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Abstract Book of National Symposium on "Frontiers in Entomology-2025"

7th Jan 2025
Venue: WTC Auditorium, ICAR-IARI, New Delhi
Virtual: ESI Zoom platform for the registered participants

Organized by
The Entomological Society of India
&
Division of Entomology
ICAR-Indian Agricultural Research Institute
New Delhi-110012

National Symposium on "Frontiers in Entomology-2025"

The event is jointly organized by The Entomological Society of India, New Delhi, and Division of Entomology, ICAR-IARI, New Delhi, on 7th January 2025 at Water Technology Center (WTC), Auditorium, ICAR-IARI, New Delhi.

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Abstract book of

National Symposium on "Frontiers in Entomology-2025"

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5 January 2025

Foreword

I am glad to know that the Division of Entomology, ICAR- Indian Agricultural Research Institute (IARI), New Delhi and Entomological Society of India (ESI) are jointly organising the National Symposium on **"Frontiers in Entomology"**, 86th Foundation Day programme of ESI & ESI Awards Ceremony on 7th January 2025.

Division of Entomology is one of the first five Divisions of the IARI established in 1905. The Division has pioneered investigations on basic and applied research frontiers in agricultural entomology to offer effective pest management solutions to the country. The Division hosts National Pusa Collections (NPC) with over five lakh specimens serves as a national repository for insect pests.

The ESI is the oldest Society of Entomology in India which is in its ninth decade of operation and has done a commendable service to the society at large. ESI Awards and recognitions are bestowed upon the practitioners of Entomology in the form of Life Time Awards, Honorary Fellows, Best Teachers, Industry Awards, and Senior & Young Scientist Awards for their significant contributions to Entomological research. The ESI Best PhD thesis Awards are given to nurture young talents. I hope these awards provide the required motivation and encouragement.

The National Symposium on **Frontiers in Entomology** will deliberate on the emerging insect pest problems in agriculture and explore next-generation solutions for their management. The panellists are drawn from academia, administrators from the Indian Council of Agricultural Research, the Plant Protection Authority of the Government of India and experts from the Plant Protection Industry.

I am glad to note that this year's, ESI Foundation Day Lecture will be delivered by **Dr D. P. Abrol**, an eminent Entomologist and NAAS Fellow, who has made significant contributions to Apiculture and Agricultural Entomological research.

I wish all the success for the event.

(Viswanathan Chinnusamy)

THE ENTOMOLOGICAL SOCIETY OF INDIA

(Established 1938)

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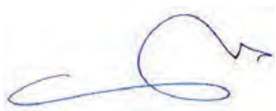
Dr. B. Shivanna

Preface

The Entomological Society of India (ESI), established in 1938, is one of the largest and most prestigious professional organizations in India, dedicated to advancing the field of entomology and related disciplines. Over the years, ESI has played a pivotal role in fostering research, education, and knowledge dissemination in entomology.

Since its inception, the society has been publishing impactful journals and literature, including the *Indian Journal of Entomology* (since 1938), the *Bulletin of Entomology*(since 1967), *Bionotes* (since 2020), *Indian Entomologist* (since 2020) and *Hexapoda* (Since 2024). These publications have served as essential resources for entomologists, researchers, and academics worldwide. Additionally, ESI has produced numerous books, technical bulletins, reports, and proceedings of conferences and symposia to further its mission of promoting entomological knowledge.

The *Indian Journal of Entomology* was first published in 1939 and has grown to become a leading publication in the field of entomological sciences. The journal is completely *open access* and publishes high-quality original research articles and reviews across a broad spectrum of topics in entomology.In 2024, ESI has taken over journal *HEXAPODA*, from Indian Academy of Entomology, Chennai further expanding its commitment to publishing comprehensive research in entomology. This journal is also *open access* and focuses on studies related to arthropods, emphasizing both foundational and innovative research. Journal adapted Continuous Article Publishing (CAP) mode which will help authors to publish their papers without waiting for allotment of issue. To recognize and encourage contributions to the field of entomology, ESI has instituted several prestigious awards in recent years, including the Young Entomologist Award (since 2020), the Senior Entomologist Award (since 2020), the ESI Best Ph.D. Thesis Award (since 2021), and the ESI Best Teacher Award (since 2022). In 2023, the society introduced the ESI Industry Award to acknowledge excellence and innovation in industrial applications of entomology. These initiatives underscore ESI's commitment to fostering talent and driving progress in entomological research and education.



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कुलपति
Dr. Ajeet Kumar Karnatak
Vice-Chancellor

PS/VC/MPUAT/2025/04.
Date: Jan 1, 2025

Message

I am extremely happy that The Entomological Society of India is organizing the Natiional Symposium on "Frontiers in Entomology – 2025" aimed at addressing pest problems and their novel management techniques. Agriculture has travelled a long way from traditional methods to present day digital agriculture and is further marching by introducing artificial intelligence and data analysis to the performance, productivity and accuracy of automation. The entomological research has transformed our understanding of insects and their ecological roles. Recent advancements in different breakthrough technologies like robotics, bio-engineering, bio-technology, artificial intelligence and IoT are broadening the horizons of Applied Entomology, changing the paradigms for the management and mass rearing of insect species of socio-economic interest. These highlight key developments in this field, including the discovery of novel insect species, the application of genomics in studying insect biology, and the utilization of insects for sustainable pest management. These breakthroughs hold promise in addressing global challenges such as biodiversity conservation and food security. In recent years the field of Entomology, due to the penetration of other disciplines, has made rapid progress. I am sure that during the symposium, the intellect and prudence of leading entomologists shall help in preparing a roadmap of Frontiers in Entomology 2025 and ahead. I wish the symposium a grand success.

01.01.25
(Ajeet Kumar Karnatak)

डॉ. वाय. जी. प्रसाद
निदेशक
Dr. Y. G. Prasad
Director

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भा.कृ.अनु.प.-केन्द्रीय कपास अनुसंधान संस्थान
ICAR-Central Institute for Cotton Research

F.No:-01(5)PPS/2024-25
Date: 03.01.2025

Message

It gives me immense pleasure to extend my hearty congratulations to the organizers and participants of the National Symposium on "Frontiers in Entomology-2025", being organized by the Entomological Society of India. This symposium provides an exceptional platform for researchers, academicians, and industry professionals to share their insights and innovations, shaping the future of entomological sciences in India and beyond.

In today's rapidly evolving agricultural landscape, the integration of cutting-edge technologies, such as the Internet of Things (IoT) and Artificial Intelligence (AI), has emerged as a game-changer in entomology and plant protection. IoT-enabled smart pest monitoring systems are revolutionizing pest surveillance, offering real-time data collection and analysis, leading to timely and precise interventions. Similarly, AI-powered tools are empowering us to predict pest outbreaks, optimize the use of crop protection strategies, and conserve beneficial insects, ensuring sustainable agricultural practices.

I am confident that this symposium will serve as a crucible of innovation, fostering collaborations and discussions that will address the current and emerging challenges in entomology. I urge all participants to actively engage in this exchange of knowledge and explore the transformative potential of IoT and AI in advancing plant protection and food security.

My best wishes to the Entomological Society of India for the success of this symposium, and I hope that the deliberations during this event will lead to meaningful outcomes for the scientific community and society at large.

Yours sincerely

(YG Prasad)

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Dr. S. N. Sushil
Director

F.NBAIR/12-4/2024-25
3rd January 2025

MESSAGE

It gives me immense pleasure to note thata "**National Symposium on Frontiers in Entomology-2025"**is being organized in conjunction with the **Foundation Day Celebration** and **Award Ceremony** of the Entomological Society of India. This special occasion is a testament to our enduring commitment to fostering excellence and innovation in the field of entomology.

Entomology in India has made remarkable strides, playing a pivotal role in agriculture, public health, and environmental conservation. Indian entomologists have successfully developed environmentally friendly strategies that have significantly reduced reliance on chemical pesticides, fostering sustainable agriculture. Breakthroughs such as the introduction of biocontrol agents for key pests and advances in semiochemicals technology for precision pest management and developing the molecular tools for pest management have underscored India's leadership in this field. Entomological research has also supported pollinator conservation, ensuring biodiversity and crop productivity. With its blend of traditional wisdom and cutting-edge science, Indian entomology continues to address pressing challenges, enriching lives and ecosystems alike.

As we commemorate the foundation of our esteemed society, we also celebrate the remarkable achievements of individuals and teams whose groundbreaking work has significantly advanced our understanding on insects and their role in ecosystems, agriculture, and public health. The award ceremony is our way of recognizing and honouring their contributions, which inspire us all to strive for greater heights.

The symposium itself promises to be an intellectually enriching experience, featuring cutting-edge research, insightful discussions, and opportunities for collaboration. From exploring novel pest management strategies to examining the ecological and molecular dimensions of insect science, this event showcases the dynamic and multifaceted nature of entomology.

On behalf of the society, I extend my heartfelt congratulations to all the awardees and express my gratitude to the organizing committee, participants, and supporters who have made this event possible. May this gathering strengthen our bonds as a community and ignite new ideas that will shape the future of entomological research and applications.

Let us come together to honour the past, celebrate the present, and envision a brighter future for entomology

03.01.25
(S.N.Sushil)

Sardar Patel Outstanding ICAR Best Institute Award Winner
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Assistant Director General
(Plant Protection and Biosafety)

भाकृअनुप
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Date: 03.01.2025

MESSAGE

It gives me an immense pleasure that the Entomological Society of India (ESI) and Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi is organizing National Symposium on "Frontiers in Entomology-2025"on January 07, 2025 on occasion of ESI Foundation Day.

India is home to a vast crop diversity, with over 160 major and minor crops thriving in its varied agroclimatic conditions. Annually, insect pests account for an estimated USD 36 billion in crop losses. In recent years, the country has experienced a rise in invasive insect pests, which have inflicted severe damage on agriculture and horticulture. These pests often enter through trade, travel, or natural migration and adapt well to India's diverse environments. Furthermore, climate change is altering pest dynamics, leading to expanded geographic ranges, population growth, and shifts in lifecycle patterns, thereby exacerbating threats to crop productivity and food security. This pressing challenge calls for collaborative efforts to develop effective strategies for pest management.

I hope that this symposium will serve as a dynamic platform for researchers and stakeholders to exchange innovative ideas and share advancements on emerging issues in crop pest management through cutting-edge tools. The insights and recommendations derived from this meeting will culminate in a valuable document, offering guidance for stakeholders to implement effective strategies for safeguarding plant health from insect pests.

I extend my heartfelt greetings and commendations to everyone involved in organizing this symposium, and I wish the event great success.

(Poonam Jasrotia)

About symposium

This symposium aims to address the emerging insect pest problems in agriculture and explore the potential of novel tools in understanding insect biology, ecology, and next generation pest management solutions for their management. In recent decades, India has witnessed an unprecedented transformation in its agricultural landscape, stimulated by advancements in technology, changing climatic conditions, and the integration of global trade practices. However, these changes have also given rise to a new wave of challenges, with emerging insect pest problems standing out as a critical concern. The impact of these pests on crop productivity and food security has intensified, with repercussions that extend beyond individual farms to affect the nation's agricultural sustainability. Rapid shifts in climate, evolving pest behaviours, and changing patterns in cropping systems have created an environment where traditional pest management strategies are becoming less effective. As a result, there is a pressing need to explore next-generation solutions tailored to these new pests' challenges.

This symposium brings together leading experts, researchers, policymakers, and industry leaders to share insights, innovations, and strategies. The theme areas of panel discussion include, prioritizing entomology research in India and plant protection strategies to manage emerging pest problems, wherein, the panellists will discuss academic and Industrial perspectives of the following issues:

- Emerging pests/Shift in pest status under climate change scenario
- Research/Management priorities
- Industrial perspectives: Newer formulations, Registration, Label claim, Combi Products, SoP's for Drone applications, and other issues

The panel discussion helps in bringing out a policy document for addressing emerging issues in entomology.

Programme Schedule
National Symposium on "Frontiers in Entomology-2025"
(7th January, 2025)

9.30-9.40 AM	**Invocation**	**PG Students**
9.40-9.45 AM	**Welcome address**	**Dr. M.K. Dhillon** Head, Division of Entomology & Vice President, ESI
9.45-9.50 AM	**Introduction of Chairman**	**Dr. V.V. Ramamurthy** President, ESI
9.50-9.55 AM	**Introduction of Speaker**	**Dr. Sachin S. Suroshe** General Secretary, ESI
10:00-10.45 AM	**ESI Foundation Day-2025 Lecture**	**Dr. D.P. Abrol** NAAS Fellow & Former Dean, SKUAST, Jammu
10.45-10.55 AM	**Remarks by Chairman& Felicitation of Speaker**	**Dr. Viswanathan Chinnusamy** Joint Director (Research) ICAR- IARI, New Delhi
10.55- 11.10AM	**Conferring ESI Honours – Life time Achievement/Hon. Fellow/Other Awards**	Joint Director (Research) & President, ESI
11.10-11.15 AM	**Vote of Thanks**	**Dr. S. Subramanian** Professor, Entomology, ICAR- IARI & Zonal President (ESI HQ, Delhi)
11.00-11.15	**Group photo & Tea Break**	
PANEL DISCUSSION		
Chairman **Dr. Poonam Jasrotia,** ADG (PP), ICAR, New Delhi **Co-chairman** **Dr. J.P. Singh**, Plant Protection Advisor to GOI **Rapporteurs** **Dr. Sachin S. Suroshe,** General Secretary ESI **Dr. P.R. Shashank,** Joint Secretary, ESI		
11.30-1.30 pm	**Panel Discussion**	**Dr. A.K. Karnatak** VC, MPUAT, Udaipur **Dr. R.S. Chandel** VC, Dr.YSPUHF, Nauni, HP **Dr. S.N. Sushil** Director, ICAR- NBAIR, Bengaluru **Dr. Vandana Tripathi** NC, Pesticide Residues, New Delhi **Dr. Archana Sinha** CIBRC, Faridabad **Industry representatives from**: Multiplex, Dhanuka, UPL, PI, ATGC
LUNCH BREAK [1:30-2:30 PM]		

