quarter, we are saddened to report the loss of two eminent entomologists, Dr. S. J. Rahman, a distinguished scientist and Senior Professor of Entomology at the Professor Jayashankar Telangana State Agricultural University in Hyderabad and C.A. Jayaprakas, a former Principal Scientist at the ICAR-Central Tuber Crops Research Institute (ICAR-CTCRI), Sreekaryam, Trivandrum, Kerala, both great supporters of ***Insect Environment.***

It is with a great sense of humbleness that we present this issue to the entomology fraternity at large.

Dr Abraham Verghese

*Editor-In-Chief*

# *Research articles*

**DOI: 10.55278/QXZD1701**

## First report of invasive nesting whitefly *Paraleyrodes bondari* Peracchi (Hemiptera: Aleyrodidae): Impact on coconut palm (*Cocos nucifera* L.) in Jaffna, Sri Lanka

**Mathula, M., Gnaneswaran, R*, Sivakalai, K., Thilaksika.V , Luckshika M. R and Arani, B**
*Department of Zoology, University of Jaffna, Jaffna, 40000, Sri Lanka*
***Corresponding author: rajig@univ.jfn.ac.lk***

**Abstract**

An invasive whitefly species *Paraleyrodes bondari* Peracchi was recorded during January 2024, for the first time in Sri Lanka. Its occurrence was observed in association with *Aleurodicus. dispersus* and *Aleurodicus rugioperculatus* and *Pseudococcus* sp. on the underside of the coconut palm leaves (*Cocos nucifera* L.) from home gardens in Jaffna district. This species is commonly known as Bondar's nesting whitefly, and is added as a new member for the coconut whitefly complex in Northern Province in Sri Lanka.

**Key words:** Bondar's nesting whitefly, Coconut Jaffna, *Paraleyrodes bondari*, Sri Lanka.

**Introduction:**

Coconut (*Cocos nucifera* L.) is an important multipurpose perennial crop of the tropics in coastal and island ecosystems (Mohri, *et.al.*, 2013). It is grown in more than 80 countries among them Indonesia, Philippines, India, and Sri Lanka are the major coconut-producing countries. Among the major challenges to coconut cultivation, pests and intracellular pathogens are the biotic threats that reduce the total production of this sector (Bourdeix, *et.al.*, 2021, Thamban, *et.al.*, 2016). Recently a complex of invasive whitefly species has become a serious threat to coconut production in Sri Lanka (Aratchige, *et al.*, 2023)

Whiteflies are very small (1–3 mm in length) bugs of the order Hemiptera and family Aleyrodidae. Adults of both sexes are winged, with the wings covered with white dust or waxy powder. They are mostly found in groups on the underside of the new leaves of their host plants. Adults cannot fly for long distances but quickly move when the plants are disturbed (Johnson and Triplehorn, 2004).

The eggs are laid singly or in groups mostly on the lower surface of the leaves. After hatching the first instar nymphs are active, and able to walk to locate suitable feeding sites. After moulting, the subsequent instars are sessile, oval and flattened with reduced legs and antennae. They look like scale insects. The last instar is called puparium because it appears morphologically different from their winged adult. But still, they actively feed on sap from the leaves and excrete honeydew (Martin, 2004).

Whiteflies damage their host plant by removing plant sap from the phloem, vectoring plant pathogens and enhancing black sooty mold fungus growth on the upper surface of the lower leaves by excreting honeydew while feeding. Loss of nutrients and inhibition of photosynthesis will cause the plant to shrivel, wilt and eventually die (Brown and Czosnek, 2002). The unique structures of all aleyrodids are used in identification. (https://keys.lucidcentral.org/keys/v3/whitefly/Old/Homepage.htm).

The history of exposure of Sri Lankan whitefly fauna was initiated by Quaintance and Baker in 1917, followed by Corbett (1926), Russell (1964), David and Jesudasan (1988) and David (1993). The invasive species *Aleurodicus dispersus* was reported for the first time by Wijesekara and Kudagamage (1990) as a fast-spreading pest.

Recently, the infestation of exotic whiteflies on coconut plantations in Sri Lanka was observed in 2019 in Kegalle district (Aratchige *et al.*, 2023), and then it spread to other districts in the wet and intermediate zones. Four species, namely *Aleurodicus rugioperculatus* Martin (Rugose Spiraling Whitefly, RSW), *Aleurodicus dispersus* Russell (Spiraling Whitefly, SW), *Paraleyrodes minei* Laccarino (Neotropical Nesting Whitefly, NW), and *Aleurotrachelus atratus* Hempel (Palm infesting whitefly), were reported as severe damage-causing pests on coconut, after the intensive survey (2019-2022) carried out by the Coconut Research Institute, Sri Lanka, in Gampaha, Colombo, Kegalle, Kandy, Kalutara, Galle, Matara, Putalam, Kurunagala, Matale, Hambantota, and Badulla districts but no incidence was reported from Northern Province up to 2022 (Aratchige *et. al.*, 2023; Karunarathne, *et. al.*, 2023; Madushani and Srisena, 2024).

During January 2024, whitefly invasion in the Northern Province was noticed on coconut trees by personal observation in one of the author's home garden (9°41'55.1"N 80°03'23"E) in Jaffna. Furthermore, complains were received from growers about infestations in their home garden and estates.

As the first step to planning for management strategies, the identification of the species of whiteflies and their distribution in the Jaffna district was explored through the field sample studies across different locations in Jaffna.

## Materials and methods

A field survey was carried out to collect whitefly samples from infested coconut trees in different locations (Table: 1) of Jaffna District from January to May 2024. Coconut leaflets infested with whiteflies were collected and taken to the Department of Zoology, University of Jaffna, Sri Lanka. Nearby vegetation was also checked for the presence of whiteflies and their leaf samples were also collected. The morphological characteristics of puparia and the adults were used in species identity (Hodges and Evans, 2005; Martin, 2004).

Collected puparia were processed (Sirisena, *et.al* 2013) to prepare stained microscopic slide mounts and then identified based on their morphological characteristics by consulting published taxonomic keys and literature. (Martin, 2000; Martin, 2004; Josephrajkumar, *et. al.,* 2020) The adult whiteflies were also examined under a stereo binocular microscope (10x4) and their external appearances were noted and photographed for easy field identification in the future.

**Results and discussion**

Three different species of invasive whiteflies were found to have invaded the coconut palm ecosystem, in different locations of the Jaffna District (Table:1). Already two of them have been reported from the southern part of Sri Lanka, as *Aleurodicus rugioperculatus* Martin (RSW), *Aleurodicus dispersus* Russell (SW) (Aratchige, *et al.*, 2023; Karunarathne, *et.al.,* 2023; Madushani and Srisena, 2024). The third one was smaller in size (1.3 mm) than the other two, but with clear "X"-shaped oblique greyish bands on both fore wings, settled in unique woolly wax nests on the lower side of the palm leaflets **(Fig:1a).** Based on its characteristics of the puparium it was identified as Bondar's nesting whitefly (BNW), *Paraleyrodes bondari* Peracchi, (Joseph Rajkumar *et al,* 2019; Martin, 2004; Martin, *et.al.,* 2000) and is reported now for the first time in Sri Lanka. This species was present in the central part of Jaffna District **(Fig: 4).**

***Paraleyrodes bondari* Peracchi, 1971 (BNW)**

Genus *Paraleyrodes* Quaintance described by Peracchi, up to now with 17 described species, almost all from the Neotropical Region and now have been reported worldwide (Martin, *et.al*., 2000).

Adults of *Paraleyrodes* are smaller than other aleurodicines and unusual in having all wing veins unbranched. Females have four articulated segments in the antenna and males have three articulated segments. The larvae and puparia of the species of *Paraleyrodes*, secrete long waxy filaments which form an annulus surrounding the feeding nymphs (Martin, 2004).

*Paraleyrodes bondari* is one of the most invasive species, native of Brazil to Honduras, first described on *Citrus* species from Brazil in 1971 (Peracchi, 1971) and later, it was detected from Madeira in 1995 (Martin, 1996) , from Hawaii around 2003, then from Florida, USA in 2011 (Stocks, 2012), where it was considered as an emerging pest.

**Table 1: Distribution of invasive whitefly species on coconut palm in Jaffna District, recorded during the survey (January - May 2024)**

| | Locations in Jaffna District, Sri Lanka | | Host plant/s | Whitefly species |
|---|---|---|---|---|
| 1 | Nelliyady | 9°48'06.4"N 80°12'01.7"E | Coconut | RSW |
| 2 | Neerveli | 9°43'06"N 80°04'40"E | Coconut | BNW, RSW, SW |
| 3 | Kopay | 9°41'55"N 80°03'23"E | Coconut, Anona, Banana, Nelli, Curry leaves, Ambarralla, Jambu | BNW, RSW. SW |
| | | | Avacado, Cinnamon | RSW, SW |
| 4 | Kokkuvil | 9°41'53"N 80°01'04"E | Coconut | BNW, RSW |
| 5 | Thaavadi | 9°42'20"N 80°01'01"E | Coconut | BNW, RSW |
| 6 | Navali | 9°42'34.8"N 79°59'14.7"E | Coconut | RSW, SW |
| 7 | Manippay | 9°43'51"N 79°59'41"E | Coconut | BNW, RSW |
| 8 | Sandilipay | 9°44'45.2"N 79°59'13.3"E | | |
| 9 | Ilavalai | 9°47'37.7"N 79°59'24.1"E | Coconut | RSW |
| 10 | Ponnalai | 9°45'11.0"N 79°54'59.5"E | | |
| 11 | Keerimalai | 9°48'46.7"N 80°00'50.7"E | | |
| 12 | Maviddapuram | 9°48'11.1"N 80°02'09.3"E | | |
| 13 | Elalai | 9°46'15.1"N 80°02'30.6"E | Coconut | RSW |
| 14 | Kuppilan | 9°45'56"N 80°03'33"E | Coconut | BNW, RSW |
| 15 | Vasavilaan | 9°47'11.8"N 80°04'43.0"E | Coconut | BNW, RSW |
| 16 | Navakiri | 9°45'29.7"N 80°05'52.8"E | Coconut | |
| 17 | Urumbirai | 9°43'05"N 80°02'27"E | Coconut | BNW, RSW, SW |
| | | | Banana | RSW, SW |
| 18 | Irupalai | 9°41'53"N 80°02'46"E | Coconut, Temple tree | BNW, RSW |
| 19 | Kondavil | | Coconut | RSW |
| 20 | Thirunelveli | 9°41'04"N 80°01'22"E | Coconut | BNW, RSW, SW |
| 21 | Inuvil | 9°42'55.0"N 80°01'14.6"E | Coconut | RSW, SW |
| 22 | Chunnagam | 9°44'15.9"N 80°01'31.2"E | Coconut, Banana | RSW, SW |
| 23 | Mallakam | 9°45'43.6"N 80°01'55.7"E | Coconut, Banana | BNW, RSW, SW |
| 24 | Usan | 9°39'48.3"N 80°14'17.7"E | Coconut | RSW |
| 25 | Kodikamam | 9°41'27"N 80°13'23"E | Coconut | BNW, RSW |
| 26 | Chavakachcheri | 9°40'02.7"N 80°09'46.0"E | Coconut | RSW, SW |
| 27 | Manthuvil | 9°41'41.3"N 80°11'37.3"E | Coconut, Banana | RSW |
| 28 | Madduvil | 9°40'43.8"N 80°08'53.5"E | Coconut | RSW |
| 29 | Navatkuli | 9°39'27.8"N 80°05'52.5"E | Coconut | RSW |
| 30 | Kaithady | 9°41'07.9"N 80°06'24.2"E | Coconut | RSW |

**SW**- Spiralling Whitefly; **RSW** – Rugose Spiralling Whitefly; **BNW** – Bondar's Nesting Whitefly

Its first entry to the Oriental region was recorded in Taiwan during 1998, reported as pest on fruit trees (Wen and Chen, 2021) and to India since 2018 (Table 2) but its occurrence has not been noticed from Sri Lanka until this study.

**Table 2: History of invasion of *Paraleyrodes bondari* Percchi, 1771 (BNW) into old world**

| Year of invasion | Country (region) | Host plants recorded | Co- existence with other species | Reference |
|---|---|---|---|---|
| 1998 | Taiwan | Citrus and Wax-apple and other 25 species belonging to 17 families | - | Wen and Chen, 2021 |
| Dec 2018 | India (Andaman & Nicobar Islands) | *Cinnamomum verum* | | Vidya *et al*. (2019) |
| 2019 | India (Kerala) | Coconut | *A. rugioperculatus* | Josephrajkumar *et al.*, 2019 |
| 2019 | | Coconut, Banana, Anona, Avocado, Guava | *Pealius nagerkoilensis* | Vidya *et al*. 2019i |
| 2020 | India (Andhra Pradesh) | Oil palm (*Elaeis guineensis Jacq.)* Coconut | *A. rugioperculatus* | Chalapathi Rao, *et al*., 2023 |
| 2020 | India (Kerala) | Coconut | *A. rugioperculatus* | Josephrajkumar *et al.*, 2019 |
| 2020 | India (Lakshadweep islands) | Coconut, Guava, Banana, Noni, Ficus, Portia tree and unidentified plant. | | Selvaraj *et al*., 2020 |
| 2021 | India (Tamil Nadu) | Coconut | *Aleurotrachelus atratus*, *A. rugioperculatus* | Selvaraj *Et al*. 2021 |
| 2021 | India (Tamil Nadu) | Cocout, Citrus, Guvava | *A. rugioperculatus* *A. dispersus* | Sundararaj *et al*. 2021 |
| 2021 | India (Tamil Nadu) | Cotton | | Sadhana, *et al*., 2021 |
| Oct 2021 | India (West Bengal) | Coconut, Arecanut, Banana, Guava and Jack fruit | *A. rugioperculatus* | Sankarganesh & Kusal 2021 |
| 2024 (Jan) | Sri Lanka (Jaffna) | Coconut, Guava, Banana, Ambarralla, Jambu, Curry leaves, Nelli, | *A. rugioperculatus*, *A. dispersus*, *Pseudococcus sp. mealy bugs* | Present study (Mathula *et al*., 2024) |

**The adult -** The adult *P. bondari* was small sized, male 1.31 ±0.07 mm and female 1.3±0.05 mm long, dull yellow body and white wings, with unbranched veins, covered with waxy dust and clear 'X'-shaped oblique greyish markings were on forewings (**Fig: 1a**). Antenna of females 0.40 as long as body length with four articulated segments and male antenna 0.72 as long as body length with three articulated segments (**Fig:1b**).

Adults constructed unique woolly wax nests (**Fig.1c**) on the abaxial surface of leaves. It laid stalked (**Fig.1d**), clustered eggs, which turned yellow at mature (**Fig.1e**) and hatched into the first instar crawler, which found a feeding site and settled. The nymphs (**Fig.1f**) were creamy yellow and transparent with the presence of marginal hairs, the pupa was flat **(Fig.1g)** with a characteristic pattern of wax around. The aedeagus is unique and easily distinguished from other *Paraleyrodes* species, resembled rod-like with anterior and posterior horns (Martin, 2004; Vidya *et al.*, 2019) and small tooth in the inner surface of each clasper **(Fig.2a)**.

**Puparium -** Ovoid in shape, pale yellow of 0.70 ±0.10 mm length and 0.43 ±0.07 mm width **(Fig.2c)** consists the following taxonomic characteristics (Peracchi,1971; Martin, 2004). The presence of seven pairs, as one cephalic and six abdominal compound wax pores were on the dorsum. The first two pairs of abdominal pores were smaller than the others. The flower-petal- like ovoid facets of the cephalic and the posterior four larger abdominal pairs have 11-13 locula **(Fig:2d)**. These compound pores produced very long cylindrical wax rods often longer than the pupal case that forms an annulus surrounding the feeding insects **(Fig:1g).** Sub triangular shape vasiform orifice with large tongue shaped lingula that extends beyond the posterior margin of vasiform orifice. The lingula had two pairs of long and stout setae and densely covered by spinules. The operculum with a sinuous anterior margin and a pair of opercular setae, covered only half of the orifice **(Fig: 2e)**.

**Co-existence and parasitism**

In the present survey, *P. bondari* was observed to co-exist with *A. rugioperculatus*, *A. dispersus* and other mealy bugs (*Pseudococcus* sp.) in the same leaflets of the coconut palm **(Fig: 3a; Table: 1)**. The co-existence of *P. bondari* with other whiteflies was already reported in India (Josephrajkumar, *et al.*, 2019; Vidya, *et., al.*, 2019; Selvaraj, *et.al.*, 2021). This indicates the probable simultaneous introduction of both species from the New World. Co-existence of these exotic whiteflies with similar habits has to be clearly identified for further studies on their bio-ecology, natural enemies and management. Josephrajkumar, *et.al.,* (2020) pointed as the co- occurrence of *P. bondari* and *A. rugioperculatus* in favorable weather conditions reduced the pestiferous potential of *A. rugioperculatus* in Pollachi. This association of nesting whiteflies with *A.*

*rugioperculatus* not only hindered the development of whiteflies, but also encouraged higher parasitism of *E. guadeloupae* on *A. rugioperculatus*. This may be one of the competitive behaviours of *P. bondari*.

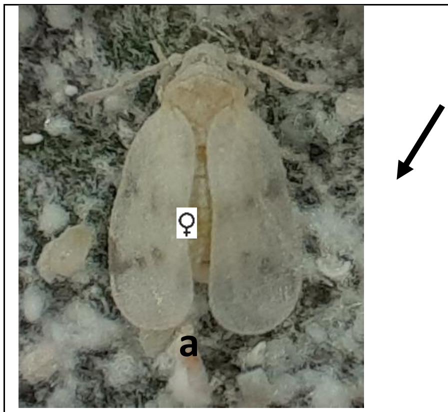
Though 40-50% natural parasitism to *A. rugioperculatus* by *Encarsia guadeloupae* was recorded during our survey **(Fig.3b),** no natural parasitism was observed on *P. bondari*. A similar observation was reported in India by Vidya, *et.al.*, 2019; Chalapathi Rao, *et al.*, 2023 & Sadhana, *et.al.*,2023. An unidentified predatory beetle larva was found to be eating the nymphs **(Fig: 3c)**. Two predatory beetle species namely *Cybocephalus nipponicus* and *Delphastus catalinae* were reported as predominant predators of *P. bondari* in cotton ecosystem in India by Sadhana, *et.al.*, (2022). Natural feeding by predator *Apertochyrsa astur was* detected by Chalapathi Rao, *et. al*., (2023) in the oil palm ecosystem in Andra Pradesh, India.

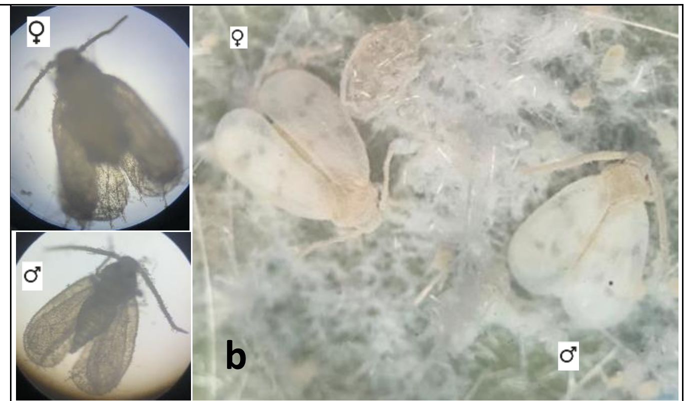
*P. bondari* is a polyphagous species that has been reported to feed and breed on more than 25 host plants mainly Banana (*Musa* spp.) Mango (*Mangifera indica*), *Citrus* spp. Cassava (*Manihot esculenta*) and Guava (*Psidium guajava*) **(Table 2)**. Another invasive species *P. minei*, closely resembles *P. bondari*, but lacks distinct markings on wings (Iaccarino, *et al.*, 2011), and constructs loosely woven woolly wax nests, females are white and males are smoky grey (Chandrika., *et al*., 2019) and has been recorded from Sri Lanka in Colombo and Gambaha districts (Aratchige *et al.*, 2023), but not detected in Jaffna during our study.

**Material studied** – *P. bondari* : 2pup, kopay 27.ii.2024; 2pup, 2♀ kopay 28.ii.2024; 3pup, 1♀Thirunelvely,06.iii.2024; 3pup 2♀ 3♂ Neervely, 7.iii.2024; 1pup.3♀ 3♂ Thirunelvely 13.iii.2024; 2 pup.1♀ 1♂ urumbirai 3.iv.2024; 2♀ 1♂ Mallakam, 3.iv.2024; 2♀,Kokuvil, 3.iv.2024; 4 pup. 2♀ 2♂ Kokuvil, 5.iv.2024; 2pup. 3♀ 2♂ Thirunelvely 6.iv.2024; 3pup. 2♀ 2♂ Thirunelveli 18.iv.2024; 3pup. 3♀ 2♂ Neerveli 18.v.2024; 3pup. 4♀ 2♂ Kodikamum 34.v.2025

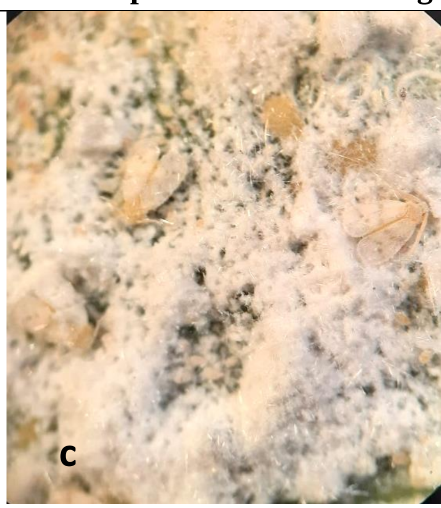
**Host plants of *P. bondari* recorded in Jaffna:** *Cocos nucifera* (coconut), *Musa sativa* (banana) *Psidium guajava* L.(Guava), *Annona muricata* (Annona), *Annona reticulate* (Annona), *Phyllanthus acidus* (nelli) *Spondias dulcis* (Ambaralla), *Dypsis Lutescens* (Bamboo Palm) , *Syzygium samarangense* (Green Wax apple- jambu), *Murraya koenigii* (curry leaves) and *Phyllanthus acidus* (Goosberry – Nelli)

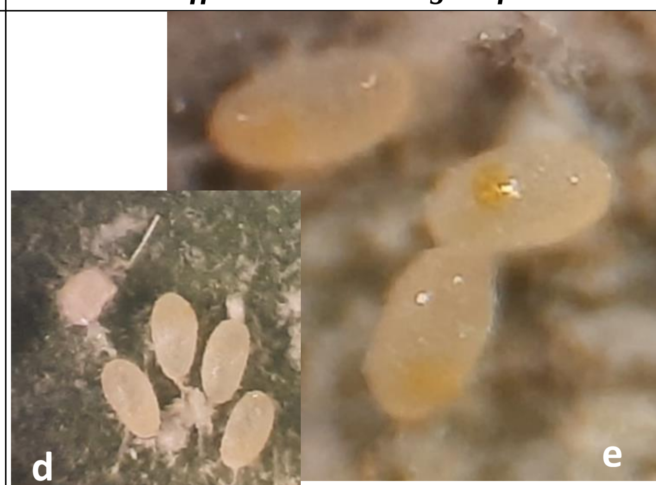
**Collectors:** R. Gnaneswaran, Mathula, M, Sivakalai,K., Thilaksika.V, Luckshika. M.R and Arani, B.




| | |
|---|---|
| a. **Adult *P. bondari* with 'X' shaped mark on forewing** | b. **Male and female adults- *P.bondari- see the difference in the length of antenna*** |

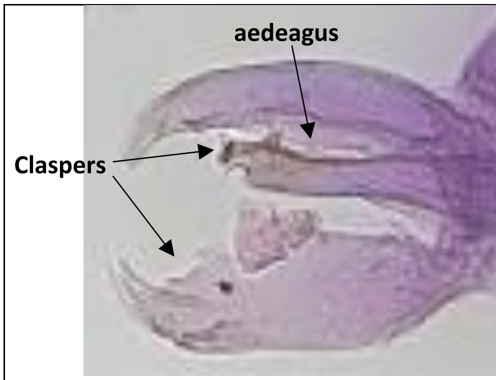


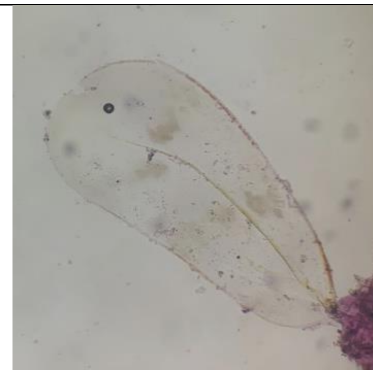

| | |
|---|---|
| c. **Adult in the woolly wax nests** | d. **Eggs of *P.bondari* – stalked –**<br>e. **Mature eggs – ready to hatch** |

| | |
|---|---|
| f. **Nymphs – with shiny fiber glass like strands** | g. **Puparium surrounded by wax rods** |

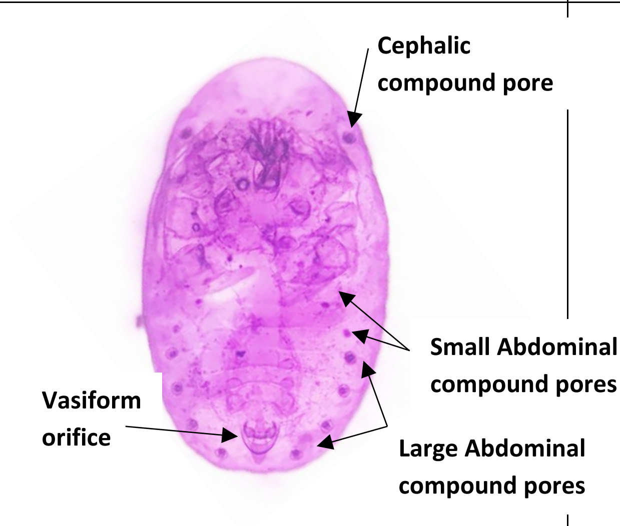
**Fig: 1 Life stages of *Paraleyrodes bondari* on coconut palm leaf in Jaffna**




**a. Male genitalia of *P. bondari* – aedeagus and claspers**

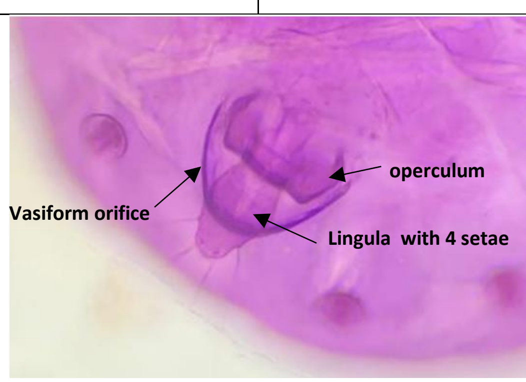


**b. Forewing of *P. bondari*- with unbranched vein**




**c: Puparium of BNW showing cephalic and abdominal compound pores and vasiform orifice**

**d: Abdominal compound pore showing flower petal facets**




**e: Vasiform orifice with tongue shaped lingula, having two pairs of setae**

**Fig: 2 Characteristic features of adult and puparium of *Paraleyrodes bondari***

**a. *P. bondari* co-existed with A. *A. rugioperculatus* and mealy bugs on coconut leaf**

**b. Natural parasitism on (RSW) *A. rugioperculatus* by *Encarsia guadeloupae***


**c. Predatory beetle larva eating pupa of *P. bondari***


**d. Infestation pattern of *P. bondari* (BNW) and *A. rugioperculatus* ( RSW)**

**Fig: 3. Co- existence, predation and infestation pattern of *P. bondari* observed in Jaffna**


**Fig: 4 Map showing the distribution of *Paraleyrodes bondari* in Jaffna, Sri Lanka (January-May 2024) (@google earth)**

**Conclusion:**

Occurrence of Bondar's Nesting Whitefly (BNW) - *Paraleyrodes bondari* is reported for the first time in Jaffna, Sri Lanka. It was spotted in the central part of the Jaffna district **(Fig: 4 map)** mainly co-existing with *A. rugioperculatus* . Peripheral regions of the peninsula, except closer to the coastal area, are severely affected by other two species (*A. dispersus and A. rugioperculatus*) without *P. bondari*. No whitefly infestations were noted in the coastal area including the lagoon periphery. In addition to transporting goods, sudden changes in weather patterns may accelerate the invasion and expansion of this pest in to newer areas. The polyphagous feeding habit and the absence of specific natural enemies for this exotic BNW, might be turn to a great menace to the agriculture sector. There is an urgent need to develop suitable management strategies by exploring potential natural enemies to manage this invasive pest to prevent its further spread to newer areas in the country.

**Acknowledgement:** Authors thank The Head, Department of Zoology, University of Jaffna for providing facilities to carry out field and the laboratory research.

**References:**

Bourdeix, R., Sourisseau, J. M., and Lin, J. (Eds.). 2021. Coconut Risk Management and Mitigation Manual for the Pacific Region. Land Resources Division, SPC.

Brown, J. K. and Czosnek, H. 2002. Whitefly transmitted viruses. Advances in Botanical Research. Edited by: Plumb RT. New York, Academic Press, 65-100.

Chandrika, M., Josephrajkumar, A. Merin, B., Krishna, A., Prathibha, P. S., Krishnakumar, V., Hegde, V. 2019. Non-Native Neotropical Nesting Whitefly, *Paraleyrodes minei* Iaccarino on Coconut Palms in India and its Co-Existence with Bondar's Nesting Whitefly, *Paraleyrodes bondari* Peracchi *Current Science*, **117** (3): 515-519.

Evans, G. A., 2008. The Whiteflies (Hemiptera: Aleyrodidae) Of The World And Their Host Plants and Natural Enemies- Version 2008-09-23 Last Revised: September 23, 2008 https://keys.lucidcentral.org/keys/v3/whitefly/PDF_PwP%20ETC/world-whitefly-catalog-Evans.pdf.

Hodges, G. S. and Evans, G. A., 2005. An identification guide to the whiteflies (Hemiptera: Aleyrodidae) of the southeastern United States. *Florida Entomologist*, **88**(4): 518-534 (28 January 2024) https://doi.org/10.1653/0015-4040(2005)88[518:AIGTTW]2.0.CO;2.

Iaccarino, F. M., Jesu R. and Giacometti R., 2011. *Paraleyrodes minei* Iaccarino, 1990 (Hemiptera: Aleyrodidiae), new species for Italy on *Citrus aurantium* L. 1758. *J. Entomol. Acarol. Res.* **43**(1):1-6.

Johnson, N. and Triplehorn, C. A., 2004. Borror and DeLong's introduction to the study of insects (7th ed.). Brooks/Cole.

Josephrajkumar, A. Chandrika, M., Merin B., Arya K., Krishnakumar, A., Vinayaka, H. and Chowdappa, P. 2019. First record of the invasive Bondar's Nesting Whitefly, *Paraleyrodes bondari* Peracchi on coconut from India. *Phyto parasitica*, **47**(3) 333-339 ref. 30

Josephrajkumar, A., Chandrika, M., Merin, B., Prathibha, P. S., Hegde, V. and Krishnakumar, V. 2020. Diagnosis of invasive whitefly species co-occurring on coconut *Current Science*, **119** (7):1101-1105.

Karunarathne, K. M. D. N., Aratchige, N. S., Meegahakubura, M. K., De Silva, P. H. P. R., Dilrukshika, D. H., Silva, D. P. M. and Samarasinghe, K. G. B. A. 2023. Identification of whitefly species (Hemiptera: Aleyrodidae) of coconut palms in Colombo and Gampaha District. International symposium on Agriculture and Environment 2023, University of Ruhuna, Sri Lanka. Abstract no. 47.

Madushani, M. A. and Sirisena, U. G. A. L., 2024. Identification of whitefly species (Hemiptera: Aleyrodidae) invaded coconut Palms in Sri Lanka. *Journal of Tropical Crop Science* **11**(1):19-32.

Martin, J. H., 2004**.** Whiteflies of Belize (Aleyrodidae: Hemiptera) Part –I Introduction and account of the subfamily Aleurodicinae- quaintance & Baker, *Zootaxa* P. 411.

Martin, J. H., Mifsud. D. and Rapisarda, C., 2000. The whiteflies (Hemiptera: Aleyrodidae) of Europe and the

Mediterranean. Basin. *Bulletin of Entomological Research.* **90**: 407–448.

Mohri, H., Lahoti, S., Saito, O., Mahalingam, A., Gunatilleke, N., Irham, Hoang, V., Gamini, H., Kazuhiko, T. and Srikantha, H. 2013. Assessment of ecosystem services in home garden systems in Indonesia, Sri Lanka, and Vietnam. *Ecosystem Services* **5:**124–36

Peracchi, A. L. 1971. Doisaleirodideospragas de Citrus no Brasil (Homoptera, Aleyrodidae). Arquivos do Museo Nacional, Rio de Janeiro **54:** 145–151.

Sadhana, V, Senguttuvan, K. and Murugan, M., 2022. Taxonomy of Whiteflies' Natural Enemies in Tamil Nadu Cotton Ecosystem, *Madras Agric. J.*, **109**: 90-94 https://doi.org/10.29321/MAJ.10.000696.

Sadhana, V, Senguttuvan, K., Murugan, M., Manikanda Boopathi, N. and Sathiah, N. 2021. First record of Bondar's nesting whitefly, *Paraleyrodes bondari* Peracchi (Hemiptera: Aleyrodidae), occurrence and infestation in the cotton ecosystem of Tamil Nadu, India. *The Pharma Innovation Journal* 2021; SP-**10**(10): 1278-1284.

Sankarganesh, E and Kusal, R. 2021. New report of Neotropical invasive Bondar's nesting whitefly, *Paraleyrodes bondari* Peracchi (Hemiptera: Aleyrodidae) from West Bengal, India. *Insect Environment* 24(4): 555-558.

Sankarganesh, E, Kusal R. and Md. Nasim A. 2023. Distribution and Identification of Invasive Whiteflies on Coconut Palms in Eastern India and Its Natural Enemies: A Biosecurity Perspective. IPM-2022 IOP Conf. Series: *Earth and Environmental Science* 1179 (2023) 012005 IOP Publishing doi:10.1088/1755-1315/1179/1/012005

Selvaraj, K., Sumalatha, B. V. And Sundararaj, R., 2020. First Record of Four Whiteflies (Hemiptera: Aleyrodidae) and Their Natural Enemies In Lakshadweep Islands, India. *Entomon* **45**(4):301-306 DOI: 10.33307/entomon.v45i4.574

Selvaraj, K, Sumalatha, B. V and R. Sundararaj 2021 New distributional record of invasive Neotropical coconut whitefly *Aleurotrachelus atratus* (Hemiptera: Aleyrodidae) in Tamil Nadu, India, *Insect Environment* **24** (2): 230-235.

Sundararaj, R., Selvaraj, K. and Sumalatha, B. V. **2021.** Invasion and expansion of exotic whitefies (Hemiptera: Aleyrodidae) in India and their economic importance *Phytoparasitica*. https://doi.org/10.1007/s12600-021-00919-7

Thamban, C., Jayasekhar, S., Chandran, K. P. and Jaganathan, D. 2016. Coconut production in Kerala, Trends, Challenges and Opportunities. *Indian coconut journal* 10-15.

Vidya. C.V., Sundararaj, R., Dubey, A.K., Haseena, B., Chellappan, M. and Henna, M. K., 2019. Invasion and establishment of Bondar's nesting whitefly, *Paraleyrodes bondari* Peracchi (Hemiptera: Aleyrodidae) in Indian mainland and Andaman and Nicobar Islands *Entomon* **44**(2): 149-154.

Wijesekara, G. A. W. and Kudagamage, C. 1990. Life history and control of spiraling whitefly *Aleurodicus dispersus* (Homoptera: Aleyrodidae) fast spreading pest in Sri Lanka. Quarterly newsletter: *Asia Pacific Plant Protection Commission*.

*MS Received on 01st July, 2024*
*MS Accepted on 02nd September, 2024*

**DOI: 10.55278/SEMB6666**

# First report of *Eupterote* sp. nr. *gardneri* Byrk, 1950 (Lepidoptera: Eupterotidae) as a defoliator pest of banana in Kerala, India with notes on its biology

**Gavas Ragesh[1]*, Chitra N.[2], Jinsa Nazeem [3], Haseena Bhaskar [4], Vijayasree P.S [3], Tom Cherian[5], Arya E.S [1], Shajan S.R[3]., Vimi Louis[1], Prakash Patil [6]**

[1] *ICAR-AICRP on Fruits, Banana Research Station, Kerala Agricultural University, Kannara (P.O), Thrissur, Kerala*

[2] *Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore (P.O), Tamil Nadu*

[3] *Agricultural Research Station, Kerala Agricultural University, Thiruvalla, Kallunkal (P.O), Pathanamthitta, Kerala*

[4] *Department of Agricultural Entomology, College of Agriculture, Kerala Agricultural University, Vellanikkara (P.O), Thrissur, Kerala*

[5] *Central Integrated Pest Management Centre, Directorate of Plant Protection, Quarantine & Storage, Block A, First Floor, Kendriya Bhavan, Kakkanad (P.O), Ernakulam, Kerala*

[6] *Project Coordinator, ICAR-AICRP on Fruits, ICAR-IIHR, Hessaraghatta Lake (P.O), Bengaluru, Karnataka*

***Corresponding author:gavas.ragesh@kau.in***

**ABSTRACT**

In this study, *Eupterote* sp. nr. *gardneri* Byrk, 1950 (=*Eupterote geminata* (Walker) ssp. *gardneri* Byrk, 1950) is recorded for the first time as a pest of banana in India. The outbreaks and crop damage caused by the hairy caterpillars of this species are documented with illustrated images. The banana cultivars Palayamkodan, Nendran, and Ney Poovan in the field, as well as cv. Popoulu in insect net house studies, were identified as preferred host varieties. Detailed morphological characteristics of the final instar caterpillar and adults, along with photographic illustrations, are provided. The biology of the pest and additional host plant records from Kerala are also discussed.

**Key words**: *Eupterote* sp, Eupterotidae, pest, defoliator, banana, economic loss, biology, host plants, India.

## Introduction

With an annual output of about 14.2 million tonnes, bananas rank first in production and third in area among fruit crops in India. They account for 13% of the total area and 33% of the production of fruits in India (NHM, 2024). Major banana-producing states in India include Maharashtra, Tamil Nadu, Karnataka, Kerala, Gujarat, Andhra Pradesh, and Assam. Although India is the largest producer of bananas in the world, insect pests limit its ability to achieve its full yield potential. Among these pests, weevils (Pseudostem weevil and Rhizome weevil) and defoliators have a significant impact on crop yield (Ragesh, 2023). The record of the notorious invasive pest, the fall armyworm (*Spodoptera frugiperda*), as a banana defoliator, suggests the possibility of additional pests (Ragesh and Sanju, 2020).

The genus *Eupterote* Hübner [1820], whose members are known as monkey moths (Bombycoidea; Eupterotidae), is represented by approximately 50 to 80 species worldwide (Nassig, 2000; Catalogue of Life, 2024). Distributed in South and Southeast Asia, these moths are medium to large in size and are mostly yellowish, brownish, or grey (Nassig, 2000; Nassig and Naumann, 2023). The family Eupterotidae is under constant revision, achieving the unique status of probably being the only lepidopteran family without a dedicated volume in the comprehensive "Lepidopterorum Catalogus," published since 1911 (Nassig and Naumann, 2023; Saini and Kaleka, 2020). Most members of the genus are nocturnal, with the exception of *E. kalliesi*, recorded from West Sumatra, which exhibits diurnal flight behavior (Nassig, 2000). Nassig and Oberprieler (2008) produced an excellent annotated catalogue of the genera of Eupterotidae, highlighting the deficiencies in earlier revisions of the family. They emphasized the need for more taxonomic and bio-ecological studies on the members of *Eupterote*. This is summarized in their statement: "The real number of species in this largest genus of Eupterotidae in Asia, and perhaps in the entire family, remains unknown." This suggests the possibility of several more species under the genus *Eupterote* that are yet to be discovered and described.

Of the 14-17 species of *Eupterote* recorded from India, sparse data on life history and host plants are known for only a few, especially *Eupterote mollifera* Walker, 1865 (a major pest of cardamom) and *Eupterote geminata* (a pest of *Gmelina arborea*) (Raha et al., 2017; Saini and Kaleka, 2020). Saini and Kaleka (2020) provided a detailed list of *Eupterote* species from India and their host plants. The host list includes *Bombax* (Malvaceae), *Sorghum* (Poaceae), *Moringa* (Moringaceae), *Piper* (Piperaceae), *Randia* (Rubiaceae), *Vitex* (Lamiaceae), *Litsea* (Lauraceae), and cardamom (Zingiberaceae) for *Eupterote fabia*; large cardamom, *Gmelina arborea* (Lamiaceae), and *Bombax ceiba* (Malvaceae) for *Eupterote undata*.

In the present study, *E. gardneri* Byrk, 1950 (=*E. geminata* (Walker) ssp. *gardneri* Byrk, 1950) is recorded for the first time attacking bananas in India. The morphological characteristics of the final instar caterpillars and adults are studied in detail. Larval host plants, including *Musa* sp. (Musaceae), *Thespesia populnea* (Malvaceae), *Bombax ceiba* (Malvaceae), and *Mangifera indica* (Anacardiaceae), are also reported for *E. gardneri* Byrk, 1950 (=*E. geminata* (Walker) ssp. *gardneri* Byrk, 1950).

## Materials and Methods

### Field survey and collection of caterpillars

The caterpillars were initially collected from banana orchards located in Erumakkadu village, Pathanamthitta district, where a severe outbreak of hairy caterpillars resulted in extensive crop damage. Simultaneously, a pest alert was issued in various crop advisory groups through social media by posting images of the caterpillars and the damage symptoms caused by their intensive feeding, in order to gather information about their occurrence in other areas. Based on the feedback received from farmers, diagnostic field visits were subsequently carried out in different localities of Kerala to collect caterpillars and record the host plants (Table 1 & Fig. 1). Caterpillars at different stages were collected by hand-picking from various host plants in the vicinity and were carefully transferred into plastic containers with their mouths covered using muslin cloth. The details of the locality and date of collection were noted on the containers, and the specimen bottles were brought to the laboratory.

**Table 1.** Collection localities of *Eupterote* sp. nr. *gardneri* in Kerala

| Sl. No. | Name and details of the location | GPS coordinates | Date of collection | Host plant & family |
|---|---|---|---|---|
| 1 | Erumakkadu, Erumakkadu village, Pathanamthitta district | 9°18'35.7"N and 76°40'37.8"E | 07/08/2023, 10/08/2023 14/08/2023 | *Musa* sp. (Musaceae), *Thespesia populnea* (Malvaceae) *Mangifera indica* (Anacardiaceae) |
| 2 | Manalai , Kodassery village, Thrissur district | Lat 10.339313° and Long 76.384535° | 29/09/2023 | *Bombax ceiba* (Malvaceae) |
| 3 | Puthukulangara of *Kochuthovala* Village, Kattappana Block, Idukki District | Lat 9.77728° and Long 77.13240° | 24/09/2023, 27/09/2023 | *Bombax ceiba* (Malvaceae) |

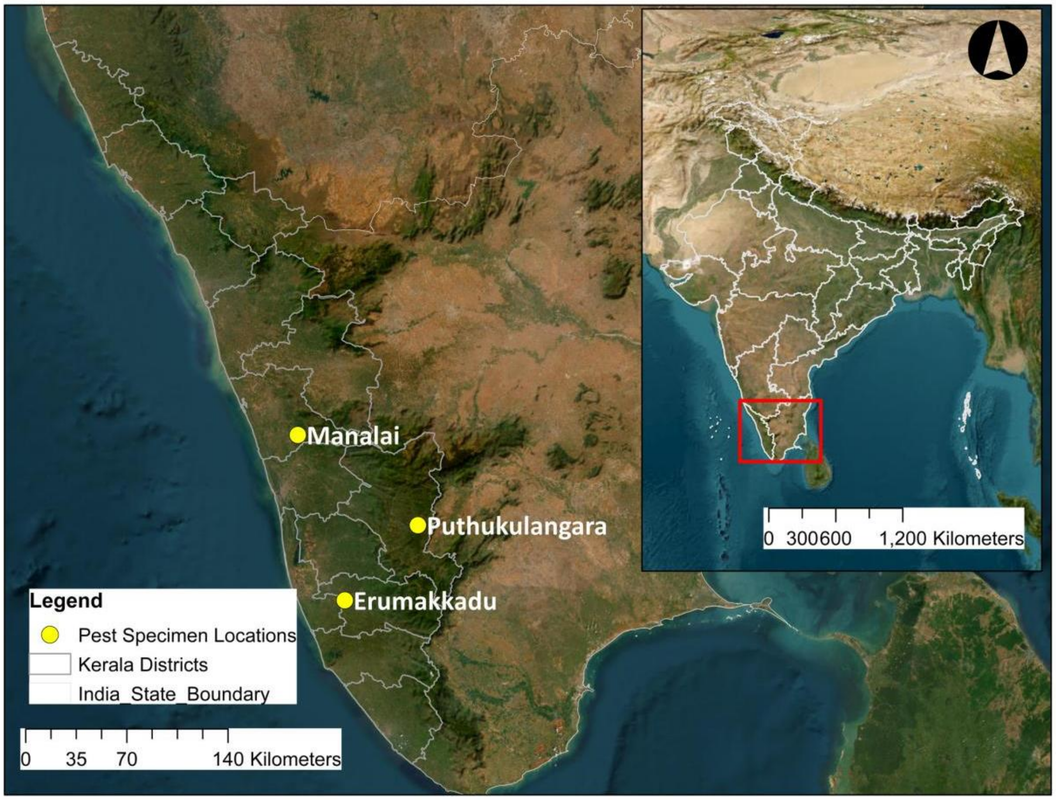



**Fig. 1:** Collection localities of *Eupterote gardneri* in Kerala

**Morphological Characterization**

The caterpillars collected from the field were reared to adults in the laboratory. The adult moths were paired and allowed to lay eggs. The external morphology of the egg, final instar caterpillar, pupa, and adult were studied. Species-level identification was established through taxonomic studies of the final instar caterpillars and adult specimens at the Department of Agricultural Entomology, Tamil Nadu Agricultural University, by the second author. The adult specimens are deposited in the Institute Insect Collection (IIC) of the Banana Research Station (BRS), Kannara, and the Biosystematics Laboratory of the Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore.

