

ISSN 0377- 9335

ENTOMON

Volume 50

December 2025

Number 4

49 YEARS OF EXCELLENCE



ASSOCIATION FOR ADVANCEMENT OF ENTOMOLOGY

ENTOMON

ENTOMON is a quarterly journal published by the Association for Advancement of Entomology devoted to the publication of original research in all facets of insects and related branches of Entomology.

EDITORIAL BOARD (2022 – 2025)

Chief Editor:

Palaniswami, M.S., ARS-ICAR (Retd), Thiruvananthapuram, India

Associate Editor:

Prathapan, K.D., Kerala Agricultural University, Thiruvananthapuram, India

Members:

Colvin John, University of Greenwich, London, United Kingdom

David, B.V., International Institute of Biotech & Toxicology, Padappai, India

David, K.J., ICAR - National Bureau of Agricultural Insect Resources, Bengaluru, India

Debanji Dey, Division of Entomology, ICAR - Indian Agricultural Research Institute, New Delhi

Jorge Ari Noriega, National Museum of Natural Science (CSIC), Madrid, Spain

Mohandas N., KAU, Thiruvananthapuram, India

Phan Quoc Toan, Center for Entomology Research, Duy Tan University, Da Nang, Vietnam

Priyadarsanan, D.R., ATREE, Bengaluru, India

Raman, A., Charles Sturt University, NSW, Australia

Susanta Kumar Chakraborty, Vidyasagar University, Midnapore, West Bengal, India

Winston, M.O. Thomson, NARI, Guyana

Address all manuscripts to the Chief Editor, ENTOMON, E mail: editor.entomon@kau.in. Submission of a manuscript to ENTOMON implies that the content has neither been published earlier nor will be sent to any other publisher without intimation. At least one of the authors need to be a member of AAE.

A fee will be charged for publication.

AAE MEMBERSHIP/ SUBSCRIPTION RATES:

Admission Fee: Rs 100/- (\$10/- for foreigners)

Life Membership Fee for individuals: Rs 6000/- (or US \$ 600/-for foreigners)

Annual Membership Fee for individuals: Rs 1000/- (US \$150/- for foreigners)

Annual subscription for institution: Rs 6000/- (in India); US \$ 600/- (outside India)

@2025 by the Association for Advancement of Entomology. All rights reserved

All remittance to the Journal or Association for Advancement of Entomology should be sent to the Secretary, Association for Advancement of Entomology, Vellayani, Thiruvananthapuram 695522. Kerala. The amount can be transferred directly to the account of Association for Advancement of Entomology in the State Bank of India, Vellayani (Branch) [Account No. 67267412481; IFS Code: SBIN0070019; Swift Code for outside India- SBININBBT44] or by cheques / drafts. Request for copies of ENTOMON should be addressed to the Secretary. Email: aae@kau.in; Web: www.entomon.in

ENTOMON is covered in the following abstracting/ indexing journals:

CABI, cabdirect.org, CAB abstracts, Review of Applied Entomology, Science citation index, Zoobank, New Entomological Taxa, Referativny Zhurnal, Zoological Records.

The NAAS rating of the journal is 5.24. The University Grants Commission has recognized ENTOMON in the official list of scientific journals (UGC- Care list Group I). ENTOMON is indexed by the SCOPUS. The journal is partnering with EBSCO for dissemination of papers published. ENTOMON is a member of the Committee on Publication Ethics (COPE).

ENTOMON

Vol. 50

December 2025

No. 4

Contents

Articles

	Page
https://doi.org/10.33307/entomon.v50i4.1573	381
Dissipation of emamectin benzoate in okra and its residual impact on okra metabolome <i>G.T. Pradeepkumar, K.P. Subhash Chandran and V. Vijayasree</i>	
https://doi.org/10.33307/entomon.v50i4.1574	397
Redescription of <i>Rawania petasata</i> (Melichar) (Hemiptera, Cicadellidae, Typhlocybinae) with a key to genera of Empoascini related to genus <i>Rawania</i> Ghauri of Oriental region <i>N. Shreya, C.M. Kalleshwaraswamy, M. Shankaramurthy, G.K. Girijesh, Sharanabasappa S. Deshmukh, K. Rajashekharappa and B.V. Champa</i>	
https://doi.org/10.33307/entomon.v50i4.1575	405
Characterization and use of green nanoparticles from the leaves of <i>Tiliacora acuminata</i> against larvae of vector <i>Culex quinquefasciatus</i> Say <i>Someshwar Singha</i>	
https://doi.org/10.33307/entomon.v50i4.1576	411
Notes on plants visited by genus <i>Paragus</i> Latreille (Diptera, Syrphidae) with an updated key to Indian species <i>Panchanan Parui, Jayita Sengupta, Mousumi Chowdhury, Bristi Roy, Sudip Mondal, Suman Kumar Saha, Moubanti Das, Atanu Naskar and Dhriti Banerjee</i>	
https://doi.org/10.33307/entomon.v50i4.1577	417
Description of a new species of <i>Hypospila</i> Guenee, 1852 (Lepidoptera, Erebidae) from Kerala, India <i>P.K. Adarsh, Joslin Treesa Jacob and Abhilash Peter</i>	
https://doi.org/10.33307/entomon.v50i4.1579	423
Biology and morphometrical analysis of rice weevil, <i>Sitophilus oryzae</i> (L.) (Coleoptera, Curculionidae) on different stored cereals <i>Gadi Prasad, Lopamudra Biswal, Saswati Parija, Arundhati Sasmal, Akhilesh Kumar Gupta and Deepa Khulbe</i>	

https://doi.org/10.33307/entomon.v50i4.1581	431
Coleopteran diversity, its distribution and the influence of environmental factors on them in the Barak river basin of Assam, India	
<i>Ankur Nandi and Sarbani Giri</i>	
https://doi.org/10.33307/entomon.v50i4.1582	445
Comprehensive assessment of pivotal silkworm races for economic traits in Jammu and Kashmir, India	
<i>R. Kiran, P. Kumaresan, Shivkumar, M.N. Ahmad , K.N. Bharath and Sardar Singh</i>	
https://doi.org/10.33307/entomon.v50i4.1583	453
Observations on the butterflies feeding on non-nectar sources in the Kolhapur District, Maharashtra, India	
<i>A.N. Patil and S.M. Gaikwad</i>	
Short Communications	
https://doi.org/10.33307/entomon.v50i4.1584	461
First record of aquatic stick insect, <i>Ranatra digitata</i> Hafiz & Pradhan, 1947 (Hemiptera, Heteroptera, Nepidae) from Kerala, India	
<i>K. Jyothylakshmi, S. Nandakumar and E. Eyarin Jehamalar</i>	
https://doi.org/10.33307/entomon.v50i4.1585	465
First report of the brown widow spider, <i>Latrodectus geometricus</i> Koch, 1841 (Araneae, Theridiidae) from southern India	
<i>R. Kishore and Vinod Sadhasivan</i>	
https://doi.org/10.33307/entomon.v50i4.1586	469
Assessment of honeybee biodiversity in the agro-climatic zones of Uttarkashi of Garhwal Himalaya, Uttarakhand, India	
<i>Abhishek Thapliyal, Vishesh Nautiyal, Deepak Rana, Ashish Thapliyal and Madhu Thapliyal</i>	
https://doi.org/10.33307/entomon.v50i4.1587	473
Notes on <i>Hyllus semicupreus</i> (Simon, 1885) (Salticidae, Plexippina) from India	
<i>Jayaraman Dharmaraj</i>	
https://doi.org/10.33307/entomon.v50i4.1588	477
<i>Tuberolachnus salignus</i> (Gmelin, 1790) (Hemiptera, Aphididae) on Apple (<i>Malus domestica</i> Borkh) in Kashmir, India	
<i>Muzafar Riyaz, Sabreena Ashraf and Rakesh Kumar Gupta</i>	
Contents of volume 50, issues 1 - 4	481
Acknowledgements to Peer Reviewers	491
Author index - Volume 50, issues 1 - 4	497
https://doi.org/10.33307/entomon.v49i5.1501	501
ENTOMON 49(5): 1—218	
MONOGRAPH Series 1, 2025	
The butterflies (Lepidoptera, Rhopalocera) of Kerala: Status and distribution	
<i>Sadasivan et al.</i>	

Dissipation of emamectin benzoate in okra and its residual impact on okra metabolome

G.T. Pradeepkumar^{1*}, K.P. Subhash Chandran² and V. Vijayasree^{3*}

¹Research and development center, Bharathiar University, Coimbatore, India.

²Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi, India.

³College of Agriculture, Kerala Agricultural University, Vellayani, India.

Email: pradeepgt@iisertvm.ac.in; kpsubhash@rediffmail.com; vijayasree.v@kau.in

ABSTRACT: Pesticide absorption is a complex process in which pesticides undergo transformation and affect plant metabolic processes and hence investigated the metabolic fate of emamectin benzoate, a macrocyclic lactone insecticide. Residues of emamectin benzoate followed first order kinetics in field with pre-harvest intervals of 1.96 and 2.54 days respectively, at single and double dose of applications. Both in leaves and fruits of okra, the emamectin benzoate metabolites, emamectin B1a1 and emamectin B1b1 accumulated up to third day and the metabolite 4''-deoxy-4''-epi-N-methylaminoavermectin-b1-benzoate was detected only in fruits and was absent in okra leaves. A comprehensive evaluation of metabolic variations in okra induced by emamectin benzoate compared to the unsprayed plant samples was conducted by UHPLC-ESI-Q-Orbitrap high-resolution mass spectrometer (HRMS) and data analysed by compound discoverer 3.3. The metabolomic results suggested that emamectin benzoate could affect the plants defence mechanism, and a total of 818 metabolites including organic acids, amino acids, phenolics, flavonoids and fatty acids, were clearly altered. The content of defence-related L-proline and other proline related compounds were significantly increased by emamectin benzoate. Many phenolics and flavonoids, such as hyperoside and quercetin, were significantly accumulated, which could benefit the plant to alleviate the stress conditions due to the application of insecticide. © 2025 Association for Advancement of Entomology

KEY WORDS: Macrocyclic lactone insecticide, metabolites, plant defence mechanism, phenolics, flavonoids

INTRODUCTION

Biotic stress especially damage caused by insect pests displays a crucial role in crop loss worldwide. Chemical pesticides are important in the ever-evolving scenario of modern agriculture, to control pest and ensure the productivity of the agricultural crops. Frequent and excess application of these pesticides might result in harmful residue accumulations in the commodities at harvest and is

having a detrimental impact on human health, environment and related ecosystem services. This also causes deviations in the normal metabolic pathways and results in the increase in concentration of some metabolites while the others may decrease. Due to the application of different neonicotinoids an increase in the content of soluble protein in okra was observed (Preetha and Stanley, 2012). Not only the pesticide concentration but also other abiotic factors are involved in pesticide uptake

* Author for correspondence

and its metabolism in the plant system (Steffens and Wieneke, 1975; Farha *et al.*, 2016).

Emamectin benzoate (EB) with new mechanism of action is an insecticide with high selectivity having strong activity against Lepidoptera (Fanigliulo and Sacchetti, 2008). As it is one of the most promising avermectin insecticide finds its place in the arsenal against agricultural pests, it becomes imperative to scrutinize its journey within the plant, especially in crops destined for human consumption. Among these crops, okra (*A. esculentus*) holds a unique position due to its cultural significance, nutritional value, and widespread consumption especially the red/purple variety (Tyagita *et al.*, 2021). EB is a synthetic derivative of abamectin, created by the fermentation of the soil actinomycete *Streptomyces avermitilis*, which consists of about 90 per cent avermectin B1a and 10 per cent avermectin B1b (Dong and Zhang, 2022). Jyot *et al.* (2014) reported that EB residues dissipated below the limit of quantification (LOQ) of 0.05 mg kg⁻¹ after 5 days at 68.1 and 136.2 g a.i. ha⁻¹ in okra. The quick degradation, absorption and translocation of EB may lessen the amount of insecticide deposited on the plant surface hence reducing the contact of natural enemies contacting the insecticides and suitably higher insecticide inside the leaf tissues effectively controlling the pest (Sun *et al.*, 2022). The residues of EB present on the plant parts are absorbed and the plants reduce the toxicity of these xenobiotic by metabolic activity. Yoshii *et al.* (2001) developed an HPLC method to analyse EB and its metabolites such as 8,9-Z-isomer, N-demethylated, N-formylated, and N-methyl formylated emamectin in different vegetables. The chemical characteristics of xenobiotic substances such as pesticides, environmental factors, metabolic variables, or the regulatory expression of different biochemical processes, all have an impact on the diversity of metabolic pathways in plants (Zhang *et al.*, 2021; Barchanska *et al.*, 2023). Environmental and physiological factors also influence plant detoxification systems (Huynh *et al.*, 2021). The level of secondary metabolites like flavonoids, hydroxycinnamic acids, catechins, anthocyanins, etc. may influence the crop plant physiology and metabolism. Zhang and Yang (2021)

found that salicylic acid, jasmonic acid, and brassinosteroids were involved in the metabolism and decontamination of pesticides. Understanding pesticide metabolism in plants is crucial step for the modification, safe and effective use of these substances, and bioremediation of polluted soil and water (Hoagland *et al.*, 2001; Van Eerd *et al.*, 2003). The metabolites variation due to the effect of pesticides on plant is mainly depend on the plant physiological properties, variety, field and soil conditions (Barchanska *et al.*, 2023).

Lei *et al.* (2020) studied the EB induced metabolic alterations in leaves of maize seedlings and found positive correlation of peroxidase, total soluble sugar, total soluble protein and proline with increase in concentration of EB. This proved the presence of oxidative metabolism to reduce the effect of exposure to EB in maize. Zhang *et al.* (2022) found that fenvalerate exposure decreased the flavonoid content by 25 per cent in lettuce leaves. The LC-HRMS study showed imidacloprid exposure increased metabolism of aminoacids (arginine, cysteine, homoserine and 4-hydroxyisoleucine) while decreased metabolism of carbohydrates (Zhang *et al.*, 2022). Huynh *et al.* (2021) studied metabolism of cyantraniliprole in tomato, where 21 metabolites were tentatively identified which varied as a function of tissue types and their developmental stages. The major transformation pathways were characterized by ring closure, followed by N-demethylation, and glycosylation.

The studies on changes in distribution patterns of the EB remains and metabolites in different crops is meagre. The knowledge of absorption, translocation and metabolism of EB in okra under natural conditions, and how the degradation products influence the formation of secondary metabolites involved in various pathways, is decisive in reducing the pesticide levels and hence, the investigation was undertaken.

MATERIALS AND METHODS

Chemicals and reagents: EB (purity 99.4%) is ISO 17034 certified reference material from M/S Sigma-Aldrich, while Proclaim 5 SG formulation was acquired from Syngenta India Ltd. LC-MS

grade methanol, acetonitrile, and anhydrous MgSO_4 , ammonium acetate (AA) were procured from Merck in Darmstadt, Germany. Reagent grade formic acid (FA) was purchased from JT Baker, New Jersey, United States. Primary Secondary Amine (PSA) was procured from Agilent Technologies, California, USA. Type 1 water was produced in the lab using Milli-Q, Direct 8 from Merk Millipore. PVDF filter (13 mm 0.22 micron) was purchased from Rankem, Haryana, India.

Field experiment: The red hybrid variety of okra (*Abelmoschus esculentus*), Aruna developed by Kerala Agricultural University was used. The field was prepared in laterite soil, in randomised block design with 25 to 30 plants in each plot. Plants were grown as recommended by Kerala Agricultural University in accordance with package of practice (Estelitta *et al.*, 2016). The field experiment was conducted during November to December 2023. The average temperature is 26 with min 24 and maximum 30°C. Average rain fall was 80mm with humidity 95 percentage at 8.46/77.07 latitude/longitude. Insecticide, EB was sprayed at the rate of 11 and 22g a.i.ha⁻¹ for three times as per the recommendation. Three weeks after germination first spray was given, second spray at fruit setting time and then third spray was given ten days after second spray. Third spray was administered after confirming the presence of sufficient fruits for harvest on days 0, 1, 3, and 5 after spraying. All harvested fruits were tender, edible and 5–6 days of maturity. The control plot where water instead of EB was sprayed. Samples were collected one hour after third spray, 1, 3, 5, 10, 15, 20, 25 and 30 days after third application. Fruits (approx. 500g) and leaf samples (fifth leaf from the apex, 10 leaves from different plants) were collected in triplicate per sample. The whole sample was ground well to get a homogenous uniform paste and 50g was stored in a deep freezer below -20°C until extraction.

Validating the method for the analysis of EB:

To evaluate the effectiveness of extraction and clean-up as well as to standardize the process for residue quantification of EB, method validation was carried out. To prepare the reference solutions needed for a calibration curve, a stock solution of

EB (1000 $\mu\text{g mL}^{-1}$) was made in HPLC grade methanol (Vijayasree *et al.*, 2014) and serially diluted (0.50, 0.25, 0.10, 0.075, 0.05, 0.025 and 0.01 $\mu\text{g mL}^{-1}$). EB was spiked into okra to test the method's repeatability and accuracy at concentrations of 0.01, 0.02, 0.05 and 0.1mg kg⁻¹. Method efficiency was verified as per SANTE 11312/2021 guideline.

Sample preparation and analysis for the assessment of pesticide residue: QuEChERS

(Pradeepkumar *et al.*, 2023; Sharma *et al.*, 2024) method of extraction was followed to extract EB (metabolites B1a1 and B1b1) in okra samples. Ten gram of the ground sample was extracted using 20ml of HPLC grade acetonitrile, cleaned up by dispersive solid phase extraction (DSPE) using PSA and MgSO_4 . The residue was then reconstituted in 2 mL of methanol and filtered through a 0.2-micron filter for UPLC-MS/MS analysis. The details of the method described elsewhere (Vijayasree *et al.*, 2014, 2015; Pradeepkumar *et al.*, 2023). Waters Acquity UPLC system equipped with a reverse phase Atlantis C-18 (2.1 mm $\times$ 100 mm, 5-micron particle size) column used for chromatographic separation. Mobile phase A is 10 per cent methanol in water/ 0.1 per cent formic acid/5m M ammonium acetate and B is 10 per cent water in methanol + 0.1 per cent formic acid + 5m M ammonium acetate. The gradient elution was given with total run time of 8 minutes. The flow rate was 0.8mL min⁻¹ and injection volume was 10 μL . The column temperature was kept at 40°C. The effluent from the LC system was introduced into AB Sciex API 3200 MS/MS system equipped with an electrospray ionization interface (ESI), operating in the positive ion mode. The source parameters were temperature 600°C; ion source gas (GS1) 50 psi, ion source gas (GS2) 60 psi, ion spray voltage 5,500 V, curtain gas 13 psi. Qualitative and quantitative ion pairs for B1a1 is 886.6:158.2, 886.6:126.2 and B1b1 is 872.5:158.2, 872.5:126.2. The retention time is 4.4 min and 4.5 min for B1a1 and B1b1, respectively. Using Microsoft Excel 2016, the quantitative findings were tabulated and the dissipation rate, half-life, and waiting period were analysed using linear regression analysis in accordance with the protocol described by Hoskins (1961).

Sample preparation for metabolite analysis and instrument settings: Sampling and sample preparation are as same as in residue analysis. After thawing the frozen sample, 5g of fruit and 4g of leaf sample were weighed into a 50mL centrifuge tube. This was extracted with 15mL methanol by vortex (Spinix vortex, Tarsons) shaking for 3 minutes and sonicated (Sonorex RK31, Bandlin) for 30 minutes. Centrifuged the sample at 7000 rpm for 5 minutes. Filtered through 0.22-micron filter and collected in 1.5mL glass LC vials with pre slit silicon septa for metabolite analysis.

For the investigation of metabolism, a high resolution mass spectrometer UPLC-ESI-Q-Orbitrap (Ultimate 3000 UPLC with Q-Exactive, Thermo Fisher Scientific) was utilized (Pan *et al.*, 2022). Using a flow rate of 0.2mL min⁻¹, the metabolites were separated using a Thermo Fisher Hypercil Gold C-18 column (150 mm x 2.1 mm, 1.9µm particle size). The column temperature was maintained at 40°C. Multistep gradient flow was used to elute the metabolites with mobile phase A, 0.1 per cent HCOOH in water and mobile phase B is methanol with 0.1 per cent HCOOH. The gradient flow was given as follows, 0 min to 2 min 5 per cent B, 10 min 70 per cent B, 20 min to 28min 98 per cent B, 29 min to 30 min 5 per cent B. HRMS data collected in both positive and negative ionisations separately. The heated ESI operated with capillary temperature of 320°C and auxiliary gas heater temperature of 250°C (Li *et al.*, 2020). The sweep cone was set to zero flow, the sheet gas flow rate was forty, and the auxiliary gas flow rate was five (All gas flows are in arbitrary units). The spray voltage was 4 KV. The full MS-ddMS2 spectra were collected at a resolution of 70000 in the mass range of 80 -1000 m/Z. dd-MS2 spectra were acquired at resolution of 17500 in centroid mode with collision energy 20 and loop count 5. EB and its known metabolites were included in the inclusion list and an exclusion list was prepared after analysing reagent blank in the same method. The mass calibration in positive and negative mode was performed prior to injection of samples.

Statistical analysis for metabolite profiling: Thermo Q Exactive tune and Xcaliber software package

was used to acquire and initial process of the LC-HRMS data. The ddMS2 chromatograms were processed to find the metabolites using compound discoverer 3.3 with work flow, untargeted metabolomics workflow (Fig. S-1). The differences between samples were identified, and performed retention time alignment (RT tolerance <0.2 min) with ChromAlign algorithm, unknown compound detection (mass tolerance <5 ppm), and compound grouping across all samples. Then elemental compositions for all compounds were predicted, filled gaps across all samples, and subtract chemical background (using Blank samples) (Deore *et al.*, 2024). The compounds were identified with respect to mzCloud (ddMS2) database and isotopic pattern matched with ChemSpider database (formula or exact mass). Using the mzCloud database, a similarity search was carried out with ddMS2 spectra for every compound for confirmation (Souza and Patti, 2021). Then differential analysis was performed (one-way ANOVA model with Tukey as post-hoc test), for determining p-values, p-values adjusted using Benjamini-Hochberg correction for the false discovery rate. Additionally, heat map-based hierarchical cluster analysis (HCA) to understand the variation in concentration of metabolites between samples and principal component analysis (PCA) to group similar samples, were carried out. Pathway analysis was performed using KEGG database through the Metabolika pathway finder, mzCloud and ChemSpider databases to identify compounds.

RESULTS AND DISCUSSION

Method validation of EB in okra: EB was estimated as sum of its metabolites (emamectin B1a + emamectin B1b). Matrix matched calibration was performed to reduce the matrix error. The matrix effect was determined by comparing the signal of EB prepared in pure solvent to okra matrix and found to be -9.5 to 14 per cent. Negative values show the reduction in signal observed with matrix. The analysis of the data on the recovery of EB fortified at four different levels indicated a mean recovery of 102 per cent (Table 1). The recovery percentage ranged from 80.0 to 118 with a standard deviation ranged from 8 to 17 per cent for EB for

the adopted method. LOQ determined as 0.01mg kg⁻¹. Given the reasonable recovery percentage (70–110) and RSD values (below 20), the approach can be deemed suitable for estimating the amount of EB residues in okra (SANTE, 2021).

Dissipation kinetics of EB in okra fruit: The initial deposit of emamectin B1a in fruits of okra for single and double dosages was 0.15 and 0.22mg kg⁻¹ and of emamectin B1b was 0.02 and 0.03mg kg⁻¹ which reached below quantitation limit after third day of spraying for both the metabolites and dosages (Table 2). The initial deposit of EB in cowpea pods, which was 0.073 and 0.153mg kg⁻¹ on the fifth and seventh day, dissipated below the quantitation level at 11.0 and 22.0g a.i.ha⁻¹, respectively (Vijayasree *et al.*, 2014). Half- life of 1.97 and 1.91 days and waiting period of 1.96 and 2.54 days, were recorded respectively, for single and double dosages where the FSSAI-MRL for EB in okra is 0.05mg kg⁻¹. EB degraded fast in rice, remaining residue become less than 0.1mg kg⁻¹ in 7 days and its half-life was 0.8 –2.8 days (Deng *et al.*, 2020). From these result it is concluded that EB is dissipating or metabolising very fast in plants and can be considered as a safe insecticide.

Profiling of metabolites in okra fruit and leaf after EB treatment (Targeted compounds): The EB and its metabolites considered as target compounds are listed in Table S-1. Emamectin B1a and emamectin B1b accumulated predominantly in one hour after third spray both in leaves and fruits of okra, however was negligible from third day on okra fruit. The metabolite 4'-deoxy-4'-epi-N-

methylaminoavermectin-b1-benzoate (MFB1a, C₅₀H₇₅NO₁₄, RT 20.869 min, m/z 913.51) was detected only in fruits as sodium adduct on second and third day and was lacking in leaves of okra. This metabolite formed by substitution of methyl and aldehyde groups in amino group of emamectin B1b. According to Hatamleh *et al.* (2022) pesticides negatively impact the biochemistry, physiological apparatus, and cellular metabolism of plants. A very close position of the EB metabolites in the PCA loadings plot (Figs. 1A, D) and low value of log₂ fold change after 3 days (Fig. 4) proved the positive correlation and complete degradation of pesticide after the 3rd day. The results were highly agreeable to the dissipation study of EB.

Metabolic profiling of non-targeted metabolites after EB treatment: Through the analysis of changes in metabolites of okra, metabolic profiling was utilized to observe the distinct behaviours of above-ground plant tissues under insecticide-induced stress as well as in unsprayed plant samples at various intervals. A total of 81 metabolites, including amino acids, nucleosides, and fatty acids were observed in addition to flavonoids. Flavonoids were highlighted in this manuscript because their presence is indicative of stress-associated metabolites produced by plants as part of their recovery and defence responses. Lin *et al.* (2025) reported the impact of pesticides on secondary metabolism of plants, especially azadirachtin increased the content of flavonoids while Tolclofos-methyl, flutolanil, carboxin, and thiram caused a significant decrease. When the non-targeted metabolites on okra fruit and leaf

Table 1 Method validation (Recovery and precision in estimation of emamectin benzoate in okra fruit)

Spiked level	0.01 mgkg ⁻¹	0.02 mgkg ⁻¹	0.05 mgkg ⁻¹	0.1 mgkg ⁻¹
Average recovery % + RSD	95.5 + 16.8	105.1 + 11.6	102.3 + 7.7	101.2 + 12.7
Matrix effect%	-14	-12	-11	-9.5
Linearity, R ²				0.995
*LOD				0.005 mgkg ⁻¹
Deviation in retention time				0.014 minutes
**LOQ				0.01 mgkg ⁻¹
Deviation in ion ratio				0.24%

*LOD – Limit of detection **LOQ – Limit of quantitation

Table 2 Persistence of residues of emamectin benzoate in/on okra and its half life

Day	Total mean residue + SD (mg kg ⁻¹)	
	Single dose	Double dose
Day 0	0.171 + 0.035	0.25 + 0.040
Day 1	0.077 + 0.039	0.142 + 0.026
Day 3	0.05 + 0.023	0.065 + 0.020
Day 5	<LOQ	<LOQ
MRL (mg kg ⁻¹)	0.05	0.05
Half-life (Days)	1.97	1.91
Waiting period (Days)	1.96	2.54
Regression equation	y = -0.307 X+1.303	y = -0.315 X+1.502

*Single dose (11.0g a.i. ha⁻¹); Double dose (22.0g a.i. ha⁻¹)

were subjected to PCA, PC1 and PC2 together explained more than 61.1 per cent (PC1–46.5 and PC2–14.6%) and 58.4 per cent (PC1–30.2 and PC2–28.2%) of the total variance, respectively. In PCA of fruit (Fig. 1A), the signals of day 0 to day 5 shows a similar variance for PC1 but significant variance in other direction. Signals of day 15 to 30 were similar but it significantly different from day 0 to day 5. This shows the significant effect of EB in the metabolism of okra. In the case of okra leaf (Fig. 1C) signal variation observed after 10 days along PC1. PCA loadings plots showed that the flavonoid compounds are susceptible to EB treatment in okra. The flavonoid content in the initial days after spray is positively correlated with EB, (Fig. 1B) but after tenth day okra showed similar content of flavonoids as control (Fig.3). Zeng *et al.* (2021) reviewed similar results of flavonoid content in different vegetables and plants as a result of intoxication of different type of insecticides. Amiri *et al.* (2022) also reported increase in flavonoid content after pesticide treatment by chemical analysis in potato plants. EB can activate the phenolic biosynthetic pathways in okra and which help the plant to reduce the stress conditions arise due to EB and get more protection from insects. Sharma *et al.* (2019) reported that plants produce increased levels of polyphenols to reduce the abiotic stress by radical scavenging effect. Qiao *et al.* (2024) reported the storage of okra at 4°C activates

flavonoid synthesis pathway. While analysing PCA of leaves (Fig. 1C), signals up to 10 days grouped together, this showed EB persisted in leaves for more days compared to fruits and there after it varies along PC2. Pan *et al.* (2022) reported 61.8 per cent of variance was explained by PCA analysis in his study on metabolism changes by pymetrozine and tebuconazole on cucumber.

In the HCA of non-targeted compounds from okra fruit and leaf, we checked 28 compounds each having more than 80 per cent match in m/z cloud results with minimum two positive annotations (Fig. 2A). While clustering along Y axis, compounds with similar metabolism patterns were clustered together forming dendrogram. The red colour indicates higher concentration and the green colour lower content. The HCA of okra fruit have 6 branches, emamectin branch include scopoletin and epigallocatechin as sub branch. This shows the similarity in concentration of flavonoid with EB. L-norleucine, L-phenylalanine, Anthranilic acid, 9-oxo-ODE, trans-3-indoleacrylic acid, indole-3-acetic acid were clustered together and showing similar pattern in concentration changes. The first two are amino acids and other compounds related to plant growth. On third day after spraying they are increased and their concentration is similar to control thereafter (Fig. 2A). 8-hydroxyquinoline, morin, hyperoside, quercetin, quercetin-3-O-rhamnoside-7-O-Glucoside were clustered and showing higher concentration on third day after EB treatment. Most of the polyphenols (catechins, quercetins etc.) showed similar pattern of higher concentrations from the day of spraying and observed a reduction in concentration after 10th day (Figs. 2, 3). Amino acids and its derivatives clustered together and showing similarity in pattern with choline in leaf and grouped in the same child branch of the dendrogram. Choline serves as a synthetic precursor for other essential cell components and signalling molecules so it was clear that amino acid synthesis was similarly regulated and overcome the stress from EB. According to Pan *et al.* adding fertilizer and insecticides together to cucumbers increased their chlorophyll content and antioxidant content (Pan *et al.*, 2022).

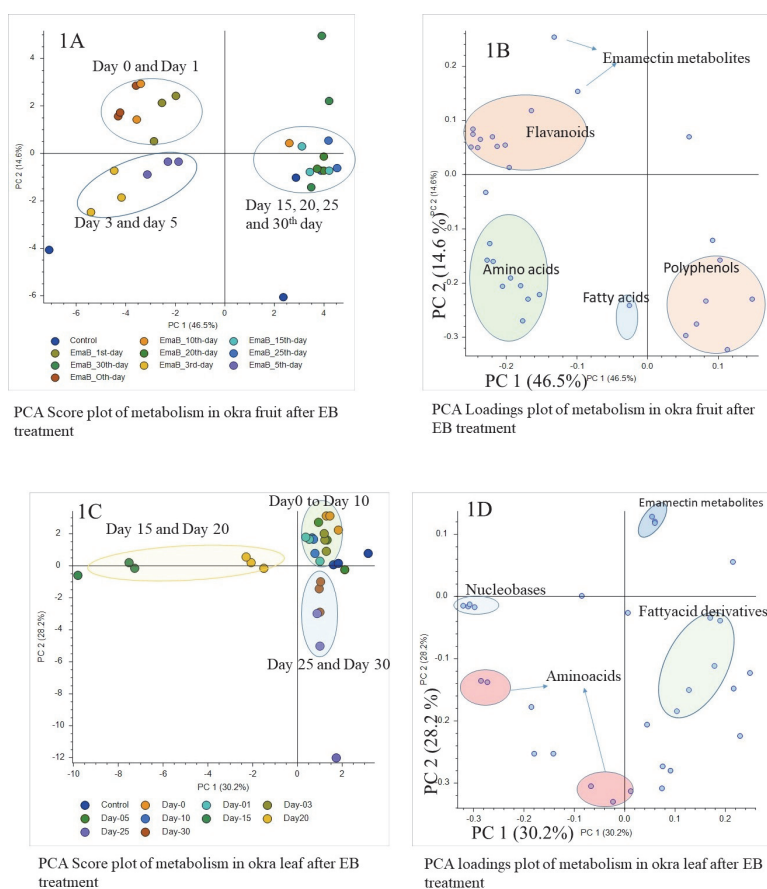


Fig. 1 PCA score plots and PCA loadings plot of metabolism in okra fruit and leaf after emamectin treatment. 1A and 1C are PCA score plots of fruit and leaves respectively. The dots with same colour represent replicates. The data variation through PC1 and PC2 were grouped. 1B and 1D are PCA loadings plots of fruit and leaves respectively. This represents the correlation between the compounds.

Compounds nearer are positively correlated and in opposite quadrants are negatively correlated. Flavonoids are positively correlated to EB while amino acids are negatively correlated to EB. The control samples were collected each day and a pooled control sample prepared and used in the study.

Differential analysis: The differential analysis results of metabolites in okra fruit after EB treatment of different days vs control. Three compounds up regulated and one down regulated in 0th day vs control, both metabolites of EB upregulated ($\log_2$ fold x $-\log_{10}$ P is 9×13.4 and 10×10.4) along with epigallocatechin (Fig. 4A). That is on the day of EB application its concentration is very high and significant. Three compounds L-phenylalanine, L-norleucine and indole-3-acetic acid have $-\log_{10}$ P-value less than 0.05, they are less significant. 11 other compounds show a $\log_2$ fold change greater than or equal to 1, in that

quercetin, scopoletin, morin, hyperoside and quercetin-3-O-rhamnoside-7-O-glucoside have $\log_2$ fold value more than 2, that is these compounds are very significant in okra metabolism under EB stress. The only compound down regulating is (+)-ar-turmerone. On third day (Fig. 4B) fold change values of EB decreased significantly but still up regulating and number of compounds have $\log_2$ fold value greater than 1 become 13. Similar results observed on fifth day but on 10th day EB have no significance in okra metabolism or it dissipated completely and epigallocatechin shows a higher $\log_2$ fold value of 7.8.

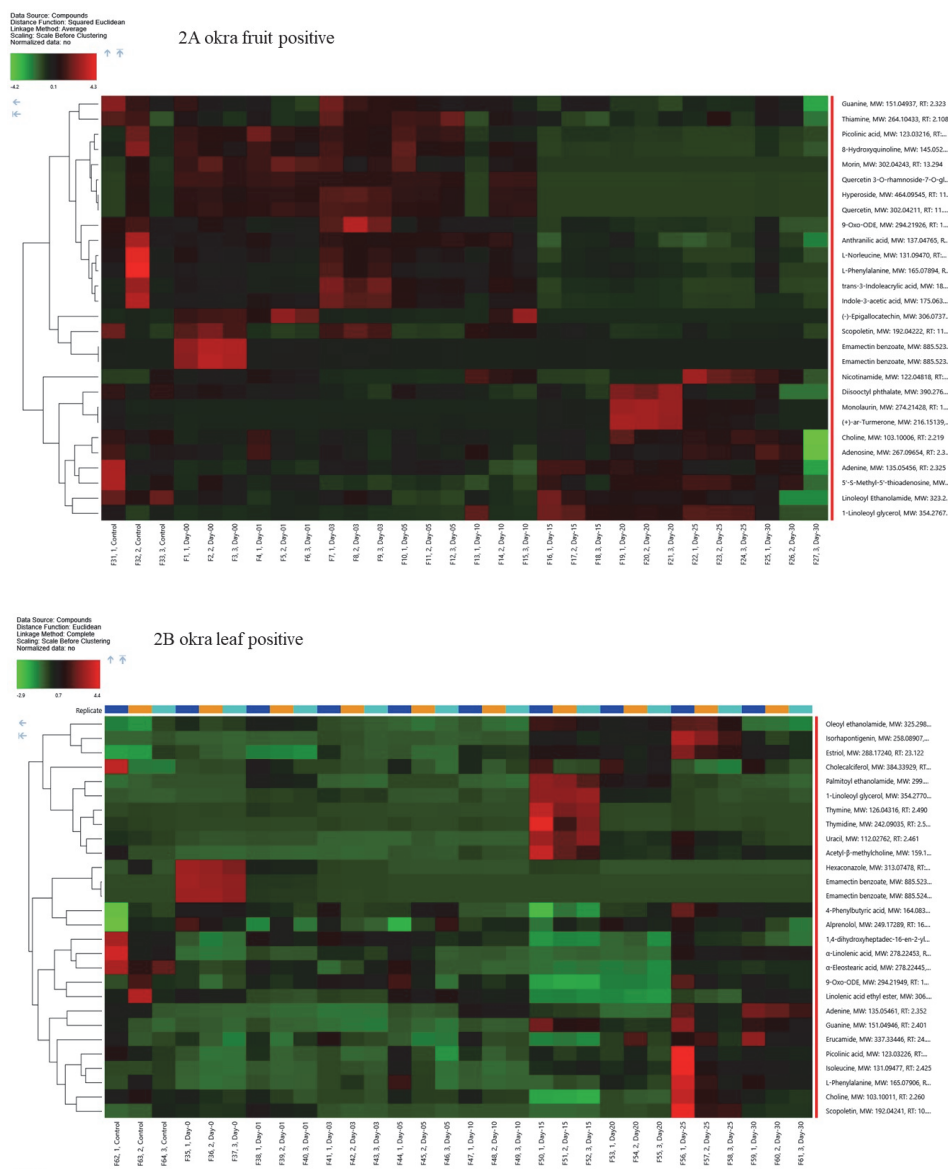


Fig. 2 heat map of metabolites in okra fruit and leaf clustered related to its area concentration in different days after emamectin benzoate treatment. Green colour represents less concentration and red colour high concentration of metabolite. In X axis labelled with day after treatment. In Y axis compounds represented in rows, and they clustered based on their similarity in concentration when days go on.

In metabolite identification, we followed the requirements for putative identification by accurate mass measurement, MS/MS spectrum comparison with database for fragment matching and retention time comparison (Fig. 3) (Zhang *et al.*, 2018; Jan *et al.*, 2021). Indole-3-acetic acid (IAA) (RT 12.34 min, $[M+H]^+$ m/z 176.0705) identified in okra fruit with other adducts $[M+Na]^+$ m/z 198.0525, $[M+H-H_2O]^+$ m/z 158.0810, and MS² fragments at m/z 130.0651 and m/z 176.0706. IAA has a complicated

stress managing mechanism and has significant role in plant growth and abiotic stress relief (Zhang *et al.*, 2022). (-)-Epigallocatechin (RT 8.54 min, $[M+H]^+$ m/z 307.0817) an important flavonoid identified in okra fruit, other adducts are $[M+Na]^+$ m/z 329.0631, $[M+K]^+$ m/z 345.0370, $[2M+H]^+$ m/z 613.1566 and MS² fragments identified are m/z 169.0496, 163.039 and 139.0391 (Fig. 5). Catechins synthesis is enhanced due to the abiotic stress factors like heat, draught, heavy metal

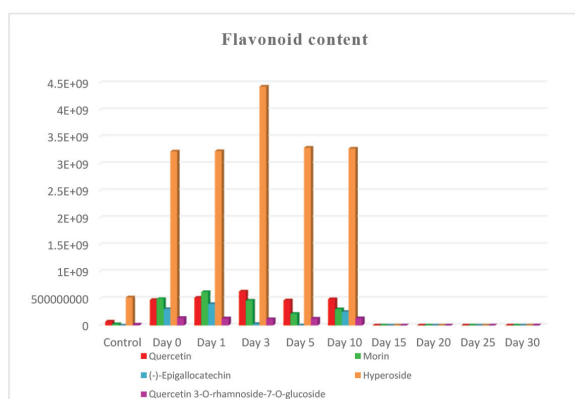


Fig. 3 Flavonoid content (Relative) in okra fruit after emamectin benzoate treatment. X- axis days after treatment of EB, Y- axis area under each peak. All the flavonoids present in okra fruit showing same trend of increasing concentration up to 10th day. There after it reduces and become similar to control.

contamination or insect attack in plants especially in tea (Ahammed *et al.*, 2023). Methyl á-eleostearate (RT 15.25 min, $[M+H]^+$ m/z 293.2473), a conjugated polyunsaturated fatty acid in higher amount on thirtieth day (73% relative variation with control) due to the response against insecticide stress. There was not much variation in its quantity on other days when compared with the control. Citral, an acyclic monoterpene aldehyde (RT 29.96 min, $[M+H]^+$ m/z 153.1273) with good stress amelioration efficacy was detected with slightly higher quantity on fifteenth and thirtieth day (26 to 28%). Melatonin and its precursor tryptophan have a significant role in enhancing plant stress tolerance to various environmental conditions, such as water scarcity (Sadak and Ramadan 2021). Quoc *et al.* (2024) reported that D-glucuronic acid, D-

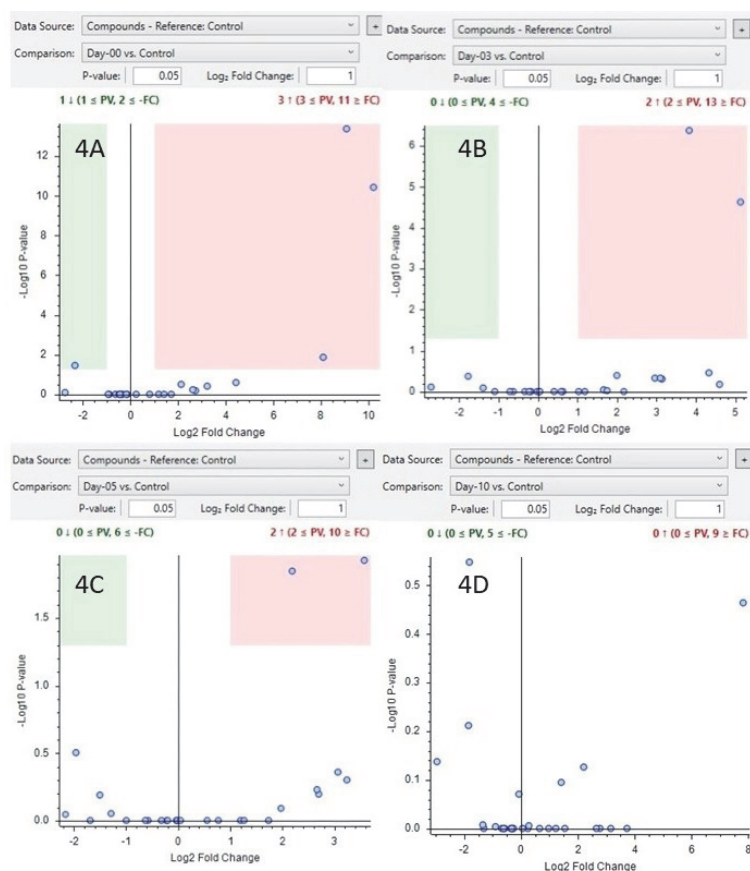


Fig. 4 Differential Analysis result of okra fruit after EB application, different day vs control. X axis of each graph is the $\log_2$ fold change in concentration and Y axis $-\log_{10}$ P-value. Compounds in the red box are upregulated and in green box are down regulated.

FC is the number of significant compounds have $\log_2$ fold value greater than 1. PV is the number of significant compounds but $-\log_{10}$ P value less than or equal to 0.05. Blue dot represents each compound

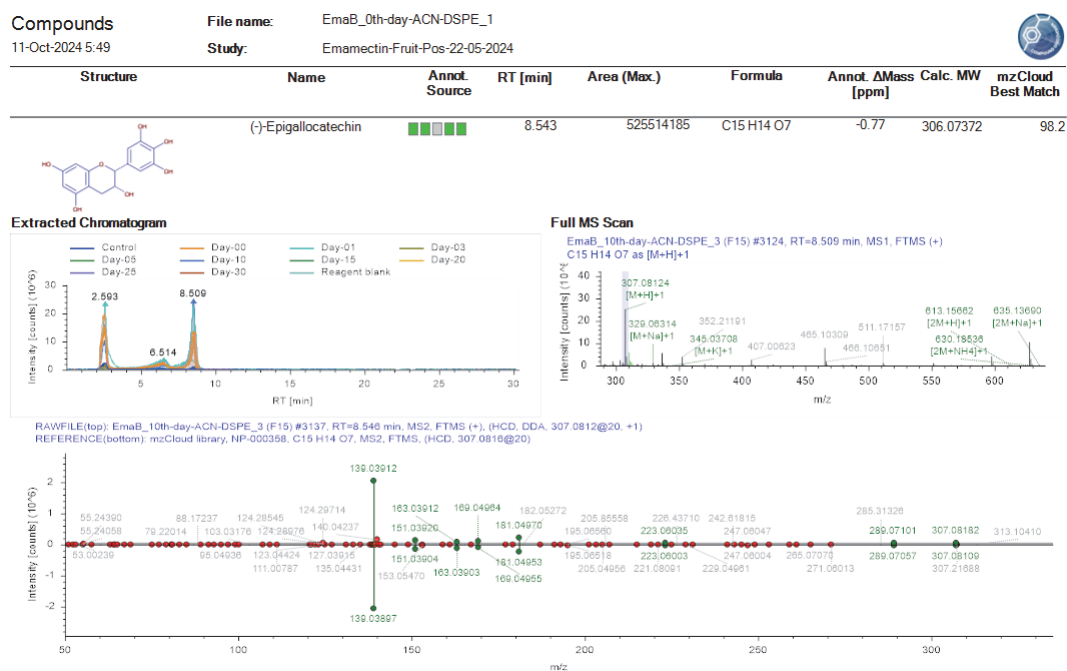


Fig. 5 The identification and confirmation of flavonoid (Epigallocatechin) from high resolution mass data ($M+H$)⁺, similarity of MS/MS fragmentation pattern with mzCloud database (98.2%) and retention time is 8.5 min

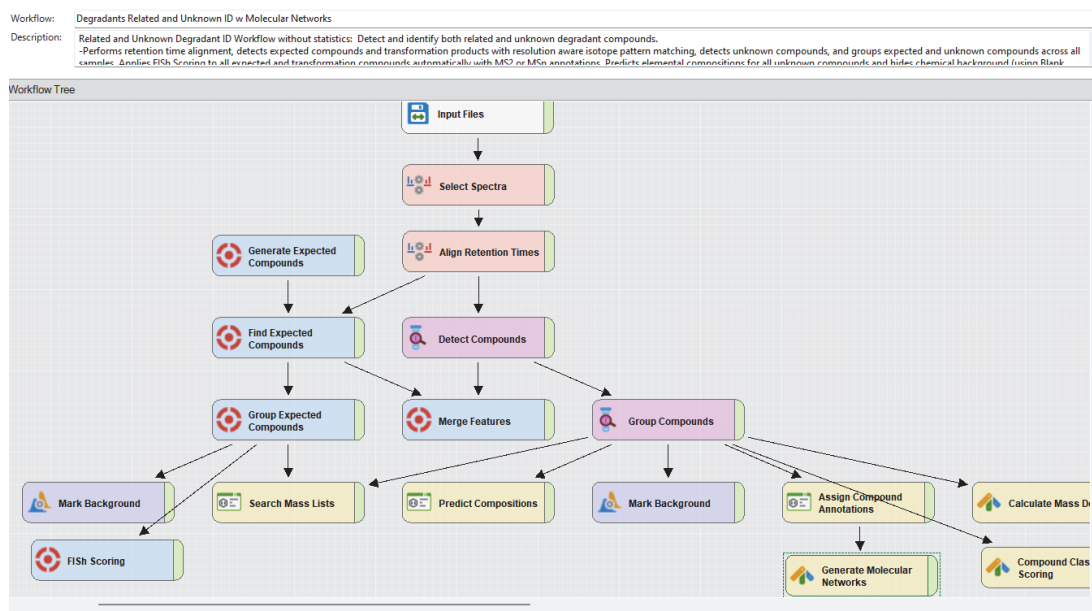


Fig. S-1 Workflow diagram given in Compound Discoverer 3.3 for target and non-target metabolomics

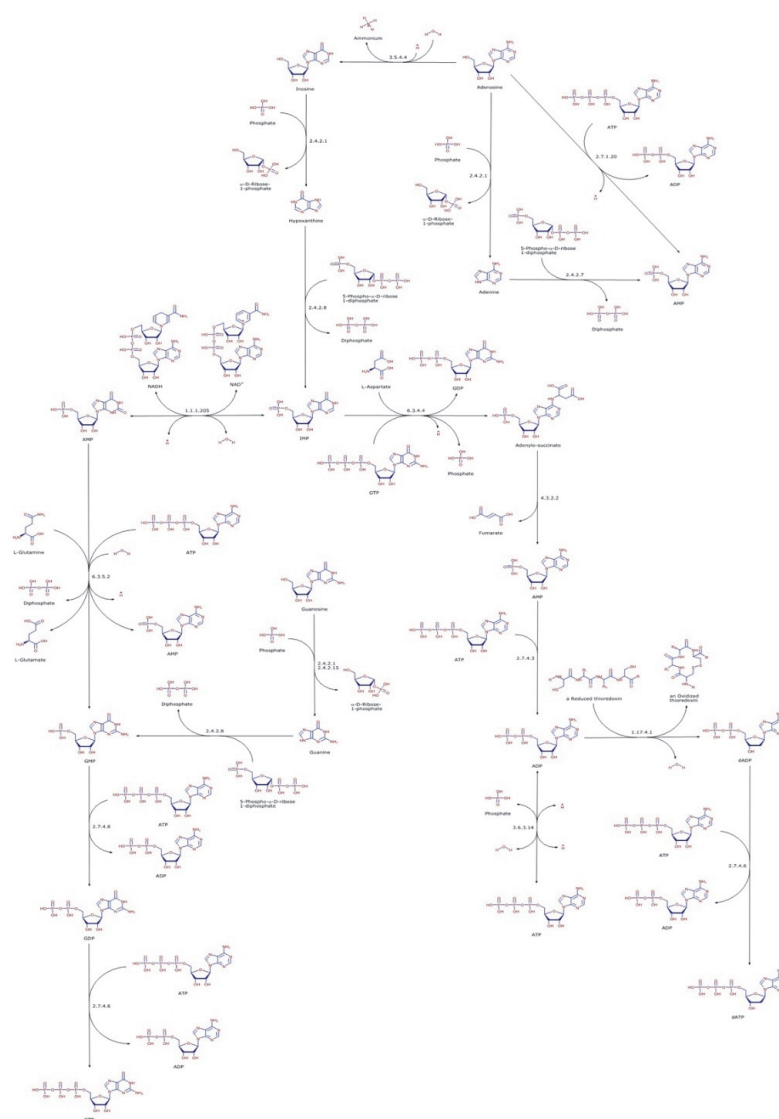


Fig. S-2 Super pathway of purine nucleotide salvage

psicofuranose, hydroxybutyric acid, D-xylose, D-galactose were increased and D-glucose decreased in rice varieties due to salt stress.