ESI AWARD LECTURES **Chairman** **Dr. Subhash Chander** Director, ICAR- National Centre for Integrated Pest Management, New Delhi **Co-Chairman** **Dr. S.N. Sushil** Director, ICAR- National Bureau of Agricultural Insect Resources, Bengaluru		
2.30-2.35 PM	**Welcome Address**	Dr. Sachin S Suroshe, General Secretary, ESI
2.35-2.50 PM	**Presentation by ESI Best Teacher Awardees/Certificate**	Dr S Subramanian Dr Badal Bhattacharya Dr. K Suresh
2.50-3.20 PM	**Presentation by ESI Senior Entomologist Awardees/Certificate**	Dr. Rajashekar Y Dr. Satnam Singh Dr. Gandhi Gracy R Dr. Subhash Rajpurohit
3.20-3.50 PM	**Presentation by ESI Industry Awardees**	Mr. Ujjwal Kumar Mr. K Sriram Dr. Shanthakumar SP
3.50-4.00 PM	**Remarks and presentation of citations**	President, ESI & Chairman and Co-Chairman of the session
TEA BREAK (4.00-4.15 PM)		
Chairman **Dr. A.K. Karnatak** VC, MPUAT, Udaipur **Co-Chairman** **Dr. R.S. Chandel** VC, Dr. YSPUHF, Nauni, HP		
4.15-4.40 PM	**Presentation by ESI Young Entomologist Awardees**	Dr. Fazil Hasan Dr. Prasannakumar NR Dr. Richa Varshney Dr. Sagar D
4.40-5.15 PM	**Presentation by ESI Best Ph.D Thesis Awardees**	Dr. Neenu Augustine Dr. Mogili Ramaiah Dr. Muthukatturaja M Dr. Keerthi MC
5.15-5.30 PM	**Remarks and Presentation of Citations**	President, ESI & Chairman and Co-Chairman of the session
5.30 PM	**Vote of Thanks**	Dr. Rajna, S. Organising Secretary

ESI Foundation Day Lecture 2025

OPPORTUNITIES AND CHALLENGES IN THE DEVELOPMENT OF BEEKEEPING OF INDIA

D. P. Abrol

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Abstract

Apiculture in conjunction with agriculture, offers great scope for income generation through beekeeping. Pollinators provide pollination services that are crucial for enhancing crop productivity and sustaining ecosystem services. Honeybees are the important pollinators of various fruits, vegetables, oilseeds, pulses and fibre crops. In order to achieve sufficient pollination to improve productivity of crops, beekeeping industry needs encouragement. In addition to providing valuable products like honey, beeswax, nectar, pollen, propolis, royal jelly and other products, beekeeping helps to provide additional source of income and employment generation to rural masses. As per estimates only 10 per cent of the existing potential for beekeeping has been utilized in the country and there is much untapped potential. India has a potential of over 200 million bee colonies as against 3.4 million colonies at present which can provide employment to over 6 million rural families. Organised honey collection using modern techniques can provide additional 120,000 tons of honey and 10,000 tons of beeswax from the forests. This can provide employment to 5 million tribal families. Increasing honeybee colonies shall not only increase production of bee products but will ensure sustainability of food production through enhanced agricultural and horticultural crop production. Beekeeping industry and its expansion faces several challenges which need to be addressed to make this industry more profitable.

Introduction

India ranks 12^{th} in mega diversity and is the 7th largest in the world, with a surface area of 3.2 million km^2. It has a land area of2.4% and accounts for 7.8% of the recorded species of the world. India has diverse physical features and climatic conditions which harbour and sustain immense biodiversity. It has a total global biodiversity with an estimated 49000 species of plants of which 4900 are endemic (Kumar and Asija, 2000). It is home to 167 important species of cereals, millets, fruits, condiments, vegetables, pulses, fibre crops and oilseeds. India has rich and varied vegetation. There are 15,000 flowering plants, of which 1,500 plant species are endangered. India has a forest cover of 21.05% (692027 km^2) of the total geographical area, the commercial exploitation of plant species for honey production is considerably very less (Sivaram and Anita, 2000). Such a diversity of climates, geographical conditions and richness of plant species offers great potential for both migratory and non-migratory beekeeping. More than 90 per cent of the potential for beekeeping still remains to be untapped. Beekeeping has become an important source of livelihood and food security through pollination (Walker and Crane 2000, Agarwal 2014). Beekeeping is now a source of employment provides nutritious food and ensuring food security through enhancing crop productivity. Number of ancillary industries based on this industry offers great scope for employment generation and commercialization of agriculture

History of beekeeping in India

Beekeeping is practiced in India since ancient times. Beekeeping has been practiced since medieval period in forest regions along the sub-Himalayan mountain ranges to the Western Ghats. Beekeeping started as capturing swarms of bees and keeping them in logs of wood, clay recetacles, and in outer walls of houses. The honey was extracted at the end of flowering by smoking and driving away the bees. The honey combs were squeezed and no efforts were made to prevent the bees from leaving the hive. No doubt beekeeping practices have changed but in some remote inaccessible areas, the old practices still continue. Mention of beekeeping found in all religious scriptures in India. Development of moveable frame hive in USA in 1851 resulted in initiation of modern beekeeping throughout the world, including India. Beekeepers using scientific techniques started at the end of nineteenth century. The first attempt to keep *Apis cerana indica* in movable frame hives was made in 1880 in Bengal and 1883-84 in Punjab and Kullu valley. However, these attempts met with very little success. In southern India, Rev. Newton devised a hive for *Apis cerana* suited for Indian climatic conditions and was called Newton hive. Rev. Newton trained several persons from 1916-17. Beekeeping work was undertaken in Travancore in 1917 and in Mysore in

1925. Royal Commission on Agriculture during (1928) gave recommendations for developing beekeeping as a cottage industry in rural areas. Beekeeping started in Madras in 1931, 1933 in Punjab, 1934 in Coorg and 1938 in Uttar Pradesh. All India Beekeepers Association was formed in 1938-39. Indian Council of Agricultural Research established two beekeeping research stations in Punjab 1945 and in Coimbatore in 1950. Recognizing the importance of beekeeping and pollination, the Indian Council of Agricultural Research in 1980, started All India Coordinated project on honeybee research and training which has as more than 28 centres at present.

Scope of beekeeping

Beekeeping has immense scope in India and other south-east Asian countries. It is a forest based industry, does not require any additional space and does not compete with any branch of agriculture. It is ideally suited as a part time occupation and provides income to rural and tribal families. The valuable products obtained from beekeeping include honey, pollen, beeswax, propolis, royal jelly and brood. Bee products serve as important ingredients for folk and traditional medicine. Honeybees serve as an important input in increasing agricultural and horticultural productivity and to maintain ecological balance by pollinating natural flora providing food to animals living in the wild. Beekeeping has been practiced by many organizations among rural and tribal families for their upliftment and as a source of self employment. Beekeeping activity has been largely concentrated in south-west hills with plantations of rubber, cardamom and coffee. It has also gained momentum in areas with dense natural vegetation such as in the Western Ghats, Jammu & Kashmir, Punjab, Haryana, Himachal Pradesh, Uttar Pradesh, Bihar, West Bengal, Assam and Meghalaya. The sub -Himalayan ranges with natural vegetation and vast agricultural and horticultural fields are most suitable for profitable beekeeping. It is estimated that such forest resources can yield 10000 tonnes of honey. Several plant species in tropical and sub-tropical moist and evergreen forests provide forage (nectar and pollen) for honey bees. Thus, the raw material for production of honey and keeping of bees is available free from nature.

Apiculture can provide a sustainable source of income and employment generation to farmers in their own villages in remote areas. Even the women and children can efficiently manage honeybee colonies. The nutritional status of the poor rural populations can improve with increased production of energy-rich honey, protein rich pollen and royal jelly. The bee products have no problem of spoilage and can be stored with careful precautions. They can be sold whenever there is a good market at prices beneficial to the producer.

Potential for honey industry in India

There are 15,000 flowering plants, of which 1,500 plant species are endangered. India has a forest cover of 21.05% (692027 km^2) of the total geographical area, the commercial exploitation of plant species for honey production is considerably very less (Sivaram and Anita, 2000). Such a diversity of climates, geographical conditions and richness of plant species offers great potential for both migratory and non-migratory beekeeping. Beekeeping has become an important source of livelihood and food security through pollination

Of nine honeybee species, India has four species of *Apis*, i.e., the true honey bees –*A. florea*, *A. cerana*, *A. dorsata* and *A. laboriosa* Smith and exotic *A. mellifera*, a European species - and several species of stingless bees of the genus *Trigona*. It is, however, expected that at least one more species of *A. florea* and three subspecies of *A. cerana* exist in India, however major portion of honey comes from the wild bee, *Apis dorsata*.

India has immense potential for development of beekeeping. Indian forests can provide shelter and food to over 120 million bee colonies (Mitta et al 2017). Despite of reduction in forest cover India still has the potential to hold over 100 million bee colonies which can provide self-employment to over 10 million rural and tribal families and produce over 700,000 tonnes of honey and 30,000 tonnes of beeswax. As per estimates only 10 per cent of the existing potential for beekeeping has been utilized in the country and there is much untapped potential. India has a potential of over 200 million bee colonies as against 3.4 million colonies at present which can provide employment to over 6 million rural families. Organized honey collection using modern techniques can provide additional 120,000 tons of honey and 10,000 tons of beeswax from the forests. This can provide employment to 5 million tribal families.

Increasing honeybee colonies shall not only increase production of bee products but will ensure sustainability of food production through enhanced agricultural and horticultural crop production. Beekeeping industry and its expansion faces several challenges which need to be addressed to make this industry more profitable

World honey production scenario

China ranks number one in yearly honey production 457,203 tonnes followed by Turkey 114,113 tonnes, Argentina 79,468 tonnes of production per year, Argentina is the third largest producer of honey. India ranks seventh after Iran, Ukraine and USA with 67,442 tonnes of production per year. Total production of honey in the world amounts 1,850,868 tonnes per year. The per capita honey consumption in India is very less (50 g/ year) as compared to other countries which indicate very little awareness among the masses for utility of honey as food and its medicinal value. Switzerland is the biggest consumer of honey, with per capita consumption of up to 2.0 kg per person per year.

Honey export scenario

The data show that New Zealand is the largest exporter of honey in the world accounting for 14.4 per cent of the world share as compare to India which accounts for 3.6 per cent only. Argentina is the second largest exporter of honey with 11.1 per cent share of the world. The honey industry in India is still far behind to achieve its goal as compared to other countries.

Honey import scenario

USA is the largest importer of honey in the world accounting 441.00 million USD. Germany is the second largest importer with USD 280.00 million of. Spain was at minimum with USD 66.00 million. The other countries had import value in between the two. The data shows that USA had 19.8 per cent of the import share as compared to other countries which ranged between 1.6 to 12.3 per cent.

Honey production scenario in India

The major producing states in India include West Bengal, Uttar Pradesh, and Punjab, and Bihar, Kerala, Karnataka, Uttarakhand: Jammu and Kashmir, Sikkim and Arunachal Pradesh. The revenue generated amounted to INR 15,579 million in 2018. The total honey production was 1.05 thousand tonnes. The country also has more than 3.5 million bee colonies. As per the reports, India exports 50% of its total honey produce to the international market.

Pricing structures for honey

Selling of honey is a major problem, the beekeepers gain only a small amount in return. They usually sell their honey at a local market or to wholesalers and other organizations. Although these vendors sell quality honey in supermarkets at a high price (around 12.87 USD $kg^{1)}$ the beekeepers only get around 10-15% of that price (Islam *et al*., 2016). This also discourages promising beekeeping entrepreneurs (Fuad *et al*., 2019). Pricing of honey is a major problem as there is no fixed support price. Consequently, large stocks of honey remain unsold as beekeepers refuse to accept lower prices. Furthermore, in India, the sale price of honey is very low as compared to other countries.

Economic value of pollination

The annual economic value of insect pollinators to agricultural productivity has been calculated as 365 million USD for Himachal Pradesh and USD 426.8 million for Kashmir in the north-western Indian Himalayas and 166.8 million USD for Uttarakhand in the central Indian Himalayas. The total value of insect pollinators to crop production would be even higher if indirect benefits, such as enhanced soil fertility and soil conservation through the pollination of various nitrogen fixing legumes and replenishing soil nutrients, were taken into account; and it would be higher still if data were available for all insect-pollinated crops cultivated in the region. By crop category, the study estimates the annual economic value of insect pollination for fruit crops at 2.3 billion USD, for oilseed crops at 233.1 million, for pulses at 2.7 million USD, for spices at USD 5.5 million USD, for tree nut crops at 50.5 million USD, and for vegetable crops at USD 78.5 million. The economic value of insect pollination is also estimated for individual crops and crop categories in the individual study areas. Of the total value of Indian agriculture USD 258.27 billion, proportion of animal pollinated crops is 84.57 billion USD, representing 32.74%. Direct contribution of insect pollination to Indian agriculture is staggering (22.52 billion USD) annually, representing 8.72%, besides spill over benefits of increase in quality traits, seed production, breeding efficiency, etc. For stagnant Indian agriculture, this "micro concept" of using honey bees for planned pollination of crops has the potential "macro-economic" impact (Chaudhary and Chand, 2017).

Worldwide value of pollinators was estimated to be 153 billion EUR(217 billion USD) representing 9.5% of the value of the world agricultural production during 2005. Vegetables and fruits benefitted 50 billion EUR each, edible oil 39 billion EUR, stimulants 7.0 billion EUR, nuts 4 billion EUR, spices 0.2 billion EUR and pulses 1.0 billion (Gallai *et al.,* 2008). In the USA, pollination value was 4.5 billion USD (Pimentel *et al.,* 1993); in Brazilian 7 billion EUR (Freitas and Imperatriz- Fonesca, 2005); in East Africa 900 million EUR (Kasina *et al*., 2009); in Uganda 370 million EUR (Munyuli, 2011) and in Netherland 1 billion (Blacquiere *et al.,* 2010). The benefits from insect pollination is 954.59 million USD in Himalayan region of Pakistan (Partap *et al.,* 2012)

Irshad and Stephen (2013) quantified 1.59 billion USD as the pollination value of crops dependent on bees for pollination in Pakistan. They found that pollination value of fruits was higher (0.98 billion USD) as compared to other crops such as vegetables (0.32 billion), nuts (0.15 billion), oilseed (0.13 billion) and spices (0.004 billion).

Bee diversity in India

There are nine honeybee species belonging to Genus Apis which include: *Apismellifera*, *A. cerana, A. nigrocincta, A. koschevnikovi, A. nuluensis*, *A. dorsata, A. laboriosa, A. florea* and *A. andreniformis* (Otis, 1997; Tingek etal., 1996). First five species nests in cavities and have multiple combs as compared to last four species nesting in the open and having a single comb. Of the nine species, only *A. mellifera* and *A. cerana* have been domesticated and economically exploited (Koeniger, 1976). *A. mellifera* is the most commercially and economically exploited species. Except for *A. mellifera*, all *Apis* species are native to Southeast Asia which has been recognized as the centre of diversity of bees. Vietnam has five species of honeybees viz., *A. cerana* Fabricius 1793, *A. dorsata* Fabricius 1793, *A. florea* Fabricius 1787, *A. andreniformis* F Smith 1958 (Ha and Lap, 1992) and *A. laboriosa* F Smith 1871 (Trung *et al*., 1996). They distribute in different areas of the country from north to south, especially in mountain forest areas.

