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FEATURING

From Dung to Decay: The Unusual Diets of Butterflies

Inspiring women entomologist: Dr. V. Kamalanathan

Entomophilately: Collecting Insects without net

INDIAN ENTOMOLOGIST

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Cover picture image: Common Mormon caterpillar by Suresh Khaire from Vadodara, Gujarat.

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THE BUZZ ON ONE HEALTH: WHY ENTOMOLOGY AND IPM MATTER

Dr. V. V. Ramamurthy
Editor-in– Chief

The One Health approach recognizes the intricate connections between human, animal, and environmental health. As we strive to address the complex health challenges of our time, it's essential that we acknowledge the critical role of entomology and Integrated Pest Management (IPM) in maintaining the delicate balance of our ecosystem. Insects, as vectors of disease and pests of crops, play a significant part in shaping human and animal health. From malaria and dengue fever to agricultural pests that compromise food security, the impact of insects on human well-being cannot be overstated. Entomology, the scientific study of insects, is vital in understanding the biology, ecology, and behaviour of these tiny creatures. By unraveling the complexities of insect biology, we can develop effective strategies for managing pest populations, reducing the spread of disease, and promoting sustainable agriculture practices. IPM, a holistic approach to managing pests, is a cornerstone of sustainable agriculture and public health. By combining physical, cultural, biological, and chemical controls, IPM minimizes the use of chemical pesticides, reduces the development of pesticide-resistant pest populations, and promotes ecosystem services.

As we move forward in our pursuit of One Health, it's imperative that we: 1. Integrate entomology and IPM into our health and agricultural policies. 2.Support interdisciplinary research and collaboration between entomologists, epidemiologists, veterinarians, and policymakers. 3. Promote sustainable agriculture practices that prioritize IPM and reduce the reliance on chemical pesticides. 4. Enhance public awareness* about the importance of entomology and IPM in maintaining human and animal health.

By embracing the principles of One Health and recognizing the vital role of entomology and IPM, we can create a more sustainable, equitable, and healthy world for all.

BEES AND THE QUEEN OF SPICES

DR. VASUKI V. BELAVADI
Professor Emeritus
Department of Entomology
UAS, GKVK, Bengaluru– 65

Cardamom (*Elettaria cardamomum* (L.) Maton), the Queen of Spices, also referred to as **small cardamom** or **true cardamom**, is native to the Western Ghats of India. It is considered as one of the world's oldest spices. Cardamom is the third most expensive spice in the world after saffron and vanilla. It was an important commodity of trade between India and Greece during 4th Century BC. Cardamom is mentioned in 3rd Century BC as a medicine for stomach and urinary disorders in Ayurvedic literature (Nair, 2006). It is also mentioned in both Charaka Samhita and Sushrutha Samhita, the ancient Indian Ayurvedic texts written in the post-Vedic period (Nair, 2011).

The major cardamom producing countries in the world are India, Indonesia, Guatemala, Sri Lanka, Tanzania and Papua New Guinea. Guatemala, India and Indonesia are the major cardamom exporting countries. In India, cardamom is cultivated in Kerala, Karnataka and Tamil Nadu (Fig. 1) and cover an area of 70,410 ha with a production of 25,230 tonnes (Anon, 2024). Kerala with 57.29% of area produces 90.63% of cardamom. During 2023, India exported 8,000 tonnes of cardamom earning over 155 million USD (~1300 crores of INR).

The Plant

Cardamom belongs to the ginger family (Zingiberaceae) and grows in clumps of 20 to 25 pseudostems (Fig. 2). It is cultivated under the shade of trees. Each pseudostem bears at the base one or two panicles that bear flowers. There are three types of cardamom – Malabar type (with prostrate panicles), Mysore type (with erect panicles) and Vazukka type (with semi-erect panicles). Malabar type is cultivated in Karnataka while Mysore and Vazukka types are more common in Kerala. Cardamom flowers are exclusively cross pollinated and depend on bees for pollination and fruit set.