Under insecticide-induced stress elevated levels of amino acids show a fundamental role in supporting plant metabolism. Accumulation of α -amino acid, D-Lactose monohydrate (RT 2.24 min, $[M+H]^+$ m/z 360.1499) in EB sprayed fruits of okra was found instantly after spray and on the tenth day (30 to 34 %). L-Tyrosine (RT 2.4 min, $[M+H]^+$ m/z 182.0811) content was found lower after fifth day of spraying when compared to the control. Higher levels of other

amino acids particularly isoleucine (RT 4.10 min, $[M+H]^+$ m/z 132.1021), and L-Phenylalanine (RT 6.68 min, $[M+H]^+$ m/z 166.0862) were noticed in sprayed leaves throughout the period of analysis. However the concentration of D-(+)-Tryptophan (RT 8.52 min, $[M+H]^+$ m/z 205.0969) was similar to that of control up to tenth day, which showed a m/z Cloud similarity of 77 per cent.

Due to insecticide toxicity, plants defence mechanism gets activated, which involves production of more signal molecules in diverse physiological processes. L-Proline (RT 2.47 min,

Table S-1. The list of metabolites analysed for profiling of metabolic changes of emamectin benzoate after application on okra fruit and leaves

No	Metabolite	Molecular formula	Molecular weight & monoisotopic mass (g mol ⁻¹)	Identified monoisotopic mass (g mol ⁻¹)	Structural change from B1b
1	Emamectin B1a	C ₄₉ H ₇₅ NO ₁₃	886.12 & 885.5238	885.5230	Methyl group on C-26
2	Emamectin B1b	C ₄₈ H ₇₃ NO ₁₃	872.09 & 871.5081	871.5078	
3	AB1a	C ₄₉ H ₇₅ NO ₁₃	886.12 & 885.5238	Not found	Methyl addition at amino group of EB1b
4	MFB1a	C ₅₀ H ₇₅ NO ₁₄	914.13 & 913.5187	913.5181	Methyl and aldehyde addition at amino group of EB1b
5	FAB1a	C ₄₉ H ₇₅ NO ₁₄	900.10 & 899.5031	Not found	Aldehyde addition at amino group of EB1b

Table S-2. Metabolic pathways identified in metabolomics study of okra fruit during EB metabolism

No.	Metabolic pathway identified	No. of compounds	Compounds matched	Identified compounds
1	Superpathway of flavones and derivatives biosynthesis	147	22	Rutin, Quercetin, Quercetin-7-O-glucoside, Quercetin-3-glucoside, Kaempferol 3,7-o-diglucoside
2	Superpathway of aromatic compound degradation via 2-oxopent-4-enoate	102	7	Anthranilate, Trans-o-hydroxybenzylidene pyruvate
3	Anaerobic aromatic compound degradation (Thauera aromatica)	74	7	Anthranilate, L-phenylalanine
4	Superpathway of purine nucleotide salvage	54	5	Adenosine, Adenine, Guanine
5	Superpathway of indole-3-acetate conjugate biosynthesis	48	6	L-Leucine, Phenylalanine, Indole-3-acetate
6	Superpathway of lipoxygenase	33	18	9,10-epoxy-10, 12Z octadecadienoate, Colneleate

[M+H]⁺ m/z 116.0709, identified in chemspider database) is such a compound which is greatly associated with stressful environment as defence molecule against biotic as well as abiotic stresses. On comparing with control, proline content was highly noticed in the emamectin sprayed fruits immediately and on the next day of spraying. Due to heavy metal-induced toxicity >20-fold increase in the free proline content was found in the leaves of metal non-tolerant *Silene vulgaris* (Sharma and Dietz 2006). Accumulation of other proline related compounds i.e., (4R)-4-(1-Aminoethyl)-L-proline (RT 2.95 min, [M+H]⁺ m/z 159.1126), prolintane (RT 13.943 min, [M+H]⁺ m/z 218.1901), (4R)-4-Fluoro-L-proline (RT 2.032 min, [M+H]⁺ (m/z

305.0713) were also seen under stress conditions by emamectin spray.

The ability of amino acids, phenolics and flavonoids to scavenge free radicals makes them useful antioxidants that help plants to withstand a variety of abiotic challenges, such as metal stress (Drzewiecka *et al.*, 2018). Hyperoside (RT 11.85 min, [M+H]⁺ m/z 465.1027) is an unique flavonoid in okra whose content was higher up to the tenth day (10 to 27%) and was untraceable after it. Quercetin (RT 11.81 min, [M+H]⁺ (m/z 303.0494) is another bioactive natural compound with antioxidative property which will be modifying plant physiology (Singh *et al.*, 2024). Plants exposed to high levels of pesticides showed a notable increase

in antioxidant levels in order to withstand the oxidative stress caused by the pesticides (Shakir *et al.*, 2018). It has been found that quercetin alleviates the toxicity of EB. In the present study, a significant amount of Quercetin 3-O-rhamnoside-7-O-glucoside (RT 11.87 min, $[M+H]^+$ (m/z 611.1604), was quantified up to the tenth day (15 to 22%) and undetectable thereafter in okra.

In this study it was verified the metabolites of EB formed during its dissipation in okra and variation in metabolomics due to EB stress. The only metabolite of EB, found in fruit is 4''-deoxy-4''-epi-N-methylaminoavermectin-b1-benzoate other than the sprayed components, EB1a and EB1b. 81 metabolites identified in total from okra fruit and leaf out of those 35 metabolites observed in both fruit and leaf of okra. Flavonoid content was increased as a result of stress from EB and scopoletin and epigallocatechin can be used as marker to EB stress. Fatty acids are comparatively less susceptible to EB stress. For the assessment of EB induced metabolite variations through metabolomics-based strategy, which included untargeted chemical profiling, and multivariate statistical analysis, the current study methodically reconnoitred the changes in metabolic pathways (list of metabolic pathways identified including the list of compounds putatively identified in each pathway is given in Table S2 and Super pathway of purine nucleotide salvage represented in Fig. S2) and distribution patterns of EB residues and metabolites in okra. Correlation of compounds in the pathways is analysed using R programme, epigallocatechin, quercetin, quercetin-3-O-Rhamnoside-7-o-glucoside have positive correlation with EB while Choline monolaurin are negatively correlated with EB stress. More information and studies may be required to find common markers for other insecticides and on different varieties of okra or other vegetables.

ACKNOWLEDGMENTS

The authors wish to express their gratitude to Bharathiar University Coimbatore for providing research facilities, Rajiv Gandhi Centre for Biotechnology, Thiruvananthapuram to provide their

analysis facility and Dr. T. Shyamala, DST Women Scientist, Indian Institute of Science Education and Research Thiruvananthapuram in the manuscript preparation.

REFERENCES

- Ahammed G.J., Wu Y., Wang Y., Guo T., Shamsy R. and Li X. (2023) Epigallocatechin-3-Gallate (EGCG): A unique secondary metabolite with diverse roles in plant-environment interaction, *Environmental and Experimental Botany* 209: 105299. doi: 10.1016/j.envexpbot.2023.105299.
- Amiri O., Nemmiche S., Hennia A., Bentamra Z., Benhachem I. and Benkhelifa M. (2022) Effect of the pesticide treatment dose on the biochemical response of the potato plants (*Solanum tuberosum* L.). *Plant Archives* 22(1): 261–267. doi: 10.51470/PLANTARCHIVES.2022.v22.no1.041.
- Barchanska H., Pszczolińska K., Perkons I., Bartkevics V., Drzewiecki S., Shakeel N. and P³onka J. (2023) The metabolic processes of selected pesticides and their influence on plant metabolism. A case study of two field-cultivated wheat varieties. *Science of The Total Environment* 875: 162709. doi:10.1016/j.scitotenv.2023.162709.
- Deng L., Chen L., Guan S., Liu J., Liang J., Li X. and Li Z. (2020) Dissipation of emamectin benzoate residues in rice and rice-growing environments. *Molecules* 25(3): 483. doi:10.3390/molecules25030483.
- Dong L. and Zhang J. (2022) Research progress of avermectin: A minireview based on the structural derivatization of avermectin. *Advanced Agrochem* 1(2): 100–112. doi:10.1016/j.aac.2022.11.001.
- Deore P., Thekkumpurath A.S., Upadhyay A. and Devarumath R. (2024) Non-target influence of imidacloprid residues on grape global metabolome and berry quality with the identification of metabolite biomarkers. *Environmental Science Pollution Research* 31:15770–15787. doi:10.1007/s11356-024-32134-2.
- Drzewiecka K., G¹secka M., Rutkowski P., Magdziak Z., Goliński P. and Mleczek M. (2018) Arsenic forms and their combinations induce differences in phenolic accumulation in *Ulmus laevis* Pall. *Journal of plant physiology* 220: 34–42. doi: 10.1016/j.jplph.2017.09.013.

- Estelitta S., Bonny B.P., Helen S. and Suma A. (2016) Package of Practices recommendations: crops 15th ed. (K.A.U). <https://kau.in/sites/default/files/documents/pop2016.pdf>.
- Fanigliulo A. and Sacchetti M. (2008) Emamectin benzoate: new insecticide against *Helicoverpa armigera*. Communications in agricultural and applied biological sciences 73(3): 651–653.
- Farha W., Abd El-Aty A., Rahman M.M., Shin H.C. and Shim J.H. (2016) An overview on common aspects influencing the dissipation pattern of pesticides: a review. Environmental Monitoring and Assessment 188: 1–21. doi:10.1007/s10661-016-5709-1.
- Hatamleh A.A., Danish M., Al-Dosary M.A., El-Zaidy M. and Ali S. (2022) Physiological and oxidative stress responses of *Solanum lycopersicum* (L.) (tomato) when exposed to different chemical pesticides. RSC advances 12(12): 7237–7252. doi:10.1039/D1RA09440H.
- Hoagland R., Zablutowicz R. and Hall J. (2001) Pesticide metabolism in plants and microorganisms: an overview. Chapter 1, ACS publications, Washington DC. 2–27. doi:10.1021/bk-2001-0777.ch001.
- Hoskins W.M. (1961) Mathematical treatment of the rate of loss of residues. Food and Agriculture Organization, FAO Plant Protection Bulletin 9: 163–168.
- Huynh K., Leonard E., Chong J.H., Palmer C. and Tharayil N. (2021) Persistence and metabolism of the diamide insecticide cyantraniliprole in tomato plants. Scientific Reports 11: 21570. doi:10.1038/s41598-021-00970-8.
- Jan R., Asaf S., Numan M., Lubna and Kim K.M. (2021) Plant Secondary Metabolite Biosynthesis and Transcriptional Regulation in Response to Biotic and Abiotic Stress Conditions. Agronomy 11(5): 968. doi:10.3390/agronomy11050968.
- Jyot G., Mandal K., Chahil G.S. and Singh B. (2014) Persistence and risk assessment of emamectin benzoate residues on okra fruits and soil. Environmental technology 35(14): 1736–1743. doi:10.1080/09593330.2014.881420.
- Lei M., Raza I., Deebe F., Jamil M., Naeem R., Azizullah A., Khattak B., Shah A., Ali I., Jin Z.S. and Khan M. D. (2020) Pesticide-induced physiological, metabolic and ultramorphological alterations in leaves of young maize seedlings. Polish Journal of Environmental Studies 29(3): 2247–2258. doi:10.15244/pjoes/108926.
- Li Y., Chen Q., Xie X., Cai Y., Li J., Feng Y. and Zhang Y. (2020) Integrated Metabolomics and Transcriptomics Analyses Reveal the Molecular Mechanisms Underlying the Accumulation of Anthocyanins and Other Flavonoids in Cowpea Pod (*Vigna unguiculata* L.). Journal of agricultural and food chemistry 68(34): 9260–9275. doi:10.1021/acs.jafc.0c01851.
- Lin Y., Jia Y., Zhou C., Wang H. and Pan C. (2025) Impact of Pesticide Abiotic Stresses on Plant Secondary Metabolism: From Plant Individuals to Ecological Interfaces. Journal of Agricultural and Food Chemistry 73(34): 21247–21263. doi: 10.1021/acs.jafc.5c05713.
- Pan L., Zhou C., Jing J., Zhuang M., Zhang J., Wang K. and Zhang H. (2022) Metabolomics analysis of cucumber fruit in response to foliar fertilizer and pesticides using UHPLC-Q-Orbitrap-HRMS. Food Chemistry 369: 130960. doi:10.1016/j.foodchem.2021.130960.
- Pradeepkumar G., Vijayasree V. and Chandran K.S. (2023) Growth dilution and its effect on pesticide dynamics in Okra. ENTOMON 48(3): 357–364. doi: 10.33307/entomon.v48i3.937.
- Preetha G. and Stanley J. (2012) Influence of neonicotinoid insecticides on the plant growth attributes of cotton and okra. Journal of Plant Nutrition 35(8): 1234–1245. doi: 10.1080/01904167.2012.676134.
- Quoc C.D., Lan A.B., Ngoc T.N., Hong T.L., Thanh T.T., Tran G.B., Hoa S.P., Hung T.N., Ngoc T.N.H., Cong H.N., Le N.N.T. and Ngoc N.T. (2024) Variations in some metabolic compounds in the roots of rice varieties (*Oryza sativa* L.) with different salinity tolerance under salinity stress during the seedling stage. Plant Physiology Report 29: 660–677. doi: 10.1007/s40502-024-00804-5.
- Sadak M.S. and Ramadan A.A.EM. (2021) Impact of melatonin and tryptophan on water stress tolerance in white lupine (*Lupinus termis* L.). Physiology and Molecular Biology of Plants 27: 469–481. doi: 10.1007/s12298-021-00958-8.
- SANTE (2021) Analytical quality control and method validation procedures for pesticide residues analysis in food and feed SANTE 11312/2021: 1–57. https://food.ec.europa.eu/system/files/2023-11/pesticides_mrl_guidelines_wrkdoc_2021-11312.pdf.
- Shakir S.K., Irfan S., Akhtar B., Rehman S. U., Daud M. K., Taimur N. and Azizullah A. (2018) Pesticide-

- induced oxidative stress and antioxidant responses in tomato (*Solanum lycopersicum*) seedlings. *Ecotoxicology* 27: 919–935. doi: 10.1007/s10646-018-1916-6.
- Sharma A., Shahzad B., Rehman A., Bhardwaj R., Landi M. and Zheng B. (2019) Response of phenylpropanoid pathway and the role of polyphenols in plants under abiotic stress. *Molecules* 24(13): 2452. doi:10.3390/molecules24132452
- Sharma N., Mandal K. and Sharma S. (2024) Validation of LCMS/MS based method for residual estimation of tolfenpyrad and emamectin benzoate in brinjal and cauliflower and their risk assessment. *Journal of Food Composition and Analysis* 106803. doi:10.1016/j.jfca.2024.106803.
- Sharma S.S. and Dietz K.J. (2006) The significance of amino acids and amino acid-derived molecules in plant responses and adaptation to heavy metal stress. *Journal of Experimental Botany* 57(4): 711–726. doi: 10.1093/jxb/erj073.
- Singh P., Arif Y., Mir A.R., Alam P. and Hayat S. (2024) Quercetin-mediated alteration in photosynthetic efficiency, sugar metabolism, elemental status, yield, and redox potential in two varieties of okra. *Protoplasma* 261: 125–142. doi:10.1007/s00709-023-01885-z.
- Souza A.L. and Patti G.J. (2021) A Protocol for Untargeted Metabolomic Analysis: From Sample Preparation to Data Processing. In: Weissig, V., Edeas, M. (eds) *Mitochondrial Medicine. Methods in Molecular Biology*, vol 2276. Springer, New York, NY. doi:10.1007/978-1-0716-1266-8_27
- Steffens W. and Wieneke J. (1975) Influence of humidity and rain on uptake and metabolism of ¹⁴C-azinphos-methyl in bean plants. *Archives of Environmental Contamination and Toxicology* 3(3): 364–370. doi: 10.1007/BF02220748.
- Sun Y., Tao S., Zhang W., Jiang B., Dai H. Y., Liu B. S., Zhang Y.J., Kong X., Zhao J. and Bai L. X. (2022) Transcriptome profile analysis reveals the emamectin benzoate-induced genes associated with olfaction and metabolic detoxification in *Spodoptera exigua* Hübner (Lepidoptera: noctuidae). *All Life* 15(1): 340–357. doi: 10.1080/26895293.2022.2052190.
- Tyagita N., Mahati E. and Safitri A. H. (2021) Superiority of Purple Okra (*Abelmoschus esculentus*) to Green Okra in Insulin Resistance and Pancreatic â Cell Improvement in Diabetic Rats. *Folia medica* 63(1): 51–58. doi: 10.3897/folmed.63.e51944.
- Van Eerd L.L., Hoagland R.E., Zablotowicz R.M. and Hall J. C. (2003) Pesticide metabolism in plants and microorganisms. *Weed science* 51(4): 472–495.
- Vijayasree V., Bai H., Mathew T. B., George T., Xavier G., Kumar N. P. and Visalkumar S. (2014) Dissipation kinetics and effect of different decontamination techniques on the residues of emamectin benzoate and spinosad in cowpea pods. *Environmental monitoring and assessment* 186: 4499–4506. doi: 10.1007/s10661-014-3714-9.
- Vijayasree V., Bai H., Beevi S. N., Mathew T. B., George T. and Xavier G. (2015) Persistence and effect of processing on reduction of chlorantraniliprole residues on brinjal and okra fruits. *Environmental monitoring and assessment* 187(5): 299. doi:10.1007/s10661-015-4530-6.
- Yoshii K., Kaihara A., Tsumura Y., Ishimitsu S. and Tonogai Y. (2001) Simultaneous determination of residues of emamectin and its metabolites, and milbemectin, ivermectin, and abamectin in crops by liquid chromatography with fluorescence detection. *Journal of AOAC International* 84(3): 910–918.
- Zeng X., Du Z., Ding X. and Jiang W. (2021) Protective effects of dietary flavonoids against pesticide-induced toxicity: A review. *Trends in Food Science and Technology* 109: 271–279. doi:10.1016/j.tifs.2021.01.046.
- Zhang J. J. and Yang H. (2021) Metabolism and detoxification of pesticides in plants. *Science of the Total Environment* 790: 148034. doi: 10.1016/j.scitotenv.2021.148034
- Zhang M., Gao C., Xu L., Niu H., Liu Q., Huang Y., Lv G., Yang H. and Li M. (2022) Melatonin and Indole-3-Acetic Acid Synergistically Regulate Plant Growth and Stress Resistance. *Cells* 11(20), 3250. doi: 10.3390/cells11203250.
- Zhang X., Ding X., Ji Y., Wang S., Chen Y., Luo J., Shen Y. and Peng L. (2018) Measurement of metabolite variations and analysis of related gene expression in Chinese liquorice (*Glycyrrhiza uralensis*) plants under UV-B irradiation. *Scientific Reports* 8: 6144. doi: 10.1038/s41598-018-24284-4.
- Zhang Y., Zhang T., Zhao Q., Xie X., Li Y., Chen Q., Cheng F., Tian J., Gu H. and Huang J. (2021) Comparative transcriptome analysis of the accumulation of anthocyanins revealed the underlying metabolic and molecular mechanisms

- of purple pod coloration in okra (*Abelmoschus esculentus* L.). *Foods* 10(9): 2180. doi: 10.3390/foods10092180.
- Zhang Y., Huang L., Liu L., Cao X., Sun C. and Lin X. (2022) Metabolic disturbance in lettuce (*Lactuca sativa*) plants triggered by imidacloprid and fenvalerate. *Science of The Total Environment* 802: 149764. doi: 10.1016/j.scitotenv.2021.149764.

(Received July 12, 2025; revised ms accepted October 31, 2025; published December 31, 2025)

Redescription of *Rawania petasata* (Melichar) (Hemiptera, Cicadellidae, Typhlocybinae) with a key to genera of Empoascini related to genus *Rawania* Ghauri of Oriental region

N. Shreya¹, C.M. Kalleshwaraswamy^{1*}, M. Shankaramurthy⁴, G.K. Girijesh²,
Sharanabasappa S. Deshmukh¹, K. Rajashekharappa¹ and B.V. Champa³

¹Department of Entomology, ²Department of Agronomy, ³Department of Horticulture, Keladi Shivappa
Nayaka University of Agricultural and Horticultural Sciences, Iruvakk, Shivamogga 577 204,
Karnataka, India.

⁴Department of Entomology, University of Agricultural Sciences, G.K.V.K., Bengaluru 560065,
Karnataka, India.

Email: kalleshwaraswamycm@uahs.edu.in

ABSTRACT: *Rawania petasata* (Melichar, 1903), breeding on leaves of *Pongamia pinnata* (L.) Pierre is redescribed and illustrated. Male specimens collected from Karnataka and Sri Lanka exhibited a pair of short, tooth-like processes at the base of the aedeagal shaft, a feature previously overlooked in the original description. Besides *Pongamia*, this species was also found on mango, *Mangifera indica* Linnaeus and cashew, *Anacardium occidentale* Linnaeus in Karnataka. These leafhoppers were collected from newly emerged leaves of these plants during March 2024 and 2025. A key to distinguish the genus *Rawania* Ghauri from Empoascini genera of Oriental region with a similar forewing venation namely, forewing with all the three apical veins arising independently from forewing cell m [apical veins Radial Posterior (RP) and Median Posterior (MP) not confluent at base] is also provided.

© 2025 Association for Advancement of Entomology

KEY WORDS: Auchenorrhyncha, forewing venation, host plants, Karnataka, leafhopper, *Pongamia*

INTRODUCTION

Leafhoppers are pests of considerable importance causing hopper burn symptoms (Viraktamath and Viraktamath, 1995). Among the leafhoppers, the tribe Empoascini, belonging to the second largest subfamily Typhlocybinae, currently includes 1,398 valid species grouped in 107 genera worldwide (Dmitriev *et al.*, 2022). In India, approximately 137 species belonging to 32 genera have been reported

(Sohi and Dworakowska, 1983; Sohi, 1998; Dmitriev *et al.*, 2022). Empoascini is one among the six tribes of subfamily Typhlocybinae and is distinguished from the other tribes by having submarginal vein between the apices of veins MP and MP+CuA in hindwing (Fig. 5B).

The genus *Rawania* was established by Ghauri (1963) with *Empoasca petasata* Melichar from Sri Lanka designated as the type species. *Rawania*

* Author for correspondence

is a monotypic genus of tribe Empoascini. Among the leafhoppers collected during the present study on the systematics of Empoascini of south India, some specimens exhibiting all the characteristics of *R. petasata* were examined. However, these specimens possessed a pair of tooth-like structures on the aedeagus, a feature not described by Ghauri (1963) in the original description.

Initially, the specimens were thought to belong to an undescribed species of *Rawania*, however, examination of male genitalia images of paralectotypes of *R. petasata*, kindly provided by Dr. Igor Malenovský from the Moravian Museum in Brno, Czech Republic, revealed that the paralectotypes also possessed a pair of tooth-like structures on the aedeagus (Fig. 2 A-C). Therefore, in this paper, additional details on the morphology of the aedeagus, not described earlier, are provided. Qin *et al.* (2014) provided a key to genera of Empoascini of China. In the present study, a key to Empoascini genera of Oriental region having forewing venation similar to that in *Rawania* in which all the three apical veins arise independently from forewing cell m (RP and MP not confluent at base) is given.

MATERIALS AND METHODS

Leafhoppers were collected from various locations across Karnataka, specifically from the young leaves of pongamia, mango and cashew trees. Measurements of various anatomical parts of the leafhoppers, including length and width, were taken using a stereo-binocular microscope equipped with an ocular grid. High-resolution images of the leafhoppers were captured using a Leica M205C stereomicroscope fitted with a DFC 425 camera. The images were processed and combined into a single, detailed composite image using Zerene Stacker software. Dissection of male genitalia was performed according to the techniques described by Oman (1949) and Knight (1965). The terminology employed for morphological descriptions follows Oman (1949) and Dietrich (2005). The nomenclature of subgenital chaetotaxy follows Qin *et al.* (2014). Drawings of the male genitalia and wing venation were prepared using a

Leica DM2000 compound microscope equipped with Camera Lucida. Dissected male genitalia were carefully placed within their respective abdomen and preserved in a drop of glycerol held in micro-vial. The micro-vial was then stoppered and attached to the pin carrying the corresponding insect specimen from which the structures were dissected. All the material examined are deposited at the University of Agricultural Sciences, G.K.V.K., Bengaluru, and Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga.

RESULTS AND DISCUSSION

Genus *Rawania* Ghauri, 1963 (Fig. 1 A-D and Fig. 3 A-K)

Rawania Ghauri 1963: 465. Type species: *Empoasca petasata* Melichar 1903, by original designation.

Diagnosis. Uniformly pale green with one black spot on either side of median line on fore margin of crown. Head about as wide as posterolateral angles of pronotum. Forewing with all apical veins arising from cell m and veins RP and MP arising separately from cell m (Fig. 5A). Male pygofer with a ventral process. Subgenital plates with group C setae uniseriate and group A setae present (Fig. 5C). Style with a group of setae at base of apophysis which is slender and smooth. Aedeagus with long preatrium dorsal apodeme short, aedeagal shaft in lateral view fairly stout and narrowing distally, with basal short process. Segment X elongate, with a hook-like anteriorly directed process arising from anterior margin directed ventrally and then anteriorly. Connective, more or less T-shaped with short stem, movably articulated with aedeagus.

Remarks. Ghauri (1963) adequately described the genus; therefore, only the diagnosis is provided here. *Rawania* is similar to four Oriental genera namely, *Austroasca* Lower, *Dialecticoperyx* Kirkaldy, *Homa* Distant, and *Kyboasca* Zakhvatkin in having all apical veins of the forewing arising separately from the cell m (RP and MP veins neither stalked nor confluent at base). *Rawania* differs from *Kyboasca*, and *Austroasca* in having uniseriate C-

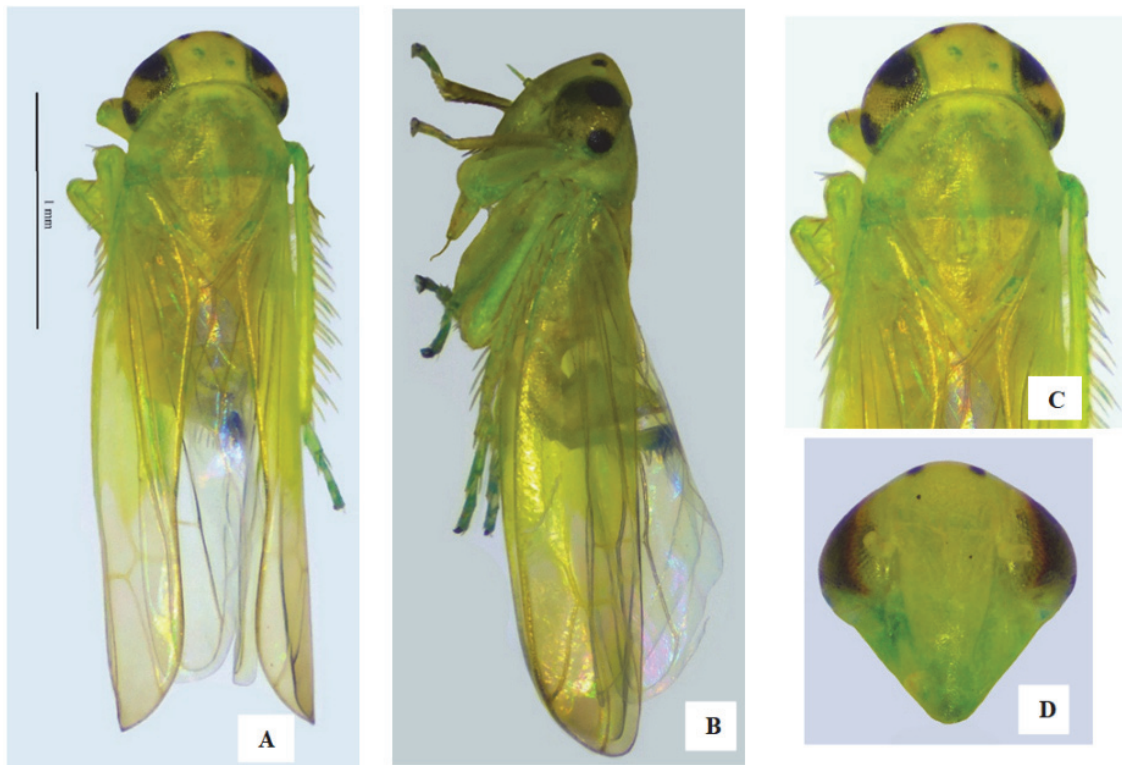


Fig. 1 *Rawania petasata* (♂): A, habitus, dorsal view; B, habitus, lateral view; C, head and thorax, dorsal view; D, face

group setae on the subgenital plates, whereas these setae are multiseriate in the latter two genera. *Rawania* differs from *Kyboasca* in having a longer and narrower process of the segment X. *Rawania* and *Dialecticopteryx* have uniseriate C-group setae, but *Rawania* differs in having a short coronal suture, whereas *Dialecticopteryx* has the coronal suture extending to the fronto-clypeus. *Rawania* is also similar to *Homa* in having a short coronal suture, and subgenital plates with uniseriate C-group setae, but *Rawania* differs from *Homa* in having a ventral pygofer process, which is absent in *Homa*. In addition, species of *Homa* have prominent red markings (Xu *et al.*, 2022; Webb and Xu, 2022) on the forewing that are absent in *Rawania*. These genera can be differentiated by the following key.

Key to genera of Empoascini having all the three apical veins arising independently from forewing cell m (RP and MP' not confluent at base) (males)

1. Subgenital plate with multiseriate group C setae 2
- Subgenital plate with uniseriate group C setae 3
2. Abdominal apodemes well-developed on all tergites; forewings with one brown spot in cell cu*Kyboasca* Zakhvatkin
- Abdominal apodemes not developed on all tergites; forewings without a brown spot in cell cu*Austroasca* Lower
3. Coronal suture reaching fronto - clypeus*Dialecticopteryx* Kirkaldy
- Coronal suture short, not reaching fronto-clypeus.....4
4. Abdominal apodemes well developed; pygofer with ventral process; connective not fused with

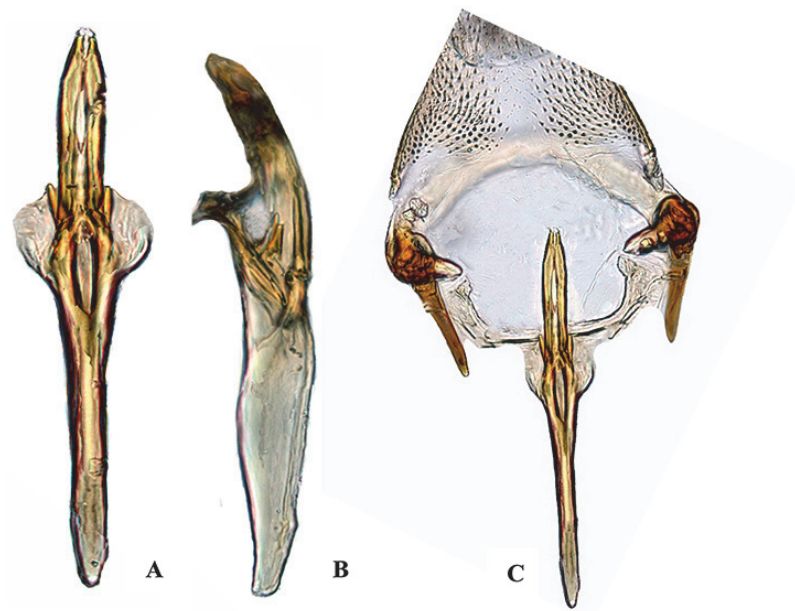


Fig. 2 *Rawania petasata*, male paralectotype: A, aedeagus, ventroposterior view; B, aedeagus, lateral view; C, aedeagus and segment X, ventroposterior view.

aedeagus.....*Rawania Ghauri*

- Abdominal apodemes not well developed; pygofer without ventral process; connective fused with aedeagus.....*Homa Distant*

***Rawania petasata* (Melichar, 1903)**

Empoasca petasata Melichar 1903: 215; Distant 1908: 406, fig. 251.

Rawania petasata (Melichar): Ghauri 1963: 466, figs 1A-L.

Empoasca sp., Gnanewaran *et al.*, 208: 8, fig. 1f.

Materials examined: INDIA: Karnataka: 6♂, 5♀, Bengaluru: GKVK, 13.077985°N, 77.578253°E, 937m, 26.iii.2024, N. Shreya, *ex Pongamia pinnata*; 3♂, Bengaluru: Kodigehalli, 918m, 13.070457°N, 77.578127°E, 10.iv.2024, N. Shreya, *ex Mangifera indica*; 1♂, Bengaluru: G.K.V.K., 13.077985°N, 77.578253°E, 937m, 14.iv.2025, N. Shreya, *ex Anacardium occidentale*; 6♂, 6♀, Shivamogga: Navile, 13.97°N, 75.57°E, 569m, 03.iv.2024, N. Shreya, *ex*

Pongamia pinnata; 1♂, 3♀, Yadgir: Bhimarayanagudi, 16.73°N, 76.80°E, 02.ii.2023, Hemanth, *ex Pongamia pinnata*.

Sri Lanka: 1♂, 4♀, Peradeniya, 22.viii.2007, Raji, *ex Nephelium lappaceum*; 1♀, Peradeniya, 12.ix.2008, R. Gnanewaran (deposited in UASB, G.K.V.K.)

Redescription: Body dark green when alive, older specimens light green with yellowish tinge; abdomen, dorsal and ventral side yellowish green; two black spots on head fore margin; eyes light yellow with two black dots at the anterior and posterior edges; forewing dull or light greenish, translucent; hindwing transparent. Body moderately robust. *Head:* including eyes, as wide as pronotum at posterolateral angles; crown, slightly longer medially than next to eye; coronal suture (remnant of stem of the ecdysial suture present on crown of head) faint and short, not extending beyond mid-length of crown; ocelli, almost in contact with inner margin of eye. *Pronotum:* convexly produced at anterior margin; posterior margin straight; pronotum and scutellum almost equal in length (Fig. 1A, B).

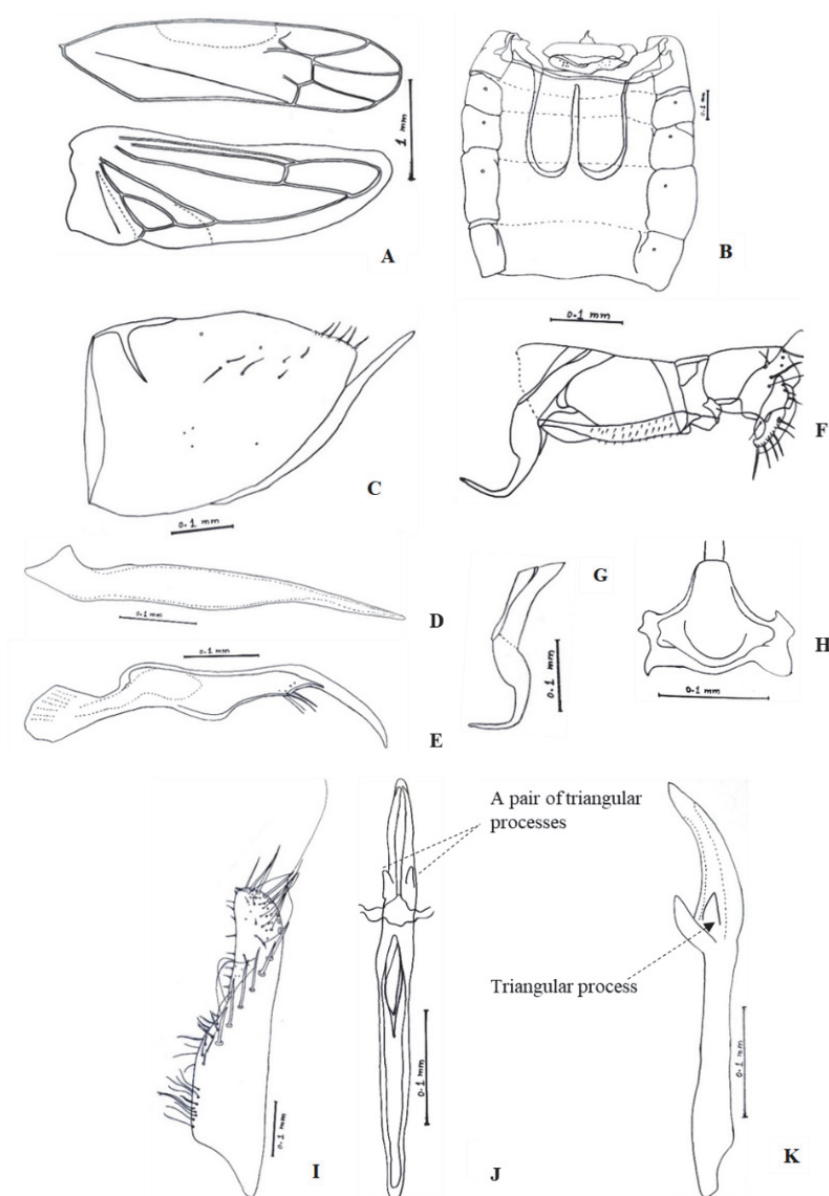


Fig. 3 Morphological features of *Rawania petasata*: A- forewing and hind wing venation; B- abdominal S2 apodemes; C- pygofer, lateral view; D- pygofer ventral process, lateral view; E- Style, dorsal view; F- segment X, lateral view; G- process segment X, lateral view; H- connective, dorsal view; I- subgenital plate, dorsal view; J- aedeagus, dorsal view; K- aedeagus, lateral view

Forewing: all three apical veins, RP, MP and MP+CuA arise from cell m separately (Fig. 5A). **Hindwing:** with CuA vein unbranched apically (Fig. 5B); **Abdominal apodemes:** (a pair of apodemes arising from second abdominal segment (2S) which are used for sound production and these vary in their size and shape) elongate (length: width= 2.26:1), (Fig. 5D) parallel to each other, arising from

2S, crossing 4th abdominal sternite, not reaching 5th abdominal sternite posterior margin (Fig. 3B).

Male-genitalia: Pygofer in lateral view, more or less triangular with posterior lobe conically rounded, posterior dorsal portion slightly pointed (Fig. 3C); pygofer processes long, arising from ventral margin of pygofer, pointed at the tip and slightly sclerotized

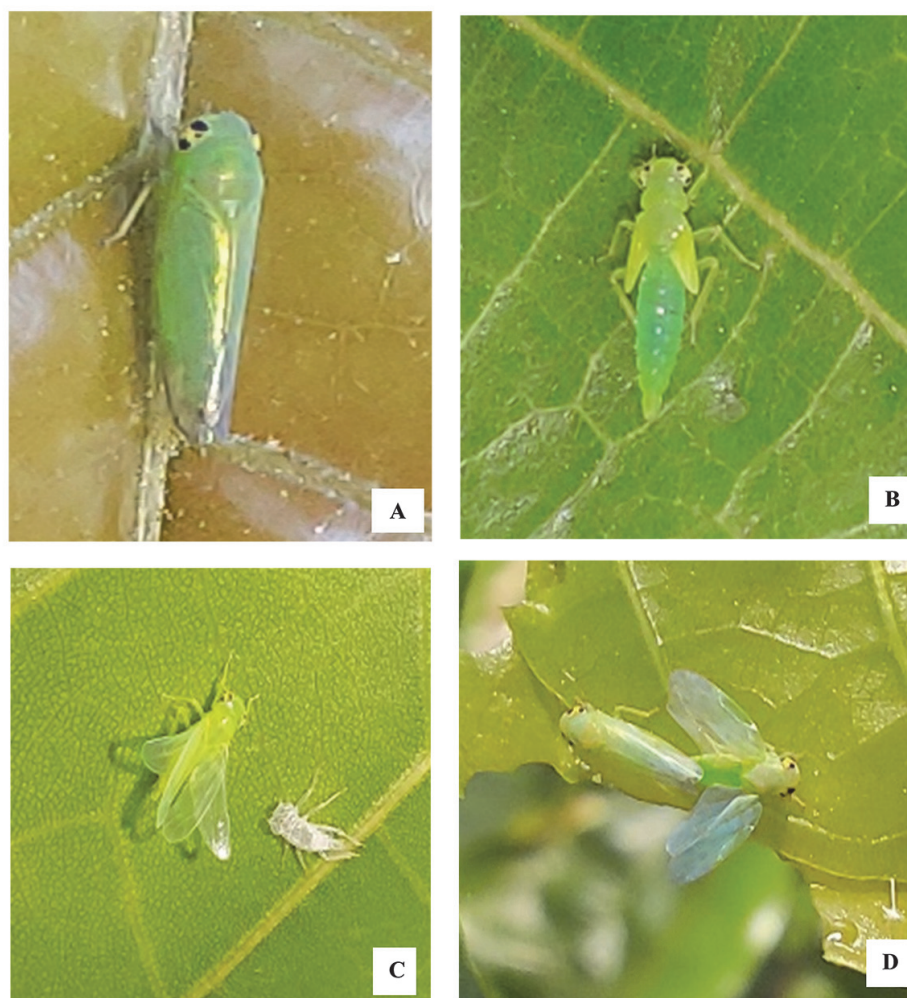


Fig. 4 *Rawania petasata* on *Pongamia pinnata*. A, adult; B, nymph; C, teneral adult; D, mating pair

and extended beyond pygofer (Fig. 3D); segment X, with numerous microsetae at ventral surface (Fig. 3F); segment X process (a pair of ventrolateral sclerotized processes arising on segment X), anteriorly directed ventral curved anteriorly forming a hook (Fig. 3G); subgenital plates, separate, elongate, (length: width = 4.93:1) (Fig. 5C), apices dark pigmented and C- group setae uniseriate (Fig. 3I); style with a group of setae at base of apophysis which is slender and smooth (Fig. 3E); aedeagus, pre-atrium long; shaft slightly curved with lateral extension at the base of shaft; pointed (triangular) structure/ process present near the base of the shaft in lateral view; shaft with a triangular process laterally on each side in dorsal view (Fig. 3 J & K).

Nymph: Light green body without black pigment or spots (Fig. 4B).

Measurements: Male: Length 3.2–3.5 mm; Head length 0.21–0.25 mm; Pronotum length 0.46–0.51 mm; Scutellum length 0.44–0.58mm; Face length 0.87–0.97 mm; Head width 0.83–0.87 mm; Vertex width 0.34–0.37mm and Pronotum width 0.85–0.89 mm (n =6).

Remarks. Gnaneswaran *et al.* (2008) identified this species as *Empoasca* sp. and reported this species on mango, rambuttan (*Nephelium lappaceum* L.) and cocoa (*Theobromae cacao* L.)

The specimens deposited in UASB, examined

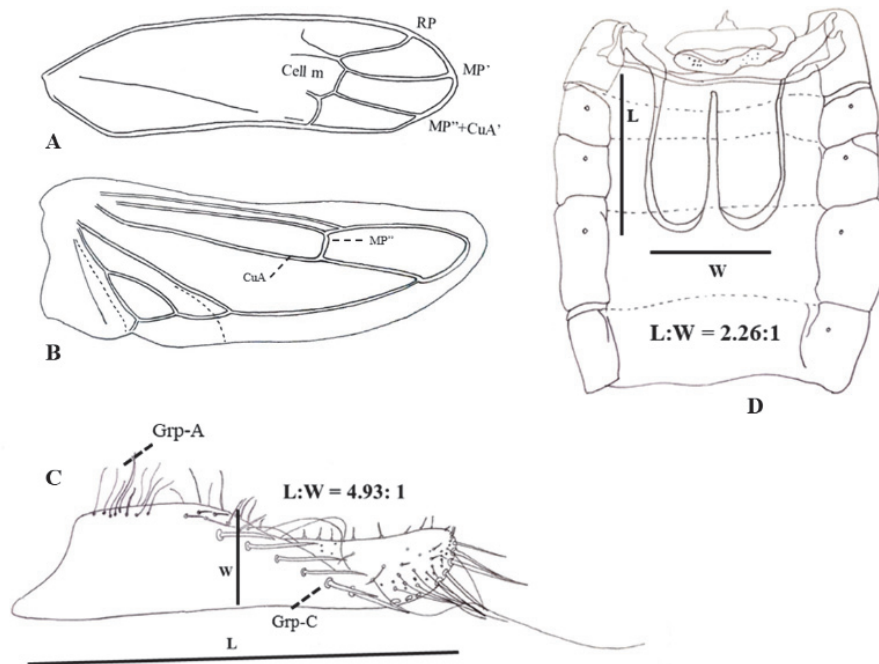


Fig. 5 A- forewing venation; B- hindwing venation; C- subgenital plate with length-width ratio; D- abdominal apodemes with length-width ratio

during this study confirm the identity of this as *Rawania petasata* Ghauri.

Host plants: *Pongamia* (*P. pinnata*), Cashew (*A. occidentale*), Mango (*M. indica*) and Rambutan (*N. lappaceum*).

Seasonal occurrence: Incidence of leafhoppers [*Empoasca motti* Pruthi, *Amrasca biguttula biguttula* (Ishida)], showed a positive correlation with maximum temperature (Sunil *et al.*, 2017), while a significant negative correlation was observed with mean relative humidity (Meena *et al.*, 2017). In the present study, both nymphs and adults were found on the tender leaves of *Pongamia* during March, indicating that their populations are higher during the new flush season, while they were absent during other seasons in the absence of new flushes. Previously, Viraktamath and Viraktamath (1985) had described three new species of mango hoppers namely, *Busoniomimus manjunathi*, *Idioscopus anasuyae* and *I. jayashriae* on mango in Karnataka indicating that mango as an important host plant for leafhoppers. Similarly, Gnaneswaran

et al., 2008 reported typhlocybae leafhoppers, *Motschulskyia (Togaritettix) serratus* from Japan, Korea, Pakistan, Australia, Taiwan, Thailand and Sri Lanka *Amrasca splendens* from India, Thailand and Sri Lanka and *Empoasca* sp. from Sri Lanka on mango. The present study marks the first report of *R. petasata* on mango in Karnataka adding significant number of leafhoppers on mango.

ACKNOWLEDGEMENTS

Authors thank Dr. C.A. Viraktamath (University of Agricultural Sciences, G.K.V.K., Bengaluru) for confirming the identity of the species and Dr. Igor Malenowsky, Moravian Museum, Brno, Czech Republic for studying the paralectotype males and providing images of male genitalia. Authors are grateful to the UAS, G.K.V.K., Bengaluru and Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga for providing facilities for research. Special thanks to P. Nirmala (ICAR-AINP-SAP, UAS, GKVK, Bengaluru) for technical support.

REFERENCES

- Dietrich C.H. (2005) Keys to the families of Cicadomorpha and subfamilies and tribes of Cicadellidae (Hemiptera: Auchenorrhyncha). *Florida Entomologist* 88 (4): 502–517.
- Distant W.L. (1908) The Fauna of British India, including Ceylon and Burma. Rhynchotha. Vol. IV. Homoptera and Appendix (Pt.). Vol. 4. Taylor & Francis. pp 501.
- Dmitriev D.A. (2022) 3I interactive keys and taxonomic databases. World Auchenorrhyncha Database. <http://dmitriev.speciesfile.org> (Accessed on 03-07-2025).
- Sohi A.S. and Dworakowska I. (1983) A review of the Indian Typhlocybinae (Homoptera: Cicadellidae) from India. *Oriental Insects* 17 (1):159–213.
- Ghuri M.S.K. (1963) New fig leafhoppers (Homoptera: Cicadelloidea) from India with redescription of allied species under new genera. *Annals and Magazine of Natural History* 6 (68): 465–475.
- Gnanesan R., Viraktamath C.A., Hemachandra K.S., Ahangama D., Wijayagundasekara H.N.P. and Wahundeniya I. (2008) Typhlocybinae leafhoppers (Hemiptera: Auchenorrhyncha: Cicadellidae) associated with horticultural crops in Sri Lanka. *Tropical Agricultural research* 20: 1–11.
- Knight W.J. (1965) Techniques for use in the identification of leafhoppers (Homoptera: Cicadellidae). *Entomologist's Gazette* 16 (4): 129–136.
- Meena A.K., Nagar R., Swaminathan R. and Viraktamath C.A. (2017) Population dynamics of two species of leafhoppers of the genus *Empoasca* Walsh, 1862 (Hemiptera: Auchenorrhyncha: Cicadellidae) on soybean in Rajasthan and their morphological characterization. *ENTOMON* 42 (4): 283–292.
- Melichar L. (1903) Homoptera- Fauna von Ceylon. iv+248. Verlag von Felix L. Dames, Berlin. iv+233pp.
- Oman P.W. (1949) The Nearctic leafhoppers (Homoptera: Cicadellidae). A generic classification and check list. *Memoirs of the Entomological Society of Washington* 3: 1–253.
- Qin D., Lu S. and Dietrich C.H. (2014) A key to the genera of *Empoascini* (Hemiptera: Cicadellidae: Typhlocybinae) in China, with descriptions of two new genera and two new species. *Florida Entomologist* 97 (4): 1493–1510.
- Sohi A.S. (1998) Taxonomic status of Indian Typhlocybinae (Homoptera: Auchenorrhyncha: Cicadellidae). *Journal of Insect Science* 11(2): 85–109.
- Sunil, Thippaiah M., Jagadish K.S. and Chakravarthy A.K. (2017) Seasonal incidence of sucking insect pests and their association with predatory coccinellid beetles on bitter melon. *ENTOMON* 42 (4): 329–334.
- Viraktamath S. and Viraktamath C.A. (1985) New species of *Busonominus* and *Idioscopus* (Homoptera, Cicadellidae, Idiocerinae) breeding on mango in south India. *ENTOMON* 10 (4): 305–311.
- Viraktamath S. and Viraktamath C.A. (1995) The leafhoppers (Homoptera: Cicadellidae) and their host plants in Karnataka. *Karnataka Journal of Agricultural Sciences* 8: 249–255.
- Webb M.D. and Xu Y. (2022) Review of the “red” *Empoascini* leafhoppers in the genera *Baguioidea* Mahmood, 1967, *Dayus* Mahmood, 1967 and *Homa* Distant, 1908 (Hemiptera, Cicadellidae, Typhlocybinae) from Asia and the West Pacific. *Zoosystema* 44 (22): 549–563.
- Xu Y., Wang Y.M., Dmitriev D.A., Dietrich C.H. and Qin D.Z. (2022) Revision of the genus *Homa* Distant (Hemiptera: Cicadellidae: Typhlocybinae). *Zootaxa* 5087 (1).

(Received September 12, 2025; revised ms accepted November 03, 2025; published December 31, 2025)

Characterization and use of green nanoparticles from the leaves of *Tiliacora acuminata* against larvae of vector *Culex quinquefasciatus* Say

Someshwar Singha*

Department of Zoology, Vivekananda Mahavidyalya, Burdwan, Sripally 713103, West Bengal, India.
Affiliated to The University of Burdwan, West Bengal, India.
Email: someshbio@gmail.com

ABSTRACT: In the present study, it was established that the efficacy of synthesized silver nanoparticles (AgNPs) from leaves of *Tiliacora acuminata* against 3rd instar larvae of the filarial vector, *Culex quinquefasciatus* mosquito. AgNPs was synthesized by 10 g of air-dried leaves of *T. acuminata* crushed and put into a beaker containing 100ml distilled water, boiled for 10 minutes at 60°C temperature and further treated with 10⁻³ M solution of silver nitrate and boiled at 60°C temperature. Nano particles were isolated by centrifuged the solution at 10,000 rpm for 15 minutes. Different concentrations of (1-5 ppm) of synthesized AgNPs were tested against *Cx. quinquefasciatus* larvae. Characterizations of AgNPs were carried out by UV-vis spectrophotometer, X-ray diffraction (XRD), scanning electron microscopy (SEM), and transmission electron microscopy (TEM) procedures. Cent percent mortality was observed at 5 ppm concentration of AgNPs against the 3rd instar larvae of *Cx. quinquefasciatus*. UV-vis spectrophotometer confirmed AgNPs from leaves of *T. acuminata* with a maximum absorption band at 450nm. Scanning electron microscopy confirmed the rough surface of the synthesized nanoparticles. From TEM analysis it was revealed that the shape of nanoparticles was ranging from oval to quasi spherical with an average diameter of 50-70nm. Their crystalline structure was confirmed by X-ray diffraction pattern. It is concluded that AgNPs from leaves of *T. acuminata* established excellent mosquito larvicidal activity against *Cx. quinquefasciatus*.