Species whose nests are single combs

1. The dwarf honeybee *Apis florea*
2. The giant honeybee *Apis dorsata*
3. Cliff bee *Apis laboriosa*
4. *Apis andreniformes*

Species whose nests have parallel combs

1. The oriental honeybee *Apis cerana*
2. The Common Or European, Honeybee *Apis Mellifera*
3. *Apis koschevnikovi*
4. *Apis nigrocincta*

5. *Apis cerana nuluensis*

Of nine honeybee species, India has four species of *Apis*, i.e., the true honey bees –*A. florea*, *A. cerana*, *A. dorsata* and *A. laboriosa* Smith and exotic *A. mellifera*, a European species - and several species of stingless bees of the genus *Trigona*. It is, however, expected that at least one more species of *A. florea* and three subspecies of *A. cerana* exist in India (Kshirsagar, 1976; Verma 1992). The biology of the stingless bees is also almost the same as that of the *Apis*. All these bees have a well-developed social organization and have similar caste differentiation, division of labour, foraging, defense and reproductive behaviours. Of the several honeybee species, *A. cerana*, and *A. mellifera* are domesticated species and serve the purpose of commercial beekeeping.

The Dwarf honeybee, *Apis florea* Fab. 1787

As its name implies, *A. florea* is the smallest of the true honeybees and appropriately called the dwarf or the little honey bee. A nest of *A. florea* consists of a single comb, whose upper part expands to form a crest that surrounds the branch or other object from which the comb is suspended. The bee is generally found in plains or lowlands in tropics and sub-tropics. It is rarely found in altitudes above 1500 m. The nests are built in bushes, densely leaved small trees in gardens and orchards, caves of buildings or sheltered boxes or wall niches in urban areas and on closely placed stalks of crop plants like Sorghum. *A. florea* bees are very hardy and can survive at extremely high temperatures reaching 50°C or more. The comb architecture is similar to honeybee species except honey storage portion which is situated at the top. Besides, honey producing *A. florea* is the important pollinator of several agricultural and horticultural crops in dry and hot plains of India.

Giant or rock bee, *Apis dorsata* Fab. 1793

The giant honeybees are mostly found in or near forests or may be observed in towns near forest areas. They nest in the open, having single-comb nesting habits like *A. florea*, suspending its nest from the under surface of its support, such as a tree limb or cliff. *A. dorsata* usually nests 3 to 25 meters above the ground. The organization of the comb is similar to that in the other honeybee species in terms of honey and pollen storage, worker brood and drone brood. Lower parts of the nest have active area known as mouth which is used for take - off and landing by workers. Communication dances by scouts and announcing the discovery of food sources also takes place. In case of *A.dorsata* dances take place in this part of the comb. The workers of *A. dorsata* are able to fly at night during moon lit nights.

A. dorsata is, inspite of its vicious nature, highly prized for honey production and pollination locally (Diwan and Salvi, 1965). Its flight range is more than 5 km (Koeniger and Vorwohl, 1979; Koeniger and Koeniger, 1980). Under normal foraging conditions they have been observed to visit floral sources 2 to 3 km away from the nest. The bees have an average tongue length of 6.683 mm (Ruttner, 1988**).** These factors provide a large foraging range, both in area and variety of plant species. . An annual production of about 2500 tonnes of beeswax from the wild rock bees was reported in 1969 (Phadke *et al*. 1969). Rock bee is an important pollinator of several crops.

Eastern honeybee*, Apis cerana* Fab.1793

The Asiatic honeybee, *A. cerana* construct multiple combs in dark enclosures such as caves, rocks and hollow of tree trunks maintaining a uniform distance known as the "bee space”. Their nesting habit in dark enclosures has made it possible for man to keep them in clay pots, logs, boxes and wall openings.

Despite their introduction into modern movable-frame hives, colonies of *A. cerana* can still be found in traditional hives in villages of most Asian countries. Thus, feral nests of *A. cerana* are less hunted compared to *A. florea* and *A. dorsata*. Natural nests of the Indian hive bee occur in tree trunks, rock crevices, ant hills, underground deserted nests of white ants or any dark enclosure, sometimes even in the open, but quite dark spaces in forests or unused rooms in buildings. *A. cerana* have a wide range of distribution from tropical coasts to temperate Himalayas upto an altitude of 3000 m. Colonies are found in forests or in agricultural areas in the plains, and even in urban areas with good vegetation. These bees are larger than the dwarf bee, but are much smaller than the rock bee. This bee is similar in size to the European hive bee in similar latitudes. Two varieties of the bees had been usually recognized - the hill variety, larger and darker, usually dark brown in colour, occurring in the hills and mountains; and the plains variety, smaller and lighter, generally reddish yellow in colour, with a cell size of about 4.15 mm, occurring in the plains. The hill variety is more aggressive, more populous, builds larger nests and produces more honey than the plains variety. The nest consists of several parallel combs with a uniform distance between them. The nests have usually 6 to 8 combs. A wide variation occurs in the number depending upon the period of stay of the nest in the location, space available in the nest site and its shape. Sometimes only 3 to 4 combs, which are narrow but about a metre long are found.

It is very interesting that the Indian hive bee does not use propolis unlike to the European honey bee *A. mellifera*. The cracks in the floor board or gaps in the hive walls or frame joints are not sealed. This may attract pests like wax moth. Fanning is used for ventilation of the hive and to remove excess quantities of water from the dilute honey before storing it. To remove the moisture-ridden air from the hive, bees undertake fanning vigorously and it is most visible at the hive entrance. The Indian hive bee fans with its head facing away from the entrance in contrast to *A. mellifera* which fans with head directed towards the entrance. Dhaliwal and Atwal (1970) observed the workers of both the species fanning side by side, but with their heads oriented in opposite directions.

A. cerana has some of the special qualities such as a) it is gentle to handle, industrious and well adapted to the ecological conditions of South and Southeast Asia, b) less susceptible than *A. mellilfera* to nosema disease not seriously affected by *Varroa* and is less prone to the attack of predatory wasps, c) can effectively defend against diseases, parasites and predators and do not require chemical treatments unlike to *A. mellifera,* d)the variety of geographical races/populations of *A. cerana* that exists in South and Southeast Asia provides excellent opportunities for the genetic improvement of this native species through selective breeding, e) *A. cerana* is sympatric in distribution and can co-exist with the two other species of Asiatic honeybees, *A. dorsata* and *A. florea*, without any adverse ecological consequences for pollination purposes. *A. cerana* is superior to *A. mellifera* in certain aspects, e.g., it is more suitable for cross-pollinating entomophilous crops grown in the small holdings of this region because of its shorter flight range and longer foraging hours than the European honeybee. Use of bee hives for pollination of agricultural and horticultural crops is another field that is gaining importance in recent years and there is an increasing demand for colonies by orchardists. Hiring colonies for pollination is also becoming a common practice. Bee colonies migrated to farm and orchard areas, to tide over adverse periods, can be utilized for crop pollination. Such migrations can help both the beekeeper and the orchardists. Besides honey, the hive bees can produce beeswax, pollen, royal jelly and bee venom.

The European honeybee, *Apis mellifera* Linnaeus, 1758

The European honeybee *A. mellifera* comprises of several subspecies or races. It was successfully introduced into India in 1965. The behaviour of *A. mellifera*in its biology, nesting, foraging, colony defense and other activities is similar to *A. cerana* (Chahal et al. 1995). It can even work in the areas where *A. cerana* cannot thrive (However, the performance of *A. mellifera* may not be the same in other agro-climatic conditions. For example, *A. mellifera* doing well in Punjab may not survive the new climatic and vegetation conditions in other parts of the country.

An important feature in which *A. mellifera* differs with *A. cerana* is its use of propolis. *A. mellifera* uses propolis to seal cracks and crevices in the nest to make it weather proof. The frames or the inner cover is often joined to the hive body with propolis. This makes inspection or management of colonies difficult. Some races are heavy propolizers. Propolis has antibacterial properties. It has several medicinal applications. With the introduction of *A. mellifera* in India it is possible to initiate production of propolis.

Stingless bees, *Trigona* spp.

Stingless bees are also called dammar bees. These bees are very small in size distributed in tropics, sub-tropics, and even in temperate regions. They build their nests in dark enclosures like cavities in branches or trunks of trees, ant hills, termite tunnels in the ground, wall crevices or any abandoned receptacle like logs, pots and tins. The nests are in the form of clusters of small uniform globular cells.

Pollen and honey are stored in conspicuously large oval cells that are constructed close to the brood cell clusters or at their periphery quite apart from them. No clear separation of honey pots is found. The brood cells of *Trigona* [*Tetragona* (now called *Tetragonula*) *iridipennis* Smith] from Castle Rock, Karnataka (Kshirsagar and Chauhan, 1977) were on average 3.12 mm broad and 4.09 mm high. The honey pots were about 6.64 mm broad and about the same in height. The pollen cells were similar to honey cells in breadth, but were 6.78 mm in height. After selecting a suitable nesting site, a new swarm closes all cracks, openings and crevices in the nest with glue like very sticky propolis. The nest is connected to the outside only through a small opening that is less than a centimetre in diameter. The tunnel opening is closed in the evening after all the outdoor work is completed for the day. It is opened every morning enabling the foragers to resume their tasks. Handling dammar bees is relatively very easy. Unlike the true honey bees, these bees do not have stinging as the defence mechanism, but have an equally effective biting behaviour, while defending their nest. When disturbed the bees attack the enemy in large numbers, usually selecting sensitive organs like eyes, nose and ears as their target. Dammar bees defend themselves from enemies by biting with the mandibles. The pots with honey and pollen stores are scooped out and pressed in a cloth to draw out honey. Honey yields are very low from few grams to maximum 500 grams. Honey is dark amber in colour. Phadke (1968) found levulose and dextrose in the ratio 32 and 20 per cent, respectively. Dextrins were found in the extent of 6 per cent, however, ash was also quite high, indicating a high mineral content. Due to the low dextrose content, honeys did not granulate even after 3 years after collection. Stingless bees have mostly been neglected in India and there are only few studies on them.

In spite of their short foraging range, they can exploit several small flowered plants like weeds and produce honey. They can be kept in receptacle. They recover and grow quite rapidly after adverse conditions that deplete the colony strength. They need little care by the beekeeper. The colonies can be divided very easily. The part of the cluster without the queen, can readily rear another queen and a full-fledged new colony gets established. These features make dammar bees ideal for keeping for honey production or for pollination of agricultural and horticultural crops that have small flowers and cannot be useful to other larger bees.

Even when several species of *Apis* are used for honey production, the stingless bees can be kept by farmers for honey production and for improved yields of their crops. The bees require little attention. The hive for stingless bees is very simple and does not require any sophisticated craftsmanship. Hence, rearing of stingless bees needs to be encouraged.

Honey industry

Honey industry depends upon the availability of flowering plants that provide food to the bees. With advancement of human societies, the association between man and honeybees gradually changed from one of hunting and killing, to that of an organized industry, in which honey bees were nurtured and made to produce honey and other valuable nutritive, medicinal and industrial materials (Crane, 1990).

Nectar and pollen

Honey is the sweet liquid produced by honeybees from nectars and other sweet substances on plants by addition of their digestive enzymes and by ripening the resultant mixture. Honey is thus a product of interaction of honeybees, the highly advanced insect groups, and plants, mainly the nectar producing flowering plant groups. Nectar serves as a source of carbohydrate energy requirements. Pollen provides the bees all their requirement of proteins for egg production, larval growth and general strength of the bee hive.

Wild honeybee colonies have been exploited for collection of honey in India, as also in a few other south-east Asian countries. The common honeybee nests that have been raided are those of the giant honeybee, *A. dorsata* and the oriental hive bee, *A. cerana*. Tribal populations collect honey from wild honeybee nests by using their traditional methods. The methods of collection of honey and beeswax from these nests have changed slightly in recent years. The attempts are being made to attract bees into logs that had been hollowed out, so that a cavity was formed to accommodate the bee hive, and to keep such log hives in protected bee gardens.

Scope of diversification in beekeeping

There is a great scope for diversification of apiculture. Besides honey, there is a great demand for other products such as pollen, propolis, royal jelly, bee wax and bee venom. Demand for rental colonies for honeybees is increasing considerably for quality and quantity of crop/fruit production. Apart from direct employment to beekeepers, the honey industry provides employment to artisans who make bee hives, apicultural equipments and honey packing materials etc.,

Mean net income from beekeeping per household in different countries

Schouten (2020) has compared the average income from beekeeping in different countries of the world. India had the highest income and ranked number one followed by Turkey, Tanzania, Ghana, Nepal, Nigeria, Kenya, Bangladesh and Zambia. Differences in income may be due to differences in harvesting of all possible by-products from the honeybees. The countries high income results from harvesting all possible by-products from honeybees (Schouten, 2020). Surveys reveal that in most of the countries beekeepers mostly rely on harvesting honey and beeswax (Moniruzzaman and Rahman, 2009; Islam *et al.,* 2016). This is a consequence of beekeepers not having access to available technology and inputs to gather and sell other bee products like pollen, propolis, bee venom, etc. (Hossain, 2017). As a result, most of the by products remain unused. The situation is further worsened by the poor marketing of bee products in local and foreign markets (Islam et al., 2016).

Marketing

Beyond honey, various other hive products, *viz.* bees wax, bee pollen, bee bread, royal jelly, propolis and bee venom greatly widen the scope of Apiculture - the bee and plant origin products elaborated by honey bees find their use in diverse ways in various industries, as food supplements, in pharmaceutical industry, in cosmetic industry, as preservative, disinfectants, etc. and have a great economic value. Depending upon the quality and package size, over the globe, the bees wax price in Indian currency varies between ₹230-1,600/ kg; bee pollen between ₹400-7,000/ kg; royal jelly between ₹2,200-32,000/ kg; propolis between ₹1,300-9,500/ kg and dry bee venom between ₹5,000-22,000/ g.

Role in beekeeping in employment generation and livelihood security

Beekeeping can be practiced by all those interested in bees and beekeeping and can be profitably managed by men, women, children, retired or working people, landless or unemployed. A number of ancillary industries are based on beekeeping, which have an indirect economic effect for improving livelihood which includes beehive manufacturers, extractor/uncapping machinery, packers' equipment, heating equipments, transport and handing equipments, other equipments such as electric generators and mobile extracting units and units dealing with quality assurance. Besides, number of industries are dependent on bee products which include honey. The large demand of honey reflects increased interest for natural and health foods. Beeswax is used in more than 300 industries and is a great source of income generation. Sale of live bees is another activity for increased income generation. Other products such as royal jelly, propolis, bee venom has great demand in the market. Paid pollination service can provide lucrative income to farmers.

Apiculture for apitherapy

Europe and many other countries have made advances in apiculture and are now leaping towards apitherapy including its various components, including also the honey massage, bee venom massage, aerosol therapy, ulleotherapy (uleterapia), venom based botox, etc. Bee venom (BV) is being administered in several ways: Puncture with whole bees (in non-specific or in specific points and zones); Yorish technique - stung at outer surface of shoulders and thighs. Number of stings is increased to 10 on 10th day, then break of 3-4 days, then number is decreased from 10 to 1 during next 10 day; Kuzmina technique: number of stings is increased to 10 bees to the 10th day, then a break of 3-4 days, then the number of bees is increased by 3 in every session (3, 6, 9,12, 15….. and 30th day); Micropuncture with the BV stinger; Injections with pure, sterile BV; Apipuncture/ apiacupuncture (apitoxin reflexotherapy); BV ointments, creams, pills, drops; *Apis* homeopathic preparations, and ultra-sound based Phonophoresis.