**Biology**

Studies on the biology were carried out under laboratory conditions at the Banana Research Station, Kannara, Kerala Agricultural University, Thrissur. The larvae collected from the field on banana and *Bombax ceiba* were allowed to complete their life cycle on the respective host plants. The adults that emerged were transferred to plastic mating boxes (square boxes of 30x20x10 cm size), paired, and allowed to lay eggs. Reproductive biology was studied by recording the pre-oviposition period, oviposition period, and fecundity.

To study the developmental duration, the caterpillars were reared on the leaves of the Indian tulip tree (*Thespesia populnea*) inside plastic boxes with proper ventilation at ambient temperature (28±2°C) and moisture conditions (70-80% RH). The duration of different life stages, viz., incubation period, larval duration, pupal period, and adult longevity, were recorded by maintaining at least 10 replications. The unexpected mortality of larvae and pre-pupae encountered during the study was compensated by maintaining an additional number of larvae.

Imaging of the life stages was done using a Canon EOS 700D camera, equipped with an EF100 mm macro lens, or with an OPPO mobile camera with the macro lens option.

**Host preference**

In the insect net house, preference of caterpillars to different banana cultivars was evaluated. Fifteen caterpillars each collected directly from infested banana orchards were released on 3 month old TC plants of four cultivars viz., Palayamkodan, Nendran, Ney poovan and Popoulu that were maintained in large pots (2x2x1.5 feet) and arranged at a distance of 3 feet in each replication. Three such replications were maintained in the study.

## Result

**Incidence of hairy caterpillars in banana**

Severe outbreaks of hairy caterpillars on banana were reported by the farmers during August, 2023 from Erumakkadu village of Pathanamthitta district, Kerala. The infested banana orchard was having about 350 plants of mixed cultivars viz., Palayamkodan, Nendran and Ney poovan. During the survey in the locality, hairy caterpillars were found gregariously feeding on banana leaves making large irregular holes leading to severe defoliation, often leaving midribs alone on leaves (Fig.2 a-f). On an average 15-98 caterpillars were found feeding on a single mature banana leaf. After completely defoliating a plant, the caterpillars were seen migrating to new plants in groups, for further feeding. In the orchard, severe infestation was noticed in the variety Palayamkodan. On interaction with the farmer, it was understood that an army of these hairy caterpillars were first observed on a single soft wood tree in the vicinity of the orchard, locally known as “Poovarasu” in Malayalam. This tree, commonly known as the Portia tree or Pacific rosewood or Indian tulip tree, *Thespesia populnea* (Malvaceae) is a medium-sized evergreen tree, up to 20 m tall with a dense crown with lanceolate leaves which has pantropical native distribution (Agroforestry Database 4.0, Orwa *et al*., 2009). This tree which reportedly had profuse flushing at that time was completely denuded by the caterpillars, leaving only very few leaves as observed in the field (Fig. 3 a). The final instar caterpillars were seen moving to nearby buildings or secluded places for pupation. However, pupation was also observed in banana leaf fold (Fig. 3 b-c). When disturbed, the larvae were found hanging on silken thread and falling to the ground or to nearby leaves, resuming their activities. While collecting the larvae some of the authors experienced irritation on skin followed by the development of painful rashes and blisters in a short while. So the rest of the collection was resumed after using hand gloves. The mango trees in the homestead near to the orchard were also defoliated by the caterpillars, leaving the midribs (Fig.3 d). The caterpillars were seen clustered in large numbers on the tree trunk (Fig. 3 e), which prompted the farmer to approach the authors for management.

Outbreaks of these caterpillars were also reported from Thrissur and Idukki districts during August through November, 2023, where the caterpillars were found feeding on the leaves of young trees of *B. ceiba* (Fig. 3 f). The caterpillars were collected from these localities also.

**Morphological characters**

Based on the taxonomic studies of final instar caterpillar and adult specimens carried out at Biosystematics laboratory of the Department of Agricultural Entomology, TNAU, the pest species was identified as *Eupterote* sp. nr. *gardneri* Byrk, 1950 (=*Eupterote geminata* (Walker) ssp. *gardneri* Byrk, 1950) (Lepidoptera: Eupterotidae).

The external morphology of the various life stages of the pest is detailed below.

**Eggs:** Newly laid eggs are yellowish, pearl or dome-shaped with a flat base, their surface smooth, slightly glossy. They are laid in clusters of 82 to 145, on the underside of leaf of *T. populnea* or on tissue paper in the laboratory. Before hatching the eggs turned dark with a prominent dark spot on the anterior end. (Fig. 4 a)

**Final instar caterpillar:** The caterpillar (approximately 55-65 mm in length) is largely greyish white in colour with alternating black and white stripes (broad lines) running along the length from the anterior end of the body (just below the head) to the posterior end, both on the dorsal and ventral side; three pairs of verruca with white hairs present on each segment (one pair each on subdorsal, supra spiracular and sub spiracular area); head, thoracic and abdominal legs reddish orange in colour; crochets arranged in mesopenellipse; spiracles prominent with reddish orange colour. (Fig. 4 b-g).

**Pupa:** Pupation is inside a loose brown cocoon constructed using larval hairs and silk filaments. Pupae 14-22 mm in length, reddish brown in color, anterior end hemispherical, posterior end conical and pointed with hooked hairs. Sexual dimorphism is exhibited with the female pupae larger than male pupae and having visible genital area. (Fig. 4 h-inset),

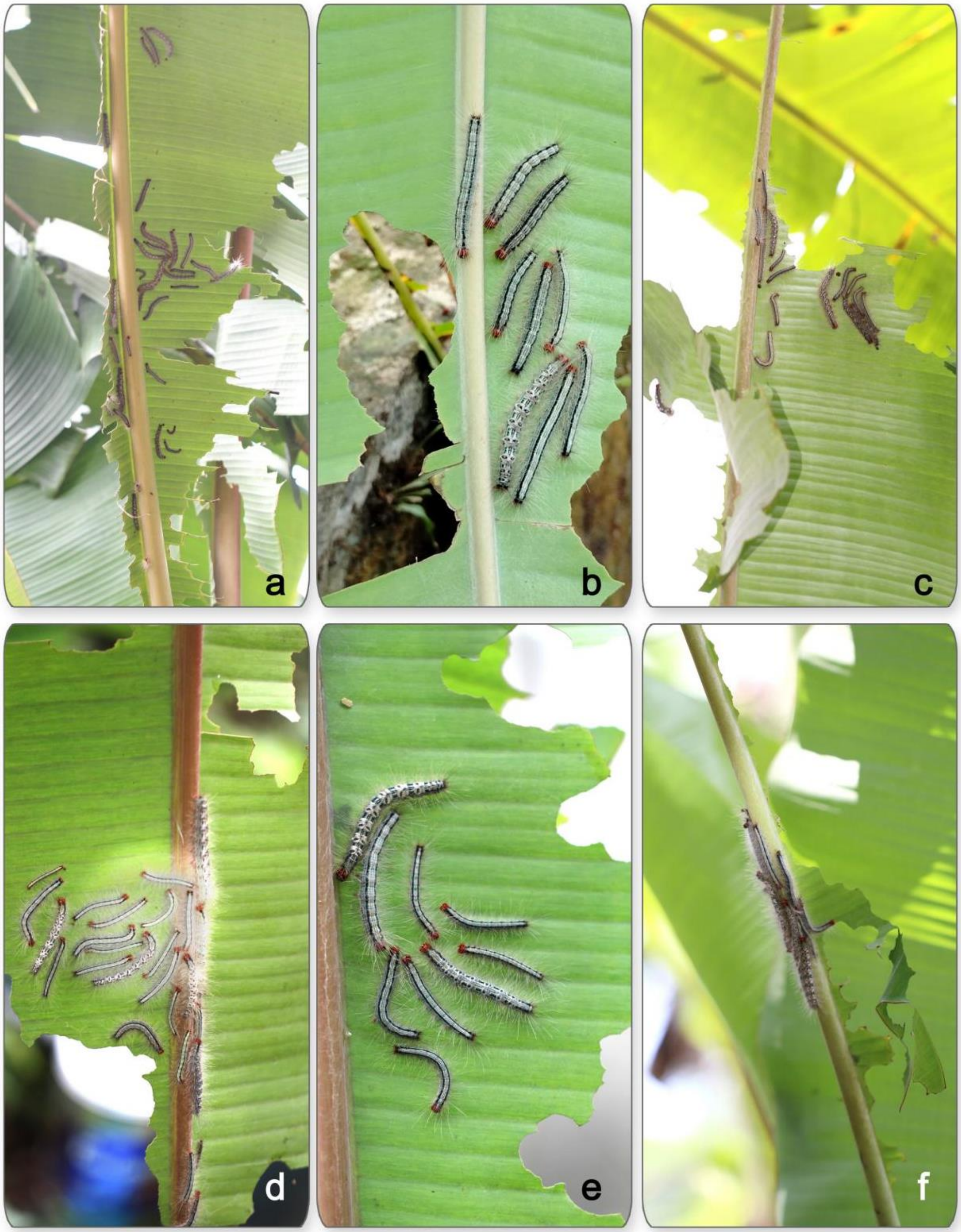



**Fig. 2 a-f** : Banana leaves showing characteristic symptom of damage due to *E. gardneri* and their gregarious feeding nature


**Fig. 3:** *Eupterote gardneri* infestation on various hosts in the field and pupation in banana : **a** Larvae on Indian tulip tree, **b-c** Pupation in banana leaf fold **d** Larvae on Mango, **e** Larvae congregated on the mango tree trunk, **f** Larvae on Indian cotton tree

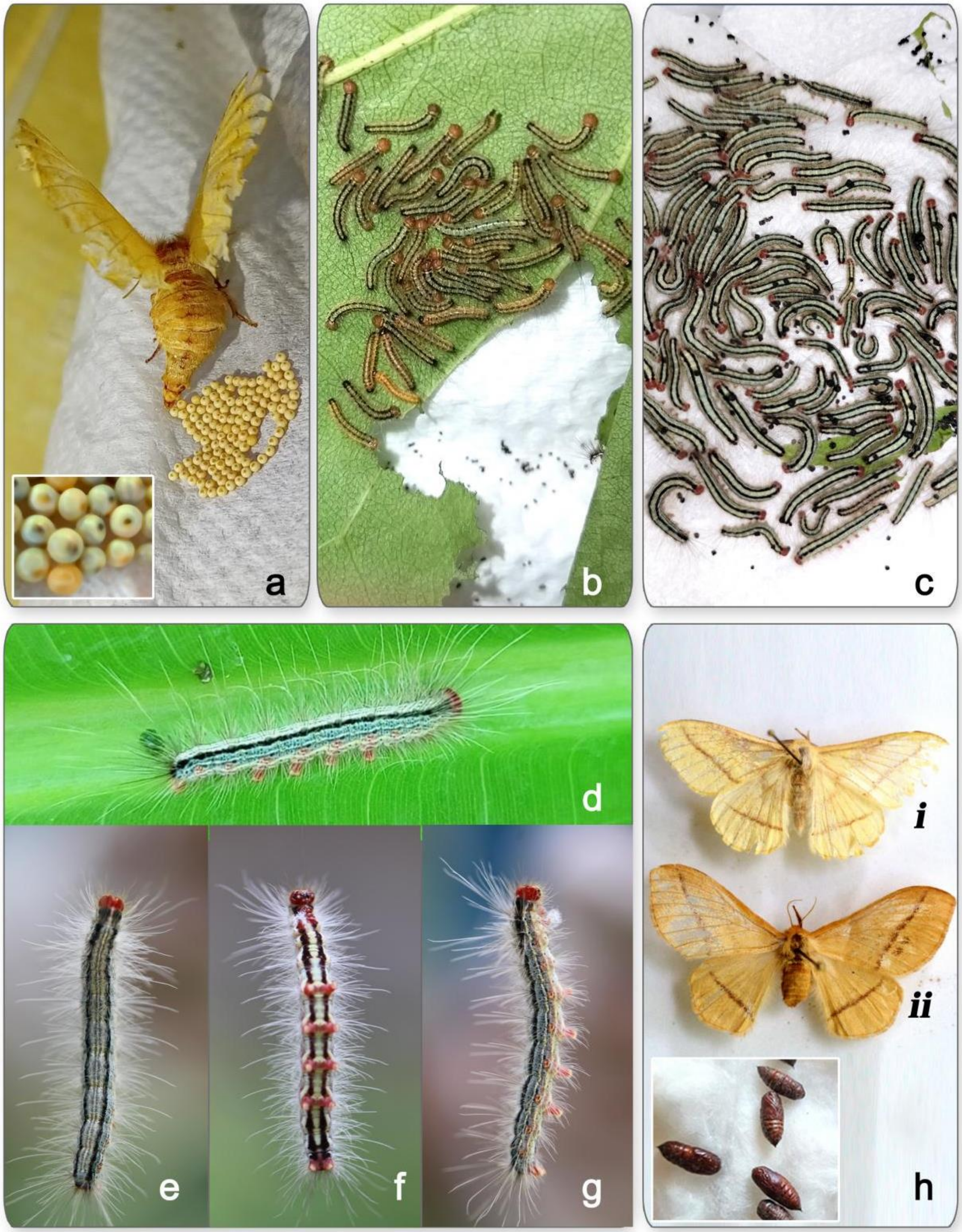



**Fig. 4** Life stages of *E. gardneri* : **a** Egg layingfemale moth and inset showing eggs before hatching, **b** First instar gregarious larvae, **c** Third instar gregarious larvae, **d** Habitus of a larva, **e** Larva-dorsal view, **f** Larva-ventral view, **g** Larva-lateral view, **h** Adult moths ***i.*** Male ***ii.*** Female with inset showing pupae

**Adult:** Adult is a medium-sized moth. Wings straw colored in males and yellowish-brown in females, prominent brown single line parallel and near to outer margins of fore and hind wings present in both sexes; antenna filiform in female and bipectinate in male; wing expanse: Male: 36-47 mm; Female: 47-56 mm; body length: Male: 11-16 mm; Female: 15-19 mm. (Fig. 4 h).

**Biology**

The *Eupterote gardneri* female recorded 0.86 ± 0.16, 0.81 ± 0.19 and 2.37± 0.44 days for pre-oviposition, oviposition and post-oviposition periods respectively at 28±2ºC temperature under laboratory conditions. Mean incubation period of 10.58 ± 1.26 days was recorded. Total larval period was completed in 45-57 days in seven instars. The pupal period lasted for 9-11days.

**Host preference**

Studies to identify the preferred varieties of banana, in insect net house, recorded approximately 48.33 (29/60) per cent of the released larvae in Palayamkodan variety, 24 h after release, with the rest feeding on Nendran, Ney poovan and Popoulu. This increased to 56.67 per cent (34/60) and 71.67 (43/60) per cent in Palayamkodan variety respectively at 48 and 72 hours after release.

In the present study, we report banana (*Musa* sp.), *T. populnea*, *B. ceiba* and *M. indica* as host plants for *E. gardneri from Kerala, India,* and add this insect to the list of defoliator pests of banana in India as a new and emerging pest problem.

**Discussion and Conclusion**

Zolotuhin (2018) while putting concerted efforts in locating and reporting types of two species of monkey moths viz., *Bombyx hibisci* Fabricius 1775 and *Bombyx orientalis* Fabricius 1793, established *Eupterote gardneri* Bryk, 1950 as valid species (bona species) with *E. bifasciata* Kishida, 1994, as its new synonym. He also observed that *E.gardneri* Bryk, 1950, differs from *E. orientalis* by the presence of reduced submarginal spots and is found in Northwards of India, in the Himalayas. Raha *et al*. (2017) recorded the presence of *E. bifasciata* (a junior synonym of *E. gardneri*) in Chhattisgarh and there by extended its distribution range significantly to the plain habitat of the Deccan Peninsular biogeographic zone. Thus with the present record of *E. gardneri* in Kerala, South India, the moth species extends its distribution range significantly to the southernmost part of India.

No reliable information could be collected from literature on host plants of *Eupterote gardneri*, as most of the earlier reports of the species was from specimens collected through light traps. Also there are no reports on the biology or host range of this species in the online data bases like Moths of India, Catalogue of life, HOSTS - a Database of the World's Lepidopteran Host plants etc. A search for host plants of *E. bifasciata* Kishida, 1994, now a junior synonym of *E. gardneri* (Zolotuhin, 2018; https://www.mothsofindia.org/Eupterote-gardneri) and, reported from India (Chhattisgarh and Uttarakhand) and Nepal also did not yield any information on host plants.

Herbivore insects have been recorded to specialize in specific plant taxa (e.g., families or genera) (Bernays and Chapman, 1994). Infestation of *E. gardneri* on members of Malvaceae *viz., Thespesia populnea* and *Bombax ceiba* in the field strengthen this theory and hence this plant family could be its specific plant taxa. Additionally, profuse larval feeding and development on banana (*Musa* sp.) is a cause of concern, banana being a commercial crop. Host specialization was observed to play a key role in developing various traits that enable the extreme diversification of phytophagous insects enabling it to adapt to a subset of host plants (Fordyce, 2010). Herbivores often adopt strategies to overcome the defensive substances contained within the plants and develop a recognition system that would identify specific plants as suitable hosts enabling them to colonize new plants (Katte *et al*., 2022). This easily explains the shift of *E. gardneri* caterpillars from *T. populnea* to *Musa* sp., after the initial attack on the tree.

We suggest that further extensive surveys are to be undertaken across different localities in south India, to collect populations of the species, in order to understand its geographical distribution and host range, as well as to resolve the taxonomic status of the species.

**Acknowledgments**

We would like to extend our heartfelt thanks to our farmer friends: Mr. Saji from Erumakkadu, Pathanamthitta district; Mr. Joppan from Kodassery, Thrissur district; and Mr. Jibi Puthukulangara from Thodupuzha, Idukki district, for their invaluable assistance during the field study. We also thank our farmer friends from the WhatsApp group “Banana Doctor” for their support.

Our sincere gratitude goes to the lepidopteran experts: Dr. Rolf G. Oberprieler from the Commonwealth Scientific and Industrial Research Organisation, Australia; Dr. Wolfgang A. Nässig from the Senckenberg Research Institute, Germany; Dr. Krushnamegh Kunte, Associate Professor and Principal Investigator at the Biodiversity Lab, National Centre for Biological Sciences (NCBS); Dr. Sanjay Sondhi from Titli Trust, Dehradun, Uttarakhand; Dr. Sujata Saini, Assistant Professor, Department of Biosciences, Chandigarh University; and Rachit Singh from the Forest Nature Conservation Group, University of Göttingen, Germany, for their valuable guidance and for sharing essential references.

We sincerely thank Dr. Ajithkumar B., Associate Professor and Head, and Mr. Sarath

R. Krishna from the Department of Agricultural Meteorology, Kerala Agricultural University, Vellanikkara, for preparing the GPS map. We gratefully acknowledge the financial support provided by ICAR-AICRP on Fruits, which significantly aided us in conducting this research.

**References**

Anonymous.2024. *Eupterote gardneri* Bryk, 1950. In Sondhi, S., Y. Sondhi, R.P. Singh, P. Roy and K. Kunte (Chief Editors). Butterflies of India, v. 3.74. Published by the Indian Foundation for Butterflies. URL: https://www.mothsofindia.org/eupterote-gardneri (assessed on 9 June, 2024)

Bernays, E. A. & Chapman, R. F.1994. Behavior: The process of host-plant selection. in Host-Plant Selection by Phytophagous Insects (Chapman & Hall, 1994).pp. 95–165

Catalogue of life. 2024. https://www.catalogueoflife.org/data/taxon/9YR. (assessed on 20 August, 2024)

Fordyce, J. A.2010. Host shifts and evolutionary radiations of butterflies. *Proc. R. Soc. B Biol. Sci.* **277**, 3735–3743.

Katte, T., Shimoda, S., Kobayashi, T., Wada-Katsumata, A., Nishida, R., Ohshima, I. et al. 2022. Oviposition stimulants underlying different preferences between host races in the leaf-mining moth *Acrocercops transecta* (Lepidoptera: Gracillariidae). Scientific Reports, 12, 14498.

Ragesh, G. 2023. Integrated Pest Management in Banana. in Compendium on Banana Graduate Readiness Programme. (Weser Books, Germany, 2023). pp.222-229.

Ragesh, G., and Balan, S. 2020. The first report on Fall Armyworm, *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) as an invasive pest in banana from Kerala, South India and notes on its behavior. *Insect Environment*. **23:** 20–24.

Raha, A., A.Majumder,A.K.Sanyal, and K.Chandra. 2017. "On Three Species of genus Eupterote Hübner from Chhattisgarh, with a Consolidated Species List of the genus from India (Lepidoptera: Eupterotidae)," *Revta Lepidoptera* **45**(180): 651-663

Saini, S and Kaleka, A.S. 2020. Revisionary notes on family Eupterotidae (Lepidoptera: Bombycoidea) with remarks on genus *Eupterote* Hübner and *Apona* Walker from India. *Advance in Biological Research*. 2020,**1**(1);6 Available from: https://www.researchgate.net/publication/381886427_Revisionary_notes_on_family_Eupterotidae_Lepidoptera_Bombycoidea_with_remarks_on_genus_Eupterote_Hubner_and_Apona_Walker_from_India [accessed Aug 14 2024].

Nassig, W. A., 2000. A new and remarkable species of *Eupterote* from the mountains of West Sumatra (Lepidoptera: Eupterotidae).– Heterocera sumatrana.12(2): 67-77.

Nassig, W. A.and Naumann, S. 2023. On a possible synonymy in the genus *Eupterote s.l.: E. olivescens* Rothschild, 1920 and *E. kalliesi* Nässig, 2000 from Sumatra, are they the same or two different species with diurnal males? (Lepidoptera, Eupterotidae, Eupterotinae). Nachr. entomol. *Ver. Apollo, N. F.* **44** (1): 27–32

Nassig, W. A.and Oberprieler R.G. 2008. An annotated catalogue of the genera of Eupterotidae (Insect, Lepidoptera, Bombycoidea) *Senckenbergiana biologica*, Frankfurt am Main, **88**(2): 53-80

National Horticulture Mission.2024. https://nhb.gov.in/report_files/banana/BANANA.htm (assessed on 10 July, 2024)

Orwa et al. 2009. Agroforestry Database 4.0, available at: https://apps.worldagroforestry.org/treedb/AFTPDFS/Thespesia_populnea.PDF (assessed on 9 June, 2024)

Zolotuhin, V.V., 2018. Nomenclature and synonymic remarks on two species of Eupterotidae (Lepidoptera) described by Johan Christian Fabricius, and notes on related species. *Zootaxa*, **4471**(2):381-386.

*MS Received on 11st July, 2024*
*MS Accepted on 12nd September, 2024*

**DOI: 10.55278/ZZZG2000**

# Evaluating artificial nest designs to enhance *Dolichodrus thoracicus* (Smith) populations in cocoa plantations a potential predator of Cocoa Pod Borer (*Conopomorpha cramerella* Snellen)

**Ahmad Saleh[1], Abu Hassan Ahmad[2], Che Salmah Md Rawi[2], Ameilia Zuliyanti Siregar[3], and Ravindra C. Joshi[4] ***

*[1]Institute Teknologi Sawit Indonesia (ITSI Medan). J. l. Willem Iskandar, Medan 20371. Sumatera Utara, Indonesia.*

*[2]School of Biological Sciences, Universiti Sains Malaysia, 11800 Penang, Malaysia.*

*[3]Department of Agro-Technology, Faculty of Agriculture, University of Sumatera Utara Jl. Dr. A. Sofyan No.3 Medan, 20155, Sumatera Utara, Indonesia.*

*[4]Graduate School of Agriculture and Related Sciences, University of Southeastern Philippines, Tagum- Mabini Campus, Apokon, Tagum City, Philippines.*

****Corresponding author: rcjoshi@usep.edu.ph; rcjoshi4@gmail.com***

## Abstract

The black ant, *Dolichoderus thoracicus* (Smith) offers a promising, sustainable solution to control the cocoa pod borer (CPB), *Conopomorpha cramerella* Snellen. Traditional insecticides are ineffective and disrupt cocoa ecosystems, highlighting the need for alternative methods. This five-year study evaluated the efficacy of twelve artificial nest designs using natural and synthetic materials. Strategically placed within cocoa trees, these nests significantly increased *D. thoracicus* populations, leading to effective CPB suppression. The most successful nest, constructed from cocoa leaves within a polyester bag, housed a remarkable 145,682 ants. Other effective combinations included cocoa leaves in plastic netting (128,119 ants), and dry nypa leaves in plastic netting (119,595 ants). These findings demonstrate the potential of artificial nests, particularly those using cocoa leaves in polyester bags, as a sustainable biological control strategy for cocoa plantations.

**Key words:** ants, artificial nest, biological control, cocoa pod borer, *Dolichoderus thoracicus*.

## Introduction

The black ant, *Dolichoderus thoracicus* (Smith), is an arboreal species found nesting in folded fallen coconut fronds, cocoa leaves, and cocoa leaf litter (Attygalle *et al*., 1998; Kalshoven, 1981; Khoo and Chung, 1989). These nests are crucial for the breeding and population growth of the ants, which play a vital role in controlling key pests like *Helopeltis theobromae* Miller (Hemiptera: Miridae) and *Conopomorpha cramerella* Snellen (Lepidoptera: Gracillaridae) in cocoa plantations (Toxopeus and Giesberger, 1993). Recognizing the importance of *D. thoracicus* in cocoa pest management, researchers have explored the use of artificial nests to manipulate and enhance ant populations. These nests, often constructed from dry cocoa leaves or polyester bags, provide breeding sites and facilitate the transfer of ant populations to new areas (Saleh, 2003; Saleh *et al*., 2006; Ho and Khoo, 1994; Saleh, 2012).

Further, *D. thoracicus* offers an additional benefit by acting as a natural disperser of *Trichoderma* sp., a beneficial fungus that combats the black pod disease (*Phytophthora palmivora*) in cocoa (Tjandra *et al*., 2014).

This study investigated an improved design for artificial nests to maximize breeding success and population levels of *D. thoracicus*, a black ant species known for its biocontrol potential against key cocoa pests within cocoa plantations. This research contributes to the development of more effective and sustainable pest management strategies in cocoa agroecosystems. By optimizing the artificial nest design based on the preferred nesting characteristics of *D. thoracicus*, we can potentially elevate the efficacy of this natural biocontrol method and promote the sustainability of cocoa production practices. This optimization process should prioritize factors that enhance the long-term persistence of the nests within the cocoa canopy.

**Materials and Methods**

The study was conducted in December 2006 at a 21.8-hectare cocoa plantation and insectary of the Bah Lias Research Station (BLRS), PT. PP. London Sumatra Indonesia Tbk (Lonsum), located in North Sumatra, Indonesia (99° 15’ 36” - 99° 21’ 36” East and 3° 8’ 24” - 3°13” 12” North). The plantation has an altitude of 32 meters above sea level and is 139 km from Medan. The average rainfall in 2008 was 1538 mm with 133 rain days/year. The average temperature range is 26.73°C, relative humidity is 53.15%, evaporation is 4.14 mm/day, sunshine duration is 4.14 hours/day, and the soil pH is 4.2-4.5 (BLRS, 2008).

The study area comprised 18-year-old cocoa clones planted at a spacing of 2 x 4 meters, initially yielding a density of 1,250 trees per hectare. However, at the time of the study, the tree density had decreased to 775 trees per hectare. Permanent shade for the cocoa trees was provided by coconut palms planted at a density of 46 palms per hectare. A well-established population of black ants *(D. thoracicus)* served as a biological control agent for the cocoa pod borer (CPB), C. cramerella. The high *D. thoracicus* population was usually supported by the abundance of cocoa mealybug *Exallomochlus hispidus* (Morrison), in over 75% of harvested cocoa pods (Saleh, 2011).

Twelve different combinations of nest materials were tested, utilizing both natural materials (leaves) and synthetic materials (plastic and polyester) known for their durability (lasting over five years). The specific materials used in each treatment are detailed in **Table 1.**

To ensure standardized placement and ecological relevance, one artificial nest from each treatment group was randomly assigned to a cocoa tree branch at a height of 1.5-2 meters. In addition, each tree received a pair of control nests constructed from dry cocoa leaves. This mirrors the established estate practice for maintaining populations of *D. thoracicus*, a beneficial ant species. This two-pronged approach serves important purposes. Firstly, it aligns with existing farm management practices, facilitating the potential future adoption of artificial nests. Secondly, it accounts for the natural variation in pre-existing ant communities on the trees, providing a more ecologically relevant baseline for evaluating the impact of the artificial nests on *D. thoracicus* populations.

Three replicates of each nest type were placed at a distance of about 5 to 10 cocoa trees within the study area. After two months, all 36 nests (12 types x 3 replicates) were collected and individually placed in separate plastic bags (40 x 60 cm). To ensure accurate population counts, the ants were then killed by freezing the bags in a deep freezer (-20°C, 100-liter volume) located in the insectary. The number and developmental stages (eggs, larvae, pupae, workers, and adults) of *D. thoracicus* in each nest were recorded separately. The data was then analyzed using ANOVA in SPSS version 21 to compare the population density of black ants in each nest type.

**Table 1. Twelve Types of Artificial Nest of *D. thoracicus*.**

**Type 1**. The nests were made from polyester bag (35 cm x 40 cm) with 25 – 30 holes (1 cm diameter) with 240 pieces of straw inside the Polyester bag.

**Type 2**. The nests were made of pieces of polyester net and Cocoa leaves. There were six rolls, each roll contained 7 folded of polyester (15 cm long x 5 cm wide) and 14 dry cocoa leaves were placed between of the folds, then placed in plastic net (35 x 40 cm).

**Type 3**. The nests were made of 60 dry nypa (*Nypa fructicans*; Arecaceae) leaves of 30 cm long placedin a plastic net (35 cm x 40 cm).

**Type 4**. The nests were made of 60 dry nypa (*Nypa fructicans*; Arecaceae) leaves leaves were placed in polyester bag (35 cm x 40 cm) with 30 to 40 holes.

**Type 5**. The nests were made of (30 cm long) dry coconut leaves in which the 40 dry coconut leaves were fastened with a plastic string.

**Type 6**. The nests were made of six rolls of polyester sheets in which each roll contained 8 folded sheets (21 cm long x 5 cm wide). Then they were put in plastic net (35 x 40 cm).

**Type 7**. The nests were made of dry cocoa leaves in which 40 dry cocoa leaves were bundled by two leaves on top and fastened with plastic string.

**Type 8**. The nests were made from a plastic net (35 cm x 40 cm) with 240 pieces of straw (25 cm long) inside it.

**Type 9**. The nests were made from polyester bag 35 cm x 40 cm with 30 to 40 holes and 40 dry cocoa leaves inside.

**Type 10**. The nests were made from plastic net, 35 cm x 40 cm with 40 dry cocoa leaves inside.

**Type 11**. The nests were made of six rolls of polyester inwhich each roll contained 8 folds of polyester (5 cm x 15 cm). Then they were placed in a polyester bag (20 cm x 40 cm) with 30 to 40 holes.

**Type 12**. The nests were made of pieces of polyester and cocoa leaves. There were 3 rolls, and each roll contained 8 folds of polyester (5 cm x 15 cm) and 21 dry cocoa leaves were placed between the folds and then they were placed in a polyester bag (35 cm x 40 cm) with 30 – 40 holes.

## Results

The mean total number of ants per nest after two months in the field varied significantly among the 12 tested nest types **(Fig. 1 and Tables 2a, 2b & 2c)**. The highest overall population was observed in the artificial nest made from cocoa leaves in a polyester bag (Nest type No. 9), with an average of 145,682 ants. This was followed closely by the nest made from cocoa leaves in a plastic net (Nest type No. 10) with 128,119 ants. The third-ranked nest was constructed from dry nypa leaves in a plastic net (Nest type No. 3) with 119,595 ants **(Table 2c).**

Importantly, the total ant population in the top five nest types (Nos. 2-6) was not statistically different from each other. However, the population in the top-ranked nest (No. 9) was significantly higher than all other nest types except for the top five (P < 0.01).

Interestingly, the commercially used nest made from dry cocoa leaves in Lonsum cocoa plantations (Nest type No. 7) ranked eighth with an average of 64,639 ants. While not significantly different from most other nest types, its population was considerably lower than the top performers.

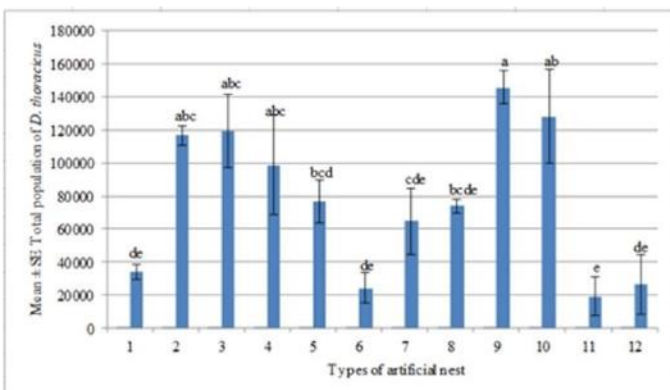



**Fig. 1. Population of all stages of *D. thoracicus* in different nest types.**

**Table 2a. Immature stages of *D. thoracicus* in relation to nest types after two months.**

| Nest Types | Immature Stages | | |
|---|---|---|---|
| | **Eggs** | **Larvae** | **Pupae** |
| Cocoa leaves in polyester bag **(Type 9)** | 48828 ± 7270.56 a | 17601±1205.38 ab | 21960±2859.826b |
| Cocoa leaves in plastic net **(Type 10)** | 41571±12075.88 abc | 19847±7142.13 a | 33039±7327.30a |
| Dry nypa leaves in plastic net **(Type 3)** | 32698±3926.17abcd | 4637±2312.77 c | 17078±529.81 bc |
| Pieces of polyester and Cocoa leaves **(Type 2)** | 46678±1312.12 ab | 8996±3391.77 bc | 13671±625.62 bcde |
| Dry nypa leaves in polyester bag **(Type 4)** | 41917±12212.99 abc | 8758±2780.70 bc | 15333±5166.62 bcde |
| Dry coconut leaves **(Type 5)** | 28897±5584.5 abcde | 8030±1556.66 c | 8602±192.61 cde |
| Straw in plastic net **(Type 8)** | 20273±494.09 cde | 9899±1471.76 bc | 10753±881 bcdef |
| Dry Cocoa leaves **(Type 7)** | 21811±7860.63 bcde | 5713±1973.68 c | 9333±2732.99 cdef |
| Straw in polyester bag **(Type 1)** | 9730±900.85 de | 1796±429.86 c | 6509±961.28 cdef |
| Pieces of polyester and cocoa leaves **(Type 12)** | 11490±88190.39de | 3188±2117.32 c | 4248±2890.61 def |
| Roll of polyester in plastic net **(Type 6)** | 6266±2446.70 e | 4858±2154.18 c | 3349±1470.22 ef |
| Roll of polyester in polyester bag **(Type 11)** | 3469±2679.59 e | 1202±777.63c | 1683±1070.71 f |

Mean in the same column followed by a different letter are significantly different (LSD test, P = 0.05).

**Table 2b. Adults of *D. thoracicus* in relation to nest types after two months.**

| Nest Types | Adults | | |
|---|---|---|---|
| | **Workers** | **Queen** | **Alate** |
| Cocoa leaves in polyester bag **(Type 9)** | 56861±4943.65 a | 429±75.51ab | 0.00±0.0 a |
| Cocoa leaves in plastic net **(Type 10)** | 33345±3529.15 bc | 317±109.77 bcde | 0.00±0.0 a |
| Dry nypa leaves in plastic net **(Type 3)** | 64573±10153 a | 609±86.75 a | 0.00±0.0 a |
| Pieces of polyester and Cocoa leaves **(Type 2)** | 46646±2552.63 b | 596±50.52 a | 0.00±0.00 a |
| Dry nypa leaves in polyester bag **(Type 4)** | 3232±10239 bc | 396±70.38 abc | 1.00±0.58 a |
| Dry coconut leaves **(Type 5)** | 30760±5221.13 bcd | 341±22.92 abc | 1.33±0.33 a |
| Straw in plastic net **(Type 8)** | 32667 ± 2944.76 bc | 345±33.49 bc | 0.000±0.0 a |
| Dry Cocoa leaves **(Type 7)** | 27455±7188.67 bcde | 326±114.89 bcd | 0.00±0.0 a |
| Straw in polyester bag **(Type 1)** | 15746±3203.95 cdef | 180±26.08 cdf | 0.33±0.33 a |
| Pieces of polyester and cocoa leaves **(Type 12)** | 7608±5079.63 f | 36±18.82 f | 0.00±0.0 a |
| Roll of polyester in plastic net **(Type 6)** | 9665±3199.52 ef | 119±55.82 def | 0.66±0.33 a |
| Roll of polyester in polyester bag **(Type 11)** | 12602±7112.98 def | 105±63.81 ef | 0.00 ± 0.0 a |

Mean in the same column followed by a different letter are significantly different (LSD test, P = 0.05).

**Table 2c. Total of all stages of *D. thoracicus* in relation to nest types after two months.**

| Nest Types | Ranking | Total (Immature Stages & Adults) |
|---|---|---|
| Cocoa leaves in polyester bag **(Type 9)** | 1 | 145682±10174.41 a |
| Cocoa leaves in plastic net **(Type 10)** | 2 | 128119±28640.87 ab |
| Dry nypa leaves in plastic net **(Type 3)** | 3 | 119595±22352.00 abc |
| Pieces of polyester and Cocoa leaves **(Type 2)** | 4 | 116586±5834.81 abc |
| Dry nypa leaves in polyester bag **(Type 4)** | 5 | 98727±30045.93 abc |
| Dry coconut leaves **(Type 5)** | 6 | 76632±13041.83 bcd |
| Straw in plastic net **(Type 8)** | 7 | 73937±4271.07 bcde |
| Dry Cocoa leaves **(Type 7)** | 8 | 64639±19749.95 cde |
| Straw in polyester bag **(Type 1)** | 9 | 33961±4643.70 de |
| Pieces of polyester and cocoa leaves **(Type 12)** | 10 | 26570±18276.56 de |
| Roll of polyester in plastic net **(Type 6)** | 11 | 242557±9282.82 de |
| Roll of polyester in polyester bag **(Type 11)** | 12 | 19061±11675.45 e |

Mean in the same column followed by a different letter are significantly different (LSD test, P = 0.05).

## Developmental Stages

The distribution of *D. thoracicus* across different developmental stages within the nests varied depending on the nest type **(Fig. 2-6).**

**Eggs**: The highest number of eggs was found in the nest made from cocoa leaves in a polyester bag (Nest type No. 9) with 48,828 eggs per nest **(Fig. 2).**

**Larvae**: The nest made from cocoa leaves in a plastic net (Nest type No. 10) had the highest larval population with 19,847 larvae per nest **(Fig. 3).**

**Pupae**: The same nest type (No. 10) also exhibited the highest number of pupae with 33,039 pupae per nest **(Fig. 4).**

**Workers**: The nest made from dry nypa leaves in a plastic net (Nest type No. 3) housed the largest worker population with 64,573 workers per nest **(Fig. 5).**

**Queens**: The highest queen count was observed in the nest made from nypa leaves in a plastic net (Nest type No. 3) with 609 queens per nest **(Fig. 6).**

While the commercially used nest made from dry cocoa leaves (Nest type No. 7) showed a lower overall population, its developmental stage distribution was within the range observed in most other nest types.

## Discussion

This study demonstrated the significant potential of specific artificial nest designs to promote the attractiveness of *D. thoracicus* populations in cocoa plantations. The observed differences in adult ant populations and developmental stages across different nest types highlighted the importance of material selection and design in determining and optimizing artificial nests for increasing black ant populations and consequently their contribution to effective biological control of cocoa pests.

Black ants appeared to prefer loose materials for nesting, likely due to the air circulation and humidity levels conducive to their breeding. This aligns with their natural nesting behavior in cocoa leaf litter and coconut leaf tubes (Attygalle *et al*., 1998; Delabie *et al*., 2007; Graham, 1991).

Both coconut and cocoa leaves proved suitable as the main natural components for artificial nests, with the coconut leaf nests supporting slightly higher ant populations. All developmental stages were observed in these nests, indicating successful breeding and development. This aligns with previous research demonstrating the suitability of these materials for manipulating black ant populations (Saleh, 2011; Saleh, 2012).

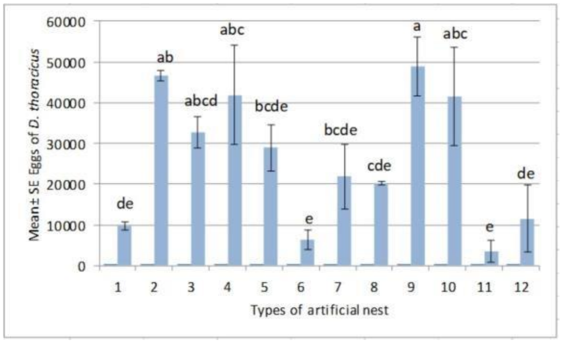



**Fig. 2. Number of eggs of *D. thoracicus* in 12 types of artificial nest.**

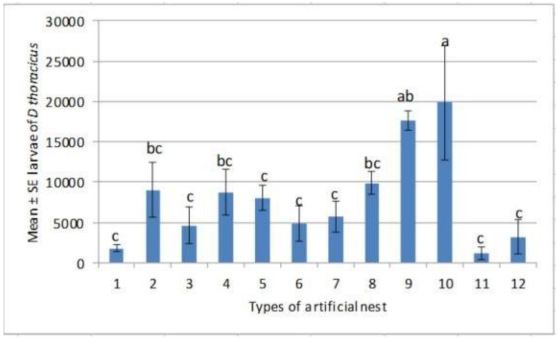



**Fig. 3. Number of larvae of *D. thoracicus* in 12 types of artificial nest.**

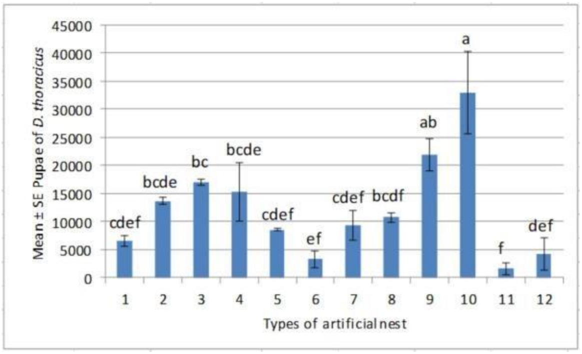



**Fig. 4. Number of pupae of *D. thoracicus* in 12 types of artificial nest.**

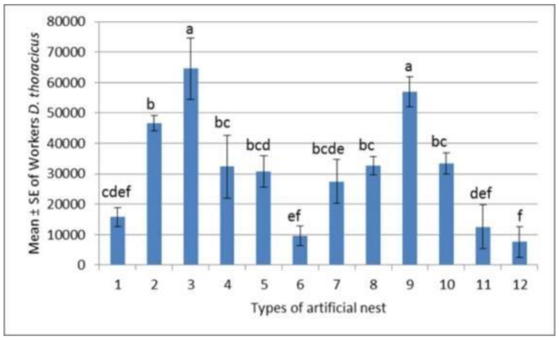



**Fig. 5. Number of workers of *D. thoracicus* in 12 types of artificial nest.**

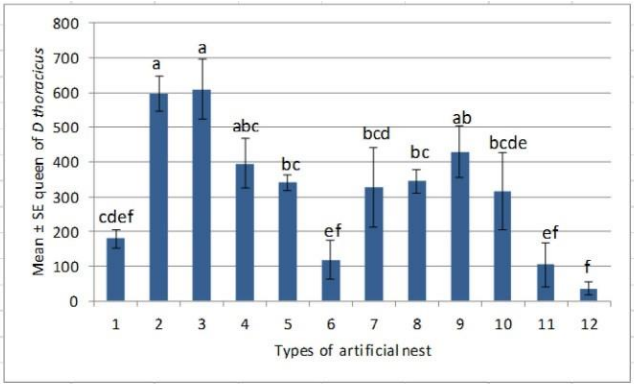



**Fig. 6. Number of queens of *D. thoracicus* in 12 types of artificial nest.**

Conversely, previous studies found that nests constructed solely from synthetic materials contained only workers and lacked ant eggs (Saleh, 2011). While synthetic materials offer longer durability, their lack of suitability for breeding highlights the importance of incorporating natural elements in artificial nest designs.