© 2025 Association for Advancement of Entomology

KEY WORDS: Silver nanoparticles, shape, size, crystalline structure, SEM, TEM, X-ray diffraction, LC₅₀ value, larvicidal activity

INTRODUCTION

Culex quinquefasciatus Say is vector of *Wuchereria bancrofti* causative agent of filariasis in tropical and subtropical region in world (Hill and Connelly, 2019). They can also transmit pathogens of avian malaria, Western equine encephalitis virus, St Louis encephalitis virus etc. Nearly about 120 million people around the world are under threat of

lymphatic filariasis, 44 million people have chronic symptoms of that disease (Bernhard *et al.*, 2003; Balasubramanian and Nikhil 2013). Every year, nearly about 700 million people are infected by mosquito borne disease, which are a major cause of human death (Tauber, 1997). Use of chemical insecticides on a routine basis also has a negative impact on human and animal health. It also increases insecticidal resistance property among

* Author for correspondence

vector population, environmental pollution and biomagnifications through food chain (Senthil-Nathan., 2020). Chemical insecticides are becoming increasingly ineffective against these insects; their indiscriminate use or high concentrations can cause severe adverse reactions. An urgent need for a new insecticide capable of overcoming insect resistance patterns and effectively combating disease-causing vectors is required (Balasubramanian and Nikhil 2013). Plants derived insecticides shows to have better result than chemical insecticide. Different phyto-chemical of plant origin including steroids, alkaloids, terpenoids and phenol have been promising result (Mathew *et al.*, 2009; Pavela, 2015). *Terminalia acuminata* belonging to the family Menispermaceae, is a wood climber mainly found in India, Sri lanka and South East Asia. In ayurveda this plant is used as an antidote for snake bites. Leaves of *T. acuminata* are ovate type with tapering at the tips. According to Singha *et al.* (2011), synergistic effect on mosquito larvicidal efficacy as observed when fruits of *Croton caudatus* with flowers of *T. acuminata* were applied on *Cx. quinquefasciatus* larvae. Tiliamasin, a bis benzyloquinoline alkaloids isolated from *T. acuminata* have larvicidal activity on *Cx. quinquefasciatus* mosquito (Sandhanam *et al.*, 2019).

This study aims to find plant-based silver nanoparticles as mosquito larvicidal to control *Cx. quinquefasciatus* as an alternate agent over chemical insecticides. The principal objective of the present study was to evaluate the mosquito larvicidal potential of synthesized silver nanoparticles of leaves of *T. acuminata* against *Cx. Quinquefasciatus* and proper characterization of nanoparticles through FTIR, XRD, SEM and TEM techniques. The present study was carried out at the Department of Zoology, Vivekananda Mahavidyalaya, Burdwan, West Bengal, India. *T. acuminata* plant were collected from bank of Hooghly, Hooghlyghat, West Bengal.

MATERIALS AND METHODS

Mosquito larvae were collected from drains surrounding Vivekananda Mahavidyalaya, Burdwan. Larvae were transferred into a plastic

tray and they were fed with a mixture of dog biscuits and yeast. Mosquito colonies were maintained at a temperature of 25-27°C with 75-85percent relative humidity. For the preparation of an aqueous solution 10 g leaves of *T. acuminata* were crushed and put in 100ml of double distilled water. 10^{-3} M silver nitrate was mixed with an aqueous solution of *T. acuminata* leaves. The mixture was stirred with vortex stirred for 5 minutes. Then the mixture was heated at 60°C temperature for 10 minutes. The colour of solution was changed from light green to the dark brown. It was centrifuged in a Remi research centrifugation instrument at 10000 rpm for 15 min. The pellet was isolated from dark brown solution and it scraped from the centrifuge tube, then dried in a vacuum desiccator. Isolated nanoparticles were used for a bioassay test (Halder *et al.*, 2013).

Larvicidal bioassay was conducted according to the protocol of WHO (2005) with slight modification. Third instar larvae of *Cx. quinquefasciatus* was used for bioassay test (Rawani *et al.*, 2013). Synthesized nanoparticles 1 to 5ppm concentrations were mixed with DMSO and added to each petri-dishes. Twenty five 3rd instar larvae of *Cx. quinquefasciatus* were transferred manually into glass Petri dishes containing 100ml of distilled water. After 24-hour mortalities were recorded against each concentration, the percentage of mortality was corrected using Abbott's formula (Abbott, 1987). All experiment was repeated three times. The control experiment was conducted without silver nanoparticles. Ms excel 2021 was used to determined average larval mortality.

An isolated pellet of silver nanoparticles was examined by using a UV-vis spectrophotometer (Shimadza, 2450, Japan). Synthesized nanoparticles show their unique surface Plasmon resonance (SPR) absorption when it was set to 1mm resolution with a range between 190 - 170 nm (Upstone, 2000). Crystalline property of synthesized nanoparticles could be confirmed by analyzed it through X-ray diffraction procedures. The isolated pellet was converted into powder for the X-ray diffraction test. The shape and size of the synthesized nanoparticles were determined by transmission

electron microscopy. The Techani 20-Philip TEM instrument was used to capture a TEM image and it was operated at 200 KV with beam current of 104.1 μ A. A copper grid containing 300 mesh sizes was used to dry the sample for overnight at 25°C temperature and in a vacuum condition. Scanning electron microscopy (SEM) was used for the determination of surface structure of the synthesized nanoparticles. Before SEM nanoparticles were coated with gold and the SEM instrument was operated at a voltage of 5 KV.

RESULTS AND DISCUSSION

Fresh leaves of *T. acuminata* stimulated bio reduction of Ag^+ to and their concentration was marked by change of solution colour from pale to deep brown colour. Further, it was confirmed by UV-vis spectrometer analyses. Characteristics surface Plasmon resonance band was observed at 450 nm wavelength (Fig. 1) for leaves of *T. acuminata*. Gope *et al.* (2023) observed a similar value. Crystalline structure of nanoparticles was confirmed by XRD pattern (Fig. 2). Different peaks at 2θ values of 37.92, 44.94, 54.4 and 64.21° of leaf *T. acuminata* synthesized AgNPs correspond to crystalline structure of silver nanoparticles. XRD pattern confirmed that leaf silver nanoparticles are crystalline in nature and have an organic coat (Kumar, 2017).

SEM was used to know the surface topography of synthesized nanoparticles (Fig. 3). It indicated that

the surface has a rough texture and is crystalline. Most of the nanoparticles were clumped by attached with each other and a few were free (Malla, 2023). By TEM analysis it was found that synthesized nanoparticles were spherical and quashi spherical in shape (Fig. 4). The average size of the nanoparticles was 50-60 nm in diameter and they were oval and quashi spherical in shape (Halder *et al.*, 2013). Different specifically functional groups in the plant extract of *T. acuminata* which were involved in reduction of Ag^+ to Ag^0 . According to Rodriguez *et al.* (2021) the bulk of the peaks were phyto-chemically present in the plant extract.

The larvicidal activity of synthesized nanoparticles from leaves of *T. acuminata* against 3rd instars larvae of *Cx. quinquefasciatus* revealed 60 percent mortality of 3rd instar larvae at 1ppm concentration of leaf AgNPs whereas 100 percent mortality was recorded at 5 ppm concentration of AgNPs

Mean larvicidal mortality ($\% \pm \text{SE}$ at 24 h) of 3rd instar larvae of *Cx. quinquefasciatus* using synthesized nanoparticles from leaves of *T. acuminata* was 60.00 ± 0.33 at 1ppm, 73.3 ± 0.88 at 2ppm, 86.6 ± 0.33 at 3ppm, 96.6 ± 0.33 at 4ppm and at 5ppm it was 100 ± 0.33 , while the control showed no mortality. LC_{50} value was 0.21ppm in AgNPs of leaves of *T. acuminata*. Probit and regression analyses of mortality rate of *Cx. quinquefasciatus* larvae by nanoparticles established LC_{50} as 0.21ppm under 24 hours of exposure (Regression equation- $Y=047X + 4.93$ and

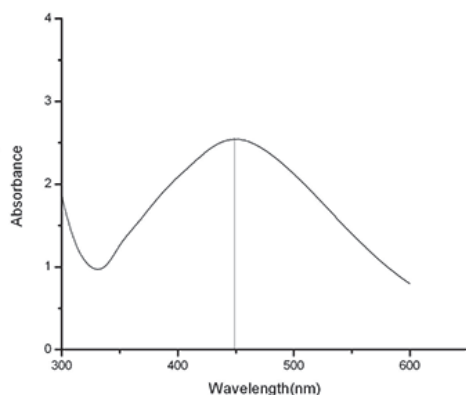


Fig.1 UV-vis spectral analysis of nanoparticles from leaves of *T. acuminata*

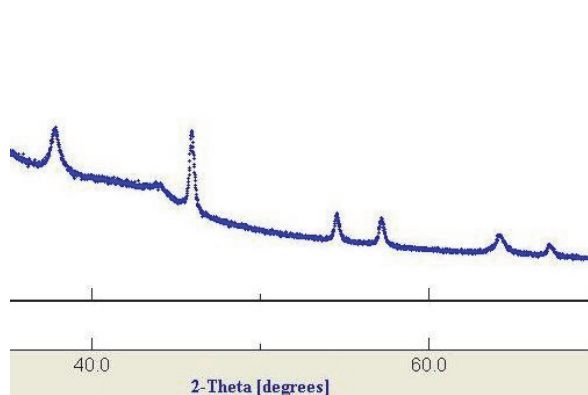


Fig. 2 XRD X-ray diffraction pattern of synthesized nanoparticles from leaves of *T. acuminata*

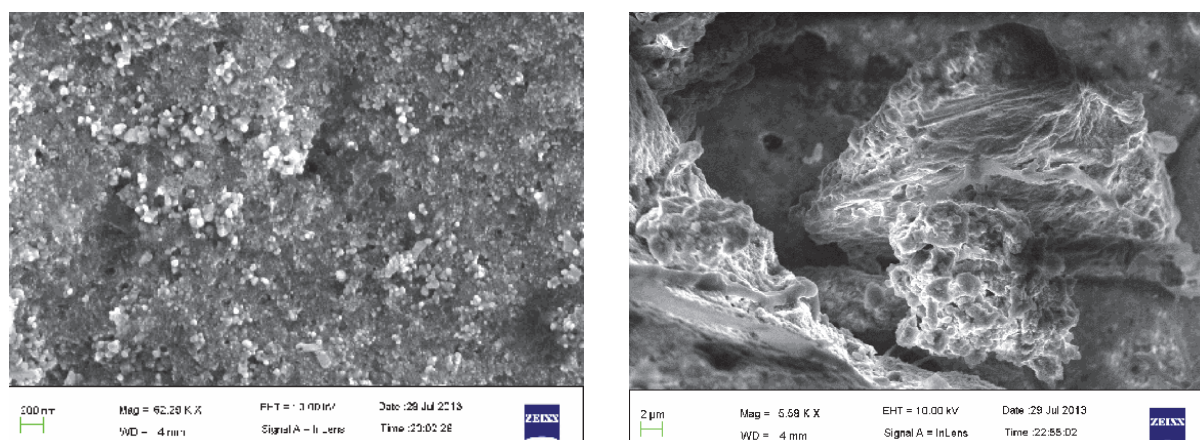


Fig. 3 SEM (scanning electron microscopy) of silver nanoparticles from leaves of *T. acuminata*

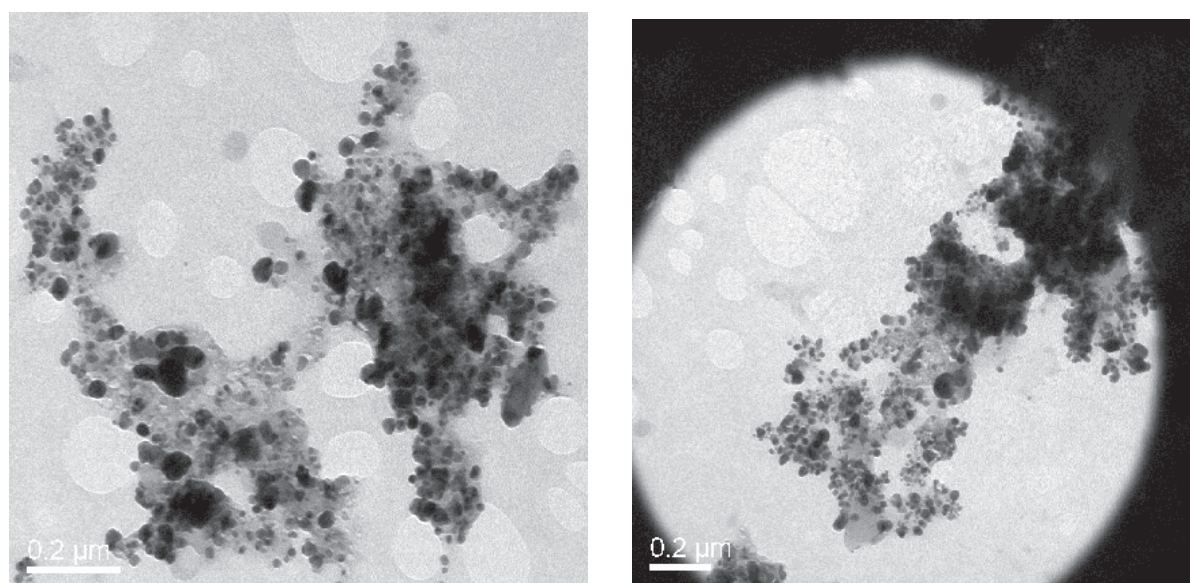


Fig. 4 TEM Transmission electron microscopy of silver nanoparticles from leaves of *T. acuminata*

R-value 0.93). According to Sutthanant *et al.* (2019) LC_{50} value of AgNPs synthesized from leaves of *Curcuma zedoaria* was 36.32ppm against 3rd instars larvae of *Cx. quinquefasciatus*. Gope *et al.* (2023) reported LC_{50} value of AgNPs at 2.09 ppm isolated from the leaf of *Phyllanthus acidus* against the same larvae. *Cx. quinquefasciatus* larvae died after treatment with AgNPs which was due to their deposition in the gut of the mosquito. AgNPs bind to the epithelial membrane of the

midgut and inactivate the midgut enzyme as well as the peroxidase effect, which may cause larval death (Madanagopal *et al.*, 2017). This study identified a safe environmentally friendly product i.e. green synthesized nanoparticles from the leaf of *T. acuminata* as a good larvicidal against *Cx. quinquefasciatus*. It can be an excellent choice as a larvicidal agent for the control of lymphatic filariasis through control of the *Cx. quinquefasciatus* population.

ACKNOWLEDGEMENTS

The author acknowledges to Prof. Ambarish Mukherjee, professor of Botany, The University of Burdwan, West Bengal, India for identifying the plant. The Author also acknowledges IIT, Kanpur, for Conducting TEM, SEM, XRD of sample provided and all my teaching faculties (Department of Zoology, Vivekananda Mahavidyalaya, Burdwan, West Bengal, India) for their normal support during this research work.

REFERENCES

- Abbott W.S. (1987) A Method of computing the effectiveness of an Insecticide. *Journal of American Mosquito Control Association* 3(2): 302–303.
- Balasubramanian R. and Nikhil T. L. (2013) Mosquito (Diptera: Culicidae) fauna in Alappuzha and Kottayam district of the Kerala state, South India. *Journal of Entomology and Zoology Studies* 1 (6): 134–137.
- Bernhard L., Bernhard P. and Magnussen P. (2003) Management of patients with lymphoedema caused by filariasis in north-eastern Tanzania. *Alternative approaches. Physiotherapy* 89: 743–749. doi: 10.1016/30031-9406(05)60500.
- Gope A., Rawani A. and Chatterjee P. (2023) Evaluation of mosquito larvicidal activity of green synthesized crystalline silver nanoparticles using leave and fruit extracts of *Phyllanthus acidus* L. *Notulae Scientia Biologicae* 15(4): 11722. doi: 10.15835/nsb15411722.
- Haldar K.M., Haldar B. and Chandra G. (2013) Fabrication, characterisation and mosquito larvicidal bioassay of silver nanoparticles synthesized from aqueous fruit extract of Putranjiva *Drypetes roxburghii* (Wall). *Parasitology Research* 112(4): 1451–1459. doi: 10.1007/s00436-013-3288-4.
- Hill S. and Connelly R. (2014) *Features Creatures: Southern house mosquito*, University of Florida, 2009. Retrieved 19 March 2014. doi:10.32473/edis-in837-2009.
- Kumar B., Smita K., Cumbal L. and Debut A. (2017) Green synthesis of silver nanoparticles using Andean blackberry extract. *Saudi Journal of Biological Sciences* 24(1): 45–50. doi: 10.1016/j.sjbs.2015.09.006.
- Madanagopal N., Lena M., Sumathi P. and Sundaravadivelan C. (2017) Effect of phytosynthesised silver nanoparticles on developmental stages of malaria vector, *Anopheles stephensi* and dengue vector, *Aedes aegypti*. *Egyptian Journal of Basic and Applied Science* 4: 212–218. doi:10.1016/j.ejbas.2017.04.005
- Malla R.K. and Chandra G. (2023) *Diospyros montana* mediated reduction, stabilization, and characterisation of silver nanoparticles and evaluation of their mosquitocidal potentiality against dengue vector *Aedes albopictus*. *Scientific Report* 13: 17202. doi: 10.22271/23487941.2023v10.i29.666.
- Mathew N., Anitha M.G., Bala T.S., Sivakumar S.M. and Narmadha R. (2009) Larvicidal activity of *Saraca indica*, *Nyctanthes arborescens*, and *Clitoria ternatea* extracts against three mosquito vector species. *Parasitology Research* 104: 1017–1025. doi: 10.1007/s00436-008-1284-x.
- Pavela R. (2015) Essential oils for the development of eco-friendly mosquito larvicides: A review. *Industrial Crops and Products* 76: 174–187. doi: 10.1016/j.indcrop.2015.06.050.
- Rawani A., Ghosh A. and Chandra G. (2013) Mosquito larvicidal and antimicrobial activity of synthesised nano-crystalline silver particles using leaves and green berry extract of *Solanum nigrum* L. (Solanaceae: Solanales). *Acta Tropica* 128(3): 613–622. doi: 10.1016/j.actatropica.2013.09.007.
- Rodriguez Y.F.B., Reyes C.A.R., Campos J.S.T., Hernandez J.G. and Gamir J.R. (2021) Infrared spectroscopy coupled with chemometrics in coffee post-harvest processes as complement to the sensory analysis. *Food Science and Technology* 145: 111304. doi: 10.1016/j.lwt.2021.111304.
- Sandhanam S.D., Pathalam G., Antony S., Sarnuel R., Michael G.P., Kedike B., Pandikumar P., Savarimuthu I. and Al-Dhabi N.A. (2019) Effect of tiliamosins, a bis, benzyliso quinoline alkaloid isolated from *Tiliacora acuminata* (Lam.) Hook.f and Tham on the immature stage of filarial mosquito *Culex quinquefasciatus* say (Diptera: Culicidae). *Experientia Parasitology* 204: 107719. doi: 10.1016/J.exppara.2019.107719.
- Senthil-Nathan S. (2020) A review of resistance mechanisms of synthetic insecticides and botanicals, phytochemicals, and essential oils as alternative larvicidal agents against

- mosquitoes. *Frontiers in Physiology* 25(10): 1591. doi: 10.3389/fphys.2019.01591.
- Singha S., Banerjee S. and Chandra G. (2011) Synergistic effect of *Croton caudatus* (fruits) and *Tiliacora acuminata* (flowers) extract against filarial vector *Culex quinquefasciatus*. *Asian Pacific Journal of Tropical biomedicine* (2): S159–S164. doi. 10.1016/s2221-1691(11)60147-0.
- Sutthanont N., Attrapadung S. and Nuchprayoon S. (2019) Larvicidal activity of synthesised silver nanoparticles from *Curcuma zedoaria* essential oil against *Culex quinquefasciatus*. *Insects* 10(1): 27. doi: 10.3390/insects10010027.
- Taubes G.A. (1997) mosquito bites back. *New York Times Magazine* 24: 40–46.
- Upstone S.L. (2000) Ultraviolet/ Visible Light Absorption Spectrophotometry. In: *Clinical chemistry*. John Wiley & Sons Ltd, Chichester. doi.10.1002/9780470027318.90547.
- WHO (2005) World Health Organization Guideline for testing Mosquitoes Adulticides for Indoor Residual Spraying and Treatment of Mosquito Nets, Geneva: World Health Organization.

(Received July 16, 2025; revised ms accepted October 24, 2025; published December 31, 2025)

Notes on plants visited by genus *Paragus* Latreille, 1804 (Diptera, Syrphidae) with an updated key to Indian species

Panchanan Parui, Jayita Sengupata*, Mousumi Chowdhury, Bristi Roy, Sudip Mondal, Suman Kumar Saha, Moubanti Das, Atanu Naskar and Dhriti Banerjee

Zoological Survey of India, New Alipore, Kolkata 700053, West Bengal, India
Email: jayitasengupata9@gmail.com

ABSTRACT: Among Diptera, hoverflies (Syrphidae) are important flower visitors, with the genus *Paragus* Latreille, 1804, widely distributed worldwide. Of more than 100 described species, 11 valid species are currently known from India, to which this study adds one additional species. An updated list of plant associations for Indian *Paragus*, including 13 newly recorded plants, along with a taxonomic key to the Indian *Paragus*, is presented. This study contributes to the taxonomic knowledge of Indian hoverflies and highlights their ecological role as pollinators.

KEY WORDS: Flower flies, pollinator, identification, new record

INTRODUCTION

Order Diptera constitutes one of the most diverse and ecologically significant groups of flower-visiting insects worldwide, often contributing proportions of floral visitors comparable to those of Hymenoptera and even dominating the pollinator assemblage in certain habitats, particularly at higher altitudes and latitudes (Klecka *et al.*, 2018). At least 86 dipteran families have been recorded visiting flowers, and more than 1100 plant species from 172 families are known to receive floral visits from flies (Inouye *et al.*, 2015). In the Indian context, Mitra (2010) reported 116 dipteran species belonging to 16 families associated with 92 flowering plant species from 39 families, demonstrating that Syrphidae is the most prominent flower-visiting family- recorded from 46 plant species, while Asteraceae stands out as the most frequently visited plant family. Notably, Mitra (2010) also reported

five species of the genus *Paragus* Latreille, 1804, exceeding the number recorded for any other syrphid genus in the dataset, indicating a high representation of *Paragus* in the documented floral visitation records of Indian Syrphidae. Owing to their predatory larvae, which feed primarily on aphids and other soft-bodied pests, species of *Paragus*, also hold considerable economic importance in agricultural and horticultural systems, serving as biological control agents (Thompson and Ghorpade, 1992).

The genus *Paragus* comprises over 100 described species and is distributed across all continents except Antarctica (Tot *et al.*, 2018; Barahona-Segovia *et al.*, 2021). The genus is currently classified into four subgenera: *Afroparagus* Vujic & Radenkovic, 2008; *Pandasyopthalmus* Stuckenberg, 1954a; *Paragus*; and *Serratoparagus* Vujic & Radenkovic, 2008 (Vujic

* Author for correspondence

et al., 2008; Tot *et al.*, 2018). The Oriental Region harbours 14 species of *Paragus*, belonging to three subgenera— *Pandasyopthalmus*, *Paragus*, and *Serratoparagus* (Thompson and Ghorpade, 1992), these three subgenera are also documented from India.

The Indian hoverfly fauna currently comprises 366 species in 77 genera, of which *Paragus* includes 12 species (Sengupta *et al.*, 2024). However, one of these species, *Paragus ambalaensis* Sodhi & Singh, 1991, was treated as *species incertae sedis* by Ghorpade (2014) and is therefore not considered a valid member of the Indian *Paragus* in the present study. Accordingly, *P. ambalaensis* is excluded from the current account. This study further restores one *Paragus* species to the Indian syrphid fauna that was previously known but omitted from the updated catalogue of Sengupta *et al.* (2024). Additionally, a consolidated list of recorded plant species visited by *Paragus* is provided, including 13 newly recorded floral associations for the genus. A brief generic diagnosis, an updated identification key to the Indian *Paragus* and representative photographs of floral visitation are also presented to facilitate accurate identification and to promote further ecological and taxonomic research on this group.

MATERIAL AND METHODS

The specimens were collected with sweep nets from agricultural lands of Bangur locality, North 24 Parganas, West Bengal, with an approximate geo coordinate range of 22°36'26"N; 88°24'37"E and approx. elevation of 23 meter in India. All the collected specimens were pinned, stretched, and examined under the Leica EZ4 microscope. The taxonomic key to the Indian species of *Paragus* was constructed based on Brunetti (1923), Thompson and Ghorpade (1992), Vujic *et al.* (2008), Haarto (2014), and Tot (2021), and the morphological terminologies follow van Steenis *et al.* (2023). The identified specimens were deposited in the National Zoological Collection of the Diptera section, Zoological Survey of India, Kolkata. The visited plants have been identified by plant taxonomist from the Indian Council of Forestry Research and Education (ICFRE).

Abbreviations used in the text: cell: bm— basal medial cell, c— costal cell, dm— discal medial cell; crossvein: dm-m— apical crossvein between M₄ (4th branch of medial vein) and M (medial vein).

RESULTS AND DISCUSSION

Genus *Paragus* Latreille, 1804

Diagnosis: Head broader than thorax; face produced into a central knob; eyes pilose; abdomen either entirely black or black with white or red fasciae; abdominal tergum 1 well developed, terga minutely punctate; r-m crossvein positioned before the middle of cell dm.

Key to the Species of Indian *Paragus* Latreille, 1804

1. Compound eye uniformly pilose, not forming vittae of contrasting colour; scutellum entirely black (Subgenus *Pandasyopthalmus* Stuckenberg, 1954a).....3
 - Pilosity of compound eyes arranged in two or more vertical vittae of different colours or reflecting light differently; scutellum entirely black or black with apex narrowly yellow or reddish 2
2. Eye pilosity forming two white vittae; posterior margin of scutellum not serrated (Subgenus *Paragus* Latreille, 1804) 8
 - Eye pilosity forming three distinct white vittae; posterior margin of scutellum distinctly serrated (Subgenus *Serratoparagus* Vujic & Radenkovic, 2008).....9
3. Face entirely yellow, without median black vitta 4
 - Face with distinct median black vitta 5
4. Terga shining black, without any coloured markings; metatarsus distinctly incrassate*atratus* Meijere, 1906
 - Tergum 3 with paired yellow maculae; metatarsus not incrassate.....*P. annandalei* Ghorpade, 1992
5. Postpedicel three times longer than wide; sternum

Table 1. Floral visitation records of the species of Indian *Paragus*.

No.	Species	Plants	Indian records	References
i.	<i>Paragus atratus</i> Meijere, 1906	<i>Solanum nigrum</i> (Solanaceae)	Assam, Uttarakhand	Mitra and Banerjee, 2007
ii.	<i>Paragus politus</i> Wiedemann, 1830	<i>Amaranthus spinosus</i> (Amaranthaceae), <i>Cynodon</i> sp. (Poaceae), <i>Lantana camara</i> (Verbenaceae), <i>Solanum nigrum</i> (Solanaceae)	Assam, Himachal Pradesh, Meghalaya, Punjab, Sikkim, Uttarakhand, West Bengal, Jammu & Kashmir	Datta and Chakraborty, 1984; Mitra and Banerjee, 2007
iii.	<i>Paragus annandalei</i> Ghorpade, 1992	<i>Solanum nigrum</i> (Solanaceae)	Himachal Pradesh, Jammu & Kashmir, Uttarakhand.	Datta and Chakraborty, 1984
iv.	<i>Paragus haemorrhous</i> Meigen, 1822	<i>Rubus fruticosus</i> agg. (Rosaceae)	West Bengal	Herkenrath, 2014
v.	<i>Paragus rufocinctus</i> (Brunetti, 1908)	<i>Amaranthus spinosus</i> (Amaranthaceae), <i>Cynodon</i> sp. (Poaceae), <i>Solanum nigrum</i> (Solanaceae)	Arunachal Pradesh, Assam, Bihar, Himachal Pradesh, Karnataka, Jammu & Kashmir, Kerala, Meghalaya, Punjab, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal.	Datta and Chakraborty, 1984
vi.	<i>Paragus tibialis</i> (Fallén, 1817)	<i>Nicotiana tabacum</i> (Solanaceae), <i>Solanum nigrum</i> (Solanaceae), <i>Amaranthus spinosus</i> (Amaranthaceae)	Arunachal Pradesh, Bihar, Himachal Pradesh, Jammu & Kashmir, Kerala, Meghalaya, Tripura, Uttar Pradesh, West Bengal.	Krsteska, 2008; Mitra and Banerjee, 2007
vii.	<i>Paragus auritus</i> Stuckenberg, 1954b	<i>Spermacoce</i> sp. (Rubiaceae), <i>Guizotia abyssinica</i> (Asteraceae), <i>Mangifera indica</i> (Anacardiaceae)	Andhra Pradesh, Karnataka, Odisha, Tamil Nadu, West Bengal.	Thompson and Ghorpade, 1992
viii.	<i>Paragus bicolor</i> (Fabricius, 1794)	<i>Lantana camara</i> (Verbenaceae), <i>Solanum nigrum</i> (Solanaceae)	Jammu & Kashmir	Datta and Chakraborty, 1984
ix.	<i>Paragus crenulatus</i> Thomson, 1869	<i>Phyla nodiflora</i> (Verbenaceae)*, <i>Persicaria</i> sp. (Polygonaceae)*, <i>Acmella uliginosa</i> (Asteraceae)*, <i>Ocimum</i> sp. (Lamiaceae)*, <i>Croton bonplandianus</i> (Euphorbiaceae)*, <i>Mikania micrantha</i> (Asteraceae)*, <i>Eclipta prostrata</i> (Asteraceae)*, <i>Mimosa pudica</i> (Fabaceae)*, <i>Ipomoea aquatica</i> (Convolvulaceae)*, <i>Lippia alba</i> (Verbenaceae)*	Assam, Bihar, Kerala, Karnataka, Maharashtra, Tamil Nadu, Tripura, West Bengal	Present study
x.	<i>Paragus quadrifasciatus</i> Meigen, 1822	<i>Cynodon</i> sp. (Poaceae)	Jammu & Kashmir	Datta and Chakraborty, 1984

xi.	<i>Paragus serratus</i> (Fabricius, 1805)	<i>Anacardium occidentale</i> (Anacardiaceae), <i>Euphorbia milii</i> (Euphorbiaceae)*, <i>Tridax procumbens</i> (Asteraceae), <i>Impatiens balsamina</i> (Balsaminaceae)*, <i>Ageratum conyzoides</i> (Asteraceae), <i>Lantana camara</i> (Verbenaceae), <i>Oxalis stricta</i> (Oxalidaceae)*, <i>Persicaria orientalis</i> (Polygonaceae), <i>Solanum nigrum</i> (Solanaceae), <i>Mangifera indica</i> (Anacardiaceae), <i>Wedelia calendulacea</i> (Asteraceae)	Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Goa, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Mizoram, Odisha, Punjab, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal, Dadra Nagar Haveli, Daman & Diu, Delhi, Jammu & Kashmir, Lakshadweep	Thompson and Ghorpade, 1992; Datta and Chakraborty, 1984; Mitra and Banerjee, 2007
xii.	<i>Paragus yerburiensis</i> Stuckenberg, 1954b	<i>Ageratum conyzoides</i> (Asteraceae), <i>Anacardium occidentale</i> (Anacardiaceae), <i>Euphorbia hirta</i> (Euphorbiaceae), <i>Guizotia abyssinica</i> (Asteraceae), <i>Mangifera indica</i> (Anacardiaceae), <i>Mimosa pudica</i> (Fabaceae), <i>Vicoa indica</i> (Asteraceae)	Andhra Pradesh, Bihar, Karnataka, Kerala, Madhya Pradesh, Odisha, Tamil Nadu, Uttar Pradesh, Uttarakhand, West Bengal, Delhi	Thompson and Ghorpade, 1992

*indicates newly recorded floral association

3 trapezoidal.....*P. rufocinctus* (Brunetti, 1908)

– Postpedicel twice as long as wide, sternum 3 squarish.....6

6. Vena spuria long, extends beyond cell dm and crossvein dm-m (Vujic *et al.*, 2008: Fig. 22); postgonite small, convex dorsally (Haarto, 2014: Fig. 2).....*P. haemorrhous* Meigen, 1822

– Vena spuria short, ending before cell dm and crossvein dm-m (Thomson and Ghorpade, 1992: Fig. 1; Tot, 2021: Fig. 8); Postgonite large, concave dorsally (Thomson and Ghorpade, 1992: Fig. 18; Haarto, 2014: Fig. 4).....7

7. Postgonite bent at a smaller angle and measures approximately equal in length as hypandrial theca (Haarto, 2014: Fig. 4).....*P. tibialis* (Fallén, 1817)

– Postgonite bent at a larger angle and approximately twice as long as the hypandrial theca (Thomson and Ghorpade, 1992: Fig. 18).....*P. politus* Wiedemann, 1830

8. Wing extensively bare, cell c and bm bare; tergum 7 in female, with a pair of prominent tubercles.....*P. quadrifasciatus* Meigen, 1822

– Wing extensively microtrichose, apical ½ or more

of cell c microtrichose; apical ¼ of cell bm microtrichose; tergum 7 in female, without tubercles *P. bicolor* (Fabricius, 1794)

– Tergum 1 nearly all black, especially behind transverse ridge, only narrowly reddish on posterior margin; wing nearly completely bare, hyaline, with only a few scattered microtrichia apically; profemur without black markings, even at base*P. yerburiensis* Stuckenberg, 1954b

– Tergum 1 extensively reddish medially, not black behind transverse ridge; profemur variably black or not at all 10

9. Large species (7.3–9.0 mm); antennae longer than face; profemur wholly brownish-yellow, with no black markings; metatibia without dark-brown annulus subapically, sometimes a brownish tinge may be present*P. auritus* Stuckenberg, 1954b

– Smaller species (5.1–6.8 mm); antennae as long as face; profemur at least basally brownish-black or black; metatibia with distinct dark-brown annulus subapically.....11

10. Wing suffused with yellowish-brown at least in cell c; metafemur almost entirely dark brown; mesonotal pile long; terga with conspicuous,

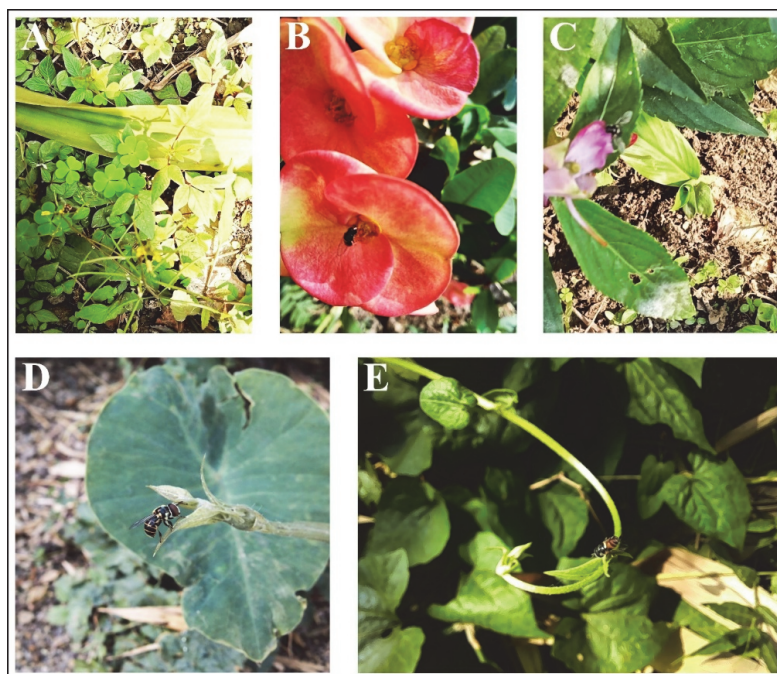


Fig. 1 A–E. Adult flies of the subgenus *Serratoparagus* visiting different plants. A. *Oxalis stricta*; B. *Euphorbia milii*; C. *Impatiens balsamina*; D–E. *Mikania micrantha*.

reclinate black pile
*P. crenulatus* Thomson, 1869
 – Wing clear, never suffused with yellowish-brown; metafemur yellow, with narrow dark brown annulus; mesonotal pile short; terga with sparse and inconspicuous black pile
*P. serratus* (Fabricius, 1805)

A total of 12 species of the genus *Paragus* were presented along with their associated host plants (Table 1). The present study highlights the diversity of plant associations among *Paragus* species. Species of the subgenus *Serratoparagus* (Fig. 1) tend to be more generalist, visiting multiple plant families, which may reflect their ecological flexibility and adaptability to diverse habitats. In contrast, some species of the subgenus *Paragus* appear more selective, feeding on specific plants, which could influence their local distribution and abundance. The present findings extend the previous reports by Datta and Chakraborty (1984), Thompson and Ghorpade (1992), and Mitra (2010). The broad host range observed in species like *P. serratus* and *P. crenulatus* suggests potential for their use in pollination studies and biological control

programs. However, the limited number of plant records for species such as *P. haemorrhous* and *P. quadrifasciatus* highlights the need for additional field observations to enhance the understanding of the ecological interactions within this genus.

ACKNOWLEDGEMENTS

The authors are grateful to the Director, Zoological Survey of India, for providing all the necessary facilities required for this study. The authors are also thankful to the members of the Diptera Section, Zoological Survey of India, Kolkata, for their constant support and help.

REFERENCES

- Barahona-Segovia R.M., Riera P., Paninao-Monsalvez L., Guzmán V.V. and Henriquez-Piskulich P. (2021) Updating the knowledge of the flower flies (Diptera: Syrphidae) from Chile: Illustrated catalogue, extinction risk and biological notes. *Zootaxa* 4959 (1): 1–178.
- Brunetti E. (1908) Notes on Oriental Syrphidae with descriptions of new species. Part I. Records of the Indian Museum 2 (1): 49–96.
- Brunetti E. (1923) The Fauna of British India, Including

- Ceylon and Burma. Diptera, Diptera. Vol. 3. Pipunculidae, Syrphidae, Conopidae, Oestridae. Taylor & Francis, London. 424 pp.
- Datta M. and Chakraborti M. (1984) Insecta: Diptera. Records of the Zoological Survey of India, 82 (1): 231–252.
- Fabricius J.C. (1794) Entomologia systematica emendata et aucta. Secundum classes, ordines, genera, species adjectis synonymis, locis, observationibus, descriptionibus. Tom. IV. C.G. Proft, Fil. et Soc., Hafniae [= Copenhagen]. 472pp.
- Fabricius J.C. (1805) Systema antliatorum secundum ordines, genera, species adiecta synonymis, locis, observationibus, descriptionibus. C. Reichard, Brunsvigae [= Brunswick]. xiv + [15]–372 + [1] + 30pp.
- Fallén F.C. (1817) Syrphici Sveciae. In: Diptera Sveciae / descripta a Carlo Frederico Fallén. Literis Berlingianis, Lundae. pp23–62.
- Ghorpade K. (2014) An updated check-list of the Hoverflies (Diptera-Syrphidae) recorded in the Indian subcontinent. Colemania 44: 1–30.
- Haarto A. (2014) Identification of the Finnish species of *Paragus* Latreille, 1804 subgenus *Pandasyopthalmus* Stuckenberg, 1954 (Diptera, Syrphidae). Sahlbergia 20(2): 2–5.
- Herkenrath P. (2014) The Hoverflies (Syrphidae) of Fen Drayton Lakes. Nature in Cambridgeshire 56: 29–20.
- Inouye D.W., Larson B.M., Ssymank A. and Kevan P.G. (2015) Flies and flowers III: ecology of foraging and pollination. Journal of Pollination Ecology 16: 115–133.
- Klecka J., Hadrava J., Biella P. and Akter A. (2018) Flower visitation by hoverflies (Diptera: Syrphidae) in a temperate plant-pollinator network. PeerJ 6: e6025.
- Krsteska V. (2008) Population dynamics of aphidophagous hoverflies on tobacco plants. Acta entomologica serbica 13(1/2): 27–41.
- Latreille P.A. (1804) Tableau méthodique des insectes. In: Société de Naturalistes et d'Agriculteurs (Ed.), Nouvelle dictionnaire d'Histoire naturelle. Vol. 24. F. Dufart, Paris. pp129–200.
- Meigen J.W. (1822) Systematische Beschreibung der bekannten europäischen zweiflügeligen Insekten. Vol. 3. Schultz Wundermann, Hamm. 416pp.
- 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(2): 95–107.
- Mitra B. and Banerjee D. (2007) Fly pollinators: assessing their value in biodiversity conservation and food security in India. Records of the Zoological Survey of India, 107 (part 1): 33–48.
- Sengupta J., Roy B., Naskar A. and Banerjee D. (2024) A Catalogue of Indian Hoverflies (Insecta: Diptera: Syrphidae). Zoological Survey of India, Kolkata. Occasional paper No. 420: 1–198.
- Stuckenberg B.R. (1954a) Studies on *Paragus*, with descriptions of new species (Diptera, Syrphidae). Revue de Zoologie et de Botanique Africaines 49: 97–139.
- Stuckenberg B.R. (1954b) The *Paragus serratus* complex, with descriptions of new species (Diptera: Syrphidae). Transactions of the Royal entomological Society of London 105 (17): 393–422.
- Thompson F.C. and Ghorpade K. (1992) A new coffee predator with notes on other oriental species of *Paragus* (Diptera: Syrphidae). Colemania 5: 1–24.
- Thomson C.G. (1869) Diptera. Species nova descriptis. In: Kongliga Svenska Vetenskaps—Akademien, Kongliga svenska fregatten Eugenies resa omkring jorden. Pt. 2. Zoologie.[Sec.] 1. Insekter. P.A. Norstedt & Soner, Stockholm. 617pp.
- Tot T. (2021) Taksonomija i Distribucija *Tribusa Paragini* Goffe, 1952 (Diptera: Syrphidae) (Doctoral dissertation, University of Novi Sad (Serbia)).
- Tot T.J., Nedeljkovic Z.S., Radenkovic S.R. and Vujic A.A. (2018) Taxonomic study of the genus *Paragus* Latreille, 1804 (Diptera: Syrphidae) in the collections of the Department of Biology and Ecology at the University of Novi Sad (FSUNS), Serbia. Zbornik Matice srpske za prirodne nauke (135): 119–127.
- Vujic A., Ståhls G., Rojo S., Radenkovic S. and Simic S. (2008) Systematics and phylogeny of the tribe Paragini (Diptera: Syrphidae) based on molecular and morphological characters. Zoological Journal of the Linnean Society, 152: 507–536.
- Wiedemann C.R.W. (1830) Aussereuropäische zweiflügelige Insekten. Zweiter Theil. Schulz, Hamm. 684pp.

Description of a new species of *Hyospila* Guenee, 1852 (Lepidoptera, Erebidae) from Kerala, India

P.K. Adarsh, Joslin Treesa Jacob and Abhilash Peter*

*Entomo Taxonomy Lab, Department of Zoology, Christ College (Affiliated to University of Calicut),
Irinjalakuda 680125, Thrissur, Kerala, India.
Email: abhilashpeter@christcollegeijk.edu.in*

ABSTRACT: A new species, *Hyospila polliceae* Abhilash & Adarsh **sp. nov.** of family Erebidae has been described from Kerala. All the specimens for this study were collected from the various localities of the Kerala state using light traps operated from dusk to dawn. The adult male and male genitalia features are illustrated to differentiate the new species with its congeners. An updated worldwide checklist for the species of *Hyospila* Guenee is also provided. © 2025 Association for Advancement of Entomology

KEY WORDS: Singappara, Erebinae, *polliceae*, costal process, Acantholipini, Pattikkad

INTRODUCTION

Erebidae is one of the most diverse families of moths in the superfamily Noctuoidea. In recent decades, there has been much debate regarding the taxonomic status and subfamilies that belong to the family Erebidae. However, a thorough molecular analysis conducted by Zahiri *et al.* in 2011 and 2012 on both Noctuoidea and Erebidae has confirmed the family status and subfamily level classification of Erebidae. Erebinae is one of the largest subfamilies of Erebidae, including more than 250 species from India (Kuniyil and Peter, 2022; Singh *et al.*, 2024). *Hyospila* is a genus of the Erebinae subfamily, which is most widely distributed in the tropics of South and Southeast Asia, as well as in Australasia. Earlier the genus was placed in various subfamilies such as Ophiderinae (Poole, 1989), later in Calpinae (Kristensen, 2003). According to Koshkin and Golovizin (2022) there has been a report of the species *Hyospila bolinoides*

migrating from China to Russia. Also recorded are a few species from South America (Moschler, 1880). The genus *Moepa* Walker and *Orrea* Walker were later synonymized under the genus *Hyospila* (Poole, 1989). Prior to the placement of the genus in the Acantholipini tribe (Kononenko and Pinratana, 2013), the genus was placed under miscellaneous genera by Holloway (2005). So far, the genus comprises 12 valid species worldwide; however, *Hyospila bolinoides* is the only species reported from India. In this information, a new species of *Hyospila* from India by analyzing the male genitalia is reported, with an updated worldwide checklist of the genus *Hyospila*.

MATERIALS AND METHODS

The adult specimens were collected from different localities of the Kerala state. The light trap method using a 160W mercury vapour lamp was used for moth collection. The collected specimens were

* Author for correspondence

killed using ethyl acetate, pinned and dried. It was then labelled and stored in airtight insect boxes. To study the genitalia structure, the last four abdominal segments were removed from the specimen and soaked in 10 per cent KOH solution overnight. It was then washed with water and dissected under the Labomed Luxeo 4D stereomicroscope. The genitalia images were taken using a Leica S8 APO stereomicroscope attached to the camera and Leica Montage software. The specimens were identified using Holloway (2005), Hampson (1894) and other published literature. The items under inspection were registered and deposited in the insect collection of WGRC, Zoological Survey of India, Kozhikode, Kerala. The genitalia and wing venation studies were conducted in accordance with Robinson (1976) and Zimmerman (1978). The terminology used in the genitalia description is based on Klotz (1970) and Orhant (1986, 2012).

RESULTS AND DISCUSSION

The adult morphology and genitalia analysis of *Hypospila* moths collected from various localities of Kerala state revealed a new species, *Hypospila polliceae* Abhilash & Adarsh sp. nov.

Systematic status

Superfamily: Noctuoidea Latreille; Family: Erebiidae Leach; Subfamily: Erebiniae Leach; Tribe: Acantholipini Fibiger & Lafontaine; Genus: *Hypospila* Guenee, 1852

Distribution: Russia, Japan South Korea, China, Taiwan, India, Sri Lanka, Nepal, Thailand, Cambodia, Vietnam, Malaysia, Indonesia, New Guinea, Australia, New Caledonia and Suriname (South America) (Moschler, 1880; Koshkin and Golovizin, 2022).

Taxonomic Note: *Hypospila* genus can be easily identified by the following characters: long, crenate antennae with densely packed cilia; palpi directed forward, conical and acute at tip; palpi brownish black coloured on upper side and clear white at lower side; thorax smoothly hairy and fairly wide; male abdomen extends well beyond hindwing and abdomen never extend beyond hindwing in female; terminal part of abdomen sub conical, smooth with

bunch of elongate hairs; legs long with long spurs; forewing elongated and apically produced; hindwing short and bit broad; wing patterns continue across both wings; a fine zigzag postmedial line, a straight distinct submarginal oblique line divides wing area to basal pale with gradually getting darker towards base and distal dark area; uncus apex possess hastate dorsal component and a bilobed ventral component with a patch of setae on each lobe; valvae simple, elongated and ovate with a broadly lobed costal process; juxta small unmodified.

***Hypospila polliceae* Abhilash & Adarsh sp. nov.**

urn:lsid:zoobank.org:pub:85B487CE-5584-4562-A486-E001B06D882A

Holotype (Fig. 2)

Diagnosis: Antenna long crenate, two third length of forewing costa; proboscis small and moderately developed; eyes smooth blackish brown; palpi three segmented, first segment upper side blackish brown lower side white; 2nd segment upwardly directed, blackish brown, reaching just above the vertex; 3rd segment half the length of 2nd segment, projecting outward, blackish brown towards base with pale white shade in the end; vertex covered with tuft of comparatively longer hair projecting outward to head; thorax, tegula and collar uniformly brown scaled without any markings; abdomen long, reaching well beyond the hindwing in male; legs long, hairy, blackish brown on outer side, mid tibia with one pair of elongated spur.