Honey massage has been reported to benefit human body in several ways: Weight reduction; Removes pathogens, salts and toxins; Relaxes entire nervous system; Improves blood circulation, metabolism; Increases lymphatic system flow; Light suction provides drainage of toxins & excess fluids, heavier suction stimulates circulation to stagnant muscles & loosens fibrous adhesions; Moisturizes and nourishes the skin and increases its elasticity; Breaks down lipid pockets (cellulites) assisting with body contouring & toning of skin; Frees from intellectual and physical chronic exhaustion; Cleanses the body, increases immunity; Produces soothing and rejuvenating effects; Eliminates acne, and helps dry and itchy skin.

Role of bee keeping in agriculture

Honeybees have been found to enhance the productivity of different crops which include all type of vegetables, fruits, oilseed crops, pulses, and fodder legumes. Honeybee pollination not only increases the quantity of crop/fruit production but improves the quality as well. It has been estimated that around 70% of the tropical crop species depend on pollinators for optimum yields and the economic value of these crops in India is USD 726 million. Though the country has attained self-reliance in food-grains production, there is a shortage of edible oil, fruits, vegetables, condiments, spices, etc. The average yield of the crops is much below in the country than the expected one. This has occurred because of inadequate pollination. There is a long way to go to achieve the required target and potential. Several investigations (Partap and Verma, 1992; 1994; Verma and Partap, 1993; 1994) have shown that honeybee pollination enhanced quality and quantity of seed production in various vegetable crops such as cabbage, cauliflower, radish, broad leaf mustard and lettuce. These results confirm the usefulness of bee pollination and its role in increasing crop productivity and improving the quality of fruits and seeds. Therefore, there is an urgent need to recognize beekeeping as an input in agriculture. For this, honeybee research in the country should be given top priority and specialized honeybee research centre should be established across the country. This will help in raising the number of honey bee colonies in the country so that, like other inputs, beekeeping in agriculture is also well utilized.

Pollination and ecosystem function

Pollinators facilitate plant reproduction, thereby performing a crucial ecological service that supports the most of the world's plant diversity and associated organisms. Evidently, pollinators are vital for maintaining both natural ecosystems and human food security. During the past two decades pollinators have seen unprecedented decline which have stimulated concerns.

Constraints in beekeeping

The development and commercial exploitation of honeybees in India is faced by many biotic and abiotic challenges which are responsible for decline of honeybee colonies and their products.

Declining of bee populations

The population of honeybees and other species has declined considerably which has serious impact on cultivation of many commercial crops and has also threatened the existence of terrestrial ecosystems (Abrol 2012, 2013). The impact of such decline can be found in Himachal Pradesh where inspite of all agronomic practices quality and quantity of fruit production has declined considerably (Partap, 2003).

Asian hive bee *A. cerana* is suffering serious decline in its entire native habitat. In Japan, beekeeping with this native bee species has been completely replaced by European honeybee, *A. mellifera* and only a few beekeepers are raising *A. cerana* colonies (Sakai, 1992). Similarly, in China, 70 percent of beekeeping in modern hives is with *A.mellifera* (Zhen-Ming *et al*., 1992). Analogously, decline has been reported in South Korea where more than 85%

of beekeeping has been replaced by the exotic *A. mellifera* (Choi, 1984). This pollinator crisis seems more acute in landscapes dominated by annual crops as these intensively managed and most highly disturbed monocultures do not provide environmental opportunities for beneficial insects.

Causes and consequences of decline in pollinator diversity

Habitat alteration

Habitat alteration is one of the most serious threats resulting in decline of honey bee populations. Habitat destruction could lead to loss of different types of flowering plants and bee flora. Scarcity of bee flora due to environmental degradation not only leads to decline in colony numbers and increases their vulnerability to the pests and diseases. Recent incidence of Thai sac brood virus disease and European foul brood in *A. cerana* might have arisen due to the stress conditions created by environmental degradation.

Pesticide poisoning of honeybees

Beekeeping and pesticides both have become essential inputs of modern agricultural management technology. Indiscriminate use of pesticides has resulted in heavy losses in beekeeping industry. However, in recent years, education and public relations have achieved much in reducing bee losses due to pesticide poisoning in the developed world.

Human practices

Honey hunting methods have been more serious for the destruction of bees. That killed most of the bees, their brood and left no honey stores for their consumption during dearth periods. Such methods have resulted in destruction of colonies, their absconding or swarming. Human predation has resulted in both temporal and spatial decline in bee populations in their native habitat (Bishop, 1992).

Parasites and diseases of honeybees

Populations of European honeybees have declined throughout the world due to wide range of diseases such as European and American foulbroods, with parasites causing additional problems in recent years. The honeybee tracheal mite (*Acarapis woodi*) was discovered in the 1920s and slowly spread throughout the world, reaching the USA in the 1980s. Today it is found in all countries except Australia, New Zealand, Scandinavia and Canada. The mite infection shortens the lives life span of bees, reducing honey production and pollination efficacy (Morse, 1978). The *Varroa spp*. mite

(*V. jacobsoni* and *V. destructor*), a more serious pest of honeybees, is cosmopolitan throughout the world, except for a few isolated countries such as Australia (Ritter 1981).

Recently, the European foul brood disease has badly affected *A. cerana* colonies (Rana *et al.,* 1987). Amongst the predators, five species of wasps and two species of wax moths, *Gallaria mellonella* and *Archoria grisella* pose a serious threat to beekeeping industry. However, because of its shimmering and evasive behavior, *A. cerana* can resist the attacks of wasps better than *A. mellifera*. In recent years, Thai sac brood virus disease has been reported from all countries where *A. cerana* is found. In early eighties, the incidence and severity of this disease increased at such an alarming rate that more than 95% of colonies infected in different countries were killed by this disease (Rana *et al.* 1986, 1987).

Climate change, pollinator declines, and competition

The collapse of pollinator mutualisms has been identified as one potential consequence of anthropogenic land use change (Allen-Wardell *et al.* 1998; Wilcock and Neiland 2002). Climate change is one of the most serious factors which directly and indirectly affect the abundance, geographic range, vigour, phenology and behaviour of both plants and pollinators (Inouye *et al.*, 2000, Lyon *et al.*, 2008, Memmott *et al.*, 2007).

The decline of other bee species

In natural systems, particularly biodiversity hotspots such as tropical rainforests, the decline in pollinator numbers has a more significant effect because their services are essential to maintain that diversity. The more plant species that are present in a habitat, the less is the access for each species to the pool of pollinators. As each pollinator declines and the 'pollination limitation' increases, the risk of extinction for any plant species also increases (Vamosi *et al.,* 2006). Pollination limitation, involving reproductive shortfall or failure of seed set, is thought to be in the range of 50-60% in rare plant species or plants found in fragmented habitats (Allen-Wardell *et al.,* 1998), and some research suggests more than 60% of plant species studied are pollination limited (Burd, 1994). Forests have the added burden of habitat loss due to agricultural encroachment, habitat fragmentation, and the invasion of Africanised bees (Roubik, 2000).

Impacts of pollinator declines

Recent declines in yield of most of the agricultural and horticultural crops is a direct indicator of pollinator decline. It has serious consequences for pollination services in agro-ecosystems, natural ecosystems, and for the maintenance of wild plant reproductive capacity. Habitat loss and fragmentation, land management practices, agricultural and industrial chemicals, parasites and diseases and the introduction of alien species are the major causes of pollinator decline. In conclusion, the country with vast resources of bee flora has great scope for its further expansion if the confronting problems are solved in right perspective

Future prospects and recommendations

Honey industry in the country can well become a major foreign exchange earner as quality standards are maintained. Using advanced methods of collection, processing and maintaining quality of health shall help in marketing of honey throughout the world. Some of the recommendations include: recognition of beekeeping as agro-industry, priority allocation and concessions to be made applicable for material needed for beekeeping, like wood for bee boxes, sugar for supplementing feeding, and medicines for bees diseases, developing an efficient export marketing network to optimize the production and exports, creating an Indian logo as a joint effort of exporters, APEDA and the Ministry of Commerce and Industry, government of India. The brand equity helps better marketing and sales at higher rates. Furthermore, housewives living in rural areas can be utilized to create additional income source for poverty ridden families. Educated people should be encouraged to participate in beekeeping, so that they can learn and introduce new methods and tools for increasing productivity and efficiency in beekeeping. Microcredits can be managed to both help people start beekeeping and expand existing businesses. Proper training focused on modern tools and technologies, harvesting the byproducts, pest, predators, and disease control should be ensured. The training organizations should ensure help for the beekeepers staying in remote areas. Government subsidies can be provided for the artificial food supplies during the dearth period. Application of pesticides should be undertaken outside the window of honeybee activity. Competitive local markets should be established to ensure the profit of the beekeepers. Research efforts should be concentrated to ensure the quality of bee products to meet the standards of global markets.

Awareness campaigns should be organized to educate the people regarding the multidimensional benefits of beekeeping via publicity in mass media.

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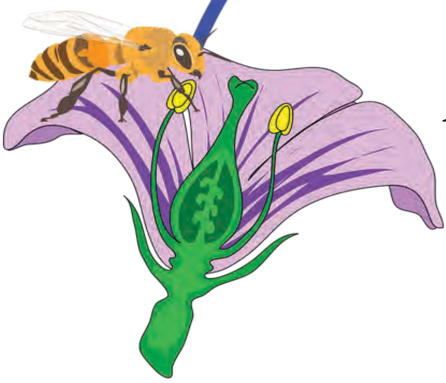

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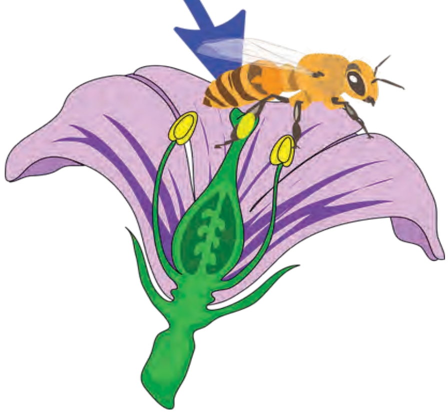

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EXPLORATION OF MAJULI WHITE GRUB BEETLE, *LEPIDIOTA MANSUETA* FOR FOOD AND FEED SECURITY

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Abstract

The white grub, *L. mansueta* was first detected in October 2005 in the farmers' field of Majuli river island, Assam, India. Field surveys conducted during 2005-2009 revealed that *L. mansueta* had appeared as an extremely severe key pest and the most severely affected crops were potato, sugarcane, Colocasia and green gram and the extent of damage varied from 42-48, 15-20, 35-40 and 30-35%, respectively. *L. mansueta* has a biennial life cycle, which is the first of its kind from North-east India. It is a unique biennial species, spending its entire life cycle under the ground except for a very short period during which adults come out of the ground for mating. Grubs are voracious feeders. However, there is no evidence showing that the adults fed on any plants either in the field or laboratory and hence this species has the unique distinction as the first Indian phytophagous white grub species with nonfeeding adults.

A parallel planning was done to carry out basic research as well as community action programmes/social engineering/farmers participatory approaches aimed at collecting adult beetles during evening hours as a practical and cost-effective method of management. This mass campaigning programme received overwhelming response and was exceedingly successful leading to massive collection and killing of about 13.51Lakhs *L. mansueta* beetles in Majuli during 2010-2023.

It is worth mentioning that some of the local tribal people relished the cooked/fried adults of *L. mansueta* as protein rich food which opened an avenue of further research on its nutritive/nutraceutical value. Efforts were made to analyse the nutritional profiling of the beetles for their further exploration as human food/animal feed. The proximate analysis of the beetles

revealed a higher amount of crude protein content (76.42%) along with other proximate parameters like crude fat (4.10%), crude fibre (5.16%), total mineral (2.98%), carbohydrate (9.18%) and moisture (2.16%). The energy content was 379.29 kcal/100 g of sample. Elemental analysis revealed the presence of 7 minerals viz., Na (27.76), K (14.20), Ca (33.33), Fe (1.64), Cu (6.52), Zn (15.55) and Mn (1.30) mg/100 g of sample. As antioxidant properties, the phenol and flavonoid content was found to be 4.00 mg catechol equivalent/g and 1.59 mg quercetin equivalent/g, respectively. The DPPH was registered 22.60 per cent whereas tannin (3.24 mg/g) as antinutritional compound was recorded at acceptable level. Fatty acid profiling showed maximum amount of saturated fatty acid (2.24%) followed by monounsaturated fatty acid (0.57%) and polyunsaturated fatty acid (0.49%). Altogether 10 fatty acids were estimated, of which palmitic acid content was recorded in maximum amount (0.28%). Amino acid profiling registered 17 amino acids, of which 8 were found essential. Considering the immense nutritional value of the beetles, a unique "Beetle fry dish" was developed and popularized through community feast. Concerted efforts have also been initiated to explore beetle powder for making biscuits and other confectioneries. This effort had tremendous impact in reducing beetle load in Majuli Island in terms of protecting the crops, enhancing crop productivity as well as improving both livelihood and nutritional security.

GENOMICS AND MICROBIOMICS APPROACHES FOR PEST MANAGEMENT

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Abstract

Molecular biological tools have redefined the contours of entomological research in the twenty-first century. The molecular markers have strengthened insect taxonomy, biotype diversity, population genetics, and insecticide resistance studies. Our studies have unravelled the genetic group diversity of *Bemisia tabaci* in the Indian subcontinent. Mitochondrial cytochrome oxidase–I–based markers could be utilized for population genetic analysis of insect pests and their associated symbionts like *Wolbachia*. Molecular analysis of target site mutations in insect genes was effectively used for designing Cleaved Amplified Polymorphic sequence markers for developing diagnostic kits for ascertaining resistance to pyrethroids and phosphine in insect pests. Biochemical markers like detoxification enzymes, antioxidant enzymes and Cytochrome P450 genes could be utilized for detecting insecticide/fumigant resistance in insect pests.

The advent of genomics has made a paradigm shift in the functional characterization of insect genes and their utilization in pest management in the past two decades. Genome-wide analysis characterized 14 odorant-binding proteins (OBPs) and 24 chemosensory proteins (CSPs) in *B. tabaci* Asia II-1. A robust computational pipeline coupled with molecular analysis has traced the evolutionary lineage of these proteins, exon-intron boundaries, retrotransposon insertion sites, splicing variants, chromosome mapping, and temporal and spatial expression of OBP and CSP genes in *B. tabaci*. Functional characterization using *in-silico* docking and competitive fluorescent binding assays with candidate ligands identified the OBPs associated with host selection and oviposition behaviour of *B. tabaci*. Understanding the genomic architecture and functional analyses of OBPs and CSPs offers new avenues for pest management.