The combination of natural (dry cocoa leaves) and synthetic (polyester bag) materials emerged as the most effective artificial nest design in this study. Nests of types 3, 9, and 10 **(Fig. 1)** exhibited the highest black ant populations after two months. All developmental stages except larvae were significantly more abundant in these nests compared to other nest types.

These findings suggest that black ants favor loose, well-ventilated, and dark environments. The ant population in the polyester and dry cocoa leaf nests was 2.2 times higher than that in the dry cocoa leaf nests alone.

**Conclusion**

The commercially used dry cocoa leaf nests (Nest type #7), while supporting a healthy ant population, could potentially benefit from material improvements for further optimization. This study suggested that incorporating synthetic materials like polyester bags could significantly enhance the nests' durability and suitability for long-term black ant population management.

These permanent nests offer several advantages, including the ability to maintain a high *D. thoracicus* population for over four years and cost-efficiency for large-scale, long-term pest management programs. The polyester bags protect the cocoa leaves from rain and direct sunlight, preventing weathering and extending the lifespan of the nests beyond four years without requiring the replacement of the leaves.

Further research could investigate the specific factors contributing to the superior performance of certain nest types, such as microclimate conditions within the nests, nest durability and resistance to environmental factors, and ease of ant colonization and establishment. Additionally, exploring the long-term efficacy and cost-effectiveness of these artificial nests in large-scale field settings would be valuable for their practical implementation in cocoa pest management strategies. By optimizing artificial nest designs and understanding the preferences of *D. thoracicus*, we can further enhance the effectiveness of this natural biological control agent of cocoa pests for sustainable cocoa production.

This study demonstrates that carefully designed artificial nests can significantly enhance *D. thoracicus* populations in cocoa plantations. The most effective design, combining natural materials (dry cocoa leaves) with a protective polyester bag, fostered the highest black ant population density across all developmental stages (except larvae) after two months. This suggests a preference for loose, well-ventilated, and dark environments. The polyester bag extends the nest lifespan beyond four years by shielding the cocoa leaves from rain and direct sunlight, eliminating the need for annual replacements – a significant advantage over commercially used nests. These findings highlight the importance of material selection and design in optimizing artificial nests for the biological control of cocoa pests.

**Future Research**

To further optimize nest design, future research should explore the specific factors influencing nest performance. This could include microclimate conditions within the nests, durability and resistance to environmental factors, and ease of ant colonization. Additionally, large-scale field studies are crucial to evaluate the long-term efficacy and cost-effectiveness of these artificial nests for practical integration into cocoa pest management strategies. By optimizing artificial nest designs and understanding the preferences of *D. thoracicus*, we can unlock the full potential of this natural biological control agent for sustainable cocoa production.

**References**

Attygalle A. B., Mutti A. Rohe., W. Maschwitz U., Garbe W. and Bestmann H. J. 1998. Trail pheromone from the pavan gland of the ant *Dolichoderus thoracicus* (Smith). *Naturwissenschaften*, **85:** 275-277. http ://dx.doi.org /10.1007/s 001140050498.

BLRS. 2008. Annual Report. Bah Lias Research Station (BLRS). Unpublished. 437pp.

Delabie J. H. C. Jahyny B.Nascimento, C. Mariano C. S. F. Lacau, S. Campiolo. Philpott S. M. and Leponce M. 2007. Contribution of cocoa plantations to the conservation of native ants (Insecta: Hymenoptera: Formicidae) with a special emphasis on the Atlantic forest fauna of Southern Bahia, Brazil. Biodivers Conserv., **16:** 2359 - 2384. http://dx.doi.org/10.1007/s10531-007-9190-6.

Graham M. K. 1991. Biological control of Helopeltis sp. in mature cocoa by the black ant *(Dolichoderus bituberculatus)* and the cocoa mealybug (*Planococcus lilacinus*). The Planter, 67:543 546.

Ho C. T. and Khoo, K. C. 1994. Some factors influencing sustenance of high activity of black cocoa ant, *Dolichoderus thoracicus* (Hymenoptera: Formicidae) in cocoa estates. 4th International Conference on Plant Protection in the Tropics. Kuala Lumpur, Malaysia. March 28-3. pp 218 - 220.

Kalshoven, L. G. E. 1981. Pest of Crops in Indonesia. Jakarta, Indonesia. pp 701. P.T. Ichtiar Baru.

Khoo K. C. A Z and Chung G.F. 1989. Use of the black cocoa ant to control mirid damage in cocoa. The planter. Kuala Lumpur, Malaysia. The Planter, **65:** 370-383.

Saleh A. 2003. Distribution of Cocoa Pod Borer (CPB), *Conopomorpha cramerella* Snellen and Potential of using Cocoa Black Ant (CBA), Dolichoderus thoracicus Smith and Cocoa Mealybugs (CM), *Cataenococus hispidus* Morrison as Biological Control Agent in Lonsum Estates, North Sumatera Indonesia. Thesis, Penang, Universiti Sains Malaysia. M.Sc.: 150pp.

Saleh A. 2011. Establishment of the Biological Control System by Black Ant, Dolichoderus thoracicus (Smith) (Hymenoptera: Formicidae) and Mealybugs, *Cataenococcus hispidus* (Morrison) (Homoptera: Pseudococcidae) Against The Cocoa Pod Borer, *Conopomorpha cramerella* (Snellen) (Lepidoptera: Gracillariidae) in North Sumatra, Indonesia. Ph.D. Thesis, Penang, Universiti Sains Malaysia. pp 204.

Saleh A. 2012. Study of various types of permanent nest to propagate the black ants, *Dolichoderus thoracicus* (Smith). (Hymenoptera: Formicidae). Indonesian Journal of Entomology. ISSN: 1829- 7722. 9 (2): 64 70. Online version: http://jurnal.pei- pusat.org. DOI: 10.5994/jei.9.2.64.

Saleh A. Abu Hassan A. and Che Salmah M.R. 2006. Establishment of Dolichoderus theracicus Smith to control *Helopeltis theobromae* Miller and *Conopomorpha cramerella* Snellen in Lonsum cocoa plantations Indonesia. IMT-GT conference. Medan, Indonesia: 15.

Toxopeus H. and Giesberger G. 1993. History of Cocoa in Indonesia. International Conference on Cocoa (ICCE). Bali, Indonesia. October 19- 21. pp. 26-29.

Tjandra A. Umrah. Esyanti R. R. and Aryantha I. N. P. 2014. Promoting *Dolichoderus thoracicus* as an Agent to Disperse *Trichoderma* sp., a Fungus that Controls the Black Pod Disease, Central Sulawesi Indonesia. Journal of Mathematical & Fundamental Science, **46(1):** 41 49.

*MS Received on 13th June, 2024*
*MS Accepted on 30th August, 2024*

**DOI: 10.55278/NXTC3735**

# First report of leaf eating caterpillar, *Trilocha varians* (Walker) (Bombycidae: Lepidoptera) on *Ficus benjamina* from Gujarat, India

**N. P. Pathan[1*], S. M. Goswami[2] and B. K. Prajapati[1]**

[1]*Department of Plant Protection, College of Horticulture, S. D. Agricultural University, Jagudan - 384460, Gujarat, India*

[2]*Department of Entomology, C. P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar- 385506, Gujarat, India*

***Corresponding author: naziya.p.pathan@sdau edu.in**

## Introduction

The genus Ficus, commonly known as figs, belongs to the family Moraceae. Various species of Ficus *viz*., *Ficus benjamina, F. neuda, F. panda etc*. have been very well utilized in the South Asian region including India. Some of them like *F. benjamina,* commonly known as weeping fig are planted to increase aesthetic value in landscape in various parts of the world including India. In traditional medicine, various parts of the plant including the leaves, bark and roots have been used to treat conditions such as: skin disorder, respiratory ailments, digestive issues and anti-microbial properties (Kumar *et al*., 2012). It has been reported that plant has anti-fungal and anti-tumor properties (Lansky *et al*., 2008). It is distributed in Sri Lanka, Java, China, Borneo, Sumatra, Taiwan, Japan, Hong Kang, Philippines, Sulawesi (Kishida, 2002) including India. It is also used to remove pollution from the environment.

*Ficus* plants are attacked by several sucking (thrips, whiteflies and mealy bugs) and chewing insect pests including lepidopteran pests in the world. The order Lepidoptera causes significant damage to major cultivated crops (Raghav and Chaudhary 2021; Dewangan and Deole 2021). *Trilocha varians* is a moth which belongs to family Bombycidae described by Francis Walker (1855). It is widespread in the oriental region *viz*., India, Pakistan, Sri Lanka, China, extending to Taiwan, the Philippines, Sulawesi, Indonesia, Borneo, Hong Kong and Java (Gurule, 2013). This insect is one of the major pests that causes huge (100 per cent) damage to the ornamental *Ficus* species. The intense onslaught of these insect pests has the potential to cause significant damage to *Ficus* plants, resulting in complete defoliation (Navasero and Navasero, 2014). The larvae of *T. varians* attacked the jackfruit and white irregular patches were produced after feeding the early instar. The reproductive potential of jackfruit is reduced due to the high infestation of *T. varians* reported in the Philippines. The pest reduced the medicinal value of *Ficus* like jackfruit and fig, Navasero *et al*. (2013).

## Materials and methods

The present study was conducted during 2019-20 at the College of Horticulture, S. D. Agricultural University, Jagudan, Gujarat, India (Latitude-23.5134° N, Longitude-72.3998° E, altitude- 95 m above MSL). Different larval instars of *T. varians* were gathered from infested leaves of *F. benjamina* within and surrounding the college garden. These collected specimens were raised on their natural diet namely, leaves of *F. benjamina*. Larvae were kept in plastic jars until the pupation occurred. Upon adult emergence, the adults were transferred to plastic containers. Subsequently, the specimens were euthanized using ethyl acetate in a killing bottle and then pinned. Identification of the specimens was conducted using morphological keys under a microscope (Ramzan *et al*., 2023).

## Results and Discussion

The adult moths that emerged were identified as *Trilocha varians* Walker 1855. Although, it was reported from the Indian subcontinent in the nineteenth century by Hampson (1894) he did not mention the exact location or habitat of its existence. Later, it was reported in many eastern and Southeast Asian countries like Japan (Kishida, 2002), the Philippines (Navasero *et al*., 2013) and Haryana, India (Kedar *et al*., 2014).

## Nature of damage of *T. varians*

Larvae of *T. varians* attack the new leaves of plants, feeding on the dorsal side of the leaves **(Fig. 1).** The appearance of white papery patches on the dorsal side of plant leaves (Singh and Brar, 2016) is a major symptom of infestation. Early instars (1$^{st}$ - 2$^{nd}$) of *T. varians* can only consume fresh green twigs of the plant (Navasero *et al*., 2013; Navasero and Navasero, 2014), while later instars (3$^{rd}$ – 5$^{th}$) are the most destructive, consuming all types of leaves, whether soft or mature. These later instars spread across the entire canopy of the plant and are difficult to locate due to their resemblance in colour to plant branches (Ramzan *et al*., 2019b). Once consumed by the larvae of the pest, the plants lose their leaves, resulting in a decline in health and eventual death (Chuenban *et al.*, 2017). Some studies indicate that larvae can consume 80-100% of foliage (Ramzan *et al*., 2019a; Singh and Brar, 2016), sometimes leading to the death of the entire plant.

## Morphological characters of *T. varians*

**Eggs:** Eggs: Eggs are typically located on the lower surface of *F. benjamina* leaves. Newly laid eggs are yellow in color and round and flat in shape. They are usually laid in parallel lines on the dorsal side of the leaves (Daimon *et al*., 2012). The yellow color of the eggs changes to black before hatching (Kedar *et al*., 2014).

**Larva:** There were five larval instars of *T. varians*, with the duration of the first instar being 2-3 days. The color of neonate larvae was grey and changed with each stage. The durations of the 1st, 2nd, 3rd, 4th, and 5th instars were 2.50 ±0.14, 3.27 ±0.28, 4.10 ±0.12, 4.95 ±0.15, and 6.99 ±0.25 days, respectively. The color of later instars was similar to that of the branches, making them difficult to locate **(Fig. 2).** A fleshy and long horn was present on the eighth abdominal segment of each larval instar (Ramzan *et al*., 2020).

**Pupa:** Pupation occurred in whitish-yellow silken cocoons, beginning from the tail and extending towards the head. The pupal period was reported to be 5-6 days. The type of pupa observed was obtect (Ramzan *et al*., 2020).

**Adult:** The head, thorax and abdomen of adults were dark reddish brown. The forewings were pale reddish brown having curved waved line. The hind wings were greyish with reddish brown outer margins. Females were larger in size than males and they also had a longer life span. Total life cycle of male and female was completed in 35.50± 2.95 and 39.30± 3.97 days, respectively (Pandey and Singh, 2023).

Earlier *T. varians* was reported for the first time on *Ficus spp*. in Haryana, India during 2014. It was also documented as a pest affecting *Ficus benjamina* in the Bathinda district of Punjab (Singh and Brar, 2016). *T. varians* has been identified as a pest of the pipal tree (*Ficus religiosa* L.) in Madurai, Tamil Nadu (Rajavel and Shanthi, 2007). Gohil *et al.* (2022) conducted a study on the diversity of moths in Bhavnagar district using a light trap and documented the presence of *T. varians* during the survey. Patel *et al*. (2023) conducted a survey to assess lepidopteran diversity within the confines of the Hemchandracharya North Gujarat University campus. Further, investigation revealed the presence of 59 butterflies and moth's species, among which *T. varians* was notably captured using a light trap. Consequently, it is discerned that prior studies did not document the occurrence of *Trilocha varians* on *Ficus*, as observed in this study. The paper focuses on a single species, namely *T. varians* of the Bombycidae family, documented within the garden premises of the College of Horticulture, S. D. Agricultural University, Jagudan (District: Mehsana). This serves as a new record of *Ficus benjamina* as a host plant for *T. varians* in Gujarat, India.

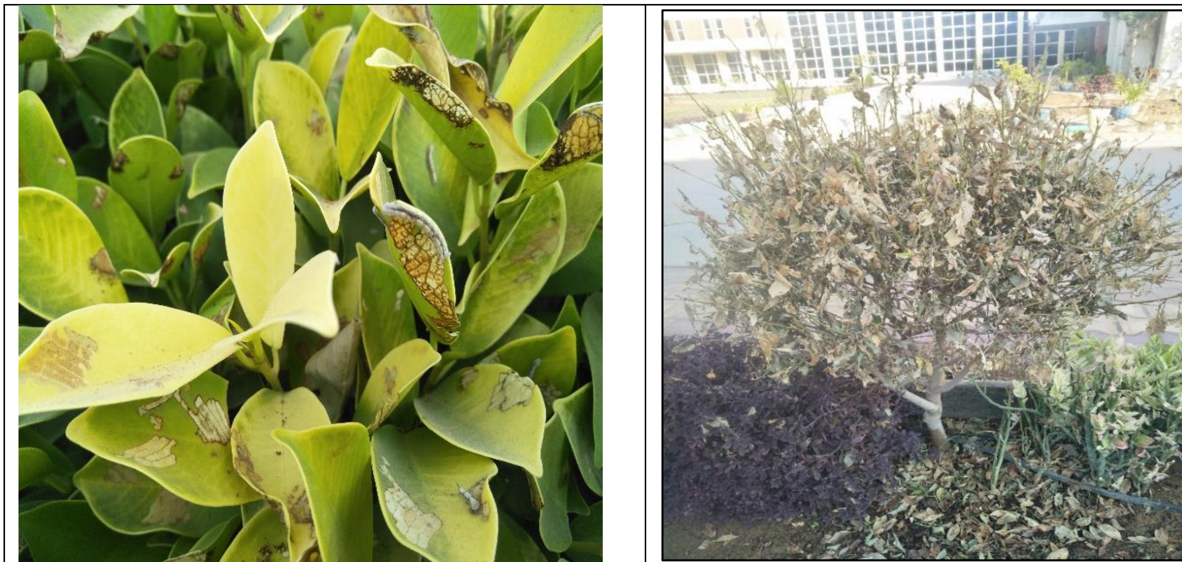


**Fig 1: *Ficus benjamina* leaves damaged by *T. varians***

**Eggs**

**Young caterpillar**

**Full grown caterpillar**

**Pupa**

**Adult**

**Mating**

**Fig 2: Different life stages of *T. varians***

**References**

Arya, P. V. Recent diversity and potential biological control studies on major ornamental *Ficus spp*. defoliating moth bombycid *Trilocha (Ocinara) varians* (Walker) (Lepidoptera: Bombycidae) 2020. *Journal of Experimental Zoology India*, **23(1):** 215-217.

Kim, K. J., Kil, M. J., Song, J. S., Yoo, E. H., Son, K. C. and Kays, S. J. 2008. Efficiency of volatile formaldehyde removal by indoor plants: contribution of aerial plant parts versus the root zone. *Journal of the American Society for Horticultural Science*, **133(4):** 521-526.

Chuenban, S., Bumroongsook, S. and Tigvattananont, S. 2017. Observation on *Trilocha varians* (Lepidoptera: Bombycidae*). International Journal Agricultural Technology*, **13(7):** 2189-2195.

Daimon, T., Fujii, T., Yago, M., Hsu, Y. F., Nakajima Fujii, T., Katsuma, S., Ishikawa, Y. and Shimada, T. 2012. Female sex pheromone and male behavioral responses of the bombycid moth *Trilocha varians*: comparison with those of the domesticated silkmoth *Bombyx mori*. Nat. Wise Aften, **99**: 207-215. https://doi.org/10.1007/s00114-012-0887-3.

Dewangan B. and Deole S. 2021. First report of leek moth, *Acrolepiopsis assectell*a (Zeller), their nature of damage on garlic crop at Raipur, Chhattisgarh. *Insect Environment*, **24(1)**: 50-52.

Gohil, B., Thakkar, K. and Gondaliya, G., 2022. Moths (Lepidoptera: Heterocera) of Bhavnagar city, Gujarat, India: A preliminary checklist. *International Journal of Entomology Research*, **7(4):** 62-71.

Gurule, S. A. and Nikam, S. M., 2013. The moths (Lepidoptera: Heterocera) of northern Maharashtra: a preliminary checklist. *Journal of Threatened Taxa*, **5**(**12**): 4693-4713.

Hampson, G., 1894. The fauna of British India, including Ceylon and Burma. Moths-Volume 2, Arctiidae, Agrostidae, Noctuidae. In: Taylor and Francis, London, pp. 609+ 325.

Kedar, S.C., Kumaranag, K. and Saini, R. 2014. First report of *Trilocha (Ocinara) varians* and its natural enemies on *Ficus spp*. from Haryana, India*. Journal of Entomology and Zoology Studies*, **2**: 268-270.

Kishida, Y. 2002. *Trilocha varians* (Walker) (Bombycidae) from Ishigaki Island, the Ryukyus. *Japan Heterocerist's Journal*, 219370.

Kumar, A., Jha, K. K., Kumar, D., Agrawal, A. and Gupta, A. 2012. Preliminary phytochemical analysis of leaf and bark (mixture) extract of *Ficus infectoria* plant. *The Pharma Innovation*, **1(5**): 71.

Lansky, E. P., Paavilainen, H. M., Pawlus, A. D. and Newman, R. A. 2008. *Ficus spp.* (fig): Ethnobotany and potential as anticancer and anti-inflammatory agents. *Journal of Ethnopharmacology*, **119(2):** 195-213.

Navasero, M.M. and M.V. Navasero. 2014. Biology of *Trilocha varians* (Walker) (Lepidoptera: Bombycidae) on *Ficus benjamina* L. in the Philippines. *Philippine Entomology*, **28(1):** 43-56.

Navasero, M.V., Navasero, M.M., Roxas, M.C. and Calumpang, S. 2013. Occurrence of the moraceae feeding bombycid, *Trilocha varians* (Walker) (Bombycid, Lepidoptera) as pest of jackfruit and some ornamental species of Ficus in the Philippines. *Journal of International Society of Southeast Asian Agriculture Science*, **19**(**2**): 41-48.

Pandey, S. and Singh, R., 2023. Biology of Leaf Eating Caterpillar *Trilocha varians* (Walker) on *Ficus microcarpa*. *Indian Journal of Entomology*, 994-996.

Patel, H., Patel, H., Patel, K. and Trivedi, J. 2023. Lepidopteran diversity of Hemchandracharya North Gujarat University Campus, Patan, Gujarat, India.

Raghav, D. K. and Chaudhary J.S. 2021. Incidence of fall armyworm, *Spodoptera frugiperda* (J.E. Smith) on potato in maize-potato crop sequence. *Insect Environment*, **24(1)**: 29-30.

Rajavel, D.S. and M. Shanthi. 2007. Note on the first occurrence of *Trilocha* (Ocinara) *varians* walker (Bombycidae: Lepidoptera) as a pest of pipal tree (*Ficus religiosa*) in Madurai, Tamil Nadu. Indian Forester**, 133**: 1706-1708.

Ramzan, M., Naeem-Ullah, U., Iqbal, N., Rasheed, Z., Saba, S., Ghaffar, H. and Saeed, S. 2020. Effect of temperature on the life cycle of *Trilocha varians* (Lepidoptera: Bombycidae) in Pakistan. *Pure and Applied Biology (PAB)*, **9(1):** 436-442.

Ramzan, M., U. Naeem-Ullah, M. Javaid, M. Nadeem, N. Iqbal and S. Saeed. 2019b. Comparative biology of *Trilocha varians* (Walker, 1855) (Lepidoptera: Bombycidae), a new pest of Ficus plant in Punjab, *Pakistan. Pak. Journal of Science*, **71(4)**: 220-225.

Ramzan, M., U. Naeem-Ullah, N. Iqbal, Z. Rasheed, S. Saba, H. Ghaffar and S. Saeed. 2019a. Effect of temperature on the life cycle of *Trilocha varians* (Lepidoptera: Bombycidae) in Pakistan. *Pure Applied Biology*, **9(1):** 436-442.

Ramzan, M., Ullah, U. N., Saba, S., Khan, M. M., Faheem, U., Rehman, A. and Hassan, W. 2023. First record of *Trilocha varians* (Bombycidae: Lepidoptera) from Pakistan. *Journal of Innovative Sciences*, **9(1):** 61-64.

Singh, A. and J. S. Brar. 2016. First record of *Trilocha varians* (Family: Bombycidae) a pest of *Ficus benjamina* (L.) and its biology in Talwandi Sabo, Dist. Bathia, Punjab. International. *Journal of Science and Nature*, **7(4**): 711-713.

*MS Received on 05th June, 2024*
*MS Accepted on 21st August, 2024*

**DOI: 10.55278/GCCG4057**

**Necrophoresis in captivity in a small and fragmented colony members of an Indian ant species *Diacamma rugosum* (Le Guillou 1842)**

**Ankita Dey and Ranajit Karmakar***

*Department of Zoology, Bidhanagar College, Salt Lake, Kolkata 700064 India*

***Corresponding author: ranajit161216@gmail.com***

**Abstract**

The primary focus was to examine how factors such as the duration of time passed since death, and the nature of death influenced the ability of *Diacamma rugosum* to undertake necrophoresis of the conspecific corpses inside the formicarium in the absence of usual nest companions. We categorized the corpses into five groups based on the type of killing. Our findings strongly supported our hypothesis that experimental undertakers required varying durations to necrophoresis for differentially killed conspecifics. In the case of mechanically killed short-term corpses, undertakers took significantly longer time to drop the corpses into the dumping area or refuse pile. We noticed a dedicated undertaker performed necrophoresis until her death.

**Keywords:** *Diacamma*, Necrophoresis, Corpse

**Introduction**

Ants are social insects, live in groups, and exhibit several behavioural features such as aggression, foraging, necrophoresis etc. (Banik *et al*., 2010; Chakravorty *et al*., 2023; Sarkar *et al*., 2023). Group living sometimes facilitates the spread of diseases among nestmates inside (Diez *et al*., 2012; Sun *et al*., 2018) and to alleviate the risk of disease spread ants have evolved to show necrophoric behaviour, which is the disposal of corpses (Heinze and Walter 2010; Renucci *et al*., 2010). Renucci *et* al. (2010) reported that *Temnothorax* sp ant workers tend to naturally bury corpses in the nest, and in some other species, workers dispose of corpses in dedicated chambers (Ribeiro and Navas, 2007). The undertakers need to differentiate dead conspecific from live ones during necrophoresis and it takes place in several steps (Ashish and Bhaskar, 2022; McAfee *et al*., 2018). It has been reported that the cause of death can influence corpse removal (Fan *et al*., 2012) and short-term changes in chemical profiles following death and are important cues that trigger the process (Diez *et al*., 2012).

Recent information about necrophoresis of *Diacamma sp* is very meagre, and we hypothesized that this species of ants would perform necrophoresis inside the ant-box with a few workers only.

## Materials and Methods

Six to eight workers of *Diacamma rugosum* (Insecta: Hymenoptera: Formicidae) were kept in the formicarium (54 x 52 x 54 $cm^3$) **(Fig. 1a).** We employed five killing methods (i) Chemical-killed [CK] (ii) Heat-killed [HK] (iii) Frozen-killed [FK] (iv) Mechanical-killed long-term [MKL] and Mechanical-killed short-term [MKS]. Diethyl ether was used in CK. Ants (HK) were killed in hot plates (70°C). Ants were killed by placing them inside deep freezer for 20 minutes in the case of FK. In the case of MKL, thumb-pressed-killed ants were kept aside for four hours before dropping into the formicarium, and in the case of MKS, the thumb-pressed-killed ants were dropped instantly. The time of first recognition of the corpse and time of taking the corpse for necrophoresis by undertakers were recorded for each category till the dropping in the final dumping area. One-way ANOVA was applied for testing significance at $p<0.01$ for the time required for necrophoresis among different killed groups.

## Results

As depicted in **Table 1**, we categorised the necrophoresis into two classes (1) Initial phase and (2) Final phase. For the CK, we recorded 28.24 ± 18.08 minutes necrophoric time before final disposal. The highest duration was observed in the MKS while the lowest duration was recorded in MKL. We have calculated the total event of necrophoresis for each killing category as depicted in column II by taking into consideration the time of the killing, the time of dropping, and the time of final disposal. We observed a similar pattern of necrophoric duration (class II) as compared with column I for all categories. One-way ANOVA test shows a significant F statistic in both categories I and II (7.88 and 7.43 respectively). As one-way ANOVA tests show significant F statistics, we have then gone for the post-hoc Tukey HSD test (Table 2).

Disposal of all kinds of corpses was carried out by undertakers at the point, which appeared to be the farthest part of the makeshift nest. A significant number of sixteen corpses were found near the boundary wall **(Fig. 3).** Once the corpse was finally disposed of (distance 37.5 ± 5.8 cm), the undertakers never necrophoresed.

In her lifetime, the red-marked undertaker performed the dead-carrying duty but following her death, the same duty was conferred upon the next member available and it was the yellow-marked ant. In one case, when the head and rest body parts were placed side by side, the undertaker necrophoresed the body part only and finally dumped it in the graveyard keeping the head part aside. The MKS corpse was first brought into the makeshift nest and then necrophoresed to the refuse pile, and for this two-stage necrophoresis undertakers took more time.

**Table 1: Different killing methods show different necrophoresis in *D. rugosum*. Time of necrophoresis is shown in two classes (I and II).**

| Sl. No. | Killing Method | Class I | Class II |
|---|---|---|---|
| | | Time (Mins) required by undertakers following the initial dropping of the corpse in the formicarium | Total time (Mins) required from killing to final dumping corpse by undertakers |
| 1 | Chemical Killed | 28.24±18.08 | 43.75±17.05 |
| 2 | Heat Killed | 8.50±3.53 | 15.00±1.41 |
| 3 | Frozen Killed | 21.50±4.94 | 31.50±4.94 |
| 4 | Mechanical Killed (Long Term) | 7.00±7.00 | 16.50±9.19 |
| 5 | Mechanical Killed (Short Term) | 207.33±100.00 | 214.66±101.50 |

**Table 2: A Post hoc Tukey HSD analysis**

| Combination | Level of significance in Category I | Level of significance in Category II |
|---|---|---|
| CK vs MKS | <0.01 | <0.01 |
| MKL vs MKS | <0.01 | <0.01 |
| MKS vs HK | <0.01 | <0.01 |
| MKS vs FK | <0.02 | <0.02 |

**Fig. 1a: The wooden-frame formicarium.**

**Fig. 1b: A bird's eye view of inside of the formicarium.**

**Fig. 2: A dead nestmate on the left and a live undertaker.**

**Fig. 3: Corpses are necrophoresed and disposed of to the soil-free part**

**Discussion**

Our results support the hypothesis that *Diacamma sp.* undertakers perform necrophoresis in captive conditions with a few fellow members, and would require different durations for the necrophoresis of differentially killed corpses. The short-term mechanically killed corpses took a significantly longer time.

Chemicals that stimulate necrophoresis are continuously present in the corpses but additional chemicals that are present in the live ants' bodies prevent necrophoresis (Choe *et al*., 2009). Choe *et al.* (2009) also reported that iridomyrmecin and dolichodial that are present on the live ant disappeared quickly following death, and elicited necrophoresis. In our study, the corpse of the MKS was necrophoresed for a significantly longer time compared to that of others. The differential necrophoresis could be attributed to that the MKS corpse retained some life signals, leading them to be initially transported to the makeshift nest but during the subsequent period spent inside the nest, further declination occurred resulting in the formation of death-related chemicals. In contrast, corpses of other categories were removed rapidly and, in those cases, the live signals dissipated quickly with the subsequent rapid emergence of death signals. Live *M. rubra* exhibited minimal amounts of oleic and linoleic acids, but the level steadily increased within 24 hrs post-mortem and remained stable for up to six days thereafter (Brian, 1973).

We recorded one dedicated undertaker at one time point in performing necrophoresis, and following her death, the next undertaker came into play. In this context, we can say that the necrophoresis of our ant was not random. Among six live nestmates, the red-marked one was always taking part in necrophoresis, and the specific behaviour of a captive individual member may be because one member at a time performed the duty of sanitation. A similar observation was noted in *Camponotus sp*, in which the captive soldier caste was never found removing conspecific corpses (Karmakar *et al*., 2012). It seems likely that following the death of an undertaker, the next potential member of the colony could get chance to perform the same duty. According to Baird *et al.* (2007), insect pathogens are found on or within worker ants, and having a single ant responsible for corpse removal reduces the risk of contamination.

For our present three-month study, we noted that the undertakers eventually disposed of all the corpses in a fixed arena, which was on the other side of the soiled area. It was already reported that *Camponotus sp* placed their nestmate corpses in cemeteries, while *D. vagans* removed the corpses in non-specific sites (Banik *et al.,* 2010). In the present study, we observed a significant number of sixteen corpses necrophoresed and found at the farthest part. This behaviour may suggest that, in nature, these ants are likely to dispose of dead conspecifics to a more distant location, while the confined space-imposed limitations on their usual necrophoresis. In the case of another ant species, Hölldobler and Wilson (1990) highlighted that a formicarium length of one meter is too restricted for the ants to exhibit the natural necrophoresis.

Ants of the present study showed no tendency to relocate corpses, leaving them in the same spot where they were finally dumped. In contrast, captive *Camponotus* sp relocated the dead conspecifics and thus, our ant species demonstrated a contrasting necrophoric behaviour. We further observed that the final two surviving ants did not exhibit any necrophoresis however, in contrast to this, the lone survivor of the captive *Camponotus sp* did display necrophoresis (Banik *et al.,* 2010).

**Conclusions**

We can infer that *Diacamma sp.* workers show necrophoresis in captive conditions, despite the absence of the stimulus, if any, from eggs, larvae, pupae or a queen. The undertakers exhibit a differential pattern for differentially killed conspecifics and, the highest necrophoric time in MKS suggests that presence of remnants of life signals after death. Our findings suggest that in captive settings, the ants display innate or hard-wired behaviour, such as necrophoresis, which is generally operative in natural colonies. Our study warrants further study to investigate the effect of other killing methods on necrophoresis for this particular species. In addition, a study could be done for a single necrophoric undertaker for corpses to understand the effect of group on necrophoresis in captivity.

**Acknowledgements**

RK is personally indebted to the late Prof. R. L. Brahmachary, Indian Statistical Institute, Kolkata for his continuous

encouragement to initiate the ant behaviour work.

**References**


Ashish, V.V. and Bhaskar, H. 2022. Necrophoresis: The funeral ways of social insects. *Insect Environment*, **25:** 106-107.

Baird, R., Woolfolk, S. and Watson, C.E. 2007. Survey of bacterial and fungal associates of black/hybrid imported fire ants from mounds in Mississippi. *Southeastern Naturalist*, **6:** 615– 632.

Banik, S., Biswas, S., Karmakar, R. and Brahmachary, R. 2010. Necrophoresis in two Indian ant species, *Camponotus compressus (*Fabricius) and *Diacamma vagans* (Smith) (Insecta: Hymenoptera: Formicidae). *Proceedings of the Zoological Society*, **63:** 87-91.

Brian, M.V. 1973. Caste control through worker attack in the ant *Myrmica*. *Insectes Sociaux*, **20:** 87–102.

Chakravorty, B., Chakraborti, S. and Karmakar, R. 2023. Separation aggression: nA captive study on two Indian ant species, *Camponotus compressus* (Fabricius 1787) and *Tetraponera* rufonigra (Jerdon 1851) (Hymenoptera: Formicidae). *Insect Environment*, **26:** 348-362.

Choe, D.-H., Millar, J. G. and Rust, M.K. 2009. Chemical signals associated with life inhibit necrophoresis in Argentine ants. *Proceedings of the National Academy of Sciences of the United States of America*, 106: 8251–8255.

Diez, L., Deneubourg, J. and Detrain, C. 2012. Social prophylaxis through distant corpse removal in ants. *Naturwissenschaften*, **99:** 833-842.

Fan, Y., Pereira, R. M., Kilic, E., Casella, G. and Keyhani, N.O. 2012. Pyrokinin β-neuropeptide affects necrophoretic behavior in fire ants (*S. invicta*), and expression of βNP in a mycoinsecticide increases its virulence. *Plos One*, **7**: e26924.

Heinze, J. and Walter, B. 2010. Moribund ants leave their nests to die in social isolation. *Current Biology*, 20: 249–252.

Hölldobler, B. and Wilson, E. O. 1990. The Ants. The Belknap Press of Harvard University Press.

Karmakar, R., Banik, S., Biswas, T., Brahmachary, R. L. and Sahu, C. R. 2012. A captive study on activity-rest, nesting and aggression behaviour of an Indian ant species, *Polyrachis lacteipennis* (Smith 1858) (Hymenoptera: Formicidae: Formicinae). *Proceedings of the Zoological Society*, **63:** 87-91.

Mcafee, A., Chapman, A., Iovinella, I., Gallagher-Kurtzke, Y., Collins, T. F., Hugo, H., Madilao, L., Pelosi, P. and Foster, L. J. 2018. A death pheromone oleic acid, triggers hygienic behaviour in honeybees (*Apis mellifera* L.). *Scientific Reporter*, **8:** 1-13.

Renucci, M., Tirard, A. and Provost, E. 2010. Complex undertaking behavior in *Temnothorax lichtensteini* ant colonies: From corpse-burying behavior to necrophoric behavior. *Insectes Sociaux*, **58:** 9-16.

Ribeiro, P. L. and Navas, C. A. 2007. The leaf-cutting ant *Atta sexdens rubropilosa*, FOREL, 1908 prefers drier chambers for garbage disposal. *Journal of Insect Behavior*, **20:** 19–24.

Sarkar, R., Banik, S. and Karmakar, R. 2023. Lipid food preference and transportation using tools by an Indian ant species *Monomorium pharaonis* (Hymenoptera: Formicidae): A field study. *Sociobiology*, **70:** e9167.

Sun, Q., Haynes, K. F. and Zhou, X. 2018. Managing the risks and rewards of death in eusocial insects. *Philosophical Transactions Royal Society of London B*. **373:** 20170258.

*MS Received on 24th June, 2024*
*MS Accepted on 03rd September, 2024*

**DOI: 10.55278/UNVS7428**

## Seasonal incidence of insect pests on *Dendrocalamus brandisii* and *Bambusa tulda*

**D. B. Megha[1*], R. N. Kencharaddi[1], Ramakrishna Hegde[2], V. Maheswarappa[2], G.N. Hosagoudar[3] and Charanakumar[4].**

[1]*Department of Forest Biology and Tree Improvement, College of Forestry, Ponnampet, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka-577204, India.*

[2]*Department of Silviculture and agroforestry, College of Forestry, Ponnampet, KeladiShivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka-577204, India.*

[3]*AHRS, Shivamogga, KeladiShivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka-577204, India.*

[4]*Department of Ecology and Environmental Science, Tumkur University, Tumakuru and Karnataka Forest Department.*

***Corresponding author rnkencharaddi@uahs.edu.in***

**Abstract**

Bamboo, often referred to as “Green Gold,” plays a crucial role as a non-wood forest resource in India, encompassing 124 species across 23 genera. The successful establishment of bamboo plantations hinges on effective nursery management. However, this valuable bamboo species face vulnerability to over 40 insect pests, particularly sap-sucking insects and defoliators. In Karnataka alone, 20 pest species have been reported. In this study conducted at the Forestry College, Ponnampet (during 2022-23), we meticulously surveyed *Dendrocalamus brandisii* and *Bambusatulda* for pest occurrences. Notable pests included sap-suckers such as *Melanaphis bambusae* and *Palmicultor lumpurensis*, as well as the leafroller *Crocidophora ptyophora* and grasshoppers. Interestingly, *C. ptyophora* and *Lymantria sp.* affected both bamboo species, while the hard scale pest was unique to *B. tulda*.

**Keywords:** Correlation, Weather, Occurrence, Bioagents, Seasonal incidence

## Introduction

“Bamboo, known as the “Green Gold,” belongs to the grass family Poaceae and encompasses over 1,250 species across 75 genera worldwide. India boasts the second-largest bamboo resource, with 125 species in 23 genera covering 15.69 million hectares, including 1.04 million hectares in Karnataka. Bamboo holds socio-cultural importance and provides environmental benefits, such as soil stabilization. *Bambusa tulda* is commercially significant, while *Dendrocalamus brandisii* is favored for its straight growth in Coorg, Karnataka. Despite its value, bamboo faces threats from insect pests, with approximately 200 species from orders like Coleoptera and

Lepidoptera affecting it. In Karnataka, bamboo hosts 20 pest species. Notable pests include coccids, sap-suckers, and defoliators like *Ceracris* and *Heiroglyphus*. Sap-suckers such as *Hippotiscus* and *Notobitus* also pose challenges. Although pest populations are typically low, their impact on bamboo ecosystems remains significant."

**Materials and Methods**

The study was conducted at the Bamboo Nursery and Plantation, Forestry College, Ponnampet, from September 2022 to June 2023. Regular surveys recorded insect pest occurrences on *Dendrocalamus brandisii* and *Bambusa tulda* every two weeks. In the nursery, 200 seedlings of each species were observed without pest control. In the plantation, three clumps of each species were randomly selected, and all culms were examined for pests.

Pest occurrences and the number of infested plants were meticulously recorded, and correlations with weather conditions were analysed. The pests were categorized as major, minor, or negligible based on their intensity, following Sivakumar's classification (2009). Monthly incidence levels were calculated from fortnightly data, and pest calendars were developed for each bamboo species.

**Experimental Results and Discussion**

In the nursery, *D. brandisii* and *B. tulda* seedlings faced infestations from *Melanaphis bambusae, Palmicultor lumpurensis, Crocidophora ptyophora*, and various grasshoppers, including *Chitaura* sp., *Oxya* sp., and *Spathosternum prasiniferum*. Similar studies, such as those conducted by Rishi (2014) in Assam, identified major pests like *Psara licarsisalis* and *Crocidophora* sp. in nurseries. Revathi and Remadevi (2011) highlighted aphids as significant pests affecting bamboo seedlings, while Viswanath *et al.* (2013) observed aphids and mealybugs on *D. brandisii* in Karnataka. The incidence of insect infestations exhibited fluctuating patterns. Grasshoppers were consistently recorded throughout the study, with incidence ranging from 0.5% to 4% on both species. This incidence correlated positively with minimum temperature and relative humidity but negatively with maximum temperature.

In bamboo plantations, *C. ptyophora* and Lymantria sp. were present on both *D. brandisii* and *B. tulda*, while hard scales were exclusive to *B. tulda*. Notably, the seasonal incidence of major pests like *M. bambusae* on *D. brandisii* and *B. tulda* in the nursery varied, with *M. bambusae* reaching a peak of 31% in May.

During our study, we observed a moderate positive correlation between maximum temperature and insect infestations, as well as a low positive correlation with minimum relative humidity (RH). These findings align with previous research by Patra et al. (2013) and Gaurav and Maha (2018). Specifically, *Palmicultor lumpurensis* exhibited a wide incidence range, peaking in

May. It positively correlated with maximum temperature but negatively correlated with minimum temperature, RH, and rainfall. These trends partially corroborate the work of Basavaraju *et al*. (2021).

Leaf rollers, such as *Crocidophora ptyophora*, were more prevalent during monsoons, showing positive correlations with humidity and rainfall. Interestingly, infestations peaked in October for *Bambusa tulda* but remained low for *Dendrocalamus brandisii*, consistent with Sisodia et al.'s (2005) observations. Notably, hard scale infestations on *B. tulda* were significant from December to May. They exhibited a strong positive correlation with maximum temperature and negative correlations with RH, rainfall, and wind velocity, as reported by Dubey et al. (2021).

In nurseries, sap-sucking pests like *Chitaura sp.* and *Palmicultorlumpurensis*, along with leaf rollers like *C. ptyophora*, were prevalent. In plantations, *C. ptyophora* and *Lymantria sp.* were common, while hard scales were specific to *B. tulda*. Our correlation analysis revealed that *Melanaphisbambusae* and *P. lumpurensis* had positive correlations with maximum temperature and minimum RH, while negatively correlating with other weather parameters. Grasshoppers, categorized as negligible pests, showed low incidence.

This study underscores the importance of understanding pest dynamics for effective bamboo management.

**References**

Adhikari, B. Bhusal, P. Kafle, K. and Rajkumar, K. C., 2021, Effects of Different Weather Parameters on Insect Pest Incidence in Paddy in SundarbazarLamjung. *Tropical Agroecosystems*, **2**(2): 82-86

Anonymous, 2021, Bamboo Resource of the Country. Indian state of Forest Report., Forest Survey of India, Dehradun, pp.1- 14.

Basavaraju, S., Kencharaddi, R. N., Kushalappa, C. G., Ramakrishna, Hegde. and Hosagoudar, G. N., 2021, Occurrence of forest nursery pests in moist deciduous forest ecosystem at Kodagu, Karnataka. *J. Entomol. Zool. Stud*., **9**(1): 1136-1141.

Dubey, V. K., Kalleshwaraswamy, C. M. and Shivanna, B. K., 2021, Seasonal Incidence of Major Sternorrhynchan Insect Pests Infesting Arecanut in South India. *Flora and Fauna*, **27** (1): 101-108.

Gaurav, S. and Maha, S. J., 2018, Seasonal incidence of different insect-pests in Kharif maize. *J. pharmacogn. phytochem*., **7**(3): 3666-3669.

Hemant, K., Mehera, B., Lal, S. and Rajiv, U. 2007, the potential of bamboo cultivation as a way forward in improving livelihood: a case study.

*MS Received on 25th June, 2024*
*MS Accepted on 16th September, 2024*

**DOI: 10.55278/AUJR5101**

# Production technique of *Encarsia guadeloupae* for the management of Rugose Spiralling Whitefly (*Aleurodicus rugioperculatus* Martin) on coconut

**S. M. Wankhede*, K. V. Malshe and S. L. Ghavale**

*Regional Coconut Research Station, Ratnagiri-415612 (Maharashtra State), India*

***Corresponding author: drsantoshwankhede@gmail.com***

## Abstract

In the years 2020-23, a field experiment on *Encarsia* production technique for managing Rugose Spiraling Whitefly (*Aleurodicus rugioperculatus* Martin) in coconut palms was conducted at the AICRP (Palms), RCRS, Bhatye, Dist. Ratnagiri, Maharashtra, to evaluate the efficacy of *Encarsia* parasitoids in controlling the rugose spiraling whitefly (RSW) on coconut palms. The study employed a completely randomized block design with five treatments and four replications. Single palms of susceptible coconut varieties were selected for each treatment. Empty plastic bottles (1-liter capacity) were collected and modified by creating three holes (5x5 cm) in the middle region. These holes were covered with muslin cloth (30x20 cm) secured by rubber bands. The modified bottles were then hung on coconut fronds. Twenty healthy RSW nymphs were identified and placed in each designed plastic bottle cage. Field-collected *Encarsia* parasitized pupae of RSW were released into the cages, and the bottle mouths were plugged with cotton. The number of healthy and parasitized RSW nymphs on leaflets was recorded at 7, 10, and 15 days after treatment application. *Encarsia* parasitized pupae of RSW at a rate of 10 per palm resulted in the highest parasitism (62.08%). This treatment significantly outperformed T2 (*Encarsia* parasitized pupae of RSW at 5 per palm, 45.69%), T1 (*Encarsia* parasitized pupae of RSW at 3 per palm, 40.13%), and the control (T5, 7.36%). *Encarsia* parasitized pupae of RSW at 8 per palm achieved a parasitism rate of 54.86%, comparable to T4. The mass production technique of *Encarsia guadeloupae* under field conditions appears safe, eco-friendly, and effective for managing rugose spiralling whitefly in coconut palms.