Wing maculation: Forewing long, acute, apex produced, comparatively long and straight costa; a black discontinuous indistinct antemedial line; forewing reniform pale centered with blackish halo, diffuses weakly towards costa; an indistinct zigzag postmedial black line present; a prominent, straight, basal pale brown and distal dark brown oblique submarginal line divide wing area; outer margin of submarginal line bordered with black scales and pale inner scales; median and submarginal lines continuous across both wings; hindwing short and broad; inner margin clothed with dense white hairs; anal margin and basal part of hindwing area covered with pale brown dense hairs; medial black band

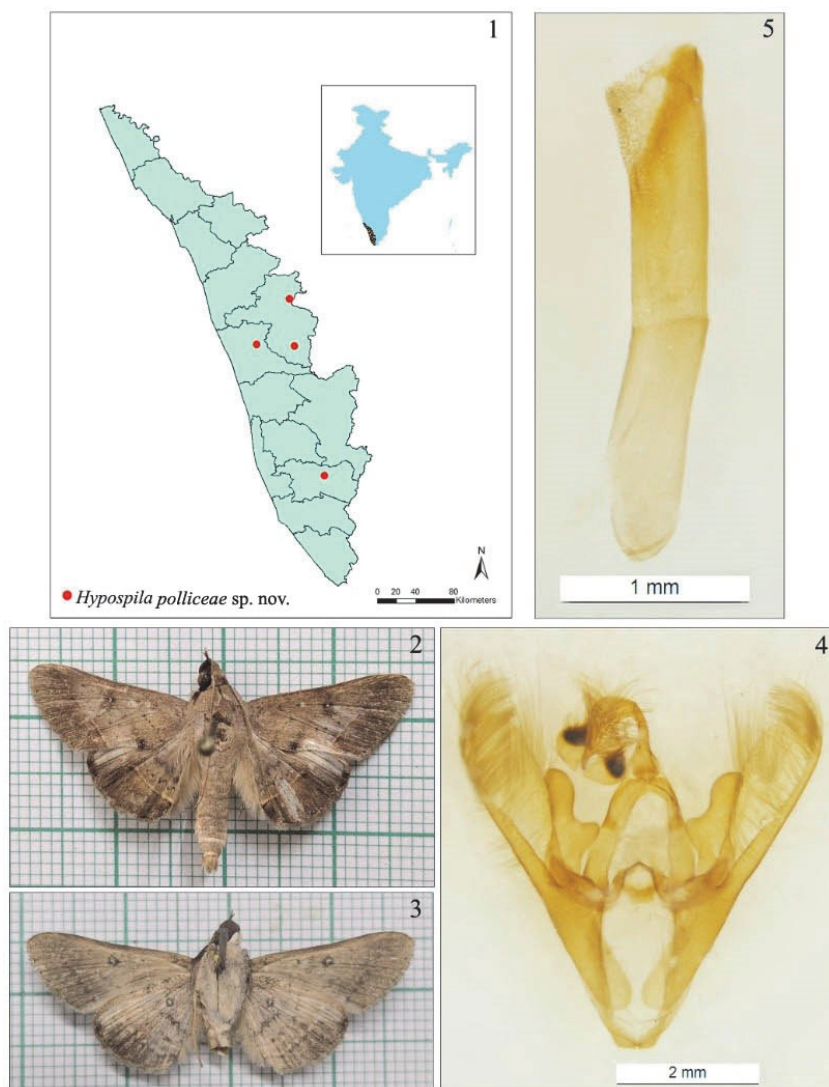


Fig. 1. Distribution map of *Hyospila polliceae* sp. nov. in Kerala; Fig. 2. Holotype male- *H. polliceae* sp. nov. Dorsal view; Fig. 3. Ventral view; Fig. 4. Male genitalia of *H. polliceae* sp. nov.; Fig. 5. Aedeagus

prominent in hindwing compared to forewing. Under side of wings marked differently; hindwing possess indistinct and incomplete submarginal, postmedial, medial lines and prominent orbicular spot on basal area (Fig. 3); forewing underside possess a clear reniform as in upper side; lower median black marking and medial line completely absent; an indistinct submarginal and zigzag post medial line present.

Wing span: 34-36mm.

Male genitalia: Genital capsule elongated; uncus dorsally hastate in shape and ventrally bilobed; lobes black; a patch of setae present on lobes; juxta large with hexagonal appearance; saccus simple, U shaped with broad base; tegumen long and broad, with a tiny ventral sclerotized protrusion in middle; sacculus long and well developed; valvae simple,

long ovate, covered with dense hair from middle to apex; valvae possess well developed unequally bilobed costal process; lobes broad; longer upwardly directed lobe, thumb-like in appearance, lateral lobe short, touching sclerotized ventral prominence of tegumen; base of costal process extends to lower part of sacculus and connected to transtilla (Fig. 4); aedeagus long, straight with well sclerotized distal half; vesica with a small scobinated area devoid of spines (Fig. 5).

Material Examined: Holotype. 1 ♂, INDIA, Kerala, Singappara, Palakkad District (10.975N, 76.642E), 29-ii-2024, Coll. Adarsh P.K. (ZSIK Regd. No. ZSI/WGRC/IR-INV 30046); Paratype. 2 ♂, INDIA, Kerala, Singappara, Palakkad District (10.975°N; 76.642°E), 29-ii-2024, Coll. Adarsh P.K. (ZSIK Regd. No. ZSI/WGRC/IR-INV 30047; CZR 977); 2 ♂, INDIA, Kerala, Pattikkad, Thrissur District (10.5496°N; 76.3352°E), 20-xii-2023, Coll. Joslin Treesa Jacob (Regd. No. CZR 132; CZR 976); 1 ♂, INDIA, Kerala, Vettolipadi, Pathanamthitta District (9.3225°N, 76.9709°E), 16-x-2023, Coll. Adarsh P.K. (Regd. No. CZR 980); 1 ♂, INDIA, Kerala, Nelliampathy, Palakkad District, (10.5354°N; 76.6936°E), 20-vi-2024, Coll. Joslin Treesa Jacob (Regd. No. CZR 981).

Distribution: India (Kerala: Palakkad, Thrissur, Pathanamthitta).

Etymology: The species name is derived from the Latin word “*pollice*” meaning ‘thumb’. The costal process of valvae in male genitalia has a thumb-like appearance, making it distinct from other species.

Remarks: The genus *Hypospila* comprises species that are very similar in their adult morphology. The species can only be distinguished by their genitalia structure. Prior to genitalia analysis, the specimens, including the proposed new species collected from various localities of Kerala, were tentatively identified as *Hypospila bolinoides* based on the morpho features. However, a detailed analysis of the genitalia of both holotype and paratype showed much difference in the costal process of valvae from the other congeners. This new species can be easily distinguished from *H.*

bolinoides by the following morphologic characters a) costal process unequally bilobed; b) long upwardly directed lobe, thumb-like in appearance; short lobe directing to the tegument region; c) juxta large, well sclerotized and hexagonal in shape.

Updated world checklist of *Hypospila* Guenee, 1852, with type locality in parenthesis

1. *Hypospila elongata* Holloway (Type locality: Solomon Island)
2. *Hypospila laurentensis* Viette (Type locality: Madagascar)
3. *Hypospila bolinoides* Guenee (Type Locality: Java)
 - = *orientalis* Leech
 - = *signipalpis* Walker
 - = *dochomotoma* turner
 - = *thermesina* Guenee
 - = *concisa* Walker
 - = *andamana* Swinhoe
4. *Hypospila biplagula* Heyden (Type locality: Namur Belgium)
5. *Hypospila infima* Moschler (Type locality: Surinam)
6. *Hypospila infimoides* Moschler (Type locality: Surinam)
7. *Hypospila iridicolor* Pagenstecher (Type locality: Amboina)
8. *Hypospila ochracea* Holloway (Type locality: Solomon Island)
9. *Hypospila pseudobolinoides* Holloway (Type locality: Solomon Island)
10. *Hypospila similis* Tams (Type locality: Samoa)
11. *Hypospila tamsi* Viette (Type locality: New Hebrides Condominium)
12. *Hypospila brunnescens* (Roepke) (Type locality: Sulawesi)

13. *Hypospila polliceae* Abhilash & Adarsh sp. nov. (Type locality: Palakkad, Kerala, India)

Discussion: It is very challenging to identify the species in the wild since proper differentiation requires genitalia investigation. Primary sorting, which was only possible in the field, was based on the appearance of the median and submarginal lines as well as the size of the hyaline on the hindwing. The adult morphology and genitalia of *Hypospila bolinoides* depicted on the website page, Moths of Borneo (Holloway, 2005) are used to compare with *H. polliceae* sp. nov. This new species can be easily distinguished from *H. bolinoides* by the following morphologic characters:

a) costal process unequally bilobed in *H. polliceae* sp. nov., whereas the costal process of *H. bolinoides* is star-shaped with three well-separated lobes.

b) long upwardly directed lobe, thumb-like in appearance in *H. polliceae* sp. nov., and a short lobe directing to the tegument region. However, in the species *H. bolinoides*, the lateral lobe is short, directed to the ventral part of the valvae, and remaining two lobes are long, and widely separated.

c) juxta large, well sclerotized and hexagonal in *Hypospila polliceae*; juxta small and weak in *H. bolinoides*. *Hypospila bolinoides* is primarily found in North, Central, and Northeast India (Assam, Manipur, Meghalaya, Mizoram, Nagaland, N. India, Tripura, Chhattisgarh, Maharashtra) (Joshi *et al.*, 2025). The endemicity of the species *Hypospila polliceae* in southern India and the limited distribution of *H. bolinoides* in the aforementioned places imply that allopatric speciation may have occurred among them.

ACKNOWLEDGEMENTS

Authors are thankful to the head of the institution, Christ College (Autonomous) Irinjalakuda, Thrissur, Kerala, for providing the facilities for the research. The first author offers sincere gratitude to UGC, Government of India, for financial support in the form of a UGC junior research fellowship (886/ (CSIR UGC NET JUNE 2018)). The second author extends sincere appreciation to management of

Christ College (Autonomous), Irinjalakuda, for the financial assistance.

REFERENCES

- Guenee A. and Boisduval J.A. (1852) Histoire Naturelle des Insectes. Species Général des Lépidoptères. Tome Septième. Noctuérites ome 3(7): 1–358.
- Hampson G.F. (1894) The Fauna of British India including Ceylon and Burma. Taylor and Francis Ltd., London. 2:1–609.
- Holloway J.D. (2005) The moths of Borneo 15 and 16: Noctuidae, Catocalinae. Malayan Nature Society 58: 1–529pp. (https://www.mothsofborneo.com/part-15-16/miscellaneous_iii/miscellaneousiii_1_1.php). accessed 5th February 2025.
- Joshi R., Zahiri R., Banerjee D. and Singh N. (2025) A catalogue of the Erebidae of India (Lepidoptera, Noctuoidea). Zootaxa 5635(1): 1–247.
- Klots A.B. (1970) Lepidoptera. In: Taxonomists' Glossary of Genitalia in insects, Tuxen (ed.). Munksgaard, Copenhagen 2: 115–130.
- Kononenko V.S. and Pinratana A. (2013) Moths of Thailand. Noctuoidea. An illustrated Catalogue of Erebidae, Nolidae, Euteliidae and Noctuidae (Insecta, Lepidoptera) in Thailand. Brothers of St. Gabriel in Thailand, Bangkok. 625pp.
- Koshkin E.S. and Golovizin V.A. (2022) New records of tropical and subtropical noctuoid moths (Lepidoptera: Erebidae, Nolidae) from Primorsky krai, Russia. Far Eastern Entomologist 456: 12–16.
- Kristensen N.P. (2003) Lepidoptera, Moths and Butterflies- Morphology, Physiology and Development. Berlin & New York, NY: Walter de Gruyter. 2: 1–578.
- Kuniyil A.P. and Peter A. (2022) A checklist of Erebiniae (Lepidoptera, Erebidae) from India. ENTOMON 47(4): 425–432.
- Moschler H.B. (1880) Beiträge zur schmetterlings-fauna von Surinam (No. 1-5). Kaiserlich-Königliche Zoologisch-Botanische Gesellschaft in Wien.
- Orhant G. (1986) Deuxième contribution à l'étude des lépidoptères hétérocères du sud-est Asiatique (1) Le complexed'espèces "ricini Fabricius" (Arctiidae: Arctiinae). Bulletin Society Science National France 50: 9–22.
- Orhant G. (2012) *Olepa neumuthi* new species from Thailand (Lepidoptera: Arctiidae). Bulletin Society Entomology Mulhouse 68(4): 61-64.

- Poole R.W. (1989) *Lepidopterorum catalogus* (NS). Fascicle 118. Noctuidae 1: 1-500.
- Robinson G.S. (1976) The preparation of slides of Lepidoptera genitalia with special reference to the micro-Lepidoptera. *Entomologist's gazette* 27(2): 127–132.
- Singh N., Kaur A., Pathania P.C., Sharma N., Kalawate A., Pallot J., Banerjee D., Talukdar A., Lenka R., Kumari A., Raha A., and Joshi R. (2024) Fauna of India. Check List: Arthropoda: Insecta: Lepidoptera. Version 1.0. Zoological Survey of India. doi: 10.26515/Fauna/1/2023/Arthropoda: Insecta:Lepidoptera.
- Zahiri R., Kitching I.J., Lafontaine J.D., Mutanen M., Kaila L., Holloway J.D. and Wahlberg N. (2011) A new molecular phylogeny offers hope for a stable family level classification of the Noctuoidea (Lepidoptera). *Zoologica Scripta* 40(2): 158–173.
- Zahiri R., Holloway J. D., Kitching I. J., Lafontaine J. D., Mutanen M. and Wahlberg N. (2012) Molecular phylogenetics of Erebidae (Lepidoptera, Noctuoidea). *Systematic Entomology* 37(1): 102–124.
- Zimmerman E.C. (1978) *Microlepidoptera Insects of Hawaii*. University Press Hawaii Honolulu 1: 1–1903.

(Received May 25, 2025; revised ms accepted September 30, 2025; published December 31, 2025)

Biology and morphometrical analysis of rice weevil, *Sitophilus oryzae* (L.) (Coleoptera, Curculionidae) on different stored cereals

Gadi Prasad, Lopamudra Biswal, Saswati Parija*, Arundhati Sasmal, Akhilesh Kumar Gupta¹ and Deepa Khulbe²

Department of Entomology, College of Agriculture, Odisha University of Agricultural Technology, Bhubaneswar 751003, Odisha, India.

¹Department of Agricultural Statistics, College of Agriculture, Odisha University of Agricultural Technology, Bhubaneswar 751003, Odisha, India.

²Department of Plant Pathology, College of Agriculture, Odisha University of Agricultural Technology, Bhubaneswar 751003, Odisha, India.

Email: saswati.parija.rs23@ouat.ac.in

ABSTRACT: Experimental rearing of *Sitophilus oryzae* (L.) in eight different cereals such as rice, wheat, oats, barley, sorghum, maize, finger millet and pearl millet has revealed that the pest can complete lifecycle in all of them. Rice and maize are found to be providing optimum living conditions to the pest and within them it can complete its lifecycle in 41 to 45 days, in maize with a mean shortest developmental duration of 40.72 days (egg 6.52, larva 28.45 and pupa 5.75 days). Maize was found to provide more viable living conditions than rice, as adults and developing stages of *S. oryzae* reared in it was significantly larger with higher adult longevity (female 18.60 days, male 12.56 days) compared to other cereals. In contrast, oats caused longest developmental period of 66.47 days (egg 13.70, larva 42.46, pupa 10.31 days), with female and male longevity reduced to 8.50 and 6.50 days respectively, and noticeable production of miniature adults due to developmental stress. Comparison with span of lifecycle in rice, rearing in wheat resulted delay of 6 days but pearl millet and barley caused delay of 12 days, finger millet resulted 16 days of delay in development while oats extended development by nearly 24 days beyond any cereal. In accordance with increase in developmental delay, body size decreased significantly across cereals, with smallest larval and adult dimensions recorded in oats. The sex ratio also varied, peaking in maize (M:F=1:1.92) and declining sharply in oats (M:F=1:0.074). Similarly, total life span was shortest in maize (female 59.42; male 54.07 days) and longest in oats (female 76.21; male 58.30 days). Morphometric observations showed that early and late instar larva measured 0.30-0.85 and 0.80-2.13mm respectively, pupae 2.58-3.77 and adults 2.60-4.53mm, with maize consistently producing the largest dimensions. Head capsule width of larval instars, a marker of health and viability prospective adults developed in maize, is significantly higher than those larvae developed in rice. © 2025 Association for Advancement of Entomology

KEY WORDS: Storage pest, adult size, delayed development, adult longevity, head capsule width

INTRODUCTION

Cereal grains, being botanically caryopses of the

Poaceae family, form nearly 90 per cent of the total caloric consumption worldwide and are the major staple diets in varied agrarian economies (Sarwar,

* Author for correspondence

2013). India holds the position of being the second-largest cereal-producing country in the world and an important exporter, with production levels exceeding 288 million metric tons in 2022-23 (webindia, 2004). Coarse grains such as rice, maize, sorghum, millets, wheat, barley, oats, and finger millet are important in Odisha. These grains have high nutritional density (65-75% starch, 6-12% protein, and 1-5% lipids), all underpinning the food security and dietary standards in peri-urban and rural communities (Webindia123, 2024). Cereal grains, despite their nutritional and economic importance, have been found with very high susceptibility to post-harvest losses caused by storage insect pests. Of these, the rice weevil, *Sitophilus oryzae* (L.) (Coleoptera, Curculionidae), is a major grain pest that causes severe qualitative as well as quantitative damage. The cosmopolitan pest is pantropical in distribution and has remarkable ecological adaptability, infesting rice, also cause sporadic infestation in wheat, maize, barley, oats, and many coarse cereals in the field and storage situations (Togola *et al.*, 2013; Binseena *et al.*, 2018). Its endophytic lifestyle, where larvae grow and feed inside the grain and short generational turnover allow for exponential population increase under optimal storage conditions (Aitken, 1975; Longstaff, 1981). Symptoms of infestation include hollow grains, powdery frass residues, high moisture content, and characteristic odour, which can lead up to 80 per cent weight loss during prolonged storage and improper management (Park *et al.*, 2004; Beckett *et al.*, 2007). Host-specificity influences developmental rate, body size and sex ratio, thereby impacting the extent and duration post harvest damages. The host range breadth of the pest is wide, has cryptic internal larval development wherein eggs, larva and pupae remain concealed within the grain kernels (Gvozdenac *et al.*, 2020) with varied and cereal type-dependent life history characters. Therefore, the aim is to study the lifecycle pathway, morphometric characters, biological and developmental features of the rice weevil (*S. oryzae*) among major cereals.

MATERIALS AND METHODS

Laboratory investigation was carried out to study

the biology and morphological characteristics of the test insect, rice weevil, on eight different cereals in the Department of Entomology, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, during 2023-2024.

Adult rice weevils were collected from infested rice and reared in sterilised jars following standard methods (Strong *et al.*, 1967; Bhandari, 2012; Sahoo, 2017; Pandey, 2019), maintained at controlled laboratory conditions at $30 \pm 2^\circ\text{C}$; 90 ± 2 per cent relative humidity (RH) with fresh grains added periodically to sustain the culture. For experimentation, whole grains of eight cereals were used: rice (*Oryza sativa*), wheat (*Triticum aestivum*), oats (*Avena sativa*), barley (*Hordeum vulgare*), sorghum (*Sorghum bicolor*), maize (*Zea mays*), finger millet (*Eleusine coracana*) and pearl millet (*Pennisetum glaucum*). The grains were disinfected at 55°C for 4 hours, and then stored in zip lock bags with small holes for air circulation. For each cereal type, 50g of grain were placed in containers with five beetle pairs, covered with muslin cloth, and maintained at $30 \pm 2^\circ\text{C}$ and 70 per cent RH. After 7 days, beetles were removed, and the experiment was replicated thrice.

Morphological features of developmental stages: Daily observations were made on egg deposition, adult emergence, and longevity. (From each experimental set, 30 grains per cereal type were dissected daily to record the precise timing of embryonic development, larval development, and pupation events.) Trinocular stereo zoom microscope (SZ-61, Olympus) with a DGI digital camera and Scope Photo v3.1 software was used to identify, measure, and photograph the developmental stages - lengths of larval instars, pupae, adults (male and female), and head capsule widths of early and late instar grubs.

Acid fuchsin staining was used for detection of the egg plugs deposited by rice weevil (Holloway, 1985; Renuka *et al.*, 2023). The first instar larvae of *S. oryzae* were identified based on their distinct shape and size of the head capsule, i.e; small, white, and possessing head capsule width (HCW) of approximately 0.20–0.25mm, with simple setae and a thin body, whereas the final (fourth) instar larvae

being larger in size relatively (HCW 0.70–0.85mm), more robust, and heavily sclerotized, showing prominent segmentation and fully developed mandibles (O'Donnell, 1967; Okram and Hath, 2019; Sharma *et al.*, 2025).

Morphological features that differentiated male and female pupae of *S. oryzae* include the structure of the pygidium, abdominal tergites: males exhibit a longer and partially membranous pygidium with specific bifurcated setae and a flanged posterior margin, while females possess a notched posterior margin and lack bifurcation, with the pygidium mostly retracted and concealed under the propygidium (Omar, 2012). Sexes (adult) were identified by rostrum structure - males having a thicker, less curved rostrum (Fox *et al.*, 2003; Omar, 2012; Azis and Kasim, 2020).

Development stages of rice weevil were tracked through both non-destructive and destructive sampling (grain dissection) due to its endophytic nature during its immature stages within grains. Embryonic development completion and hatching were followed by monitoring with acid fuchsin staining to observe egg plugs or identification of egg plug disappearance and larval feeding tunnel initiation (Holloway, 1985; Renuka *et al.*, 2023). Development from first instar to completely developed larva was determined through regular dissections in which growth in head capsule width and body length was taken into account to differentiate successive instars of the larvae (O'Donnell, 1967; Okram and Hath, 2019; Sharma *et al.*, 2025). Pupation was recognized by the discovery of an immobile, non-feeding pupal stage in the dissection of grains, with pupae easily distinguishable from larval instars in morphology and developmental level (Okram and Hath, 2019). Finally, eclosion or the emergence of adult weevils was ascertained by visual sighting of exit holes on the grains/the sight of adult beetles on the storage substrate after daily observation or scheduled sampling.

Statistical analysis: The observations on developmental stages, length, and parts of the rice weevil were analyzed using one-way ANOVA in a completely randomized design, with standard error

of mean (SEM) and critical difference (CD) calculated for interpretation of biological variation through partitioning of various components (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Biology of rice weevil on different stored cereals:

Embryonic development: The incubation period of the rice weevil was examined across various stored cereals using the acid fuchsin method where, the gelatinous egg plugs exhibited a deep cherry-red color, while the feeding sites displayed a light pink hue, indicating the presence of eggs. The data revealed a significant variation in the incubation period, ranging from 6.52 to 13.70 days, with the longest periods observed in oats (13.70 days) and finger millet (12.16 days), which were statistically similar. In contrast, the shortest incubation period (6.52 days) was noted in maize (Table 1), these observations aligns with findings of Singh *et al.* (2017), who reported an incubation period of 6 to 7 days for rice weevils on the rice cultivar Pusa-221. Additionally, Meghwal (2010) found that the incubation period for rice weevils extended to 7 days on maize at a temperature of 26°C and RH of 65 per cent.

Larval development: The larval stage lasted between 28.45 days and 42.46 days. The longest larval duration was observed in oats (42.46 days), which was comparable to that in finger millet (39.22 days). In contrast, the shortest larval period occurred when the weevils were reared in maize (28.45 days), followed closely by rice (28.98 days) and wheat (33.37 days), which were also similar in duration. Jadhav (2006) previously noted that the larvae underwent four instars, with their larval period ranging from 21 to 30 days and an average of 25.8 ± 3.70 days for those on maize (Table 1). Likewise, Bheemanna (1986) reported a larval period of 25 to 34 days in the CSH-5 sorghum hybrid.

Pupal development: The maximum pupal period was observed in oats (10.31days) and minimum period was observed in maize (5.75days) followed

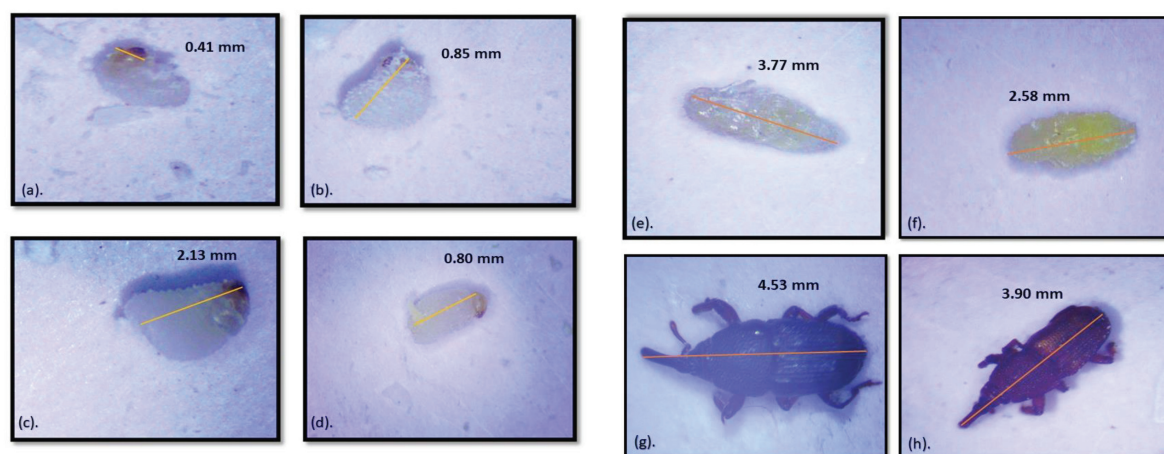


Fig.1 Morphometrics of larval, pupal and adult stages of rice weevil, *Sitophilus oryzae* (L.). (a) Early instar head capsule width (in Maize), (b) Early instar body length (in Maize), (c) Late instar body length (in Maize), (d) Late instar body length (in Oats), (e) Female pupa (in Maize), (f) Male pupa (in Oats), (g) Female adult (in Maize), (h) Male adult (in Maize)]

by rice (6.43days) and wheat (6.85days) which were at par. Swamy *et al.* (2014) observed the pupal period of rice weevil ranged from 8 to 11days on maize which supported the pupal period reported in this experiment with varying from 5.75 days to 10.31days (Table 1). Further, this was well supported by the findings of Kumar *et al.* (2016) who reported the rice weevil completed its pupal period within 6.75 to 7.08 days in wheat.

Span of lifecycle: The total development period was lowest on maize (40.72days) and rice (43.87days), whereas highest in oats (66.47days) which was at par with finger millet (59.68days). This indicated that the developmental period was significantly affected by the diet they consumed (Table 1). The present result confirmed the findings of Akthar *et al.* (2017) recorded the total development on rice and wheat is 37 and 36 days respectively and likewise, development period in maize ranging from 39.00 to 45.00 days on different maize hybrids was observed by Yevoor (2003).

Longevity of weevils: From the data it was evident that the adult female lived longer than male. The results showed that female had a maximum longevity in maize with (18.60 days) and minimum in oats (8.50days) followed by finger millet (9.75 days) which was comparatively longer than the

male weevil which has shorter longevity of in oats (6.50 days) and at par with finger millet (7.50 days) and maximum longevity in maize 12.56 days followed by rice (10.27 days) and wheat (9.80 days) (Table 1). The present findings align with previous studies reporting consistently higher longevity in adult females than males across various cereals. Okram *et al.* (2019) observed female and male lifespan of 14.47 ± 0.69 and 12.98 ± 0.98 days respectively on stored rice, while Yevoor (2003) reported 9.50 and 7.32 days on maize; and Rojasara and Patel (2020) recorded 8.6 ± 0.82 and 5.8 ± 0.82 days on Jaya rice.

The total life cycle of males and females also varied, in which male had a shorter life time than female. Life cycle of female weevil was maximum (76.21days) in oats, which was more than the male on oats (71.15days) followed by finger millet (71.76days). The shortest life cycle of female was on maize (59.42days) followed by rice (59.71days) and wheat (67.12days) which were at par. The life cycle of male was the longest in oats (71.15days) and the shortest on maize (54.07days) followed by wheat (58.30days) and rice (58.35days) (Table 1). Okram *et al.* (2019) reported total life cycles of 50.35 ± 1.85 days for males and 51.84 ± 1.56 days for females across a temperature range of 12.39-27.89°C and 58.33-88.81 RH; Rojasara and

Table 1. Duration of developmental stages, adult longevity, life cycle (days) and sex ratio of *Sitophilus oryzae* (L.) on different stored cereals

Cereals	Duration of stages				Adult longevity/ life cycle				Sex ratio (M:F)
	ED	LD	PD	TDP	AL(F)	AL(M)	LC(F)	LC(M)	
Rice	8.46	28.98	6.43	43.87	15.40	10.27	59.71	58.35	1:1.78
Wheat	9.24	33.37	6.85	49.46	13.20	9.80	67.12	58.30	1:1.56
Oats	13.70	42.46	10.31	66.47	8.50	6.50	76.21	71.15	1:0.74
Barley	11.26	39.19	6.27	56.71	11.60	8.50	67.17	59.50	1:1.38
Sorghum	9.50	37.97	7.14	54.60	12.50	8.72	69.25	60.03	1:1.42
Maize	6.52	28.45	5.75	40.72	18.60	12.56	59.42	54.07	1:1.92
Finger millet	12.16	39.22	8.30	59.68	9.75	7.50	71.76	63.40	1:1.09
Pearl millet	11.40	37.48	6.27	55.15	10.50	7.90	70.95	61.13	1:1.22
SE(m)±	0.53	1.97	0.37	2.70	0.49	0.37	3.43	3.02	
CD (0.05%)	1.60	5.93	1.12	8.19	1.47	1.13	10.29	9.05	

ED – Egg development; LD – Larva development; PD – Pupal development; TDP – Total developmental period; AL(F) – Adult longevity (Female); AL(M) – Adult longevity (Male); LC(F) – Life cycle (Female); LC(M) – Life cycle (Male)

Patel (2020) recorded significantly longer durations on Jaya rice (83.12/ $\pm$ 4.43 days for males and 110.8/ $\pm$ 3.35 days for females), while Bheemanna (1986) observed 38–53 days on sorghum, and Kundu *et al.* (2018) found 40.00/ $\pm$ 0.82 and 53.43/ $\pm$ 0.61 days for males and females, respectively, in DPW-62150 wheat.

Morphology of rice weevil on different cereals:

Morphometric analysis of developing stages:

Larval instar length varied with the cereal type, ranging from 0.30–0.85mm in early instars, with the maximum recorded in maize (0.85/ mm; Fig. 1b) followed by rice (0.74mm) and wheat (0.65mm), and the minimum in oats (0.30mm) and finger millet (0.31mm); late instars ranged from 0.80–2.13mm, with the highest in maize (2.13mm; Fig. 1c) followed by rice (1.90mm) and wheat (1.70mm), and the lowest in oats (0.80mm) and finger millet (0.93mm) (Fig. 1d, Table 2). These findings align with Rojasara and Patel (2020), who reported instar lengths from 0.56/ $\pm$ 0.01mm to 2.18/ $\pm$ 0.01mm, Singh *et al.* (2017) who recorded an average larval length of 2.9/ $\pm$ 0.2mm, and Hazarika (2001) who noted freshly emerged and mature larvae measured 1.4/ $\pm$ 0.21mm and 2.5/ $\pm$ 0.23mm, respectively.

Head capsule width of early and late larval instars varied across cereals, ranging from 0.23–0.41/ mm, with the maximum in maize (0.41/ mm) (Fig. 1.a) at par with rice (0.38/ mm), and the minimum in oats (0.23/ mm); for late instars, the smallest width was also in oats (0.24/ mm), followed by finger millet (0.29/ mm), while the highest was recorded in maize (0.73/ mm), followed by rice (0.55/ mm) and wheat (0.42/ mm). These results are consistent with Hazarika (2001), who reported head capsule widths of 0.21/ $\pm$ 0.02/ mm in early and 0.62/ $\pm$ 0.02/ mm in late instars, and with Rojasara and Patel (2020), who documented widths of 0.44/ $\pm$ 0.01/ mm to 0.57/ $\pm$ 0.06/ mm across four larval instars in Jaya rice.

The length of pupae differed between sexes in cereal crops, with females consistently being longer than males (Table 2). The maximum male pupal length was recorded in maize (3.27/ mm), followed by rice (3.12mm) and wheat (3.07mm), while the minimum was in oats (2.58/ mm) (Fig. 1f), followed by finger millet (2.78mm) and pearl millet (2.85mm). Female pupae showed maximum length in maize (3.77mm; Fig. 1e) and minimum in oats (2.67mm), comparable to finger millet (2.71mm). These findings align with Jadav (2006), who

reported pupal lengths of 3.41–3.46mm in maize, and Rojasara and Patel (2020) recorded 2.24–2.40mm in Jaya rice.

Morphometric analysis of adult weevils:

Average adult body length ranged from 2.60–3.90mm, with the maximum recorded in maize (3.90/mm) (Fig. 1h), followed by rice (3.48mm) and wheat (3.17mm), and the minimum in oats (2.60mm), at par with finger millet (2.70mm) and pearl millet (2.87mm); female adults were longer, with the highest length in maize (4.53mm) (Fig. 1g) and the lowest in oats (2.77mm), followed by finger millet (2.87mm) and pearl millet (2.93mm), which were statistically similar. These observations are in line with Choudhury and Chakraborty (2014), who reported male and female lengths of 2.9 ± 0.6 and 2.8 ± 0.6 mm, respectively, on Sambha Mashuri rice whereas, Thakkar and Parikh (2020) noted male and female lengths respectively of 3.18 ± 0.26 and 4.28 ± 0.76 mm on rice, and 3.43 ± 0.17 and 4.6 ± 0.41 mm on maize.

During the experiment, embryonic development (ED), larval development (LD), and pupal development (PD) on rice were seen to amount to a developmental period of 43.87 days, adult

longevity of females and males being 15.40 and 10.27 days, respectively, and a sex ratio of 1:1.78 (M:F). Comparison with other grains showed maize to have considerably shorter development times (40.72 days), greater adult longevity (18.60 days for females, 12.56 days for males), and greater male-female sex ratio (1:1.92), making it a more appropriate host compared to rice, although rice is highly favored since it hosts comparatively quick development and strong adult longevity. On the contrary, cereals like oats had extended developmental periods (66.47 days) and decreased survivorship as adults, suggesting retarded or delayed growth on these mediums.

Morphometric analysis of rice weevil reveals tremendous body length and head capsule width variation according to cereal host. Maize accommodated the maximum body measurements throughout larval instars (early: 0.85mm; late: 2.13mm), pupae (male: 3.90mm; female: 4.53mm), and adult weevils (male HCW: 0.41mm; female HCW: 0.73mm), which reflects the ideal nutritional and physical conditions to grow. Rice, the main diet, also gave comparatively large dimensions (early larva 0.74mm; late larva 1.90mm; pupae male 3.48mm, female 3.53mm) which were much larger

Table 2. Morphometrics of developmental stages of *Sitophilus oryzae* (L.) on different stored cereals

Cereals	Body length(mm)						HCWL (mm)	
	Larval instar		Pupa		Adult weevil			
	Early	Late	Male	Female	Male	Female	Early	Late
Rice	0.74	1.90	3.12	3.35	3.48	3.53	0.38	0.55
Wheat	0.65	1.70	3.07	3.31	3.17	3.33	0.34	0.42
Oats	0.30	0.80	2.58	2.67	2.60	2.77	0.23	0.24
Barley	0.44	1.30	2.91	3.15	2.90	3.03	0.30	0.34
Sorghum	0.56	1.60	2.97	3.25	3.07	3.20	0.32	0.39
Maize	0.85	2.13	3.27	3.77	3.90	4.53	0.41	0.73
Finger millet	0.31	0.93	2.78	2.71	2.70	2.87	0.28	0.28
Pearl millet	0.38	1.20	2.85	2.81	2.87	2.93	0.29	0.32
SE(m)±	0.025	0.061	0.142	0.222	0.097	0.089	0.008	0.022
C.D(0.05%)	0.08	0.18	0.42	0.67	0.29	0.27	0.03	0.07

HCWL - Head capsule width of larval instar (mm)

than those found on oats, where smaller body sizes (early larva 0.30mm; late larva 0.80mm; pupae male 2.60mm, female 2.77mm) reflect developmental stress. The statistically significant morphometric differences ($P < 0.05$) mirror host suitability differences that presumably affect the biological fitness and infestation potential of rice weevil on various cereals. Morphometric differences align with differences in developmental durations and longevity of adults, further indicating that maize and rice are the most suitable hosts for the rice weevil among the cereals examined. These observations are essential for developing host-specific pest management approaches targeting highly susceptible grains during storage.

Based on the observed patterns of development, it can scientifically be affirmed that *S. oryzae* has a shorter developmental period and achieves much larger body and head capsule sizes when cultured on rice and maize than in other tested cereals. These measures strongly suggest that rice and maize are the optimal and preferred hosts of this pest, most probably because of their optimum nutritional and biochemical composition favorable to growth and increased fitness. Consequently, the cereals warrant highest-priority storage vigilance and selective management interventions to avert exacerbated infestation threats.

ACKNOWLEDGEMENTS

The authors are grateful to the Department of Entomology, College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar for providing laboratory facilities for the smooth conduct of the experiment.

REFERENCES

- Aitken A.D. (1975) Insect travellers, I: Coleoptera. HMSO, London, Technical Bulletin 31 pp.
- Akhter M., Sultana S., Akter T. and Begum S. (2017) Oviposition preference and development of rice weevil, *Sitophilus oryzae* (Lin.) (Coleoptera: Curculionidae) in different stored grains. *Bangladesh Journal of Zoology* 45(2): 131–138.
- Azis T.M.F. and Kasim K.F. (2020) Prediction of *Sitophilus oryzae* Gender Using Logistic Regression Model. *ARNP Journal of Engineering and Applied Sciences* 15(8): 1006–1010.
- Beckett S.J., Fields P.G. and Subramanyam B. (2007) Disinfestation of stored products and associated structures using heat. In: *Heat treatments for postharvest pest control: theory and practice*, CABI, Wallingford, UK. pp. 182–237.
- Bhandari G.R. (2012) Biology and management of rice weevil, *Sitophilus oryzae* (Linnaeus) on stored sorghum. M.Sc. Thesis, Navsari Agricultural University, Navsari, India.
- Bheemanna M. (1986) Studies on biology of rice weevil *Sitophilus oryzae* Linnaeus (Curculionidae: Coleoptera) and host resistance in sorghum. M.Sc. (Agri.) Thesis, University of Agricultural Sciences Dharwad.
- Binseena S.R., Anitha N., Paul A., Amritha V. S. and Anith K. N. (2018). Management of rice weevil, *Sitophilus oryzae* using essential volatile oils. *ENTOMON* 43(4): 277–280.
- Choudhury S.D. and Chakraborty K. (2014) Study on both the life cycle and morphometrics of *Sitophilus oryzae* on rice cultivar Samba mashuri in laboratory condition. *Journal of Applied Science and Research* 2(6): 22–28.
- Fox C.W., Dublin L. and Pollitt S.J. (2003) Gender Differences in Lifespan and Mortality Rates in Two Seed Beetle Species. *Functional Ecology* 17(5): 619–626.
- Gomez K.A. and Gomez A.A. (1984) *Statistical procedures for agricultural research* 2nd edition. John Wiley & Sons, New York, 680 pp.
- Gvozdenac S., Tanasković S., Vukajlović F., Prvulović D., Ovuka J., Višacki V. and Sedlar A. (2020) Host and ovipositional preference of rice weevil *Sitophilus oryzae* depending on feeding experience. *Applied Ecology and Environmental Research*, 18(5), 6663–6673.
- Hazarika N. (2001) Susceptibility of some newly developed rice varieties to *Sitophilus oryzae* (L.) (Curculionidae: Coleoptera). M.Sc. (Agri.) Thesis, Assam Agricultural University, Jorhat.
- Holloway G. J. (1985) The effect of increased grain moisture content on some life history characteristics of *Sitophilus oryzae*. *Journal of Stored Products Research*, 21(2): 77–82.
- Jadhav K. (2006) Biology and management of rice weevil, *Sitophilus oryzae* L. in pop sorghum. Doctoral dissertation, University of Agricultural Sciences. Dharwad.

- Kumar A., Meena H.R., Meena B.M., Meena A.K. and Sharma, K.C. (2016) Biology and eco-safe management of rice weevil through botanicals and inert material in stored wheat. *Journal of Entomological Research* 40(2): 191–194.
- Kundu B., Hath T.K., Okram S. and Chakraborty D. (2018) Biology of *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) on Four Different Germplasms of Stored Wheat Grains. *International Journal of Current Microbiology and Applied Sciences* 7(6): 2401–2406.
- Longstaff B.C. (1981) Biology of the grain pest species of the genus *Sitophilus* (Coleoptera: Curculionidae): A critical review. *Protection. Ecology* 3(2): 83–130.
- Meghwal H.P. (2010) Bio-ecology and Management of *Sitophilus oryzae* (Linn.) in Stored Maize. Doctoral dissertation, MPUAT, Udaipur.
- O'Donnell A.E. (1967) Determination of Larval Instars of the Rice Weevil, *Sitophilus oryzae*. *Journal of the Arkansas Academy of Science* 21: 74–78.
- Okram S. and Hath T.K. (2019) Biology of *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) on stored rice grains during different seasons in Terai agro-ecology of West Bengal. *International Journal of Current Microbiology and Applied Sciences* 8(4): 1955–1963
- Omar Y.M.M. (2012) Morphological studies on some external and internal structures of rice weevil, *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae), A Major Pest of the Stored Cereals in Egypt. *Journal of Plant Protection and Pathology* 3(8): 843–863.
- Pandey C. (2019) Biology, damage and management of rice weevil, *Sitophilus oryzae* L. on stored rice. M.Sc. Thesis, Birsra Agricultural University, Ranchi, India.
- Park D.S., Peterson C., Zhao S. and Coats J.R. (2004) Fumigation toxicity of volatile natural and synthetic cyanohydrins to stored-product pests and activity as soil fumigants. *Pest Management Science* 60(8): 833–838.
- Renuka V.V.L., Prakash H.S., Singh S., Kumar S. and Rao P.R. (2023) Natural colours could be used as dye to identify *Tribolium* eggs in stored flour. *Journal of Stored Products Research* 100: 102005.
- Rojasara A.D. and Patel D.R. (2020) Biology of rice weevil *Sitophilus oryzae* (L.). *Indian Journal of Entomology* 82(3): 595–597.
- Sahoo G. (2017) Biology of rice weevil, *Sitophilus oryzae* Linn. in stored milled rice and its management using botanical and inorganic inert materials under coastal climatic condition of Odisha. Ph.D. Thesis, Odisha University of Agriculture and Technology, Bhubaneswar, India.
- Sarwar M.H., Sarwar M.F., Sarwar M., Qadri N.A. and Moghal S. (2013) The importance of cereals (Poaceae: Gramineae) nutrition in human health: A review. *Journal of cereals and oilseeds* 4(3): 32–35.
- Sharma V., Chaudhary R. and Kumar S. (2025) Biology of *Sitophilus oryzae* (L.) on Stored Rice. *Biological Forum* 17(4): 33–36.
- Singh B.K.P. (2017) Study on the life cycle of *Sitophilus oryzae* on rice cultivar Pusa 2-21 in laboratory condition. *International Journal of Education and Applied Sciences Research* 4(2): 37–42.
- Statista (2004) Production volume of cereals in India from financial year 2002 to 2021, with estimates for 2022. (February 2024) <https://r.search.yahoo.com> (Last seen September 2024)
- Strong R.G., Sbur D.E. and Partida G.J. (1967) Rearing Stored-Product Insects for Laboratory Studies: Lesser Grain Borer, Granary Weevil, Rice Weevil, *Sitophilus zeamais*, and Angoumois Grain Moth. *Journal of Economic Entomology* 60(4): 1078–1082.
- Swamy K.N., Mutthuraju G.P., Jagadeesh E. and Thirumalaraju G.T. (2014) Biology of *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) on stored maize grains. *Current Biotica* 8(1): 76–81.
- Thakkar B. and Parikh P. (2018) Effects of host grains on the rice weevil *Sitophilus oryzae* (L.). *Indian Journal of Entomology* 80(4): 1427–1430.
- Togola A., Seck P.A., Glitho I.A., Diagne A., Adda C., Toure A. and Nwile F.E. (2013) Economic Losses from Insect Pest Infestation on Rice Stored on-farm in Benin. *Journal of Applied Sciences* 13: 278–285.
- Webindia123. (2024) <https://www.webindia123.com/orissa/economy/agriculture> (last seen September 2024)
- Yevoor (2003) Biology and management of rice weevil, *Sitophilus oryzae* (Linn.) in maize grains. M. Sc. (Agri.) Thesis, University of Agricultural Sciences, Dharwad.

Coleopteran diversity, its distribution and the influence of environmental factors on them in the Barak river basin of Assam, India

Ankur Nandi and Sarbani Giri*

Department of Life Science and Bioinformatics, Assam University, Silchar 788011, Assam, India.

Email: giris111aus@gmail.com; sarbani.giri@aus.ac.in

ABSTRACT: The research aimed to assess beetle diversity across ecologically protected, semi-protected, and forested areas of Barak river basin area of Assam, India, with a focus on identifying species diversity and analysing its association with a variety of environmental parameters such as pH, temperature and precipitation. A total of 83 beetle species were identified, with *Adoretus sinicus* emerging as the most dominant species. Several rare species were also documented. Shannon-Wiener Diversity Index (H') calculated to be 3.663, indicating a relatively high species diversity. Simpson's diversity index (0.9704) indicated a well-balanced community. Shannon's Equitability Index 0.829, indicate a fairly even distribution. Pielou's Evenness Index (0.829) showed that species in the community are evenly distributed. Low value of Berger-Parker index (0.0725) explains that most abundant does not dominate the community, which complements the high diversity and evenness values. Whittaker's Beta Diversity Index calculated (3.34), points towards significant species turnover, suggesting that each site has a relatively unique community composition and that overall biodiversity is high across the study sites. The CCA data variation in the community. In the first axis CCA1, soil pH and precipitation have strong but opposing influences. Soil pH positively contributed whereas precipitation negatively contributed towards variation. In the second axis CCA2, specific humidity showed an important role in determining the variation, suggesting that environmental parameters play a crucial role in shaping the spatial patterns of species assemblages. *Adoretus sinicus* and *Anomala marginipennis* were exceptionally common on the highly invasive plant *Melastoma malabathricum* and seemed to be frequently feeding on the nectar and leaves of this plant, though *A. marginipennis* is a non-specific consumer of most flowering plants. During late autumn months when the activity of these beetles was at the highest, not a single undamaged *M. malabathricum* was found in the study sites. Many species from families like Cerambycidae, Scarabaeidae and Chrysomelidae were collected during the post-monsoon and early summer months, from March to August, indicating a coherent seasonal pattern. © 2025 Association for Advancement of Entomology

KEY WORDS: Biodiversity, diversity index, coleopteran key species

INTRODUCTION

The Eastern Himalayas ranging from eastern Nepal, north east India, Bhutan, part of Tibet and part of

China, is major biodiversity hotspot (Tordoff *et al.*, 2012). The river Barak basin of southern Assam, India, is a part of eastern Himalayas and represents a complex, rich and river-based ecosystem that has

* Author for correspondence

a lot of economic and conservation values. Barak Valley is characterized by a diverse array of forest types, microhabitats, floral and faunal diversity and ecological interactions (Baruah *et al.*, 2013). No dedicated documentation of the coleopteran diversity from Barak river basin has been undertaken so far which creates a gap in the existing knowledge on coleopteran biodiversity. However, compositions of Scarabaeidae have been evaluated for the state of Assam (Das *et al.*, 2016; Bhattacharya *et al.*, 2017). Aquatic beetles have also been evaluated and reported from selected wetlands such as Sonduba Beel, Deepor Beel and Hakama Beel (Ahmed *et al.*, 2025; Choudhury and Gupta, 2015; Mahanta *et al.*, 2024) as well as the Majuli River island (Borkataki *et al.*, 2018). Cerambycid beetles have also been evaluated at a state level (Mitra *et al.*, 2017). Small scale checklists of selected regions such as Chakrashila Wildlife Sanctuary and Jorhat District (Barman and Gupta, 2016; Bhattacharyya *et al.*, 2021). Due to climate change, global warming, anthropogenic activities and habitat loss, the insect diversity is at great threat. Recent studies have highlighted that beetles are one of the most significant pollinators (Muinde and Katumo, 2024). Decline of beetle population is an indicator of over-intensified land degradation leading to reduced agriculture turnover of the agriculture based economy (Bianchi *et al.*, 2007; Fiser *et al.*, 2025). Yet, while beetles play an essential role in maintaining ecological balance, little is known about the distribution and diversity and the threats of beetles from this region. The current study aims to quantify beetle diversity, analyse habitat associations and identify indicator species by employing active and passive sampling methods alongside environmental data collection to capture insights into habitat preferences, seasonal patterns and species richness and to establish the stability of the coleopteran community.

MATERIALS AND METHODS

The insect samples were documented during field survey and the data was collected using a combination of active sampling methods such as hand-picking and opportunistic encounters as well as passive sampling methods such as light traps,

pitfall traps and litter sampling. Survey information from snowball sampling of the locals regarding the description and location of insect samples were incorporated along with publicly available distribution data of animals from expert-curated databases such as university to decide the optimal study area selection. Environmental data such as temperature, humidity, vegetation type, and canopy cover, undergrowth density, soil moisture and microhabitat features were noted down. Identification of insects was done using morphological keys using field guides and existing literature (Vazirani, 1968; Stibick, 1980; Maulik, 1910; Marshall, 1916; Pal, 1992; Rajagopal and Kumar, 1993; Leschen and Węgrzynowicz, 1998; Chakraborty and Chakraborty, 2000; Poorani, 2002, 2019; Douglas, 2011; Johri *et al.*, 2010; Ghosh and Nilsson, 2012; Jadhav and Sharma, 2012; Jolivet *et al.*, 2012; Thakare *et al.*, 2012; Gupta *et al.*, 2014; Hegde *et al.*, 2014; Geiser, 2015; Kumawat *et al.*, 2015; Masek *et al.*, 2015, 2018; Arya and Tamta, 2016; Kushwaha *et al.*, 2017; Jadhao and Bhongade, 2018; Kumar, 2018; Kariyanna *et al.*, 2019; Prathapan *et al.*, 2019; Chandra *et al.*, 2021; Makarov and Kazantsev, 2022; Deb and Subramanian, 2023; Maquart *et al.*, 2023; Sreedevi *et al.*, 2023).

Study area: Existing literature on beetle distribution and habitat preference (Chung *et al.*, 2000; Driscoll and Weir, 2005) were followed to determine the ideal locations for the study. Six sites were selected (Table 1).

Sampling design: The sampling work was carried out over a two-year period in the afore mentioned 6 locations, from the autumn of 2022 to the autumn of 2024, with special attention to the active seasons of beetles. Sampling efforts were intensified during the post-monsoon and monsoon months, which align with the peak periods of beetle activity which occur between March and June as well as September and November. This strategy was adopted to maximize the likelihood of capturing a representative sample of the beetle populations during their most active phases in the subtropical forest ecosystems under study. Random sampling was conducted to study different habitats. Sampling was carried out

across various forest types and altitudes, ensuring a wide spatial representation of the study area. Species that were difficult to identify in the field were photographed or collected and identified later with the aid of taxonomic keys.

Key environmental parameters such as temperature and humidity were measured using portable digital devices at the time of each collection to capture the immediate microclimatic conditions in which beetle populations were observed.

Vegetation characteristics were also meticulously documented, with vegetation type, canopy cover, and undergrowth density being recorded for each sampling location.

In addition to the environmental data collected, broader climatic data were recorded at each sampling site to account for weather influences on beetle activity and distribution.

From the gathered data, Shannon-Weiner Diversity Index (H') and Simpson's Diversity Index were used to understand the diversity of the beetle species. Additionally, Shannon's Equitability Index, Simpson's Evenness Index and Pielou's Evenness Index were calculated to understand the species evenness. Margalef's Richness Index was calculated to adjust species richness for sample size. Berger-Parker Dominance Index was calculated to understand the dominance of the most abundant species in the community. Whittaker's Beta Diversity Index was calculated to understand the species turnover rate. Effective Number of species (ENS) was calculated. Finally, the effect of environmental variables on the variance was calculated using Canonical Correspondence Analysis and Distance-based Redundancy Analysis. One-way ANOVA was used to compare significance of relevant data, with a significance threshold set at $p < 0.05$.

1) Shannon-Weiner Diversity Index

$$H' = - \sum_{i=1}^S P_i \ln(P_i)$$

Where, S = Total number of species.

P_i = Proportion of individuals of species "i" relative

to the total number of individuals.

$\ln(P_i)$ = Natural logarithm of the proportion of species "i".

2) Simpson's Diversity Index

$$D = 1 - \sum P_i^2$$

Where, P_i = Proportion of individuals of species "i" relative to the total number of individuals.

3) Shannon's Equitability Index

$$E = \frac{H'}{\ln(S)}$$

Where, H' = Shannon-Weiner Diversity Index; S = Species richness.