Next-generation sequencing platforms have heralded a new era in the metagenomic analysis of microbes associated with insects. Whole genome shotgun sequencing uncovered the gut bacterial diversity in three Lepidopteran insect species viz., Muga silkworm, *Antherea assamensis* (monophagy), Cotton bollworm *Helicoverpa armigera* (polyphagy) and diamondback moth, *Plutella xylostella* (oligophagy). NGS coupled with culture-dependent approaches identified the beneficial gut microflora from of Muga silkworm, *Antheraea assamensis* which could be used for developing probiotics for the sustainable rearing of Muga silkworms in North Eastern regions of India.

A nationwide consortium formed under the aegis of the National Honey Mission explored the gut bacterial diversity to identify the core bacteriome associated with major honey bee species in India. Functional analysis has also identified the scope for utilizing the cellulolytic gut bacteria from honey bees for bioremediation of crop residues. Studies with white grub species, *Lepidiota mansueta*, Anomola *dorsalis*, and *Anomola dimidiata* have identified and characterized novel gut bacterial isolates and core gut bacteriome in white grub species. The fitness traits of *B. tabaci* genetic groups are shaped by the presence of endosymbionts. Fluorescence in situ hybridization (FISH) and infection frequency analyses demonstrated insecticide resistance/susceptibility in whitefly, *B. tabaci* is strongly associated with the infection frequency of secondary symbionts *viz.*, *Cardinium* and *Rickettsia B. tabaci* populations. Structural and functional analysis of Genomics and gut microbiomics insects offer scope for biotechnological applications and for developing novel management strategies. Capacity building on genomic tools would enable students of Generation -X ready to face the challenges of pest management in the new millennium.

ESI Senior Entomologist Awardees

PATHWAY FROM EVOLUTION TO ELUCIDATION: THRIVING TO ACHIEVE ECOFRIENDLY PEST MANAGEMENT

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Abstract

As advancements in science progress every day, new challenges and new solutions are evolving alongside them. Advancement in sequencing technology, coupled with bioinformatics analysis, has revealed many mysteries and elucidated the biological mechanism previously unknown. I have been working in this line to harness the molecular methods to understand the insects' evolution and physiology, eventually bringing out the novel pest management strategies. I have done work on insect genomics to cater to the various needs, *viz.,* species identification through DNA barcoding, identifying important genes & pathways encoding important traits & molecular mechanisms of insecticide resistance, and developing a database for the insect genomic information. The genes and pathways further utilised for the development of novel strategies to combat the pests via gene silencing. The major problem in the farming community is the proper identification of insects and timely intervention. My research was mainly focused on these two issues: for insect' identification, I have developed DNA barcodes for more than 350 insect species and molecular characterisation of 320 genes from insects. The molecular data helped in the description of 14 new species and 3 new genera. The *de novo* transcriptome analysis was conducted to know the molecular mechanisms for the insecticide resistance and found the important genes and pathways in around six important insects have been sequenced, *de novo* assembled, and analysed to identify the important gene families, pathways, and genes. The effect of sublethal doses of agrochemicals and the interplay in the biological fitness have been investigated by gene expression studies. I have also investigated the putative functional role of gut microflora in the insecticide resistance using metagenome analysis in two important insect pests. I have also contributed to the development of a database on insect molecular aspects. This database is called MODII—Molecular Database on Indian Insects. AGIS (Arthropod Germplasm Information System), an online software tool, has been developed for the first time in the country for the storage of information related to live arthropod genetic resources in India.

DISCOVERING ECO-FRIENDLY FUMIGANTS: MEDICINAL PLANT RESOURCES FROM INDO-BURMA'S BIODIVERSITY HOTSPOTS

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Abstract

Biodiversity conservation efforts often focus on plants and animals, yet the vast potential of insect pest control using botanical sources remains largely untapped for human benefit. In the northeastern states of India, some studies have started exploring bioactive molecules derived from local plant diversity, but insect pest control from natural origins has been largely overlooked. Indigenous communities in these regions have long utilized plant-based products as grain protectants and antifeedants. These traditional practices hold great promise for discovering natural insecticides, offering an environmentally friendly alternative to synthetic chemicals while addressing concerns about human health and the growing issue of insect resistance.

This research aims to identify, isolate, and characterize novel bioactive molecules from plants that could lead to the development of eco-friendly, biodegradable phyto-insecticides for pest control, particularly for grain protection against storage pests and for combatting crop-damaging insects. The study builds on the traditional knowledge of various ethnic groups in northeastern India, who have long used local bioresources as insecticides. As the demand for safer, more sustainable alternatives to chemical pesticides grows, there is a clear need to explore natural agents that can mitigate human health risks, ecological damage, and insect resistance.

In our research, we employed a bioassay-guided approach to isolate natural fumigant molecules from medicinal plants in the Northeast region of India. These molecules were characterized using physical-chemical and spectroscopic techniques (IR, 1H NMR, 13C NMR, and Mass) and identified as Isosecotanapartholide, 2,3-dimethyl maleic anhydride, coffee furanone and dihydro-p-coumaric acid. These bioactive molecules showed high toxicity at

very low concentrations, effectively controlling stored product insects such as *Sitophilus oryzae*, *Tribolium castaneum*, and *Corcyra cephalonica*. At a dosage of 100 PPM, the treated grains were free from infestation, demonstrating their potential for grain protection. Moreover, the isolated molecules had no adverse effect on seed germination or plant growth, as there were no significant differences between the control and treated grains. The insecticidal activity of these molecules, observed in fumigant bioassays, suggested a neurotoxic effect similar to that produced by organophosphates. Our findings indicate that these molecules are potent acetylcholinesterase (AChE) inhibitors, with Isosecotanapartholide exhibiting dose-dependent and time-dependent inhibition of AChE in both test insects. Additionally, the molecules caused significant impairment of antioxidant enzymes, suggesting that their insecticidal activity might be linked to both AChE inhibition and oxidative stress. However, further research is needed to fully elucidate the molecular pathways involved in their toxic effects.

Importantly, Isosecotanapartholide, coffee furanone and dihydro-p-coumaric acid were found to be non-toxic to mice at doses up to 1600 mg/kg body weight, highlighting their selective toxicity to insects and safety for mammals. This makes them promising candidates for use as natural fumigants in stored grain pest control, offering an environmentally sustainable alternative to chemical fumigants (methyl bromide and phosphine).

RNAI TECHNOLOGY: SHAPING THE FUTURE OF INSECT-PEST CONTROL

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Abstract

RNAi is a natural phenomenon that was considered an oddity when it was first observed in petunias. It exists in many organisms as a means of protecting against viruses and transposons, molecular invaders that would otherwise plague a host genome and wreak havoc. It is noteworthy that this method of protecting the integrity of the eukaryotic genome is highly evolutionarily conserved: dsRNA entering the cell is targeted for immediate destruction. With the advent of refinement in biotechnological tools this concept has been turned into a new technique that is able to suppress the expression of specific endogenous genes through the use of double-stranded RNA (dsRNA). The technique was first demonstrated in *Caenorhabditis elegans* and subsequently in human and other mammalian cells. The new technology, called *RNA interference* (RNAi), is also frequently called *gene knockdown*. Other related terms include *post-transcriptional gene silencing* (in plants), *cosuppression* (older term, in plants), and *quelling* (in fungi). Down regulation of the expression of specific genes through RNA interference (RNAi), has been widely used for genetic research in insects. The method has relied on the injection of double-stranded RNA (dsRNA), but recent results have shown that dsRNA fed as a diet component can be effective in down regulating targeted genes. RNAi in insects. RNAi mediated gene silencing has been achieved in number of insects species (aphids, whitefly, mosquito, brown plant hopper, *Helicoverpa armigera*, *Gryllus bimaculatus*, *Spodoptera*, corn rootworm, many mite and tick species) besides model insect, *Drosophilla*, *Tribolium*, silkworm and honeybee. To date dsRNAs resulting in an RNAi response have been used to study functional genomics in more than 30 insect species from a variety of different orders, including Diptera, Coleoptera, Lepidoptera, Isoptera, Orthoptera, Hymenoptera and Hemiptera. Our RNAi work in cotton insects started with collaboration with the Department of Entomology, University of Kentucky, USA where we explored the RNAi efficiency in 37 insect species belonging to nine different orders. This study

gave insights about the differential RNAi response across insect species with coleopteran exhibiting high RNAi efficiency and least responsive were the lepidopterans. Hemipterans and other insect orders showed partial response to this phenomenon. Following this we conducted studies on RNAi with cotton pests such as whiteflies, leafhoppers, thrips, mealybug and cotton bollworms. Different potential targets of whitefly were identified, which can be used in future to develop RNAi based transgenic or dsRNA based formulations. These targets include vital genes associated with osmoregulation (aquaporins, diuretic hormone and calcitonin like receptor), moulting associated genes such as ECRs and virus transmission associated genes (heat shock proteins). Besides these sucrose transporters, vitellogenin, IAP (inhibitor of apoptosis) and other genes associated with vital processes have been evaluated through dsRNA feeding assays for their efficacy against whitefly. RNAi efficiency varies significantly across different insects groups. In hemipterans including whitefly, the gut nucleases act as major obstacle in the feeding RNAi by degrading the dsRNA before its processing into siRNA. To improve feeding RNAi efficiency in whitefly, dsRNA targeting potential genes (Hsp70, Snf7 and IAP) were conjugated with chitosan and carbon quantum dots (CQD) and fed to the whitefly through membrane feeding assay. The chitosan-coated particles improved the RNAi efficiency by improving the knockdown of the respective mRNA transcripts of the targeted genes compared to the naked dsRNA. Besides sucking insects the nanoparticles tethered dsRNA against various genes has been used to improve RNAi efficiency in cotton bollworms. In addition to this we have also identified dsRNA against the nuclease genes (dsRNAsesI and dsRNAsesII) in whitefly and American bollworm. The dsRNA targeting nuclease genes (dsRNAsesI and dsRNAsesII) in the diet protected the dsRNA of target genes and has increased the efficiency of dsRNA from degradation before the processing of dsRNA to siRNA.Likewise,many genes have been also been screened in cotton leafhopper, thrips and mealybug using RNAi technology. The heat killed bacteria containing dsRNA against target gene is being evaluated against various cotton insects to use the technology as spray formulation. We are in process of narrow down the key genes in all cotton insects which can be used in future for its management through transgenic or dsRNA formulations. The talk gives the insights of my journey on RNAi in different cotton insect-pests as well as future prospects and challenges for taking this tool to field for insect-pest management.

ESI Young Entomologist Awardees

DIAPAUSE IN *CHILO PARTELLUS*: ECOLOGICAL, BEHAVIORAL, AND PHYSIOLOGICAL PERSPECTIVES

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Abstract

Diapause is a critical survival strategy for the spotted stem borer, *Chilo partellus* (Swinhoe), a significant pest affecting cereal crops like maize and sorghum. This physiological state involves the suspension of development and metabolic activities, enabling the insect to conserve energy and resources during periods of stress, such as extreme temperatures or the absence of host plants. The phenomenon is triggered by environmental cues, including changes in photoperiod and temperature, which synchronize the insect's life cycle with the seasonal availability of its food sources. In regions with distinct seasons, diapause ensures the continuity of *C. partellus* populations, as the larvae can withstand adverse conditions and resume development when favorable conditions return.

Diapause impacts the feeding and movement patterns of *C. partellus* larvae. During this dormant phase, larvae cease active feeding and display minimal movement, reducing energy expenditure. This state of inactivity not only supports survival but also influences post-diapause behaviors. For instance, the ability of *C. partellus* to inflict damage on crops and its susceptibility to insecticides can vary between diapausing and non-diapausing populations. Such behavioral changes underline the ecological significance of diapause, as they affect the pest's overall capacity to thrive and spread in its environment.

Moreover, diapause is characterized by profound biochemical changes within the larvae. Lipid reserves play a vital role during this period, as they provide the energy required to maintain cellular functions in the absence of feeding. Studies have highlighted differences in the lipid composition of diapausing larvae, with specific fatty acids being critical for sustaining the dormant state. Additionally, diapause affects the reproductive physiology of *C. partellus*, influencing fertility and population growth after diapause

termination. These physiological adaptations are integral to the insect's ability to re-establish populations and maximize reproductive success once conditions become suitable.

Genetic regulation also plays a key role in diapause, governing the processes that enable *C. partellus* to enter, maintain, and exit this state. Understanding the genetic basis of diapause provides valuable insights into its adaptive significance and offers potential avenues for pest control. By targeting the genetic mechanisms underlying diapause, it may be possible to develop innovative strategies that disrupt this survival tactic, thereby reducing the pest's ability to persist in challenging environments.

The comprehensive understanding of diapause in *C. partellus* has significant implications for pest management. Insights into the timing and triggers of diapause can inform the development of strategies to control pest populations more effectively. For instance, interventions can be timed to target the insect during vulnerable stages, such as before or after diapause. Furthermore, the physiological and genetic knowledge of diapause can support the design of advanced management techniques, such as disrupting diapause induction or enhancing the effectiveness of traditional control measures. Diapause research thus provides a foundation for improving the sustainability and efficiency of pest management strategies for this economically important species.

EXPLORING BOTANICAL, GENETIC RESOURCES AND BIOTECHNOLOGICAL APPROACHES FOR SUSTAINABLE MANAGEMENT OF THE KEY PESTS

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Abstract

Exploring botanical and genetic resources, along with biotechnological approaches, offers innovative solutions for sustainable management of key pests. These methods leverage natural plant defences, genetic resistance, and advanced technologies to reduce pest damage while minimizing environmental impact. In South India, control failures of the invasive South American leaf miner, *Phthorimaea absoluta*, were observed due to reduced susceptibility to insecticides. Bioassays on field samples confirmed this resistance, which was linked to four cytochrome P450 (CYP) genes: CYP248f (flubendiamide), CYP272c and CYP724c (cyantraniliprole), and CYP648i (indoxacarb). These findings led to the development of an Insecticide Resistance Management (IRM) strategy to manage the pest sustainably. As part of this strategy, the insecticidal properties of essential oils (EOs) from *Ocimum basilicum* and *Mentha piperita* were tested. *M. piperita* EO showed 100% mortality of *P. absoluta* at an LC_{50} of 1.78 µl/ml, mainly due to alloaromadendrene, levomenthol, and santolina triene. *O. basilicum* EO achieved 90% mortality at an LC_{50} of 3.58 µl/ml, with humulene, alpha-farnesene, estragole, and 4-cerene as key contributors. Among binary compounds, Levomenthol and alpha-pinene caused 100% mortality with LC_{50} values of 13.18 and 16.10 µl/ml. Toxicity was linked to changes in enzyme activities, suggesting EOs as alternatives to synthetic insecticides. Likewise, *Annona squamosa* seed extract also showed 95-98% mortality against aphids (*Aphis gossypii,A. craccivora* and *Myzus persicae*) offering an eco-friendly solution to reduce pesticide residues on crops.