**Key words**: Coconut, *Encarsia*, Mass production, Rugose spiralling whitefly

## Introduction

Rugose spiralling whitefly was reported from Florida, America in 2009. In India, it was noticed in Polachi (T.N.) and Pallakkad (Kerala) in August 2016. The pest was distributed unevenly along national highways, isolated garden near water bodies, restricted garden etc. This was observed at Regional Coconut Research Station, Bhatye, Ratnagiri during August, 2017 in Maharashtra and attended pest status after May, 2018 and noticed everywhere in Konkan region of

Maharashtra (Wankhede *et al*., 2021). The immature and adult whitefly causing damage to the coconut by their sucking feeding habit, siphon out coconut sap by selective feeding from the abaxial of the coconut leaflets. For the ecofriendly management of RSW the aphelinid parasitoid *Encarsia guadeloupae* Viggiani was the only major natural enemy encountered on the spiralling whitefly causing 20.70% parasitism in January 2000, which had increased to 95.68% by December 2001 (Mani *et al*., 2004). *Encarsia formosa* is a parasitoid used worldwide for the biological control of whiteflies on vegetables and ornamental plants grown in greenhouses (Hoddle *et al*., 1998). Kos *et al.*, (2009) observed that the *Encarsia* parasitoid was determined on 14 host plants in the greenhouse and *E. tricolor* on 11 host plants in the greenhouse and on one host plant in the field. *E. inaron* and *E. longicornis* appeared only on one host plant in a greenhouse. Release programs of *Encarsia formosa* are most effective (Dai *et al.*, 2014) when the initial population of whiteflies is quite low. Though it is the potent bioagent, but the availability of *Encarsia* is the problem because it is very difficult to rear under laboratory condition. Considering the facts in view, the present research work was proposed to find out the production techniques of *Encarsia* under field conditions.

**Materials and methods**

An experiment was conducted at AICRP (Palms), RCRS, Bhatye, Dist. Ratnagiri, Maharashtra, during 2020-23 to develop a production technique for *Encarsia*—a parasitoid used in managing the rugose spiralling whitefly (*Aleurodicus rugioperculatus* Martin) on coconut palms.

The study involved five treatments:

T1: *Encarsia* parasitized pupae of RSW at 3 per cage

T2: *Encarsia* parasitized pupae of RSW at 5 per cage

T3: *Encarsia* parasitized pupae of RSW at 8 per cage

T4: *Encarsia* parasitized pupae of RSW at 10 per cage

T5: Control (no *Encarsia* release)

Single palms of susceptible coconut varieties (especially orange and green dwarf) were selected for each treatment. Modified plastic bottle cages, with holes covered by muslin cloth, were hung on coconut fronds. Healthy RSW nymphs were placed in these cages, and field-collected *Encarsia* parasitized pupae were released. Observations were recorded at 7, 10, and 15 days after treatment application. The percentage parasitism of *Encarsia* was calculated using the corrected mortality formula.

**Results and discussion**

The pooled data from three years (as depicted in **Table 1**) revealed that treatment T4—where *Encarsia* parasitized pupae of RSW were released at a rate of 10 per palm—

achieved the highest parasitism (62.08%). This treatment significantly outperformed T2 (*Encarsia* parasitized pupae of RSW at 5 per palm, 45.69%), T1 (*Encarsia* parasitized pupae of RSW at 3 per palm, 40.13%), and the control (T5, 7.36%). Treatment T4 was comparable to T3 (*Encarsia* parasitized pupae of RSW at 8 per palm, 54.86%).

*Encarsia formosa*, a widely used parasitoid, plays a crucial role in the biological control of whiteflies on vegetables and ornamental plants grown in greenhouses (Hoddle *et al.*, 1998). The developmental time for *Encarsia* varies, ranging from 22.7 days at 27.5°C to 47.4 days at 17.5°C (Matadha *et al.*, 2004). Hu *et al.* (2002) found that the parasitoid developmental rates differ significantly based on the host instar parasitized. Development occurs more rapidly when 3rd and 4th instar GHWFs (greenhouse whitefly) are offered for parasitization compared to 1st or 2nd instars. Although the percentage of emergence is not affected by the host's age at the time of parasitization, adult longevity and emergence patterns vary greatly depending on the instar parasitized.

**Table 1. Pooled data of *Encarsia* parasitisation on Rugose spiraling whitefly (RSW) during 2020-21 to 2022-23**

| Treatment No. | Treatment Details | *Encarsia* parasitism on RSW (%) | | | | Total cost/ treatment (Rs.) |
|---|---|---|---|---|---|---|
| | | 2020-21 | 2021-22 | 2022-23 | Pooled Mean | |
| T1 | *Encarsia* parasitized pupae of RSW @ 3/cage | 58.33 (7.40) | 47.50 (6.76) | 14.58 (3.76) | 40.13 (5.97) | 14.37 |
| T2 | *Encarsia* parasitized pupae of RSW @ 5/cage | 64.58 (7.83) | 52.50 (7.09) | 20.00 (4.47) | 45.69 (6.46) | 14.57 |
| T3 | *Encarsia* parasitized pupae of RSW @ 8/cage | 69.58 (8.19) | 59.17 (7.54) | 35.83 (5.93) | 54.86 (7.22) | 14.87 |
| T4 | *Encarsia* parasitized pupae of RSW @ 10/cage | 71.66 (8.37) | 67.50 (8.11) | 47.08 (6.70) | 62.08 (7.72) | 15.07 |
| T5 | Control | 7.08 (2.65) | 9.58 (3.13) | 5.42 (2.30) | 7.36 (2.69) | 10.94 |
| SE ± | | 0.30 | 0.33 | 0.23 | 0.28 | |
| CD@5% | | 0.94 | 1.02 | 0.71 | 0.89 | |

*(Figures in parenthesis are square root (x+0.5) transformed value)*

The cost required for T4–*Encarsia* parasitized pupae of RSW @ 10/palm treatment was Rs. 15.07 only. However, it can be easily mass production technique of *Encarsia* for the management of rugose spiralling whitefly without affecting the biodiversity.

**Conclusion:**

The *Encarsia* parasitized pupae of RSW @ 10/palm treatment was found safe, cheap and eco-friendly effective technique that can produce *Encarsia* under field conditions for the management of rugose spiraling whitefly infesting coconut palms.

**Acknowledgements:**

The authors are thankful to Dr. BSKKV, Dapoli for providing funds, technical help and timely guidance for conducting the experiment.

**References**

Dai Peng, Ruan Changchun, Zang Liansheng, Wan Fanghao, and Liu Liazhoa (2014). Effects of rearing host species on the host-feeding capacity and parasitism of the whitefly parasitoid *Encarsia formosa*. *Journal of Insect Science*, 14(1):118.

Matadha Deepak, Hamilton George C., and Lashomb James H. (2004). Effect of temperature on development, fecundity, and life table parameters of *Encarsia citrina* Craw (Hymenoptera: Aphelinidae), a parasitoid of Euonymus scale, *Unaspis euonymi* (Comstock), and *Quadraspidiotus perniciosus* (Comstock) (Homoptera: Diaspididae). *Environmental Entomology*, 33(5): 1185–1191.

Hoddle M. S., Driesche Roy Van, and Sanderson John P. (1998). Biology and use of the whitefly parasitoid *Encarsia formosa*. *Annual Review of Entomology*, 43(1): 645-669.

Hu Jing S., Gelman Dale B., and Blackburn Michael B. (2002). Growth and development of *Encarsia formosa* (Hymenoptera: Aphelinidae) in the greenhouse whitefly, *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae): Effect of host age. *Archives of Insect Biochemistry and Physiology*, 49(3): 125–136.

Kos Katarina, Željko Tomanović, Helena Rojht, Matej Vidrih, and Stanislav Trdan (2009). First massive occurrence of greenhouse whitefly parasitoid, *Encarsia formosa* Gahan (Hymenoptera: Aphelinidae) on greenhouse whitefly, *Trialeurodes vaporariorum* [Westwood] (Homoptera: Aleyrodidae) in Slovenia. *Acta Agriculturae Slovenica*, 93(3): 284-291.

Mani M., Krishnamoorthy A., and Venugopalan R. (2004). Role of the aphelinid parasitoid *Encarsia guadeloupae* in the suppression of the exotic spiralling whitefly, *Aleurodicus dispersus* on banana in India. *Biocontrol Science and Technology*, 14(6): 619-622.

Wankhede, S. M., Shinde, V. V., and Ghavale, S. L. (2021). Status of rugose spiralling whitefly (*Aleurodicus rugioperculatus* Martin) in Konkan region of Maharashtra. *Pest Management in Horticultural Ecosystems*, 27(2): 190-195.

*MS Received on 14th June, 2024*

*MS Accepted on 07th August, 2024*

**DOI: 10.55278/ARRX5718**

## Diversity of moth families in Urban Bangalore with trends in weather patterns

**Lakshmi K P*, T A Vibha, Thanusha Lokesh and Ashok Sengupta**
*Kendriya Vidyalaya No. 1, AFS Jalahalli, Jalahalli West, Near KG Halli, Bengaluru, Karnataka, India – 560015*
***Corresponding author*: lkp741curious@gmail.com***

### Abstract

This work focuses on moths, which serve as pollinators in an ecosystem. The study area, Kendriya Vidyalaya No.1 in Jalahalli (Latitude: 13.05527, Longitude: 77.53591), is a biodiverse green space within the bustling city of Bengaluru. The study sheds light on the diversity and characteristics of moths in a natural ecosystem closely surrounded by urban development. Data on various moth species were collected from an iNaturalist project, which had already documented the area's biodiversity over more than a year. The present study enhanced this dataset with additional observations. Remarkably, over 230 moth species were recorded in just one year, including the first photographic documentation of a moth from the family Palaeosetidae in India. Researchers classified this data to explore the seasonal diversity of different moth families within the study area. As part of the project, a mercury vapor lamp trap was set up to evaluate its effectiveness in attracting moths. Additionally, the flowering plant species in the study area were documented, classified, and compared with existing data. This allowed researchers to relate observed moth families with the plant species they pollinate. Overall, work contributes significantly to our understanding of moth ecology in this unique urban-natural interface.

**Key Words:** Pollinators, Biodiversity, Urban ecosystem, Jalahalli, Bengaluru, iNaturalist, Species diversity, Palaeosetidae, Seasonal diversity,

### Introduction

Butterflies and moths belong to the order Lepidoptera. Of the two, the image of butterflies is the one that is most often invoked in our minds. But what about their nocturnal cousins, the moths? What is their role in the ecosystem? The answer to this question is what motivated us to do this study on moths. Moths are often overlooked as pollinators, since the cover of night hides them from our view. As a result, there is very little scientific data on them. But, the role of moths as pollinators has been confirmed by many researchers [MacGregor et al, 2014; Van Zandt, 2019; Walter et al, 2020; Ganganalli et al, 2022; Anderson et al, 2023; Arora et al, 2023]. As Anderson et al (2023) reported, it is becoming evident that moths are just as efficient, if not more efficient pollinators than butterflies and possibly, even bees. They play many other important roles, as primary consumers, as the food source for a number of organisms and also in nutrient recyclers. They also act as bio-indicators due to their response to changing temperatures, light, rainfall patterns etc. Moths far outnumber butterflies in terms of number of species [Carter, 1992]. In this project, we studied their behaviour in the ecosystem of the school campus of Kendriya Vidyalaya No.1, Jalahalli, Bengaluru. It is an example of a green space in an urban ecosystem, which act as a refuge for biodiversity in this age of rapid deforestation and environmental degradation. The objective of this study was to find and classify the diversity of moths through field work and study the seasonality of the different families. We also identified the species of flowering plants in the area and attempted to correlate it with the families of moths with reference to previous studies.

## Materials and Methods

The steps taken for the study were as follows. First, we joined the iNaturalist project "Kendriya Vidyalaya School No. 1 Jalahalli, Bengaluru Biodiversity". (Latitude: 13.05527, Longitude: 77.53591). A mercury vapour lamp was set up at the school to document moths. The resulting observations were then documented in the iNaturalist project. The data from the iNaturalist project was exported to a spreadsheet in .csv file format after filtering out the data on moths. Graphs were subsequently created from the data to study the seasonality of the various families. Weather data of North Bengaluru was collected from the agro-meteorology department website of Gandhi Krishi Vigyan Kendra (GKVK), Bengaluru which was used to check for relation between the appearances of moths and the weather patterns. The flowering plants species of the area were also documented and identified through iNaturalist. Below is a description of the light trap experiment which was conducted:

The objective of the experiment was to setup a light trap and to study its efficiency in attracting moths. Most moths are attracted to light, mainly white and ultraviolet (UV) light (Baker, R.R., 1987). There are two types of light traps which are commonly used: Actinic tube traps and Mercury vapour lamps. In terms of efficiency, the mercury vapour lamp has been found to be more efficient than the actinic tube trap in attracting moths. This is because the mercury vapour lamp emits UV rays which moths are highly attracted to compared to the white and blue light emitted by the actinic tube trap. Due to this, a mercury vapour lamp trap was chosen for this experiment.

**Construction: Fig. 1** shows the mercury vapour lamp trap. The experiment was done during night. It was made sure that there were no sources of light pollution such as street lights. This could distract the moths from their path. For construction, a large white cloth was put up. The mercury vapour lamp was mounted on a stand. The moths attracted by the light would land on the white cloth.

**Fig. 1: Mercury vapour lamp trap**

**Table 1** presents the observations made in a single night. It was observed that the mercury vapour lamp attracted a number of moths belonging to different species.

**Table 1: Observations of the light trap**

| Type of trap | No. of moths observed | No. of species of moths observed |
|---|---|---|
| Mercury Vapour trap | 8 | 7 |

**Fig. 2: Agathia (Guenée.) recorded on the lamp trap during the experiment.**

**Results and Discussion**

Through the experiment, it was observed that the bigger the moth, the later it appeared at night. Bigger moths appear later at night because they use light to navigate. When there is light pollution, they cannot find their path properly. Thus, this is an exclusively urban adaptation. Twenty-five families of moths have been recorded on the school campus so far. **Table 2**: Families of moths observed gives the data of the families and number of families of moths observed in the area of study:

Erebidae is one of the families with the greatest number of species in India. This could be the cause as to why it is abundant in the area of study. The other abundant families, Crambidae, Geometridae, Noctuidae and Pyralidae, also have a greater number of species. A similar set of families have come out on top in terms of species diversity in the work done by Singh *et al*, 2022.

There is a peak in the number of moths observed in the July-October and March-April. At the same time, we can observe an increase in humidity and cloud cover. There is a long dip in the number of moths observed in the time period of November-March and in that period we can observe sudden decrease of temperature till February and then a sudden increase till April. This could mean that moths are affected by sudden changes in temperature. However, there is a drop in number of observations in May-July. This is not well-explained by changes in any of the weather parameters.

**Table 2: Families of moths observed**

| Family | Frequency of sighting | Family | Frequency of sighting |
|---|---|---|---|
| Erebidae (Leach.) | 228 | Eupterotidae (Swinhoe.) | 2 |
| Crambidae (Latreille.) | 147 | Palaeosetidae | 2 |
| Geometridae (Leach.) | 91 | Stathmopodidae (Meyrick.) | 2 |
| Noctuidae (Latreille.) | 31 | Metarbelidae (Strand.) | 2 |
| Pyralidae (Latreille.) | 21 | Tortricidae (Latreille) | 2 |
| Nolidae (Bruand.) | 11 | Euteliidae (Grote) | 1 |
| Psychidae (Boisduval.) | 10 | Plutellidae (Guenée.) | 1 |
| Uraniidae (Blanchard.) | 6 | Depressariidae (Meyrick.) | 1 |
| Oecophoridae (Bruand.) | 6 | Autostichidae(Le Marchand.) | 1 |
| Sphingidae (Latreille.) | 6 | Alucitidae (Leach.) | 1 |
| Thyrididae (Herrich-Schäffer.) | 4 | Tineidae (Latreille.) | 1 |
| Pterophoridae (Zeller.) | 3 | Saturniidae | 1 |
| Limacodidae | 3 | | |

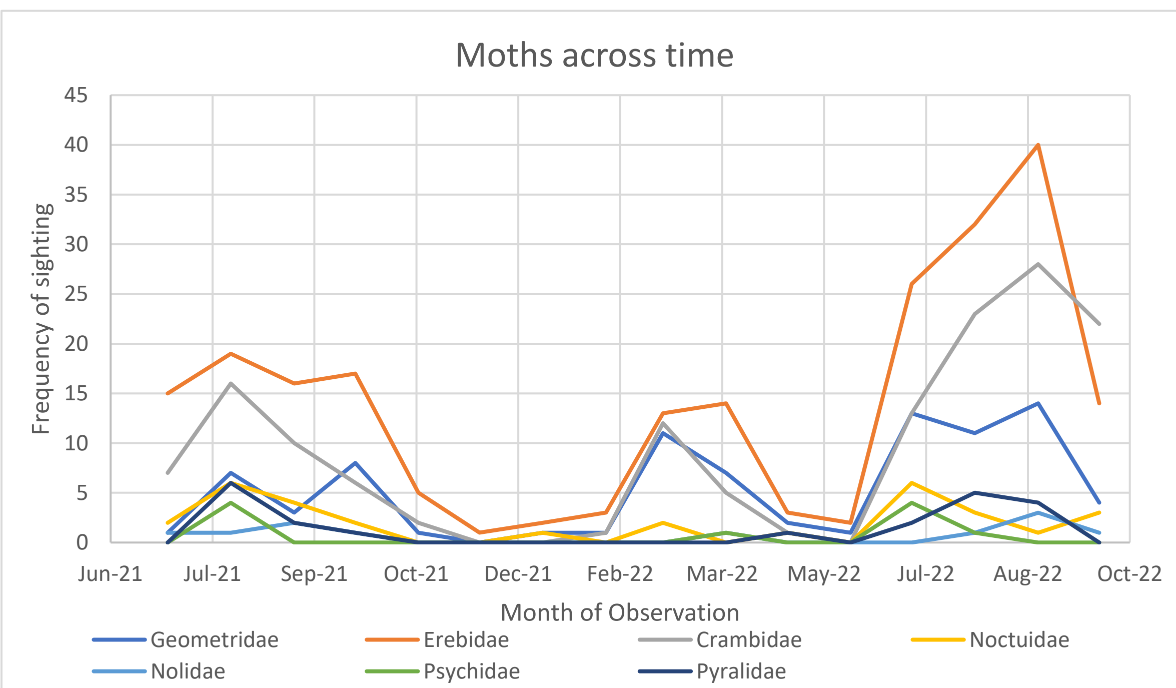



**Fig. 3: Number of observations of seven families of moths (2021-2022)**

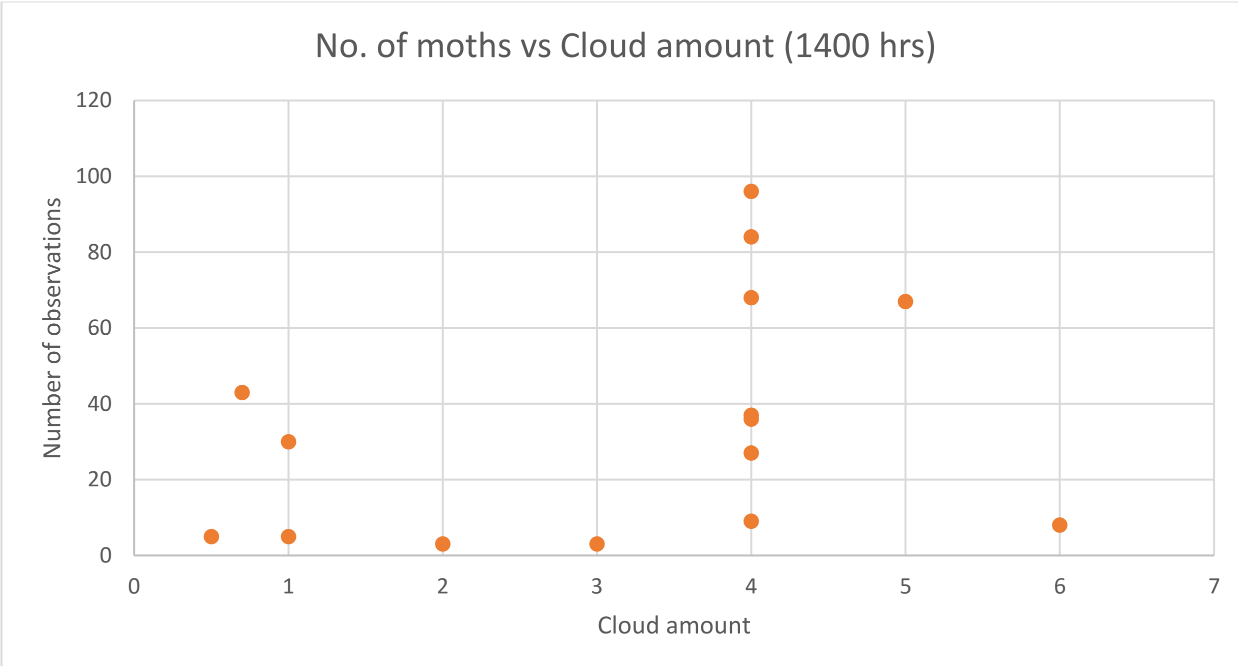



**Fig. 4: Number of moths vs Cloud amount (1400 hrs, in Octas) of North Bangalore July 2021 – September 2022)**

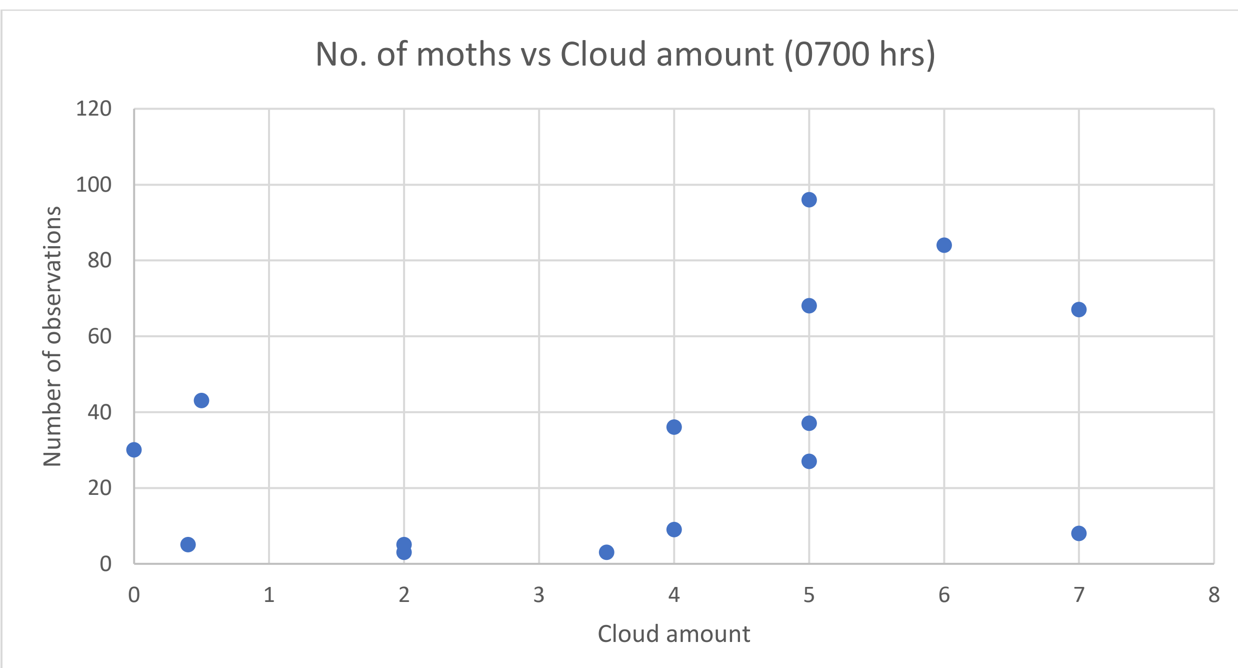



**Fig. 5: Number of moths vs Cloud amount (0700 hrs, in Octas) of North Bangalore (July 2021 – September 2022)**

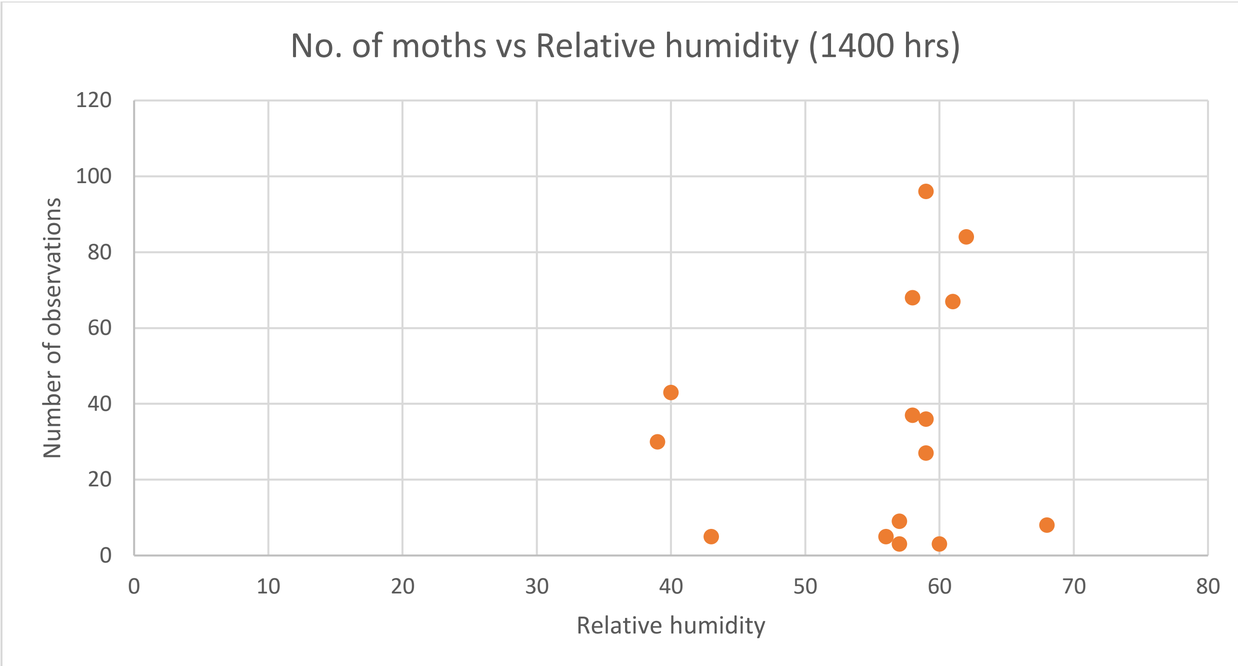



**Fig. 6: Number of moths vs Relative Humidity (1400 hrs, in %) of North Bangalore (July 2021 – September 2022)**

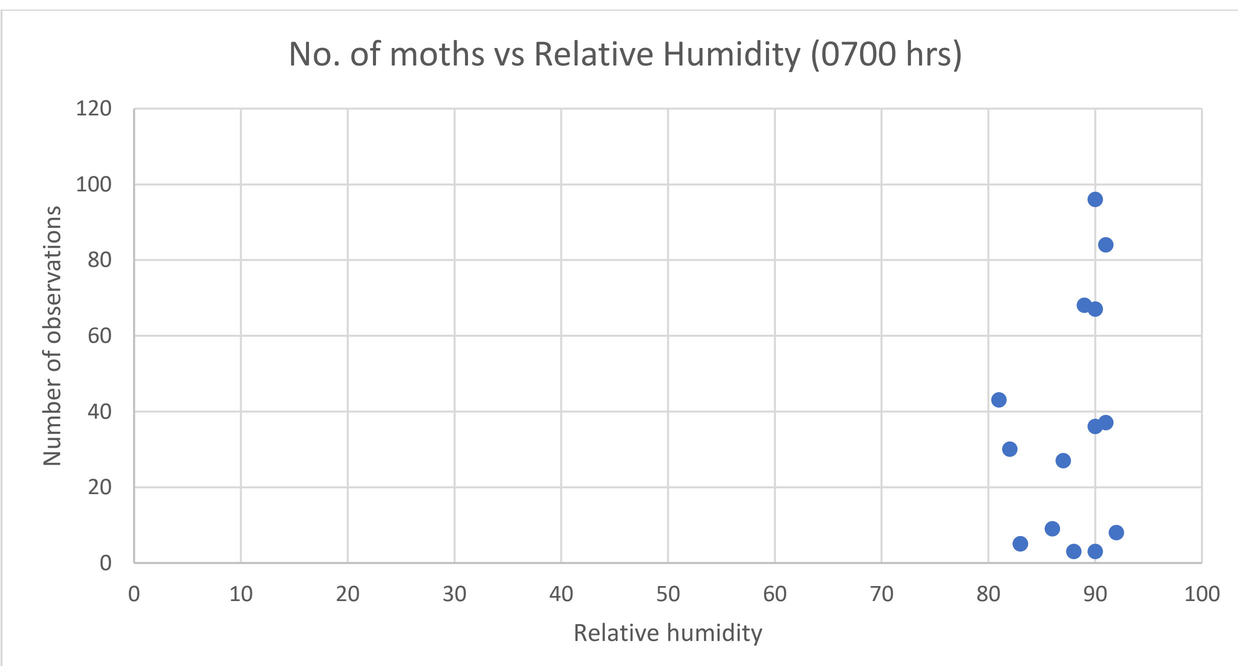



**Fig. 7: Number of moths vs Relative Humidity (0700 hrs, in %) of North Bangalore (July 2021 – September 2022)**

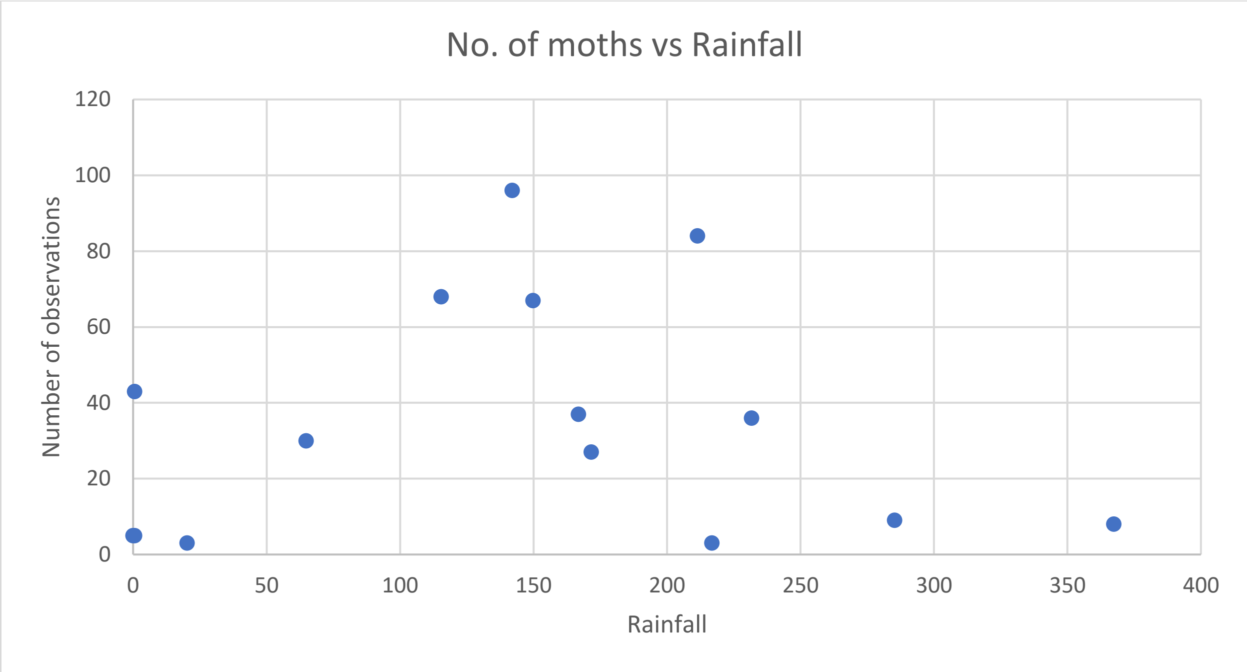



**Fig. 8: Number of moths vs Rainfall (0830, in mm) of North Bangalore (July 2021 – September 2022)**

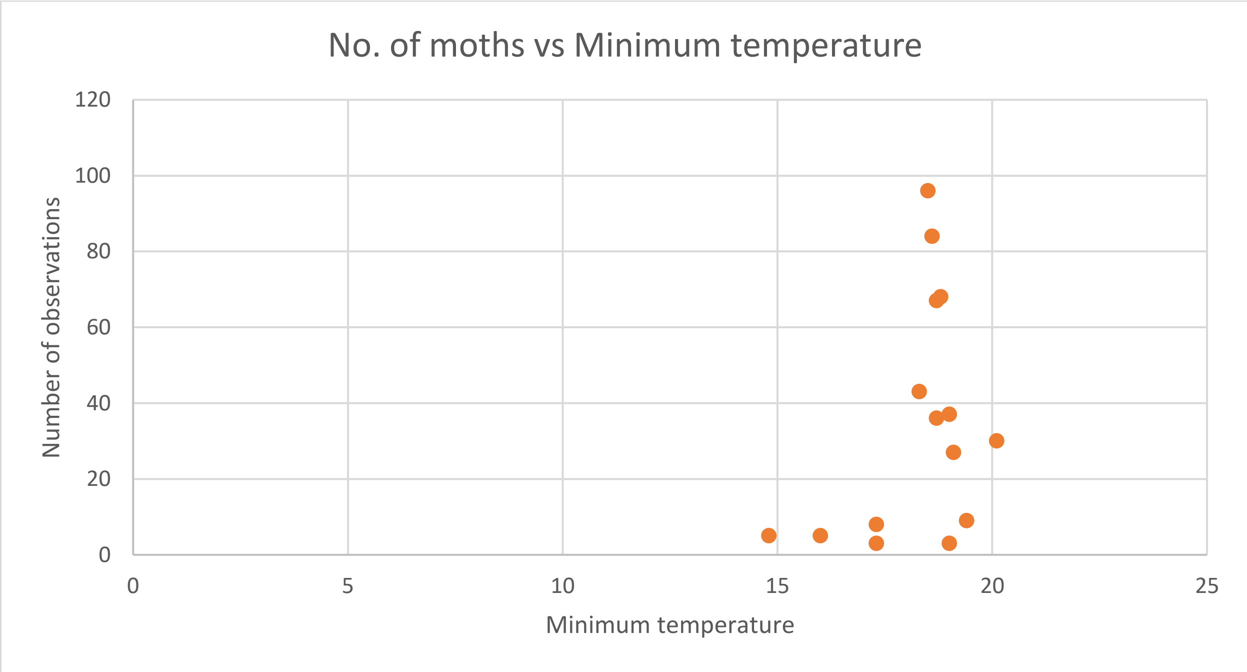



**Fig. 9: Number of moths vs Minimum air temperature (in °C) of North Bangalore (July 2021 – September 2022)**

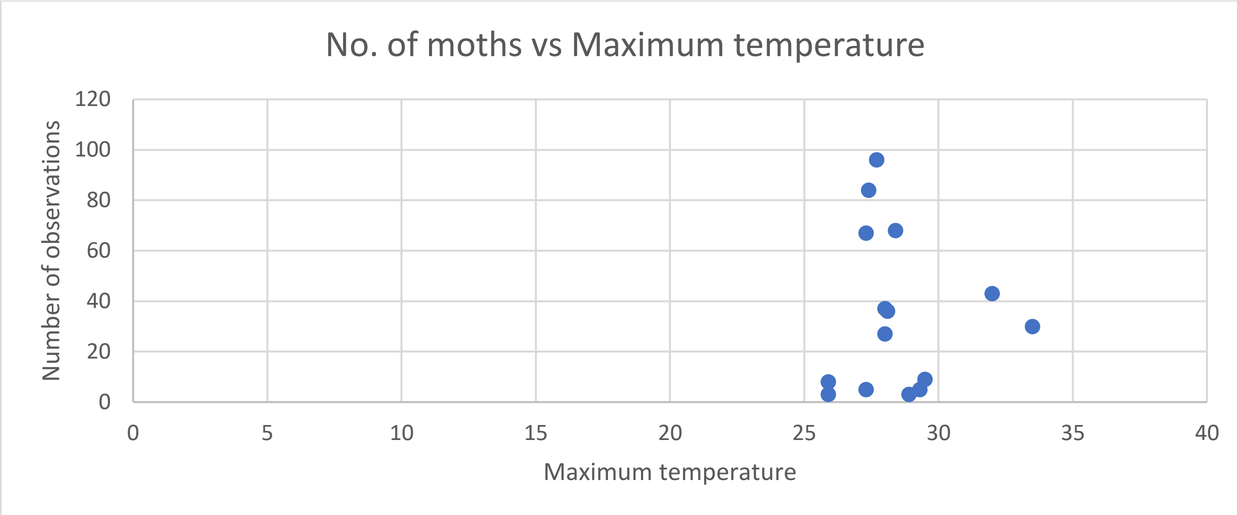



**Fig. 10: Number of moths vs Maximum air temperature (in °C) of North Bangalore (July 2021 – September 2022)**

**Table 3: Flowering plant species found in the area of study:**

| Common Name | Scientific name | False Ashoka | Monoon longifolium |
|---|---|---|---|
| Crown Flower | Calotropis gigantea ((Linn.) Dryand.) | Simpleleaf Chastetree | Vitex trifolia (Linn.) |
| Nightshades | Solanum (Linn.) | Night-flowering Jasmine | Nyctanthes arbor-tristis (Linn.) |
| Yellow alder | Turnera ulmifolia (Linn.) | Mogra | Jasminum sambac ((Linn.) Aiton) |
| African tulip tree | Spathodea campanulata (P.Beauv.) | Bonesets, Blazingstars, and allies | Eupatorieae (Cass.) |
| Flax-leaved Horseweed | Erigeron bonariensis (Linn.) | Monkey pod tree | Samanea saman ((Jacq.), Merr.) |
| Garden balsam | Impatiens balsamina (Linn.) | Tabernaemontana | Tabernaemontana (Plum.) |
| Beggarticks | Bidens (Linn.) | Clitoria ternatea albiflora | Clitoria ternatea albiflora (Linn.) |
| Yellow Flame Tree | Peltophorum pterocarpum ((D.C.) K.Heyne) | Asiatic butterfly-bush | Buddleja asiatica (Lour.) |
| Sensitive Plant | Mimosa pudica (Linn.) | Yellow bauhinia | Bauhinia tomentosa (Linn.) |

| Common Name | Scientific name | False Ashoka | Monoon longifolium |
|---|---|---|---|
| Pink Snakeweed | Stachytarpheta mutabilis ((Jacq.) Vahl) | Hibiscuses | Hibiscus (Linn.) |
| Centratherum | Centratherum (Cassini) | Malvaviscus | Malvaviscus (Fabr.) |
| Trailing daisy | Sphagneticola trilobata ((Linn.) Pruski) | Pink jasmine | Jasminum polyanthum (Franch.) |
| Jabonera de Madagascar | Catharanthus roseus ((Linn) G.Don) | Sorghum | Sorghum bicolor ((Linn.) Moench.) |
| Markhamia | Markhamia lutea ((Benth.) K.Schum) | Sandburs | Cenchrus (Linn.) |
| Straggler daisy | Calyptocarpus vialis (Less.) | Sapindus laurifolius | Sapindus laurifolius (Linn.) |
| Ageratums | Ageratum (Linn.) | Ashokam | Saraca asoca ((Roxb.) Wild.) |
| Marigolds | Tagetes (Linn.) | Orchid Trees | Bauhinia (Linn.) |
| Sanguinaria | Alternanthera ficoidea ((Linn.) Sm.) | Jaundice curative tree | Wrightia tinctoria ((Roxb.) R.Br., Mem. Wern. Soc. 173.) |
| Rattlepods | Crotalaria (Linn.) | Crepe Jasmine | Tabernaemontana divaricata (R.Br.) |
| Firebush | Hamelia patens (Jacq.) | | |

Out of the six families of moths and seven families of flowering plants studied in the Himalayas (Singh et al, 2022) five families of moths (Erebidae, Crambidae, Geometridae, Noctuidae and Nolidae) and four families of plants (Fabaceae, Oleaceae, Poaceae and Malvaceae) have been observed in our area of study. From the pollen transfer network, we can see that these moths do pollinate the flowering plants species. Therefore, it can be inferred that in the area of study of this project as well, the same pollen transfer networks could be in place and the moths could play an important role in the pollination of these flowers. From all the observations, both the existing data and those obtained through our fieldwork, the immense diversity of moths in the green space in an urban ecosystem could be noticed. From the data, it was possible to determine the seasonality of the diverse families of moths of the area of study. The behavioural characteristics of moths, such as the response to light and the time of appearance, were studied using the light trap. The species of flowering plants were also identified, which the moths could be potentially pollinating, and were correlated with the moth families.

## Conclusions

There is a huge diversity of moths even in urban ecosystems. K V 1 Jalahalli, the area of study, is a biological hotspot for moths, having recorded 233 species of moths in just one year, when compared to only 89 species of butterflies. Families of moths in the area of study show seasonality, which show some relation with changes in temperature, cloud cover and humidity. Light traps are a highly effective way of spotting moth species. Moth families observed could act as pollinators for some of the flowering plant families found in the area of study.

## Acknowledgements

We thank Mr. Mahesh R, Research associate, TNHS, who helped us in clarifying our queries and the curators of the NCBS museum, Bengaluru, for giving us the opportunity to see the carefully curated specimens. We also express our sincere gratitude to Dr. Anil Kumar K R, Fluidyn Consultancy Pvt. Ltd, Bangalore, for his valuable guidance in the editorial and analysis process of this article.

## References

Anderson, M, Rotheray, E. L. and Mathews, F., March 29, 2023, “Marvellous moths! pollen deposition rate of bramble (Rubus futicosus L. agg.) is greater at night than day”,. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0281810

Arora, R. and Kaur, J., 2023, Scientists’ warning on loss of insect biodiversity and implications for sustainable agriculture, *Insect Environment* **26**(2): 161-167.

Baker, R.R., 1987, “Integrated use of moon and magnetic compasses by the heart-and-dart moth, Agrotis exclamationis” https://doi.org/10.1016/S0003-3472(87)80214-2

Carter, David, 1992 “Butterflies and Moths (Eyewitness Handbooks)”. Dorling Kindersley, Inc., New York.

Ganganalli, S. M. and Bhaskar, H, 2022 “Global crop pollinators-not just bees!”, *Insect Environment* **25**(1): 116-118.

GKVK Agrometeorology department website – Weather data for North Bangalore https://uasbangalore.edu.in/index.php/research-en/agrometerology-en

iNaturalist project “Kendriya Vidyalaya No. 1 Jalahalli Biodiversity” https://www.inaturalist.org/projects/kendriya-vidyalaya-no-1-jalahalli-biodiversity

MacGregor, J.C., Pocock, M.J.O., Fox, R and Evans, M.D., December 13, 2014, “Pollination by nocturnal Lepidoptera, and the effects of light pollution: a review”. https://doi.org/10.1111/een.12174

Personal communication with R, Mahesh, Research associate, TNHS.

Singh, N, Lenka, R, Chatterjee, P and Mitra, D, February 17, 2022, "Settling moths are the vital component of pollination in Himalayan ecosystem of North-East India, pollen transfer network approach revealed". https://doi.org/10.1038/s41598-022-06635-4

Van Zandt, P.A., Johnson, D.D., Hartley, C, LeCroy, K.A., Shew, W, Davis, B.T. and Lehnert, M.S., July 19, 2019, Which moths might be pollinators? Approaches in the search for the flower-visiting needles in the Lepidopteran haystack, https://doi.org/10.1111/een.12782

Walton, R.E., Sayer, C.D., Bennion, H, and Axmache, J. C., May 13, 2020, "Nocturnal pollinators strongly contribute to pollen transport of wild flowers in an agricultural landscape". https://doi.org/10.1098/rsbl.2019.0877

*MS Received on 06th June, 2024*
*MS Accepted on 21st August, 2024*

**DOI: 10.55278/QMNU7571**

# Biology of brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenes) under laboratory condition

**Kiran Kumar Behera, Satya Narayan Satapathy*, Chandan Kumar Panigrahi, Priyanka Bhowmik and Priyanka Priyadarshini**

*Department of Entomology, Faculty of Agricultural Sciences (IAS), Siksha "O" Anusandhan Deemed to be University, Bhubaneswar- 751029, Odisha, India*

****Corresponding author:satyanarayansatapathy40@gmail.com***

*ORCID ID:0000-0002-3202-1717

## Abstract

In 2022-23 a laboratory study was conducted at Department of Entomology, Faculty of Agricultural Sciences (IAS)[20.288596,85.764828], SOA-DU, Bhubaneswar to study about the biology of brinjal shoot and fruit borer biology or lifecycle. The parameters including egg, different instars of larvae, pupae and adults were highest in the last generation that was held in the month of Dec- Jan and the lowest of the parameters were recorded in the second generation held in the month of Aug – Sep. These changes in the parameters depending on the month were due to the variation in temperature. Likewise, the length of time spent in various developmental phases was noted. Recorded period includes egg (3-5 days), larva (12-18 days), pupa (8-12 days) and total developmental period (32-37 days) respectively. The average lifespan of male moths was 4.60 ± 1.00 days with a range of 3 to 7 days, while female moths had an average lifespan of 5.60±1.16 days with a range of 4 to 8 days. The average number of eggs laid by female moths was 69.53±9.35 eggs/female, with a range of 49 to 82 eggs.