4) Simpson's Evenness Index

$$ED = \frac{1/D}{S}$$

Where, D = Simpson's Diversity Index; S = Species richness.

5) Pielou's Evenness Index

$$J' = \frac{H'}{H'_{\max}}$$

Where, H' = Shannon-Weiner Diversity Index.

$H'_{\max}$ = Maximum possible Shannon-Weiner Diversity Index if all species were equally common (i.e., $= \ln(S)$).

6) Margalef's Richness Index

Where, S = Species richness; N = Total number of individuals.

7) Berger-Parker Dominance Index

Where, N_i = Number of individuals in the species with the highest abundance.

N = Total number of individuals.

8) Effective Number of Species

Where, H' = Shannon-Weiner Diversity Index.

9) Whittaker's Beta Diversity Index

Where, $\tilde{\alpha}$ = Gamma diversity, i.e., total species richness across all the communities.

= Average alpha diversity for all the communities.

10) Canonical Correspondence Analysis, was calculated.

11) Distance-based Redundancy Analysis, a constrained ordination method that correlates beta diversity with environmental variables using a dissimilarity matrix (Bray-Curtis Dissimilarity).

RESULTS AND DISCUSSION

A total of 83 beetle species were identified under 17 families during different seasons Pre-monsoon (March, April, May), Monsoon (June, July, August), Post-monsoon (September, October, November) and Winter (December, January, February). Cerambycidae had the highest diversity, followed by Chrysomelidae (Table 2, 3).

Shannon-Wiener Diversity Index (H') calculated to be 3.663, indicating a relatively high species diversity and a complex community where individuals are spread across many species, with no single species overwhelmingly dominant. Simpson's Diversity Index calculated was 0.9704. This emphasizes species dominance, indicating a low probability that any two randomly encountered individuals belong to the same species. This suggests high diversity, with many species contributing equally to the community structure.

Shannon's Equitability Index 0.829, indicate a fairly even distribution (where 1 would be perfect evenness). This mean no species is dominant in

the community. Simpson's Evenness Index (0.9704) showed high evenness in the community. Pielou's Evenness Index was calculated to be 0.829, showing that species in the study community are evenly distributed. Margalef's Richness Index was calculated to be 14.727. Margalef's richness index adjusts species richness for sample size and a moderately rich community with 83 species. It accounts for the sample size (262 individuals), showing a high richness compared to the number of individuals sampled. Berger-Parker Dominance Index was calculated to be 0.0725. The Berger-Parker index explains the ratio of the most abundant species (19 individuals) to the total number of individuals (262). A low value of 0.0725 suggests that the species that most abundant does not dominate the community, which complements the high diversity and evenness values.

Effective Number of Species (ENS) was calculated to be 38.978. This value translates the Shannon-Wiener index into a real number, showing that the diversity in the study community is equivalent to having approximately 39 equally abundant species. Given the actual richness of 83 species, this suggests that certain species are more common than others, but the community is still diverse. Whittaker's Beta Diversity Index calculated (3.34), points towards significant species turnover, suggesting that each site has a relatively unique community composition and that overall biodiversity is high across the study sites.

With the total constrained inertia accounting for 100 per cent of the variation (2.761), the CCA data shows that the first two axes explain 50.03 per cent

Table 1. Different sites of the study along with their respective GPS and Altitudinal data

Site	Location	GPS Coordinates	Altitude
Site A	Assam University Campus	24.687201, 92.752392	67.4m
Site B	Assam University (Ecoforest)	24.682907, 92.754419	72m
Site C	Irongmara village	24.694397, 92.736169	22.3m
Site D	Duwarbond	24.629053, 92.698161	37m
Site E	Bhaga	24.544872, 92.767693	75.1m
Site F	Garultala	24.431203, 92.827408	58.3m

Table 2. Distribution and diversity of coleopterans belonging to different families in the sites of Barak river basin, Assam

No.	Species	No. of observations	Season
Cerambycidae			
1.	<i>Aristobia approximator</i> (Thomson, 1865)	6	Monsoon
2.	<i>Aristobia reticulator</i> (Fabricius, 1781)	1	Post-Monsoon
3.	<i>Baralipion maculosum</i> Thomson, 1857	2	Pre-Monsoon
4.	<i>Batocera rubus</i> (Linné, 1758)	3	Pre-Monsoon
5.	<i>Chlorophorus annularis</i> (Fabricius, 1787)	4	Pre-Monsoon
6.	<i>Epepeotes uncinatus</i> Gahan, 1888	2	Pre-Monsoon
7.	<i>Nepiodes bowringi</i> (Gahan, 1894)	1	Pre-Monsoon
8.	<i>Oberea</i> sp.	2	Monsoon
9.	<i>Olenecamptus bilobus</i> (Fabricius, 1802)	2	Monsoon
10.	<i>Palimna</i> cf. <i>annulata</i> (Olivier, 1797)	1	Pre-Monsoon
11.	<i>Prionomma</i> (<i>Ancyloprotus</i>) <i>bigibbosum</i> (White, 1853)	1	Monsoon
12.	<i>Sthenias tonkineus</i> Pic, 1925	1	Post-Monsoon
13.	<i>Stromatium barbatum</i> (Fabricius, 1775)	5	Pre-Monsoon
14.	<i>Thylactus simulans</i> Gahan, 1890	1	Monsoon
15.	<i>Xylorhiza adusta</i> (Wiedemann, 1819)	1	Pre-Monsoon
16.	<i>Xystrocera globosa</i> (Olivier, 1795)	2	Post-Monsoon
Coccinellidae			
17.	<i>Cheilomenes sexmaculata</i> (Fabricius, 1781)	4	Winter
18.	<i>Chilocorus nigrinus</i> (Fabricius, 1798)	3	Pre-Monsoon
19.	<i>Coccinella transversalis</i> Fabricius, 1781	7	Winter
20.	<i>Diekeana</i> sp.	16	Pre-Monsoon
21.	<i>Henosepilachna vigintioctopunctata</i> (Fabricius, 1775)	2	Pre-Monsoon
22.	<i>Micraspis discolor</i> (Fabricius, 1798)	14	Pre-Monsoon
23.	<i>Micraspis univittata</i> (Hope, 1831)	9	Pre-Monsoon
Scarabaeidae			
24.	<i>Adoretus</i> (<i>Lepadoretus</i>) <i>sinicus</i> Burmeister, 1855	19	Pre-Monsoon
25.	<i>Anomala bilobata</i> Arrow, 1912	1	Pre-Monsoon
26.	<i>Anomala marginipennis</i> Arrow, 1912	7	Pre-Monsoon
27.	<i>Apogonia</i> sp.	2	Pre-Monsoon
28.	<i>Catharsius molossus</i> (Linnaeus, 1758)	2	Pre-Monsoon
29.	<i>Copris</i> sp.	1	Pre-Monsoon
30.	<i>Dicheros</i> (<i>Coryphe</i>) <i>bimacula</i> (Wiedemann, 1823)	2	Post-Monsoon
31.	<i>Holotrichia</i> sp.	5	Pre-Monsoon
32.	<i>Lepidiota</i> sp.	1	Monsoon

33.	<i>Onitis</i> sp.	1	Post-Monsoon
34.	<i>Onthophagus</i> sp.	1	Post-Monsoon
35.	<i>Popillia</i> sp.	1	Post-Monsoon
36.	<i>Schizonycha</i> sp.	4	Pre-Monsoon
Chrysomelidae			
37.	<i>Altica</i> sp.	5	Winter
38.	<i>Basiprionota decemmaculata</i> (Boheman, 1850)	1	Monsoon
39.	<i>Cassida (Crepidaspis) circumdata</i> Herbst, 1799	2	Post-Monsoon
40.	<i>Cassida (Crepidaspis) diomma</i> Boisduval, 1835	1	Monsoon
41.	<i>Aspidomorpha sanctaecrucis</i> (Fabricius, 1792)	16	Monsoon
42.	<i>Aspidomorpha miliaris</i> (Fabricius, 1775)	7	Post-Monsoon
43.	<i>Aulacophora indica</i> (Gmelin, 1790)	17	Pre-Monsoon
44.	<i>Dercetina</i> sp.	2	Pre-Monsoon
45.	<i>Galerucella placida</i> Baly, 1878	1	Monsoon
46.	<i>Lilioceris</i> sp.	1	Monsoon
47.	<i>Luperomorpha</i> sp.	1	Pre-Monsoon
48.	<i>Monolepta</i> sp.	8	Pre-Monsoon
49.	<i>Platycorynus peregrinus</i> (Herbst, 1783)	2	Pre-Monsoon
50.	<i>Podontia</i> sp.	2	Pre-Monsoon
51.	<i>Craspedonta</i> sp.	1	Monsoon
Carabidae			
52.	<i>Cicindela assamensis</i> Parry, 1844	1	Monsoon
53.	<i>Clivina</i> sp.	2	Post-Monsoon
54.	<i>Macrocheilus</i> sp.	1	Monsoon
55.	<i>Cicindela (Cosmodela) virgula</i> Fleutiaux, 1894	2	Pre-Monsoon
56.	<i>Craspedophorus mandarinus</i> (Schaum, 1854)	1	Monsoon
57.	<i>Cylindera (Ifasina) spinolae</i> (Gestro, 1889)	1	Pre-Monsoon
58.	<i>Scarites</i> sp.	1	Monsoon
59.	<i>Orthogonius</i> sp.	1	Pre-Monsoon
60.	<i>Pheropsophus (Stenaptinus) jessoensis</i> A.Morawitz, 1862	1	Monsoon
Tenebrionidae			
61.	<i>Cistelomorpha</i> sp.	1	Pre-Monsoon
62.	<i>Strongylium</i> sp.	5	Monsoon
Curculionidae			
63.	<i>Acicnemis</i> sp.	1	Pre-Monsoon
64.	<i>Desmidophorus hebes</i> Gyll. in Schoenh., 1837	2	Pre-Monsoon
65.	<i>Ectatorhinus</i> sp.	1	Post-Monsoon
66.	<i>Myllocerus</i> sp.	7	Monsoon

67.	<i>Phytoscaphus fractivirgatus</i> Marshall, 1923	1	Monsoon
68.	<i>Sternuchopsis</i> sp.	1	Post-Monsoon
Elateridae			
69.	<i>Agrypnus</i> sp.	1	Post-Monsoon
70.	<i>Cryptalaus sordidus</i> (Westwood, 1848)	1	Monsoon
71.	<i>Melanotus</i> sp.	1	Pre-Monsoon
Dytiscidae			
72.	<i>Cybister</i> sp.	8	Winter
73.	<i>Sandracottus chevrolati</i> (Aubé, 1838)	1	Pre-Monsoon
Lucanidae			
74.	<i>Prosopocoilus biplagiatus</i> (Westwood, 1855)	3	Pre-Monsoon
75.	<i>Prosopocoilus girafa</i> (Olivier, 1789)	1	Post-Monsoon
Lycidae			
76.	<i>Lycostomus similis</i> (Hope, 1831)	2	Post-Monsoon
77.	<i>Platerodrilus</i> sp.	1	Monsoon
Staphylinidae			
78.	<i>Platydracus</i> sp.	1	Winter
Prionoceridae			
79.	<i>Prionocerus bicolor</i> Redtenbacher, 1868	4	Winter
Lymexylidae			
80.	<i>Melittomma</i> sp.	1	Pre-Monsoon
Cleridae			
81.	<i>Tenerus</i> sp.	1	Monsoon
Endomychidae			
82.	<i>Eumorphus quadriguttatus</i> (Illiger, 1800)	1	Monsoon
Erotylidae			
83.	<i>Tetraphala</i> sp.	1	Monsoon

of all variation in the community. In the first axis CCA1, soil pH and precipitation have strong but opposing influences. Soil pH positively contributes whereas precipitation negatively contributes towards variation. In the second axis CCA2, specific humidity plays an important role in determining the variation. Sites and species showed distinct distributions across these gradients, reflecting the influence of habitat heterogeneity on community structure. These findings suggest that environmental parameters play a crucial role in shaping the spatial patterns of species assemblages. It revealed that the environmental variables fully

explain the variation in species composition, with the total inertia (1.76) entirely accounted for by the constrained model (100% explained variance). The first three canonical axes (CAP1, CAP2, and CAP3) together capture 76 per cent of the variance, with CAP1 alone contributing 35.22 per cent, thus emphasizing its key role in determining variance. Environmental parameters such as temperature and specific humidity positively influence CAP1 and CAP2, while soil pH is dominant in CAP1, and soil moisture as well as precipitation contribute negatively to CAP1. Sites cluster based on ecological similarity, with A (Site

1) distinctly influenced by CAP2 and CAP5. The biplot further shows the strong influence of environmental gradients; indicated by arrow lengths and directions; on species composition, with temperature and humidity being positively correlated (Fig. 1). The use of Bray-Curtis dissimilarity captures species turnover, and it also demonstrates the dominant role played by the selected environmental factors in driving biodiversity patterns. This data suggests that the forests of Barak Valley is highly diverse in terms of the beetle population inhabiting it, with a large number of species (83) spread relatively evenly across the total documented individuals (262). No single species dominates the ecosystem, as reflected by the low Berger-Parker dominance index and high evenness

values across different indices (Pielou's, Shannon's equitability, and Simpson's evenness). High evenness suggests that niche differentiation is well established, reducing the likelihood of competitive exclusion. This balance often contributes to ecosystem stability, making it less susceptible to disturbances, as the community doesn't rely on just a few dominant species for its overall functioning.

The effective number of species (ENS of ~39) shows that despite having 83 species, the community functions as though there are approximately 39 equally common species. This highlights a slight skew toward some species that are more abundant than others, but overall diversity is maintained. This is important because ecosystems with high

Table 3. Number of species, families, their habitat and time of occurrence in the sites of Barak river basin, Assam

Family	Genera	Species	Guild	Habitat	Occurrence
Cerambycidae	15	16	Herbivores (wood/stem borers)	Tree bark, leaves	Nocturnal/ diurnal
Chrysomelidae	13	15	Herbivores (leaf feeder)	Leaves, foliage	Diurnal
Scarabaeidae	12	13	Detritivores, Coprophagous, Root feeder	Leaf litter, under stones	Nocturnal
Carabidae	8	9	Predators (opportunistic ground hunters)	Leaf Litter, under Stones	Nocturnal
Coccinellidae	6	7	Predators (aphidophagous, coccidophagous)	Leaves, foliage	Diurnal
Curculionidae	6	6	Herbivores (phytophagous)	Tree bark, leaves	Diurnal
Elateridae	3	3	Larvae: Soil/root feeders; Adults: Herbivores (occasionally predators)	Tree bark, leaf litter	Nocturnal
Tenebrionidae	2	2	Detritivores	Leaf litter, under stones	Nocturnal
Dytiscidae	2	2	Aquatic Predators	Streams, Ponds	Diurnal
Lucanidae	1	2	Larvae: Wood borers; Adults: Herbivores (occasionally predators)	Tree bark	Diurnal
Lycidae	2	2	Fungivores / Nectar & pollen feeders (some larvae detritivores)	Leaves, foliage	Diurnal
Lymexylidae	1	1	Wood-borers	Tree bark	Diurnal
Staphylinidae	1	1	Predators / Scavengers	Leaf litter	Nocturnal
Erotylidae	1	1	Fungivores	Leaf litter	Nocturnal
Endomychidae	1	1	Fungivores	Tree bark	Nocturnal
Cleridae	1	1	Predators	Leaves	Diurnal
Prionoceridae	1	1	Larvae: Predators; Adults: Pollen feeders	Leaves	Diurnal

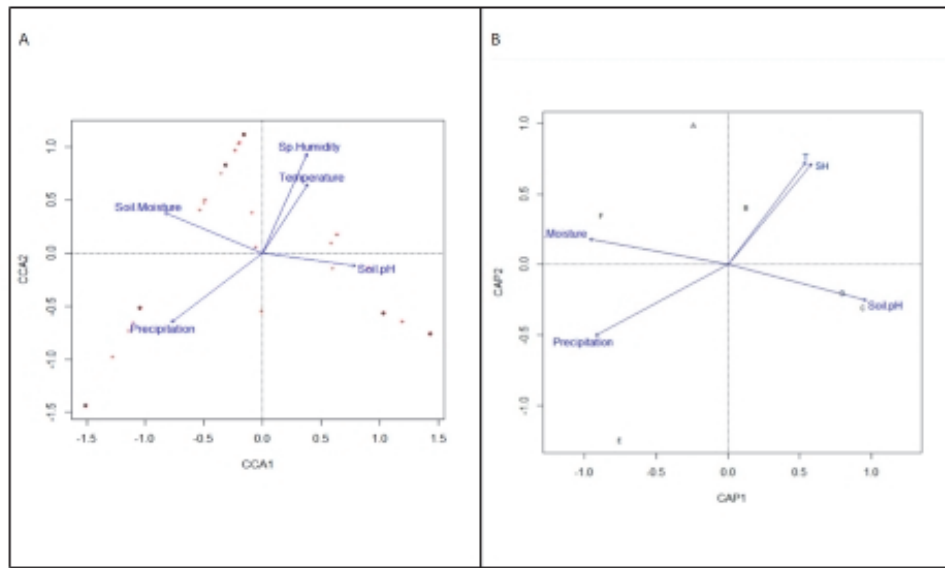


Fig. 1 A) CCA plot showing the impact of different environmental factors across the axes and DB-RDA plot showing the impact of different environmental factors on the beta diversity of the population across the axes

B) DB-RDA plot showing the impact of different environmental factors on the beta diversity of the population across the axes CAP1 and CAP2. T refers to Temperature and SH refers to Specific Humidity. Here, A, B, C, D, E and F correspond with Site 1, Site 2, Site 3, Site 4, Site 5 and Site 6 in a Bray-Curtis distance relationship respectively.

effective species numbers are typically more resilient to disturbances such as climate change, habitat fragmentation, or invasive species introduction. The species diversity across different sites was also significantly varied, with the large Whittaker's Beta Diversity index value suggesting a large environmental variability across the studied sites. This could mean differences in habitat types, microclimates, or resources available at each site, promoting distinct species assemblages. It suggests that each site contributes uniquely to the overall diversity (gamma diversity) of the region. However, it is of note that the small sample size increases the potential for inaccuracies in this data. Of particular note were the overwhelming presence of Cerambycidae in site 5 and of Chrysomelidae, Lucanidae and Lycidae in site 2. Site 2 also had the highest alpha diversity, hinting towards the faunal health of this forest.

The results of both Canonical Correspondence Analysis (CCA) and distance-based Redundancy Analysis (db-RDA) display the critical role of environmental variables in shaping the species

composition and biodiversity patterns. The extremely high explanation of variance by environmental factors in both analyses highlights the influence of these factors in structuring ecological communities. Soil pH and precipitation consistently emerged as dominant drivers of species turnover, emphasizing their ecological importance in the studied sites. Conservation strategies should, therefore, focus on maintaining and restoring these two critical environmental variables and mitigate anthropogenic activities that alter soil pH in this region.

The clustering of sites based on species composition relative to environmental gradients helps to provide a framework for understanding habitat heterogeneity. Site 1 and Site 5 exhibit distinct scores on the axes, which may represent ecological outliers with unique microhabitats or resource availability present in these sites, possibly pointing out the observed presence of water bodies in both. These site-specific distinctions highlight the diversity of environmental variables within the study area and the corresponding variability in ecological

communities. This spatial differentiation is essential for identifying habitats that may support unique or specialized species. The clustering of sites based on species-environment relationships can guide the establishment of ecological corridors and conservation areas to promote connectivity and ecosystem resilience.

Of particular note are several interesting habit and habitat patterns observed during this work. *Adoretus sinicus* and *Anomala marginipennis* were exceptionally common on the highly invasive plant *Melastoma malabathricum* and seemed to be frequently feeding on the nectar and leaves of this plant, though *A. marginipennis* is a non-specific consumer of most flowering plants. During late autumn months when the activity of these beetles was at the highest, not a single undamaged *M. malabathricum* was found in the study sites. This indicates the potential of *A. sinicus* and *A. marginipennis* for biological control of this invasive plant.

Longhorn beetles (Cerambycidae) proved to be the most diverse group in this region and many of these species dependent on a particular group of plants or forest conditions, such as *Stromatium barbatum* being dependent on teak (*Tectona grandis*) and other timber plants, making them sensitive to changes in the forest plant diversity caused by deforestation and fragmentation. This indicates their potential as bioindicators. *Calotropis gigantea* was observed to be the most common host plant for *Platycorynu speregrinus*. These beetles form a complex with the toxic milkweed plant, consuming it despite its toxic latex. This highlights the presence of specific beetle-plant feeding complexes that might prove to be key points of interest for conservation in this region. High diversity of Lady beetles (Coccinellidae), like *Cheilomenes sexmaculata* and *Coccinella transversalis*, are natural pest controllers. Their high numbers, such as *Diekeana admirabilis* (16 individuals), suggest a healthy population of predators that feed on aphids and other small pests, pointing to an ecosystem balance.

Many species from families like Cerambycidae, Scarabaeidae and Chrysomelidae were collected

during the post-monsoon and early summer months, from March to August, indicating a coherent seasonal pattern. This aligns with known periods of increased beetle activity when temperatures rise and food resources (like fresh vegetation and decomposing organic matter) become more abundant (Datta, 1982; Latha, 2019). Particularly for longhorn beetles and scarabs, there's a noticeable uptick in observations during the monsoon/post-monsoon months (June to August), corresponding with increased humidity, which encourages tree decay and forms nutrient-rich environments. These are ideal conditions for these beetles. Further analysis could link these trends to local climatic changes, offering a model for how beetles might respond to climate variability.

Certain species, like *Prosopocoilus girafa* (Giraffe stag beetle) and *Platerodrilus* sp. (Trilobite beetle), are important because of their rarity and distinctive biology (Dong *et al.*, 2014; Makarov and Kazantsev, 2022). Their presence could point towards specific microhabitats as well as conservation importance due to their specialized ecological roles.

A few beetles, such as *Anomala bilobata*, are potential agricultural pests, with scarab beetles sometimes causing damage to crops (Koppenhöfer and Fuzy, 2009). Lebbek borer (*Xystrocera globosa*), mango longhorn beetle (*Batocera rubus*), and Chinese rose beetle (*Adoretus sinicus*) are pest potential in agricultural settings (Spafford *et al.*, 2016; Mani, 2022; Singh *et al.*, 2022). The recorded data on these species can be used to model potential pest outbreaks and help design sustainable pest management strategies. Relatively high count of *Adoretus sinicus* (19 individuals) and other scarabs shows a stable system that promotes organic material breakdown and soil enrichment, likely supporting plant growth and soil fertility. Scarab beetles, such as *Catharsius molossus* (dung beetles), are essential for soil health as they help aerate the soil and improve nutrient cycling by burying dung (Singh *et al.*, 2021). The presence of multiple wood-boring beetles, including *Aristobia reticulator* and *Oberea* sp., suggests that the study area might consist of some fragmented or degraded forest patches (Saint-Germain and Drapeau, 2011). Wood-boring beetles thrive in areas where trees

Table 4. Environmental parameters in the sites of Barak river basin, Assam

Sites	Temperature (°C)	Specific humidity (g/kg)	Mean soil Moisture (%)	pH of soil	Mean precipitation
1	16.95 - 28.1	8.09 - 20.64	22.92	5.4 - 5.81	8.62mm/day
2	16.34 - 27.21	8.09 - 20.64	28.43	5.79 - 6.35	8.62mm/day
3	15.48 - 27.19	7.53 - 19.9	17.15	5.34 - 7.47	8.62mm/day
4	17.15 - 27.91	7.53 - 19.9	13.61	6.72 - 7.82	8.62mm/day
5	14.97 - 26.33	6.83 - 18.84	26.94	5.53 - 5.87	12.18mm/day
6	15.04 - 27.22	6.83 - 18.84	33.82	4.89 - 5.71	12.18mm/day

are stressed or dying, which could result from habitat fragmentation or other anthropogenic pressures. Comparing current data with historical records, changes in the distribution and abundance of certain species due to climate change might be observed. For example, species typically associated with warmer climates, such as *Aspidimorpha sanctaecrucis* could be expanding their habitat range into this region as temperatures increase (Muhaimin *et al.*, 2019).

ACKNOWLEDGEMENTS

The authors are thankful to the Head, Department of Life Science and Bioinformatics, Assam University, Silchar, Cachar, Assam for providing the support to undertake the study. AN-Data collection, Data interpretation, First draft of Manuscript writing; SG- Conceptualization, Supervision, Data interpretation and manuscript writing.

REFERENCES

- Ahmed G., Das A., Das A.N. and Gogoi B. (2025) Entomofaunal diversity of aquatic insects in Hakama Beel wetlands: a study in Assam, India. Wealth of Northeast India. XYZ Publishers, Guwahati. 220pp.
- Arya M. K., and Tamta P. (2016). Study on distribution and diversity of beetles (Insecta: Coleoptera) in different elevational zones of Binsar Wildlife Sanctuary, Almora, Uttarakhand, India. Journal of Entomology and Zoology Studies 4: 311–316.
- Barbhuiya H. A., Dutta B. K., Das A. K., and Baishya A. K. (2013). An annotated checklist of the Grasses (Poaceae) of Southern Assam. Check List 9(5): 980–986.
- Baruah M., Chakraborty G. and Choudhury M.D. (2013) Contribution to the flora of Barak Valley: conservation status and economic potential of herbaceous plant resources of Cachar District of Assam, India. International Journal of Bioresource and Stress Management 4 (2): 137–146.
- Bhattacharyya B., Bhagawati S., Manpoong N.S., Das P.P.G. and Devi E.B. (2021) Species diversity and relative abundance of scarab beetles in Jorhat district of Assam, India. Journal of Entomology and Zoology Studies 9 (3): 123–131.
- Bhattacharyya B., Handique G., Pujari D., Bhagawati S., Mishra H., Gogoi D. and Debnath H. (2017) Species diversity and relative abundance of scarab beetle fauna in Assam, northeast India. Journal of Entomology and Zoology Studies 5 (1): 711–716.
- Borah N. and Garkoti S.C. (2011) Tree Species composition, diversity, and regeneration patterns in undisturbed and disturbed forests of Barak Valley, South Assam, India. International Journal of Ecology and Environmental Sciences 37(3): 131–141.
- Borah N., Rabha D. and Athokpam F.D. (2016) Tree species diversity in tropical forests of Barak valley in Assam, India. Tropical Plant Research 3(1): 1–9.
- Borkataki S., Bhattacharyya B., Bhagawati S., Taye R.R. and Mishra H. (2018) Aquatic insect fauna of Majuli River Island of Assam. Journal of Entomology and Zoology Studies 6 (4): 1253–1257.
- Borogayary B., Das A. and Nath A. (2018) Tree species composition and population structure of a secondary tropical evergreen forest in Cachar district, Assam. Journal of Environmental Biology 39(1): 67–71.
- Chakraborty P. and Chakraborty S. (2000) Agrypninae

- (Coleoptera: Elateridae) of India: A taxonomic review and checklist. Records of the Zoological Survey of India 98(3): 71–83.
- Chandra K., Gupta D., Ghosh J., Das P., and Bhunia D. (2021) Insecta: Coleoptera. Faunal Diversity of Biogeographic Zones of India: North-East. Zoological Survey of India, Kolkata. pp377–451.
- Choudhury D. and Gupta S. (2015) Aquatic insect community of Deepor Beel (Ramsar site), Assam, India. Journal of Entomology and Zoology Studies 3 (1): 182–192.
- Chung A., Eggleton P., Speight M., Hammond P. and Chey V. (2000) The diversity of beetle assemblages in different habitat types in Sabah, Malaysia. Bulletin of Entomological Research 90(6): 475–496.
- Datta A.K. (1982) Studies on ground beetles (Coleoptera: Insecta) of Dooars area (Jalpaiguri: West Bengal) with special reference to their taxonomy, seasonal activity and density by pitfall experiment [Doctoral thesis, University of North Bengal]. University of North Bengal, Siliguri. <https://ir.nbu.ac.in/handle/123456789/982>
- Das M., Bhattacharyya B., Pujari D. and Handique G. (2016) Faunal composition of scarab beetles and their hosts in Assam. In: Arthropod Diversity and Conservation in the Tropics and Sub-tropics (Eds. C. Chakraborty and A. Mitra), Springer Singapore, Singapore. pp335–344.
- Deb R. and Subramanian K. (2023) New Record of *Sandracottus* Species (Coleoptera: Dytiscidae) from Western Ghats of India. Uttar Pradesh Journal of Zoology 44(21): 10–15.
- Deka K., Borthakur S. and Tanti B. (2017) Distribution and population dynamics of *Calamus nambariensis* Becc. – An endemic and threatened cane of Assam. Annals of Plant Sciences, 6(12): 1829–1834.
- Dikshit K.R. and Dikshit J.K. (2014) Natural Vegetation: Forests and Grasslands of North-East India. In: North-East India: Land, People and Economy. Advances in Asian Human-Environmental Research. Springer, Dordrecht. pp213–255. doi: 10.1007/978-94-007-7055-3_9.
- Dong X.M. and Jiang L. (2024) Species-specific larval acoustic behaviour of three stag beetles (Coleoptera: Lucanidae), with emphasis on their stridulatory organs and acoustic signals. Arthropod Structure & Development 80: 101300.
- Douglas H. (2011) Phylogenetic relationships of Elateridae inferred from adult morphology, with special reference to the position of Cardiophorinae. Zootaxa 2900(1): 1–45.
- Driscoll D.A. and Weir T. (2005) Beetle responses to habitat fragmentation depend on ecological traits, habitat condition, and remnant size. Conservation Biology, 19(1): 182–194.
- Geiser M. (2015) Taxonomy, phylogeny and biogeography of the Prionoceridae (Insecta: Coleoptera: Cleroidea) in the Indochinese Subregion [Doctoral dissertation, University of Basel]. Universität Basel, Basel. <https://edoc.unibas.ch/>
- Ghosh S.K. and Nilsson A.N. (2012) Catalogue of the diving beetles of India and adjacent countries (Coleoptera: Dytiscidae). Skörvnöpparn Supplement 3: 1–77.
- Grégoire J.C. (1988) Larval gregariousness in the Chrysomelidae. In: Biology of Chrysomelidae (Eds. P. Jolivet, E. Petitpierre and T.H. Hsiao), Springer, Dordrecht. pp253–271.
- Gupta D., Chandra K. and Khan S. (2014) An updated checklist of scarabaeoid beetles (Coleoptera: Scarabaeoidea) of Pench Tiger Reserve, Madhya Pradesh, India. Journal of Entomology and Zoology Studies 2(5): 225–240.
- Hegde V., Lal B., and Chandra K. (2014). Tenebrionidae (Coleoptera) Fauna of Chhattisgarh, India. Zoo's Print 29(12): 31–34.
- Jadhao M.F. and Bhongade A.H. (2018) Occurrence of carabid beetles (coleoptera: carabidae) in rice fields during kharif season. International Journal of Researches in Biosciences, Agriculture and Technology 6(5): 168–172.
- Jadhav S. and Sharma R. (2012) Insecta: Coleoptera: Rhynchophora: Curculionidae. Zoological Survey of India, Fauna of Maharashtra, State Fauna Series 20: 527–528.
- Johri P., Vishnu Dayal V.D., and Reeta Johri R.J. (2010) Diversity of terrestrial insects around the natural wetland (Jalesar) in district Unnao, Uttar Pradesh, India. Journal of Experimental Zoology, India 13(2): 305–328.
- Jolivet P., Petitpierre E. and Hsiao T.H. (2012) Biology of Chrysomelidae. Springer Science & Business Media, Dordrecht. 465pp.
- Kariyanna B., Gupta R., Mohan M. and Vitali F. (2019) Wood-boring longhorn beetles (Coleoptera: Cerambycidae) of agroforest ecosystem in India. Indian Journal of Entomology 81(1): 108–126.

- Koppenhöfer A.M. and Fuzy E.M. (2009) Long-term effects and persistence of *Steinernema scarabaei* applied for suppression of *Anomala orientalis* (Coleoptera: Scarabaeidae). *Biological Control* 48(1): 63–72.
- Kumar S. (2018). Identification of Scarabaeid beetles (Coleoptera) in vicinity of sugarcane crop in the western plain zone of Uttar Pradesh, India. *Journal of Pharmacognosy and Phytochemistry* 7(5S): 111–115.
- Kumawat M., Singh K.M. and Ramamurthy V. (2015) A checklist of the Long-horned Beetles (Coleoptera: Cerambycidae) of Arunachal Pradesh, northeastern India with several new reports. *Journal of Threatened Taxa* 7(12): 7879–7901.
- Kushwaha R.K., Chakraborti U., Roy S., Biswas O. and Mitra B. (2017) Diversity of Ground beetles (Insecta: Coleoptera: Carabidae) from Indian Sundarban with seven new records. *Bioscience Discovery* 8(3): 335–339.
- Latha T. (2019) Seasonal activity of dung beetles (Scarabaeinae) in a forest in South Western Ghats. *International Journal of Forest, Animal and Fisheries Research* 3(2): 58–64.
- Leschen R.A. and Węgrzynowicz P. (1998) Generic catalogue and taxonomic status of Languriidae (Cucujoidea). Paper presented at the *Annales Zoologici* 48(3/4): 221–243.
- Mahanta B., Patar K., Osmani A.Q. and Kusre D. (2019) Aquatic insect community on Sonduba Beel, Morigaon District, Assam, India. *Journal of Aquatic Biology* 34 (2): 45–53.
- Makarov K.V. and Kazantsev S. (2022) Larva, pupa or adult? The female of *Platerodrilus* case (Coleoptera: Lycidae). *Diversity* 14(12): 1063.
- Mani M. (2022) Pests and their management in fig. *Trends in Horticultural Entomology*, Springer, Singapore. Doi: 10.1007/978-981-19-0343-4_26735–745.
- Maquart P.-O., Yamamoto S., Sopha S., Chhorn S., Phak S., Sinovas P. and Boyer S. (2023). Stag beetle fauna of Cambodia (Coleoptera: Lucanidae). *Journal of Asia-Pacific Entomology* 26(1): 102008.
- Marshall G. A. (1916). Some injurious Indian weevils (Curculionidae)—II. *Bulletin of Entomological Research* 6(4): 365–373.
- Masek M., Motyka M., Kusy D., Bocsek M., Li Y. and Bocak L. (2018) Molecular phylogeny, diversity and zoogeography of net-winged beetles (Coleoptera: Lycidae). *Insects*, 9(4): 154.
- Masek M., Palata V., Bray T. C. and Bocak L. (2015) Molecular phylogeny reveals high diversity, geographic structure and limited ranges in neotenic net-winged beetles *Platerodrilus* (Coleoptera: Lycidae). *PloS one* 10(4): e0123855.
- Maulik S. (1910) Named specimens of Chrysomelidae in the Indian Museum. *Records of The Indian Museum* pp202–213.
- Medhi P., Borthakur S., and Hore D. (2010). Phyto resources from North Cachar Hills of Assam, India-IV: Bamboos and Rattans. *Journal of Bamboo Rattan* 9(3): 115–125.
- Mitra B., Chakraborti U., Mallick K., Bhaumik S. and Das P. (2017) An updated list of cerambycid beetles (Coleoptera: Cerambycidae) of Assam, India. *Records of the Zoological Survey of India* 117(2): 78–90.
- Muhaimin A., Halim M., Zulaikha S. S., and Yaakop S. (2019). Habitat preferences of leaf beetles (Coleoptera: Chrysomelidae) based on abiotic factors: A study from Fraser's Hill, Pahang, Malaysia. In: *Proceedings of the IOP Conference Series: Earth and Environmental Science*, IOP Publishing. doi:10.1088/1755-1315/269/1/012035.
- Nath S.S., Beypi R. and Baruah M.K. (2024). Status of bamboo species in Cachar district of Barak valley, Assam, India. *Annals of Plant and Soil Research* 26(2): 487–491.
- Pal R. and Singh D. (2016) Endemic Orchids of Northeast India. *Bioprospecting of Indigenous Bioresources of North-East India* In: Purkayastha, J. (eds) *Bioprospecting of Indigenous Bioresources of North-East India*. Springer, Singapore. pp31–44. doi: 10.1007/978-981-10-0620-3_3
- Pal T.K. (1992) On a Collection of Passalidae and Lucanidae (Insecta: Coleoptera) from Arunachal Pradesh, India. *Records of the Zoological Survey of India* 90(1-4): 135–145. doi: 10.26515/rzsi/v90/i1-4/1992/160977
- Poorani J. (2002) An annotated checklist of the Coccinellidae (Coleoptera)(excluding Epilachninae) of the Indian subregion. *Oriental Insects* 36(1): 307–383.
- Poorani J. (2019) Coccinellidae of the Indian subcontinent. *Indian Insects: Diversity and Science*, CRC Press, Boca Raton. pp223–246.
- Prathapan K.D., Poorani J., Kumari S.A., Anuradha C., Padmanaban B. and Thanigairaj R. (2019) Species composition and diagnoses of leaf-and fruit-

- scarring beetles (Coleoptera, Chrysomelidae) infesting bananas and plantains (Zingiberales, Musaceae) in the Indian subcontinent. *Deutsche Entomologische Zeitschrift* 66(2): 179–202.
- Rajagopal D. and Kumar P. (1993) Morphological characters of predatory larvae of eight species of Indian carabid beetles (Coleoptera: Carabidae). *Journal of Entomological Research* 17(4): 319–325.
- Rajbongshi P. and Das T. (2024) High-Value Plant Resources in Riparian Areas. *High-Value Plants: Novel Insights and Biotechnological Advances* (Eds. Singh T.A., Sarangi P.K. and Singh C.B.), Apple Academic Press, Boca Raton. pp205–228.
- Saint-Germain M. and Drapeau P. (2011) Response of saprophagous wood-boring beetles (Coleoptera: Cerambycidae) to severe habitat loss due to logging in an aspen-dominated boreal landscape. *Landscape ecology* 26: 573–586.
- Singh A.P., De K., Uniyal V.P. and Sathyakumar S. (2021) An experimental study on bioturbation and dung removal activities of *Catharsius molossus* (Linnaeus, 1758) (Coleoptera: Scarabaeidae) in the Greater Himalaya. *Journal of Asia-Pacific Biodiversity* 14(2): 169–173.
- Singh A.R., Firake D., Akoijam R., Sharma S., Singh Y., Thokchom S. and Behere G. (2022) Record of three Cerambycid pests associated with tree bean (*Parkia timoriana*) decline in Northeast India. *National Academy Science Letters* 45(3): 213–217.
- Spafford H., Ching A., Manley M., Hardin C. and Bittenbender H. (2016) Management of Chinese rose beetle (*Adoretus sinicus*) adults feeding on cacao (*Theobroma cacao*) using insecticides. *Insects* 7(2): 28.
- Sreedevi K., Mahendiran G., and Chandana P. S. (2023). Ground Beetles (Coleoptera: Carabidae). *Insect Predators in Pest Management* (Ed. Omkar) CRC Press, Boca Raton. pp175–186.
- Stibick J.N. (1980) A revision of the Hypnoidinae of the world (Col. Elateridae): part/ IV. The Hypnoidinae of India (Section/ 12). *Revista Española de Entomología* 54(1–4): 247–273.
- Thakare V.G., Zade V.S., and Hegde V.D. (2012) Darkling Beetles (Coleoptera: Tenebrionidae) of Melghat Tiger Reserve, Central India. *Journal on New Biological Reports* 1(1): 29–32.
- Tordoff A., Baltzer M., Fellowes J., Pilgrim J. and Langhammer P. (2012) Key biodiversity areas in the Indo-Burma hotspot: process, progress and future directions. *Journal of Threatened Taxa* 4 (8): 2779–2787.
- Vazirani T. (1968) Notes on collection of Hispinae and Cassidinae (Coleoptera: Chrysomelidae) from NE India. *Records of the Zoological Survey of India* pp143–152.

(Received August 20, 2025; revised ms accepted October 31, 2025; published December 31, 2025)

Comprehensive assessment of pivotal silkworm races for economic traits in Jammu and Kashmir, India

R. Kiran*, P. Kumaresan, Shivkumar, M.N. Ahmad, K.N. Bharath and Sardar Singh

Silkworm Improvement Section, Central Sericultural Research & Training Institute, Pampore 192121, Jammu and Kashmir, India.

Email: kiranr.csb@nic.in

ABSTRACT: The present study aims for a comparative study including performance and stability of parental lines Shogetsu Hosho, Shunrei Shogetsu and N124xC124. The economic traits of the three selected silkworm races evaluated revealed that fecundity in Shogetsu Hosho ranged from 424 to 600 eggs, in Shunrei Shogetsu it was 478–611 and in N124xC124 it ranged 438–565. The effective rate of rearing (ERR) in Shogetsu Hosho ranged from 11.74 to 15.64 kg, while in Shunrei Shogetsu it was 13.16–17.57 and in N124xC124 it ranged 11.99–16.65 kg. Single cocoon weight (SCW) was in the range of 1.38–1.62, 1.50–1.98, 1.44–1.95 g, respectively for Shogetsu Hosho, Shunrei Shogetsu and N124xC124 races. The single shell weight (SSW) ranged from 0.28 to 0.34 g in Shogetsu Hosho, 0.30–0.38 g in Shunrei Shogetsu and 0.27–0.31 g in N124xC124 races. The silk ratio percentage (SR%) was in the range of 18.18–22.37, 17.51–20.65, 14.36–20.96, respectively for Shogetsu Hosho, Shunrei Shogetsu and N124xC124 races. All races exhibited a moderate range of egg-laying capacity, with Shunrei Shogetsu showing the highest potential (up to 611 eggs per month), followed by Shogetsu Hosho (up to 600) and N124xC124 (up to 565). Multiple trait evaluation index (MTEI) values of the three races were found to be in the order of Shunrei Shogetsu followed by Shogetsu Hosho and N124xC124. Stability varied among traits and silkworm races. N124xC124 was found to be stable (value close to one) for fecundity (0.81) and SCW (1.06), while Shogetsu Hosho showed stability for ERR (0.99). The Francis coefficient of variation for fecundity placed Shunrei Shogetsu in the fourth quadrant, indicating a higher mean with low variation, followed by Shogetsu Hosho in the third quadrant (high mean and high variation) and N124xC124 in the first quadrant (low mean and low variation), indicating comparatively greater stability in Shunrei Shogetsu. Similarly, for ERR, N124xC124 appeared in the fourth quadrant, followed by Shunrei shogetsu (third quadrant) and Shogetsu Hosho (second quadrant). For SCW, the order was Shunrei Shogetsu (third quadrant) and both N124xC124 and Shogetsu Hosho in the first quadrant. In the case of SSW, Shunrei Shogetsu occupied the third quadrant, Shogetsu Hosho spanned the second and third quadrants and N124xC124 was in the first quadrant. For SR, Shunrei Shogetsu was in the fourth quadrant, followed by Shogetsu Hosho (third quadrant) and N124xC124 (second quadrant). Overall, Shunrei Shogetsu showed better stability across most traits, followed by Shogetsu Hosho and N124xC124. However, when all three methods used are ranked according to the traits, ranked according to Shogetsu Hosho, followed by Shunrei Shogetsu and N124XC124. © 2025 Association for Advancement of Entomology

KEY WORDS: Silkworm, bivoltine, evaluation, traits, stability

* Author for correspondence

INTRODUCTION

Sericulture, a vital agro-based industry, significantly boosts many economies. This is largely because silk holds major commercial importance in textiles and mulberry silkworms, which produce over 95 per cent of the world's silk. India currently stands in second position in silk production where an increase in the bivoltine silk has made a huge impact on the economic growth. In financial year 2024-25 alone, India produced about 10,160 MT of bivoltine silk. The raw silk production of bivoltine silk 1995-96 was about 475 MT. The CAGR growth year by year from 1995, stands at 11.14 per cent. The remarkable growth of the bivoltine silk was influenced by the various mulberry, silkworm breeding programmes and extensive extension programmes bringing awareness among the farmers who previously preferred multivoltine or cross breed (GoI, 2013, 2024; Bavachikar *et al.*, 2023; Londhe and Chougale 2022; CSB 2024, NAAS 2024).

The strategic utilization of three pivotal parental races, namely Shogetsu Hosho, Shunrei Shogetsu and N124xC124, has played a pivotal role in propelling India to a dominant position in bivoltine silk production. The subsequent development of bivoltine single hybrids, such as SH6xNB4D2 in the northern states and CSR double hybrids in the southern states, has further bolstered India's standing in the global silk industry. These three foundational parental races were instrumental in the creation of highly promising breeds like SH6 (Shogetsu Hosho), CSR2, CSR5, CSR6 (Shunrei Shogetsu), NB4D2, NB18 and KA (N124xC124). Moreover, these foundational breeds were employed in the development of advanced races, including CSR4, CSR8 (SL), CSR12 and the most recent Gen2 and Gen3, where NB4D2, KA, CSR5 and CSR2 played vital roles as parental components (Bindroo *et al.*, 2014). The impact of these evolved races has extended to hybrid evaluation programs, culminating in the release of influential hybrids such as CSR double hybrids, SH6xNB4D2 and CSR2xCSR4 into the field. These identified hybrids have significantly contributed to the sustained growth of bivoltine silk production for over two decades, marking a substantial stride in India's silk industry.

In general, use of three parental lines has brought a remarkable growth to bivoltine sericulture industry of the country which was previously known for multivoltine silk. Currently, the usage of the three parental races is restricted to germ plasm programmes. Economic traits stability analysis in breeding refers to the evaluation of the stability of economically important traits over time and across different environments. This analysis helps breeders understand how well the genetic makeup of a population will persist and remain consistent over time and in different environments. The changed environmental variables due to climate change pose a challenge to breeders in order to identify a stable breed/ hybrid for a stable crop. The present study aims for a comparative study including performance and stability of the three parental lines discussed above.

MATERIALS AND METHODS

The three silkworm races were reared during five spring seasonal rearing under recommended rearing conditions (Krishnaswami 1978; 1983). First to third instar larvae were fed KNG and Ichinose mulberry varieties (27- 28°C; 85-90% RH) and fourth and fifth instars with Goshierami leaves (24-26 °C; 70-80% RH). The three races were reared in three replications, with 250 larvae retained after the third moult. At the end of fifth instar, mature larvae were manually collected and transferred to collapsible plastic mountages for spinning. Rearing parameters were subsequently assessed using the following equations.

Fecundity: Number of late born larva+ number of unfertilized eggs + number of dead eggs + number of colors changed eggs+ number of larvae brushed

$$\text{ERR (kg)} = \frac{\text{Weight of cocoon harvested/}}{\text{Number of worms retained after 3rd moult}} \times 10,000$$

$$\text{SCW (g)} = \frac{\text{Weight of 10 cocoons (g)}}{10}$$

$$\text{SSW (g)} = \frac{\text{Weight of 10 cocoon shells (g)}}{10}$$

$$\text{SR\%} = \frac{\text{Single cocoon shell weight (g)}}{\text{Single cocoon weight (g)}} \times 100$$

The multi trait evaluation index (MTEI) was computed using the formula specified by Mano et al. (1993).

$$\text{MTEI} = \frac{(A-B)}{(C \times 10)} + 50$$

Where: A: value obtained for a specific trait of a given race; B: mean value of the same trait across all the considered race; C: standard deviation of the particular trait across all the considered race; 10 and 50: standard unit and fixed value.

Stability parameters were measured using three parameters: Francis variation coefficient (CV_i), Eberhart and Russell regression coefficient (B_i) by following equations (1966).

Eberhart and Russell (Regression coefficient): When the regression coefficient of a hybrid is one (B_i = 1), it is considered stable and exhibits a unit response. Eberhart and Russell proposed a model to assess the behavior of cultivars, which was utilized for the evaluation in this case. The model is described as follows:

$$B_i = \frac{\sum_j (Y_{ij} - \bar{Y}_i - \bar{Y}_j + \bar{Y}_{..})(\bar{Y}_j - \bar{Y}_{..})}{\sum_j (\bar{Y}_j - \bar{Y}_{..})^2}$$

Francis variation coefficient: The stability dataset was evaluated as per the Francis and Kannenberg based on the coefficient of variation, mean yield and environmental variance. The stability model by Francis and Kannenberg expressed by the following equation. A race is considered stable if it has a large mean yield and a small coefficient of variation.

$$CV_i = \left(\frac{\sum_j (Y_{ij} - \bar{Y}_i)^2}{\frac{s-1}{\bar{Y}_i}} \right) \times 100$$

RESULTS AND DISCUSSION

The economic traits of the three selected silkworm races evaluated in the present study revealed that fecundity in Shogetsu Hosho ranged from 424 to

600 eggs, in Shunrei Shogetsu it was 478–611 and in N124xC124 it ranged 438–565 (Fig. 1). The yield per 10,000 larvae by weight in Shogetsu Hosho ranged from 11.74 to 15.64 kg, while in Shunrei Shogetsu it was 13.16–17.57 kg and in N124xC124 it ranged 11.99–16.65 kg (Fig. 2). SCW was in the range of 1.38–1.62, 1.50–1.98, 1.44–1.95g, respectively for Shogetsu Hosho, Shunrei Shogetsu and N124xC124 races (Fig. 3). The SSW ranged from 0.28 to 0.34g in Shogetsu Hosho, 0.30–0.38g in Shunrei Shogetsu and 0.27–0.31g in N124xC124 races (Fig. 4). The SR percentage was in the range of 18.18–22.37, 17.51–20.65, 14.36–20.96, respectively for Shogetsu Hosho, Shunrei Shogetsu and N124xC124 races (Fig. 5). All races exhibited a moderate range of egg-laying capacity, with Shunrei Shogetsu showing the highest potential (up to 611 eggs per month), followed by Shogetsu Hosho (up to 600) and N124xC124 (up to 565). As with fecundity, a range of cocoon yield was observed across all races. Shunrei Shogetsu again exhibited the highest potential, indicating its suitability for higher production, followed by N124xC124 and Shogetsu Hosho. Considerable variation was also recorded in cocoon characters, with the highest average values for single cocoon weight, shell weight and shell ratio observed in Shunrei Shogetsu, followed by Shogetsu Hosho and N124xC124 (Figs. 1–5).

This study focused on five key economic traits of silkworms: fecundity, cocoon weight, shell weight and shell ratio. These traits significantly impact various micro-industries within sericulture. In silkworm breeding programs, a well-established approach involves employing a MTEI. This index considers the combined value of multiple traits, providing a more comprehensive picture of a silkworm race's performance. MTEI is a widely used methodology in Japan and elsewhere (Mano et al., 1993; Singh and Subba Rao 1993). The evaluation index values calculated as per Mano index among the traits varied considerably where, the cumulative evaluation index values of the three races were found to be in the order of Shunrei Shogetsu followed by Shogetsu Hosho and N124xC124 (Table 1).

Shunrei Shogetsu demonstrated a balanced performance across different metrics in fecundity, ERR, SCW, SSW and SR, while in Shogetsu Hosho. It's important to note that MTEI assigns a single index value based on a pre-determined weighting system for each trait tailored to the specific breeding goals. However, in general silkworm breeders refrain from using the evaluation index since use of evaluation index for negative traits is a major problem. By incorporating additional relevant indices, we can create a more nuanced picture of a race's suitability for different breeding objectives within the sericulture industry.