The Southeast Asian thrips, *Thrips parvispinus* (Karny), a major pest of chilli crops, was also studied for host plant resistance. Out of 481 germplasm

accessions screened, 14 identified with resistance to *T. parvispinus*. The accession IIHR-B-HP-79 (*C. frutescens*) showed the highest resistance, with significantly lower damage to leaves and fruits and holds great promise as a valuable genetic resource for breeding programs aimed at developing thrips-resistant cultivars. Further research on RNA interference (RNAi)-mediated control of *P. absoluta* on tomato plants focused on juvenile hormone binding protein and v-ATPase B. Exogenous application of dsRNA targeting these genes resulted in effective pest control, suggesting RNAi as a promising approach for managing lepidopteran pests. In *Bemisia tabaci*, the predominant Asia I genetic group in South India, host plants were found to influence the insect's endosymbiotic bacterial populations, which affect virus transmission. Feeding on different host plants led to significant changes in endosymbionts, particularly reducing *Wolbachia* levels. Furthermore, *Arsenophonus* concentrations increased in whiteflies feeding on tomato plants infected with Tomato leaf curl Bangalore virus (ToLCBV). Using Smart technology and Y2H, 102 protein interactions were identified between ToLCBV coat protein and *B. tabaci* proteins, including heat shock proteins and vitellogenins. These interactions suggest novel targets for developing future whitefly control strategies, such as RNAi or insecticide targeting. Overall, these studies provide botanical, genetic resource, and biotechnological approaches for the sustainable management of key pests.

WORKING WITH TINY ASSASSINS: EXPLOITING AND POPULARIZING INSECT BIOCONTROL AGENTS FOR INSECT PEST MANAGEMENT

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Abstract

Biological control is one of the valuable ecosystem services, offering ecofriendly alternative to chemicals and has an important role in integrated pest management. Augmentative biocontrol should be one of the options when pest damage occurs. Worldwide, more than 350 species of insect natural enemies are used against insect pests. Initially hymenopteran parasitoids were comprising the major use in augmentative biological control but since 2005-06 the majority of market has been captured by predatory mites and heteropteran predators in protected and high-value crops in open field conditions comprising 80-90% of the invertebrate biocontrol market. In this regard, efforts were made to collect and characterized indigenous mirid, anthocorid and geocorid bugs. The rearing protocols have been developed for these bugs. Laboratory, greenhouse and open field studies indicated the potential of these bugs against thrips, mites and neonates of lepidopteran insects. Furthermore, this research indicates the interaction between these predators and biopesticides and how these two components could be used together to reduce pest incidence. In India, more than 13 insect predators and parasitoids are being multiplied in many states on a small scale. Among them, trichogrammatids are produced by more than 25 states. As the rearing protocol have been developed for these predatory bugs and mites, these indigenous predators could be exploited as one of the components of Biointensive pest management (BIPM) in protected cultivation against thrips and mites. This research also highlights that predator-In-First approach helps to build up the population of these bugs before pest arrives and thus helps in curtailing pest incidence and insecticide uses. This research has opened an avenue to explore indigenous heteropteran predators that are amenable to

rearing, offering valuable insights for their potential use in the management of insect pests. The ongoing research on the early establishment of predatory bugs plays a crucial role in enhancing biological control and its associated ecosystem services.

Popularization of biological control and availability of predators and parasitoids are the area which needs to be strengthen. Research also indicates that integrating trichogrammatids with other Integrated Pest Management (IPM) practices in a farmer-participatory mode resulted in a 49.74% reduction in insecticidal sprays and a 28.49% increase in cotton yield, demonstrating that the timely use of bioagents can reduce insecticide reliance. Furthermore, the research indicated that biointensive pest management (BIPM) packages, including trichogrammatids and biopesticides, led to a reduction in fall armyworm (FAW) incidence and are now being implemented in maize-growing areas. Overall, these studies demonstrated the potential of indigenous predators and parasitoids in managing insect pests and offering a practical example of how biological control can be successfully translated from the laboratory to land.

THERMAL STRESS *VIS-A-VIS* REPRODUCTIVE PHYSIOLOGY OF INVASIVE FALL ARMYWORM, *SPODOPTERA FRUGIPERDA* (J.E. SMITH)

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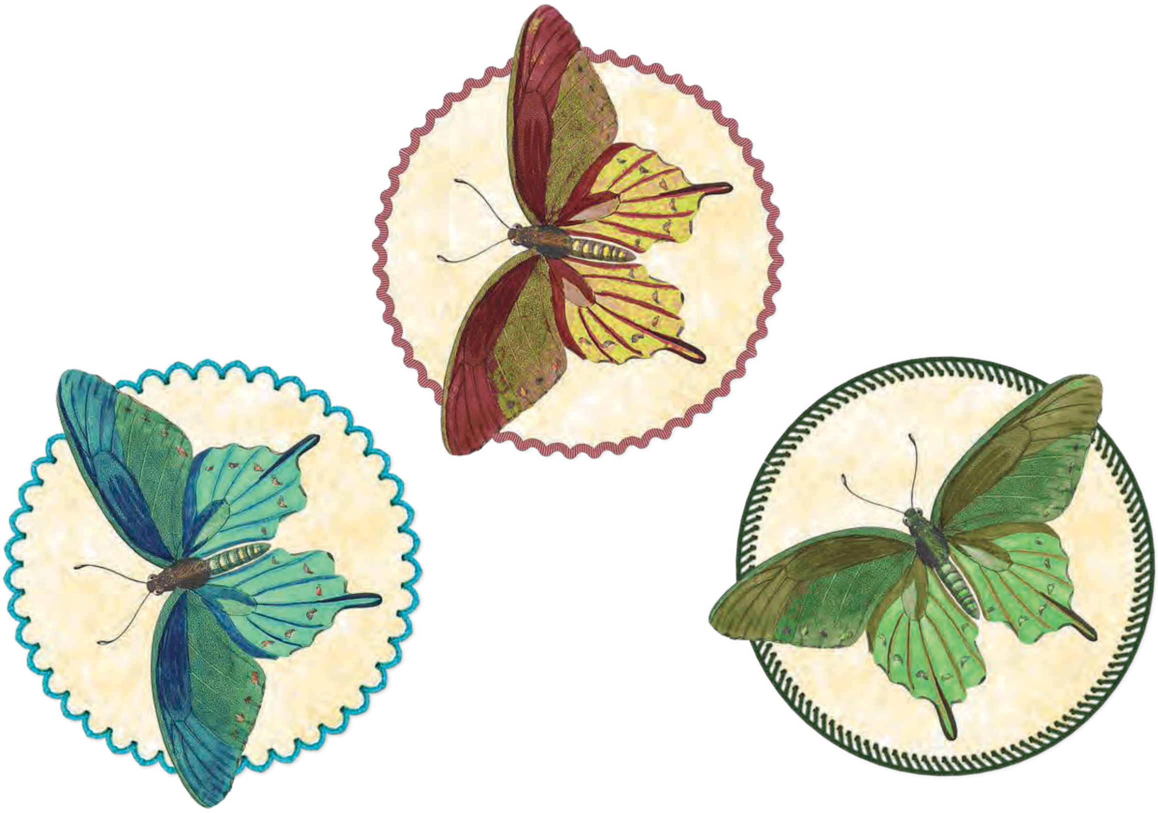
Abstract

The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) is a devastating polyphagous pest native to tropical and subtropical regions of America. Temperature is one of the critical abiotic factors determining the distribution and abundance of insects. Ambient temperature often fluctuates with shorter periods of extreme high temperature, termed as hot events. Insects being ectotherms, they are easily affected by these hot events, which do not necessarily result in insect mortality, but their effect is rarely considered in population prediction. In this regard, investigations were undertaken to study the impact of heat stress on reproductive physiology of fall armyworm. Chickpea based meridic diet and rearing procedure was developed to facilitate continuous rearing & efficiency of the diet was assessed with the natural host; constructed fertility life table with biotic potential estimation of *S. frugiperda* on both natural and meridic diet. Influence of host nutrition *viz*., meridic diet, corn and castor on fatty acid profiling revealed that highest percent of polyunsaturated fatty acid (PUFA) viz., linoleic acid was recorded in both male and female adults of meridic diet fed larvae. In the process of standardizing rearing, documented native parasitoid complex of fall armyworm from Northern India *viz*., *Chelonus* nr. *blackburni*, *Chelonus formosanus* Sonan, *Coccygidium* sp. and *Temelucha* sp. from the field collected eggs and larvae. As a routine, *S. frugiperda* were reared for reproductive physiology experiments, serendipitously we observed an adult with an uncertainty in wing morphology suggesting it to be a gynandromorph. Genitalia dissection revealed that it is asymmetrical with male genitalia structures observed on one-half and female genitalia structures on the other half depicting the bilateral type of gynandromorphism. Copulation and courtship patterns showed that 58.39%

of the females exhibited calling in the absence of males and 88.18% of females in the presence of males on the first scotophase. The onset time of calling was early in females when males were present. The copulation duration of *S. frugiperda* varied between 78.00 ± 7.35 min and 197.14 ± 11.06 min. Reproductive behavior of different aged adults envisaged that copulation duration was highest in 1-day male (DM) × 3-day female (DF) mating combination, while fecundity in 2 DM × 1 DF combination. Influence of hot events (42^{0}C for 2, 4 and 6 h) on reproductive physiology of fall armyworm, showed that fecundity was negatively affected in stressed male combination, whereas it had positive impact in stressed female combination signifying the hormesis effect. Thus, hot events had detrimental effects on reproductive output of *S. frugiperda* especially through paternal effects thereby influencing its population dynamics. Transgenerational effects of thermal stress were evident up to F_2 generation for developmental attributes with prolonged developmental duration, reduced maturation success, female biased sex ratio and hampered reproductive attributes. A trade-off between reproduction and survival strategies was evident under thermal stress with the allocation of resources between them. Understanding the persistence of thermal stress across generations at both biological and biochemical level and offers insights into further studies on demography of fall armyworm under current and future climate change scenario.

ESI Industry Awardees



INNOVATIVE AND SUSTAINABLE SOLUTIONS FOR CROP PROTECTION AND MOSQUITO VECTOR MANAGEMENT

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Abstract

The agro-economic status of the country has largely relied on inorganic pesticides and fertilizers, which contributed to high crop yields. However, by the year 2000, the need for sustainable farming solutions was increasingly highlighted by environmental scientists and global leaders. In early 2005 many insect biocontrol units across the globe embarked their journey in Eco enterprise faced an unexpected decline in mass production of egg parasitoid *Trichogramma chilonis* and *Trichogramma japonicum,* a careful examination on the same led to findings such as inadvertent intra-guild competition, self-line selection resulting in inferior intraspecific genotypes, undesirable fitness traits, and the occurrence of thelytokous or deuterotokous strains. This study opened the gateway to successfully use intraspecific plasticity and traditional breeding techniques in *T. chilonis* to develop superior strains such as positive fitness, indicative fecundity, normal sex ratio, host seeking attributes and improved overall productivity. In another project, a cost-effective, eco-friendly method for insect genomic DNA isolation was developed, avoiding toxic chemicals like β-mercaptoethanol and costly reagents like lysozymes. Using just 0.05 g samples of *Trichogramma* sp., the protocol yields pure, intact DNA suitable for PCR, hybridization etc, outperforming conventional methods in efficiency and simplicity.

Another industrial project on insect and medicinal plant diversity, focusing on *Morinda citrifolia* and *M. pubescens*, led to crop protection strategies for plantations in Kerala and Karnataka. Major pests, including *Maconellicoccus hirsutus* and *Planococcus citri*, were managed using biocontrol agents like *Cryptolaemus montrouzieri, Scymnus craccivora, Chrysoperla carnea,* and with suitable combination of plant based and microbial products. *M. citrifolia* essential oil showed promising larvicidal and insect-repellent properties,

offering eco-friendly crop pest and vector management solutions against mealy bugs and *Anopheles stephensi*.

Virulent strains of fungi like *Nomuraea rileyi* and *Metarhizium anisopliae* managed pests like *Spodoptera litura* and *Helicoverpa armigera*, while bacterial isolates showed promising antifeedant and mosquitocidal properties. A total of 475 chickpea rhizosphere bacteria isolated were screened for their control efficacy against the corresponding pest *H. armigera* out of which eight potential strains were identified based on molecular taxonomy using 16S rDNA with gene submissions in NCBI. *Bacillus thuringiensis* MSSRF S1, *Bacillus amyloliquefaciens* MSSRF S2, *Bacillus cereus* MSSRF S4, *Bacillus thuringiensis* MSSRF S5, *Enterobacter cloacae* MSSRF S8, *Exiguobacterium mexicanum* MSSRF S9, *Proteus hauseri* MSSRF S11 and *Pseudomonas aeruginosa* MSSRF S20 exhibited pest control attributes. Possible environmental association and mode of action of the chickpea rhizosphere bacteria and the naturally existing chick pea pest control microbes were explored. This study emphasizes the tritrophic interaction between host plants, pests, and their beneficial microbiome. It also highlights the potential of *Exiguobacterium mexicanum* compounds for crop protection through chemical characterization and identification. The same was tested successfully on multiple crop pest and mosquitoes species which are vectors of dreadful diseases such as malaria, dengue, yellow fever, chikungunya etc. Farm level survey and research across India have given deep insights on the need for pesticide and crop protection guidance for farmers and the same to be given in regional languages so that the farmers can themselves act instantly and use right pesticide at right dosage, hence developed a mobile based application software AGRICENTRAL based integrated pest management recommendations and machine learning and successfully launched in Indian market free of cost for farmers and the same is used by lakhs farmers across India. Thirteen other significant industrial innovations in the field of entomology and product development were internationally patented under the Patent Cooperation Treaty (PCT).