**Key words:** Brinjal shoot and fruit borer, biology, *Leucinodes orbonalis*

## Introduction

In India, brinjal ranks in the second position and is grown in spring, autumn, summer as well as in the rainy season. Being an important vegetable crop the major drawback is the infestation by insect and non insect pests (Kumar and Singh, 2013). Researchers have proved that almost 36 insect pests are involved in causing severe devastation to the crop, starting from the time of plantation till the harvest (Regupathy *et al.*, 1997). Recent havoc in the damage of egg plant is caused by the most harmful pest brinjal shoot and fruit borer, which is now present everywhere around the nation that grows vegetables (Dutta *et al.*, 2011; Latif *et al.*, 2010).

The brinjal shoot and fruit borer (BSFB) causes losses ranging from 70-92%`(Chakraborti and Sarkar, 2011;

Saimandir and Gopal, 2012). The BSFB is considered as one of the most noxious pests in vegetables as the damage caused by the pest is detrimental and causes economic loss to man and the loss is even higher when the climate is mild (Dhandapani *et al.,* 2003). The most devastating stage is the larval stage, the caterpillars are creamy white in colour when they are young and once they attain maturity they turn to light pinkish colour (Lall and Ahamad, 1965). The caterpillars bore into the midrib of leaves, the petiole and even the young growing shoots (Pradhan, 1969). When the eggplant attains the fruiting stage it bores into the flowers as well as fruits, they generally enter via the calyx and feed the inner content of the fruit, as a result the fruiting buds fall off (Butani and Varma, 1976). The fruits which have the circular exit holes, loose their value and turn unfit for human consumption (Kavitha *et al.,* 2008). The studies on this devastating pest help the farmer to be aware about the vulnerable stages of the crop and can act as a pre-requisite knowledge to apply proper management strategies in proper time against the notorious pest.

## Materials and Methods

A series of lab studies were conducted to know the biology of the Brinjal Shoot and Fruit Borer and the experiment was carried out in the laboratory of the Department of Entomology, Faculty of Agricultural Sciences (IAS), SOADU, Bhubaneswar, Odisha.

The biology of *L. orbonalis* was investigated under ambient conditions of 25º±1ºC and 70± 2% RH. Infested fruits that were obtained from the field and were stored in 60 x 60 x 60 cm acrylic cages until the moths emerged. After emerging, moths were gathered and stored in 15cm X 10cm glass jars for matting and egg lying by females. One jar held about fifty moths, which were fed 10% honey solution using cotton swabs. The muslin cloths and elastic bands securely sealed the jar openings. Moths deposited their eggs on the muslin cloth, which was gathered daily along with the eggs. Before *L. orbonalis* larvae were reared, a few larvae were released onto the cut end of a well-washed potato tuber to test the insect's acceptance to the food source. The further lifecycle was studied under a microscope. About 100 fresh eggs were collected in a petri dish and covered with a filter paper on top so as to record the parameters (Hatchability as well as incubation period). Daily observations were taken on the number of larval instars to determine survival as well as the duration of the respective larval instars. In a petri dish of 10 cm diameter about 10 neonate larvae were taken and cut potato slices were given as food for the larvae. On each new day, these larvae were transferred into a new petri dish, where fresh food *i.e.* freshly sliced potato pieces were given to the larvae as the feed. The freshly emerged adults were taken in the jar to record the adult longevity. The eggs were laid in the black muslin cloth and they were counted daily in order to record the fecundity of adults. All five generations of this insect were taken to carry out the experiment.

**Data analysis**

The data on all relevant observations thus obtained were subjected to CRD statistical analysis, as per Gomez and Gomez (1984).

**Results and Discussions:**

The present investigation revealed that the incubation period of *L.orbonalis* ranged from 3 to 5 days, the mean duration can be represented as 4.33 ±1.02 days. The first instar larvae lasted for a duration of 2 to 3 days and it had a mean of 2.21±0.22 days. The tendency of shoot and fruit borer to infest the shoot region first and then infest the fruit region was seen in this laboratory experiment. The larvae also bored into buds and voraciously fed on the innermost content of the fruits and filled the entry openings with excreta. The range of second instar larvae varied from about 1 to 4 days with a mean of 2.70±0.60 days duration. 2 to 4 days was the range of the grown-up third instar larvae having a mean duration of 2.93±0.49 days. The observed range of fourth instar larvae was estimated to be 3 to 5 days with the mean duration being 3.50± 0.40 days. With a mean duration of 2.36±0.23 days, the larvae of 5$^{th}$ instar had a range of 2-3 days. Combining all the instars, the larval period was summed to about 12 to 18 days with a mean duration of 13.67 ± 0.50 days. With the following experiment we have also found that about 1 to 2 days was the range for the pre oviposition period and it also had a mean duration range of 1.50 ± 0.51 days. Additionally, 2 to 4 days with 2.87 ± 0.82 days mean was referred as the range of oviposition.9.30 ± 0.95 days were considered to be the mean pupal period which actually ranged from 8 to 12 days. Male adult longevity ranged from 3 to 7 days with a mean of 4.60 ± 1.00 days while the female lifespan of the moth was observed to be 4 to 8 days with a mean of 5.60 ± 1.16 days. The mentioned data from the following experiment stated that the lifecycle of *L.orbonalis* was considered to be 32 to 37 days having mean duration of 34.20 ± 1.71 days. Fecundity is considered to be one of the most important factors when the lifecycle of an organism is considered. Interestingly mean fecundity of the brinjal shoot and fruit borer was considered to be 69.53 ± 9.35 eggs / female with a total range of 49 – 82 eggs / female. The present findings were confirmed by Bindu *et al.*( 2015) who reported that a single female of brinjal shoot and fruit borer on an average lays 81.2 ± 9.07 eggs / female with a range of 48 to 83 eggs / female , while the duration of other lifestages were 3.8 ± 0.84 days (eggs) , 2.6 ± 0.55 days (1$^{st}$ Instar) , 2.8 ± 0.71 days (2$^{nd}$ Instar) , 3.2 ± 0.84 days (3$^{rd}$ Instar) ,3.4 ± 0.89 days (4$^{th}$ Instar) , 2.8 ± 0.55 (5$^{th}$ Instar) , 8.6 ± 0.89 days (pupa) , 5.8±0.71 days (female) and in case of male it is 4.2 ± 0.84 days. According to Jat *et al.* (2003) *L. orbonalis* larvae had five instars and 4.30, 12.63 and 9.24 days were the incubation, larval and pupal periods respectively. Range of 7.40, 2.43 and 1.26 days were the pre-oviposition,

oviposition and post-oviposition periods respectively, whereas the longevity of male and female moths was 1.82 and 3.12 days, respectively. Similar results were also reported by other scientists like, Onekutu *et al.* (2013), Atwal and Dhaliwal (2005), Alam *et al.* (1982), Sandanayake and Edirisinghe (1992), Yin (1993), Pal *et al.* (2003) and Maravi *et al*. (2013).

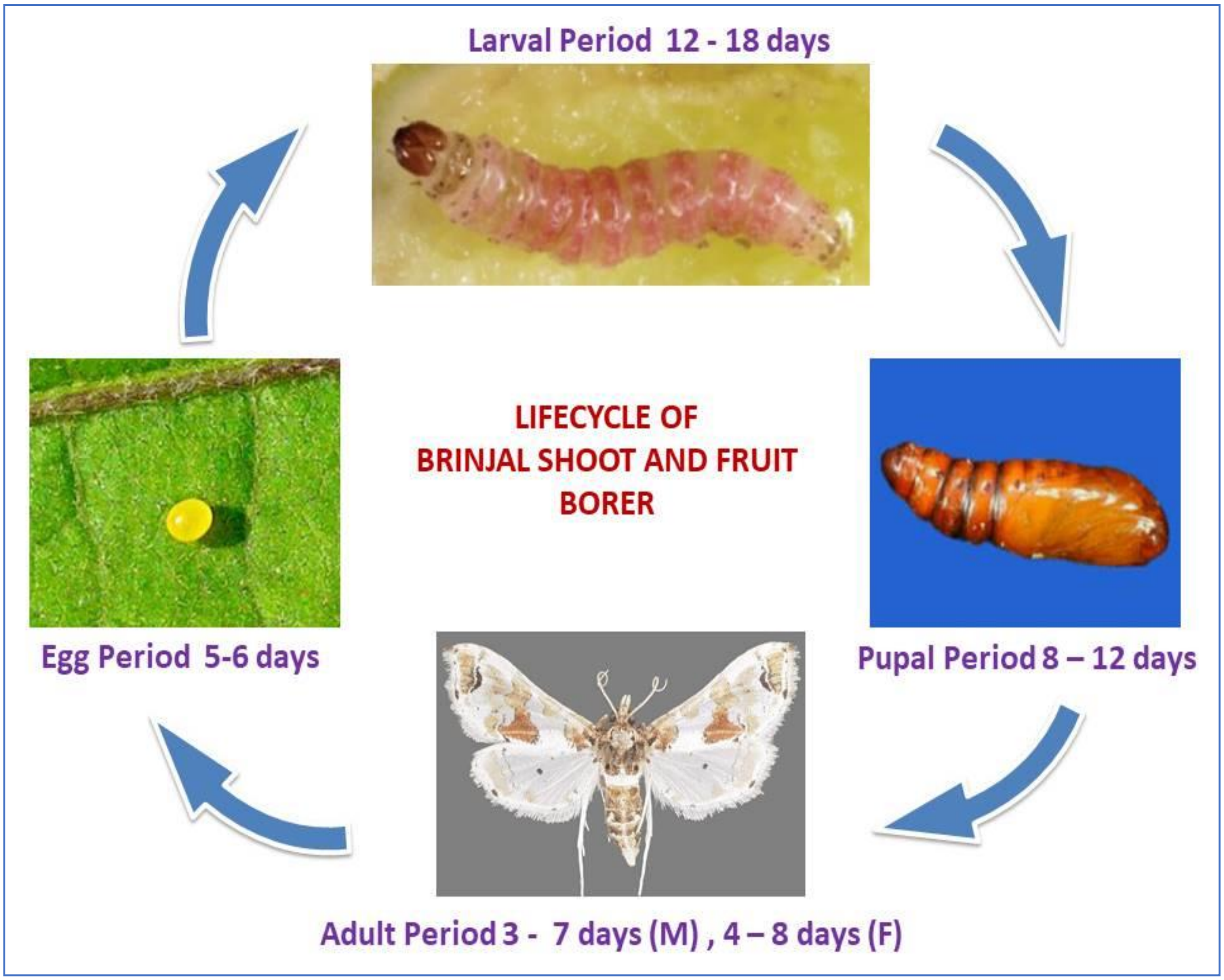



**Fig. 1: Lifecycle of *Leucinodesorbonalis* Guenes [Abhishek & Dwivedi (2021)]**

**Table 1: Biological parameters of *Leucinodesorbonalis*Guen, on brinjal during the period December-February,2022-2023 (Data based on 10 pairs)**

| Biological Events | Mean±SE | Range |
|---|---|---|
| **Fecundity(egg/female)** | 69.53±9.35 | 49-82 |
| **Incubation Period(days)** | 4.33±1.02 | 3-5 |
| **Larval Period(days)** | | |
| Instar-I | 2.21±0.22 | 2-3 |
| Instar-II | 2.70±0.60 | 1-4 |
| Instar-III | 2.93±0.49 | 2-4 |
| Instar-IV | 3.50±0.40 | 3-5 |
| Instar-V | 2.36±0.23 | 2-3 |
| **Total larval period(days)** | 13.67±0.50 | 12-18 |
| Purpal Period(days) | 9.30±0.95 | 8-12 |
| Pre-oviposition period(days) | 1.50±0.51 | 1-2 |
| Oviposition period(days) | 2.87±0.82 | 2-4 |
| **Adult longevity(days)** | | |
| Male | 4.60±1.00 | 3-7 |
| Female | 5.60±1.16 | 4-8 |
| Total life cycle(days) | 34.20±1.71 | 32-37 |

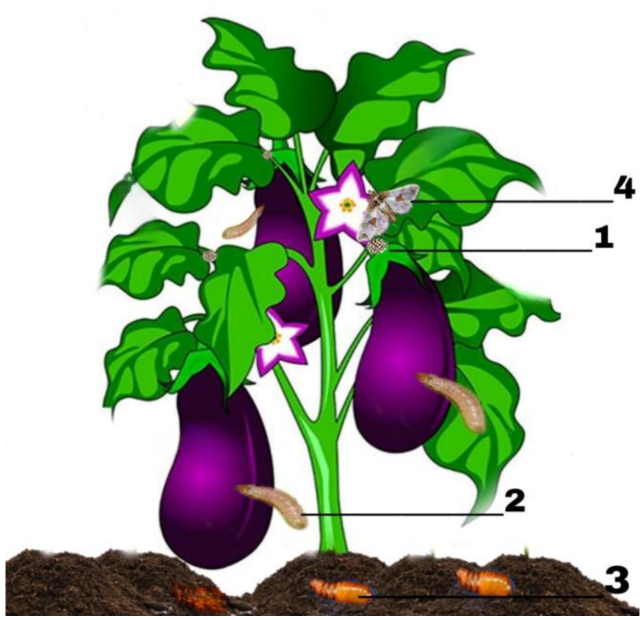



**Fig. 2: Indicating, 1:Eggs of *Leucinodes orbonalis* Guenes, 2:larvae of *Leucinodes orbonalis* Guenes boring into the fruits of brinjal, 3:Pupae of *Leucinodes orbonalis* Guenes pupating in soil, 4: Adults of *Leucinodes orbonalis* Guenes**

## Conclusion:

Eggs of the pest were creamy white which on maturity turned orange and finally to black in colour before hatching. The eggs were laid singly and were oval to elongate in shape. An incubation period of 3 to 5 days was also seen. The larvae were initially dirty white in colour, which on maturity turned into a pinkish colour and subsequently passed five instars to turn into a full-grown one. In the present study, it was found that 9 to 12 days is the typical range of the larval period, the average larval period is of 11.29 days which is in context with have found that larval period ranges from 9 to 18 days at different laboratory conditions. The pupation took place in the glass jar and muslin cloth, but in natural conditions, it occurs in soil, fruits and leaves of the plants. This experimental study has also revealed that the pupal period ranges from 6 – 17 days and is dependent on temperature. The adults of brinjal shoot and fruit borer were small with whitish wings; the head is prominently brown in colour. In females the abdominal tip is pointing and is tapering towards the end, but in males it is blunt with hairy like structures. The adult longevity varied from 3.5 to 4.5 days.

## Acknowledgement

The authors are sincerely thankful to the Head, Department of Entomology, Faculty of Agricultural Sciences for making available the facilities to conduct the research.

## References

Abhishek, T and Dwivedi, S. 2021. Review on integrated management of brinjal shoots and fruit borer, *Leucinodesorbonalis* (Guenee). Journal of Entomology and Zoology Studies, **9(1),** 181-189.

Alam M A, Rao P K and Rao B H K. 1982.Biology of brinjal shoot and fruit borer, *Leucinodesorbonalis* Guen. *Indian Journal of Agricultural Science*, **52** (6): 391-395.

Atwal AS and Dhaliwal GS. 2005. Agricultural pest of South Asia and their management, Kalyani Publishers, New Delhi, **4(2):**172-174.

Bindu S P, Pramanik A and Padhi G K. 2015.Studies on the biology and physical measurements of shoot and fruit borer (*Leucinodesorbonalis* Guen.) of brinjal in West Bengal, India.*Global Journal of Biology, Agriculture and Health Sciences*, **4**(1); 215-219.

Butani D K and Verma S. 1976. Pests of vegetables and their control: Brinjal. *Pesticides*, **10**(2): 32 – 38.

Chakraborti S and Sarkar P K. 2011. Management of *Leucinodesorbonalis* Guen. on eggplant during the rainy season in India.*J. Protect. Res.,* **51**: 325- 328.

Dhandapani N, Shlkar U R and Murugan M. 2003. Bio-intensive pest management

(BIPM) in major vegetables crops. *An perspective Food, Agriculture & environment* vol. 2: 333-339.

Dutta P, Singha A K, Das P and Kalita S. 2011.Management of brinjal fruit and shoot borer, *Leucinodes orbonalis* Guen. in agro-ecological conditions of West Tripura. *Scholarly J. agric. Sci*., 1:16-19.

Gomez K A and Gomez A A. 1984. *Statistical procedures for agricultural research*. John wiley & sons.

Jat K L, Swaroop S and Maurya RP.2003. Screening of brinjal varieties for resistance to shoot and fruit borer, *Leucinodes orbonalis* Guen. *Haryana Journal of Horticultural Sciences*, **32**:152-153.

Kavitha V S, Revathi N and Kingsley S. 2008. Biology of brinjal pest, *Leucinodes orbonalis* Guen. of erode region in Tamil Nadu. *Journal of Entomological Research*, Vol. **32**: No.3; pp. 255-257.

Kumar S and Singh D. 2013. Seasonal incidence and economic losses of brinjal shoot and fruit borer, *Leucinodesorbonalis* Guen. *Agricultural Science Digest-A Research Journal*, **33**(2): 98-103.

Lall B S and Ahmad S Q. 1965. The biology and control of brinjal (Eggplant) fruit and shoot borer *Leucinodesorbonalis* Guen. *Journal of Economical Entomology*. **58**(1): 448-451.

Latif M A, Rahman M M and Alam M Z. 2010. Efficacy of nine insecticides against shoot and fruit borer, *Leucinodesorbonalis* Guen. (Lepidoptera: Pyralidae) in eggplant. *Journal of pest science*, ***83***;391-397.

Maravi M S, Dubey V K and Paikra M K. 2013. Relative Study of Shoot and Fruit Borer Infestation on Transgenic and Non-transgenic Varieties of Brinjal (*Solanummelongena). Indian Horticulture Journal*, **3**; 74-77.

Onekutu A. 2011. Bioecologgy and Management of *Leucinodesorbonalis* Guen. on Solanumgilo Raddi, Unpublished PhD Thesis, University of Ibadan, Nigeria. **349p**p.

Pal A, Shukla B C and Pal A. 2003. Biology and morphometry of brinjal shoot and fruit borer in Chhattisgarh. *JNKVV Research Journal*; **37**(1): 63-66.

Pradhan S. 1969. Pests of vegetables. **In**: Insects Pests of Crops. National Book Trust, India, New Delhi, pp. 96 – 109.

Regupathy A, Palanisamy S, Chandramohan N and Gunathilagaraj K. 1997.A guide on crop pests. Sooriya Desk Top Publishers, Coimbatore, 264p.

Saimandir J and Gopal M. 2012.Evaluation of synthetic and natural insecticides for the management of insect pest control of eggplant (*Solanummelongena* L.) and pesticide residue dissipation pattern.*American Journal of Plant Science*, **3**: 214-227.

Sandanayake W R M. 1992. Instar determination and larval distribution in brinjal shoot and fruit borer, *Leucinoides orbonalis* (Guen). *Ceylon Journal of Science*, vol. **22**; 50-59.

Yin RG. 1993. Bionomics of *Leucinodes orbonalis* Guenee and its control. *Entomological Knowledge*,**30**(2); 91 - 92.

*MS Received on 02nd June, 2024*
*MS Accepted on 22th August, 2024*

**DOI: 10.55278/CJJP7621**

# Baseline observations on butterfly fauna in a cemetery in central Bengaluru, Karnataka

**Srijan Srivastava, Abhinandan Singh, Farhan Imdad and M Jayashankar***

*Department of Zoology, School of Life Sciences, St. Joseph's University, Bengaluru-560027, Karnataka*

***Corresponding author: jayashankar.m@sju.edu.in***

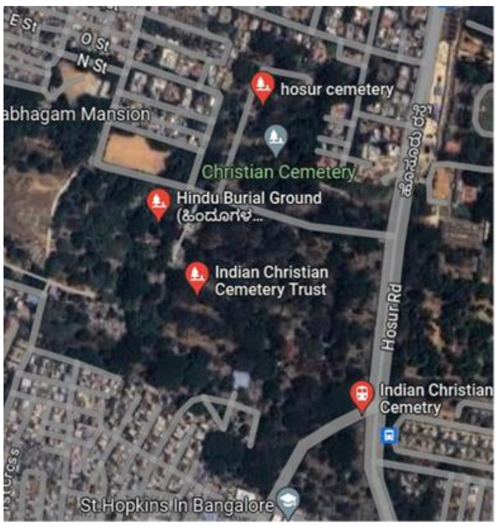
Insects are unparalleled champions of biodiversity, accounting for over half of all known species in the world (Alfred et al., 1998). Among these, butterflies stand out as an intriguing subgroup that has fascinated humans for generations. Studying these creatures not only provides insights into their biology but also opens doors to a deeper understanding of the rich tapestry of life on Earth. Despite extensive studies, butterflies in graveyards have not yet been documented in any part of the world.

The main objectives of this study were to document all butterfly species in a cemetery setting and determine the types of habitats available in the cemetery. Cemeteries also serve as spots of rich floral diversity, which harbor different species of butterflies. A study was undertaken to investigate opportunistic butterfly sightings in a cemetery context to comprehend the ecological dynamics and plant-insect interactions. Through systematic observation and data collection, capturing various butterfly species within the cemetery environment during January – March 2024, we were able to confirm the existence of multiple species of butterflies in the cemetery. Analysis of the several microhabitats the cemetery landscape afforded revealed a wide diversity of butterflies, including both common and unusual species.

The current survey was conducted at five cemeteries in Bengaluru, specifically the Indian Christian Cemetery (12.954181 N, 77.602781 E), St. Patrick's Cemetery (12.95450 N, 77.60448 E), Hosur Catholic Cemetery (12.95485 N, 77.60307 E), Hosur Road Protestant Cemetery (12.95576 N, 77.60298 E), and Hindu Burial Ground (12.955069 N, 77.602355 E) **(Map 1).**

The study was conducted between 8:00 AM and 12:00 PM using a random sampling method. An iPhone 15 and a DSLR (Nikon Coolpix P50) were used to document the observed species, while the BNHS Field Guide "Butterflies of India" by Isaac Kehimkar facilitated the identification of butterflies in the field. The identified species were cross-checked using 'iNaturalist: A Community for Naturalists and Citizen Scientists'.

We recorded a total of 20 distinct species of butterflies belonging to 17 genera and 4 different families (Table 1). The highest number of species were from the Nymphalidae family, with 9 distinct species. It has been discovered that variables like floral resources, vegetation structure, and environmental factors affect the variety of butterflies (Basavarajappa and Santhosh, 2018). The biological richness and habitat suitability of the ecosystem under study are highlighted by this variety. With seven distinct species, the Nymphalidae family showed the greatest diversity of species.




**Map 1: A satellite image of the observed cemetery area in Central Bengaluru**

Comparing the survey region with more nectar-rich plants and blooming trees to the region with dried-up vegetation and fewer flowering plants revealed a distinct butterfly community. There appears to be a relationship between specific butterfly species and different plant types based on observations. The abundance of butterflies varies depending on the type of flora available in a location, particularly when comparing dried-up vegetation to nectar-rich foliage. In locations with dried-up vegetation, butterflies may have inadequate supplies, involving fewer blooming plants and less nectar. Some Nymphalidae species may still be found in these locations, particularly those that are adaptive and can thrive in a variety of environments. However, the total abundance of butterflies may be lower than in locations with more diversified and healthy flora. Several of the butterfly species we observed have been seen to frequent regions with profuse blooming plants in search of nectar.

These include-

- Great Eggfly, *Hypolimnas bolina* (Linnaeus, 1758)
- Common Sailor, *Neptis hylas* (Linnaeus, 1758)
- Common Cerulean, *Jamides celeno* (Cramer, 1775)
- Common Castor, *Ariadne merione* (Linnaeus, 1763)
- Chestnut-streaked Sailer, *Neptis jumbah* (Moore, 1858)

The importance of urban green areas in maintaining butterfly populations is shown by the diversity and dispersion of butterflies observed in the cemetery. It was our first attempt to study butterflies in this region, further research is necessary to document seasonal occurrence.

**Table 1: Species observed during observations**

| Fig. No. | Common Name | Scientific Name | Migratory Status | WPA Status |
|---|---|---|---|---|
| **Family Nymphalidae** | | | | |
| 1. | Lemon Pansy | *Junonia lemonias* | Native to India | Not Scheduled |
| 2. | Chocolate Pansy | *Junonia iphita* | Native to India | Not Scheduled |
| 3. | Great Eggfly | *Hypolimnas bolina* | Native to India | Not Scheduled |
| 4. | Common Castor | *Ariadne merione* | Native to India | Not Scheduled |
| 5. | Common Evening Brown | *Melanitis leda* | Native to India | Not Scheduled |
| 6. | Common Sailor | *Neptis hylas* | Native to India | Not Scheduled |
| 7. | Chestnut-streaked Sailer | *Neptis jumbah* | Native to India | Schedule II |
| 8. | Plain Tiger | *Danaus chrysippus* | Native to India | Not Scheduled |
| 9. | Double-branded Crow | *Euploea sylvester* | Native to India | Not Scheduled |
| **Family Lycaenidae** | | | | |
| 10. | Zebra Blue | *Leptotes plinius* | Native to India | Not Scheduled |
| 11. | Common Cerulean | *Jamides celeno* | Native to India | Not Scheduled |
| 12. | Lesser Grass Blue | *Zizina otis* | Native to India | Not Scheduled |
| **Family Pieridae** | | | | |
| 13. | Common Grass Yellow | *Eurema hecabe* | Migratory | Not Scheduled |
| 14. | The Wandering Psyche | *Leptosia nina* | Native to India | Not Scheduled |
| 15. | Lemon Migrant | *Catopsilia pomona* | Partially Migratory | Not Scheduled |
| 16. | Mottled Emigrant | *Catopsilia pyranthe* | Partially Migratory | Not Scheduled |
| **Family Papilionidae** | | | | |
| 17. | Lime Swallowtail | *Papilio demoleus* | Native to India | Not Scheduled |
| 18. | Common Jay | *Graphium doson* | Native to India | Not Scheduled |
| 19. | Common Mormon | *Papilio polytes* | Native to India | Not Scheduled |
| 20. | Crimson Rose | *Pachliopta hector* | Native to India | Schedule II |

*WPA- Wildlife Protection Act (1972) status

**Fig. 1.** ***Junonia lemonias***

**Fig. 2.** ***Junonia iphita***

**Fig. 3.** ***Hypolimnas bolina***

**Fig. 4.** ***Ariadne merione***

**Fig. 5.** ***Melanitis leda***

**Fig. 6.** ***Neptis hylas***

**Fig. 7.** ***Neptis jumbah***

**Fig. 8.** ***Danaus chrysippus***

**Fig. 9.** ***Euploea sylvester***

**Figure 10.** ***Leptotes plinius***

**Figure 11.** ***Jamides celeno***

**Figure 12.** ***Zizina otis***

**Fig. 13. *Eurema hecabe***

**Fig. 14. *Leptosia nina***

**Fig. 15. *Catopsilia pomona***

**Fig. 16. *Catopsilia pyranthe***

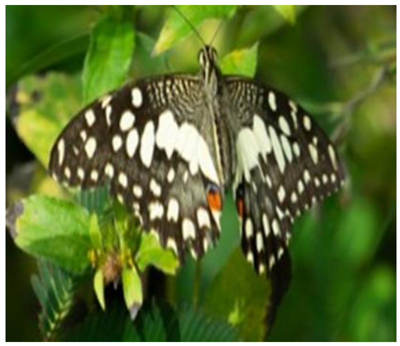


**Fig. 17. - *Papilio demoleus***

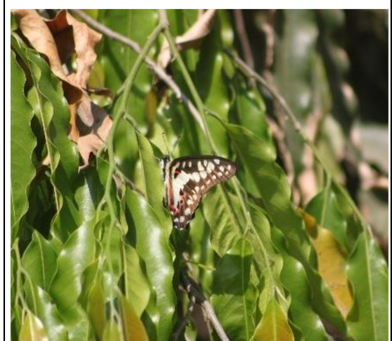


**Fig. 18. *Graphium doson***

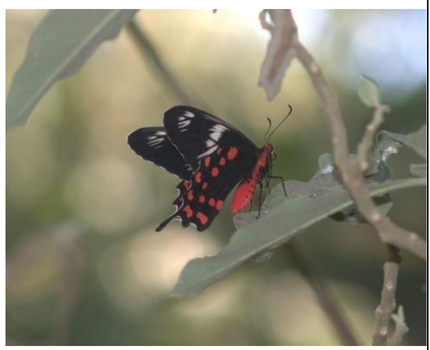


**Fig. 20. *Pachliopta hector***

There are several reasons to study butterflies in cemeteries, including ecological monitoring, biodiversity evaluation, and ongoing conservation efforts. This study reveals the ecological value of cemeteries in supporting local ecosystems and explores the complex network of species diversity. By identifying the specific habitat preferences of butterflies within these areas, we can obtain valuable information to guide focused conservation efforts.

Butterflies are extremely sensitive indicators of environmental health due to their precise habitat requirements, food preferences, and complex life cycle dynamics (Thomas, 2005). They react acutely to temperature variations, vegetation patterns, and pesticide exposure, making them excellent indicators of changes in their immediate environment. Through careful monitoring of butterflies, we can gather important information about changes in local ecosystems, which is crucial for conducting thorough evaluations of environmental quality and biodiversity (Chakravarthy et al., 1997).

The study emphasizes the importance of cemeteries as critical urban green spaces that provide resources and a haven for butterfly populations. This contribution is particularly noteworthy in the context of protecting these species in increasingly fragmented environments. Understanding how cemeteries support butterfly species enhances our knowledge of urban biodiversity and highlights the potential of non-traditional habitats to serve as essential refuges for fauna in human-dominated areas. It underscores the importance of incorporating both built and natural areas into conservation initiatives (Thomas et al., 1998).

Urban green spaces play a crucial role in maintaining butterfly diversity in cities (Subhashini, 2020). The variety of butterfly species observed in our study emphasizes the importance of these areas for urban biodiversity conservation. Our findings align with other studies that have documented significant butterfly diversity in urban and semi-urban areas (Chandekar, 2015; Bindulekha and Amalnath, 2017). As this was our first attempt to study butterflies in this region, further surveys are necessary to document seasonal occurrences.

**Acknowledgments**

We are thankful to the authorities of the cemetery for their invaluable assistance during our study.

**References**

Alfred, J. R. B., A. K. Das, and A. K. Sanyal. 1998. "Faunal diversity in India." ENVIS Centre. Zoological Survey of India, Kolkata, pp. 495,

Basavarajappa, S., and Santhosh, S. 2018. “Butterfly species composition and diversity in a protected area of Karnataka, India,” International journal of biodiversity and conservation, vo.10, no.10, pp. 432-443,

Bindulekha, D. S. and Amalnath, S. 2017. “A Preliminary Study on the Biodiversity of Insects Collected from A College Campus: Thiruvananthapuram District, Southern Kerala,” *International Journal of Science and Survey* (IJSR). 6: 1631–1634.

Chakravarthy A.K, Rajagopal D., and Jagannatha R.1997. “Insects as bioindicators of conservation in the tropics.” *Zoo’s print J*,. **12**: 21-25,

Chandekar S.K. 2015. "Species Diversity of Butterflies from Khed Tahsil of Pune District (MS) India," *Academic Journal of Entomology*. **8**(2):56-64.

Kehimkar I. 2008. The Book of Indian Butterflies. Bombay natural History Society and Oxford University Press, Mumbai.

Subhashini, A. 2020. The butterfly diversity in an open forest in Bangalore-urban," International *Journal of Zoology Studies*. **5** (3): 11-16

Thomas J. 2005. "Monitoring change in the abundance and distribution of insects using butterflies and other indicator groups," The Royal Society.; **28**:339-357.

Thomas, J. A., D. J. Simcox, J. C. Wardlaw, G. W. Elmes, M. E. Hochberg, and R. T. Clarke. 1998. "Effects of latitude, altitude and climate on the habitat and conservation of the endangered butterfly *Maculinea arion* and its Myrmica ant hosts." Journal of Insect Conservation **2** (1): 39-46.

*MS Received on 30th June, 2024*
*MS Accepted on 23rd September, 2024*

**DOI: 10.55278/QSPW7544**

# Efficacy of bioagents on major insect pests of *Dendrocalamus brandisii* and *Bambusa tulda* in nursery

**D. B. Megha[1], R. N. Kencharaddi[1*], Ramakrishna Hegde[2], V. Maheswarappa[2]**
**G.N. Hosagoudar[3] and Charanakumar[4]**

[1]*Department of Forest Biology and Tree Improvement, College of Forestry, Ponnampet, KeladiShivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka-577204, India.*

[2]*Department of Silviculture and agroforestry, College of Forestry, Ponnampet, KeladiShivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka-577204, India.*

[3]*AHRS, Shivamogga, KeladiShivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka-577204, India.*

[4]*Department of Ecology and Environmental Science, Tumkur University, Tumakuru and Karnataka Forest Department.*

***Corresponding author: rnkencharaddi@uahs.edu.in***

## Abstract

Bamboo, a vital non-wood forest resource, faces significant threats from insect pests such as *Melanaphis bambusae* and *Palmicultor lumpurensis*. Traditional chemical controls carry risks to non-target species and human health, necessitating exploration of alternative approaches. In this study conducted during 2022-2023, we assessed the efficacy of biocontrol agents against major pests affecting *Dendrocalamus brandisii* and *Bambusatulda*. Our findings revealed that Azadirachtin was the most effective agent, followed by *Metarhizium anisopliae*, *Lecanicillium lecanii*, and *Beauveria bassiana*. Conversely, *Bacillus thuringiensis* demonstrated the least effectiveness.

**Keywords: Bioagent, *Dendrocalamus brandisii, Bambusa tulda***

## Introduction

Although chemical pest control remains popular and cost-effective, it carries inherent risks to non-target insects and human health. Consequently, there has been growing interest in biological agents, including fungi, bacteria, and viruses. Among these, entomopathogenic fungi stand out as particularly effective, with approximately 750 species known to infect insects and mites. These fungi offer a promising alternative to chemical pesticides, especially in forest nurseries where minimizing chemical use is encouraged.

Effective pest management in forestry is essential for maintaining healthy seedlings and overall productivity. By integrating eco-friendly methods, we can reduce reliance on chemical treatments and simultaneously enhance environmental quality. Such practices benefit various stakeholders, including forest departments, NGOs, and farmers.

## Methodology

In the 2021-22 field experiments conducted at the Bamboo nursery and plantation in Ponnampet (12.1515° N, 75.9430° E), we assessed the efficacy of entomopathogens against aphids (*Melanaphis bambusae*) and mealybugs (*Palmicultor lumpurensis*) on both *Dendrocalamus brandisii* and *Bambusatulda*. The study followed a Completely Randomized Design (CRD) with six bioagent treatments and four replications in the nursery. For detailed treatment information, refer to **Table 1**.

**Table 1. Details of treatments imposed against major insect pests of the bamboo**

| Treatment | Treatment details | Dosage |
|---|---|---|
| $T_1$ | *Beauveria bassiana*2 x $10^8$ cfu/ g | 2g/l |
| $T_2$ | *Metarhizium anisopliae* 2 x $10^8$ cfu /g | 2g/l |
| $T_3$ | *Lecanicilliumlecanii*2 x $10^8$ cfu /g | 2g/l |
| $T_4$ | *Bacillus thuringiensis* 2 x $10^8$ cfu /g | 2g/l |
| $T_5$ | Azadirachtin 0.03% EC | 2ml/l |
| $T_6$ | Un Treated Control (UTC) | Water spray |

Evaluation of entomopathogens against *Melanaphis bambusae* infestations in *Dendrocalamus brandisii*, Azadirachtin demonstrated the highest reduction (62.93%) after 7 days of treatment (DAT), followed by *Beauveria bassiana* (49.94%). At 14 DAT, *B. bassiana* achieved the most substantial reduction (86.99%), with *Metarhizium anisopliae* showing the next best reduction (77.97%), followed by Azadirachtin and *Lecanicillium lecanii*. Conversely, *Bacillus thuringiensis* exhibited the least reduction (67.45%).

When assessing the efficacy of entomopathogens against *Palmicultor lumpurensis* on *D. brandisii*, Azadirachtin again led with a reduction percentage of 69.21% at 7 DAT, followed by *M. anisopliae* (41.05%). After 14 days, *B. bassiana* achieved the highest reduction (84.91%), with *M. anisopliae* as the next effective agent (76.19%). Turning to *Bambusatulda*, we observed that Azadirachtin had the best reduction (67.03%) against *M. bambusae* at 7 DAT, followed by *M. anisopliae*, while *B. thuringiensis* showed the least impact

(39.65%). At 14 DAT, *B. bassiana* excelled with an 85.84% reduction, followed by Azadirachtin (79.07%). For *P. lumpurensis* on *B. tulda*, Azadirachtin achieved the highest reduction (69.23%) at 7 DAT, followed by *M. anisopliae*, *L. lecanii*, and *B. bassiana* (35.67%). After 14 days, *B. bassiana* remained effective (79.95%), along with *Azadirachtin* (74.51%) and *M. anisopliae* (65.04%), while *B. thuringiensis* exhibited the lowest reduction (51.32%).

## Discussion

The study revealed significant reductions in *Melanaphis bambusae* and *Palmicultor lumpurensis* populations on *Dendrocalamus brandisii* due to various treatments. Initially, Azadirachtin achieved the highest reduction, but by day 14, *Beauveria bassiana* demonstrated the greatest impact, highlighting the increasing effectiveness of entomopathogens over time. Additionally, *Metarhizium anisopliae* and *Lecanicillium lecanii* performed well. These findings align with previous research on neem oil's efficacy against aphids and mealybugs. The entomopathogens' mode of action involves spore germination and penetration, which becomes more pronounced over time, offering a promising alternative to chemical pesticides.

## References

Basavaraju, S., 2020, Management of Forest Nursery Insect Pests Using Entomopathogen. M.Sc. Thesis, Univ. Agric. Horti. Sci., Shivamogga.

Boopathi. T, Palaniappan, K., Pillai, M. K., Subbarayalu, M. and Madhaiyan, R., 2013, Pathogenicity, Ovicidal Action, and median lethal centrations ($LC_{50}$) of entomopathogenic fungi against Exotic Spiralling Whitefly, *Aleurodicusdispersus* Russell. *J. Pathog*., 1–7.

Erol, A. B., Abdelaziz, O., Birgücü, A. K., Senoussi, M. M., Oufroukh, A. and Karaca, I., 2020, Effects of some entomopathogenic fungi on the aphid species, *Aphis gossypii* Glover (Hemiptera: Aphididae). *Egypt. J. Biol. Pest Control*., **30**:108-112

Gomez, K.A. and Gomez, A.A., 1984. Statistical procedures for agricultural research. John Wiley & Sons. pp.68-72.

Halder, J., Kushwaha, D., Rai, A.B., Singh, A. and Singh, B., 2017, Potential of entomopathogens and neem oil against two emerging insect pests of vegetables. *Indian J. Agric. Sci*., **87** (2): 220–224.

Henderson, C.F. and Tilton, E.W., 1955, Tests with acaricides against the brown wheat mite. *J. Econ. Entomol.*, **48**(2): 157-161.

Huang, P., Yao, J., Lin, Y. and Yu, D., 2021, Pathogenic characteristics and infection-related genes of Metarhizium anisopliae FM-03 infecting *Planococcuslilacinus.Entomol. Exp. Appl.*, **169**(5)

Saranya, S., Ushakumari, R., Jacob, S. and Philip, B. M., 2010, Efficacy of different entomopathogenic fungi against cowpea aphid, *Aphis craccivora* (Koch). *J. Biopestic.*, **3**: 138.

Sayed, A. M. M. and Dunlap, C. A., 2019, Virulence of Some Entomopathogenic Fungi Isolates of *Beauveria bassiana* (Hypocreales: Cordycipitaceae) and *Metarhizium anisopliae* (Hypocreales: Clavicipitaceae) to *Aulacaspistubercularis* (Hemiptera: Diaspididae) and *Iceryaseychellarum* (Hemiptera: Monophlebidae) on Mango Crop. J. *Econ. Entomol.*, **112**(6): 2584–2596.

*MS Received on 07th June, 2024*
*MS Accepted on 02nd August, 2024*

## Review articles & Short notes

**DOI: 10.55278/CAOD4279**

# Mating Disruption: An effective tool for selective area-wide pest management

**Pranita Roy[1], Sagar D[2]*, Jessa Joseph[1], Jayashree S[1], Darshana Brahma[1] and Adarsh Sharma[1]**

[1]*Division of Crop Protection, ICAR- Indian Institute of Horticultural Research, Bengaluru-560 089, India*

[2]*Division of Genomic Resources, ICAR- National Bureau of Agricultural Insect Resources, Bengaluru- 560 024, India.*

***Corresponding author: garuda344@gmail.com**

**Abstract**

Mating disruption is a cutting-edge approach in pest control that uses synthetic sex pheromones to disrupt the mating patterns of insect pests. This method offers a greener alternative to traditional pesticides, helping to minimise the resistance, resurgence and residues. Mating disruption works by interfering with the pests' natural communication signals, thereby it reduces successful mating, gradually decreasing pest populations. However, there are challenges to overcome, such as the high cost of pheromone dispensers and the labour required for their application. Environmental factors can also impact the effectiveness of this technique. To maximize its potential, mating disruption should be combined with other pest management strategies. Despite these hurdles, this method holds great promise for promoting sustainable agriculture by addressing global challenges in pest management, food security, and environmental protection. Continued innovation and overcoming existing limitations will be key to its broader adoption in management of insect pests.

**Keywords:** Mating disruption, Pest management, Pheromone, Behavioural Manipulation, Chemical Alternatives

## Introduction

The trend in pest management is shifting towards reducing the reliance on pesticides, favouring more environmentally friendly approaches that emphasize ecological intensification and lower human inputs, particularly in terms of chemical usage (Garibaldi *et al*., 2019; Beckman *et al*., 2020). In this context, behavioural manipulation is an effective method to support this transition, as it employs techniques that disrupt pest communication and habits, thereby minimizing their adverse effects on agricultural productivity (Foster and Harris, 1997). Behavioural manipulation in pest control utilizes both natural and synthetic signals, including pheromones, kairomones, sounds, and vibrations, to disrupt essential behaviors like feeding and mating (Čokl and Millar 2009; Agarwal and Sunil 2020). These methods align seamlessly with a multidisciplinary approach, fostering robust and synergistic interactions among diverse fields such as biology, ecology, mechanics, chemistry, and computer science.

Pheromone-mediated approaches for controlling insect pests have emerged as effective and environmentally friendly alternatives to conventional insecticides. These strategies utilize natural chemical signals released by insects, which can influence behaviours such as mating and aggregation. Pheromone traps are commonly employed to monitor and capture target pests, including cotton bollworms and fruit flies, thereby aiding in pest density assessment and early detection of infestations. One of the most promising applications of pheromones is mating disruption, where synthetic sex pheromones are released into the environment to interfere with the normal mating behaviour of pests, significantly reducing their reproduction rates and subsequent crop damage (Sarfraz *et al*., 2006; Witzgall *et al*., 2010b).

**What is mating disruption?**

Mating disruption is a pest management strategy aimed at controlling specific insect pests by introducing artificial signals that interfere with their ability to find mates, thereby preventing mating and disrupting their reproductive cycle. This technique primarily utilizes synthetic sex pheromones, which are chemical signals released by female insects to attract males. When these synthetic pheromones are dispersed in lager quantity in the environment, they can mask the natural pheromone signals, causing confusion among male insects as they search for females. Consequently, the chances of successful mating are significantly reduced, which can lead to a decline in pest populations over time.

**History:** *La confusion sexuelle* or mating disruption, was first discussed by the *Institut National De La recherche Agronomique* (National Institute for Agricultural Research) in 1974 in Bordeaux, France. Winemakers in France, Switzerland, Spain, Germany, and Italy were the first to use the method to treat vines against the larvae of the moth genus *Cochylis* (Wikipedia, 2024). By 1970s, the first commercial mating disruption product (Gossylure) were introduced, targeting pests like the pink bollworm, which posed significant threats to cotton crop (Suterra, 2024).

Mating disruption technology in India started gaining prominence for the management of pink bollworm (*Pectinophora gossypiella*) in cotton crop around late 2010s. Significant efforts to implement this technology were observed during the 2019-2020 season. One major initiative, "Project

Bandhan," was launched to deploy mating disruption techniques across multiple states, targeting a substantial number of cotton-growing areas in North India (Krishak Jagat, 2024) (Agri News, 2022) .

**Key components of mating disruption**

1) **Synthetic Pheromones:** Synthetic pheromones are chemical compounds designed to mimic the natural pheromones produced by insects.