The riddle for a silkworm breeder resides in the management of important economic traits as there are several economic traits where some are positively correlated with each other while some are negatively correlated. Economic traits related to fecundity includes important interconnected traits such as number of larvae hatched and number larvae brushed, late born larvae. These associated economic traits concern with the industry involving silkworm egg production and chawki rearing centres where high fecundity is a desirable trait to maximise the egg production (Ullal and Narashimhanna, 1981; Mirhosseini *et al.*, 2005; Singh *et al.*, 2011; Neshagaran *et al.*, 2014).

Similarly, cocoon weight and its associated traits concern sericulture famers, where higher number of cocoons and weight defines the economy of farmer. The cocoon weight represents several associated economic traits such as pupation rate indicating survivability, cocoon weight comprising weight of pupa and shell (Ksham *et al.*, 1995; Mirhosseini *et al.*, 2005; Neshagaran *et al.*, 2014). Further, the shell weight has an association with post cocoon sector which has a correlation with the associated traits such as length of silk spun by the larva and denier indicating thickness of the filament. Thus, the economic traits selected under in the present study was an attempt to compare performance of the three important races along with stability of the same as these individual economic trait has a direct correlation with diverse sectors such as egg production centres and chawki rearing centers (fecundity and associated traits), sericulture farming community (cocoon weight and associated

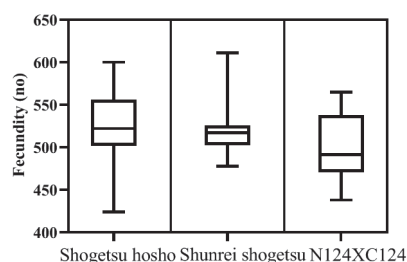


Fig. 1 Range of fecundity from Shunrei Shogetsu, Shogetsu Hosho, N124XC124 reared in five different environments.

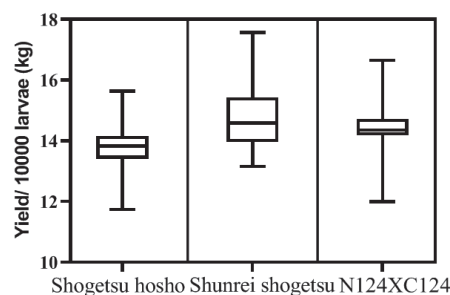


Fig. 2 Range of ERR from Shunrei Shogetsu, Shogetsu Hosho, N124XC124 reared in five different environments

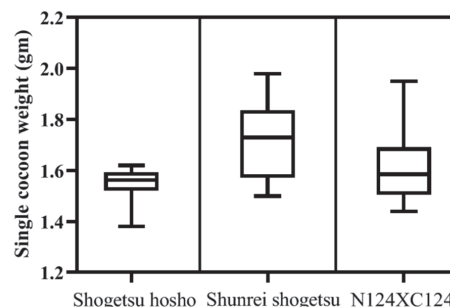


Fig. 3 Graph depicting the range of SCW from Shunrei Shogetsu, Shogetsu Hosho, N124XC124 reared in five different environments.

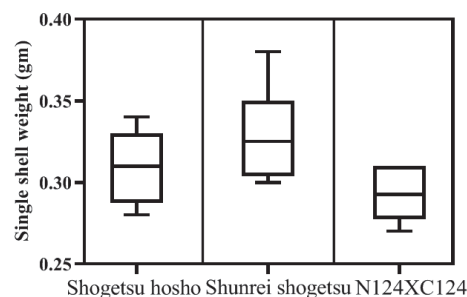


Fig. 4 Graph depicting the range of SSW from Shunrei Shogetsu, Shogetsu Hosho, N124XC124 reared in five different environments.

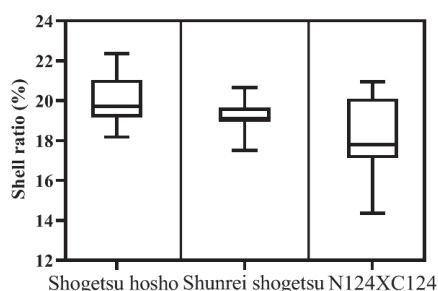


Fig. 5 Graph depicting the range of SR percentage from Shunrei Shogetsu, Shogetsu Hosho, N124XC124 reared in five different environments.

traits) and post cocoon sector (shell weight and associated traits) with significant impact on the economy.

The stability analysis evaluates the variance of the traits, providing an indication of trait variation within the population. The stability of a trait is determined by the correlation between the mean of the trait and the mean of the environment. A stable trait remains constant over time and across different environments, while an unstable trait may vary greatly. According to the Eberhart and Russell model, stable varieties are defined as those with a regression coefficient of one and a regression deviation that isn't significantly different from zero. In the present study, as expected, stability varied among traits and silkworm races. N124xC124 was found to be stable (value close to one) for fecundity (0.81) and SCW (1.06), while Shogetsu Hosho showed stability for ERR (0.99). Results for the other traits are varying (Table 2). The stability of a trait can be assessed by examining the correlation between the average trait value and the average environmental conditions. Genes, as internal factors, play a crucial role in trait expression. However, environmental factors can significantly influence gene expression and, consequently, the resulting phenotype. Even with identical genetic makeup, organisms can develop different observable traits depending on their environment. A stable trait is one that remains constant over time and in different environments, while an unstable trait may vary greatly (Reza and Rahman, 2005; Zhao *et al.*, 2007; Ahsan and Rahman, 2008; Rahmathulla, 2012; Muniraju and Mundkur, 2018). For instance, in silkworm breeding various economic traits such as

fecundity, cocoon weight, silk quality are considered. Identification of a breed with stable performance in all the economic parameters is essential as each economic traits confer to different micro industries within the field of sericulture. Overall, stability analysis of economic traits is a critical component of breeding programs as it helps breeders to make informed decisions about the development of a stable breed or hybrid (Pour-Aboughadareh *et al.*, 2022; Lee *et al.*, 2023; Khandelwal *et al.*, 2024).

The Francis coefficient of variation for fecundity placed Shunrei Shogetsu in the fourth quadrant, indicating a higher mean with low variation, followed by Shogetsu Hosho in the third quadrant (high mean and high variation) and N124xC124 in the first quadrant (low mean and low variation), indicating comparatively greater stability in Shunrei Shogetsu. Similarly, for ERR, N124xC124 appeared in the fourth quadrant, followed by Shunrei shogetsu (third quadrant) and Shogetsu Hosho (second quadrant). For SCW, the order was Shunrei Shogetsu (third quadrant) and both N124xC124 and Shogetsu Hosho in the first quadrant. In the case of SSW, Shunrei Shogetsu occupied the third quadrant, Shogetsu Hosho spanned the second and third quadrants and N124xC124 was in the first quadrant. For SR (%), Shunrei Shogetsu was in the fourth quadrant, followed by Shogetsu Hosho (third quadrant) and N124xC124 (second quadrant). Overall, Shunrei Shogetsu showed better stability across most traits, followed by Shogetsu Hosho and N124xC124 (Figs. 6–10).

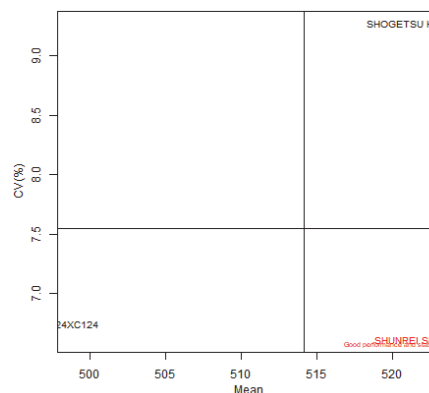


Fig. 6 Graph depicting the coefficient of variation and mean fecundity of Shunrei Shogetsu, Shogetsu Hosho, N124XC124 averaged over five environments.

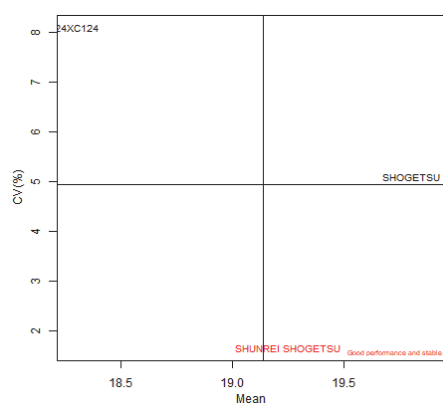


Fig. 7 Graph depicting the coefficient of variation and mean SR percentage of Shunrei Shogetsu, Shogetsu Hosho, N124XC124 averaged over five environments.

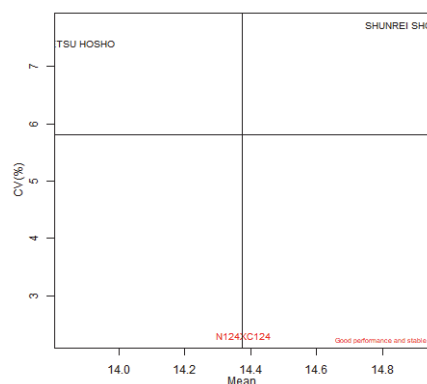


Fig. 10: Graph depicting the coefficient of variation and ERR of Shunrei Shogetsu, Shogetsu Hosho, N124XC124 averaged over five environments.

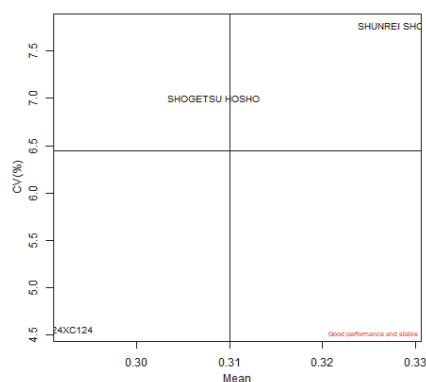


Fig. 8 Graph depicting the coefficient of variation and mean SSW of Shunrei Shogetsu, Shogetsu Hosho, N124XC124 averaged over five environments.

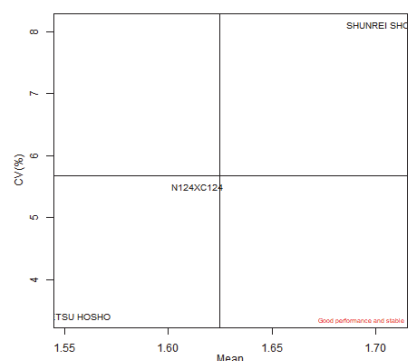


Fig. 9: Graph depicting the coefficient of variation and mean SCW of Shunrei Shogetsu, Shogetsu Hosho, N124XC124 averaged over five environments.

In the present study, stability analysis of the three pivotal parental races Shogetsu Hosho, Shunrei Shogetsu and N124×C124 revealed their distinct

adaptive responses and genetic buffering capacities against environmental fluctuations. Since these three races played a pivotal role in the evolution of the majority of bivoltine breeds in India, maintaining a comprehensive, environment-specific database of their performance parameters becomes crucial. Such a repository would be invaluable if breeders need backcross with the original parental lines in cases of degeneration or loss of key genetic traits. Moreover, this information could serve as a reference framework for future breeding programs, enabling breeders to select parental races based on documented stability indices and adaptive performance across environments. Furthermore, the present study demonstrates that stability analysis is a valuable tool for shortlisting breeds or hybrids, as it provides insights into performance variation across diverse environments and serves as a complementary tool to the widely used Mano evaluation index, which considers only economic trait performance.

These three foundational parental races were instrumental in the creation of highly promising breeds like SH6 (Shogetsu Hosho), CSR2, CSR5, CSR6 (Shunrei Shogetsu), NB4D2, NB18 and KA (N124×C124). Moreover, these foundational breeds were employed in the development of advanced races, including CSR4, CSR8 (SL), CSR12 and the most recent Gen2 and Gen3, where NB4D2, KA, CSR5 and CSR2 played vital roles as parental components. The impact of these evolved races has extended to hybrid evaluation programs,

Table 1 Evaluation index values of N124XC124, Shogetsu Hosho, Shunrei Shogetsu in the selected traits

Race	Fecundity	Yield per 10,000 larvae	Single cocoon weight	Single shell weight	Silk Ratio (%)
Shogetsu Hosho	55	40	41	49	59
Shunrei Shogetsu	56	60	61	60	51
N124XC124	38	50	49	40	39

Table 2. Stability values of the three silkworm races N124XC124, Shogetsu Hosho, Shunrei Shogetsu using Eberhart and Russel's model

Race	Fecundity	ERR	SCW	SSW	SR
N124XC124	0.81	0.43	1.06	0.13	2.02
Shogetsu Hosho	1.57	0.99	-0.05	1.55	0.55
Shunrei Shogetsu	0.62	1.58	1.99	1.33	0.43

culminating in the release of influential hybrids such as CSR double hybrids and CSR2xCSR4 in the southern states and SH6xNB4D2 in the northern states. These hybrids have become dominant in bivoltine silk production, further bolstering India's standing in the global silk industry. In conclusion, evaluating all traits collectively provides a nuanced picture of the economic potential of each race, making them valuable for future breeding programs.

A stable trait is one that remains constant over time and in different environments, while an unstable trait may vary greatly (Reza and Rahman, 2005; Zhao *et al.*, 2007; Ahsan and Rahman, 2008; Rahmathulla, 2012; Muniraju and Mundkur, 2018). For instance, in silkworm breeding various economic traits such as fecundity, cocoon weight, silk quality are considered. Identification of a breed with stable performance in all the economic parameters is essential as each economic traits confer to different micro industries within the field of sericulture. Overall, stability analysis of economic traits is a critical component of breeding programs as it helps breeders to make informed decisions about the development of a stable breed or hybrid (Pour-Aboughadareh *et al.*, 2022; Lee *et al.*, 2023; Khandelwal *et al.*, 2024). In the three models tested, a considerable variation was observed with each performing better in few traits which

increases the complexity of the breeder while catering to the different micro industries within the sericulture as discussed before. However, when all three methods used are ranked according to the traits, ranked according to Shogetsu Hosho, followed by Shunrei Shogetsu and N124XC124. Although the aim of the study was not to identify or shortlist a breed, the comparative performance of the three breeds with historical pivotal parental races, propelling India to a dominant position in bivoltine silk production.

ACKNOWLEDGEMENT

The authors would like to thank Central Silk Board and Central Sericultural Research and Training Institute, Pampore, Jammu and Kashmir for providing financial assistance.

REFERENCES

- Ahsan M.K. and Rahman S.M. (2008) Genetic variability and correlation analysis in hybrids of mulberry silkworm, *Bombyx mori* L. for egg characters. University Journal of Zoology Rajshahi University 27: 13–16.
- Bavachikar P.N., Lakshmi H., Raju P.J., Tettamanti G., Mohamed A. and Mamillapalli A. (2023) Effect of heat shock on embryonic development and its impact on commercial traits of silkworm *Bombyx mori* L. ENTOMON 48(3): 383–396.
- Bindroo B.B., Naseema Begum A., Mal Reddy N. and Moorthy S.M. (2014) Pedigree of bivoltine [V2] silkworm breeds (*Bombyx mori* L.) developed at CSRTI, Mysore. Central Sericultural Research & Training Institute, Central Silk Board, Min. of Textiles, Govt. of India, Mysore. 40pp.
- CSB (2024). Bivoltine Promotion. <https://perfectergonomicssystems.in/csb/schemes/centrally-sponsored/bivoltine-promotion> (Accessed on 19 May, 2025).

- Eberhart S.A. and Russell W.A. (1966) Stability parameters for comparing varieties. *Crop science*, Madson 6: 36–40.
- GoI (2013) Mulberry Raw Silk Production in India. Ministry of Textiles. https://texmin.nic.in/sites/default/files/Mulberry/Raw/Silk/Production/in/India_0.pdf (Accessed on 19 May, 2025).
- GOI (2024) India-France Bilateral Relations. Embassy of India, Paris. Available from: <https://www.eoiparis.gov.in/content/at.pdf> (Accessed on 19 May, 2025).
- Khandelwal V., Patel R., Choudhary K.B., Pawar S.B., Patel M.S., Iyanar K., Mungra K.D., Kumar S. and Satyavathi C.T. (2024). Stability analysis and identification of superior hybrids in pearl millet [*Pennisetum glaucum*(L.) R. Br.] using the multi trait stability index. *Plants* 13: 1101.
- Krishnaswami S. (1978) New technology of silkworm rearing. Bulletin No. 2, Central Sericultural Research and Training Institute, Mysore.
- Krishnaswami S. (1983) Evolution of new bivoltine races for traditionally multivoltine areas of south India. *Indian Silk* 22: 3–11.
- Ksham G., Kumar S.N., Nair S. and Datta R.K. (1995) Herita- heritability, genetic and phenotypic correlation studies on fitness and quantitative traits of bivoltine silkworm *Bombyx mori* L. *Indian Journal of Sericulture* 34: 22–27.
- Lee S.Y., Lee H.S., Lee C.M., Ha S.K., Park H.M., Lee S.M., Kwon Y., Jeung J.U. and Mo Y. (2023) Multi-environment trials and stability analysis for Yield-Related Traits of Commercial Rice Cultivars. *Agriculture* 13: 256.
- Londhe S.D. and Chougale A.K. (2022) Effects of magnetic field on the histology of silk gland of silkworm, *Bombyx mori* L. (Lepidoptera, Bombycidae). *Entomon* 47(4): 433–436.
- Mano Y., Nirmal Kumar S., Basavaraja H.K., Mal Reddy N. and Datta R.K. (1993) A new method to select promising silkworm hybrid combination. *Indian Silk* 30: 53.
- Mirhosseini S.Z., Ghanipoor M., Shadparvar A. and Etebari K. (2005) Selection indices for cocoon traits in six commercial silkworm (*Bombyx mori* L.) lines. *The Philippine Agricultural Scientist* 88(3): 328–336.
- Muniraju E. and Mundkur R. (2018) Tracing of evolution in silkworm, *Bombyx mori* L., on the basis of molecular studies. In: Trends in insect molecular biology and biotechnology (Eds. Kumar D. and Gong C.), Springer, Calcutta. pp67–84.
- NAAS (2024) Prioritizing agricultural policies. Available from: <https://naas.org.in/Policy/Papers/policy/0110.pdf> (Accessed on 19 May, 2025).
- Neshagaran H.R., Seidavi A. and Gharahveysi S. (2014) A review on correlation, heritability and selection in silkworm breeding. *Journal of Applied Animal Research* 44(1): 9–23.
- Pour-Aboughadareh A., Khalili M., Poczaï P. and Olivoto T. (2022) Stability indices to deciphering the genotype-by-environment interaction (GEI) effect: an applicable review for use in plant breeding programs. *Plants* 11: 414.
- Rahmathulla V.K. (2012) Management of climatic factors for successful silkworm (*Bombyx mori* L.) crop and higher silk production: a review. *Psyche: A Journal of Entomology* 121234: 1-12.
- Reza A.M.S. and Rahman S.M. (2005) Genetic parameters of some yield and yield contributing traits in silkworm, *Bombyx mori* L. *University Journal of Zoology, Rajshahi University* 24: 55-58.
- Singh T. and Subba Rao G. (1993) Multiple traits evaluation index to screen useful silk worm (*Bombyx mori*) hybrid genotypes. *Giornale Italiano di Entomologia* 6: 319-382.
- Singh T., Bhat M. and Khan M. (2011) Critical analysis of correlation and heritability phenomenon in the silkworm, *Bombyx mori* (Lepidoptera: Bombycidae). *Advances in Bioscience and Biotechnology* 2(5): 347-353.
- Ullal S.R. and Narashimanna M.N. (1981) Handbook of practical sericulture. Central Silk Board, Bangalore, 61-82.
- Zhao Y., Chen K. and He S. (2007) Key principles for breeding spring-and-autumn using silkworm varieties: from our experience of breeding 873× 874. *Caspian Journal of Environmental Sciences* 5(1): 57-61.

Observations on the butterflies feeding on non-nectar sources in the Kolhapur District, Maharashtra, India

A.N. Patil and S.M. Gaikwad*

Department of Zoology, Shivaji University, Kolhapur 416004, Maharashtra, India
Email: smg_zoo@unishivaji.ac.in

ABSTRACT: This study aimed to collect seasonal data on butterfly species that feed on various non-nectar sources. The photographic records of 68 butterfly species from six families, which feed on nutrients from six different non-nectar food sources, including dung, bird droppings, caterpillar excreta, ripened fruit, plant exudates, plant oozing sap, and mud, are provided. Among these 68 butterfly species, the Nymphalidae family were the most speciose with a total of 39 species, followed by the Lycaenidae with eight species, Hesperidae with nine species, Papilionidae and Pieridae with five species each and Riodinidae with a single species. Seasonal observations showed that the highest number of species was observed consuming food components during the summer season (45 species), followed by the rainy (17 species) and winter (13 species) seasons. The present study highlights the importance of all these non-nectar food sources of butterflies for their survival. Additionally, the findings of this study would be crucial in framing conservation strategies of butterflies. © 2025 Association for Advancement of Entomology

KEY WORDS: Food, mud puddling, excreta, plant metabolites, sap, conservation

INTRODUCTION

Insects obtain their food from a variety of sources (liquid, solid, etc.). Butterflies have a feeding apparatus in the form of a long, hollow, sucking tube called a proboscis to extract liquid food (Haribal, 1992). Although flower nectar is the main food source for a number of butterflies, they also absorb nutrients from other sources such as wet soil, urine, bird droppings and mammal excrement, plant exudates (metabolites), overripe fruits, and tree sap etc. (Haribal, 1992; Krenn, 2008; Gunathilagaraj *et al.*, 2015; Bhakare and Ogle, 2015). Mud puddling is a phenomenon in which butterflies aggregate on soil or dung to absorb moisture and nutrients like Sodium (Inoue *et al.*, 2015; Vinod and Kumar, 2021).

Some butterfly species engage in mud puddling in groups of the same species or of diverse species, while others do it independently. When there is nectar scarcity, butterflies prefer mud puddling, from which they absorb essential nutrients for flight, survivability and mating (Ankola *et al.*, 2021). In addition to mud puddling, butterflies are attracted to the volatiles produced by fruits during fermentation, which provide sugar and alcohol for energy (Sourakov *et al.*, 2012; Bhakare and Ogale, 2015). For feeding, butterflies belong to the subfamily Danainae, congregate on plants such as *Crotalaria* spp. and *Helitropium indicum*, which contain pyrrolizidine alkaloids, used to produce sex hormones and used in their defence mechanisms (Bhakare and Ogale, 2015), while some feed on

* Author for correspondence

sticky plant sap oozing from plant stem like *Cassia* (Bhakare and Ogale, 2015). In this study, we aimed to collect data on butterfly species feeding on various non-nectar sources in relation to the season. We presented season wise photographic records of 68 butterfly species belonging to six families feeding on non-nectar food sources.

MATERIALS AND METHODS

Field observations were carried out targeting various habitats in Kolhapur district, such as: Grassland and Savanna at Shivaji University campus; semi-evergreen forest at Ajara, Giroli, Konewadi, Manoli, Padsali, Pawangad, and Talaye Bk.; and modified habitats such as plant nurseries- Akshay and Sajeev nurseries in Kagal and Kolhapur respectively. Observations were recorded between December 2022 to April 2025, targeting all three seasons. Opportunistic observations were made visually during the daytime (0700-1600 hrs) and documented using Nikon D500 and Nikon D5600 DSLR cameras mounted with Nikor 70-300 and 200-500mm lenses. Butterfly species were mostly recorded feeding on natural sources, but additional ripped orange fruits were also provided during some observations. Butterfly species identification was done using Haribal (1992); Gunathilagaraj *et al.* (2015); Kunte (2000); Bhakare and Ogale (2015); Kasambe (2016), as well as the website Butterflies of India (<http://www.ifoundbutterflies.org> Accessed on 30th May, 2025) and confirmed by M.J. Palot, Zoological Survey of India, WRC, Pune. Dr. M.M. Lekhak, of the Department of Botany, Shivaji University, Kolhapur, identified the plants. Identification of the moth *Mangina syringa* (Cramer, [1775]) was done using Kirti and Singh (2013), as well as from the website, Moths of India (<http://www.mothsofindia.org>, Accessed on 18th June, 2025).

RESULTS AND DISCUSSION

A total of 68 species of butterflies belonging to six families, namely Nymphalidae, Lycaenidae, Papilionidae, Pieridae, Riodinidae and Hesperidae were observed feeding on the non-nectar sources such as mud, plant exudates, plant oozing sap, bird droppings, moth caterpillar excreta, dung and ripped

orange fruit (Table 1). Among these, a maximum of 40 species were observed obtaining nutrients by mud puddling on wet soil located along the streams and lakes etc., while nine species from excrement of birds, eight species from plant exudates, six species from plant oozing sap, three species from dung and two species from ripped fruit.

Among the butterflies that obtain food components through mud puddling, 20 species of the family Nymphalidae, five species of the family Pieridae, four species of Papilionidae, five species of Hesperidae, five species of Lycaenidae and one species of Rhodiniidae were recorded. Nymphalidae was the only family recorded feeding on plant exudates and plant oozing sap, with eight and six species, respectively. Three species of Nymphalidae, three species of Lycaenidae, two species of Hesperidae and one species of Papilionidae were observed feeding on bird droppings and moth caterpillar excreta. Two species of the family Lycaenidae and one species of the family Nymphalidae were recorded feeding on the essential food components of dung. Only two species of the family Nymphalidae were recorded feeding on ripe orange fruit. The species *Euploea core core* was observed consuming food components from the excreta of the caterpillar of the moth *M. syringa*.

This study showed that the number of species and individuals of each species feeding on non-nectar sources varied seasonally. The summer season had the maximum number of butterfly species feeding on non-nectar sources (45 species), followed by monsoon (17 species) and winter (13 species) (Table 1; Fig. 1). Additionally, four species (*E. aconthea*, *P. A. polymnestor*, *T. liminace exotica*, *E. core core*) were observed feeding on non-nectar sources in both summer and winter seasons, three species (*H. bolina jacintha*, *D. genutia genutia*, *E. core core*) in summer and rainy seasons, one species (*E. core core*) in rainy and winter seasons, and only a single species (*E. core core*) was recorded throughout the year (Fig.1).

In the summer season, maximum species (29 species) were recorded during mud puddling, six species on plant exudate, three species on plant

PLATE I **Butterflies recorded during Mud puddling**



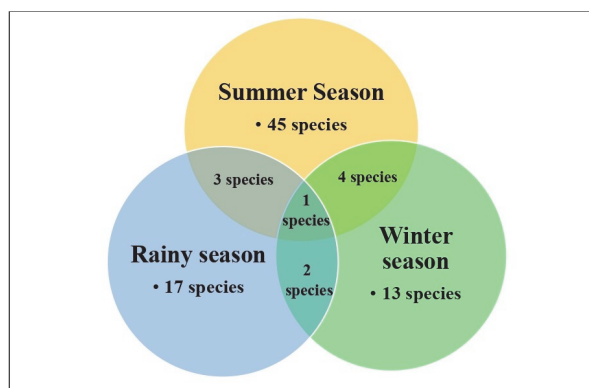


Fig. 1 Diagram showing seasonal observations of butterfly species feeding on non-nectar sources

metabolites, six species on bird excreta and only one species on dung. In the rainy season, the maximum species (eight) observed during mud puddling, two species on bird excreta, two species on fruits and five species on plant metabolites. No species observed on dung and on plant exudate in the rainy season. In the winter season, the maximum species (six) during mud puddling, five species on plant metabolites, two species on dung and one species on excreta were recorded. No species recorded on plant exudate and fruits in the winter season (Table 1).

Table 1. List of butterflies feeding on the non-nectar sources along with respective season

Family/ Species	Locality	Seasons		
		Summer	Rainy	Winter
Feeding Source/ 1. Mud puddling				
Family Nymphalidae				
1. <i>Charaxes solon solon</i> (Fabricius, 1793)	SUK	-	+	-
2. <i>Cirrochroa thais thais</i> (Fabricius, 1787)	Manoli	+	-	-
3. <i>Danaus genutia genutia</i> (Cramer, [1779])	Manoli	+	-	-
4. <i>Danaus chrysippus chrysippus</i> (Linnaeus, 1758)	SUK	-	+	-
5. <i>Doleschallia bisaltide</i> (Cramer, [1777])	Manoli	+	-	-
6. <i>Elymnias caudata</i> Butler, 1871	Manoli	+	-	-
7. <i>Euploea core core</i> (Cramer, [1780])	Manoli	+	-	-
8. <i>Euthalia aconthea</i> (Cramer, [1777])	AN	+	-	+
9. <i>Euthalia lubentia arsada</i> Fruhstorfer, 1913	Manoli	+	-	-
10. <i>Hypolimnas bolina jacintha</i> (Drury, 1773)	Manoli	+	+	-
11. <i>Junonia iphita</i> (Cramer, [1779])	Manoli	+	-	-
12. <i>Kallima horsfieldii</i> (Kollar, [1844])	Manoli	+	-	-
13. <i>Melanitis leda</i> (Linnaeus, 1758)	Manoli	+	-	-
14. <i>Neptis hylas varmona</i> Moore, 1872	Manoli	+	-	-
15. <i>Neptis jumbah</i> Moore, [1858]	Manoli	+	-	-
16. <i>Pantoporia hordonia hordonia</i> (Stoll, [1790])	Manoli	+	-	-
17. <i>Parantica aglea aglea</i> (Stoll, [1782])	Manoli	+	-	-
18. <i>Tirumala limniace exoticus</i> (Gmeilin, 1790)	Manoli	+	-	-
19. <i>Tirumala septentrionis dravidarum</i> (Fruhstorfer, 1899)	Manoli	+	-	-
20. <i>Moduza procris</i> (Cramer, [1777])	Manoli	+	-	-
Family Pieridae				
1. <i>Appias albina swinhoei</i> (Moore, [1905])	Manoli	+	-	-
2. <i>Catopsilia pomona</i> (Fabricius, 1775)	SN	-	-	+
3. <i>Eurema brigitta rubella</i> (Wallace, 1867)	Ajara	-	+	-
4. <i>Eurema hecabe hecabe</i> (Linnaeus, 1758)	Ajara	-	+	-
5. <i>Leptosia nina nina</i> (Fabricius, 1793)	SUK	-	-	+
Family Papilionidae				
1. <i>Graphium doson eleius</i> (Fabricius, 1907)	SN	-	+	-
2. <i>Graphium teredon</i> (C. & R. Felder, 1865)	Manoli	+	-	-
3. <i>Papilio Agenor polymnestor</i> Cramer [1775]	Talaye Bk.	+	-	+
4. <i>Papilio polytes polytes</i> Cramer, [1775]	Manoli	+	-	-
Family Hesperidae				
1. <i>Badamia exclamationis</i> (Fabricius, 1775)	Manoli	+	-	-
2. <i>Caprona agama agama</i> (Moore, [1858])	Manoli	+	-	-
3. <i>Notocrypta curvifascia</i> (C. & R. Felder, 1862)	Manoli	+	-	-
4. <i>Udaspes folus</i> (Cramer, [1775])	Manoli	+	-	-
5. <i>Hasora chromus chromus</i> (Cramer, 1780)	SUK	-	+	-

Family Lycaenidae				
1. <i>Chilades pandava pandava</i> (Horsfield, [1829])	SN	-	-	+
2. <i>Eucrysops cnejus cnejus</i> (Fabricius, 1798)	Giroli	-	+	-
3. <i>Prosotas dubiosa indica</i> (Evans, [1925])	Manoli	+	-	-
4. <i>Neopithecops zalmora</i> (Butler, [1870])	Manoli	+	-	-
5. <i>Zizina otis</i> (Fabricius, 1787)	SUK	-	-	+
Family Riodinidae				
1. <i>Abisara bifasciata bifasciata</i> Moore, 1877	Manoli	+	-	-
Feeding Source/ 2. Plant Exude				
Family Nymphalidae				
1. <i>Elymnias caudata</i> Butler, 1871	SUK	+	-	-
2. <i>Euthalia aconthea</i> (Cramer, [1777])	SUK	+	-	-
3. <i>Charaxes bharata</i> (C. & R. Felder, [1867])	SUK	+	-	-
4. <i>Kallima horsfieldii</i> (Kollar, [1844])	SUK	+	-	-
5. <i>Melanitis leda</i> (Linnaeus, 1758)	SUK	+	-	-
6. <i>Melanitis phedema Varaha</i> Moore, 1857	SUK	+	-	-
Feeding Source/ 3. Plant metabolites: a) <i>Crotalaria retusa</i>				
Family Nymphalidae				
1. <i>Tirumala limniace exotica</i> (Gmeilin, 1790)	SUK	+	-	+
2. <i>Euploea core core</i> (Cramer, [1780])	SUK	-	+	+
3. <i>Danaus genutia genutia</i> (Cramer, [1779])	SUK	+	+	-
4. <i>Danaus chrysippus chrysippus</i> (Linnaeus, 1758)	SUK	-	+	-
5. <i>Parantica aglea</i> (Stoll, [1782])	SUK	-	+	-
Feeding Source/ 3. Plant metabolites: b) <i>Helitropium indicum</i>				
6. <i>Parantica aglea</i> (Stoll, [1782])	SUK	-	-	+
7. <i>Danaus chrysippus chrysippus</i> (Linnaeus, 1758)	SUK	-	-	+
8. <i>Euploea core core</i> (Cramer, [1780])	SUK	+	+	+
Feeding Source/ 4. Excreta				
Family Nymphalidae				
1. <i>Hypolimnas bolina jacintha</i> (Drury, 1773) *	SUK	-	+	-
2. <i>Euploea core core</i> (Cramer, [1780]) *	Pawangad	-	+	-
3. <i>Euploea core core</i> (Cramer, [1780]) **	SUK	-	-	+
Family Papilionidae				
1. <i>Papilio polymnestor polymnestor</i> Cramer [1775]	Manoli	+	-	-
Family Hesperidae				
1. <i>Caprona agama agama</i> (Moore, [1858])	Manoli	+	-	-
2. <i>Udaspes folus</i> (Cramer, [1775])	Manoli	+	-	-
Family Lycaenidae				
1. <i>Aceytlepis puspa felderi</i> Toxopeus, 1972	Manoli	+	-	-
2. <i>Prosotas nora ordates</i> (Moore, [1875])	Manoli	+	-	-
3. <i>Lampides boeticus</i> (Linnaeus, 1767)	Konewadi	+	-	-

Feeding Source/ 5. Dung Family Nymphalidae				
1. <i>Cyrestis thyodamas indica</i> Evans, 1924	Talaye Bk.	-	-	+
Family Lycaenidae				
1. <i>Zizeeria karsandra</i> Moore, 1865	Padasali	+	-	-
2. <i>Nacaduba beroe</i> (C. & R. Felder, [1865])	Talaye Bk.	-	-	+
Feeding Source/ 6. Fruit Family Nymphalidae				
1. <i>Melanitis leda</i> (Linnaeus, 1758)	SUK	-	+	-
2. <i>Euthalia aconthea</i> (Cramer, [1777])	SUK	-	+	-

SUK - Shivaji University Campus, Kolhapur; SN - Sajeev Nursery, Kolhapur; AN - Akshay Nursery, Kagal; Summer (Feb.-May); Rainy (June-Sept.); Winter (Oct.-Jan.); * bird excreta, ** caterpillar excreta; + presence, - absence.

Chandekar *et al.* (2018) recorded feeding of butterflies on mud, tree sap, dung and alkaloids from Mulshi Tahsil, Pune district, Maharashtra. Ganeshwari *et al.* (2022) recorded 111 species of butterflies belonging to six families during mud puddling from Algarkovil Hills, Madurai, Tamil Nadu. Out of the six families, they recorded the highest number of Nymphalid species, 34. The present study also found that out of the recorded six families of mud puddling butterflies, the Nymphalidae family accounted for the highest number of species (19). Of the 25 butterfly species recorded by Suwarno *et al.* (2019) from four families (Lycaenidae, Nymphalidae, Papilionidae and Pieridae) during mud puddling from the Alas River at the Soraya Research Station in Subulussalam district, Aceh Province, Indonesia, the present study recorded six species (*Euthalia aconthea*, *Graphium doson*, *Papilio polytes polytes*, *Appias albina*, *Catopsilia pomona* and *Eurema hecabe*) during mud puddling. Few studies have documented the sap-feeding behaviour of butterflies. Salazar-E (2013) reported that 17 species of butterflies were attracted to the exuding sap of two trees in Colombia, the Escobo tree and the Aguacate tree. Bhakare and Ogle (2015) observed that nymphalid butterflies feed on the sticky sap of *Cassia* trees. The present study is consistent with the observations of the above two studies, i.e., six species of nymphalid butterflies feed on the sap of *Cassia siamea* out of the total recorded species. However, Young (1975) did not find any nymphalid species of butterflies feeding on sap in the Barranca Forest of Costa Rica. After examining plant metabolites, Nakka *et al.* (2013) reported the presence of

pyrrolizidine alkaloids in *Crotalaria retusa* and Stegelmeier (2011) in *Helitropium* sp. According to Bhakare and Ogale (2015), butterflies use pyrrolizidine alkaloids in their defence mechanisms and to produce sex hormones. In the present study, three species of butterflies were observed feeding on the sap of *C. retusa* and *Helitropium indicum*.

According to Bhakare and Ogale (2015), some species of butterflies feed on the sweet secretions (honeydew) of Homoptera such as aphids, while the present study has found that the lycaenid butterfly (*Lampides boeticus*) feeds on the aphid's honeydew-like secretion/ excreta. In the present study, when ripe oranges were broken open and kept outside, it was found that *Melanitis leda* and *E. aconthea* species feed on the ripe orange fruits. Similarly, Shiha (2016) have recorded *M. leda* feeding on Carambola fruits and *E. aconthea* feeding on Pineapple, Carambola, Papaya, Litchi, Mango and Guava from some areas of Bangladesh. The present study on butterfly feeding from non-nectar sources reveals that such behaviour plays a significant role in fulfilling the nutritional requirements of butterflies beyond what floral nectar provides. Butterflies were observed utilizing various alternative sources such as ripened fruits, animal excreta, plant exudates, and moist soil (mud-puddling). Such non-nectar sources might play a vital role in maintaining butterfly physiology, reproduction, and survival, especially during periods of nectar scarcity. These findings emphasize that butterfly conservation strategies should consider the availability of both nectar and non-nectar resources in natural habitats.

ACKNOWLEDGEMENTS

The authors are thankful to the Department of Zoology, Shivaji University Kolhapur, for providing laboratory facilities and the Chhatrapati Shahu Maharaj National Research Fellowship (CSMNRF) 2022, Government of Maharashtra, for financial assistance. The authors are also thankful to the Maharashtra State Biodiversity Board, Nagpur and Principal Chief Conservator of Forests (Wildlife), Maharashtra State, for the necessary permits.

REFERENCES

- Ankola K., Aishwarya D., Anusha R., Vaishnavi N., Supriya V.K. and Puttaraja H.P. (2021) Ecological significance of puddling as a behavioural phenomenon in the life history of butterfly *Papilio polytes* Linn. (Lepidoptera: Papilionidae). *Journal of Asia-Pacific Entomology* 24: 1–6. doi: 10.1016/j.aspen.2020.10.014.
- Bhakare M. and Ogale H. (2018) A Guide to Butterflies on Western Ghats (India): Includes Butterflies of Kerala, Tamil Nadu, Karnataka, Goa, Maharashtra, and Gujarat states. Milind Bhakare (privately published). 496pp.
- Chandekar S.K., Karkar H.S., Nimbalkar R.K. and Mahajan D.M. (2018) Study of butterfly diversity in Mulshi Tahsil, Pune District, Maharashtra, India. *International Journal of Scientific Research in Science and Technology* 5(2): 21–26.
- Ganeshwari C., Kavibharathi P., Meenakshi P., Preethi S. and Rajendran P. (2022) A study on the mud puddling activity of butterflies in Alagarkovil Hills, Madurai, Tamil Nadu, India Uttar Pradesh *Journal of Zoology* 43(2): 1–10.
- Gunathilagraj K., Perumal T.N.A., Jayaram K. and Ganesh Kumar M. (2015) South Indian Butterflies. Krab media & Marketing, Bangalore. 357pp.
- Haribal M. (1992) The Butterflies of Sikkim Himalaya and their Natural History. Sikkim Nature Conservation Foundation, Gangtok. 217pp.
- Inoue T.A., Ito T., Hagiya H., Hata T., Asaoka K., Yokohari F. and Niihara K. (2015) K⁺ Excretion: The other purpose for puddling behaviour in Japanese *Papilio* Butterflies PLoS ONE 10(5): e0126632. doi: 10.1371/journal.pone.0126632.
- Kasambe R. (2016) Butterflies of Western Ghats. An e-Book. Self-published, Mumbai. https://www.researchgate.net/profile/RajuKasambe/publication/312056076_Butterflies_of_Western_Ghats_First_edition/links/59f06f18458515bfd07bf16c/Butterflies-of-Western-Ghats-First-edition.pdf. 327pp. (Accessed on 1 July, 2024).
- Kirti J.S. and Singh N. (2013) Studies on external genitalia of *Mangina syringa* (Cramer) (Lepidoptera: Erebidiae: Arctinae) *ENTOMON* 38(2): 59–64.
- Krenn H.W. (2008) Feeding on neotropical butterflies (Lepidoptera, Papilionoidea). *Stapfia* 80: 295–304.
- Kunte K. (2000) India a Lifescape: Butterflies of Peninsular India. University Press (India) Private Limited, Hyderabad. 254pp.
- Nakka S., Kumar B.V. and Devendra B.N. (2013) Analysis of pyrrolizidine alkaloid from *Crotalaria retusa* L. *Der Pharma Chemica* 5(6): 6–11.
- Salazar-E J.A. (2013) Butterflies (Lepidoptera: Papilionoidea) attracted to tree sap (Exudates) in Colombia. *Boletín Científico Centro De Museos Historia Natural* 17(2): 227–245.
- Shihan T.R. (2016) An observation on the fruit feeding behavior of butterflies in some areas of Bangladesh. *Journal of Threatened Taxa* 8(12): 9479–9485. doi: 10.11609/jott.2519.8.12.9479-9485.
- Sourakov A., Duehl A. and Sourakov A. (2012) Foraging behaviour of the Blue Morpho and other Tropical butterflies: The chemical and electrophysiological basis of Olfactory preferences and the role of color. Hindawi Publishing Corporation *Psyche* (Article ID 378050). pp10. doi: 10.1155/2012/378050.
- Stegelmeier B.L. (2011) Pyrrolizidine Alkaloid – Containing toxic plants (*Senecio*, *Crotalaria*, *Cunoglossum*, *Amsinckia*, *Helitropium*, and *Echium* spp.) *Veterinary Clinics of North America: Food Animal Practice* 27(2): 419–428.
- Suwarno S., Rasnovi S., Utami S.D., Rizki A. and Dahelmi D (2019) Mud-puddling behavior of butterflies in the Soraya research station, district of Subulussalam, Aceh, Indonesia. *IOP Conference Series: Earth and Environmental Science* 364: 012027. doi: 10.1088/1755-1315/364/1/012027.
- Vinod M. and Kumar K.S. (2021) Puddling an interesting behaviour in butterflies. *Kerala Karshakan e-journal* 9(5): 8–11.
- Young A.M. (1975) Feeding behaviour of Morpho butterflies (Lepidoptera: Nymphalidae: Morphinae) in a seasonal tropical environment. *Revista De Biologia Tropical* 23(1): 101–123.

First record of aquatic stick insect, *Ranatra digitata* Hafiz & Pradhan, 1947 (Hemiptera, Heteroptera, Nepidae) from Kerala, India

K. Jyothylakshmi¹, S. Nandakumar^{1*} and E. Eyarin Jehamalar²

¹P.G. and Research department of Zoology, N.S.S College, Pandalam 689501, Kerala, India.

²6-72, Parakani, Painkulam 629173, Kanyakumari district, Tamil Nadu, India.

Email:nandakumar78@gmail.com

ABSTRACT: Water stick insects of the genus *Ranatra* Fabricius, 1790 are common inhabitants of lentic or slow-moving aquatic habitats. This is the first record of *Ranatra digitata* Hafiz & Pradhan, 1947 from Kerala. The data adds on the total number of known species of *Ranatra* from Kerala. Additionally, some notes on the bionomics of this species are also given to intensify the information on their ecology.

© 2025 Association for Advancement of Entomology

KEY WORDS: Distribution, water scorpions, bionomics, ecology

Water stick insects or water scorpions are slender predatory insects of the family Nepidae and can be commonly seen in still or sluggish water bodies. They have a body length in the range 15- 45mm (Schuh and Slater, 1995). The genus *Ranatra* Fabricius, 1790 is characterized by elongated tubular or cylindrical body with large spherical eyes, long pliable respiratory tube, anterior femur longer than pronotum, a noticeable keel or a modification on the metasternum (Yule and Yong, 2004; Basu *et al.*, 2018). Other stick insects coming under the genus *Cercotmetus* apparently resemble *Ranatra* and enough to be mistaken for them at a glance. On closer examination, *Ranatra* can be distinguished by the presence of long and slender respiratory appendages instead of the short and stout respiratory appendages of the *Cercotmetus* (Basu *et al.*, 2018). The genus *Ranatra* is

widespread and a total of 12 species under the genus have been so far reported from India (Thirumalai, 2007). In India, bio-ecological investigations on some Nepidae were conducted by Rao (1976). Only four species of *Ranatra* viz., *R. elongata* Fabricius, 1790, *R. filiformis* Fabricius, 1790, *R. varipes varipes* Stal, 1861 and *R. varipes atrophica* Montandon, 1903 have been documented yet from Kerala (Thirumalai, 2007; Ranjini, 2025). Now *R. digitata* Hafiz & Pradhan, 1947 has been reported for the first time from Kerala.

It was collected from Sasthamkotta lake, the largest freshwater lake of Kerala in Kollam District. A D-frame net with a 500µm mesh size was used to collect samples. Obtained samples were preserved in ethanol (70%) and taken to the laboratory for in-depth taxonomic analysis. The genital segments and

* Author for correspondence

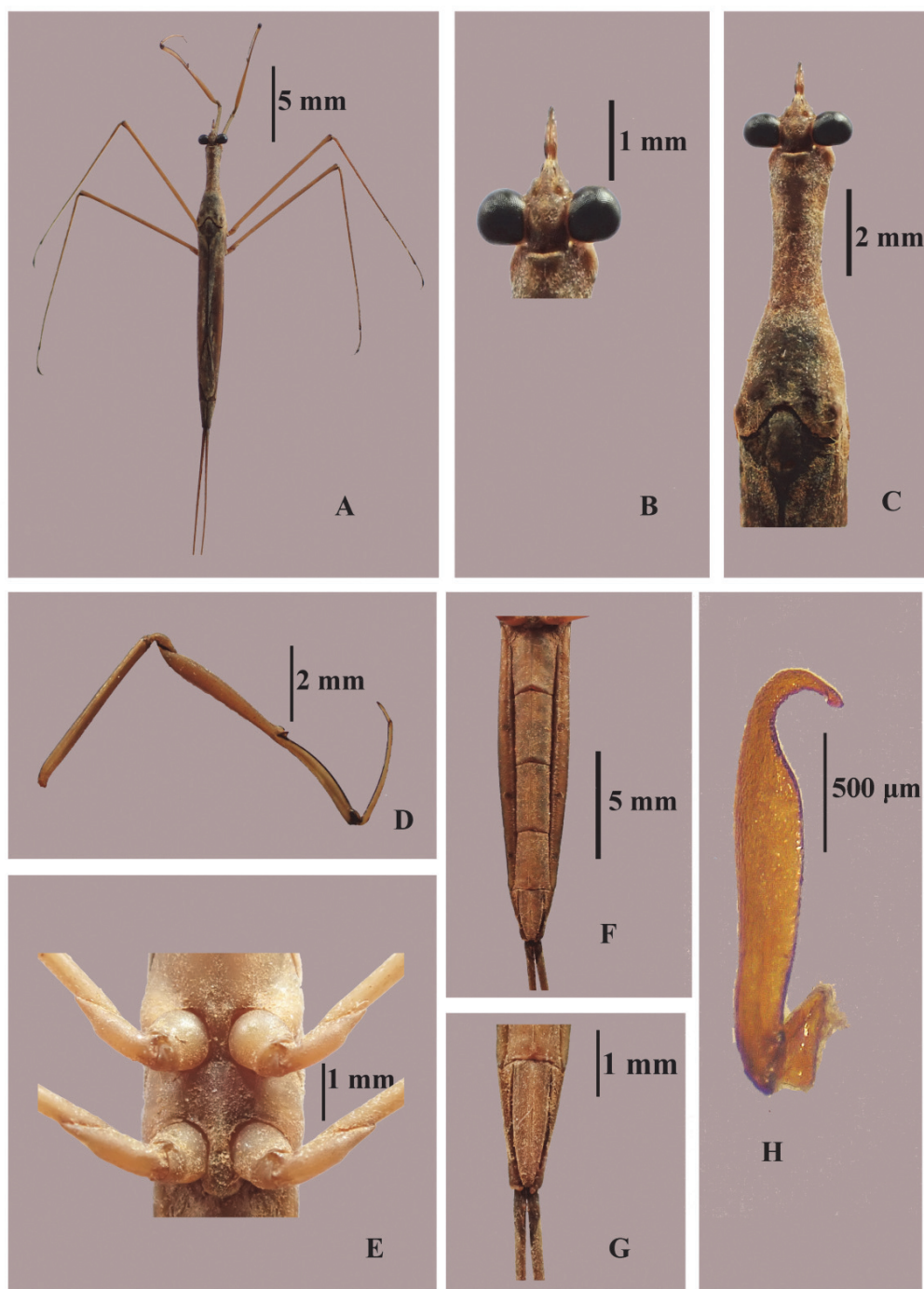


Fig. 1 A- H. *Ranatra digitata* Hafiz & Pradhan, 1947; A- Dorsal view; B- Head; C- Head, Pronotum and Scutellum; D- Forefemur; E- Metasternal keel; F- Abdominal sternites, ventral view; G- Genital segment, ventral view, H- Male paramere

related structures of male specimens were dissected and immersed in potassium hydroxide (10%) for 30 minutes for detailed morphological analysis. Olympus SZ51 stereomicroscope was used to examine the material and the pictures were captured using Olympus TG-6 digital camera. Image of the male paramere was captured using Leica stereo zoom microscope (Leica S9i), with the software Leica application suite (Version 4.12). Identification was performed with the aid of standard literatures and monograph (Hafiz and Pradhan, 1947; Jehamalar and Chandra, 2016; Basu *et al.*, 2018; Tran and Zettel, 2021).

Characterization of *Ranatra digitata* Hafiz & Pradhan, 1947

Ranatra digitata Hafiz & Pradhan, *Rec. Indian Mus.*, 45 (4): 347-376.

Order Hemiptera Linnaeus, 1758; Suborder Heteroptera Latreille, 1810; Infraorder Nepomorpha Popov, 1968; Superfamily Nepoidea Latreille, 1802; Subfamily Ranatrinae Douglas & Scott, 1865; Genus *Ranatra* Fabricius, 1790

Materials examined: 2 ♂, Sasthamkotta Lake; Punnakkadu Kadavu, Kollam district, Kerala, 8 m amsl., 9°2' 41.27"N and 76°37' 44.17" E, 27.iii.2022, Coll. Jyothylakshmi K and S. Nandakumar.

Diagnosis: Body length- 28mm; Colour- yellowish brown; head without tubercle; interocular space slightly constricted than eye width; antennal joints covered with spiny bristles; second joint of antennae digitate, shorter than the third; third antennal joint curved; mesosternum with a 'V' shaped slit between mid coxae; metasternum convex at posterior margin; respiratory siphon slightly shorter than the body; siphon length 22- 25 mm; male paramere- hook shaped apically and broad at middle (Fig. 1A-H).