IMPORTANCE OF SURFACTANTS, WETTING AGENTS, BIO STIMULANTS, REPELLANTSININTEGRATED PEST MANAGEMENT

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Abstract

After extensive survey across Pesticide companies revealed that they market Insecticides, Fungicides, Herbicides, Miticides to relevant crops as per the label claim by Central Insecticide board. It was found that all these Pesticides are sprayed indiscriminately on crops where the efficacy of pesticides are affected due to different leaves surfaces where the spray droplets bounce off plant foliage. Evonik – Germany Manufactures Surfactants where they market to various pesticides companies across the world. UPL a Pioneer in Crop Protection were not marketing Surfactants in India. Evonik had two surfactants which include Ammoniacal Surfactants which was found effective when used along with pesticides on Cereals. Evonik also Manufactures Silica Based Surfactants which was found effective when used along with Pesticides especially on Horticultural crops. UPL Management decided to launch both surfactants in two brand names U- WET (Ammoniacal surfactant) and U- WET SUPER (Silica Based Surfactants) Both products were launched across India which was well received by farmers who cultivated both Cereals and Horticultural crops. Ocean Agro Industries Private Limited Manufactures Wetting Agents in the brand name WET WELL which was well accepted by farmers especially Cardamom farmers in Idukki District. Wetting agents are earliest formulation of sticking agents which were sold by SANDOZ and TEEPOL and INDOFIL as INDTRON especially on crops grown on Hilly areas. Bio stimulants are substances or micro-organism applied to plants with the aim to enhance nutrition efficiency, abiotic stress tolerance and or crop quality traits regardless of its nutrient content. Suma Agro India Private Limited Manufactures Ortho Silicic Acid in brand name Silgro, where Silica plays a main role in protecting plants from Insect and fungal infestation. This product was well received by Monocot crops which include Paddy and Sugarcane. UPL also promoted Ortho Silicic

acid in the brand name GAINEXA from Privi Life Science Pvt ltd. Ortho Silicic acid comes under FCO as beneficial element fertilizer that boost overall plant health. Ortho Silicic acid optimizes Crop nutrient status, reduces yield gap, improves crop quality (taste, nutritional status, color etc.) Suma Agro also Manufactured Chitosan Oligosaccharide in brand name CHITOPRO which was found effective in controlling Fungal and Viral diseases in Horticultural Crops cultivated in Dharmapuri and Krishnagiri. There are other Bio Stimulants which are widely used in not only in IPM but also Soil Health especially Humic acid, Fulvic acid & Ulmic acid. Ocean Agro industries Private Limited were the first Manufacturers of Bio stimulant in the Brand Name Amrut Sanjeevani. This product was well accepted by Vegetable farmers in Theni District. In Rayappan patti village, Theni district farmers used to bring the Amrutsanjeevani empty bottle to ask for the brand. Organic carbon a derivative extracted from Lignite was pioneered by Suma Agro who sold Humic acid in the brand name HUMICAS and JEEVAN was widely used by Tamil Nadu Agricultural department for promoting organic agriculture among farmers. Finally, Eco sense Labs pioneered Citronella based repellant HERBITOK which is promoted by UPL.

CAPACITY BUILDING AND TRAINING OF FUMIGATION, URBAN PEST MANAGEMENT, ANDFOOD SAFETY STAKEHOLDERS – MY CONTRIBUTION AND JOURNEY SO FAR

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Abstract

Globally, fumigation, urban pest management, and food safety are gaining importance as these areas directly impact the protection of property and human health. With growing societal awareness about hygiene and food safety, risks associated with urban pests, microorganisms, and food contaminants are being taken seriously. Consequently, Fumigation, urban pest management and food safety businesses have grown exponentially. A positive business environment and promising growth trends have attracted professionals, including students, to explore careers in fumigation, urban pest management, and food safety, either as entrepreneurs or working professionals.

Being active in this sector, I assessed and realized the need for capacity building and training key stakeholders to deliver quality services that protect property and community health while ensuring operational safety for professionals handling pesticides. Over my 30+ years in this sector, I have focused on planning and executing training and capacity-building initiatives. Below are some of my key contributions and initiatives:

Good fumigation practices training for commercial stakeholders in grain handling was designed and executed under my supervision in India and in many Asian countries which also included 2,000 village- level training programs in India under the "Save Grain Campaign" to support farmers. We also managed to conduct five State Agricultural University (SAU) workshops in collaboration with the Entomological Society of India (ESI), bringing together stakeholders, students, and farmers. Bhutan's National Quarantine Standards was developed by us in consultation with PQ officials of Bhutan.

In urban pest management segment under our supervision 5000 pest control technicians were trained in Asia. Similarly, we designed and conducted Pest Management Strategy Training for business owners in the pest management sector. Now we are introducing professional Urban Entomologist courses in collaboration with ESI and the Indian Pest Control Association (IPCA).

In Food safety domain we collaborated with the Food Safety and Standards Authority of India (FSSAI) as part of their Train the Trainer program during the introduction of FSSAI regulations and numerous workshops were organized by us to raise awareness among Food Business Operators about the FSSA Act and regulations. To disseminate technical information about technical aspects and sustainable solutions in these subjects, paper presentations have been done by me at various global platforms.

Over the past 31 years, my contributions have centered on post-harvest management, urban entomology as well as food safety focusing training, developing innovative processes, empowering technicians, and advancing sustainability. We also worked closely with associations, societies, and institutions globally to foster knowledge-sharing and awareness.

As I look back on this journey, I am filled with gratitude for the opportunities to create a lasting impact on post-harvest protection, urban pest management and food safety. I remain committed to furthering these efforts, driving innovation, and contributing to a sustainable future.

Certificates of Appreciation

WING SPOT IN A TROPICAL AND A TEMPERATE DROSOPHILID: C=C AND CONSERVED THERMAL RESPONSE

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Abstract

Wings are primarily used in flight and also play a role in mating behaviour in many insects. In many *Drosophila* species, wings exhibit a variety of pigmentation patterns. In some sexually dimorphic Drosophilids, a pigmented spot pattern is found at the top-right edge of the male wings. Our understanding of wing spot thermal plasticity in sexually dimorphic species is limited and links wing spots primarily with sexual selection. Here, we investigated the wing pigmentation response of two species with wing spots: *D. biarmipes* and *D. suzukii* species to thermal variation. We exposed freshly hatched larvae of both the species to three different growth temperatures and checked for wing pigmentation in adult males. Our results indicate wing pigmentation is a plastic trait in the species studied and that wing pigmentation is negatively correlated with higher temperature. In both species wings were darker at lower temperature compared to higher temperature. Further, *D. suzukii* exhibits darker wing pigmentation compared to *D. biarmipes*. Variation in wing pigmentation in both *D. suzukii* and *D. biarmipes, D. suzukii* could reflect habitat level differences; indicating a strong G*E interaction. Raman spectral analysis indicated a shift in chemical profiles of pigmented vs. non-pigmented areas of the wing. The wing spot was found enriched with carbon-carbon double-bond compared to the non-pigmented wing area. We report that C=C formation in spotted area is thermally controlled and conserved in two members of suzukii subgroup *D. biarmipes* and *D. suzukii*. Our study indicated a conserved mechanism of the spot formation in two *Drosophila* species coming from contrasting distribution ranges.

ESI Best PhD Thesis Awardees

ECO-FRIENDLY PEST MANAGEMENT STRATEGIES FOR SUSTAINABLE ORGANIC CULTIVATION OF CAULIFLOWER

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Abstract

Cauliflower (*Brassica oleracea* L. var. *botrytis*), a vital winter vegetable in India, is valued for its nutritional and low-calorie content. However, its production is hindered by biotic and abiotic factors, particularly insect pests that reduce yield and quality. Farmers often use synthetic insecticides to combat pests, leading to issues such as pesticide residues, pest resurgence, and resistance. This necessitates sustainable and eco-friendly pest management strategies. The study investigated the biology and demography of two major pests: mustard aphid, *Lipaphis erysimi* (Kaltenbach) (Hemiptera: Aphididae), and diamondback moth, *Plutella xylostella (L.)* (Lepidoptera: Plutellidae), on five brassicaceous vegetables using the 'TWOSEX-MS Chart' software. The nymphal duration of *L. erysimi*, varied across host plants, ranging from 5.82 days on mustard to 8.80 days on broccoli. The *L. erysimi* had the highest biotic potential and reproduction rate on mustard, whereas broccoli had the lowest. Similarly, under field conditions, *L. erysimi* showed significant population growth on cauliflower and cabbage. The doubling time was shortest on mustard (1.98 days) and longest on broccoli (3.30 days). The results on demography of *P. xylostella* on five hosts shows that, development periods differed significantly among hosts. The population reared on mustard and cabbage exhibited the highest fecundity (234 and 231 eggs per female, respectively), while knol khol had the lowest (133 eggs per female). The r-value, representing population growth, was highest on mustard (0.20) and lowest on knol khol (0.14). Field studies evaluated intercropping systems and biopesticides. Intercrops such as calendula and marigold significantly reduced pest incidence and enhanced natural enemy populations. Calendula intercropping recorded the lowest *P. xylostella* larvae (6.58/plant) and attracted beneficial insects like syrphids, coccinellids, and parasitoids (*Cotesia*

vestalis and *Cotesia glomerata*). The tri-trophic interaction of candytuft flower with *D. rapae* significantly influenced the decline in aphid populations; for every increase in one *D. rapae*, there was a decrease of 48.53 aphids in 2018. Different intercropping systems resulted in varying percent increases in cauliflower yield compared to the control: candytuft (39.14%), calendula (52.44%), marigold (50.21%), cineraria (13.77%), and flower mix (14.77%). Intercropping of calendula resulted in the highest revenue return of 11.33/rupee invested (calendula IS), as against the monocrop of cauliflower (1.58). Biopesticides were tested for their efficacy against *P. xylostella*. Spinosad was the most effective, reducing pest populations by 65.92% in 2017-18 and 73.08% in 2021-22. Other effective treatments included azadirachtin, *Bacillus thuringiensis*, and *Beauveria bassiana*, though with varying levels of control. Persistence toxicity (PT) studies showed spinosad had the longest residual effect, followed by azadirachtin and *B. thuringiensis*. The study highlights the potential of eco-friendly pest management approaches, including biological control, intercropping, and biopesticides, to promote organic cauliflower cultivation. Calendula intercropping and spinosad emerged as the most effective strategies for reducing pest damage and enhancing yield, offering sustainable alternatives to synthetic insecticides.

BIOSYSTEMATIC STUDIES ON LEAFHOPPER (HEMIPTERA: CICADELLIDAE) SPECIES ASSOCIATED WITH BAMBOO FROM INDIA

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Abstract

Leafhopper family Cicadellidae (Order: Hemiptera) is one of the largest insect family with over 22,000 described species. They are economically important as most species cause considerable damage by directly feeding on the plants and a few others by being vectors of plant pathogens. The current study aimed at identification, compilation of as checklist, description/ redescription with formulations of keys for the taxa at all levels and molecular characterization of leafhopper species associated with bamboo. Attempt was also made to solve problems of misidentification due to existence of colour polymorphism among the species. Explorations conducted at 35 locations of 12 states of India led to the collection and study of around 8000 specimens. For the descriptions, emphasis was given to male genitalia variations. The annotated checklist compiled included details of valid name, synonyms, type locality, location of depository and geographical distribution along with new records from India. This checklist included 12 tribes, 38 genera and 65 species from India and also included details of 12 first records for India along with 13 new locality records established during the current studies. Diagnostic keys were also prepared for identification at all taxonomic levels. Forty six species belonging to 32 genera from 12 tribes under 5 subfamilies resulted in the discovery new genera *viz., Bambuphaga* gen. nov.; *Niranjana* gen. nov., and *Shanaya* gen. nov.; and new species *viz*., *Bambuphaga balajii* sp. nov.,*Mukariella viraktamathi* sp. nov., *Mohunia manohari* sp. nov., (Mukariini),*Myittana (Myittana) bidentata* sp. nov., *Niranjana bicaudospina* sp. nov., *Niranjana indica* sp. nov., *Niranjana curvielongata* sp. nov., *Shanaya spatulata* sp. nov., and *Shanaya abeeri* sp. nov. to science. Phylogenetic analysis based on morphological and molecular data 28S (D2 & D9-D10) and Histone (H3) revealed the paraphyletic nature of tribes.

TAXONOMY, BIO–ECOLOGY, DISTRIBUTION AND CONSERVATION PRIORITIES OF MAYFLY (INSECTA: EPHEMEROPTERA) IN SELECTED STREAMS OF SOUTHERN WESTERN GHATS, INDIA

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Abstract

The Ephemeroptera (mayflies) are the oldest order of winged insects, with a lifespan ranging from hours to days as adults. They evolved around 280-350 million years ago, likely from Lepismatoid ancestors. The order is represented by approximately 40 families and 3,330 species worldwide, with 204 species in the Indian sub-region. Mayflies are found in lentic and lotic freshwater habitats and are key biological indicators of water and habitat quality. Their ecological role includes contributing to zoobenthos production and nutrient cycling. Mayflies' life cycles vary by region, with tropical species often having multiple generations per year, while temperate species may take years to mature. In India, the study of Ephemeroptera dates back to 1843, with notable contributions from researchers over the years. The Western Ghats' unique geography and climate have fostered endemic species, but anthropogenic climate change and habitat destruction threaten their survival. Mayflies are important in nutrient transfer between aquatic and terrestrial environments. Despite their ecological significance, their weak dispersal capabilities and sensitive life stages make them ideal for phylogenetic and biogeographic studies. Notable discoveries in India include new genera such as *Petersula* and *Edmundsula*, which are Gondwanan relicts. In this study, diversity, taxonomy, bio-ecology, and conservation priorities of mayflies were investigated (Insecta: Ephemeroptera) in the 60 selected stream/ riverine regions of the southern Western Ghats from three states viz., Tamil Nadu (TN), Kerala (KL), and Karnataka (KA). A total of 11,137 individuals belonging to 88 species from 13 families of mayflies were recorded in the Western Ghats. Diversity and distributional studies were done for the mayfly communities collected from 2017 to 2020, and in three different seasons viz.,

Pre-monsoon (March-June), Monsoon (July- November), and Post–monsoon (December- February) in 2018-2019 in 60 selected streams/ rivers of the southern Western Ghats. The distributional patterns of mayflies were analyzed in the selected streams/ rivers of the south of Western Ghats. The present study found that the mayfly taxa *Baetis* sp. (RTU14) and *Caenis* sp. (RTU16) were present in all collection sites of the Western Ghats. The burrowing mayfly species of the genus *Ephemera* in the Western Ghats were reviewed based on the character distribution and present status of materials in the National Museums. Four new species viz., *Ephemera kapilaensis* sp. nov., *Ephemera kodai* sp. nov., *Ephemera kudremukha* sp. nov. & *Ephemera subramanyai* sp. nov. were described based on nymph and adult characters from montane and submontane streams/ rivers of the Western Ghats. Molecular evolutionary relationships of the genus *Ephemera* were analyzed. CCA was done for the analysis of bio-ecological aspects of mayfly communities in the Western Ghats. Conservation priorities of mayfly communities were analyzed through various knowledge shortfalls with regard to the Western Ghats mayflies. A checklist and dichotomous key for the larvae of mayflies in the Western Ghats, and key for the larvae and adult (male imago) of the newly described species were provided.

MOLECULAR CHARACTERIZATION OF ACARICIDE RESISTANCE IN BROADMITE, *POLYPHAGOTARSONEMUS LATUS* (BANKS) (TARSONEMIDAE: ACARI)

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Abstract

Broad mite/ yellow mite, *Polyphagotarsonemus latus* (Banks), is one of the devastating pests of chilli, capsicum, mulberry and many economically important crops. A decreased susceptibility of this mite to commonly used acaricides was ascertained in many populations across different locations. Hence, investigations were undertaken to determine the levels of acaricide resistance at the field level, the stability of resistance over generations, the rate of developmental risk of resistance under acaricide selection and molecular characterization of fenazaquin resistance in *P. latus*.