**Table 1: Examples of sex pheromones used in mating disruption (Source: Gogi *et al*., 2017)**

| **Insects** | **Lure** | **Chemical Names** | **Reference** |
|---|---|---|---|
| Pink Bollworm *Pectinophora gossypiella* | Gossylure | (1:1 mixture of Cis, Cis and Cis, trans isomers of 7,11E-hexadeca-7,11- dien-1-yl acetate) | (Hummel *et al*. 1973; Golub *et al*. 1983) |
| Brinjal shoot and fruit borer *Leucinodes orbonalis* | Leucilure | Mixture of (E)-11 hexadecenyl Acetate & (E)-11-Hexadecen-1-o1 (100:1) | (Zhu *et al*. 1987) |
| Diamondback moth *Plutella xylostella* | Nomate-DBM, Checkmate-DBM | (Z)- Heaxadecanal -11- enal & (Z)-hexzadec-11- enyl Acetate OR mixture of (Z)-11-hexadecenal (Z-11- 16: Ald) and (Z)-11 hexadecenyl acetate (Z-11-16: Ac) | (Tamaki *et al*. 1977) |
| Red palm weevil *Rhynchophorus ferrugineus* | Ferrolure (Ferrugineol") | 4-methyl-5-nonanol | (Hallett *et al*. 1993) |
| Tobacco cutworm *Spodoptera litura* | Litlure | a mixture of cis-9, trans-11-tetradecadienyl acetate (component A) and cis-9, trans-12- tetradecadienyl acetate (component B) | (Tamaki *et al*. 1973) |
| Cabbage looper *Trichoplusia ni* | Looplure | (Z)-7-dodecenyl acetate | (Shorey *et al*. 1972; Bjostad *et al*. 1980) |
| European corn borer *Ostrinia nubilalis* | ECB-Lure | Z11- and E11- tetradecenyl acetate (Z11- and E11-14: OAc) | (Ishikawa *et al*.1999; Linn *et al*. 2007; Miura *et al*. 2009) |

2) **Dispensers:** A pheromone dispenser is a device that releases synthetic pheromones to disrupt the mating behaviour of pest insects. There are various types of dispensers used for pheromone release in pest management. Hand-applied dispensers include twist ties and sachet dispensers. Twist ties are small devices that are twisted around branches or plant stems and are commonly used in orchards to disrupt moth mating (Witzgall *et al*., 2010a). Sachet dispensers are small pouches containing pheromone and are placed in fields or orchards for the same purpose (Witzgall *et al*., 2010a).

Aerosol dispensers are automated devices that release pheromone sprays at regular intervals and are effective in large-scale applications such as vineyards and orchards (Cardé and Minks, 1995). Microencapsulated dispensers involve pheromones encapsulated in tiny beads or capsules that are sprayed onto crops, providing controlled release over time (Shorey and Gerber, 1996).

Fiber dispensers consist of fibres impregnated with pheromone, which are hung or laid out in the target area and are used for crops like cotton and maize (Cocco and Delrio, 2008). Reservoir dispensers are larger containers that slowly release pheromones over an extended period, making them suitable for long-term disruption in larger areas (Miller and Gut, 2015). Lastly, passive dispensers are simple devices that rely on diffusion for pheromone release and are often used in smaller or localized areas (Witzgall *et al*., 2010a).

**SPLAT® Technology**

SPLAT® (Specialized Pheromone and Lure Application Technology) is a controlled-release emulsion designed to manage insect pests by deploying chemical compounds. This technology works by disrupting pest reproduction through mating disruption, luring and killing target species, or repelling them. The wax-based formula gradually releases pheromones over periods ranging from two weeks to six months, making it effective in reducing pest populations by interfering with their natural behaviour (Hemant *et al*., 2023). Acquired by ISCA Technologies, Inc. (Riverside, CA, U.S.A.) in 2004, SPLAT® formulations have been successfully commercialized both domestically and internationally. ISCA Technologies is a global leader in the development of semiochemicals for pest management. The company has refined the use of semiochemicals including pheromones, plant volatiles, flower oils, sugars, and proteins to influence insect behaviour, thereby effectively protecting crops and forests.

3) **Application methods for disruption of mating in insects**

Pheromone application methods vary based on the scale and specific requirements of the target area. Hand application involves manually placing pheromone dispensers in the desired location. Although this method is labor-intensive, it allows for precise placement and is often used in smaller fields or orchards. Common types of hand-applied dispensers include twist ties and sachet dispensers. In contrast, mechanical application employs machinery to distribute pheromones more efficiently over larger areas. This approach can involve the use of sprayers, which distribute microencapsulated pheromones or other formulations evenly across crops (Shorey & Gerber, 1996), or automated dispensers that can be mounted on tractors or other farm equipment to release pheromones as they move through the fields (Miller & Gut, 2015). Aerial application uses aircraft, such as drones or planes, to disperse pheromones over extensive areas, making it particularly useful for large-scale operations and difficult-to-access terrains. An innovative technology in this field is PheroDrop, developed by NovAgrica as part of the PHERA project. PheroDrop can be mounted on drones, allowing for efficient and rapid application. It is capable of covering 12 hectares in just 30 minutes during a single flight, significantly enhancing the efficiency of pheromone application (NovAgrica).

**Ingredients for Mating Disruption Formulations**

Mating disruption formulations are composed of several key ingredients that work together to effectively manage pest populations. The active ingredient is a synthetic pheromone that mimics the natural sex pheromone of the pest, disrupting mating behaviours (Witzgall *et al*., 2010a; Shorey & Gerber, 1996). In addition to the active ingredient, inert ingredients are included to enhance the formulation's performance. These can include stabilizers, carriers, and other substances that aid in the effective release and dispersion of the pheromone (Witzgall et al., 2010a; Mafra-Neto and Stelinski, 2006). Stabilizers are used to protect the pheromone from degradation, ensuring its longevity and efficacy. Carriers, such as waxes or oils, are materials that help disperse the pheromone throughout the environment. Release agents are substances that control the rate at which the pheromone is released, optimizing its impact on pest populations.

**How does mating disruption work?**

There are several mechanisms by which mating disruption works:

1) **Camouflage of the female's pheromone plume or masking:** The synthetic pheromone when released in the air may camouflage or mask the natural pheromone. This can occur when the synthetic pheromone closely resembles the natural signal.

2) **False trail following:** This mechanism of mating disruption works under the situation where many numbers of controlled released device are placed in field. The males follow the pheromone

plume but their zigzag flight takes them to the device. This reduces the chance of mating.

3) **Imbalance of sensory input:** In some conditions like using incomplete pheromone blend can also work in reducing mating. Due to the synthetic pheromone the male may not be able to perceive the natural pheromone.

4) **Desensitization:** Due to constant exposure to high concentrated synthetic pheromone the males become nonresponsive to the female pheromone. This could be due to the fact that the sensory cells of their antennal sensillae adapt and cease reacting to the minute amounts of pheromone released by females, or it could be the result of the brain's decision-making region becoming overwhelmed and acclimated to the lack of female pheromone.

**Mating disruption as a tool in Integrated Pest Management**

Mating disruption is an effective tool in Integrated Pest Management (IPM) for controlling pest populations. Its primary benefit lies in reducing insecticide use, as it decreases the likelihood of mating among target pests. By doing so, we rely less on broad-spectrum insecticides, which helps to conserve beneficial insects and other natural enemies. Mating disruption is also highly selective, targeting only the male individuals of a specific pest species, which aids in the conservation of non-target organisms. Furthermore, because this technique does not directly kill insects, the development of resistance is less likely compared to conventional insecticides. It is particularly effective when applied over large areas, creating an environment less conducive to the pest's reproduction and allowing natural enemies to thrive, thus providing additional suppression of the pest population. When integrated with the release of biological control agents, mating disruption can enhance the overall effectiveness of pest management by creating favorable conditions for bioagents and reducing pest populations. Overall, mating disruption is a valuable component of a comprehensive IPM program, complementing cultural practices, monitoring, and the judicious use of selective insecticides to effectively manage pest populations.

**Limitations**

While mating disruption is an effective tool in Integrated Pest Management (IPM), it has several disadvantages. As the initial costs are high, as the purchase of pheromone dispensers and application equipment can be expensive, particularly for large-scale operations. Additionally, regular monitoring and replacement of dispensers contribute to ongoing maintenance costs. The process is labor-intensive, as hand-applied dispensers require significant labour for placement and maintenance, especially in large fields. Regular monitoring is also necessary to assess effectiveness and determine the need for replacement. The effectiveness of mating disruption can vary due to environmental factors, such as weather conditions like wind, rain, and temperature, which can affect pheromone dispersion and efficacy. Differences in pest behaviour and biology can also influence the success of this method. Pheromone dispensers have a limited effective range, requiring careful placement to ensure coverage of the entire target area, which may not be as effective in very large fields or areas with high pest populations. Additionally, mating disruption often needs to be integrated with other pest management strategies, such as biological control and cultural practices, for optimal results. This approach requires a good understanding of pest biology and behaviour, as well as expertise in pheromone application techniques.

**Key market players around the world**

The global agricultural pheromones market, particularly in the context of mating disruption, is characterized by several key players and trends that are shaping its growth. Mating disruption is expected to hold a significant market share, driven by its effectiveness and sustainability compared to traditional pesticides. Some global companies are: ATGC Biotech Pvt Ltd. from India, Koppert Biological Systems based in the Netherlands, Shin-Etsu Chemical Co., Ltd from Japan, Isagro Group located in Italy, Biobest Group NV from Belgium, Suterra LLC in the US, Russell IPM in the UK, ISCA Technologies also from the US, BASF from Germany, and Bio Control from Brazil are notable companies in the field of biological pest control and pheromone-based solutions.

**Conclusions**

As our historical background gives evidence of the irrational use of pesticide that led to many environmental problems including resistance development, resurgence and residues harming not only plants, and beneficial organisms but also humanity. Mating disruption can be one such method, which holds significant promise for the future of sustainable agriculture. By addressing its limitations and fostering innovation, MD can play a pivotal role in tackling global challenges related to pest management, food security, and environmental conservation.

**References**

Agarwal, M. L. and Sunil, V. 2020. Basic behavioural patterns in insects and applications of behavioural manipulation in insect pest management. *Journal of Entomology and Zoology Studies*, **8**:991–996.

AgriNews. 2022. 'Project Bandhan' to use mating disruption technique to stop spread of cotton PBW. Retrieved from https://www.agrinews.in

Beckman, J., Ivanic, M., Jelliffe, J. L., Baquedano, F. G., and Scott, S. G. 2020. Economic and food security impacts of agricultural input reduction under the European Union Green

Deal's Farm to Fork and biodiversity strategies.

Bjostad, L. B., Gaston, L. K., Noble, L. L., Moyer, J. H., & Shorey, H. H. (1980). Dodecyl acetate, a second pheromone component of the cabbage looper moth, *Trichoplusia* ni. *Journal of Chemical Ecology*, **6**: 727-734.

Cardé, R.T. and Minks, A.K. 1995. Mating Disruption of Moth Pests in Vineyards and Orchards Using Aerosol Devices. *IOBC/WPRS Bulletin*.

Cocco, A. and Delrio, G. 2008. Pheromone-Based Pest Management in Field Crops: Cotton and Maize. *Crop Protection Journal*.

Čokl, A. A. and Millar, J. G. 2009. Manipulation of insect signaling for monitoring and control of pest insects: pp. 279-316 Springer, Netherlands.

Foster And, S. P. and Harris, M. O. 1997. Behavioral manipulation methods for insect pest-management. *Annual review of entomology*, **42**(1): 123-146.

Garibaldi, L. A., Pérez-Méndez, N., Garratt, M. P., Gemmill-Herren, B., Miguez, F. E. and Dicks, L. V. 2019. Policies for ecological intensification of crop production. *Trends in ecology & evolution*, **34**(4): 282-286.

Gogi, M. D., Nawaz, A., Sufyan, M., Sarfraz, R. M. and Liburd, O. E. 2017. Biorational approaches in pest management. *Sustainable Insect Pest Management*, 231-233.

Golub M., Weatherston, J. and Benn, M.H. 1983. Measurement of release rates of gossyplure from controlled release formulations by mini-airflow method. *Journal of Chemical Ecology,* **9**: 323-333.

Hallett, R.H., Gries, G., Borden, J.H., Czyzewska, E., Oehlschlager, A.C., Pierce, H.D., Angerilli Jr., N.P. D. and Rauf, A. 1993. Aggregation pheromones of two Asian palm weevils, *Rhynchophorus ferrugineus* and *R. vulneratus*. *Naturwissenschaften*, **80**: 328-331.

Hummel, H. E., Gaston, L. K., Shorey, H. H., Kaae, R. S., Byrne, K. J. and Silverstein, R. M. (1973). Clarification of the chemical status of the pink bollworm sex pheromone. *Science*, **181**(4102): 873-875.

Ishikawa, Y., T. Takanashi, C.G. Kim, S. Hoshizaki and S. Tatsuki (1999). *Ostrinia* spp. in Japan: Their host plants and sex pheromones. *Entomologia Experimentalis et Applicata*, **91**: 237–244.

Krishak Jagat. 2024. India conducts the largest field experiment to ward off pink bollworm in cotton. Retrieved from https://www.en.krishakjagat.org

Kumar, H., Sagar, D. and Nebapure, S. M. 2023. SPLAT: a green technology for insect pest management. *Insect Environment*, **26**(3): 369-374.

Linn, C. E., Domingue, M. J., Musto, C. J., Baker, T. C., and Roelofs, W. L. (2007). Support for (Z)-11-hexadecanal as a pheromone antagonist in *Ostrinia nubilalis*: flight tunnel and single sensillum studies with a New York population. *Journal of chemical ecology*, **33**: 909-921.

Mafra-Neto, A. and Stelinski, L. 2006. SPLAT, an ecologically sound and effective solution for IPM. *Insect Science and its Application*, **26**(4): 291-295.

Miller, J.R. and Gut, L.J. 2015. Advances in Pheromone Dispenser Technology for Pest Management. *Pest Management Science*, **71**(9): 1231-1242.

Miura, N., Nakagawa, T., Tatsuki, S., Touhara, K. and Ishikawa, Y. 2009. A male-specific odorant receptor conserved through the evolution of sex pheromones in Ostrinia moth species. *International journal of biological sciences*, **5**(4): 319.

NovAgrica. (n.d.). *PHERA project*. Retrieved July 30, 2024, from https://www.novagrica.com/phera/

Sarfraz, R. M., Evenden, M. L., Keddie, B. A. and Dosdall, L. M. 2006. Pheromone-mediated mating disruption: a powerful tool in insect pest management. *Outlooks on Pest Management*, **17**(1): 36-45.

Shorey, H.H. and Gerber, R.G. 1996. Microencapsulation Technology for Pheromone Dispersion. *Journal of Economic Entomology*, **89**(6): 1502-1508.

Shorey, H. H., Kaae, R. S., Gaston, L. K. and McLaughlin, J. R. 1972. Sex pheromones of Lepidoptera. XXX. Disruption of sex pheromone communication in *Trichoplusia ni* as a possible means of mating control. *Environmental Entomology*, **1**(5): 641-645.

Suterra. 2024. Exploring the history of mating disruption. Retrieved from https://www.suterra.com/blog/exploring-the-history-of-mating-disruption

Tamaki, Y., Noguchi, H. and Yushima, T. 1973. Sex pheromone of *Spodoptera litura* (F.)(Lepidoptera: Noctuidae): isolation, identification, and synthesis. *Applied entomology and zoology*, **8**(3): 200-203.

Tamaki, Y., Kawasaki, K., Yamada, H., Koshihara, T., Osaki, N., Ando, T. and Kakinohana, H. 1977. (Z)-11-Hexadecenal and (Z)-11-hexadecenyl acetate: sex-pheromone components of the diamondback moth (Lepidoptera: Plutellidae). *Applied Entomology and Zoology*, **12**(2): 208-210.

Wikipedia. 2024. Mating disruption. Retrieved from https://en.wikipedia.org/wiki/Mating_disruption on 06 August 2024

Witzgall, P., Kirsch, P. and Cork, A. 2010a. Pheromone Dispensers for Mating Disruption of Insect Pests. *Annual Review of Entomology*, **55**: 511-530.

Witzgall, P., Kirsch, P. and Cork, A. 2010b. Sex pheromones and their impact on pest management. *Journal of chemical ecology*, **36**: 80-100.

Zhu, P. C., Kong, F. L., Yu, S. D., Yu, Y. Q., Jin, S. P., Hu, X. H. and Xu, J. W. 1987. Identification of the sex pheromone of eggplant borer *Leucinodes orbonalis* Guénee (Lepidoptera: Pyralidae). *Bioscience*, **43**:1347–1348.

*MS Received on 18th June, 2024*
*MS Accepted on 12nd September, 2024*

**DOI: 10.55278/KEIH4062**

**Chemical defence strategies in insects**

**Pavan Kumar[1*], Kishore Chandra Sahoo[2] and Anand Harshana[3]**

*[1] Department of Entomology, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Gujarat- 385506*

*[2] ICAR-Indian Agricultural Research Institute, Dirpai Chapori, Gogamukh, Dhemaji, Assam-787035*

*[3] Department of Entomology, College of Agriculture (RVSKVV), Indore, Madhya Pradesh-452001*

***Corresponding author: pavanvenkatakumar3423@gmail.com***

## Introduction

Every organism in the universe has developed its own defence mechanisms. According to Darwin's theory of natural selection, only those that adapt to overcome the struggles for existence survive. For survival, organisms must defend against various biotic and abiotic stresses (Francis, 2007). Insects, in particular, have evolved a range of adaptations to achieve this, including behavioural defences, protective constructions, structural defences, and chemical defences.

**Behavioural defence:** It includes jumping, reflex bleeding, reflex dropping, thanatosis (feigning death), and threatening pose. In behavioural defence, insects learn to jump or fly far away from their natural enemies through their hind legs and wings. In reflex bleeding, insects release body fluids through intersegmental joints which frightens and repels the natural enemies away from the insect (Stocks, 2008). In reflex drooping, insects move far from their natural enemies by drooping or falling from the substratum by a silken thread. In thanatosis insects behave like dead ones so the enemy who wants to eat fresh food does not eat and go away from the insect. In the threatening pose, insects behave combatively which intimidates their natural enemies (Sheikh *et al.*, 2017).

**Protective constructions**: Insect protective constructions include the production of stalked eggs (Ruzicka, 2013), frothy secretion of spittlebugs, portable cases of bag warm (Sugiura, 2016), protective cocoon of pupa, and hard shell of lac insects. Some insects lay their eggs in protective structures like the egg pods of grasshoppers, and cockroach ootheca. In some insects, frothy secretions are secreted over the eggs to avoid desiccation. Some insects like lacewing and white flies, lay stalked eggs to overcome the danger of predation. In the case of spittlebugs, frothy secretions from their malpighian tubules cover the entire body and help in protection from desiccation and enemies (Balzani *et al.*, 2023). Most insect pests pupate in a cocoon, which protects the immobile pupa from adverse conditions.

**Structural defences**: They consists of a horny integument, sclerotised anal cerci, raptorial legs, and tentacles. In beetles, their integument is very hard and known as horny integument which helps in protection from the birds as the beak is not able to penetrate through the integument. Earwig has sclerotised and sickle-shaped anal cerci which is used in defence and prey capturing. Preying mantis have raptorial forelegs with serrated teeth with tibia having blade-like surfaces used in defence and prey capturing.

**Chemical Defense Strategies:**

Venom is a poisonous substance produced by animals and is inserted into or sprayed on its enemies as a chemical strategy for defence. In insects, epidermal cells produce the venom. The epidermal cell nucleus produces the proteins through the transcription and translation process. The produced proteins are known as venom. Most insect venom are proteins, but exceptionally some secondary metabolites may also be used as venom. Adjacent to venom-producing epidermal cells, some cells are modified to form ducts which assist in transporting to the extracellular cuticular process having an opening at their tip. Muscles are associated with the glands and by the movements of muscles the glands secret them through the ducts. Epidermal cells, ducts and extracellular cuticular processes are the structures associated with insect venom production (Bridges and Owen, 1984).

**Hymenoptera**

Most of the hymenopteran insects are venomous. The ovipositor and other associated structures of the abdomen are modified into the sting, which is present at the tip of the gaster. For stinging, the gaster needs to bend and this is achieved by the flexible movements of the petiole. Ants inject venom by biting or stinging. Some ants, spray the venom on the wounds caused by their mandibles. In case of biting, mandibular glands help in the production of venom. Mandibular glands are associated with the mandibles. These glands have the duct to release their secretion. The ducts connect to an opening known as mandalus. The mandibular duct and mandalus are connected by lamellae. The base of the mandalus connects to the adjacent prepharnyx by a cuticular ligament. No muscles are associated with the mandibular glands for their secretions, they depend on the contraction of prepharnyx. Muscular movements of the pharyngeal wall help release secretions from mandibular glands (Richter *et al.*, 2021).

In some ants like *Componotus* sp. mandibular glands are swollen and reach the tip of the abdomen, whenever the enemy comes near, these glands are broken down by the contraction of the abdomen gaster. Secretions from broken glands are sticky and trap the enemy making it immobile (Jones *et al.*, 2004). So, to protect their colonies they sacrifice their life by rupturing their own body known as autothysis. In the olden days mandibles of army ants were used for stitching wounds on torn skin (Schiappa and Van Hee, 2012).

In yellow crazy ants and wood ants, poison is produced in the poison gland situated at the abdomen behind the sting. Muscles are associated with poison glands. Most of their venom contains formic acid. During spraying, ants contract their poison gland where formic acid is stored. It is passed onto the sting and is propelled up to a distance of one meter (Li *et al.*, 2021).

During stinging, fire ants (*Solenopsis* sp.*)* capture the substratum with the help of their mandibles, by curving the gaster through the petiole and then inserting its sting into the substratum. After removing its sting, it rotates the gaster to another point and again inserts. This way, the fire ant stings several times in a semicircular manner. Its venom contains the alkaloid known as piperidine and a small number of proteins that cause the development of blisters on human skin which may lead to secondary infection (Fox, 2014). Some ants produce formic acid as their venom. In fact, the name formic acid was given to it when John Ray isolated this chemical from the ant named *Formica* sp. (Rourke, 1950).

Honey bees are social insects with a queen, a few drones, and several workers. A sting is present in workers and queens. Workers use their stings to defend their colony while queens use them for killing other queens. A sting is a modified ovipositor with venom-producing acid glands or venom glands that are paired sac-like structures. Gland secretions are stored in the venom sac temporarily and are released during stinging (Van Marle and Piek, 1986). Venom consists of toxic proteins known as melittin, hyaluronidase, phospholipases A, acid phosphatases, and histamine with nearly 501 compounds (Banks and Shipolini, 1986). Muscles are associated with poison glands and their contraction helps in the secretion of venom. After stinging, the sting gets stuck to the substratum because of its barbed nature. Serrated margins of the sting (barbed) get stuck to the stung substratum as a result whenever a honey bee tries to pull back its sting, entire glands along with some portions of the alimentary canal come out from the body, leading to death of worker bee after stinging. Similar to the *Componotus* sp. worker bees also show autothysis. This does not happen in the queen. The queen’s sting doesn’t have a barbed tooth. As the gland remains with the removed sting, venom production is continuous even after stinging.

Vespidae and Sphecidae wasps catch caterpillars and inject their venom. The venom causes nervous system failure in the caterpillar bringing it into an unconscious state. The caterpillar is then taken and kept inside the mud nests. Inside the nest, several cells are present. In each cell, the mother wasp lays stalked eggs and covers them with mud. After some days the emerging young ones start feeding on those caterpillars which remain moribund but fresh, without any decomposition to provide food to their young ones. This is achieved by the biochemical effects of the venom injected by the wasp into the caterpillar (Konno *et al.,* 2016).

Another interesting behaviour is seen in the cynipid wasp (*Alloxysta brevis)*. This wasp is a parasitoid of aphids. It comes to aphids to insert their eggs into the body. The ants which are attracted to the honeydew secretions of the aphids protect them from the wasp. If the wasp encounters ants, the ants catch the wasp with their mandibles. The wasp then releases the repellent substance that makes the ant release its mandibles and move away from the wasp. Now the wasp is free to insert its eggs into the aphid.

**Isoptera**

In the Nasute type of soldier termite, epidermal cells below the frons region of the head are modified for the production of substances by transcription and translation, these substances act as venom and are released out through tube-like outgrowth of the cuticle on the frons region of the head (extracellular cuticular process) with an opening at the tip. These Secretions contain mucopolysaccharides, lipids and terpenes which help in defence (Moore, 1968).

**Heteroptera**

Stink bugs produce volatile irritant substances containing esters, alcohols, aldehydes, and 4-oxo-2-alkene through odoriferous glands. In nymphs, odoriferous glands are present on the dorsal surface of the abdomen whereas, in adults, the position changes from the abdomen to the metathorax and a gland opening is present between the two legs. Shifting of position is due to wing development in the adult which covers the dorsal surface of the abdomen (Moraes *et al.,* 2008).

**Coleoptera**

Coleopterans are known as masters of chemical defence. Like other insects, coleopterans cannot fly quickly from their enemies. First, they lift their thickened forewings (elytra), then open their membranous hind wings which is used for flight, and this takes time. To overcome this, they evolved a well-developed chemical defence. The Carabid beetle spray concentrated formic acid on the attackers (Rossini *et al.,* 1997) and the bombardier beetle abdomen contains a reaction chamber in which hydroquinone and hydrogen peroxide are released. In the presence of enzyme catalase and peroxidase, hydroquinone converts to quinone with the byproducts of oxygen and heat. The released heat removes the water present in the secretion. Finally, a mixture of highly irritating quinone is explosively ejected in a rapid pulsed spray (McIntosh and Lawrence, 2018).

The abdomen of the rove beetle contains the defence glands and the secretions mixed with the rectal fluid contain a mixture of compounds such as short-chain alcohols and esters along with oxygenated terpenoids (Dettner, 1993). Blister beetle venom contains cantharidin. Cantharidin is highly irritating and toxic. Beetle releases cantharidin through reflex bleeding. Cantharidin can act both ways, at higher concentrations as a poison (Blum, 1999) and at lower concentrations as semiochemicals, attracting other insects known as cantharidophiles. The fire beetle, *Neopyrochora flabellate,* does not produce cantharidin but acquires it by feeding. The ingested cantharidin plays a major role in courtship behaviour such as the acceptance of the male for mating with the female. During mating, males transfer cantharidin to females and the females incorporate it into their eggs to get protection from the enemies (Eisner *et al.,* 1996b).

The haemolymph of adult coccinellid beetles contains the coccinellin alkaloid in a non-toxic form. During the defence, alkaloids get activated by chemical reactions and released outside through reflexed bleeding. While in larvae and pupae, glandular hairs secrete the venom, in some whirligig beetles belonging to the family Gyrinidae, gyrinidal venom is produced which acts as a deterrent. The giant water bug of the Belostomatidae family produces a formidable venom (Holloway *et al.,* 1991).

**Neuroptera**

The eggs of green lacewing have carboxylic acid, esters and aldehyde venoms coated on the stalk to help repel the ants and other predators (Eisner *et al.,* 1996a).

Besides this, some insects take the poisonous material from plants and store it in tissues such as fat bodies. This stored poison can be used for defence. Larvae of the European pine sawfly (*Neodiprion sertifers)*, eat coniferous plants that contain toxic compounds such as iridodial glycosides, glucosinolates and alkaloids. These compounds are separated from the food material and stored in oesophageal pouches (Opitz *et al.*, 2010). Australian spitfire sawfly larvae sequester oils from eucalyptus plants and store them in oesophageal pouches which when regurgitated helps in defence (Schmidt *et al.*, 2010). In the case of hairy caterpillars like moringa hairy caterpillars, hairs are glandular, if we touch the hairs it leads to a burning sensation (Mullen and Zaspel, 2019). In slug caterpillar scoli is poisonous with peptide compounds (Walker *et al.*, 2021).

**Conclusion:**

Understanding insect chemical defences holds immense potential. By mimicking these natural deterrents, we can develop safer and more targeted pest control methods. By studying the chemical composition, venom can be artificially prepared and used as an insecticide. For example, wasp venom causes nervous system failure in the caterpillars, if the caterpillar becomes a major pest, then knowing the chemicals of wasp venom can be used as an insecticide against the caterpillar. Additionally, studying these intricate chemical pathways can offer insights into developing new medicines and pharmaceuticals.

**Table 1 Insects producing the venom**

| S. No. | Insect producing venom | Chemical composition of venom |
|---|---|---|
| 1. | Fire ant (*Solenopsis* sp.) | Solenopsin A, Piperidine (Fox, 2014) |
| 2. | Carpenter ant (*Componotus* sp.) | Formic acid (Hefetz and Blum, 1978) |
| 3. | Sticky ant (*Componotus saunderi*) | Sticky secretions of mandibular glands (Jones *et al.*, 2004) |
| 4. | Honey bee | Melletin, Hyaluronidase, Phospholipases A, Acid phosphatases, Histamine, Acid glucosamine (Banks and Shipolini, 1986) |
| 5. | European pine sawfly larva (*Neodiprion sertifers*) | Iridodial glycosides, glucosinolates, Alkaloids. (Opitz *et al.*, 2010) |
| 6. | Stink bug | Esters, Alcohols, Aldehydes, 4-oxo-2-alkene (Moraes *et al.*, 2008) |
| 7. | Carabid beetle | Concentrated formic acid (Rossini *et al.*, 1997) |
| 8. | Bombardier beetle | Quinones +Heat +Oxygen (McIntosh and Lawrence, 2018) |
| 9. | Rove beetle | Alcohols, esters, oxygenated terpenoids such as iridodial and dihydro Pentalactone (Dettner, 1993) |
| 10. | Blister beetle | Cantharidin (Blum, 1999) |
| 11. | Fire-colored beetle (*Neopyro flabellate*) | Cantharidin (Eisner *et al.*, 1996b) |
| 12. | Fire fly (*Photuris vesicularis*) | Lucibufagins (González,1999) |
| 13. | Coccinellid beetle | Coccinellin alkaloid (Laurent *et al*., 2002) |
| 14. | South American saturniid caterpillar | Histamine (amines and aromatic compounds) (Deml and Dettner, 1993). |
| 15. | *Schizura* sp. | Formic acid (Morgan *et al*., 2010) |
| 16. | Green lacewing | Carboxylic acid, Esters, Aldehydes (Eisner *et al.*, 1996a) |
| 17. | Nasute soldier termite | Mucopolysaccarides, Lipids, Terpenes (Baker and Walmsley., 1982) |
| 18. | Wasp | Serotonin and Hyaluronidase (Dongol *et al*., 2014) |

**References**

Baker, R. and Walmsley, S. 1982. Soldier defense secretions of the South American termites *Cortaritermes silvestri*, *Nasutitermes sp* and *Nasutitermes kemneri*. *Tetrahedron*, **38**(13): 1899-1910. DOI: 10.1016/0040-4020(82)80039-2

Balzani, P., Nencioni, A., Grillini, M., Masoni, A., Zuri, F., Picchi, M. S., Frizzi, F., Sacchetti, P., Cantini, C. and Santini, G. 2023. Spittlebug invisibility cloak: Experimental tests on the antipredatory effect of the froth of Philaenus spumarius. *Bulletin of Insectology*, **76**(1): 21–28.

Banks, B. E. and Shipolini, R. A. 1986. Chemistry and pharmacology of honey-bee venom. *Venoms of the Hymenoptera: Biochemical, Pharmacological and Behavioural Aspects*, 329–416. DOI:10.1016/B978-0-12-554770-3.50011-5

Blum, M. S. 1999. Arthropod Semiochemicals as Multifunctional Natural Products. Biologically Active Natural Products: Agrochemicals, CRC Press, Boca Raton, London, New York, 147.

Bridges, A. R. and Owen, M. D. 1984. The morphology of the honey bee (*Apis mellifera* L.) venom gland and reservoir. *Journal of Morphology*, **181**(1): 69–86. DOI: 10.1002/jmor.1051810107

Hefetz, A. and Blum, M. S. 1978. Biosynthesis and Accumulation of Formic Acid in the Poison Gland of the Carpenter Ant *Camponotus pennsylvanicus*. *Science*, 201(4354): 454–455. DOI: 10.1126/science.201.4354.454

Deml, R. and Dettner, K. 1993. Biogenic amines and phenolics characterize the defensive secretion of saturniid caterpillars (Lepidoptera: Saturniidae): a comparative study. *Journal of Comparative Physiology B*, **163**(2). DOI: 10.1007/BF00263597

Dettner, K. 1993. Defensive secretions and exocrine glands in free-living staphylinid bettles—their bearing on phylogeny (Coleoptera:Staphylinidae). *Biochemical Systematics and Ecology*, **21**(1): 143–162. DOI:10.1016/0305-1978(93)90020-R

Dongol, Y., Dhananjaya, B.L., Shrestha, R.K. and Aryal, G. 2014. Pharmacological and immunological properties of wasp venom. *In*: Gowder, S.J.T. (Ed.), Pharmacology and Therapeutics. InTech, Vienna, pp. 49–83. DOI: 10.5772/57227

Eisner, T., Attygalle, A. B., Conner, W. E., Eisner, M., MacLeod, E. and Meinwald, J. 1996a. Chemical egg defense in a green lacewing (*Ceraeochrysa smithi*). *Proceedings of the National Academy of Sciences*, **93**(8): 3280–3283. DOI: 10.1073/pnas.93.8.3280

Eisner, T., Smedley, S. R., Young, D. K., Eisner, M., Roach, B. and Meinwald, J. 1996b. Chemical basis of courtship in a beetle (*Neopyrochroa flabellata*): Cantharidin as precopulatory “enticing” agent. *Proceedings of the National Academy of Sciences*, **93**(13): 6494–6498. DOI:10.1073/pnas.93.13.6494.

Fox, E. G. P. 2014. Venom toxins of fire ants. *Venom Genomics and Proteomics*, 1–16. DOI:10.1007/978-94-007-6649-5_38-1

Francis, K. A. 2007. Charles Darwin and the Origin of Species. Westport, CT: Greenwood Press, p. 43.

González, A. 1999. Studies on the defensive chemistry of Utetheisa ornatrix (Lepidoptera: Arctiidae) and Photuris versicolor (Coleoptera: Lampyridae). Cornell University.

Holloway, G. J., De Jong, P. W., Brakefield, P. M. and De Vos, H. 1991. Chemical defence in ladybird beetles (Coccinellidae). I. Distribution of coccinelline and individual variation in defence in 7-spot ladybirds (*Coccinella septempunctata*). *Chemoecology*, **2**(1): 7–14. DoI:10.1007/BF01240660

Jones, T. H., Clark, D. A., Edwards, A. A., Davidson, D. W., Spande, T. F. and Snelling, R. R. 2004. The Chemistry of Exploding Ants, *Camponotus* SPP. *Journal of Chemical Ecology*, **30**(8): 1479–1492. DOI: 10.1023/b:joec.0000042063.01424.28

Konno, K., Kazuma, K. and Nihei, K. 2016. Peptide toxins in solitary wasp venoms. *Toxins*, **8**(4): 114. DOI: 10.3390/toxins8040114

Laurent, P., Braekman, J.-C., Daloze, D. and Pasteels, J. M. 2002. In vitro production of adaline and coccinelline, two defensive alkaloids from ladybird beetles (Coleoptera: Coccinellidae). *Insect Biochemistry and Molecular Biology*, **32**(9): 1017–1023. DOI: 10.1016/S0965-1748(02)00038-3

Li, S., Yuan, W., Wang, P., Su, Z., Kulhavy, D. L., Zhao, F. and Bullard, S. H. 2021. Chemical War Between Fire Ants (*Solenopsis invicta*) and Rasberry Crazy Ants (*Nylanderia fulva*). In T. Pullaiah and M. R. Ielmini (Eds.), Invasive Alien Species (1st ed., pp. 353–368). Wiley. DOI:10.1002/9781119607045.ch52

McIntosh, A. C. and Lawrence, J. 2018. The Extraordinary Design of the Bombardier Beetle: A Classic Example of Biomimetics. *Proceedings of the International Conference on Creationism*, **8**(1): 6. DOI:10.15385/jpicc.2018.8.1.27

Moore, B. P. 1968. Studies on the chemical composition and function of the cephalic gland secretion in Australian termites. *Journal of Insect Physiology*, **14**(1): 33–39. DoI:10.1016/0022-1910(68)90131-5

Moraes, M. C., Pareja, M., Laumann, R. A. and Borges, M. 2008. The chemical volatiles (semiochemicals) produced by neotropical stink bugs (Hemiptera: Pentatomidae). *Neotropical Entomology*, **37**(5): 489–505. DOI:10.1590/S1519-566X2008000500001

Morgan, E.D. 2010. Biosynthesis in insects. Cambridge, UK: Royal Society of Chemistry, p. 29.

Mullen, G. R. and Zaspel, J. M. 2019. Moths and butterflies (Lepidoptera). In *Medical and veterinary entomology* (pp. 439–458). Elsevier. DOI:10.1016/B978-012510451-7/50020-7

Opitz, S. E. W., Jensen, S. R. and Müller, C. 2010. Sequestration of Glucosinolates and Iridoid Glucosides in Sawfly Species of the Genus Athalia and Their Role in Defense Against Ants. *Journal of Chemical Ecology*, **36**(2): 148–157. DOI: 10.1007/s10886-010-9740-3

Richter, A., Schoeters, E. and Billen, J. 2021. Morphology and closing mechanism of the mandibular gland orifice in ants (Hymenoptera: Formicidae). *Journal of Morphology*, 282: 1127–1140. DOI: 10.1002/jmor.21358

Rossini, C., Attygalle, A. B., González, A., Smedley, S. R., Eisner, M., Meinwald, J. and Eisner, T. 1997. Defensive production of formic acid (80%) by a carabid beetle. *Proceedings of the National Academy of Sciences*, **94**(13): 6792–6797. DoI:10.1073/pnas.94.13.6792

Rourke, F. J. 1950. Formic acid production among the Formicidae. *Annals of the Entomologil Society of America*, **43**(3): 437–443. DoI:10.1093/aesa/43.3.437

Ruzicka, Z. 2013. Protective role of the egg stalk in Chrysopidae (Neuroptera). *European Journal of Entomology*, **94**(1): 111–114.

Schiappa, J. and Van Hee, R. 2012. From Ants to Staples: History and Ideas Concerning Suturing Techniques. *Acta Chirurgica Belgica*, **112**(5): 395–402. DOI:10.1080/00015458.2012.11680861

Schmidt, S., McKinnon, A. E., Moore, C. J. and Walter, G. H. 2010. Chemical detoxification vs mechanical removal of host plant toxins in Eucalyptus feeding sawfly larvae (Hymenoptera: Pergidae). *Journal of Insect Physiology*, **56**(12): 1770–1776. DOI: 10.1016/j.jinsphys.2010.07.006

Sheikh, A. A., Rehman, N. Z. and Kumar, R. 2017. Diverse adaptations in insects: A review. *Journal of Entomology and Zoology Studies*, **5**(2), 343–350.

Stocks I. 2008. Reflex bleeding (autohemorrhage). *Encyclopedia of Entomology* JL Capinera 34–41 Berlin: Springer.

Stocks, I. 2008. Reflex bleeding (Autohemorrhage). *Encyclopedia of Entomology*, 3132–3139.

Sugiura, S. 2016. Bagworm bags as portable armour against invertebrate predators. *Peer J*, **4**(2), e1686. DOI: 10.7717/peerj.1686

Van Marle, J. and Piek, T. 1986. Morphology of the venom apparatus. Venoms of the Hymenoptera: Biochemical, Pharmacological and Behavioural Aspects; Piek, T., Ed, 17–44.

Walker, A. A., Robinson, S. D., Paluzzi, J.-P. V., Merritt, D. J., Nixon, S. A., Schroeder, C. I., Jin, J., Goudarzi, M. H., Kotze, A. C., Dekan, Z., Sombke, A., Alewood, P. F., Fry, B. G., Epstein, M. E., Vetter, I. and King, G. F. 2021. Production, composition, and mode of action of the painful defensive venom produced by a limacodid caterpillar, *Doratifera vulnerans*. *Proceedings of the National Academy of Sciences*, **118**(18), e2023815118. DoI:10.1073/pnas.2023815118.

*MS Received on 15th June, 2024*
*MS Accepted on 29th August, 2024*

**DOI: 10.55278/MNXH2958**

# Comprehensive review of the Silverleaf Whitefly: *Bemisia argentifolii* (Bellows and Perring) and *Bemisia tabaci* (Gennadius) Biotype B/MEAM1

**Mbaye Ndiaye**
*Plant Protection Directorate, Thiaroye-Dakar, Senegal P.O. Box: 20054*
***Corresponding author: mbaye.ndiaye18@yahoo.com***

Whiteflies (Homoptera: Aleyrodidae) include about 1,500 species worldwide, with only a few being significant agricultural pests. The most prominent is the cotton whitefly, *Bemisia tabaci*, followed by the greenhouse whitefly, *Trialeurodes vaporariorum*. *B. tabaci* is known for its genetic diversity, forming a cryptic species complex with a global presence. *B. tabaci* thrives in tropical, subtropical, and some temperate regions, posing a major threat to greenhouse crops. It is particularly concerning in the Sahel, where it affects numerous agricultural and horticultural crops. The species is primarily dispersed through internationally traded plants.

Ranked among the top 100 invasive organisms globally, *B. tabaci* has a broad host range, attacking over 500 plant species across 74 families. It is a pest on more than 900 host plants worldwide, causing significant damage to crops like squash, melons, cucumbers, tomatoes, eggplants, potatoes, cotton, okra, beans, soybeans, peanuts, and various ornamental plants.

## Identification of *Bemisia argentifolii*

### Taxonomy and History

*Bemisia* belongs to the order Homoptera and the family Aleyrodidae, though its taxonomy is highly debated. *Bemisia tabaci*, also known as strain A, was first collected in the United States in 1897 and described by Gennadius in 1889 (Keith, 1997). The taxonomy of *Bemisia* became contentious again in 1980 when an aggressive strain appeared in poinsettia crops in Florida, causing severe damage in the Southeastern United States (Perring, 1995). Strains A and B were identified as the two most significant phylogenetic groups of *B. tabaci* from an agricultural perspective.

### Morphological Studies

Rosell *et al.* (1995) examined specific morphological characteristics of various *Bemisia* populations from different global locations to determine their use in identification. Using electron microscopy, they focused on the length and width of dorsal and caudal bristle tissues. The results indicated that these characteristics were not exclusive to strain B, leading to the conclusion that the biological differences between these geographically isolated species form a complex of biotypes, including *B. tabaci* A and B.

## Genetic Identification

Campbell *et al.* (1995) suggested that identification based on 18S rDNA sequences could be useful for determining genetic distances among whitefly taxa. This method, when corroborated with morphological classification, could classify insects at subfamily, tribe, genus, and species levels. However, the minimal nucleotide differences—only one in 18S rDNA—between *B. tabaci* A and B highlighted the difficulty in finding clear morphological distinctions between these taxa. Campbell et al. also studied variations in *Bemisia* based on maternally inherited bacterial symbionts. They found that the 16S rDNA of primary endosymbionts in *B. tabaci* A and B was identical. A second bacterial symbiont was present in both strains, but a third bacterium was detected only in strain B. This led to the conclusion that the divergence of these lineages likely occurred very recently.

## Distinctive Biological Characteristics

Several specialists argue that strain B of *B. tabaci* has enough distinctive biological traits to be considered a separate species. For instance, strain B lays more eggs, and if strains A and B cross, their offspring are not viable. Adults of strain B live longer than those of strain A. Field monitoring has shown that strain B is not limited to the same host plants as strain A. When both strains were fed poinsettia, strain B produced more honeydew, although its amino acid and carbohydrate composition was similar to that of strain A. Strain B's superior sap access contributes to its performance. Perring (1995) noted that strain B effectively displaced strain A from its habitat. Ecologically, Odum (1970) suggested that neighbouring species with similar habitats or lifestyles do not coexist in the same place unless they use different food sources, are active at different times, or occupy different niches. This led to the description of strain B as a new species, *B. argentifolii*, due to the silver-like symptoms it causes on squash (Perring, 1995). *B. argentifolii* is also known as the sweet potato whitefly strain B, Florida strain, cotton strain B, poinsettia strain B, or California *B. tabaci* strain (Perring, 1995).

## Recent Studies and Nomenclature

Adan *et al.* (1999) reported that *B. tabaci* B has been widely accepted as a new species in the new world. A recent study showed that strain B can cross with a non-B biotype (Mediterranean species, formerly known as biotype Q) from Spain.

For convenience, the new strain is referred to as:

- Strain B (biotype B)
- *Bemisia argentifolii* Bellows, Perring, Gill & Hendrick, 1994
- *Bemisia tabaci* (B biotype)
- *Bemisia tabaci* B

- *Bemisia tabaci* Middle East Asia Minor 1 species
- Middle East Asia Minor 1 (MEAM1) species (*Bemisia tabaci*)

This distinguishes it from the milder infestation of the earlier known *Bemisia tabaci* strain A (Cuthbertson, 2015).

**Advanced Identification Techniques**

MacLeod *et al.* (2022) explored using a deep-learning convolutional neural network (CNN) trained on puparial images to identify consistent differences in puparial morphology. Fifteen molecular species, identified via DNA barcoding and confirmed through extensive molecular characterizations and crossing experiments, were analyzed. The results demonstrated that all 15 species could be successfully discriminated based on puparium morphology alone. This level of discrimination was achieved for laboratory populations reared on both hairy-leaved and glabrous-leaved host plants. Cross-tabulation tests confirmed the generality and stability of the CNN discriminant system trained on both ecophenotypic variants.

**Origin of *Bemisia***

The exact origin of *Bemisia* is unknown. Campbell et al. (1995) suggest that the genus likely originated in tropical Africa, with *B. tabaci* being introduced to other tropical regions and the southern part of North America relatively recently. This introduction was likely followed by that of *B. argentifolii*. Hoddle (1999) speculates that *B. argentifolii* may have originated in India or Pakistan, given the high number and diversity of *Bemisia* parasitoids found in these countries.