Distribution: India: Chhattisgarh, Bihar, Haryana, Himachal Pradesh, Madhya Pradesh, Odisha and West Bengal.

Remarks: It is wide spread and commonly found species in India. The type specimens of *R. digitata* were collected by Hafiz & Pradhan (1947) from Titilagarh of Odisha and Patna of Bihar. *R. digitata*

have homology with *R. flagellate* Lansbury, 1972. The latter can be distinguished from the other by the following taxonomic characters such as gap between middle coxae nearly equal to the gap between hind coxae; hind femur somewhat exceeding the anterior border of operculum (Tran and Zettel, 2021).

Bionomics: *R. digitata* was collected from vegetated microhabitat of the lake. It is very difficult to spot them at a quick glance due to their floating stick appearance. The species is found among aquatic macrophytes near the edges of water. The species is slow moving and sometimes remain motionless at the middle of vegetation mass near the edges of the lake. The colour ranges from yellowish brown to dark brown. So they can hide well with the background of fallen twigs and decaying vegetation. It shows predatory behaviour for food acquisition, with the help of their raptorial forelegs and sharply pointed mouthparts. The species is carnivorous, like other *Ranatra* sp. and it feeds on other aquatic insects, tadpoles, small fishes and small invertebrates as their prey.

Present inventory is the first record of *R. digitata* from Kerala, it has been previously reported from the other states of India by Hafiz & Pradhan (1947), Jehamalar and Chandra (2016) and Basu *et al.* (2018). Under the genus *Ranatra*, only four species namely *R. elongata* Fabricius, 1790, *R. filiformis* Fabricius, 1790, *R. varipes varipes* Stal, 1861 and *R. varipes atrophata* Montandon, 1903 have so far been reported from Kerala. Hence, this current report adds another species of *Ranatra* to the state fauna.

ACKNOWLEDGEMENTS

The first author is grateful to the University of Kerala for the Research Fellowship and to the Principal of N.S.S. College, Pandalam, for giving facility in the PG and Research Department of Zoology to finish the work. The authors are indebted to Dr. A. Biju Kumar, Professor and Head, Department of Aquatic biology and Fisheries, University of Kerala, Kariavattom, Thiruvananthapuram for the facilities and encouragement. The authors sincerely acknowledge

the assistance of Dr. Jini Jacob, Postdoctoral Fellow, Department of Aquatic biology and Fisheries, University of Kerala, Kariavattom, Thiruvananthapuram for her help in photo documentation.

REFERENCES

- Basu S., Chandra K, Subramanian K.A. and Saha G.K. (2018) Water bugs (Insecta: Hemiptera: Heteroptera) of Himalayan and sub-Himalayan regions of West Bengal, India. *Journal of Threatened Taxa* 10 (12): 12619–12714.
- Hafiz H.A. and Pradhan K.S. (1947) Notes on a collection of aquatic Rhynchota from the Patna State, Orissa, with descriptions of two new species. *Records of the Indian Museum* 45 (4): 347–376.
- Jehamalar E.E. and Chandra K. (2016) Additional records of aquatic and semi-aquatic Heteroptera (Insecta: Hemiptera) from Chhattisgarh, India. *Records of the Zoological Survey of India* 16 (2): 99–109.
- Ranjini, S. (2025) New records of two species of the genus *Ranatra* Fabricius, 1790 (Hemiptera: Heteroptera: Nepidae) from Kerala, India. *Munis Entomology and Zoology* 20(1): 1512–1515.
- Rao T.K.R. (1976) Bioecological studies on some aquatic Hemiptera–Nepidae. *ENTOMON* 1(2): 123–132.
- Schuh R.T. and Slater J.A. (1995) *True Bugs of the World (Hemiptera: Heteroptera): classification and natural history*. Cornell University Press, Ithaca New York. pp336.
- Thirumalai G. (2007) A synoptic list of Nepomorpha (Hemiptera: Heteroptera) from India. *Records of the Zoological Survey of India. Occasional Papers* 273: 1–84.
- Tran A.D., and Zettel H. (2021) Taxonomy of the *Ranatrabiroid* group sensu Lansbury, 1972 (Nepomorpha: Nepidae), with descriptions of two new species. *Raffles Bulletin of Zoology* 69: 507–521.
- Yule C.M. and Yong H.S. (2004) *Freshwater invertebrates of the Malaysian region*. Academy of Sciences Malaysia. pp861.

(Received July 26, 2025; revised ms accepted September 19, 2025; published December 31, 2025)

First report of the brown widow spider, *Latrodectus geometricus* Koch, 1841 (Araneae, Theridiidae) from southern India

R. Kishore^{1*} and Vinod Sadhasivan²

¹*Sálim Ali Centre for Ornithology and Natural History, South India Centre of Wildlife Institute of India, Anaikatty Post, Coimbatore 641108, Tamil Nadu, India.*

²*Kanniyakumari Nature Foundation, South SLB Road, Ramavarmapuram, Nagercoil 629001, Tamil Nadu, India.*

Email: kishorewfw@gmail.com; svinod@gmail.com

ABSTRACT: *Latrodectus geometricus* (Koch, 1841) is a widow spider native to Africa and introduced in to several countries from both the Americas to Japan. Three adult female *L. geometricus* with three egg-sacs were observed in Nagercoil, Kanniyakumari district, Tamil Nadu. The present record extends its known distributional range to further south being the southernmost occurrence of the species in India.

© 2025 Association for Advancement of Entomology

KEY WORDS: Spider, egg-sac, Tamil Nadu, occurrence, distributional range

The family Theridiidae includes 129 genera, with the genus *Latrodectus* (Walckenaer, 1805) represented by 35 species worldwide. The genus *Latrodectus* is known for its notorious behaviour of male feasting by females and the highly potent neurotoxin. In India, until 2007, only *L. hasselti* Thorell, 1870 was known from the genus (Pocock, 1900; Daniel and Soman, 1961; Tikader, 1987; Siliwal and Kumar, 2001; Hippargi *et al.*, 2012). Subsequently *L. geometricus* Koch, 1841 (Shukla and Broome, 2007), *L. elegans* Thorell, 1898 (Kananbala *et al.*, 2012) and *L. erythromelas* (Schmidt and Klaas, 1991; Srinivasulu *et al.*, 2013) were added to the list of widow spiders in India (World Spider Catalog, 2024).

In 1900, Pocock reported *L. geometricus* from Karachi (Pakistan) which was once in the British

India. And after that in 2007, *L. geometricus* was first reported from Pune, Maharashtra (Shukla and Broome, 2007). Later on, Satam (2015) redescribed the species and significantly the male was reported for the first time in India. In the same year the species was sighted in few other places within Gujarat (Vasava *et al.*, 2015). After that no further sightings of the species was reported from southern India. Thus, this is the first published record of occurrence of *L. geometricus* in Southern India.

On 19 May 2024, A mature female was observed on a web with three ruptured egg sacs under the seat of the scooter parked at a residential area in Nagercoil, Kanniyakumari district, Tamil Nadu (8.160773° N; 77.416273° E) (Fig. 2). While close examining; vehicle, we observed two other mature females moving along the web build within the rim

* Author for correspondence

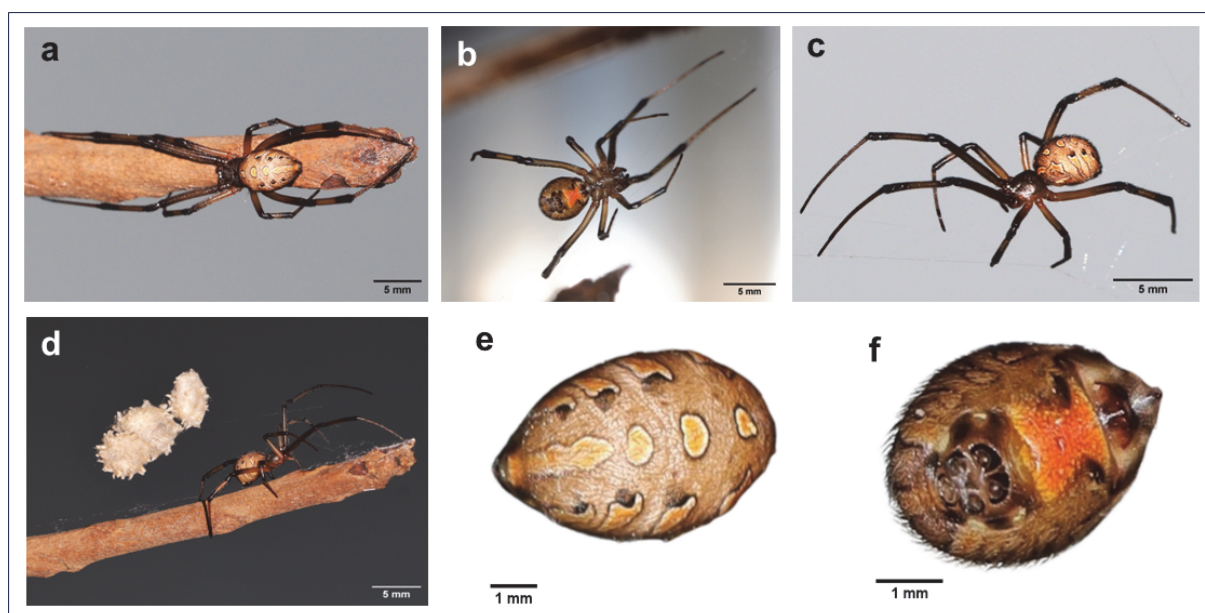


Fig. 1 *Latrodectus geometricus* (Koch, 1841) recorded in Nagercoil, Kanniyakumari district, Tamil Nadu. a-dorsal view of adult female; b- ventral view of adult female; c- lateral view of adult female; d- an adult female and typical egg-sacs with conical protuberances; e- dorsal view of abdomen pattern; f- Ventral view of abdomen with distinct hourglass marking and spinneret

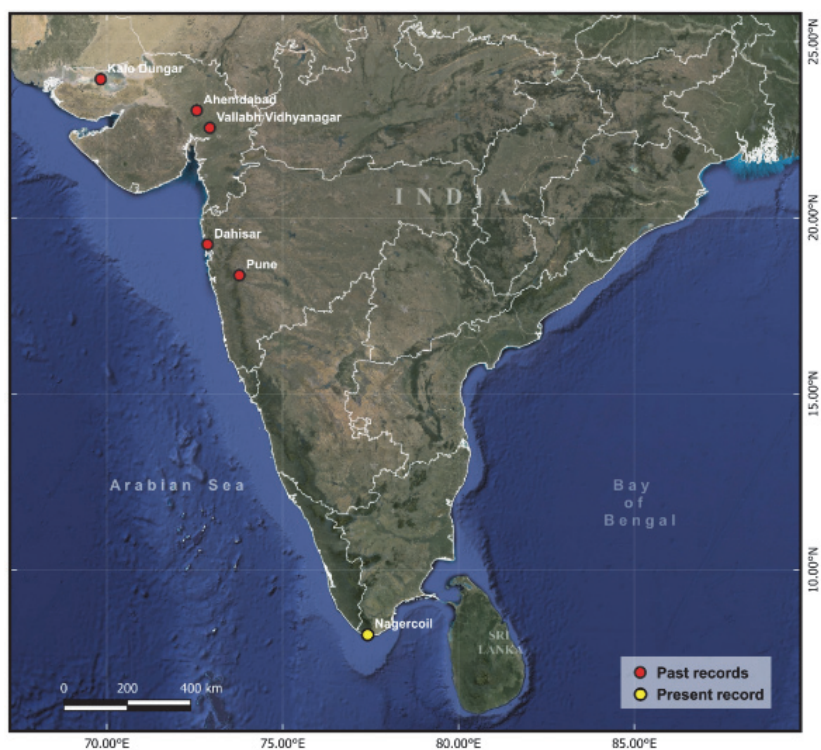


Fig. 2 Map illustrating the occurrence of *Latrodectus geometricus* in India with past records (red dots) and the present record (yellow dot) in Tamil Nadu (Source: Google Satellite Imagery modified using QGIS Desktop 3.34.8)

of the wheel. The vehicle was occasionally used and remained parked near the garden. Though it is a residential area with moderately busy roads, almost all the houses around that area had a small garden imparting a green environment.

Photographic documentation was done using DSLR Camera (Canon 200D ii). The specimen was identified up to species level by comparing the morphological characters of the specimen and egg-sac from the past literature (Fig. 1a-f) (Koch, 1841a; Smithers, 1944; Shukla and Broome, 2007; Satam, 2015). Typical and distinct bright orange hour glass marking on the ventral surface of abdomen is present (Fig. 1b, f) (Shukla and Broome, 2007). The conical protuberances on the egg-sac are the unique identification key for *L. geometricus* among other *Latrodectus* species (Fig. 1d) (Smithers, 1944; Abalos, 1962; Satam, 2015). The past and present records of the species in India was represented in the map using QGIS software (QGIS Desktop 3.34.8) (Fig. 2).

The present record from Nagercoil, Tamil Nadu is about 1,715km southward from Dahisar in Maharashtra, the recent record of the species in India. This is the first published report of *L. geometricus* in Southern India, along the southern Western ghats of Tamil Nadu. Man-made structures have provided ideal habitats for brown widows, facilitating their rapid range expansion and leading to their cosmopolitan distribution (Garb *et al.*, 2004). The recent southward expansion of the genus *Latrodectus* in India may have resulted from increased transportation networks associated with the country's major industrial corridors, facilitated by globalization and rapid development (Vasava *et al.*, 2015; Roopha *et al.*, 2021). The present record extends the known geographical distribution of this species to further south, being the southernmost occurrence of the species in Indian Subcontinent.

REFERENCES

- Abalos J.W. (1962) The egg-sac in the identification of species of *Latrodectus* (black-widow spiders). *Psyche: A Journal of Entomology* 69: 268–270.
- Daniel J.C. and Soman P.W. (1961) Observations on the spider *Latrodectus hasseltii indicus* with a note on arachnidism. *Journal of the Bombay Natural History Society* 58 (3): 823–826.
- Garb J.E., González A. and Gillespie R.G. (2004) The black widow spider genus *Latrodectus* (Araneae: Theridiidae): Phylogeny, biogeography, and invasion history. *Molecular Phylogenetics and Evolution* 31: 1127–1142.
- Hippargi R.V., Bolde P.M., Manthen S.V. and Shaikh A.R. (2012). Ecology of venomous spider *Latrodectus hasseltii* Thorell, 1870 (Araneae: Theridiidae) from Solapur and Osmanabad District, Maharashtra. *Indian Journal of Arachnology* 1 (1): 169–174.
- Kananbala A., Manoj K., Bhubaneshwari M., Binarani A. and Siliwal M. (2012) The first report of the widow spider *Latrodectus elegans* (Araneae: Theridiidae) from India. *Journal of Threatened Taxa* 4 (7): 2718–2722.
- Koch C.L. (1841) Die Arachniden. C.H. Zeh'sche Buchhandlung, Nürnberg, Achter Band, 41–131, pl. 265–288 (f. 621–694); Neunter Band, 1–56, pl. 289–306 (f. 695–726). doi:10.5962/bhl.title.43744.
- Pocock R.I. (1900) The Fauna of British India, Arachnida. Taylor and Francis, London. 279 pp.
- Roopha P.D., Kishore R., Joshua D., Charles A.A. and Vimal, N.P. (2021) Record of the redback spider from the Eastern Ghats of Tamil Nadu. *Zoo's Print* 36(10): 15–18.
- Satam Y. (2015) Redescription of *Latrodectus geometricus* Koch, 1841 (Araneae: Theridiidae) with a new record of male from Mumbai (India). *Indian Journal of Arachnology* 4 (2): 37–42.
- Schmidt G. and Klaas P. (1991) Eine neue *Latrodectus* Spezies aus Sri Lanka (Araneida: Theridiidae). *Arachnologischer Anzeiger* 14 : 6–9.
- Shukla A. and Broome V.G. (2007) First report of the brown widow spider, *Latrodectus geometricus* C.L. Koch (Araneae: Theridiidae) from India. *Current Science* 93: 775–777.
- Siliwal M. and Kumar D. (2001) Rare sighting of poisonous spider *Latrodectus hasseltii indicus* Simon (Araneae: Theridiidae) in the cotton field of Baroda District, Gujarat. *Current Science* 81: 1170–1171.
- Smithers R.H.N. (1944) Contributions to our knowledge of the genus *Latrodectus* (Araneae) in South Africa. *Annals of the South African Museum* 36: 263–312.
- Srinivasulu C., Srinivasulu B., Javed S.M.M., Seetharamaraju M., Jyothi S.A., Srinivasulu C.A. and Tampal F. (2013) Additions to the araneofauna

- of Andhra Pradesh, India – Part II. Records of interesting species of the comb-footed genera *Latrodectus*, *Rhomphaea* and *Coleosoma* (Araneae: Theridiidae). *Journal of Threatened Taxa* 5(10): 4483–4491. doi:10.11609/JoTT.o2660.4483–91.
- Tikader B.K. (1987) *Handbook of Indian Spiders*. Zoological Survey of India, Calcutta.
- Vasava A.G., Patel M., Parasharya B.M., Mistry V., Patel P., Mehta D., Patel D. and Patel K. (2015) Record of brown widow spider, *Latrodectus geometricus* Koch, 1841 (Araneae: Theridiidae) from Gujarat, western India, with notes on its distribution, habitat and natural history. *Acta Arachnologica* 64(1): 5–9. doi:10.2476/asjaa.64.5.
- Walckenaer C.A. (1805) *Tableau des aranéides ou caractères essentiels des tribus, genres, familles et races que renferme le genre Aranea de Linné, avec la désignation des espèces comprises dans chacune de ces divisions*. Dentu, Paris, 88pp.
- World Spider Catalogue (2024) *World Spider Catalog*. Version 25.0. Natural History Museum Bern. Available at: <https://wsc.nmbe.ch/genusdetail/3502> (accessed 28 May 2024).

(Received August 02, 2025; revised ms accepted October 25, 2025; published December 31, 2025)

Assessment of honeybee biodiversity in the agro-climatic zones of Uttarkashi of Garhwal Himalaya, Uttarakhand, India

Abhishek Thapliyal¹, Vishesh Nautiyal¹, Deepak Rana¹, Ashish Thapliyal^{2*} and
Madhu Thapliyal³

¹Department of Biotechnology, Graphic Era (Deemed to be University), Clement Town, Dehradun 248002, Uttarakhand, India.

²Department of Microbiology, Graphic Era (Deemed to be University), Clement Town, Dehradun 248002, Uttarakhand, India.

³Department of Zoology, R.C.U. Govt. P.G. College, Uttarkashi 249193, Uttarakhand, India.
Email: ashish.thapliyal@geu.ac.in

ABSTRACT: The richness and relative abundance of honeybee species were assessed from the Uttarkashi area in Uttarakhand, India. Surveys were conducted in twelve agroclimatic zones from March to May 2025 using the aerial netting technique for the collection of honeybees foraging on different floral resources. Of the total of 291 specimens, the representation included five honeybee species: *Apis cerana* F., *A. mellifera* L., *A. laboriosa* Smith, *A. florea* F. and *A. dorsata* F. Predominant one was *A. cerana*, representing 57.7 per cent of the total population, followed by *A. mellifera* (19.2%), *A. laboriosa* (11.6%), *A. florea* (5.8%) and *A. dorsata* (5.4%). These results indicate the predominance of both native and invasive species of honeybees in the area. Shannon (H2) and Simpson (1–D) diversity indices were highest for *A. cerana* (0.3172 and 0.333), indicative of its broad adaptability and even distribution of specimens across the habitats. © 2025 Association for Advancement of Entomology

KEY WORDS: *Apis* fauna, Shannon index, Simpson's index, relative abundance

As members of the Apoidea group, honeybees are important plant pollinators and frequent visitors to flowers in both natural and agricultural environments (Hristov *et al.*, 2020; Lupi *et al.*, 2025; Muñoz-Urias *et al.*, 2025). Honeybees, together with other wild pollinators, play a crucial role in preserving plant diversity and sustaining our food supply (Nouredine and Nizar, 2020). Honeybees are highly valued for their significant contributions to humanity, particularly for their crucial role in the pollination of agricultural and

horticultural crops (Chalapathy *et al.*, 2024). Approximately 80 percent of the world's major food crops rely on pollination by honeybees, underscoring their critical role in global food security (Klei *et al.*, 2007; Requier *et al.*, 2023; Richardson, 2023). Bees play an essential role in ecosystem maintenance since they are the most important and primary pollinators of many of our staple food crops (Raymann and Moran, 2018). A reduction in their diversity can indicate underlying environmental issues such as habitat destruction, excessive

* Author for correspondence

pesticide use, or the effects of climate change (Yang *et al.*, 2023; Ali *et al.*, 2025). Understanding honeybee diversity is essential for setting conservation priorities (Requier *et al.*, 2019). Certain species may be rare, unique to specific regions, or at risk of extinction (such as *Apis laboriosa* in the Himalayas), and without proper documentation, they could remain overlooked and vulnerable (Otis *et al.*, 2024). In Uttarakhand, *Apis cerana* and *A. mellifera* are key species supporting local apiculture (Tiwari *et al.*, 2013; Chauhan *et al.*, 2025; Ghosh *et al.*, 2025). However, limited documentation exists on honeybee diversity in Uttarkashi, which is vital for understanding ecological balance in Himalayan agroecosystems. This study aims to assess honeybee diversity and relative abundance across twelve agro-climatic zones of Uttarkashi district.

This study was conducted in different agro-climatic zones of Uttarkashi, which is present in one of the Himalayan states (Uttarakhand) of India. Uttarkashi district lies in the northwestern part of Uttarakhand state in India. It is bounded by North Latitudes 30° 27' 18" and 31° 27' 42" and East Longitudes 77° 48' 26" and 79° 24' 00". Twelve different locations were selected for the survey of *Apis* fauna. These were Mori, Purola, Sankri, Barkot, Harshl, Dharali, Jhala, Manpur, Kamad, Kumarkot, Dhanpur and Morem (Fig. 1). This study was conducted from 24th March 2025 to 19 May 2025. Sampling was done between 11 am to 3:00 pm when foraging activity was highest. At each site, 10 sweeps were performed using a 15-inch aerial net attached to a 3-meter pole. Collected specimens were preserved and identified using standard taxonomic keys. Relative abundance (%) was calculated as the number of individuals of a species divided by the total number of bees collected. Biodiversity was estimated using Shannon (H2) and Simpson (1-D) indices. Data analysis was performed using Python (v3.11) and Microsoft Excel 2021.

After pooling all the data, the relative abundance of different honeybee species was computed and expressed as a percentage using the following formula.

$$\text{Relative abundance} = \frac{\text{Number of individuals of species}}{\text{Total number of all honeybees}} \times 100$$

Shannon (H2) and Simpson's (1-D) Diversity Indices were used to measure species richness, evenness, and dominance, helping assess biodiversity levels and ecological balance across different habitats or study sites. After pooling all the data diversity (Shannon Diversity Index (H2)) of different honeybee species was computed and expressed as a formula: $H' = -\sum(pi \times \ln pi)$

Simpson's (1-D) diversity was expressed as a formula: $1-D = 1 - \sum(pi^2)$

Out of 291 honeybee specimens collected, five species, *A. cerana*, *A. mellifera*, *A. laboriosa*, *A. dorsata* and *A. florea* were recorded across twelve agro-climatic zones of Uttarkashi. Among them, *A. cerana* comprised the most abundant species (57.7%) followed by *A. mellifera* (19.2%), *A. laboriosa* (11.6%), *A. florea* (5.8%) and *A. dorsata* (5.4%) (Fig. 1). Shannon (H2) and Simpson (1-D) diversity indices were highest for *A. cerana* (0.3172 and 0.333), indicative of its broad adaptability and even distribution of specimens across the habitats (Table 1). *A. mellifera* had slightly lower diversity indices while exhibiting a preference for presence in a few managed apiary zones. *A. laboriosa* was largely encountered in higher altitude sites i.e. Sankri, confirming its preference for cooler high-altitude habitats. The low indices for *A. dorsata* and *A. florea* also reflect nesting preference ecology, with *A. dorsata* occupying higher taller trees and cliffs, while *A. florea* was commonly located in shrub landscapes near lower-altitude habitat zones. Its ecological adaptability to Himalayan agro-ecosystems and its

Table 1. Combined species count with Shannon and Simpson diversity indices

Species	Total	Shannon (H2)	Simpson (1-D)
<i>Apis cerana</i>	168	0.3172	0.333
<i>A. mellifera</i>	56	0.3171	0.037
<i>A. laboriosa</i>	34	0.2508	0.0137
<i>A. dorsata</i>	16	0.1595	0.003
<i>A. florea</i>	17	0.1659	0.0034

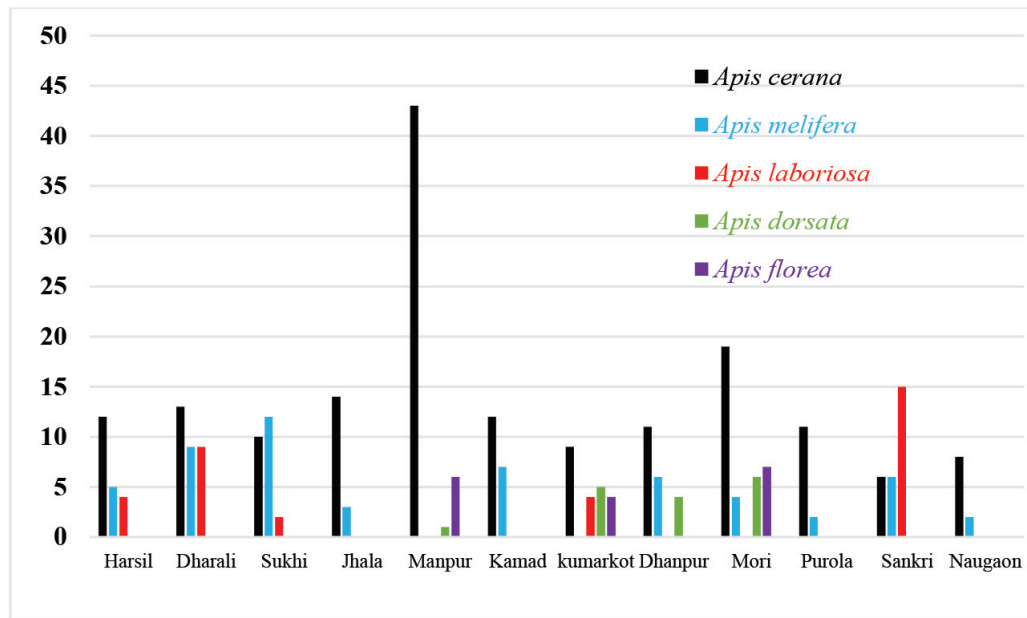


Fig.1 Relative abundance of different honeybees in Uttarkashi and its vicinity

significance for sustainable apiculture are highlighted by the prevalence of *A. cerana*, a local and traditionally managed bee. Despite its economic importance, *A. mellifera* seems less suited to higher elevations because of climate constraints. The study's overall findings demonstrate Uttarkashi's rich honeybee diversity, which is dominated by native species that have adapted to a variety of floral and climatic circumstances.

ACKNOWLEDGMENT

The authors wish to express their gratitude to Graphic era Deemed to be University for providing field and research facilities for the conduct of the study.

REFERENCES

- Ali M., Khan F.Z.A. and Ahmad M.A. (2025) Insect Pollinators and Food Security Under the Changing Climate. In: Food Systems and Biodiversity in the Context of Environmental and Climate Risks: Dynamics and Evolving Solutions Cham: Springer Nature Switzerland. pp263–293.
- Chalapathy C.V., Sivaram V., Seetharam D.S. and Patil S.J. (2024) Comparative morphometric studies between black and yellow strains of Indian honeybee-*Apis cerana*. ENTOMON 49(4): 559–564.
- Chauhan D.S., Negi G.C.S. and Joshi R. (2024) Effect of Honey Bee (*Apis cerana*) Dominated Insect Pollination on Yield and Quality of Mustard, Buckwheat and Plum in a Central Himalayan Agro-Ecosystem. International Journal of Ecology and Environmental Sciences 50(4): 543–556.
- Ghosh S., Abrol D.P. and Jung C. (2025) The State of Beekeeping in India: Insights, Gaps, and Emerging Opportunities. Entomological Research 55(10): e70069.
- Hristov P., Neov B., Shumkova R. and Palova N. (2020) Significance of Apoidea as main pollinators. Ecological and economic impact and implications for human nutrition. Diversity 12(7): 280.
- Klein A.M., Vaissière B.E., Cane J.H., Steffan-Dewenter I., Cunningham S.A., Kremen C. and Tscharntke T. (2007) Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B: Biological Sciences 274(1608): 303–313.
- Lupi D., Giuliani C., Fico G., Malabusini S., Sorvillo C. and Giovanetti M. (2025) Enhancing Pollinator Support: Plant–Pollinator Dynamics Between

- Salvia yangii* and *Anthidium* Bees in Anthropogenic Landscapes. *Biology* 14(8): 1084.
- Muñoz-Urias A., Araujo-Alanis L., Huerta-Martínez F.M., Jacobo-Pereira C. and Razo-León A.E. (2025) Effects of urbanization and floral diversity on the bee community (Hymenoptera, Apoidea) in an oak forest in a Protected Natural Area of Mexico. *Journal of Hymenoptera Research* 98: 47–68.
- Raymann K. and Moran N.A. (2018) The role of the gut microbiome in health and disease of adult honey bee workers. *Current Opinion in Insect Science* 26: 97–104.
- Requier F., Pérez-Méndez N., Andersson G.K., Blareau E., Merle I. and Garibaldi L.A. (2023). Bee and non-bee pollinator importance for local food security. *Trends in ecology & evolution* 38(2): 196–205.
- Richardson K. (2023) Beekeeping role in enhancing food security and environmental public health. *Health Economics and Management Review* 4(4): 69–79.
- Tiwari P., Tiwari J.K., Singh D. and Singh D. (2013) Traditional beekeeping with the Indian honey bee (*Apis cerana* F.) in District Chamoli, Uttarakhand, India. *International Journal of Rural Studies* 20(2): 1–6.
- Yang Y., Wu Y., Long H., Ma X., Shariati K., Webb J. and Chen J. (2023) Global honeybee health decline factors and potential conservation techniques. *Food Security* 15(4): 855–875.

(Received November 22, 2025; revised ms accepted December 20, 2025; published December 31, 2025)

Notes on *Hyllus semicupreus* (Simon, 1885) (Salticidae, Plexippina) from India

Jayaraman Dharmaraj*

Department of Biotechnology, RVS College of Arts and Science, Coimbatore 641402, Tamil Nadu, India.

Email: dharmaraj590@gmail.com

ABSTRACT: *Hyllus semicupreus* (Simon, 1885) is called as heavy jumper spider. Observations of this species as non-sexual cannibalism phenomenon on *Nerium oleander* plants is reported. *H. semicupreus* species sample was analysed by DNA barcoding for confirmation. The result was analysed with the other *Hyllus* species followed by NCBI. © 2025 Association for Advancement of Entomology

KEY WORDS: DNA barcoding, food availability, jumping spider, *Nerium oleander*, habitat

The jumping spider genus *Hyllus* Koch, 1846 is represented by 67 species worldwide (WSC, 2024), of which, four species are known from India: *Hyllus bos* (Sundevall, 1833), *H. diardi* (Walckenaer, 1837), *H. pudicus* and *H. semicupreus* (Simon, 1885) (Caleb *et al.*, 2024). *H. semicupreus* was originally described from Guntakal District, Andhra Pradesh, India (Simon, 1885). The species was originally placed in the genus *Thyene* (Simon, 1903) and was later transferred to *Sandalodes* (Prószyński and Tąbka, 1980), before finding its place in *Hyllus* (Prószyński, 1990). Recent observations have shed light on the diverse ecological roles and feeding habits of *H. semicupreus*. Some studies have documented the feeding behavior in a variety of contexts. For instance, nonsexual cannibalism has been observed (Rajashree, 2022), and oophagy, the consumption of eggs, was recorded in this species, predation on coreid bug eggs (Ahmed *et al.*, 2018) and dipteran fly (Ahmed and Satam, 2015), araneophagy, where

H. semicupreus fed on an *Oxyopes* species (Sharma, 2020) and on a social spider (Muralidharan, 2022). Additionally, myrmecophagy, involving the predation of a queen red weaver ant in Odisha, India, was recently reported. The present study focuses on an additional observation of non-sexual cannibalism with new observations on secretions from its abdomen.

The specimen was hand collected and preserved in 70(%) ethanol. Field photographs and video recording were taken with the help of a camera Vivo Y73(64MP+2MP+2MP). The species identity was confirmed with both morphology and DNA analysis by using COI gene. The DNA isolation and DNA barcoding was performed at the Rajiv Gandhi Centre for Biotechnology, Kerala. The obtained sequence was submitted to GenBank. During a routine field survey on 8 December 2023, between 15:10 and 16:12 IST, at RVS College of Arts and Science, Coimbatore, Tamil Nadu

* Author for correspondence



Fig. 1



Fig. 2



Fig. 3



Fig. 4

Fig. 1 *Hyllus semicupreus* (Simon, 1885) female feeding on another younger female

Fig. 2 Hiding under the leaf.

Fig. 3, 4 Live female with milk-like liquid oozing from both sides of the abdomen, *Hyllus semicupreus* (Simon, 1885).

(11.026988N, 77.1327E), I observed a remarkable instance of predatory behavior in *H. semicupreus* on *Nerium oleander* plants. A female spider was seen feeding on another female of the same species (Figure 1). The feeding female had captured its prey by the front legs and continued to devour it for over an hour.

An intriguing observation was made during this process: a milk-like secretion was noted oozing from the lateral sides of the abdomen of the feeding female (Figure 3 & 4). The exact nature of this secretion is unclear, maybe the secretion came out between the fighting behaviour from male species, and further investigation is required to determine its significance. The feeding behavior was continuously monitored for two hours until the female finished consuming the prey and released the carcass. The feeding female was subsequently collected and sent for DNA barcoding at the Rajiv Gandhi Centre for Biotechnology, Kerala. DNA barcoding done for confirmation. The partial COI gene was successfully amplified, and the sequence has been deposited in GenBank (Accession number: PP338231).

>PP338231.1 *Hyllus semicupreus* isolate Hs1 cytochrome c oxidase subunit I (COX1) gene, partial cds; mitochondrial

GAAGTCTATGAGAGTTTAAATTCGGATAG
AATTGGGTCAGACTGGGAGATTTTAGG
AAATGAACATTTATATAATGTAATTGTT
ACAGCTCATGCATTTGTAATAATTTTTT
TTATAGTAATACCCATTATAATTGGGG
GTTTTGGAAATTGATTAGTTCCATTAATA
TTAGGAGCACCTGATATAGCTTTTCCT
CGAATAAATAATTTGAGATTTTGATTGTTA
CCTCCTTCTTTAATATTATTATTCTTC
TATAGTTGAAATAGGAGTAGG AGCTGGGT
GAAGTGTATATCCTCCTTTGG CATCTATT
GTTGGACATAATGGAAGATCAGTAGA
TTTTGCTATTTTTCTTTACATTTGGCTGGTG
CTTCTTCTATTATAGGAGCTATTAAT
TTTATTCTACTATTATTAATATACGTTTCGGTA
GGAATATCAATAGATAAGATTT
CGTTATTTGTTTGATCGGTAATGATT
ACTGCTATTTTATTATTATTGTC
TTTACCTGTATTAGCAGGTGCTAT

ACKNOWLEDGEMENTS

The author thank Dr. John Caleb for entire support for the improvement of manuscript. The author also thanks to DBT and RVS College of Arts and Science for financial assistance for the DNA analysis.

REFERENCES

- Ahmed J. and Satam Y. (2015). The structure and utilization of silk constructs by *Hyllus semicupreus* (Simon, 1885) (Araneae: Salticidae). *Peckhamia* 125.1: 1-3.
- Ahmed J.D.E., Hill R.J., Pearce A.N.S., Kumar R., Khalap and Mohan K. (2018). Oophagy by *Hyllus semicupreus* (Araneae: Salticidae: Plexippina). *Peckhamia* 171.1:1-6.
- Caleb J.T.D. and Sankaran P.M. (2024). Araneae of India. Version 2024, online at <http://www.indianspiders.in>
- Muralidharan S. (2022). Predation on *Stegodyphus* (Araneae: Eresidae) by (*Hyllus semicupreus*) (Araneae: Salticidae) in Tamil Nadu, India. *Peckhamia* 276.1: 1-2.
- Prószyński J and Ąbka M. (1980). Remarks on Oligocene amber spiders of the family Salticidae. *Acta Palaeontologica Polonica* 25: 213-223.
- Prószyński J. (1990). Catalogue of Salticidae (Araneae): synthesis of quotations in the world literature since 1940, with basic taxonomic data since 1758. *Wyższa Szkoła Rolniczo-Pedagogiczna Siedlce*, 366 pp.
- Rajashree K. (2022). Nonsexual cannibalism by a female (*Hyllus semicupreus*) (Araneae: Salticidae: Plexippina). *Peckhamia* 260.1: 1-2.
- Sharma M. and Oli B. R. (2020). Araneophagy by (*Hyllus semicupreus*). *Peckhamia* 244.1: 1-2.
- Simon E. (1885). Matériaux pour servir à la faune arachnologiques de l'Asie méridionale. I. Arachnides recueillis à Wagra-Karoor près Gundacul, district de Bellary par M. M. Chapter. II. Arachnides recueillis à Ramnad, district de Madura par M. l'abbé Fabre. *Bulletin de la Société Zoologique de France* 10(1): 1-39.
- Simon E. (1903). Histoire naturelle des araignées. Deuxième édition, tome second. Roret, Paris, pp. 669-1080.
- Subhrakanta J., Rakesh K.M., Sanjay K.D., and Hemanta K. (2022). Myrmecophagy by a jumping spider

- (Araneae: Salticidae: Hyllus semicupreus),
feeding on a red weaver ant queen (Hymenoptera:
Formicidae: Oecophylla smaragdina). Peckhamia
259.1: 1-3.
- Walckenaer, C. A. (1837). Histoire naturelle des insectes:
aptères. Librairie encyclopédique de Roret.
- World Spider Catalog (2024). World Spider Catalog.
Version 25.0. Natural History Museum Bern,
online at <http://wsc.nmbe.ch>, doi: 10.24436/2

(Received October 08, 2025; revised ms accepted November 01, 2025; published December 31, 2025)

***Tuberolachnus salignus* (Gmelin, 1790) (Hemiptera, Aphididae) on Apple (*Malus domestica* Borkh) in Kashmir, India**

Muzafar Riyaz^{1*}, Sabreena Ashraf² and Rakesh Kumar Gupta¹

¹*Division of Entomology, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu 180009, Jammu & Kashmir, India.*

²*Department of Entomology, Punjab Agricultural University, Ludhiana 141004, Punjab, India.
Email: bhatmuzaffar471@gmail.com*

ABSTRACT: This study reports the first occurrence of the invasive pest *Tuberolachnus salignus*, commonly known as the giant willow aphid, on apple (*Malus domestica* Borkh.) in Kashmir, India. Previously known to infest willows (*Salix* spp.) and poplars (*Populus* spp.), this record expands its host range to include a commercially important fruit crop. Live observations of winged adult aphids and apterae on the stems of apple trees are accompanied by detailed taxonomic descriptions, morphological features, and photographic documentation to facilitate identification. The pest's biology, distribution, and ecological adaptability are also discussed, shedding light on its potential and possible impact on apple orchards in temperate regions. Given the invasive nature of this species and its ability to exploit new hosts, the findings emphasize the need for extensive field surveys throughout the Kashmir Valley and other parts of the Northwestern Himalayas. Such surveys will help determine the pest's prevalence, host-selection behaviour, and seasonal biology in this new environment. Understanding these factors is critical to developing targeted and sustainable pest management strategies to mitigate the potential economic damage to apple cultivation. © 2025 Association for Advancement of Entomology

KEY WORDS: Apple, emerging pests, giant willow aphid, host plants, invasive pest

Tuberolachnus salignus (Gmelin), also known as the giant willow aphid, belongs to the family Aphididae in the order Hemiptera. The species is a sap-sucking invasive pest that mainly feeds on the sap from the stems and branches of willows and poplars (*Populus* spp.) (Sage and Tucker, 1997; Collins *et al.*, 2001; Sopow *et al.*, 2017); moreover, willow is considered its primary host (Blackman and Eastop, 1994). *T. salignus* is considered to have originated in Asia, but since then it has colonised practically every part of the planet where its host

species can be found. This species is now considered to be almost cosmopolitan (Blackman and Eastop, 1994), and it is ubiquitous anywhere willow grows (Charles *et al.*, 2014; Szelegiewicz, 1962). *T. salignus* can be spotted on plants during the winter (Czerniakowski, 2007; Molnár, 2003); although it is more likely to be found on host plants in the late summer or autumn months before disappearing until the following growing season across Europe. Since there are no male individuals, giant willow aphid reproduction is determined to be

* Author for correspondence

exclusively parthenogenic (Blackman and Eastop, 1994). In North America and Europe, it has been found that there is extremely little genetic variation within the species (both assumed to be part of the invasive range). In a study carried out by Aradottir *et al.* (2012), 660 samples were collected from 27 distinct populations located in five different countries. However, the authors only found 16 possible genotypes. In addition, there may be more than one genotype present in dense colonies of *T. salignus*, probably because of clustering and dispersion. In India, *T. salignus* can be found in the northwestern and eastern parts of the country. The species was first reported from Karnataka, India, on *Salix tetrasperma* (Joshi, 1980), and later in the Spiti Valley of Himachal Pradesh, India (Sharma and Thakur, 1993). Recently, it was reported on *Salix alba* and *S. tetrasperma* in the high-altitude, cold arid region of Ladakh, India (Hussain *et al.*, 2021).

Kashmir valley referred to as “*The Apple Bowl of India*,” is the primary producer of apples in the country, accounting for the majority of the country’s production. Along with the Kashmir valley, apples are cultivated in the nearby states of Himachal Pradesh and Uttarakhand as well (Riyaz *et al.*, 2018). Every year, the horticulture industry provides over Rs. 10,000 crore (7% GSDP) to the state’s revenue in Jammu and Kashmir (Govt. of Jammu and Kashmir, 2024). *T. salignus*, a recently found invasive pest from Kashmir Valley, India, is reported on apple during the course of this study.

Study site and sampling: During the insect sampling surveys in the northwestern Himalayas across both natural and agrarian ecosystems. On November 3, 2024, a single winged adult was collected and photographed in the Tehsil Herman, District Shopian, Kashmir, India (32°42’25”N 74°56’25”E) at an altitude of 2,146m with a day temperature of 14°C. Since the species was collected in an apple orchard, the majority of the vegetation around the area was fully covered with apple plantations and other fruit crops like pears, plums, and peaches. The area is mostly made up of agricultural lands with an average temperature of 13°C and 660mm of annual precipitation (Riyaz and Sivasankaran, 2022).

Identification, photography and sample deposition: Based on the morphological characteristics described in the available literature (Blackman and Eastop, 1994), the identification of the winged adult specimen was confirmed. The photographs of the live specimen on the possible new host were taken using a Redmi Note 9 Pro mobile camera (Xiaomi Communications Co., Ltd., China) with an external 25 mm macro lens attached. An Olympus BX-41 microscope was used for additional detailing of the body structures. The collected specimen is deposited in the Insect museum of Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu with voucher number SKUAST-JMU-289.

Distribution and host plants: India- Karnataka (Joshi, 1980), Himachal Pradesh (Sharma and Thakur, 1993), Ladakh (Hussain *et al.*, 2021). Elsewhere- (Bochniarz, 2020). Willow is the primary host of *T. salignus*. In the study of Sopow *et al.*, (2017), the presence of this aphid was established on fifty different species and hybrids of plants, including both woody and shrub forms (Tun *et al.*, 2020). On a side note, the presence of *T. salignus* on black poplar (*Populus nigra* L.) was reported and documented (Charles *et al.*, 2014). Aphids in various stages of development were seen feeding on the *Coprosma macrocarpa* shrub in New Zealand (Sopow *et al.*, 2017). There is evidence that *T. salignus* aphids consume sap from cambium-area phloem sieve tubes that have just undergone differentiation (Mittler, 1957).

Description (adult): Adult females are either wingless or have wings. Adult gigantic willow aphids have a body length of 5.0 to 5.8 mm and are among the biggest aphids seen anywhere in the world (Fig. 1a). Adults (Apterae) without wings are a medium to dark brown colour, and they feature multiple rows of black spots. Their whole body is coated in tiny hairs, which give the abdomen a glistening golden-gray coloration. A big “thorn” or tubercle that is dark brown in colour can be seen in the middle of their back (Fig. 1b). Honeydew is secreted by a pair of siphunculi, which are big, low cones located at the rear of the abdomen. Winged adults (alates) are distinguished by the presence of two pairs of transparent wings that are held above the animal’s

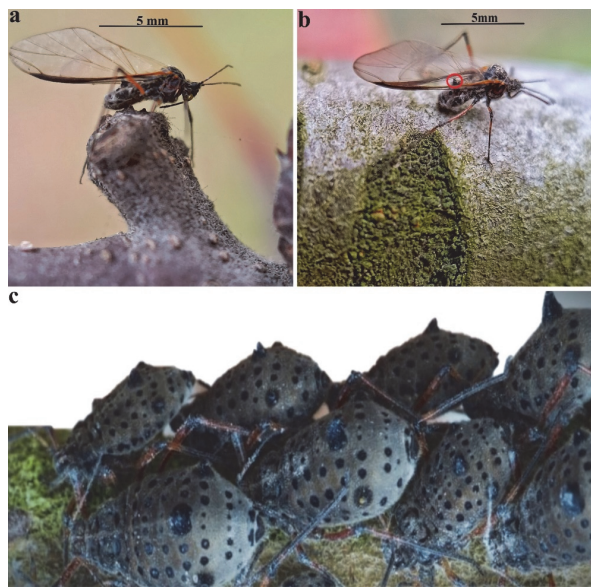


Fig. 1 a) *T. salignus* (Adult winged alate) with a body size of 5mm on a freshly pruned apple twig. b) *T. salignus* (Adult winged alate) on an apple branch with a “thorn” or tubercle on abdomen. c) Group of *T. salignus* apterae having mid-brown to dark brown with several rows of black sclerotic patches

body. The leading margin of the forewing is a shade of dark brown. With three sets of legs that are all somewhat reddish in colour and a pair of antennae that are less than half the length of the body. The underside of the head has a rostrum that is rather short and is used to hold the stylets that are used for feeding. The apterous morph of *T. salignus* is characterized by a mid- to dark-brown body adorned with multiple rows of black, sclerotic patches (Fig. 1c). The body surface is densely covered with fine, hair-like setae, imparting a greyish-golden sheen to the abdominal region. A prominent dark brown dorsal tubercle is located centrally on the thorax, anterior to the siphunculi, which are positioned on large, dark, conical bases. The antennae are relatively short, measuring less than half the length of the body. Notably, *T. salignus* is among the largest aphid species, with a body length ranging 5.0 to 5.8mm.

The possible host shift of *T. salignus* from willow to apple will likely driven by a confluence of abiotic and biotic pressures, and climate change (Liu *et al.*, 2017; Salisbury *et al.*, 2022). The widespread planting of willow windbreaks adjacent to apple orchards provides the essential ecological bridge

for dispersal. Subsequently, environmental stressors, potentially including climate-change-induced temperature shifts, drought, or overcrowding on primary willow hosts may degrade host suitability, prompting alate aphids to engage in exploratory feeding on the phylogenetically related and readily available apple trees (Skendzic *et al.*, 2021). The aphid’s known polyphagous tendency and high phenotypic plasticity, evidenced by its recorded colonization of numerous woody plants, provided the pre-adapted capability to not only probe but also successfully establish reproducing colonies on this novel, economically critical host (Salisbury *et al.*, 2022).

This paper documents a new and significant concern for this vital industry: the first confirmed presence of the giant willow aphid, *T. salignus* on apple trees in the region. Previously considered a specialist on willow, this field observation confirms a critical host shift by *T. salignus* onto a major commercial crop. This finding represents a potentially serious escalation of the pest pressure facing Kashmiri orchards. Regardless of the cause, the establishment of *T. salignus* on apple signals a new and emerging threat to apple production.

The findings underscore the critical and immediate need for systematic monitoring, in-depth research into its impact on apple yield and health, and the rapid development of integrated management strategies to protect the economic security of the Kashmir Valley.

ACKNOWLEDGEMENT

The authors are thankful to Head of the department, Division of Entomology, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu for extended support and guidance.