Bioassays with field populations of *P. latus* collected from five districts of Karnataka, namely Bengaluru, Chikkaballapur, Haveri, Ramnagara and Tumkur, showed varying intensities of acaricide resistance. The resistance ratios ranged from 26.03 to 81.16 folds for diafenthiuron, 27.35 to 83.47 folds for dicofol, 9.72 to 45.42 folds for fenazaquin, 8.77 to 16.84 folds for propargite and 48.37 to 163.39 folds for spiromesifen. A decline in field-evolved resistance varying from 14.11 to 102.53 folds was observed over the generations of laboratory rearing in the absence of acaricide selection pressure, indicating the recessive nature of resistance alleles. Further, the risk of the development of fenazaquin resistance in laboratory-selected populations was determined using a sub-population of *P. latus*. The response of *P. latus* to fenazaquin selection over generations revealed 11.63 folds increase in LC50 value with a realized heritability (h^2) value of 0.20. It was observed that only 26 generations were required for a 10-fold increase in LC50 and the fenazaquin-selected strain also developed moderate cross-resistance to the other tested acaricides.

The research established genomic resources for *P. latus* for the first time through *de novo* transcriptome sequencing that resulted in 129 million high-quality reads and 17,697,517,328 bases. From the transcriptome, 33 transcripts of cytochrome P450s (*CYP*s) were identified that comprised of five new *CYP* families containing 24 novel genes that are not reported from any other living system. Additionally, 20 glutathione S-transferases (*GST*s), 21 carboxyl/cholinesterases (*CCE*s) and 36 ATP binding cassette (*ABC*) transporters were identified and categorized. The differential expression analysis between fenazaquin-resistant and susceptible samples identified 21 genes coding for major families of detoxification enzymes or possible novel detoxification players.

Since there were no prior reports on reference genes in *P. latus*, the expression stability of six candidate housekeeping genes were analyzed. Of these, ribosomal protein S18 (*RPS18*) and ribosomal protein 49 (*RP49*) were observed to be the most stable reference genes across fenazaquin-resistant and susceptible populations. Validation of comparative transcriptome data by quantitative real-time PCR was performed for four putative *CYP* genes, viz. *CYP4725A2*, *CYP4726A1*, *CYP4CL3* and *CYP4CF4* and two each of *GST*s, *CCE*s and *ABC*s. The qRT-PCR results correlated with the transcriptome data where the genes showed similar target regulations. This study provides a valuable resource for understanding how *P. latus* metabolizes xenobiotics using potential detoxification genes. Also, the genes identified from the transcriptome could be screened to obtain potential targets for RNA interference technology to knock down the resistance- conferring genes from this pest.

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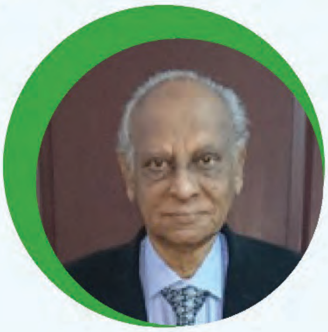

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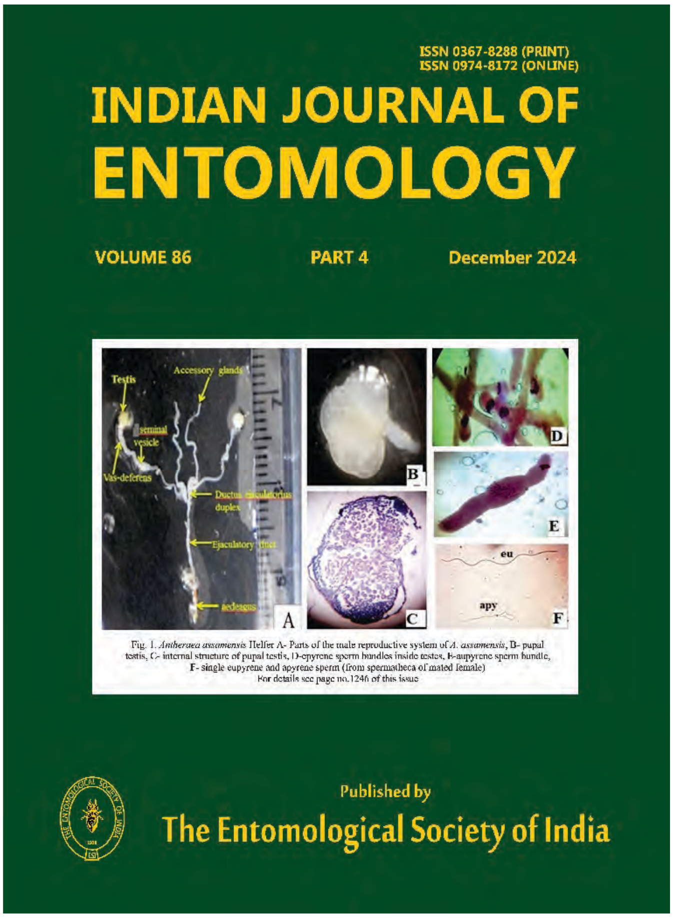

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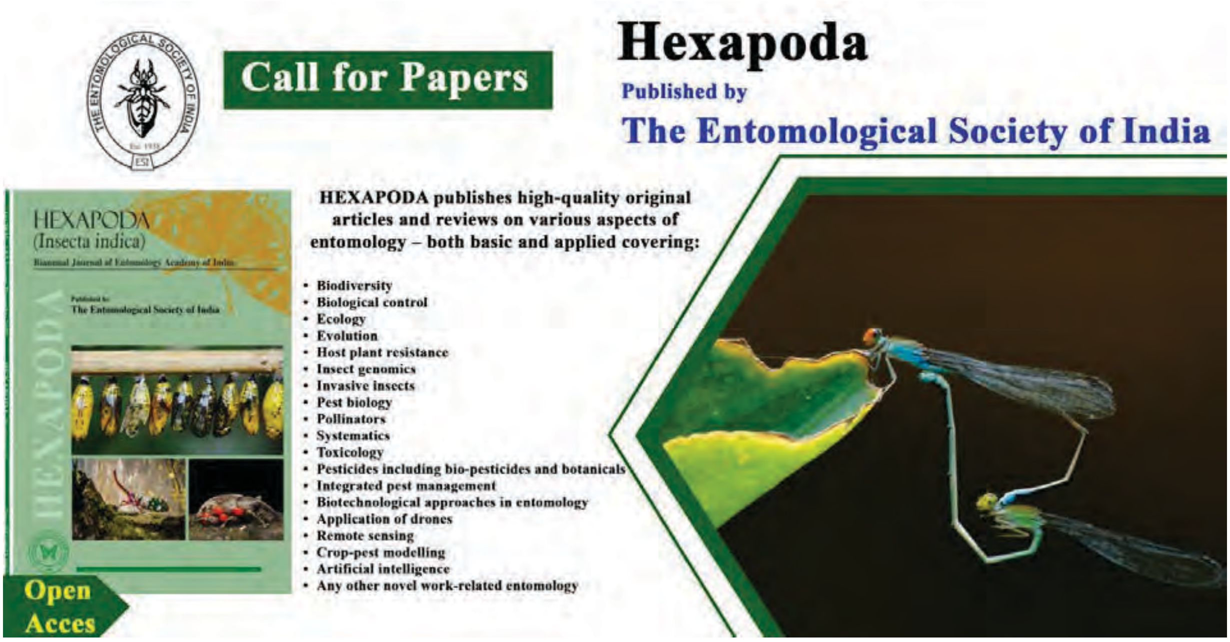

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Entomology Students Conclave ESC2025
(March 15 to 17, 2025)
Venue: AAU, Jorhat, Assam

ESC 2025

Event for Students & Research Scholars

Explore, Innovate, Present! Be the Future!

ENTOMOLOGICAL SOCIETY OF INDIA

Serving the scientific community since 1938

ABOUT ESC2025

Building upon the success of the inaugural Entomology Student Conclave (ESC2024) held in Bengaluru, we are delighted to welcome you to ESC2025 at Assam Agricultural University, Jorhat, Assam. This unique event presented by The Entomological Society of India (ESI) brings together students, young researchers, and experts to engage in meaningful discussions, share innovative research, and explore emerging trends in the field of entomology. It fosters a collaborative environment where aspiring scientists can deepen their understanding of insects and other arthropods, while also networking with peers and established professionals. ESC2025 is more than a traditional conference, it is an event organized and coordinated by young researchers, for young researchers.

WHO CAN PARTICIPATE?

- Students of M. Sc. and Ph. D. on roll and those who have completed their degree till 31 January 2025 (Registered students)
- Research scholars who are working in *Ad-hoc* positions as YP/JRF/SRF/RA in research projects are permitted to present their M. Sc. or Ph. D. thesis work (Maximum age limit 32 as on 31 January 2025)
- Faculty/scientists and/or other delegates can attend the event only as mentors and should bear the cost of their logistics.

GUIDELINES FOR ESC2025

- Shortlisted candidates selected during the initial screening will be offered the opportunity to deliver their presentations in person/virtual.
- TRAVEL GRANT: Limited travel support is available to the candidates who do not have fellowship/research assistance (limited to 20). The candidates are required to submit separate application for travel grant on ESC2025 portal.
- For best oral and posters outstanding presenters at ESC2025 will be recognized.
- Certificate of participation will be provided to all registered candidates.

SUBMISSION OF ABSTRACT

- The abstracts are to be submitted only on the online portal of ESC2025.
- Candidate should submit only one abstract in a specific theme.
- The detailed guidelines are provided in the portal and candidates should strictly adhere to the template.
- Last date for submission of abstracts is 15.01.2025 (12.00 PM).
- The details of short-listed candidates oral, poster and virtual presentations will be intimated by 15.02.2025.

WHAT TO EXPECT AT ESC2025?

- Captivating Presentations and Workshops: Dive deep into the science of entomology with expert-led sessions that cover everything from insect behavior to the latest research in arachnids. Gain hands-on experience and learn about cutting-edge techniques in the field.
- Networking Opportunities: Connect with fellow students, researchers, and professionals who share your passion. Forge lifelong friendships and collaborate on future projects in an environment that fosters mutual learning and growth.
- Engaging Discussions and Panels: Participate in thought-provoking discussions and panels that address current challenges and advancements in entomology. Gain insights into various career paths and the impact of entomological research on global issues.
- Cultural Exchange: Experience the local culture and traditions as you interact with participants from different backgrounds. Discover how different regions celebrate and study insects, and gain a global perspective on entomological science.

SPONSORSHIP

PLATINUM: Rs. 300000.00	GOLD: Rs. 200000.00
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Space for exhibiting the products, 10 min slots for presentations

ESI EVENTS AT A GLANCE

ESI Foundation Day 2024

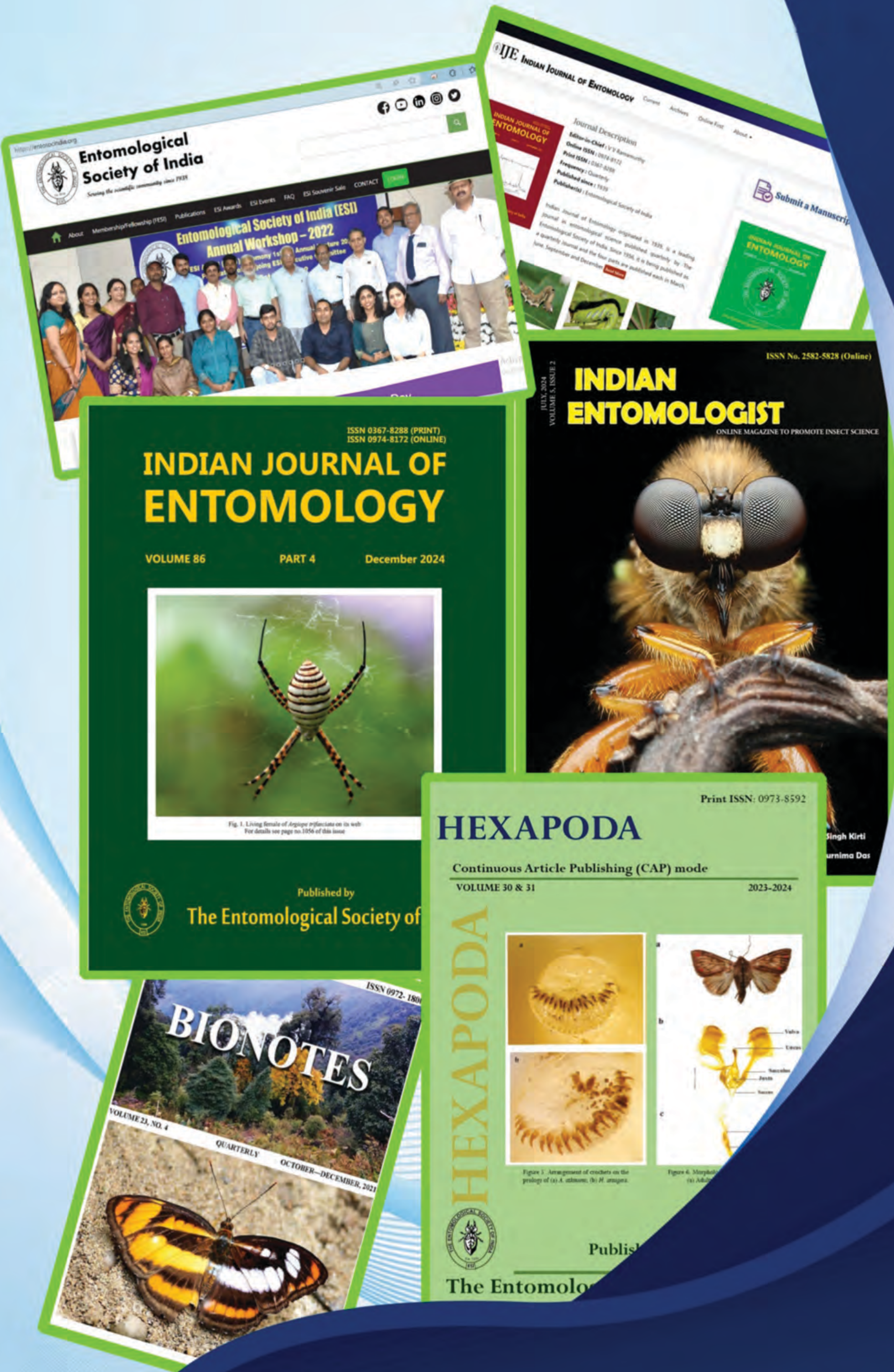
ESI Foundation Day 2024

Entomology Students Conclave 2024

NATIONAL CONCLAVE ON STINGLESS HONEY BEES 2024

NORTH ZONE INTER-UNIVERSITY ENTOMOLOGY QUIZ – 2024
organized by
DEPARTMENT OF ENTOMOLOGY, CSK HIMACHAL PRADESH KRISHI VISHVAVIDYALAYA, PALAMPUR 176062 (H.P.) &
ENTOMOLOGICAL SOCIETY OF INDIA

The Department of Entomology, School of Agriculture, Lovely Professional University in collaboration with the Entomological Society of India (ESI), New Delhi organized a One-week "Skill Development Program on "Insect-Inspired Art and Design" (19th to 25th November 2024)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