**Reproduction**

*B. argentifolii* exhibits a high reproduction rate, with thousands of individuals coexisting on the same plant. It is a bisexual species, with males and females living together in the same environment. Males are particularly important as they can cause crop damage and transmit diseases. Genetically, individuals resulting from sexual reproduction show more variability compared to those from parthenogenesis (Agrios, 1997).

Population parameters of *B. argentifolii* reared on poinsettia at 25 ± 1°C, 70% RH, and a photoperiod of 13.5 hours light and 10.5 hours dark were studied by Ndiaye (2000) using the Chi two-sex life table (1988).

**Infestation and Symptoms**

*Bemisia argentifolii* infests over 500 plant species across 74 families (Allen *et al.*, 1995), causing severe damage to crops like squash, melon, cucumber, tomato, eggplant, potato, cotton, okra, Guinea sorrel, beans, soy, peanut, gerbera, salvinia, poinsettia, and many ornamental plants.

**Host Plant Diversity and Population Growth**

The wide range of host plants allows *B. argentifolii* to evade natural enemies specific to one plant type, maintaining pest populations year-round. Females easily find suitable egg-laying sites, leading to continuous population growth as they move between wild plants and crops. The accumulation of sorbitol, a thermos-protective and osmoregulatory hormone, helps *B. argentifolii* withstand high temperatures (Wolf et al., 1997). Additionally, cotton can cool its leaves through transpiration, reducing leaf temperature from 50°C to 41°C (Skinner, 1996). Increased humidity shortens the development time of immature stages, resulting in larger larvae (Ndiaye, 2000).

**Feeding and Symptoms**

*B. argentifolii* feeds by sucking sap, causing symptoms such as dwarfism, irregular fruit maturity, silver spots, whitish crowns, weak rooting, poor growth, defoliation, and even plant death. This leads to reduced crop yields (Hendrix *et al.,* 1995). For instance, a one-fifth reduction in soybean yield was observed with an infestation of five whiteflies per plant at the 4-leaf stage, showing strong correlations between root dry weight, pod weight, and seed weight (Ndiaye, 2000).

**Honeydew and Sooty Mold**

Honeydew, a mixture of sugars secreted by *Bemisia*, is deposited on leaves and falls to the ground. It serves as an energy source for ants, which protect the whiteflies from predators and parasitoids. Unconsumed honeydew promotes the growth of black sooty mold (*Capnodium* spp., *Cladosporium* spp., or *Alternaria* spp.), degrading product quality and interfering with plant metabolism by reducing photosynthesis, thus lowering yields (Oetting and Buntin, 1995; Hoddle, 1999).

**Virus Transmission and Phytotoxemia**

*Bemisia* transmits many Gemini viruses, serious pathogens of important crops (Scott et al., 1995; Brown and Bird, 1995; Chen, 1996). Additionally, *Bemisia* causes phytotoxemia, though the responsible molecules are not characterized. Jimenez *et al.* (1994) proposed two hypotheses:

- Molecules similar to microbial toxins in insect saliva are injected into the host plant and translocated apically.
- Mobile secondary messengers from damaged plant cells trigger physiological changes in plant development.

**Indirect Damage**

The presence of whiteflies can lead to the development of resistance and phytotoxicity due to insecticide use for control (Brazzle, 1998; Oetting and Buntin, 1995).

## Resistance to Insecticides

### Resistance Issues

The presence of whiteflies has led to significant resistance problems. Brazzle (1998) reported that in six locations in California's San Joaquin Valley, *Bemisia argentifolii* populations showed notable resistance to the organophosphate chlorpyrifos (Lorsban®), and the pyrethroids fenpropathrin (Danitol®) and bifenthrin (Capture®). In Arizona, resistance to pesticide mixtures has also been observed. Insects resistant to organophosphates often exhibit cross-resistance to carbamates, and those resistant to DDT show some resistance to pyrethroids. *Bemisia tabaci* is highly adaptable and resistant to almost all pesticides used for its control, including organophosphates, carbamates, pyrethroids, neonicotinoids, and buprofezin (Horowitz *et al.*, 2020).

### Control Challenges

Controlling *Bemisia* with insecticides is challenging because adults and immature stages infest the undersides of leaves, which are difficult to reach. This biological behavior, combined with resistance, has significant financial implications. Producers often resort to overdosing and increasing the number of applications. If this fails, they must use new, generally more expensive pesticides. Phytotoxicity and the toxicological and ecotoxicological side effects of pesticide application also add to the cost of resistance (Oetting and Buntin, 1995).

### Economic Impact

The economic impact of *Bemisia* infestation is substantial. In 1991, losses attributed to *B. argentifolii* in the United States were estimated at 350 billion CFA francs (Naranjo *et al.*, 2000). In China's Laioning province, cotton cultivation areas dropped from 125,000 hectares in the 1960s and 1970s to a few thousand hectares in the 1980s due to *Bemisia* (Rumei *et al.*, 1995). In West and Central Africa, *Bemisia* infestation led to a 7% reduction in cotton yield during the 1998 and 1998-99 seasons (Fichet, 1999). In Senegal and Burkina Faso, cotton production declines were significant, with losses of 38,450 tonnes and 338,130 tonnes in 1997 and 1998, and 11,600 tonnes and 284,000 tonnes in 1998 and 1999, respectively.

### Genomic Insights

Studies of the *B. tabaci* genome have identified 49 plant genes integrated into its genome, an unprecedented number of gene transfers between plants and an insect (Clément and Maumus, 2022). The genome also contains 142 horizontally transferred genes from bacteria or fungi, including those encoding hopanoid/sterol synthesis and xenobiotic detoxification enzymes not found in other insects, highlighting unique biological adaptations (Wenbo *et al.*, 2016). The extent of horizontal gene transfer in shaping eukaryote evolution remains an open question, but Xia *et al.* (2021) demonstrated that whiteflies have hijacked a plant detoxification gene to neutralize plant toxins, providing clear evidence of this phenomenon.

**Summary**

The genome of *Bemisia tabaci* includes genes transferred from bacteria, fungi, and plants, enhancing its resistance to insecticides, detoxification capabilities, and virus transmission. These genetic features contribute to its invasiveness and effectiveness as a virus vector. The genome helps resolve the cryptic species complex of *B. tabaci* and provides insights for developing new control strategies. *B. tabaci* and *B. argentifolii* are closely related, with *B. argentifolii* being more virulent and harder to control. Effective management of *B. argentifolii* could also address *B. tabaci* infestations, as both species share similar environments and ecological niches. Chemical pesticides are commonly used but offer only short-term solutions. Addressing the resistance and control challenges of these species requires more sustainable approaches.

**References**

Adan A., Ronda M., Cifuentes D., Cenis J. L., Beitia F., 1999. Laboratory studies on the crossing of two biotypes of *Bemisia tabaci* (Gennadius, 1889) present in Spain. Proceedings of the 7th Spanish Congress of Entomology, Almeria (8-12th November, 1999).

Agrios G. N., 1997. Plant Pathology. Fourth Edition. Academic Press. 635 pp.

Allen J. C., Bellows T. S., Evans T. R., Fasulo M. L., Flint P. B., Goodell T. X., Liu R. L., Nichols J. W., Norman, T. M. Perring D. G., Riley A. N., Sparks P. A., and Toscano N. C. 1995. Silverleaf Whitefly, *Bemisia argentifolii* Bellows & Perring. United States Department of Agriculture, Whitefly Knowledgebase.

Anonymous. (No date). Tobacco Whitefly, *Bemisia tabaci.* Insecticide Resistance Action Committee IRAC. https://irac-online.org/pests/bemisia-tabaci/

Anonymous. 2018. IRM for sustainable whitefly control with special reference to *Bemisia tabaci*. Designed & produced by IRAC Sucking Pest WG, December 2018, Poster Ver. 2.2 IRAC. chrome-extension://efaidnbmnnni bpcajpcglclefindmkaj/https://irac-online.org/documents/bemisia-tabaci-irm-poster/?ext=pdf

Brazzle, J. 1998. Silverleaf whitefly. Resistance Management Guidelines. University of California, Cooperative Extension. 24 pp.

Brown, J. K. and J. Bird. 1995. Introduction of an exotic whitefly (*Bemisia*) vector facilitates secondary spread of Jatropha Mosaic Virus, a gemini virus previsiouly vectored exclusively by the “Jatropha” Biotype. pp 69-76. *In* D. Gerling and R. T. Mayer [eds], Bemisia 95: Taxonomy, Biology, Damage Control and Management. Intercept, UK.

Brown, J. K., J. Bird, D. R. Frohlich, R. C. Rosell, I. D. Bedford and P. G. Markham. 1995. The relevance of variability within the *Bemisia tabaci* species complex to epidemics caused by subgroup III gemini viruses. pp 77-89. *In* D. Gerling and R. T. Mayer [eds], *Bemisia* 95: Taxonomy, Biology, Damage Control and Management. Intercept, UK.

Campbell, B. C., J. D. Steffen-campbell, and R. J. Gill. 1995. Origin and radiation of whiteflies: an initial molecular phylogenetic assessment. pp 29-51. *In* D. Gerling and R. T. Mayer [eds], Bemisia 95: Taxonomy, Biology, Damage Control and Management. Intercept, UK.

Chen, H. H. 1996. Transmission of tomato leaf curl gemini virus by *Bemisia argentifolli* (Homoptera: Aleyrodidae). Master's Thesis. National Chung Hsing University. Taiwan.

Chi, H. 1988. Life-table analysis incorporating both sexes and variable development rates among individuals. *Environ. Entomol.* 17: 26-34.

Clément G., and Maumus F. 2022**.** Multiple horizontal acquisitions of plant genes in the whitefly *Bemisia tabaci. Genome Biology and Evolution*, Volume 14, Issue 10, October 2022, evac141, https://doi.org/10.1093/gbe/evac141.

Cuthbertson A. 2015 *Bemisia tabaci* (MEAM1) (silverleaf whitefly).

Publication: CABI Compendium https://doi.org/10.1079/cabicompendium.8925

Fichet, M. 1999. Une Campagne 1998-1999 Difficile. Coton et Développement. Rev. Trim. No. 30 -Avril-Mai-Juin 1999.

Gerling, D. and R. T. Mayer. 1995. Introduction. pp v. *In* D. Gerling and R. T. Mayer, [eds], Bemisia 95: Taxonomy, Biology, Damage Control and Management. Intercept, UK.

Hendrix, D., T. Steele and Jr. H. H. Perkins. 1995. *Bemisia* honeydew and sticky cotton. pp 189-199. *In* D. Gerling and R. T. Mayer [eds], *Bemisia* 95: Taxonomy, Biology, Damage Control and Management. Intercept, UK.

McAuslane H. J. (2000) common name: sweetpotato whitefly B biotype or silverleaf whitefly scientific name: *Bemisia tabaci* (Gennadius) or *Bemisia argentifolii* Bellows & Perring (Insecta: Hemiptera: Aleyrodidae). Publication Number: EENY-129, University of Florida.

https://entnemdept.ufl.edu/creatures/veg/leaf/silverleaf_whitefly.htm

Hoddle, M. S. 1999. The biology and management of silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring (Homoptera: Aleyrodidae) on greenhouse grown ornamentals. Department of Entomology, University of California, Riverside, USA.

Horowitz, A. R., Ghanim, M., Roditakis, E., Nauen, R., et Ishaaya, I. (2020). Insecticide resistance and its management in Bemisia tabaci species. *Journal of Pest Science*, **93**(3), 893910.

Jimenez, D. R., R. K. Ykomi, R. T. Mayer and J. P. Shapiro. 1994. Cytology and physiology of silverleaf whitefly-induced squash silverleaf. *Physiological and Molecul. Plant Pathol.* **46**: 227- 242

Keith, R. H. 1997. Population biology of establishment and impact of introduced natural enemies. Agric. Res. Ser. U.S. Department of Agriculture 501 South Chapel Street, Newark, DE 19713, USA.

MacLeod N., Canty R. J., and Polaszek 2022. Morphology Based Identification of *Bemisia tabaci* Cryptic Species Puparia via Embedded Group-Contrast Convolution Neural Network Analysis. Syst Biol.; 71(5): 1095–1109. Published online 2021 Dec 24. doi: 10.1093/sysbio/syab098

Naranjo, S. E., G. D. Butler, Jr. and T. J. Henneberry. 2000. Bibliography of *Bemisia tabaci* and *Bemisia argentifolii* - 2000 Addendum. *In* Silverleaf Whitefly: National Research, Action and Technology Transfer Plan, 1997-2001; Second annual review of the second 5-year plan. USDA-ARS (in press).

Ndiaye, M. 2000. Life history traits of the silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring (Homoptera: Aleyrodidae) on Poinsettia and its damage on soybean. Master's Thesis. National Pintung University of Science and Technology. Taiwan.

Odum, E. P. 1970. Fundamental of ecology, Third Edition. W.B. Saunders Company, Philadelphia, Pennsylvania.

Oetting, R. D. and G. D. Buntin. 1995. *Bemisia* damage expression in commercial greeenhouse production. pp 201-208. *In* D. Gerling and R. T. Mayer [eds], Bemisia 95: Taxonomy, Biology, Damage Control and Management. Intercept, UK.

Perring, T. M. 1995. Biological differences of two species of *Bemisia* that contribute to adaptative advantage. pp 133-142. *In* D. Gerling and R. T.

Rosell, R. C., I. D. Bedford, P. G. Markham, D. R. Frohlich and J. K. Brown. 1995. Morphological variation. pp 147-149. *In* D. Gerling and R. T. Mayer [eds], Bemisia 95: Taxonomy, Biology, Damage Control and Management. Intercept, UK.

Rumei, X. 1995. The Occurrence and distribution of *Bemisia* in China. pp. 125-131 *in* D. Gerling and Richard T. Mayer, eds. Bemisia 95: Taxonomy, Biology, Damage control and Management. Intercept, UK.

Scott, J. W., S. M. R. Stevens, J. H. M. Barten, C. R. Thome, J. E. Polston, D. J. Schuster and C. A. Serra. 1995. Introgression of resistance to whitefly-transmitted geminiviruses from *Lycopersicon chilense* to Tomato. pp 153-166. *In* D. Gerling and R. T. Mayer [eds], Bemisia 95: Taxonomy, Biology, Damage Control and Management. Intercept, UK.

Skinner, R. H. 1996. Leaf temperature effects on *Bemisia argentifolli* (Homoptera: Aleyrodidae) oviposition. Environ. Entomol. 25: 1371-1375.

Wenbo C., Daniel KH, Zhangjun F. 2016. The draft genome of whitefly *Bemisia tabaci* MEAM1, a global crop pest, provides novel insights into virus transmission, host adaptation, and insecticide resistance. *BMC Biology* volume 14, Article number: 110 (2016).

Wolfe, G. R., D. L. Hendrix, M. E. Salvucci. 1997. A thermos-protective role for sorbitol in the silverleaf whitefly, *Bemisia argentifolii*. *J. Insect Physiol.* **44:** 597-603.

Xia J., Guo Z, Yang Z., Han H., Wang S., Xu H., Yang X., Yang F., Wu Q., Xie W., Zhou X., Dermauw W., Turlings T. C. J., Zhang Y. (2021) Whitefly hijacks a plant detoxification gene that neutralizes plant toxins. PMID: **34171320** DOI: 10.1016/j.cell.2021.06.010.

*MS Received on 26th May, 2024*
*MS Accepted on 1st September, 2024*

**DOI: 10.55278/FCSW2946**

**Succession of insect pests complex and their natural enemies on broccoli**

**S. Hariharan* and C. Narendra Reddy**
*College of Agriculture, Rajendranagar, PJTSAU, Hyderabad, Telangana, India-500030.*
**Corresponding author*: ***hariharanselvamvpm1999@gmail.com***

## Introduction

Broccoli (*Brassica oleracea* L. var. *italica*) is a member of the genus *Brassica* and family Brassicaceae. The term broccoli is derived from the Latin word *brachium* meaning arm or branch (Dixon, 2006). Originating in the Mediterranean region, broccoli is now widely grown in China, India, USA, Spain, Mexico and Italy. In India, it is grown in Himachal Pradesh, Uttar Pradesh, the hilly areas of the Nilgiri Hills, Jammu and Kashmir and the northern plains. Maison (1965) listed 51 insect pests that harm cruciferous vegetables worldwide, emphasizing the need to minimize losses for enhanced quality and yield. Understanding the succession of pests and their natural enemies at different crop stages would help identify their peak activity time. This knowledge can then be used to develop an appropriate management plan. However, this succession pattern varies across regions, influenced by different harvest times and changing climate scenarios. Therefore, it is essential to maintain up-to-date knowledge for the successful implementation of pest control strategies.

## Material and Methods

A field study was conducted in Horticulture Garden, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad (170 32'N latitude and 780 41'E longitude) during *rabi*, 2022-23 to investigate the succession of insect pest complex and their natural enemies on broccoli (Shishir F1 hybrid; Known-you seed). The experiment was laid out in a 100 $m^2$ area, divided into four quadrates of 25 $m^2$ (5 m x 5 m). Seedlings of 30 days age were transplanted with a spacing of 60 cm x 45 cm. Observations on different insects were recorded on five randomly selected plants in each quadrate at weekly intervals (SMW) starting from one week after transplanting. No plant protection measures, such as pesticide spraying, were implemented during the crop period.

## Results and Discussion

The results of the present study revealed that a total of eight insect pest species *viz*., *Plutella xylostella*, *Myzus persicae*, *Attractomorpha* sp., *Monolepta signata*, *Euproctis* sp., *Crocidolomia pavonana*, *Spodoptera litura* and *Nezara viridula* were found infesting broccoli **(Fig. 1a - 1h) (Table 1)**. Among the natural enemies, four species of coccinellids *viz*., *Menochilus sexmaculatus*, *Brumoides suturalis*, *Harmonia octomaculata* and *Coccinella transversalis* and one syrphid fly *Ischiodon scutellaris* **(Fig. 1i – 1n)** was found to predate upon *M. persicae* and two unidentified braconid parasitoids were observed during the crop period. One braconid species was found to parasitize *P. xylostella* and another braconid on *M. persicae* under natural conditions **(Table 2).** Thus, a total of fifteen insect species was recorded at different growth stages of broccoli belonging to six orders *viz*., Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera and Orthoptera, representing eleven families. Observations revealed that the crop was initially attacked by *P. xylostella*, *M. persicae*, *Attractomorpha* sp., *M. signata* and *Euproctis* sp. during the seedling stage. Notably, *Attractomorpha* sp., *M. signata* and *Euproctis* sp. were only observed up to the vegetative stage, while *P. xylostella* and *M. persicae* persisted throughout the entire crop period. Activity of *C. pavonana* and *S. litura* was noted from the vegetative stage until harvest, while *N. viridula* appeared only at the harvest stage. Among the eight species of insect pests recorded on broccoli, four species *viz*., *P. xylostella*, *M. persicae*, *C. pavonana* and *S. litura* were viewed to be of major significance.

In case of natural enemies, *C. transversalis* exhibited maximum period of activity being found throughout the crop period and therefore, it may be considered a predator of major importance. Boopathi *et al*. (2012) and Sharma *et al*. (2017) also studied the incidence of insect pests and their natural enemies on broccoli from seedling to harvest stage and reported twenty six and twenty three insect species at various stages of broccoli crop growth, respectively. The present results on the succession of insect pests and their natural enemies on broccoli align with the findings observed on different crucifers by Badjena and Mandal (2005), Pawar *et al*. (2010), Shah *et al*. (2013), Gaikwad *et al*. (2018), Anjali and Pandya (2019), Sahu *et al*. (2019) and Gopika *et al*. (2022). Therefore, the present findings offer a comprehensive account of the succession of insect pests complex and their natural enemies on broccoli under the agroecological conditions of Rajendranagar, Hyderabad which can be used to plan an effective pest management strategy.

**Acknowledgements**

The authors are grateful to the Department of Entomology, College of Agriculture, Rajendranagar and all the staff of PJTSAU, AICRP on Pesticide Residues, and ARI Vegetable research station for their continuous support throughout the research work.

**Table 1. Succession of insect pests on broccoli during *rabi* 2022-23**

| Common name | Scientific name | Order: Family | Period of occurrence | Stage of plant attacked | Nature of damage |
|---|---|---|---|---|---|
| Diamondback moth | *Plutella xylostella* | Lepidoptera: Plutellidae | November 12 to January 14 | Seedling to harvest | Defoliator |
| Aphid | *Myzus persicae* | Hemiptera: Aphididae | November 12 to January 14 | Seedling to harvest | Sap feeder |
| Grasshopper | *Attractomorpha* sp. | Orthoptera: Pyrgomorphidae | November 12 to November 25 | Seedling, Vegetative stage | Defoliator |
| Flea beetle | *Monolepta signata* | Coleoptera: Chrysomelidae | November 12 to November 25 | Seedling, Vegetative stage | Defoliator |
| Hairy caterpillar | *Euproctis* sp. | Lepidoptera: Erebidae | November 12 to December 9 | Seedling, Vegetative stage | Defoliator |
| Leaf webber | *Crocidolomia pavonana* | Lepidoptera: Crambidae | November 26 to January 14 | Vegetative stage to harvest | Defoliator |
| Tobacco caterpillar | *Spodoptera litura* | Lepidoptera: Noctuidae | November 26 to January 14 | Vegetative stage to harvest | Defoliator |
| Stink bug | *Nezara viridula* | Hemiptera: Pentatomidae | December 24 to January 7 | Harvest stage | Sap feeder |

**Table 2. Succession of natural enemies on broccoli during *rabi* 2022-23**

| Common name | Scientific name | Order: Family | Period of occurrence | Host |
|---|---|---|---|---|
| Coccinellid | *Menochilus sexmaculatus* | Coleoptera: Coccinellidae | November 12 to December 2 | *Myzus persicae* |
| | *Brumoides suturalis* | Coleoptera: Coccinellidae | November 12 to December 9 | *Myzus persicae* |
| | *Harmonia octomaculata* | Coleoptera: Coccinellidae | November 12 to December 9 | *Myzus persicae* |
| | *Coccinella transversalis* | Coleoptera: Coccinellidae | November 12 to January 14 | *Myzus persicae* |
| Parasitoid | Unidentified | Hymenoptera: Braconidae | November 19 to January 14 | *Plutella xylostella* |
| Parasitoid | Unidentified | Hymenoptera: Braconidae | November 26 to January 14 | *Myzus persicae* |
| Syrphid fly | *Ischiodon scutellaris* | Diptera: Syrphidae | December 3 to January 14 | *Myzus persicae* |

**a. *Plutella xylostella***

**b. *Myzus persicae***

**c. *Attractomorpha* sp.**

***d. Monolepta signata***

***e. Euproctis sp.***

***f. Crocidolomia pavonana***

**g. *Spodoptera litura***

**h. *Nezara viridula***

**i. *Menochilus sexmaculatus***

**j. *Brumoides suturalis***

**k. *Harmonia octomaculata***

**l. *Coccinella transversalis***

**m. *Ischiodon scutellaris* maggot**

**n. *I. scutellaris* adult**

**Fig. 1a – 1n. Insect pests and natural enemies recorded on broccoli during *rabi* 2022-23**

**References**

Anjali, G.P and Pandya, H.V. 2019. Investigations on population dynamics of diamondback moth, *Plutella xylostella* Linn. and natural enemies on cabbage, *Brassica oleracea* var. *capitata* Linn. *Journal of Entomology and Zoology Studies*, **7**(4): 1209-1212.

Badjena, T and Mandal, S.M.A. 2005. Seasonal incidence of major insect pests and predators in cauliflower. *Annals of Plant Protection Sciences*, **13**(2): 472-473.

Boopathi, T and Pathak, K.A. 2012. Seasonal abundance of insect pests of broccoli in North Eastern Hill Region of India. *Madras Agricultural Journal*, **99**(1): 125- 127.

Dixon, G.R. 2006. *Vegetable brassicas and related crucifers*. CABI Publishing, Oxfordshire, UK.

Gaikwad, A.D., Bhede, B.V., Bokan, S.C and Bhosle, B.B. 2018. Seasonal incidence of major insect pests, natural enemies on cauliflower and their correlation with weather parameters. *Journal of Entomology and Zoology Studies*, **6**(5): 952- 956.

Gopika, R., Sonkamble, M.M and Lad, A.G. 2022. Seasonal incidence of major insect pests of cabbage and their correlation with weather parameters. *Journal of Entomological Research*, **46**(1): 154-157.

Maison, B.L. 1965. Insect pests of crucifers and their control. *Annual Review of Entomology*, **10**(2): 233-256.

Pawar, V.R., Bapodra, J.G., Joshi, M.D., Ghadge, S.M and Dalve, S.K. 2010. Incidence of leaf webber, *Crocidolomia binotalis* (Zeller) on mustard. *International Journal of Plant Protection*, **3**(1): 130-131.

Sahu, B., Pachori, R., Navya, R.N and Patidar, S. 2019. Pest succession of major insect pest of cabbage. *Journal of Experimental Zoology India*, **20**(10): 1-7.

Shah, R., Ahmed, S and Poswal, A. 2013. Population dynamics of insect pests, parasitoids and predators in cabbage and cauliflower agro-ecosystems. *Journal of Entomological Research*, **37**(2): 129-137.

Sharma, D., Singh, S., Kaul, V., Suheel, H.A., Ganai, A and Kumar, M. 2017. Population dynamics of major insect pests and their natural enemies in broccoli. *Indian Journal of Entomology*, **79**(4): 493-497.

*MS Received on 30th June, 2024*
*MS Accepted on 12nd September, 2024*

**DOI: 10.55278/QNHZ8878**

# Assessing niche partitioning and interspecific interactions between stingless bees and ants in St. Joseph's College (Autonomous), Bengaluru

**Akanksha Tiwari, Aakash Ghosh, Nandita Madhu, Maria Anjum, Abhishek Mishra, and M. Jayashankar***

*Department of Zoology, School of Life Sciences, St. Joseph's University, Bengaluru-560027.*

***Corresponding author: jayashankar.m@sju.edu.in***

*Passiflora vitifolia* ('perfumed passionflower'/'grape-leaved passionflower') is a common exotic perennial flowering vine in India. The trunks are 2-3 cm wide and become woody in mature plants, with trilobed leaves and bright red flowers. Flowering occurs occasionally throughout the year, predominantly during dry periods. Self-incompatibility is a characteristic feature of this plant. Stingless bees and ants seek nectar by often punching holes through the corollas of the flowers. Ants also collect pollen (Snow, 1982). Most abundant in the Neotropics, stingless bees are found in Asia, Africa, America, and Australia (Goh *et al*., 2023). Pollen is an important resource and is collected in their pollen baskets. Other sources of food include animal meat, fungal spores, nectar, plant sap, fruit juice, resins, mud, wood pulp, bark, leaves, small stones, seeds, faeces, and epicarps (Grüter, 2020).

Stingless bees visit ant-free flowers more often. When both ants and bees are present on the same flower, they divide the niche by location. If ants are foraging on the bracts, bees will hover and forage inside the flower, and vice versa. They may occupy different regions of the same flower simultaneously, such as pedicels, stamens, and stigmas. The foraging patterns of ants and stingless bees differ, influencing their ability to occupy and utilize available resources (Neto et al., 2014).

The study was conducted in late November to early December 2021. The study site was a green patch near Gate 1, St. Joseph's College (Autonomous), now St. Joseph's University, Bengaluru (12.96242109403278, 77.5965023018482) **(Map 1 and 2)**. The campus has a dense occurrence of stingless bee nest sites (Murthy and Jayashankar, 2022). The green patch features dense growth of *Passiflora vitifolia* **(Fig. 1)**, which supports a healthy population of various ant and stingless bee species.

The equipment used was limited to a modern mobile phone. Its photography application was used to capture images of the observations, and a timer application was used to track the duration of each observation. All-occurrence sampling was conducted to assess the interactions between stingless bees and ants. The sampling was carried out in 30-minute sets. Four team members observed four specific spots in the green patch, recording the interactions, their nature, and their characteristics.


**Map1: Google Maps Image of St Joseph's College.**


**Map 2: Satellite View of St Joseph's College.**

Niche partitioning was observed between stingless bees and several ant species. The bees were predominantly seen hovering over the pollen-laden anthers, collecting pollen. They were also observed on the bracts of closed buds, accessing extra floral nectaries. The ants occupied the base and inner coronal elements of the flowers, making their way to the nectar cup located within the basal part of the flower. They were also found on other extra floral nectaries present at the stipules, petioles, and bracts of buds, as well as inside closed buds. In several instances, the bees were seen avoiding the closed buds.

The nature of the interspecific interactions between the ants and the stingless bees was either neutral or negative. No positive interactions were recorded. Neutral interactions mainly consisted of proximal coexistence in a small area. Negative interactions mostly involved repulsions and collisions. A repulsion occurred when either the ant or the bee changed its direction of movement upon encountering the other. A collision occurred when both the ant and the bee physically crashed into each other. A total of 43 neutral interactions and 24 negative interactions were recorded **(Fig. 2)**. Temperature was noted during the observations, but it did not significantly influence the interactions.

The majority of the observed interactions were more neutral than negative, which can be attributed to niche separation resulting from the physical structure of the flower. Niche separation decreases competition between species, allowing for more pollination and, consequently, a greater population of bees and ants. The inner coronal elements are accessible only to smaller ants, which can crawl inside to reach the nectar cup, the innermost chamber. The anthers are on top and completely exposed, allowing bees to conveniently access the pollen. This physical structure of the flower facilitates niche separation between ants and stingless bees.

**Fig 1. *Passiflora vitifolia* plant under observation in the campus**

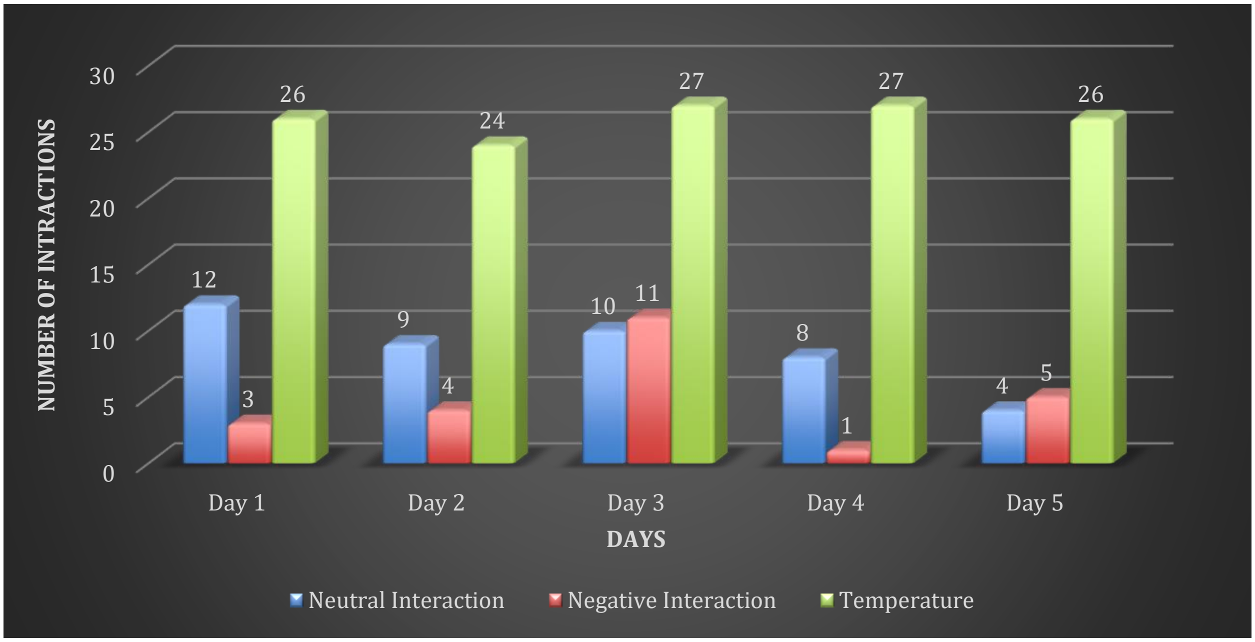



**Fig 2. Interaction between Stingless bee and different species of Ants**

**Summary**: The study observed that interactions between ants and stingless bees were predominantly neutral or negative, with no positive interactions recorded. Neutral interactions involved coexistence in close proximity, while negative interactions included repulsions and collisions. The physical structure of the *Passiflora vitifolia* flower promotes niche separation, reducing competition and allowing both ants and bees to access different parts of the flower. This separation supports increased pollination and larger populations of both insects.

**Acknowledgements**

Authors are thankful to Mr. Sachin Bhaskar for discussion on the floral biology of the *Passiflora vitifolia.*

**References**

Grüter, C. 2020. Stingless Bees: Their Behaviour, Ecology and Evolution.

Goh, L.P.W., Jawan, R., Faik, A.A.M., and Gansau J.A. (2023). A review of stingless bees' bioactivity in different parts of the world. *J Med Life*. **16(1):**16-21.

Murthy, R and Jayashankar, M. 2022. Observations on stingless bees in St. Joseph's College (Autonomous), Bengaluru. *Insect Environment*. **25 (1):** 89-91.

Neto, M. A., Izzo, T. J., Raimundo, R. L. G and Feres, D.C.R. (2003). Reciprocal interference between ants and stingless bee attending the honeydew – producing homopteran *Aetalion reticulatum* (Homoptera: Aetaliondae). *Sociobiology*. **42 (2):**369-380.

Snow, A. A. 1982. Pollination intensity and potential seed set in *Passiflora vitifolia*. *Oecologia.*, **55(2):** 231-237.

*MS Received on 26th June, 2024*
*MS Accepted on 22nd September, 2024*

**DOI: 10.55278/XVBV2191**

**Insect pests and cropland birds: To till or no-till**

**Mahesh.V[1], Adarsh [2] and M. Jayashankar[2*]**

*[1]Department of Zoology, Bangalore University, J.B. Campus, Bengaluru-560056*

*[2]Department of Zoology, School of Life Sciences, St. Joseph's College (Autonomous), Bengaluru-560027.*

***Corresponding author: jayashankar.m@sju.edu.in***

In India, insecticides constitute more than half of all pesticides applied. According to the Economic Survey (2015-2016) (Mathew 2016; Grewal *et al*. 2017), there has been a rise in pesticide residues in the food consumed in India. Exposure to different types and levels of pesticides results in both acute and chronic health problems. Misapplication of pesticides can cause moderate human health issues. Birds, wildlife, domestic animals, fish, and livestock all suffer as a result of pesticide pollution in the environment (ICAR Report 1967; Nayak and Solanki 2021; Upadhyay and Nishant, 2016).

Integrated pest management approaches are suggested and followed to mitigate these issues. Birds have been found to reduce the white grub population by 45 to 65% during three subsequent ploughings (Parasharya *et al.* 1994). In Thailand, ducks are released onto rice fields in the Integrated Rice Duck Farming (IRDF) system following the transplantation of seedlings. Ducks naturally peck at insects, stir up paddy water to prevent weeds from sprouting, and supply organic matter for rice plants to flourish (Suh, 2014).

Tillage, apart from increasing the porosity of the soil, disturbs unwanted insects at their most vulnerable stages, exposing eggs, grubs, and adults to the harsh environment where they may freeze, overheat, desiccate, or be eaten by birds (Gupta and Gavkare, 2014). Observations from experimental fields at the Indian Institute of Horticultural Research (IIHR) (13.135°N 77.493°E), Bengaluru, in May 2012, illustrated that House Crows and Jungle Crows (Corvidae), Cattle Egrets (Ardeidae), Mynas (Sturnidae), and Paddy Field Pipits or Indian Pipits (Motacillidae) were observed feeding on the grubs and other insects exposed during tilling.

Arable land provides essential foraging opportunities to many European farmland birds. However, various factors have contributed to the reduction in the value of arable cropland as a food source, such as the increased use of pesticides and the introduction of genetically modified crops engineered to limit weed and insect populations (Ron et al. 2011). An estimated 76% of the risk to farmland birds is attributable to the loss of food resources, driven largely by changes in cropped areas (Butler *et al.* 2010). Species abundance and diversity in zero-tillage crop fields were found to be higher compared to intensively cultivated fields (Kaur *et al*. 2017).

**Fig. 1. Jungle crow and Myna**

**Fig. 2. Jungle and House crow feeding**

**Fig. 3. Cattle egrets**


**Fig. 4. Cattle egret and Myna**


**Fig. 5. Cattle egret, House crow and Myna near a Tiller**

**Fig. 6. Paddy Field Pipit or Indian Pipit**

## References


Grewal, A. S., Singla, A., Kamboj, P., and Dua, J. S. (2017). Pesticide residues in food grains, vegetables and fruits: A hazard to human health. *Journal of Medicinal Chemistry and Toxicology*, *2*(1), 40–46. doi:10.15436/2575-808X.17.1355

Gupta, S., and Gavkare, O. (2014). White grub. brahmina coriacea. a potential threat to potato. *Journal of Industrial Pollution Control*, *30*(2), 357–359.

Indian Council of Agricultural Research, Report of the Special Committee on Harmful Effects of Pesticides, Indian Council of Agricultural Research. (1967) p. 78. New Delhi.

Kaur, J., T.K. Kler, J.S. Kang and M. Kumar. 2017. Impact of zero tillage agriculture on the avian fauna in Ludhiana, Punjab. *Journal of Environmental Biology*. **38** 689-695

Mathew,R. (October 13, 2016). Idukki faces grave health risks from pesticides. *Hindu*.

Nayak, P., and Solanki, H. (2021). Pesticides and Indian agriculture- a review. *International Journal of Research Granthaalayah*, **9**(5), 250–263. doi:10.29121/granthaalayah.v9.i5.2021.3930

Parasharya, B. & Dodia, J. & Mathew, Kuzhivelil & Yadav, Deena. (1994). Natural regulation of white grub (Holotrichia sp: Scarabidae) by birds in agroecosystem. *Journal of Biosciences.* **19**. 381-389. 10.1007/BF02703175.

Ron J. Johnson, Julie A. Jedlicka, John E. Quinn, and James R. Brandle. 2011. Global Perspectives on Birds in Agricultural Landscapes. In W.B. Campbell and S. López Ortíz (eds.), Integrating Agriculture, Conservation 55 and Ecotourism: Examples from the Field, Issues in Agroecology – Present Status and Future Prospectus 1

Suh, J. (2014). *'Theory and reality of integrated rice–duck farming in Asian developing countries: A systematic review and SWOT analysis,' Agricultural Systems, Elsevier, 125*(C) (pp. 74–81).

Upadhyay, R., and Nishant, N. (2016). Presence of pesticide residue in vegetable crops: A review. *Agricultural Reviews*, ***37***(3), 173–185. doi:10.18805/ag.v37i3.3533


*MS Received on 16th June, 2024*
*MS Accepted on 29th August, 2024*

**DOI: 10.55278/CQZE6340**

**The role of Drosophila in pollination: A comprehensive review**

**B.P. Harini[2], Mahesh.V[1], and M. Jayashankar[1]***

[1, 2] *Department of Zoology, Bangalore University, Bengaluru-560056.*

[1]**Department of Zoology, St. Joseph's University, Bengaluru-560027.*

***Corresponding author: jayashankar.m@sju.edu.in***

## Abstract

Pollination is a process where plants provide breeding sites as a reward for pollination. Pollinators can be divided into three groups based on their ovipositing sites and the larval food of insects' ovule parasites: This group includes insects like fig wasps and yucca moths, found in only five plant lineages. These pollination systems exhibit very high pollinator specificity. Pollen parasites: Primarily consisting of thrips (Thysanoptera), these insects engage in pollen parasitism. The specificity of these pollinators is generally low. Larvae in decomposed flowers: Insects such as certain beetles (Coleoptera) and flies (Diptera) lay their eggs in decomposed flowers and inflorescences. These adaptations have evolved repeatedly through different pathways in various plant taxa. Pollinator specificity varies, and shifts in pollinators may occur between related or unrelated insects. The common fruit fly (Drosophila spp.), with over 1600 species in its genus, is not only a model organism in genetics but also acts as a pollinator. As plants are sedentary by nature, they require a mechanism to achieve gene transfer, which is facilitated through pollination. Insect pollination is one of the most common forms. The flies not only pollinate but also oviposit their eggs in the respective plants. They are attracted to the plants as actual, deceptive, or brood site pollinators.

**Keywords:** Pollination, *Drosophila.*

## Introduction

Pollination is a critical ecological process that facilitates plant reproduction and contributes to biodiversity. While many studies focus on traditional pollinators such as bees and butterflies, recent research has begun to highlight the role of non-traditional pollinators, including various species of Drosophila. These small flies, often associated with decaying fruit, have been observed visiting flowers and engaging in pollination behaviors. Notably, Drosophila species have been documented as effective pollinators for certain plant species, including orchids. This article aims to explore the mechanisms through which Drosophila contribute to pollination, the ecological implications of their interactions with flowering plants, and their potential in pollination research.

**Actual Pollination:** Several species of Drosophila removed the Pollinia from the flower of different plant species exhibiting active pollination, *Drosophila ananassae* pollinated the flowers of *Bulbophyllum lilacinum* Ridl., *B. peninsulare* Seidenf., and *Bulbophyllum* sp. (yet to be identified). (Teck and Hong, 2012). The Pleurothallidinae's genus *Dracula erythrochaete, D. felix, D.lafleurii, D. morleyi, D. pubescens, D. sodiroi, D. vinacea, Manevallia bicolor, M. demissa, M. Floribunda, M. fonsecae, M. infiracta, M. pachyura, Pleurothallis dorotheae, P. eumecocaulon, P. phyllocaradioides , Specklinia dunstervillei ,S. endotrachys, S. pfavii ,S. remotiflora, S. spectabilis* were all pollinated by different members of the Drosophilidae family (Karremans and, Diaz-Morales, 2019). *Alocasia odora* was pollinated by its specific pollinators such as *Colocasiomyia alocasiae* (Okada) and *C. xenalocasiae* (Okada) (Diptera: Drosophilidae). These flies use the spadix of *A. odora* as breeding sites too (Miyake and Yafuso. 2003). *Arum palaestinum* was pollinated by *Drosophila phalerata, D. immigrans, D. hydei, D. melanogaster, D. simulans* and *Arum orientale by Drosophila subobscura , D. busckii , D. hydei* (Gibernau *etal.*, 2004). *Cypripedium bardolphianum* was pollinated by the members of Drosophillidae. W.W. Sm. & Farrer (Zheng *et al.*, 2010 – c/f Bernhardt & Edens-Meier, 2010). Drosophila species, have also been reported to pollinate *Bulbophyllum penicillium* (C.S.P. Parish and Rchb. f.) in Southeast Yunnan, China (Liu *et al.*, 2010). *Drosophila (Sopophora) rufa* pollinated *Cosmostigma racemosum* (Family Asclepiadaceae). Drosophilidae family was also able to actively increase the pollination and also the seedling and fruit formation on Arabica coffee thereby rendering actual pollination. (Parikesit *et al.*, 2018)

**Brood site Pollination** Seven species of drosophila *viz*., *D*. aff. *bromeliae*, *D*. aff. *florae*, *D. neocardini*, *D. malerkotliana*, *D. mesostigma*, *D. equinoxialis*, and *D. latifasciaeformis* were found to pollinate two species of *Aristolochia, A. maxima* and *A. inflate*. *Drosophila* spp. are the predominant visitors, pollinators of Aristolachia sps and primary pollinators of *A. maxima* which is pollinated by diverse sps. of Drosophila while the latter is pollinated by single specialized sps. (Sakai, 2002)**.** *Drosophila* aff. *Bromeliae* and *D*. aff. *florae* are "generalist flower-breeders," which breed on flowers of variety of species including *Datura* (Solanaceae) and *Ipomea* (Convolvulaceae) (Patterson and Stonne,1952); Carson, 1971). *Drosophila latifasciaeformis* visiting *A. maxima* were also bred from *Borassus* flowers (Palmae) (Brncic, 1986). Other *Drosophila* flies are opportunistic flower breeders. *Drosophila cardinoides* visiting and bred from *A. maxima* flowers has been reared from flowers of Araceae, Heliconiaceae, Solanaceae, Zingiberaceae, as well as fruit of Annonaceae and Clusiaceae, and mushrooms (Pipkin, 1965; Brncic, 1986).

**Deceptive pollination** The flies in *Arum palaestinum* Solomon's lily pollinate deceptively by mere odour attractant from the flower i.e., deceptive pollination, insects are bamboozled into performing nonrewarded pollination., the flies are attracted by the odour composed of volatiles characteristic of yeast, and produces an antennal detection pattern similar to that elicited by a range of fermentating products. The different fly species found include *D. simulans*, *D. melanogaster*, *D. subobscura*, *D. hydei*, *D. immigrans*, *D. busckii* (Stokl *et al.,* 2010)**.** Eight species of drosophila *viz*., *D. hydei*, *D. mercatorum*, *D.* aff. *repleta*, *D. ananassae*, *D. fuscolineata*, *D. immigrans*, *D*. aff. *bifurca*, *D. nigrohydei* were found to pollinate four species of Specklinia *viz*., *S. endotrachys*, *S. pfavii*, *S. remotiflora* and *S. spectabilis* (Karremans, *etal.,* 2015

## Summary

This article reviews the emerging evidence of Drosophila species as significant pollinators for various plant species and examines how these flies are attracted to plants, facilitating pollination either deceptively or genuinely. It also discusses the unique adaptations of these flies that enhance their role in pollination, such as their attraction to specific floral traits, including color, scent, and nectar availability. The study highlights the first documented case of Drosophila pollination in Specklinia orchids. By understanding the contributions of Drosophila as pollinators, we can gain insights into the complexities of pollination networks and the importance of conserving diverse pollinators among different insect species in the face of environmental change.