REFERENCES

- Aradottir G. I., Hanley S.J., Collins C.M., Dawson K.J., Karp A., Leather S.R., Shield I.F. and Harrington R (2012) Population genetics of *Tuberolachnus salignus*, an obligate parthenogenetic aphid. *Agricultural and Forest Entomology* 14(2): 197–205. doi: 10.1111/j.1461-9563.2011.00559.x

- Blackman R.L. and Eastop V.F. (1994) Aphids on the world's trees: An identification and information guide. CAB International, UK.
- Bochniarz A. (2020) Giant willow aphid (*Tuberolachnus salignus* Gmelin, 1790): A literature review. Polish Journal of Agronomy 30(43): 113–124. doi: 10.26114/pja.iung.449.2020.43.11
- Charles J.G., Nef L., Allegro G., Collins C., Delplanque A., Gimenez R. and Augustin S. (2014) Insect and other pests of poplars and willows. In Poplars and willows: Trees for society and the environment. Rome: Food and Agriculture Organization/CAB International. pp 459–526. doi: 10.1079/9781780641089.0459
- Czerniakowski Z.W. (2007) Bugs (Homoptera) on short-rotation coppice plantations. Progress in Plant Protection 47(4): 330–333.
- Government of Jammu & Kashmir (2025) Economic Survey 2024–2025, Directorate of Economics and Statistics, Srinagar. 85pp.
- Hussain B., War A.R., Singh S. and Ahmad S. (2021) First record of an invasive pest, giant willow aphid, *Tuberolachnus salignus* (Gmelin) (Homoptera: Aphididae), on *Salix alba* in the cold arid region of Ladakh, India. Entomological News 129(5): 538–545. doi: 10.3157/021.129.0508
- Josh, S. (1980) Aphids (Homoptera: Aphididae) and their hosts from Karnataka, India. Biosystematica 2(1): 19–32.
- Mittler T.E. (1957) Studies on the feeding and nutrition of *Tuberolachnus salignus* (Gmelin) (Homoptera, Aphididae): I. The uptake of phloem sap. Journal of Experimental Biology 34(3): 334–341.
- Molnár N. (2003) Population dynamics features of willow-feeding aphids. Acta Phytopathologica et Entomologica Hungarica 38(1–2): 125–135.
- Riyaz M., Mathew P., Paulraj G. and Ignacimuthu S. (2017) Entomophily of apple ecosystem in Kashmir valley, India: A review. International Journal of Scientific Research in Biological Sciences 5(5): 146–154.
- Riyaz M. and Sivasankaran K. (2022) First record of *Xanthia (Cirrhia) icteritia* (Hufnagel, 1766) (Noctuidae: Xyleninae) from India. Journal of Threatened Taxa 14(8): 21745–21748. doi: 10.11609/jott.7846.14.8.21745-21748
- Sage R.B. and Tucker K. (1997) Invertebrates in the canopy of willow and poplar short rotation coppices. In Biomass and energy crops. Cirencester, Royal College of Agriculture, UK. pp105–112.
- Salisbury A., Mansfield L., Edwards G. and Aradottir G.I. (2022) Quince (*Cydonia oblonga* Mill), an unusual host for the giant willow aphid *Tuberolachnus salignus* Gmelin (Homoptera: Aphididae). British Journal of Entomology and Natural History 35(4): 416–418.
- Skendzic S., Zovko M., Ivković I. P., Lešić V. and Lemić D. (2021) The impact of climate change on agricultural insect pests. Insects 12(5): 440. doi: 10.3390/insects12050440.
- Sharma G.C. and Thakur J.R. (1993) Biology of giant willow aphid, *Tuberolachnus salignus* (Gmelin) (Homoptera: Aphididae) in the cold arid zone of HP. Indian Forester 199(8): 648–653.
- Sopow S.L., Jones T., McIvor I., McLean J.A. and Pawson S.M. (2017) Potential impacts of *Tuberolachnus salignus* (giant willow aphid) in New Zealand and options for control. Agricultural and Forest Entomology 19(3): 225–234. doi: 10.1111/afe.12211.
- Szelegiewicz H. (1962) Materiały do poznania mszyc (Homoptera, Aphididae): 1. Podrodzina Lachninae. Fragmenta faunistica 10(6): 63–96.
- Tun K.M., Minor M., Jones T. and McCormick A.C. (2020) Volatile profiling of fifteen willow species and hybrids and their responses to giant willow aphid infestation. Agronomy 10(9): 1404. doi: 10.3390/agronomy10091404

Contents Volume 50

No. 1

- <https://doi.org/10.33307/entomon.v50i1.1405>** 1
 A new species of the genus *Herpetogramma* Lederer (Lepidoptera, Crambidae) from India
M. Shankara Murthy, S.K. Nagaraj, A. Prabhuraj and P. Maheswara Reddy
- <https://doi.org/10.33307/entomon.v50i1.1406>** 7
 Compatibility of *Beauveria bassiana* (Balsamo) Vuillemin, an entomopathogenic fungi, with selective insecticides for enhanced pest management
Cincy Thomas, Joseph Tom and C. A. Jayaprakas
- <https://doi.org/10.33307/entomon.v50i1.1407>** 13
 Molecular characterization of *Ceylonitermellus sahyadriensis* Emerson, 1960 (Termitidae, Nasutitermitinae) - a rare species from Kerala part of Western Ghats, India
Edwin Joseph, Jobin Mathew, C.P. Rayeefa Fathima, J. Kalyani, Jeeva Elizabeth Vince, Bristo Joby Mathews and T. Ayyaya Babu
- <https://doi.org/10.33307/entomon.v50i1.1408>** 19
 Age-related comb dimensions of the red dwarf honeybee, *Apis florea* F. (Hymenoptera, Apidae) in the plains of Karnataka, India
S.K. Ramyarani and N. Nagaraja
- <https://doi.org/10.33307/entomon.v50i1.1409>** 25
 Diversity and foraging activity of pollinators of *Foeniculum vulgare* Miller in Bikaner, India
J.G. Adlin Prajula, Syed Mohammad Ibrahim and A.B. Sruthi
- <https://doi.org/10.33307/entomon.v50i1.1410>** 33
 Bio-efficacy of botanical soap formulations fortified with essential oils against *Henosepilachna vigintioctopunctata* (Fab.) (Coleoptera, Coccinellidae) and evaluation of its shelf life
S.R. Neeraja, R. Narayana and M.S. Nisha

- <https://doi.org/10.33307/entomon.v50i1.1412>** 39
 Descriptions of polar gynandromorphic specimens of *Culicoides oxystoma* Kieffer and *Obsoletus* group (Diptera, Ceratopogonidae) from West Bengal, India
Ankita Sarkar, Paramita Banerjee and Abhijit Mazumdar
- <https://doi.org/10.33307/entomon.v50i1.1413>** 47
 Odonata diversity of mid-elevation catchments of the Bavali river from Coorg landscape of central Western Ghats, peninsular India
Vibhu Vijayakumaran, Kalesh Sadasivan and Vinayan Padmanabhan Nair
- <https://doi.org/10.33307/entomon.v50i1.1414>** 61
 Pollination potential of stingless bee *Tetragonula iridipennis* Smith. (Hymenoptera, Apidae) in pumpkin (*Cucurbita moschata* Duchex Poir)
K.S. Kedswin, M.R. Srinivasan, Sake Manideep and Talapala Sai Kumar
- <https://doi.org/10.33307/entomon.v50i1.1415>** 67
 Effective sanitation practices mitigate coffee berry borer, *Hypothenemus hampei* (Ferrari, 1867) (Coleoptera, Curculionidae) infestation in robusta coffee in Indonesia
Wilyus, Wilma Yunita, Fadila Amelia Futri and Ravindra C. Joshi
- <https://doi.org/10.33307/entomon.v50i1.1416>** 73
 A new species of *Euphaea* Selys, 1840 (Odonata, Euphaeidae) from Wayanad, Western Ghats, Kerala, India
S.S. Anooj, C. Susanth, Kalesh Sadasivan, Shriram Dinkar Bhakare, Dattaprasad Sawant and Vinayan Padmanabhan Nair
- Short Communications**
- <https://doi.org/10.33307/entomon.v50i1.1417>** 85
 Partial characterization of lipase in male moth of *Maruca vitrata* (Fabricius) (Lepidoptera, Pyralidae)
Sushma A. Jadhav and Ramesh M. Gejage

	483
https://doi.org/10.33307/entomon.v50i1.1418	89
New host and distribution records of <i>Hemiptarsenus orizae</i> Narendran (Hymenoptera, Eulophidae) from Kerala, India <i>Sreejina Sreedharan Kallyadan, Shreevihar Santhosh and Mannankadiyan Nasser</i>	
https://doi.org/10.33307/entomon.v50i1.1419	93
Rediscovery of <i>Trochoideus desjardinsi</i> Guérin-Méneville, 1838 (Coleoptera, Endomychidae, Pleganophorinae) with a new record from Mumbai, Maharashtra, India <i>Drashti Danani, Harshad Parekar and Amol Patwardhan</i>	
https://doi.org/10.33307/entomon.v50i1.1420	97
Life cycle and morphometrics of leaf roller, <i>Haritalodes derogata</i> (Fabricius) on cotton in Surat, Gujarat, India <i>N.S. Dalsaniya, R.D. Patel, G.R. Bhanderi, H.R. Desai and Malireddi Prasanna</i>	
https://doi.org/10.33307/entomon.v50i1.1421	103
Screening of rice cultivars against Angoumois grain moth, <i>Sitotroga cerealella</i> (Olivier) (Lepidoptera, Gelechiidae) <i>Vaishali Zote and Abhishek Shukla</i>	
https://doi.org/10.33307/entomon.v50i1.1422	107
Exploring plant seed extracts as potential sources of trypsin inhibitors for insect pest management: screening and characterization of inhibitory activity <i>S.K. Sreejina and V.M. Kannan</i>	
https://doi.org/10.33307/entomon.v50i1.1423	113
Strategy on the predation of arboreal weaver ant <i>Oecophylla smaragdina</i> (Fabricius) on a ground nesting ant <i>Camponotus compressus</i> (Fabricius) <i>Khokan Naskar, Srimanta Kumar Raut and Sangita Maiti Dutta</i>	
https://doi.org/10.33307/entomon.v50i1.1430	119
Obituary - Prof. V.K.K. Prabhu <i>Prof. Dr. Oommen V. Oommen</i>	
Author Index	121

No. 2

- <https://doi.org/10.33307/entomon.v50i2.1454>** 123
 Ultra-structural description of *Haemaphysalis* species on goats in Kerala, south India
Kajal T Annasaheb, Bindu Lakshmanan, Amrutha Anand and Indu V Raj
- <https://doi.org/10.33307/entomon.v50i2.1456>** 131
 Assessing the impact of foliar insecticides on yellow stem borer *Scirpophaga incertulas* and rice yield enhancement
B.N. Balaji, Pandit, L. Vijaykumar and B. Shivanna
- <https://doi.org/10.33307/entomon.v50i2.1457>** 137
 Foraging interaction of stingless bee *Tetragonula travancorica* with flowers in ornamental plants
C.L. Anchu, V. Vijayasree, R.L. Abhijith and A. Sheena
- <https://doi.org/10.33307/entomon.v50i2.1458>** 145
In Silico biological evaluation of propolis for modulating Ghrelin, Leptin and CYP17A1 gene pathways in Polycystic Ovary Syndrome
Ashmitha Elangovan, N. Aarthi and P.B. Harathi
- <https://doi.org/10.33307/entomon.v50i2.1459>** 153
 Description of a new species of genus *Chloropaga* Hampson (Lepidoptera, Nolidae) from India
Harkanwal Singh
- <https://doi.org/10.33307/entomon.v50i2.1460>** 157
 Efficacy of botanicals and synthetic acaricides against *Aceria noxia* Flechtmann & Tassi, 2020 in vegetable amaranth, *Amaranthus tricolor* L.
K.P. Krishna Keerthi, K.M. Sreekumar, B. Ramesha, C. Vidya and P.K. Sajeesh
- <https://doi.org/10.33307/entomon.v50i2.1461>** 163
 Effectiveness of plant essential oil nanoemulsions in controlling, *Leptocorisa oratoria* (Hemiptera, Alydidae) in lab and field conditions
M. Amrutha and Vimala K John

<https://doi.org/10.33307/entomon.v50i2.1464>

175

A new black fly species of subgenus *Gomphostilbia* Enderlein, 1921 (Simuliidae, Diptera) from Eastern Ghats, India

S. Vijayan and S. Anbalagan

<https://doi.org/10.33307/entomon.v50i2.1465>

183

Microbial analysis of hive stored pollen of Indian honey bee, *Apis cerana indica* (Fabricius) (Hymenoptera, Apidae)

V. Abhishek, Mani Chellappan, M.T. Ranjith, K. Surendragopal and Seeja Thomachan

<https://doi.org/10.33307/entomon.v50i2.1469>

191

A new species of *Zographetus* Watson, 1893 (Lepidoptera, Hesperidae, Hesperinae) from the Western Ghats, Peninsular India

Kalesh Sadasivan, Baiju Kochunarayanan, Sujitha Prabhakaran Chandrika, Toms Augustine, Muhamed Jafer Palot, Jebine Jose, Sojan Munnar and Vinayan Padmanabhan Nair

<https://doi.org/10.33307/entomon.v50i2.1470>

203

A new species of *Lyriothemis* Brauer, 1868 (Odonata, Libellulidae) from the Western Ghats of Peninsular India

Kalesh Sadasivan, Jebine Jose, Muhamed Jafer Palot, Shanassudheer, Toms Augustine, Baiju Kochunarayanan, Vinayan Padmanabhan Nair and Maya George

Short Communications

<https://doi.org/10.33307/entomon.v50i2.1471>

215

An unusual new record of *Pseudoathyreus orientalis* (Laporte, 1840) (Coleoptera, Bolboceratidae, Athyreinae), an eremian species from the Deccan Peninsula, India and designation of its neotype

Aparna Sureshchandra Kalawate

<https://doi.org/10.33307/entomon.v50i2.1472>

219

First record of the genus *Lemuriana* Distant, 1905 (Hemiptera, Cicadidae, Lamotialnini) from Kerala, India

A. Anjana and K.T. Teji

<https://doi.org/10.33307/entomon.v50i2.1473>

225

Evaluation of food consumption of *Zygogramma bicolorata* Pallister 1953, on *Parthenium hysterophorus* in Dehradun, Uttarakhand, India

Yashika Negi, Veena Maurya, Madhu Thapliyal and Ashish Uniyal

https://doi.org/10.33307/entomon.v50i2.1474	
New distribution of the myrmicine arboreal ant, <i>Paratopula intermedia</i> Sheela and Narendran (Formicidae, Myrmicinae) from south India <i>Thresiamma Varghese</i>	229
https://doi.org/10.33307/entomon.v50i2.1475	
Record of <i>Ulomimus indicus</i> Bates, 1873 (Coleoptera, Tenebrionidae) from south India <i>T.K. Viswanath, V.D. Hegde and K.M. Remia</i>	231
https://doi.org/10.33307/entomon.v50i2.1476	
<i>Leptocorisa</i> Latreille (Alydidae) species abundance and distribution in paddy fields of Thrissur, Kerala, India <i>M. Amrutha and Vimala K John</i>	235
https://doi.org/10.33307/entomon.v50i2.1477	
Report on the rediscovery of <i>Thacona ferreopicta</i> (Hampson, 1900) (Lepidoptera, Scranciidae) with the first description of female genitalia from India <i>M.P. Unnikrishnan, Ryan A. St Laurent and Sapna Jacob</i>	239
https://doi.org/10.33307/entomon.v50i2.1478	
New records of egg parasitoids (Hymenoptera, Chalcidoidea, Trichogrammatidae) from Kashmir Valley, Jammu and Kashmir, India <i>Rabiya Irshad, Mohd Yousuf, Mohsin Ikram, Syed Faizan Anayat and Tahmeena Maqsood</i>	243
https://doi.org/10.33307/entomon.v50i2.1479	
Obituary - Dr. K.S.S. NAIR <i>Dr. George Mathew</i>	247
Author Index	251

No. 3

https://doi.org/10.33307/entomon.v50i3.1520	
Six new additions to the Indian butterfly (Lepidoptera) fauna from Upper Siang, Arunachal Pradesh, India <i>Monsoon Jyoti Gogoi, Rajkamal Goswami, Seena Narayanan Karimbumkara and Agur Litin</i>	253

<https://doi.org/10.33307/entomon.v50i3.1521>

261

Study of egg laying pattern and hatching line formation of *Culicoides peregrinus* Kieffer and *C. oxystoma* Kieffer (Diptera, Ceratopogonidae), vector of bluetongue virus

Paramita Banerjee, Ankita Sarkar and Abhijit Mazumdar

<https://doi.org/10.33307/entomon.v50i3.1522>

269

Aquatic beetles (Dytiscidae, Gyrinidae, Haliplidae, Hydrophilidae, Noteridae) of the Papikonda National Park from the Eastern Ghats, Andhra Pradesh, India

*Shiva Shankar, Devadoss Kumar, Deepa Jaiswal,
Karuthapandi Madasamy and Shrikant Jadhav*

<https://doi.org/10.33307/entomon.v50i3.1523>

291

Molecular identification and phylogenetic analysis of spiralling whitefly, *Aleurodicus dispersus* Russell (Hemiptera, Aleyrodidae) from different agroecological zones of Kerala, India

Drisya Pavithran, J.V. Siji, C.A. Jayaprakas and B.G. Sangeetha

<https://doi.org/10.33307/entomon.v50i3.1524>

299

Characterization and antibacterial properties of oak tasar and mulberry silkworm pupae oils

Kusumala Suman, Devika Srivastava and R. Venkatesh Kumar

<https://doi.org/10.33307/entomon.v50i3.1525>

307

Bioefficacy of certain insecticides in cabbage against lepidopteran pests

*Ravi Singh, Sameer Kumar Singh, Kamal Ravi Sharma,
Umesh Chandra and Pradeep Kumar Dalal*

<https://doi.org/10.33307/entomon.v50i3.1526>

311

Effect of aqueous extracts of *Pithecellobium dulce* (Roxb.) Benth against *Pediculus humanus capitis* De Geer, 1778 (Psocodea, Pediculidae)

*Susmita Gudulkar, Himanshu Dawda, Usha Mukundan
and Somnath Kangralkar*

<https://doi.org/10.33307/entomon.v50i3.1527>

317

High levels of endogenous polyamines indicate superiority of *Morus alba* L. varieties for improved silk production in *Bombyx mori* L.

*Brinda Goda Lakshmi Didugu, Sayyad Sadiya Kousar,
Degsew Bezabih Gebresilassie, Vaishnavi Ponugupati,
Haroon Rashid MD, Madhavi Kasa and Anitha Mamillapalli*

<https://doi.org/10.33307/entomon.v50i3.1528> 325

Toxic effects of pesticides on the green lacewing, *Chrysoperla zastrowi sillemi* (Esben-Peterson) (Neuroptera, Chrysopidae)

N. Santhana Bharathi, T.P. Rabeesh and K. Sujatha

<https://doi.org/10.33307/entomon.v50i3.1529> 335

Evaluating wetland health using Odonata diversity and seasonal shifts in Tulshi Reservoir, Maharashtra, India

Rahul S. Kamble, Gajanan K. Sontakke and Sagar A. Vhanalakar

<https://doi.org/10.33307/entomon.v50i3.1530> 347

Rediscovery of *Eristalinus (Merodonoides) multifarius* (Walker, 1852) (Diptera, Syrphidae) from Kerala, India and its molecular phylogeny

Aiswarya Joy, S.S. Anooj, Manju Mary Paul, B.Ramesha and K.M. Sreekumar

<https://doi.org/10.33307/entomon.v50i3.1531> 355

New state records and distributional range extensions of termite species in India

M. Roy, J. Basak, B. Baraik and K. Rajmohana

Short Communications

<https://doi.org/10.33307/entomon.v50i3.1532> 363

Effect of host plants on the feeding potential of *Episyrphus balteatus* (De Geer) preying on two different aphid species

Kimmi Kumari and Md. Equbal Ahmad

<https://doi.org/10.33307/entomon.v50i3.1533> 367

First record of *Leptus* Charles De Geer, 1778 (Acari, Erythraeidae) larval parasitism on *Eyprepocnemis alacris alacris* Serville, 1838 (Orthoptera, Acrididae) from Kerala, India

T. Deepthy and R.S.M. Shamsudeen

<https://doi.org/10.33307/entomon.v50i3.1534> 371

Studies on developmental biology of lesser grain borer, *Rhyzopertha dominica* (F.) (Coleoptera, Bostrichidae) at different seasons on paddy

V. Ramalakshmi, Deepayan Padhy, T. Mounika, Manish Kumar Yadav and Goutam Hosamani

<https://doi.org/10.33307/entomon.v50i3.1535>

375

First record of *Tachardiaephagus tachardiae* (Howard, 1896) (Hymenoptera, Chalcidoidea, Encyrtidae) from an invasive Lac insect, *Kerria destructor* Talukder and Das, 2020 (Hemiptera, Kerriidae)

Anil Kumar Dubey, A. Rameshkumar and S.R. Koteswar Rao

Author Index

379

No. 4

<https://doi.org/10.33307/entomon.v50i4.1573>

381

Dissipation of emamectin benzoate in okra and its residual impact on okra metabolome

G.T. Pradeepkumar, K.P. Subhash Chandran and V. Vijayasree

<https://doi.org/10.33307/entomon.v50i4.1574>

397

Redescription of *Rawania petasata* (Melichar) (Hemiptera, Cicadellidae, Typhlocybinae) with a key to genera of Empoascini related to genus *Rawania* Ghauri of Oriental region

N. Shreya, C.M. Kalleshwaraswamy, M. Shankaramurthy, G.K. Girijesh, Sharanabasappa S. Deshmukh, K. Rajashekharappa and B.V. Champa

<https://doi.org/10.33307/entomon.v50i4.1575>

405

Characterization and use of green nanoparticles from the leaves of *Tiliacora acuminata* against larvae of vector *Culex quinquefasciatus* Say

Someshwar Singha

<https://doi.org/10.33307/entomon.v50i4.1576>

411

Notes on plants visited by genus *Paragus* Latreille (Diptera, Syrphidae) with an updated key to Indian species

Panchanan Parui, Jayita Sengupta, Mousumi Chowdhury, Bristi Roy, Sudip Mondal, Suman Kumar Saha, Moubanti Das, Atanu Naskar and Dhriti Banerjee

<https://doi.org/10.33307/entomon.v50i4.1577>

417

Description of a new species of *Hypospila* Guenee, 1852 (Lepidoptera, Erebiidae) from Kerala, India

P.K. Adarsh, Joslin Treesa Jacob and Abhilash Peter

<https://doi.org/10.33307/entomon.v50i4.1579>

423

Biology and morphometrical analysis of rice weevil, *Sitophilus oryzae* (L.) (Coleoptera, Curculionidae) on different stored cereals

Gadi Prasad, Lopamudra Biswal, Saswati Parija, Arundhati Sasmal, Akhilesh Kumar Gupta and Deepa Khulbe

https://doi.org/10.33307/entomon.v50i4.1581	431
Coleopteran diversity, its distribution and the influence of environmental factors on them in the Barak river basin of Assam, India	
<i>Ankur Nandi and Sarbani Giri</i>	
https://doi.org/10.33307/entomon.v50i4.1582	445
Comprehensive assessment of pivotal silkworm races for economic traits in Jammu and Kashmir, India	
<i>R. Kiran, P. Kumaresan, Shivkumar, M.N. Ahmad , K.N. Bharath and Sardar Singh</i>	
https://doi.org/10.33307/entomon.v50i4.1583	453
Observations on the butterflies feeding on non-nectar sources in the Kolhapur District, Maharashtra, India	
<i>A.N. Patil and S.M. Gaikwad</i>	
Short Communications	
https://doi.org/10.33307/entomon.v50i4.1584	461
First record of aquatic stick insect, <i>Ranatra digitata</i> Hafiz & Pradhan, 1947 (Hemiptera, Heteroptera, Nepidae) from Kerala, India	
<i>K. Jyothylakshmi, S. Nandakumar and E. Eyarin Jehamalar</i>	
https://doi.org/10.33307/entomon.v50i4.1585	465
First report of the brown widow spider, <i>Latrodectus geometricus</i> Koch, 1841 (Araneae, Theridiidae) from southern India	
<i>R. Kishore and Vinod Sadhasivan</i>	
https://doi.org/10.33307/entomon.v50i4.1586	469
Assessment of honeybee biodiversity in the agro-climatic zones of Uttarkashi of Garhwal Himalaya, Uttarakhand, India	
<i>Abhishek Thapliyal, Vishesh Nautiyal, Deepak Rana, Ashish Thapliyal and Madhu Thapliyal</i>	
https://doi.org/10.33307/entomon.v50i4.1587	473
Notes on <i>Hyllus semicupreus</i> (Simon, 1885) (Salticidae, Plexippina) from India	
<i>Jayaraman Dharmaraj</i>	
https://doi.org/10.33307/entomon.v50i4.1588	477
<i>Tuberolachnus salignus</i> (Gmelin, 1790) (Hemiptera, Aphididae) on Apple (<i>Malus domestica</i> Borkh) in Kashmir, India	
<i>Muzafar Riyaz, Sabreena Ashraf and Rakesh Kumar Gupta</i>	
Contents of volume 50, issues 1 - 4	481
Acknowledgements to Peer Reviewers	491
Author index - Volume 50, issues 1 - 4	497
https://doi.org/10.33307/entomon.v49i5.1501	501
ENTOMON 49(5): 1—218	
MONOGRAPH Series 1, 2025	
The butterflies (Lepidoptera, Rhopalocera) of Kerala: Status and distribution	
<i>Sadasivan et al.</i>	

ACKNOWLEDGEMENTS

To Peer Reviewers

The EDITORIAL BOARD of ENTOMON encompasses abundant and sincere appreciation and thanks to the following peer reviewers for sparing their precious time in judgmentally going through the manuscripts and suggesting productive comments and assessments on the articles published in the ENTOMON volume 50, issues 1 to 4, during 2025.

Abubakar Adeoye, Department of Zoology, Kwara State University, Malete, Kwara State, Nigeria.

Ahammed Shabeer Thekkumpurath, ICAR-National Research Centre for Grapes, Pune 412307, Maharashtra, India.

Aijaz A Wachkoo, Department of Zoology, Government Degree College, Kulgam, Chawalgam Road, Kulgam 192231, Jammu & Kashmir, India.

Allen F. Sanborn, Emeritus Professor, Barry University, Biology, Miami, United States.

Amandeep Kaur, Department of Entomology, Punjab Agricultural University, Ludhiana, Punjab, India.

André-Philippe Drapeau Picard, Montréal Insectarium - Space for Life, 4581, rue Sherbrooke Est, Montréal, Québec, H1X 2B2, Canada.

Anil Kumar Dubey, Hemiptera Section, Zoological Survey of India, New Alipore 700053, Kolkata, West Bengal, India.

Anooj S.S., Asst. Professor, Dept. of Entomology, College of Agriculture, Kerala Agricultural University, Vellayani, Trivandrum 695522, Kerala, India.

Anup Chandra, Division of Crop Protection, Agricultural Entomology, ICAR - Indian Institute of Pulses Research, Kalyanpur, Kanpur 208024, Uttar Pradesh, India.

Ashish D. Tiple, Department of Zoology, Dr. R.G. Bhoyar Arts, Commerce and Science College, Seloo (Vidyabharati), Wardha 442104, Maharashtra, India.

Balasubramanian, R., Group leader, Department of Medical Entomology & Zoology, ICMR-National Institute of Virology, Dept. of Health Research, Min. of H&FW, Pune 411001, Maharashtra, India.

Banothu Dasmabai, Department of Veterinary Parasitology, College of Veterinary Science, P.V. Narasimha Rao Telangana Veterinary University, Rajendranagar, Hyderabad 500030, Telangana, India.

Baskaran, V., Acarology, Department of Agricultural Entomology, Centre for Plant Protection Studies, Tamil Nadu Agricultural University, Coimbatore 641003, Tamil Nadu, India.

Bhupendra Kumar; Department of Zoology, Banaras Hindu University, Varanasi 221005, Uttar Pradesh, India.

Damayanti Bakra, Department of Zoology, Vidyasagar Metropolitan College, Kolkata, West Bengal, India.

David Sommer, Department of Zoology, Faculty of Science, Charles University, Viničná 7, CZ-128 43 Praha 2, Czech Republic.

Evans Asirvadam, Associate Professor (Rtd), Department of Zoology, University College, Thiruvananthapuram 695034, Kerala, India.

Fazil Hasan, Division of Entomology, ICAR-Indian Agricultural Research Institute, Pusa, New-Delhi 110012, India.

Floyd W. Shockley, Collections Manager, Department of Entomology, National Museum of Natural History Smithsonian Institution, MRC 165, Washington, DC 20013-7012, USA.

Geetha Iyer, Suchindrum 629704, Tamil Nadu, India.

George Mathew, Forest Health Division, Kerala Forest Research Institute, Peechi 680653, Kerala, India.

Guru Pirasanna Pandi G, Entomology Division, ICAR-National Rice Research Institute, Cuttack, Odisha, India.

Hemant Ghate, Head (RTd), Zoology Department, Modern College, Shivajinagar, Pune 411005, Maharashtra, India.

Jhansi Lakshmi, V., Division of Crop Protection, Entomology, Directorate of Rice Research, Rajendranagar, Hyderabad 500030, Andhra Pradesh, India.

Kalesh Sadasivan, TNHS Lepidoptera Research Group, Travancore Nature History Society, MBRR, Mathrubhumi Road, Vanchiyoor, Thiruvananthapuram 695035, Kerala, India.

Kathirvelu C., Department of Entomology, Faculty of Agriculture, Annamalai University, Annamalai Nagar 608 002, Tamil Nadu, India.

Kesavan Subaharan, ICAR - National Bureau of Agricultural Insect Resources, Attur Layout, Yelahanka Campus, Bangalore 560 064, Karnataka, India.

Khan, M.S. Oilseed Entomology; All India Coordinated Research Project on Rapeseed & Mustard, G.B. Pant University of Agriculture and Technology, Pantnagar 263145, Uttarakhand, India.

Kousik Mandal; Pesticide Residue Analysis Laboratory, Department of Entomology, Punjab Agricultural University, Ludhiana 141004, Punjab, India.

Kubendran, T., Miscellaneous Insect Order (MIO) Section, Zoological Survey of India, Ministry of Environment, Forest & Climate Change, Government of India, Prani Vigyan Bhawan, New Alipore, Kolkata 700 053, West Bengal, India.

Kunal Ankola, Department of Life Sciences, Jnana Bharathi Campus, Bangalore University, Bengaluru, India/ Genomics and Proteomics Lab, Department of Studies in Sericulture, Manasagangotri, University of Mysore, Mysuru, Karnataka, India.

Mahmoud Abbas Ali, Plant Protection Department, Faculty of Agriculture, South Valley University, Qena, Egypt.

Manjunath Gowda, Department of Sericulture, GKVK, University of Agricultural Sciences, Bengaluru 560065, Karnataka, India.

Md. Ehtashamul hassan, Officer-in-charge, Hemiptera Section, Zoological Survey of India, M-Block, New Alipore, Kolkata 700 053, West Bengal, India.

Meena Kumari, Department of Zoology, Govt. College, Kullu 175101, Himachal Pradesh, India.

Mohammad Hayat, Department of Zoology, Aligarh Muslim University, Aligarh 202002, Uttar Pradesh, India.

Noppadon Makbun, 211/5 Moo 4, Takhli, Nakhon Sawan 60140, Thailand.

Padmakumari, A.P., AICRP (Entomology), ICAR- Indian Institute of Rice Research, Rajendranagar 500 030, Hyderabad, Telangana, India.

Palatty Allesh Sinu, Department of Zoology, Central University of Kerala, Kasaragod 671320| Kerala, India.

Palot, Muhamed Jafer, Western Ghat Regional Centre, Zoological Survey of India, Jaffer Khan Colony, Kozhikode, Kerala, India.

Prasad, G., Dept. of Zoology, Faculty of Science, University of Kerala, Thiruvananthapuram 695581, Kerala, India.

Priyadarsanan Dharma Rajan, Ashoka Trust for Research in Ecology and the Environment (ATREE), Royal Enclave, Srirampura, Jakkur Post, Bengaluru 560064, Karnataka, India.

Quoc Toan Phan, The Center for Entomology & Parasitology Research, College of Medicine and Pharmacy, Duy Tan University, 120 Hoang Minh Thao, Lien Chieu, Da Nang, Vietnam.

Rajgopal N.N., ICAR-National Bureau of Agricultural Insect Resources, H.A. Farm Post, Bellary Road, Bengaluru 560024, Karnataka, India.

Rashmi R Shanbhag, Forest and Wood Protection Division, Institute of Wood Science and Technology, Bengaluru, Karnataka, India.

Reghu Ravindran, Department of Veterinary Parasitology, College of Veterinary and Animal Sciences, Kerala Veterinary and Animal Sciences University, Mannuthy 680651, Kerala, India.

Sampath Kumar, M., Division of Germplasm Conservation and Utilisation, ICAR-National Bureau of Agricultural Insect Resources, H.A. Farm Post, Bellary Road, Bengaluru 560024, Karnataka, India.

Sanaullah Bhat, Department of Zoology, Kumaun University, S.S.J. Campus, Almora 263 601, Uttarakhand, India.

Sandeep Singh, Department of Entomology, All India Coordinated Research Project on Fruits, Department of Fruit Science, Punjab Agricultural University, Ludhiana 141004, Punjab, India.

Sankar, M., Division of Parasitology, ICAR - Indian Veterinary Research Institute, Izatnagar 243122, Bareilly, Uttar Pradesh, India.

Sankararaman Harihara Krishnan, Parasitoid Taxonomy and Biocontrol laboratory, Department of Crop Protection (Entomology), Vanavarayar Institute of Agriculture, Manakkadavu, Pollachi 642103, Tamil Nadu, India.

Sankarsan Roy, Zoological Survey of India, M- Block, New Alipore, Kolkata 700053/ District Entomologist-Public Health Branch, Department of Health & Family Welfare (Govt. of WB), office of the CMOH, Zilla Swasthya Bhawan, Ranchi Road, Purulia, West Bengal, India.

Santhosh Shreevihar, Insect Ecology and Ethology Laboratory, Department of Zoology, Malabar Christian College, University of Calicut, Kozhikode 673635, Kerala, India.

Selvakaran Devasahayam, Former Head of Crop Protection, ICAR - Indian Institute of Spices, Marikunnu, Kozhikode 673012, Kerala, India.

- Selvanarayanan, V., Department of Entomology, Faculty of Agriculture & Former Controller of Examinations, Annamalai University 608 002, Tamil Nadu, India.
- Senguttuvan, K., Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore 641003, Tamil Nadu, India.
- Shashidhar Viraktamath, Biosystematic Laboratory, Department of Entomology, University of Agricultural Sciences, GKVK, Bengaluru 560065, Karnataka, India.
- Sheela, S., Zoological Survey of India, (Headquarters), Ministry of Environment, Forest & Climate Change (Govt. of India), Prani Vigyan Bhawan, New Alipore, Kolkata 700053, West Bengal, India.
- Shelley Acharya, Zoological Survey of India (Headquarters), Ministry of Environment, Forest & Climate Change (Govt. of India), Prani Vigyan Bhawan, New Alipore, Kolkata 700053, West Bengal, India.
- Shivanna, B., Department of Agricultural Entomology, University of Agricultural Sciences, GKVK, Bengaluru 560065, Karnataka, India.
- Shuddhasattwa Maitra Mazumdar, Central Silk Board, Govt. of India, Dharampur, Dumka 814103, Jharkhand, India.
- Snehasish Routray, Department of Entomology, Sri Venkateswara Agricultural College, Acharya N.G. Ranga Agricultural University, Tirupati, Andhra Pradesh, India.
- Souvik Sen, Arachnida & Technical Section, Zoological Survey of India, Ministry of Environment, Forest & Climate Change, Govt. of India, Prani Vigyan Bhawan, M-Block, New Alipore, Kolkata 700 053, West Bengal, India.
- Srimoyee Basu, Vector control, Health Department, Kolkata Municipal Corporation, Kolkata 700012, West Bengal, India.
- Srinivasa, N., Department of Agril. Entomology, UAS, Bengaluru/ 111, Amalasn, 3roå, Bhuvanewavinagar, Dosarahalli Road, Bengaluru 560024, Karnataka, India.
- Sudhir Singh, Systematic Laboratory, Forest Entomology Division, Forest Research Institute, Dehradun, Uttarakhand, India.
- Sureshan, P.M., Western Ghat Regional Centre, Zoological Survey of India, Kozhikode 673006, Kerala, India.

Susanth, C., Prakriti, SNRA-20; Indira Nagar, Peroorkada, Thiruvananthapuram 695005, Kerala, India.

Thirupathaiah Yeruva, Central Sericultural Research and Training Institute, Mysuru, Karnataka 570008, India.

Uniyal, V.P., Department of Biosciences, Graphic Era (Deemed to be University), Dehradun 248002, Uttarakhand, India.

Viraktamath, C.A., Biosystematic Laboratory, Department of Entomology, University of Agricultural Sciences, GKVK, Bengaluru 560065, Karnataka, India.

Winston M.O.Thompson, P.O. Box 7226, Bellevue, WA 98008, USA.

AUTHOR INDEX

Volume 50, Issues 1-4

- | | |
|------------------------------------|-----------------------------------|
| Aarthi N., 145 | Atanu Naskar, 411 |
| Abhijit Mazumdar, 39, 261 | Avyaya Babu T., 13 |
| Abhijith R.L., 137 | Baiju Kochunarayanan, 191, 203 |
| Abhilash Peter, 417 | Balaji B.N., 131 |
| Abhishek Shukla, 103 | Baraik B., 355 |
| Abhishek Thapliyal, 469 | Basak J., 355 |
| Abhishek V., 183 | Bhanderi G.R., 97 |
| Adarsh P.K., 417 | Bharath K.N., 445 |
| Adlin Prajula J.G., 25 | Bindu Lakshmanan, 123 |
| Agur Litin, 253 | Brinda Goda Lakshmi Didugu, 317 |
| Ahmad M.N., 445 | Bristi Roy, 411 |
| Aiswarya Joy, 347 | Bristo Joby Mathews, 13 |
| Akhilesh Kumar Gupta, 423 | Champa B.V., 397 |
| Amol Patwardhan, 93 | Cincy Thomas, 7 |
| Amrutha Anand, 123 | Dalsaniya N.S., 97 |
| Amrutha M., 163, 235 | Dattaprasad Sawant, 73 |
| Anbalagan S., 175 | Deepa Jaiswal, 269 |
| Anchu C.L., 137 | Deepa Khulbe, 423 |
| Anil Kumar Dubey, 375 | Deepak Rana, 469 |
| Anitha Mamillapalli, 317 | Deepayan Padhy, 371 |
| Anjana A., 219 | Deepthy T., 367 |
| Ankita Sarkar, 39, 261 | Degsew Bezabih Gebresilassie, 317 |
| Ankur Nandi, 431 | Desai H.R., 97 |
| Anooj S.S., 73, 347 | Devadoss Kumar, 269 |
| Aparna Sureshchandra Kalawate, 215 | Devika Srivastava, 299 |
| Arundhati Sasmal, 423 | Dhriti Banerjee, 411 |
| Ashish Thapliya, 469 | Drashti Danani, 93 |
| Ashish Uniyal, 225 | Drisya Pavithran, 291 |
| Ashmitha Elangovan, 145 | Edwin Joseph, 13 |
| Aswati Parija, 423 | Equbal Ahmad Md., 363 |

- Eyarin Jehamalar E., 461
Fadila Amelia Futri, 67
Gadi Prasad, 423
Gaikwad S.M., 453
Gajanan K. Sontakke, 335
Girijesh G.K., 394
Goutam Hosamani, 371
Harathi P.B., 145
Harkanwal Singh, 153
Haroon Rashid MD, 317
Harshad Parekar, 93
Hegde V.D., 231
Himanshu Dawda, 311
Indu V Raj, 123
Jayaprakas C.A., 7, 291
Jayaraman Dharmaraj, 473
Jayita Sengupta, 411
Jebine Jose, 191, 203
Jeeva Elizabeth Vince, 13
Jobin Mathew, 13
Joseph Tom, 7
Joslin Treasa Jacob, 417
Jyothylakshmi K., 461
Kajal T Annasaheb, 123
Kalesh Sadasivan, 47, 73, 191, 203
Kalleshwaraswamy C.M., 397
Kalyani J., 13
Kamal Ravi Sharma, 307
Kannan V.M., 107
Karuthapandi Madasamy, 269
Kedswin K.S., 61
Khokan Naskar, 113
Kimmi Kumari, 363
Kiran R., 445
Kishoer R., 465
Koteswar Rao S.R., 375
Krishna Keerthi K.P., 157
Kumaresan P., 445
Kusumala Suman, 299
Lopamudra Biswal, 423
Madhavi Kasa, 317
Madhu Thapliyal, 225, 469
Maheswara Reddy P., 1
Malireddi Prasanna, 97
Mani Chellappan, 183
Manish Kumar Yadav, 371
Manju Mary Paul, 347
Mannankadiyan Nasser, 89
Maya George, 203
Mohd Yousuf, 243
Mohsin Ikram, 243
Monsoon Jyoti Gogoi, 253
Moubanti Das, 411
Mounika T., 371
Mousumi Chowdhury, 411
Muhammed Jafer Palot, 191, 203
Muzafar Riyaz, 477
Nagaraj S.K., 1
Nagaraja N., 19
Nandakumar S., 461
Narayana R., 33
Neeraja S.R., 33
Nisha M.S., 33
Panchanan Parui, 411
Pandit, 131
Paramita Banerjee, 39, 261

- Patel R.D., 97
- Patil A.N., 453
- Prabhuraj A., 1
- Pradeep Kumar Dalal, 307
- Pradeepkumar G.T., 381
- Rabeesh T.P., 325
- Rabiya Irshad, 243
- Rahul S. Kamble, 335
- Rajashekharappa K., 397
- Rajkamal Goswami, 253
- Rajmohana K., 355
- Rakesh Kumar Gupta, 477
- Ramalakshmi V., 371
- Ramesh M. Gejage, 85
- Ramesha B., 157, 347
- Rameshkumar A., 375
- Ramyarani S.K., 19
- Ranjith M.T, 183
- Ravi Singh, 307
- Ravindra C. Joshi, 67
- Rayeefa Fathima C.P., 13
- Remia K.M., 231
- Roy M., 355
- Ryan A. St Laurent, 239
- Sabreena Ashraf, 477
- Sagar A. Vhanalakar, 335
- Sajeesh P.K., 157
- Sake Manideep, 61
- Sameer Kumar Singh, 307
- Sangeetha B.G., 291
- Sangita Maiti Dutta, 113
- Santhana Bharathi N., 325
- Sapna Jacob, 239
- Sarbani Giri, 431
- Sardar Singh, 445
- Sayyad Sadiya Kousar, 317
- Seeja Thomachan, 183
- Seena Narayanan Karimbumkara, 253
- Shamsudeen R.S.M, 367
- Shanas Sudheer, 203
- Shankara Murthy M., 1, 397
- Sharanabasappa S. Deshmukh, 397
- Sheena A., 137
- Shiva Shankar, 269
- Shivanna B., 131
- Shivkumar, 445
- Shreevihar Santhosh, 89
- Shreya N., 39
- Shrikant Jadhav, 269
- Shriram Dinkar Bhakare, 73
- Siji J.V., 291
- Sojan Munnar, 191
- Someshwar Singha , 405
- Somnath Kangralkar, 311
- Sreejina S.K., 107
- Sreejina Sreedharan Kallyadan, 89
- Sreekumar K.M., 157, 347
- Srimanta Kumar Raut, 113
- Srinivasan M.R., 61
- Sruthi A.B., 25
- Subhash Chandran K.P., 381
- Sudip Mondal, 411
- Sujatha K., 325
- Sujitha Prabhakaran Chandrika, 191
- Suman Kumar Saha, 411
- Surendragopal K., 183

- Susanth C., 73
Sushma A. Jadhav, 85
Susmita Gudulkar, 311
Syed Faizan Anayat, 243
Syed Mohammad Ibrahim, 25
Tahmeena Maqsood, 243
Talapala Sai Kumar, 61
Teji K.T., 219
Thresiamma Varghese, 229
Toms Augustine, 191, 203
Umesh Chandra, 307
Unnikrishnan M.P., 239
Usha Mukundan, 311
Vaishali Zote, 103
Vaishnavi Ponugupati, 317
Veena Maurya, 225
Venkatesh Kumar R., 299
Vibhu Vijayakumaran, 47
Vidya C., 157
Vijayan S., 175
Vijayasree V., 137, 381
Vijaykumar L., 131
Vimala K John, 163, 235
Vinayan Padmanabhan Nair, 47, 73, 191, 203
Vinod Sadhasivan, 465
Vishesh Nautiyal, 469
Viswanath T.K., 231
Wilma Yunita, 67
Wilyus, 67
Yashika Negi, 225

The butterflies (Lepidoptera, Rhopalocera) of Kerala: Status and distribution

Kalesh Sadasivan^{1,11*}, P.C. Sujitha², Muhamed Jafer Palot³, V.C. Balakrishnan⁴, Toms Augustine⁵, Baiju Kochunarayanan^{1,6}, Edayillam Kunhikrishnan⁷, Jebine Jose^{1,8}, V.M. Anila^{1,9}, R. Mahesh^{1,10}, T.K. Sreenivasan¹² and Vinayan P Nair^{1,13}

¹TLRG (TNHS Lepidoptera Research Group), Travancore Nature History Society (TNHS), MBRR, Mathrubhumi Road, Vanchiyoor, Thiruvananthapuram 695035, Kerala, India.

²Institute of Tropical Research Ecology and Conservation (INTREC), Sreerangam, Puravoorkonam, Karakulam, Thiruvananthapuram 695564, Kerala, India.

³Zoological Survey of India, Western Ghat Regional Centre, Kozhikode 673006, Kerala, India.

⁴Society for Environmental Education in Kerala, Edat, Kannur 670327, Kerala, India.

⁵Pathippallil House, Poovarani 686577, Kottayam, Kerala, India.

⁶Sreerangam, Puravoorkonam, Karakulam 695564, Kerala, India.

⁷TC1/2021, Jayamanju, Edassery Nagar, Kumarapuram, Medical College, Thiruvananthapuram 695011, Kerala, India.

⁸Kaduvathookil House, Elikulam 686577, Kottayam, Kerala, India.

⁹Karickathil, Kottavatom 691322, Punalur, Kerala, India.

¹⁰Kattiparambu Madam, Thekumbhagam, Tripunithura 682301, Ernakulam, Kerala, India.

¹¹Greeshmam, BN439, Bapuji Nagar, Medical College, Thiruvananthapuram 695011, Kerala, India.

¹²Thayyil House, Konnakuzhy 680721, Thrissur, Kerala, India.

¹³Postgraduate & Research Department of Zoology, Alphonsa College, Arunapuram 686574, Pala, Kottayam

Email: kaleshs2002in@gmail.com; pcsujitha43@gmail.com; palot.zsi@gmail.com; vcbalakrishnan@yahoo.co.in; tomsaugustine@gmail.com; baijupaluvally@gmail.com; ekunhi@gmail.com; jebinkj2002in@gmail.com; anilavm08@gmail.com; maheshgreen96@gmail.com; sreenivasankonnakuzhy@gmail.com; vinayanpnair@gmail.com

ABSTRACT: The butterfly fauna of Kerala state in southern India with respect to taxonomy, population status, and distribution is discussed. The recent taxonomic changes and justifications for the same are mentioned. The current checklist of butterflies of the Western Ghats stands at 337 species, including 42 endemics while that of Kerala stands at 328 species with 41 WG endemics. Amongst the states lying along the Western Ghats biodiversity hotspot, Kerala has the highest butterfly diversity with 19 Papilionidae, 32 Pieridae, 97 Nymphalidae, two Riodinidae, 96 Lycaenidae, and 82 Hesperidae species. Twenty-two butterflies are in the IUCN Red List of threatened species, of which two are Near Threatened and the rest are in the Least Concern category. Regarding WLP 1972 and its amendments, it was observed that of the 70 species listed from Kerala, four are protected under Schedule I only, one species under Schedule I & II, one under Schedule II and IV, one under Schedule IV, and 63 species under Schedule II. Thirty-six species are migratory. Taxonomic evidences for splitting of the two Western Ghat *Argynnis* into *A. hybrida* Evans, 1912 and *A. castetsi* Oberthür, 1891; distinguishing *Elymnias caudata* Butler, 1871 from *E. hypermnestra undularis* (Drury, 1773); separating *Abisara bifasciata suffusa* Moore, 1882 from *A. echerius prunosa* Moore, 1879, *Baracus hampsoni* Elwes & Edwards, 1897 from *B. subditus* Moore, [1884]; and the species level elevation of Western Ghat taxa namely *Bindahara moorei* Fruhstorfer, 1904, *Ancema sudica* (Evans, 1926), *Halpe hindu* Evans, 1937, and *Hyarotis coorga* Evans, 1949, from the northeast Indian taxa are provided. A subspecies of Spotted Royal–*Tajuria maculata sureshi* **ssp. nov.**, is described from Kerala. In addition, an updated checklist of the known larval hostplants of butterflies of Kerala is provided containing more than 1800 larval feeding records with over 350 new observations, and about 800 species of plants. © 2025 Association for Advancement of Entomology

Statement of ownership and other particulars of ENTOMON

(Form IV, Rule 8 of Registration of Newspapers (Central) Rules 1956)

1. Place of publication : Thiruvananthapuram
2. Periodicity of publication : Quarterly
3. Printer's name, nationality and address : Prof. Dr. K.D. Prathapan, Indian,
Secretary,
Association for Advancement of Entomology,
Department of Agricultural Entomology,
College of Agriculture,
Kerala Agricultural University, Vellayani PO,
Thiruvananthapuram 695522, Kerala, India
4. Publisher's name, nationality and address : - do-
5. Editor's name, nationality and address : Dr. M.S. Palaniswami, Indian,
Chief Editor, ENTOMON,
Association for Advancement of Entomology,
Thiruvananthapuram 695522, Kerala, India
6. Name and address of the
Individual who owns the paper : Association for Advancement of Entomology,
Department of Agricultural Entomology,
College of Agriculture,
Kerala Agricultural University, Vellayani PO,
Thiruvananthapuram 695522, Kerala, India

I, Dr K. D. Prathapan, Secretary, Association for Advancement of Entomology, here by declare that the particulars given above are true to the best of my knowledge and belief.

Sd/-

Thiruvananthapuram 695522

Prof. Dr. K.D. Prathapan

31 December 2025

Publisher, ENTOMON



Association For Advancement of Entomology

(Reg. No 146/1975)

*Department of Agricultural Entomology, Kerala Agricultural University,
Vellayani, Thiruvananthapuram 695522, Kerala, India.*

web: www.entomon.in; Email: aae@kau.in

EXECUTIVE COMMITTEE (2022 – 2025)

President: Professor N. Mohandas, Former Head, Department of Agricultural Entomology & Research Coordinator, Kerala Agricultural University, Thiruvananthapuram 695522, Kerala, India.

Vice Presidents:

1. Professor S. Devanesan, Former Dean, College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram 695522, Kerala, India.
2. Professor G. Prasad, Head of Department of Zoology, University of Kerala, Kariavattom, Thiruvananthapuram 695581, Kerala, India.
3. Dr. R. Rajendran, Consultant, National Centre for Disease Control, Govt of India, Cherthala 688524, Kerala, India.

Secretary: Professor Dr. K.D. Prathapan, Department of Agricultural Entomology, Kerala Agricultural University, Vellayani, Thiruvananthapuram 695522, Kerala, India.

Joint Secretaries:

1. Dr. D.A. Evans, Former Associate Professor, Department of Zoology, University College, Thiruvananthapuram 695034, Kerala, India.
2. Professor O.P. Reji Rani, Department of Agricultural Entomology College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram 695522, Kerala, India.
3. Dr. S. Shanas, Assistant Professor (Agricultural Entomology), Department of Agricultural Entomology, College of Agriculture, Kerala Agricultural University, Thiruvananthapuram 695002, Kerala, India.

Treasurer: Dr. Thania Sara Varghese, Assistant Professor, Department of Agricultural Entomology, College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram 695522, Kerala, India.

Members:

1. Dr. Hebsibai, Former Professor, Department of Agricultural Entomology, College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram 695522, Kerala, India.
2. Professor G. Madhavan Nair, Former Head, Department of Agricultural Entomology, College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram 695522, Kerala, India.
3. Dr. T. Sivakumar, Subject Matter Specialist (Entomology), KVK, ICAR - Central Plantation Crops Research Institute, Kayamkulam 690533, Kerala, India.
4. Dr. T. Santhosh Kumar, Assistant Professor, Department of Agricultural Entomology, College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram 695522, Kerala, India.
5. Dr. S. Poopathi, Scientist-G (Director Grade), Head of Microbiology and Molecular Biology, Vector Control Research Centre, Indian Council of Medical Research, Pondicherry 605006, India.
6. Dr. Ambili Paul, Department of Agricultural Entomology, College of Agriculture, Kerala Agricultural University, Vellayani, Thiruvananthapuram 695522, Kerala, India.
7. Dr. E.R. Harish, Senior Scientist, Division of Crop Protection, ICAR - Central Tuber Crops Research Institute, Sreekarayam, Thiruvananthapuram 695017, Kerala, India.
8. Dr. M.S. Palaniswami, Chief Editor, ENTOMON, AAE.
9. Dr. K.M. Sreekumar, Professor and Head, Department of Agricultural Entomology, Kerala Agricultural University, College of Agriculture, Padannakkad, Nileswaram, Kasargod, Kerala, India.
10. Dr. C. Bijoy, Assistant Professor and Research Supervisor, Department of Zoology, Christ College (Autonomous), Irinjalakuda, Thrissur 680 125, Kerala, India.



Published by :
Association for Advancement of Entomology
Email : aae@kau.in; web: www.entomon.in