## References

Brncic, D. (1986). Ecology of flower breeding Drosophila. In The genetics and biology of Drosophila 3b, edited by M. Ashburner, H. L. Carson, and J. N. Thompson, Jr., 333-382. Academic Press, London, UK.

Carson, H. L. (1971). Flower-breeding Drosophila and their times and places of breeding. *Evolution*, **25**(4), 686-699.

Gibernau, M., Macquart, D. & Prezetak, G. (2004). Pollination in the Genus Arum- a review. Aroideana 27: 148–166.

Karremans AP, Diaz-Morales M *The Pleurothallidinae: Extremely High Speciation Driven By Pollinator Adaptation,* Conference Papers / Systematics / Karremans And Dlaz-Morales page 366-388.

Karremans, A. P., Pupulin, F., Grimaldi, D., Beentjes, K. K., Butôt, R., Fazzi, E. G., Kaspers, K., Kruizinga, J., Roessingh, P., Smets, E. F., & Gravendeel, B. (2015). Pollination of Specklinia by nectar-feeding Drosophila: The first reported case of a deceptive syndrome employing aggregation pheromones in Orchidaceae. *Annals of Botany*, **116**(3), 437-455.

Liu, Z. J., Chen, L. J., Liu, K. W., Li, L. Q., & Rao, W. H. (2010). A floral organ moving like a caterpillar for pollinating. *Journal of Systematics and Evolution*, **48**(2), 102-108.

Mitra, B. (2010). Diversity of flower visiting flies (Insecta: Diptera) in India and their role in pollination. *Records of the Zoological Survey of India*, *110*(Part 2), 95-107.

Miyake, T., & Yafuso, M. (2003). Floral scents affect reproductive success in fly-pollinated Alocasia odora (Araceae). *American Journal of Botany*, **90**(3), 370-376.

Patterson, J. T., & Stone, W. S. (1952). *The evolution in the genus Drosophila*. Macmillan. (New York, NY, USA).

Parikesit, P. T., Widodo, H. S., & Widoretno, W. (2018). Active pollination by Drosophilidae on coffee flower (Coffea arabica L.) and its effects on seedling and fruit formation. Biodiversitas *Journal of Biological Diversity*, **19**(5), 1765-1772.

Pipkin, S. B. (1965). The influence of adult and larval food habits on population size of neotropical ground-feeding Drosophila. *American Midland Naturalist*, **74**, 1-27.

Purwantiningsih, B., Leksono, A. S., & Yanuwiadi, B. (2012). *Jurnal Berk Penel Hayati*, 17, 165-172.

Sakai, S. (2002). A review of brood-site pollination mutualism: plants providing breeding site for their pollinators. *Journal of Plant Research*, 115, 0161–0168.

Sokolowski, J., Sturtz, A., Dafni, A., Svatos, A., Doubsky, J., Knaden, M., Sachse, S., Hansson, B. S., Stensmyr, M. C. (2010). A deceptive pollination system targeting Drosophilids through olfactory mimicry of yeast. *Current Biology*, **20**, 1846-1852.

Stökl, J., Brodmann, J., Dafni, A., Ayasse, M., & Hansson, B. S. (2010). Smells like yeast: Exquisite floral mimicry in orchids. *Function*, **4**(11), 287-294.

Teck, O. P., Hong, T. K. (2012). Three species of Bulbophyllum Section Racemosae pollinated by Drosophila flies. *Malesian Orchid Journal*, 9.

Zheng, G., Li, P., Tai, Y., An, D., Kou, Y., and Luo, Y. (2010). Flowering and fruit set dynamics in Cypripedium. *Acta Ecologica Sinica*, **12**, 3182-3187.

*MS Received on 26th July, 2024*
*MS Accepted on 22nd September, 2024*

**DOI: 10.55278/NMPK4885**

## Diversity assessment of odonates in Bheemanakuppe, South Bengaluru

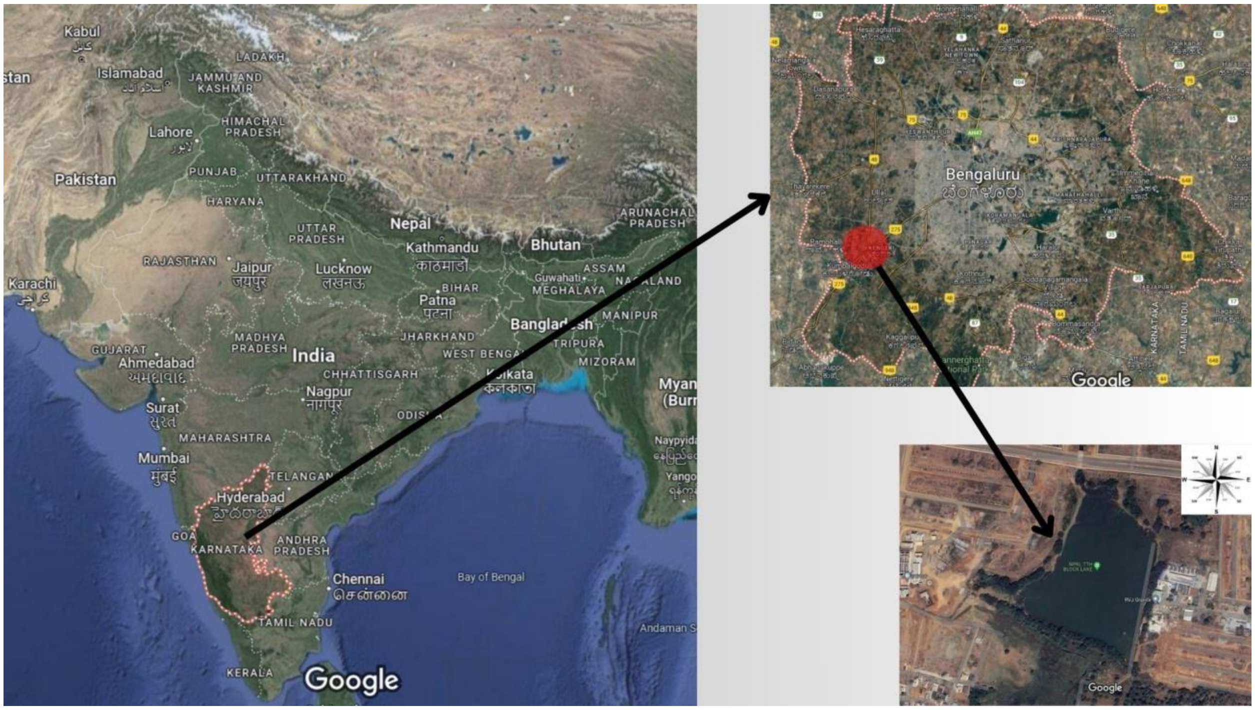
**Aleena K.J, G.S. Harrington Deva and M. Jayshankar Munirathinam***
*Department of Zoology, St. Joseph's University Bengaluru-560027, India*
***Corresponding author: jayashankar.m@sju.edu.in***

The order Odonata from the class Insecta includes some of the most ancient flying insects, with approximately 6,300 species and subspecies of dragonflies (suborder Anisoptera) and damselflies (suborder Zygoptera) inhabiting freshwater ecosystems worldwide (Tsuda, 1991; May, 2019; Sharma et al., 2007). India, with its diverse ecosystems and various habitat types, hosts over 488 species of odonates (Subramanium and Babu, 2017).

Habitat preferences vary among species: dragonflies often prefer larger water bodies such as lakes, ponds, and slow-moving rivers, while damselflies favor smaller, more vegetated water bodies including marshes, streams, and temporary pools (Kalita and Ray, 2015; Kumar et al., 2018). Despite their small size, odonates are dominant predators in both larval and adult stages, preying on a variety of small insects including mosquitoes, flies, and other aquatic invertebrates (Vashishth et al., 2002). Odonate larvae are particularly effective in controlling mosquito populations in aquatic ecosystems, providing a safe and effective method for pest elimination (Saha et al., 2012).

However, habitat loss and fragmentation, pollution, climate change, drainage, and the conversion of wetlands for agriculture and development significantly reduce suitable breeding and foraging grounds for odonates. Additionally, invasive species pose significant challenges to odonate populations worldwide (Anon. a, 2024). Therefore, conservation efforts aimed at preserving freshwater habitats and mitigating anthropogenic impacts are essential.

The area selected for the present observations is NPKL 4th Block Lake, located at coordinates 12.91442265419682, 77.4342195876245 in Bheemanakuppe, Bengaluru (Map 1). The lake has a perimeter of approximately 750 meters and covers an area of about 32,750 square meters (Google Earth Pro). It is surrounded by *Pongamia pinnata* trees, which harbor weaver ant nests (Harrington and Jayshankar, 2023). The water body is situated near an upcoming highway and is adjacent to a quarry.




**Map 1: Study Site (NPKL 4th block Lake)**

This study was conducted from February 24th to April 31st, 2024. Surveys were carried out in two intervals: the morning session from 10:00 AM to 12:00 PM, and the evening session from 2:30 PM to 4:00 PM. The line transect method was used in the morning session as a preliminary approach, while the point count method was employed in the afternoon session, focusing on areas within the land border and the lake (adopted from Anja et al., 2021).

Insect nets were utilized to capture odonates for closer identification. A field guide (Subramaniam, 2005) was used for species identification, and both mobile photography and DSLR cameras were employed to capture images of the odonates for further analysis.

In this study, we recorded 10 species of odonates **(Table 1, Figs 1-10)**, including 8 species of dragonflies (Lindeniidae) and 2 species of damselflies (Coenagrionidae). *Brachythemis contaminata* and *Crocothemis servilia* were found to be abundant. The diversity indices calculated were as follows: Simpson's Index (D): 0.1321, Simpson's Index of Diversity (1-D): 0.8679, Shannon-H Index (H'): 5.7104, and Evenness Index (E): 2.48, indicating good diversity and evenness. Similar diversity studies have been conducted in nearby areas (Kumar *et al*., 2023).

Plastic pollutants and quarry leachate effluent discharge into the lake were observed. Future detailed studies on the diversity and impacts of anthropogenic activities on odonate populations are necessary.

**Table 1: List of Odonates found during the study in NPKL 4th block Lake**

| S. No. | Scientific Name | Common Name | Family | No of Sightings |
|---|---|---|---|---|
| **1** | *Ictinogomphus rapax* | Common club tail | Lindeniidae | 24 |
| **2** | *Aethriamanta brevipennis* | Scarlet marsh hawk | | 29 |
| **3** | *Brachythemis contaminata* | Ditch jewel | | 44 |
| **4** | *Crocothemis servilia* | Scarlet skimmer | | 37 |
| **5** | *Orthetrum sabina* | Slender skimmer | | 19 |
| **6** | *Trithemis aurora* | Crimson marsh glider | | 27 |
| **7** | *Rhyothemis variegata* | Common picture wing | | 9 |
| **8** | *Neurothemis tullia* | Pied paddy skimmer | | 15 |
| **9** | *Ceriagrion coromandelianum* | Coromandel marsh dart | Coenagrionidae | 4 |
| **10** | *Ischnura senegalensis* | Senegal Golden Dartlet | | 5 |

**Fig. 1: *Ictinogomphus rapax***

**Fig. 2: *Rhyothemis variegata***

**Fig. 3: *Trithemis aurora***

**Fig. 4: *Neurothemis tullia***

**Fig. 5:** ***Aethriamanta brevipennis***

**Fig. 6*:* *Brachythemis contaminata***

**Fig. 7:** ***Crocothemis servilia***

**Fig. 8:** ***Orthetrum sabina***

**Fig. 9:** ***Ceriagrion coromandelianum***

**Fig. 10:** ***Ischnura senegalensis***

**References**

Anonymous a. https://shareok.org/handle/11244/316786.

Google Earth Pro. Version - 7.3. 2017. NPKL 4th Block lake, elevation 1371.6m. Ruler-Polygon. Available at: https://earth.google.com/intl/earth/versions/#earth-pro.

Anja, H., Fernandez, G.R. and Aureli, F. 2021. Line-transect versus point-transect sampling: the effects of survey area and survey effort on method efficiency for Geoffroy's spider monkeys. *Wildlife Research*, 48(7).

Harrington, D. and Jayshankar M. 2023. Nest abundance of Asian weaver ant (*Oecophylla smaragdina*) around NPKL 7th Block Lake, Bheemanakuppe, Southern Bengaluru. *Insect Environment*, 26(2):150 – 153.

Kalita, G. J. and Ray, S. D. 2015. Studies on the diversity and habitat preference of odonates in Deepor Beel Bird Sanctuary, Kamrup, Assam. *Journal of Entomology and Zoology Studies*, 3(2): 278–285.

Kumar, P., Sharma, S. and Barman, J. 2018. Habitat Preference of Odonates (Dragonfly and Damselfly) along with its Diversity, Abundance, and Richness in Madan-Kamdev temple area (Dewangiri hill) of Kamrup (R) district of Assam, India. *International Journal of Plant, Animal and Environmental Science*, 8(3): 8-18

Kumar, V., Deva, H.G.S. and Munirathinam, J. 2023. A preliminary documentation of the insect diversity in and around Asirvanam monastery, Bengaluru. *Insect Environment*, 26(2): 175-180.

May, M.L. 2019. Odonata: Who They Are and What They Have Done for Us Lately: Classification and Ecosystem Services of Dragonflies. *Insects*, 10(3):62. DOI: 10.3390/insects10030062. PMID: 30823469; PMCID: PMC6468591.

Saha, N., Aditya, G., and Banerjee, S., and Saha, G. 2012. Predation potential of Odonates on mosquito larvae: Implications for biological control. *Biological Control*, 63 (1): 1-8. DOI: https://doi.org/10.1016/j.biocontrol.2012.05.004

Sharma, G., Sundararaj, R. and Karibasvaraja, L.R. 2007. Species diversity of Odonata in the selected provenances of sandal in Southern India. *Zoos' Print Journal*, 22(7): 2765-2767. DOI:10.11609/JoTT.ZPJ.

Subramanian, K. A. 2005. Dragonflies and Damselflies of Peninsular India field guide. Project Lifescape. A collaborative project of the Centre for Ecological Sciences, Indian Institute of Science, Bengaluru, and Indian Academy of Sciences, Bengaluru. 118 pages

Subramanian, K.A. and Babu, R. 2017. Checklist of Odonata (Insecta) of India. Version 3.0. www.zsi.gov.in.

Tsuda, S. 1991. A distributional list of worlds Odonata. Osaka. pp 362

Vashishth N., Joshi, P. C and Singh, A. 2002. Odonata community dynamics in Rajaji National Park, India. *Fraseria*, 7: 21-25.

*MS Received on 6th June, 2024*
*MS Accepted on 17th September, 2024*

**DOI:10.55278/SCRM6802**

## Regenerating the lost appendages: the insect way

**Penuballi Swathi*, Haseena Bhaskar and Nimisha A. M**
*Department of Agricultural Entomology, College of Agriculture, Vellanikkara, Kerala Agricultural University*
***Corresponding author: penuballi-2020-21-041@student.kau.in***

Regeneration is the sequence of morphogenetic events that restores the normal structure of an organ after its partial or total amputation (Das, 2015). Regenerative abilities have been observed with varying potentials across several taxa, ranging from vertebrates to invertebrates. In the phylum Arthropoda, 35 genera of the subphylum Crustacea and 38 genera of the class Insecta are capable of regenerating limbs (Maginnis, 2006). The high incidence of appendage amputation due to competition, predation, moulting difficulties, and pathogenic infections has driven the development of significant regenerative capacities in insect taxa. However, unlike other organisms, insects do not exhibit regeneration of appendages if they are lost during the adult stage.

Hemimetabolous insects possess higher limb regenerative capabilities compared to holometabolous insects. In stick insects, rapid loss or autotomy of legs occurs at the joints between the trochanter and femur, which form weak points known as preferred breakage points (PBPs). These PBPs facilitate leg detachment when the insect is attacked by a predator or experiences unsuccessful shedding of the exoskeleton during a moult (Maginnis, 2006).

**Fig. 1 Autotomy of middle leg in stick insects**

**PC:** https://www.pentaxforums.com/forums/12-post-your-photos/345984-macro-stick-insect-missing-leg.html

**Fig. 2 Leaf footed bug (Family: Coreidae) without hindleg**

**PC:** https://www.dreamstime.com/stock-image-reduviid-bug-leaf-missing-leg-image83271

At the cellular level, regeneration occurs through two distinct processes: epimorphosis and morphallaxis. In epimorphosis, cell division recreates lost structures, while in morphallaxis, lost tissues are formed by reorganizing existing tissue. This process involves wound healing, blastema formation at the amputation site, and cell repatterning of dedifferentiated tissue.

During wound healing, haemolymph accumulates at the wound site and hardens to form a scab. Subsequently, epidermal cells migrate beneath the flattened haemocytes to form a continuous epidermal layer under the scab, which then proliferates to form the blastema. The appendage segments are soon re-established (repatterning phase) through the constriction of the epidermis, recreating the lost structures. This process has been documented in cockroaches (Nakamura et al., 2008), where all the segments of the leg distal to the plane of amputation were restored sixteen days after amputation, coinciding with the nymph's moult.

Regeneration of antennae in insects has been reported only in the suborder Heteroptera (Hemiptera), most frequently in the infraorder Pentatomorpha. In the chinch bug, *Oncopeltus fasciatus* (Lygaeidae), after the amputation of two or three antennal segments, the final number of segments was one less than in a normally developed antenna. However, the remaining segments grew abnormally larger and exhibited bristle patterns characteristic of the last two antennal segments, suggesting compensation for the lost segments through excessive growth (Ikeda-Kikue and Numata, 1991). Teratological studies on the antennae in the family Aradidae (Hemiptera) have shown different levels of growth and sensilla development in regenerated antennae compared to normally grown ones (Taszakowski and Kaszyca-Taszakowska, 2020).


**Fig. 3 Normally developed antenna (c) and regenerated antenna (d) in *Aradus betulinus* (Hemiptera: Aradidae)**

Different signaling pathways, such as JNK signaling, JAK-STAT signaling, Hippo signaling, and Wnt signaling, are involved at the molecular level in forming new tissue after the original tissue is damaged (Suzuki et al., 2019). These pathways activate specific genes involved in wound healing, cell proliferation, and redifferentiation. In *Drosophila*, JAK-STAT signaling triggered by wound healing activates signal-dependent transcription factors (STATs), which in turn lead to blastema formation and cell differentiation (Alfonso-Gonzalez and Riesgo-Escovar, 2018). Additionally, the hormone ecdysteroid plays an important role in the regenerative growth of lost tissue by regulating the molting cycle. Laboratory studies conducted on the flesh fly, *Sarcophaga peregrina*, showed that low levels of ecdysteroids were necessary for wound healing and limb differentiation (Kunieda et al., 1997).

Appendage regeneration can have significant consequences on various aspects of fitness in insects. The allocation of resources to regenerate a lost appendage negatively affects somatic or reproductive growth. For instance, leg regeneration in the pink-winged stick insect, *Sipyloidea sipylus* (Lonchodidae: Phasmatodea), stunts wing growth. Additionally, regenerated appendages are often imperfect and come with performance costs, such as reduced foraging efficiency and reproductive success (Maginnis, 2006).

Recent advances in molecular tools have revived interest in regeneration studies. A thorough understanding of the regeneration mechanisms in non-model organisms like insects can pave the way for progress in human regenerative medicine in the near future.

Regeneration in insects can impact their fitness by diverting resources from growth and reproduction, often resulting in imperfect appendages. Advances in molecular tools are enhancing our understanding of these processes, potentially benefiting human regenerative medicine.

**References**

Alfonso-Gonzalez, C., Riesgo-Escovar, J. R. 2018. Fos metamorphoses: lessons from mutants in model organisms. Mech Dev, **154**: 73-81.

Das, S. 2015. Morphological, molecular, and hormonal basis of limb regeneration across pancrustacea. *Integrative and Comparative Biology*, **55**(5): 869–877.

Ikeda-Kikue, K., & Numata, H. 1991. After removal of the distal segment in *Riptortus Clavatus* (Thunberg) (Heteroptera: Alydidae). In *Int. J. Insect Morphol. & Embryol*, **20**: 2.

Kunieda, T., Kurata, S., Natori, S. 1997. Regeneration of Sarcophaga imaginal discs in vitro: implication of 20-hydroxyecdysone. *Dev Biol*, **183**: 86–9

Maginnis, T. L. 2006. Leg regeneration stunts wing growth and hinders flight performance in a stick insect (*Sipyloidea sipylus*). *Proceedings of the Royal Society B: Biological Sciences*, **273(**1595): 1811–1814.

Nakamura, T., Mito, T., Bando, T., Ohuchi, H., & Noji, S. 2008. Molecular and cellular basis of regeneration and tissue repair: Dissecting insect leg regeneration through RNA interference. In *Cellular* *and Molecular Life Sciences*, **65** (1): 64 - 72.

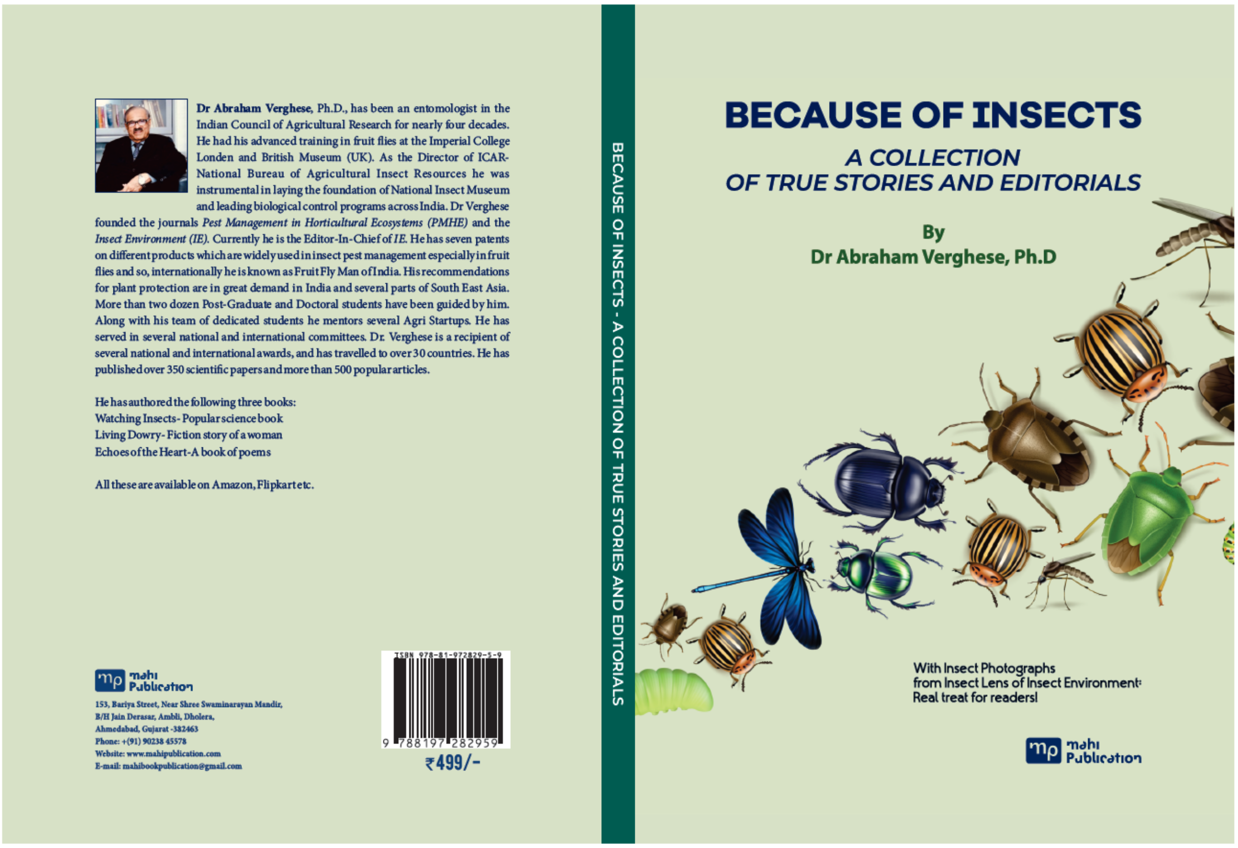
Suzuki, Y., Chou, J., Garvey, S. L., Wang, V. R., and Yanes, K. O. 2019. Evolution and regulation of limb regeneration in arthropods. *Evo-Devo: Non-model Species in Cell and Developmental Biology*, 419-454.

Taszakowski, A., and Kaszyca-Taszakowska, N. 2020. Teratological cases of the antennae in the family Aradidae (Hemiptera: Heteroptera). *Scientific Reports*, **10**(1): 1027.

*MS Received on 02nd June, 2024*
*MS Accepted on 11th September, 2024*

# BECAUSE OF INSECTS

## Book Reviews




**Book available online on Amazon**

The book "Because of Insects" is a compilation of real observations made on a variety of insects and their environments. It is highly useful for teachers, researchers, and students. Each editorial of the IE volume highlights both old and new problems related to crop husbandry, management strategies, and the way forward, all of which are well documented.

The author of the book is a renowned entomologist and ornithologist of India, often referred to as the "Fruit Fly Man" for his groundbreaking technologies in managing fruit flies in fruits and vegetables. This technology is very popular and widely accepted in the country and Southeast Asia. His devotion, dedication, and commitment to research, teaching, and assigned work are highly appreciated in the scientific community. Even after his retirement from active service, he has been engaged in disseminating knowledge, techniques, and management strategies to end users, enhancing the quality production and productivity of horticultural crops.

The timely publication of IE is commendable, thanks to the contributors and the editorial board, with special reference to the editor-in-chief, who left no stone unturned despite his busy research schedule. The experiences of IE in India and elsewhere generate interest among researchers, academics, and students, providing more exposure to the insect world. The beautiful, real photographs of different insects are very attractive and draw the attention of upcoming entomologists.

The book addresses pressing issues such as climate change, insect migration, and population dynamics, which demand accelerated research and solutions. It also provides insights and exposure to many countries around the world, along with memoirs of renowned entomologists and scientists with whom the author has interacted. This is commendable.

I am confident that the book will spark more interest in readers' minds due to its excellent language and writing style. From the core of my heart, I compliment Dr. Verghese for compiling true stories and the long journey of IE into this book.

**Review by K. K. Kumar, Ph D**
**Ex. Director, ICAR-I LRI and NRC Litchi,**
**Ranchi-834002, Jharkhand**

"Because of Insects" is a wonderful collection of editorials and real-life stories penned by Dr Abraham Verghese, former Director, ICAR-NBAIR, Bangalore, former Project Coordinator, AICRP on Biological control and one of the leading entomologists of our country. I would term this compilation as a well-crafted narration by an author who has truly mastered the craft of storytelling.

After the initial nine chapters focusing on his journey with birds and insects, editorials of Insect Environment from 1998 till date follow. These editorials cover various important entomology related topics: for e.g. the latest pest outbreaks, entry of invasives, feasible methods to manage them, the beneficial insects which need to be conserved, insects of biodiversity significance, and all these are accompanied by clear and perfect images. There are sections which pay homage to some of the great entomologists, who have contributed immensely to entomological science. Hence, needless to mention that all the chapters are of immense value to young and senior researchers, especially entomology students.

Dr Verghese's writing style is unique, which combines clarity and emotion, with a clear concern for scientific validity. A special mention about the wonderfully well written first chapter "Genesis and Rootage", wherein the author expresses his respect for and gratitude to his father (a non-entomologist) who was responsible for his entry into the world of insects and to great entomologists who maneuverer the wheels to ensure that his journey was totally rewarding, thus giving a beautiful emotional touch to the chapter.

I have known the author for around 40 years and always considered him a wonderful raconteur, with the ability to turn even mundane experiences into hilariously entertaining stories. Thus, as might be expected, each one of the articles and editorials in this book is bedecked with the most appropriate and appealing title, fascinating content and fitting denouement.

"Because of insects" is a perfect balance between descriptive detail and concise expression. The author through his conversational tone, has managed to invite the readers into the narrative and keep them captivated without overwhelming them. For students and researchers in general and entomologists in particular, this book is highly relatable and a 'must read'.

**Dr (Ms) Chandish R Ballal**
**Former Director, ICAR-NBAIR, Bangalore**
**Former Project Coordinator, AICRP on Biological Control**

The book "Because of Insects: A Collection of True Stories and Editorials" by Dr. Abraham Verghese is an inspiring compilation of true experiences and influential insights from the author's life journey. Dr. Verghese, a renowned entomologist with extensive knowledge of insect management, particularly fruit flies, shares his editorials from the journal 'Insect Environment' since its inception in 1998.

This book is a treasure trove of stories that reflect Dr. Verghese's passion for insects and his moral support for extending knowledge about these fascinating creatures. The topics covered include biodiversity preservation, invasive species and quarantine awareness, insights into desert, aquatic, and marine ecosystems, integrated pest management approaches, the effects of climate change on insects, and mitigation strategies, as well as export-oriented crop management.

The compilation highlights key concepts such as the establishment of insect butterfly parks and museums, initiatives and success stories in fruit fly management, insect conservation, and thrust areas in entomology. Dr. Verghese emphasizes the need for research writings that are applied in nature and can be immediately adopted by stakeholders. Over the years, his editorials provide readers with glimpses of changes in insect pests and various interventions for their management worldwide.

In addition to discussing the pestiferous nature of insects, the book also explores their importance in biodiversity and the development of butterfly parks. Dr. Verghese's writing style is simple and easy to understand, making the book accessible to both entomologists and non-entomologists interested in learning about insects.

The author also shares his cherished memories with renowned personalities who have played key roles in his journey, signifying his gratitude towards them. Several pictures with explanations effectively introduce these individuals to the readers. Undoubtedly, reading this book will be a treat for anyone interested in insects.

**Dr. V. Sridhar,**
**Principal Scientist (Entomology)**
**Division of Crop Protection,**
**ICAR-Indian Institute of Horticultural Research,**
**Bengaluru – 560 089**

'***Because of Insects***' is a fascinating, mind boggling book which includes a compilation of the author's scientific journey. Each word is well-thought-out and is composed into sentences, which showcases his epiphany in literature.

His thoughts have been well structured and each chapter conveys a different understanding and imparts great knowledge. The book also raises awareness about diversity in Entomology. The author tries to have an ecological impact by raising an issue about endangered species.

The photographs used in the book are ethereal and up to their description. While reading, I could imagine the beautiful scenery and complex emotions the author felt. The author has gracefully elated tactile and visual imagery.

The thirst for knowledge led him to visit many countries for research work. As I was turning the page over, I wondered if there had been a country he hadn't travelled to and a culture he wasn't swooned by.

Despite being an entomologist he followed his passion of watching birds and has made phenomenal observations. In pursuit of reading a book for its vocabulary, I became fascinated by its content and was truly inspired by the book '***Because of Insects'***.

***Miss. Hima Pournami M. C***
**10$^{th}$ A Standard**
**Daffodils English School**
**Sanjaynagar, Bengaluru-94**

# IE BLOG

**Revolution in Stingless Bee Culture- Meliponiculture**

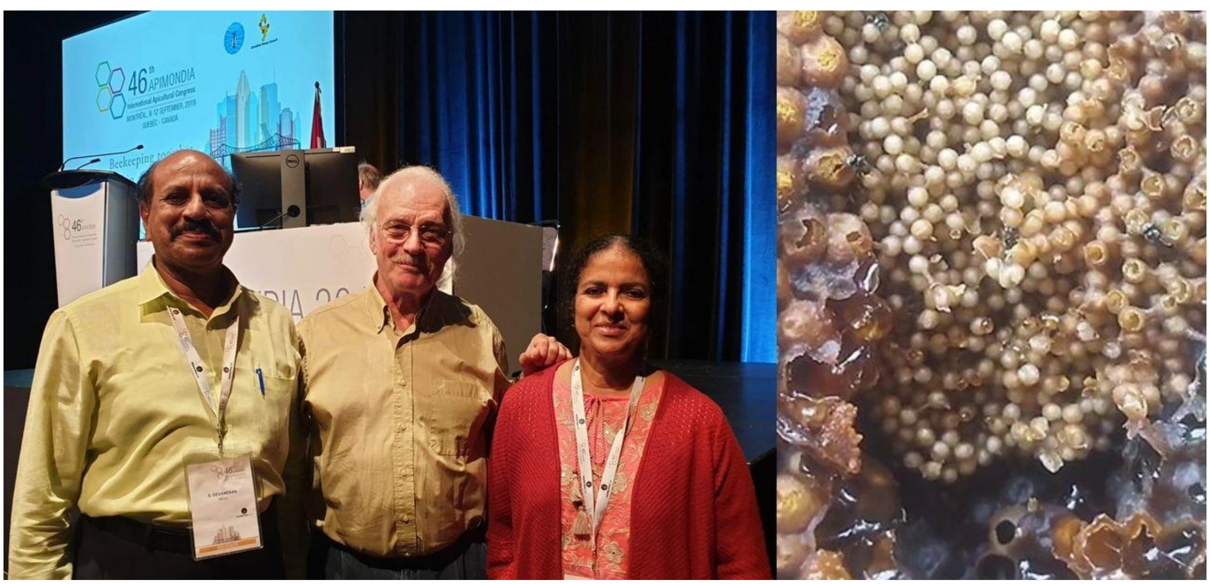
Small Bee Giant Leap

The Federation of Indigenous Apiculturists (FIA) whose secretary is Dr. Stephen Devanesan in association with ICAR-AICRP on Honey Bees & Pollinators, NABARD etc., organized a National Conclave on stingless honey bees at Thiruvananthapuram, Kerala, India on 18-19 June 2024. More than 300 participants gathered and important deliberations were made as follows.

Meliponiculture should be promoted in all states with support of FIA. Stingless bees for pollination in poly houses should be encouraged. Promoting Meliponiculture in urban areas. The stingless bee's medicinal honey is of high value and should be more commercialized. Prof. Devanesan is an active apiculturist-scientist of the country. He emphasized the livelihood scaling up of farmers even through Meliponiculture.

Dr. Stephen Devanesan, General Secretary, FIA is the Former Dean, Faculty of Agriculture, & Associate Director of Research, Kerala Agricultural University.

A detailed report on this will appear in Insect Environment 27 (3) September 2024




Left Pic: Dr.Stephen Devanesan with Dr. David W Roubik, Smithsonian Tropical Research Institute, USA (Middle) and Dr. K S Premila, KAU (Right). Right Pic: Stingless bee hive

# INSECT LENS

***Mating pair of Aak fruit fly, Dacus persicus (Tephritidae: Diptera) on Calotropis fruit***

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

***Green Chaffer, Anomala albopilosa (Scarabaeidae: Coleoptera)***

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

***Syrphid fly, Eristalinus sp. (Syrphidae: Diptera) relishing the nectar offered by the invasive weed Parthenium***

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

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

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

***Common carder bee, Bombus pascuorum (Apidae: Hymenoptera)***

***Author:*** *Dr. Sevgan Subramanian*
***Location:*** *Geneva, Switzerland (June 2024)*
***Email:*** *ssubramania@icipe.org*

***Anthrenus angustefasciatus* (Dermestidae: Coleoptera)**

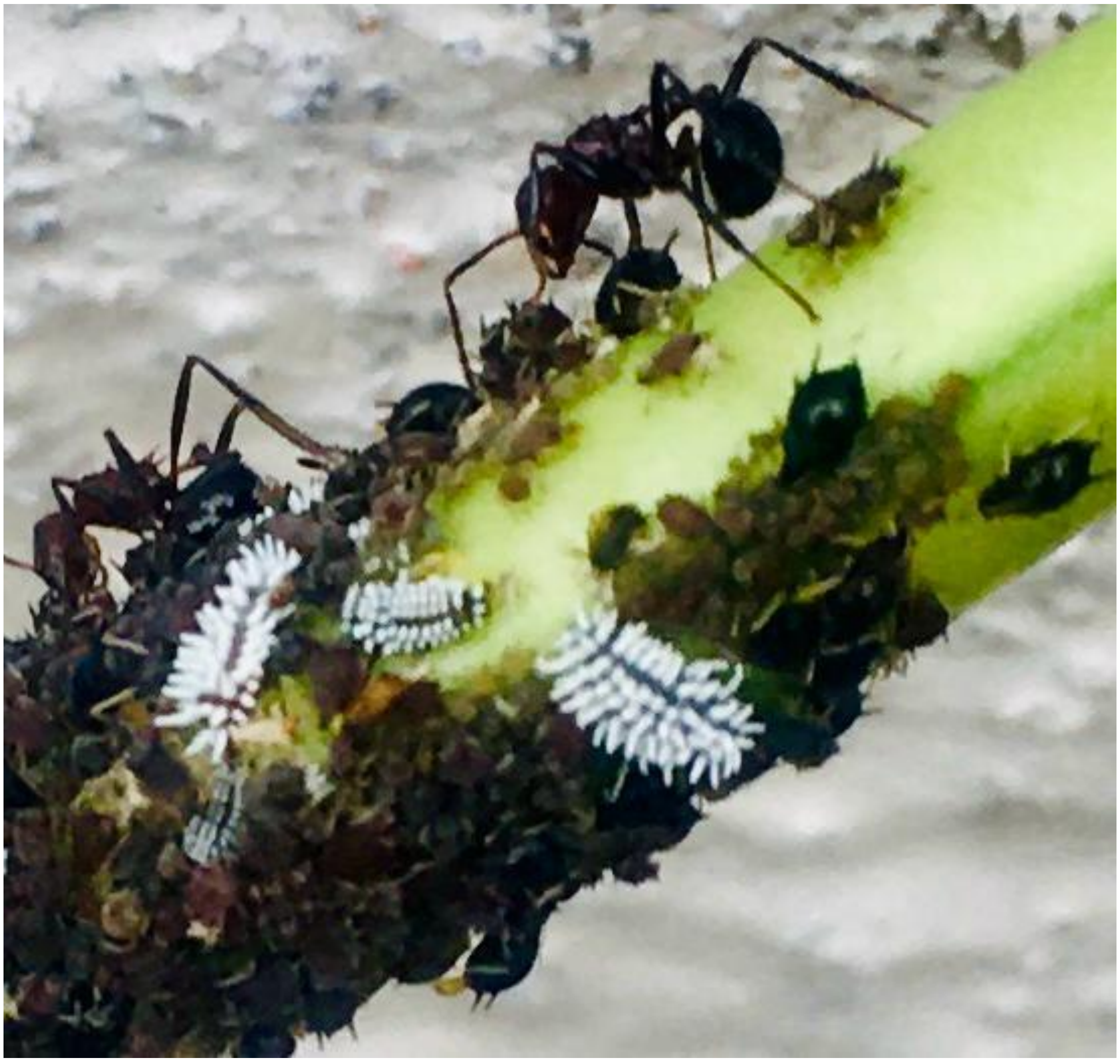
***Author:*** *Dr. Sevgan Subramanian*
***Location:*** *Geneva, Switzerland (June 2024)*
***Email:*** *ssubramania@icipe.org*

***Dacus persicus (Tephritidae: Diptera) egg laying on Calotropis***

***Author:*** *Dr. Keshav Mehra Bikaner*
***Location:*** *Bikaner, Rajasthan*
***Email:*** *Keshav.mehra35@gmail.com*

***Owl fly, (Ascalaphidae: Neuroptera*) *and Wax scale, Ceroplastes sp. (Coccidae: Hemiptera)***

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



***An ant, Myrmicaria brunnea attending to cowpea aphid. The Predator Scymnus sp. is also seen***

***Author:*** *Dr. Abraham Verghese*
***Location:*** *Bangalore, Karnataka, India.*
***Email:*** *abraham.avergis@gmail.com*

***Grey Swallow tail moth, Micronia aculeata (Uraniidae: Lepidoptera)***

***Author:*** *Dr. Nagaraj, D.N., Project Head (Entomologist) Ento. Proteins Pvt. Ltd., Mangalore*
***Location:*** *Vardamoola village Sagar taluk, Shivamogga Dist.*
***Email:*** *nasoteya@yahoo.co.in*

***Ant (unidentified)***

***Name:*** *Mr. Rushikesh Rajendra Sankpal, Assistant Professor (Biotechnology)*
***Location:*** *Warananagar, Maharashtra*
***Email:*** *rushisankpal@gmail.com*

***Common evening brown, Melanitis leda (Nymphalidae: Lepidoptera)***

***Author:*** *Ruchita Naidu D, Trainee Lecturer, RV Learning Hub, Bangalore, India.*
***Location:*** *R.T. Nagar, Bangalore, India*
***Email:*** *naiduruchita2000@gmail.com*

***Bee (unidentified)***

***Name:*** *Mr. Rushikesh Rajendra Sankpal, Assistant Professor (Biotechnology)*
***Location:*** *Warananagar, Maharashtra*
***Email:*** *rushisankpal@gmail.com*

# IE Extension




**Extension in agriculture plays a crucial role in disseminating knowledge, empowering farmers, and advancing agricultural development. Integrating technology with agri inputs can significantly enhance the effectiveness of these roles "Dr. Abraham Verghese delivered a lecture on 'New Horizons in Plant Health Extension,' with a special focus on plant protection. The event was organized by Dr. Leslie Coleman Agri Knowledge Club at the Karnataka State Department of Agriculture (KSDA), under the leadership of Director Dr. G.T Puthra."**



**Dr Abraham Verghese presenting at a farmers training program on Plant Health Management in mango organized by VIT School of Agricultural Innovation and Advanced Learning at Vellore, Tamil Nadu**

**Rashvee Non-insecticidal Climate Resilient Liquid Fruit fly Lure demonstration at farmers field in Kadahalli village, Kolar, Karnataka**

**Team interacting with farmers at Shreenidhi plant health clinic**

**IE team visiting Dr. Kadire Gowda, Joint Director and Dr. Ranjitha, Deputy Director, at Lalbhagh Department of Horticulture, Government of Karnataka**

**IE team with Agricultural officers, Government of Karnataka**

**Latest fruit fly management technology Rashvee Non-insecticidal Climate Resilient Liquid Fruit fly Lure at Horticulture Exhibition, Hosahudya Village, Devanhalli Taluk**

**With Dr. G.S. Prakash and Dr. Harish at Horticulture Exhibition, Hosahudya Village, Devanhalli Taluk**

**BECAUSE OF INSECTS - A COLLECTION OF TRUE STORIES AND EDITORIALS BOOK released by the Director ICAR-NBAIR Dr. S.N Sushil at ICAR-IIHR**

**Rashvee-IPRS team with tomato farmer at Chikkaballapur, Karnataka**

**Insect Environment team with Dr. Chandish Balal, ICAR-NBAIR and Scientists of ICAR-IIHR at ICAR IIHR, Bengaluru**


**Insect Environment team Dr. S N. Sushil, Director, ICAR-NBAIR and Scientists of ICAR-IIHR at Hesserghatta, Bengaluru**



**With farmers at Shreenidhi Plant Health Clinic,  Vijayapura, Devanahalli, Karnataka**

**Rashvee team with pomegranate farmer at Gudibande, Chikkaballapur, Karnataka**

**MoU Meeting between Rashvee IPRS and BeeGlobal Team**


**Rashvee IPRS team with pomegranate farmer at Attibele, Hoskote, Karnataka**

**Field examination of Rashvee Liquid Lure Trap in grapes orchard at Hosahalli, Chikkaballapur**

**Our team at field, Vijayapura, Devanahalli, Karnataka**

**Inspecting the Rashvee Liquid Lure Trap in a Pomegranate Orchard, Vijayapura, Devanahalli, Karnataka**


**Dr Rashmi M A with Dr. Prashanth from Ag Organics Bengaluru at Shreenidhi Agrochemicals, Vijayapura**

**Chrysanthemum Cultivation: Farmers and researchers at Vijayapura, Devanahalli, Karnataka**

**Our team with farmers at field, Vijayapura, Devanahalli, Karnataka**



**Insect Environment and AVIAN Trust are collaborating with the Bee Global team to raise awareness among students about honey bee conservation and its significance- Visit to Bee Global, Bettahalasur, Karnataka**

**Dr. Abraham Verghese with Mango farmers at Vellore, Tamil Nadu**

**Field Visit to Manjunath's (Farmer) Blooming Rose Field -Variety Arka Savi**

**Dr. Abraham Verghese with G. Parmeshwara Home Minister Government of Karnataka**


**Mr. Raghavendra V.G receiving trophy of excellence award for outstanding team work and achievement of Shreenidhi Agro Chemicals Plant Health Clinic from ICL growing solutions India**


**Dr. Abraham Verghese delivering an invited lecture at International Conference on Plant Protection in Horticulture (ICPPH-2024) - Advances and Challenges**


**Dr M A Rashmi presenting paper on at International Conference on Plant Protection in Horticulture (ICPPH-2024) - Advances and Challenges**


**Dr. M. A. Rashmi receiving Fellow AAPMHE of Association for Advancement of Pest Management in Horticultural Ecosystems award at ICPPH-2024**

**IE team with Dr P. Parvatha Reddy Former Director ICAR IIHR, Dr. R. Selvarajan, Director of ICAR-National Research Centre for Banana (NRCB) and Dr. V. Ambethkar, TNAU, Trichirapalli**

**With students at poster presentation in International Conference on Plant Protection in Horticulture (ICPPH-2024) - Advances and Challenges**


**IE team with Dr. Tusar Kanti Behera, Director ICAR-IIHR**