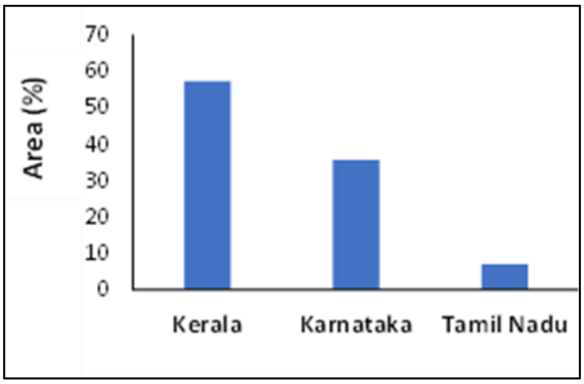

Fig. 1 Area under cardamom cultivation.

Fig. 2. Cardmom crop.

Cardamom Flower

The flower is hermaphrodite self-compatible, with three greenish sepals and petals (Fig. 3). The petals fuse at the base to form a nectar tube of about 23 mm long. The flower has a broad whitish lip like structure, referred to as labellum or flabellum that protrudes from the tip of the nectar tube and has pinkish nectar guide markings. Labellum acts as a landing platform for bees and the nectar guides lead bees to the nectar tube. According to Parameshwar and Venugopal (1974) the labellum is formed by the fusion of three modified anthers. Ovary is trilocular, each locule with nine ovules. There is a single style with an expanded stigma above the anther lobe. Anthers are herkogamous Because of the location of stigma above the anther lobe (approach herkogamy), self-pollination is avoided. Further, pollen grains are sticky, and hence require an agent.

Figure 3: Cardmom flower.

Floral Biology

Flowering commences by last week of April and will continue till first week of November, with peak flowering between June – August. Anthesis (flower opening) occurs in the early morning between 4.30 and 6.30 am. Anthers dehisce and release pollen grains around 7.30 am. Pollen remains viable the whole day and though stigma is also receptive all through the day, peak receptivity is around 12 noon. Longevity of individual flowers is between 15 to 18 hours and should get pollinated on the same day of anthesis (Belavadi and Parvathi, 2000).

Flower visitors

Cardamom flowers are visited by several species of bees including honey bees, stingless bees and solitary bees like the blue banded bees. Of these the honey bees, mainly *Apis cerana* and *A. dorsata* are the most frequent visitors, especially during the peak flowering months. Visitation frequency depends on the flower density (Belavadi et al., 1993). In the beginning and end of the season when the number of flowers per clump will be less than five (Fig. 4), honey bees ignore cardamom, as they have to spend more energy and have to visit more flowers distributed on several clumps. Since a forager bee gets only about 0.3 µl in each flower (Belavadi and Parvathi, 2000). The crop (stomach) capacity of a foraging *A. cerana* is ~ 40 µl. Hence, to fill its crop it has to visit about 125 to 135 flowers. If the number of flowers per plant is 4, the bee has to fly around not less than 30 clumps and the spacing between clumps will be 1.8 m, which is both energy and time consuming. Foragers of *A. cerana* commence foraging by the end of May or in the beginning of June and their activity keeps away *Amegilla* spp . When the density/number of flowers per clump increases beyond 15 or 20, *A. dorsata* start appearing and they will replace the *cerana* bees. In the months of April, May and again from September to November, the flowers are mostly visited by the blue banded bees (*Amegilla* spp.) (Fig. 5).

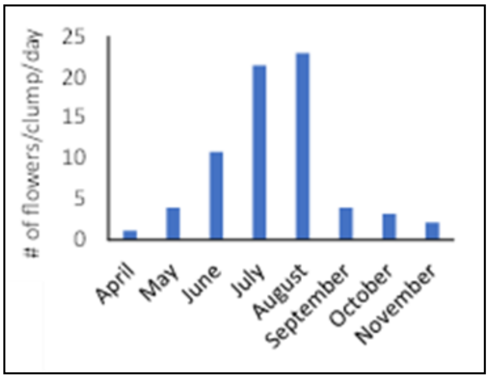

Fig. 4 Flower density in different months.

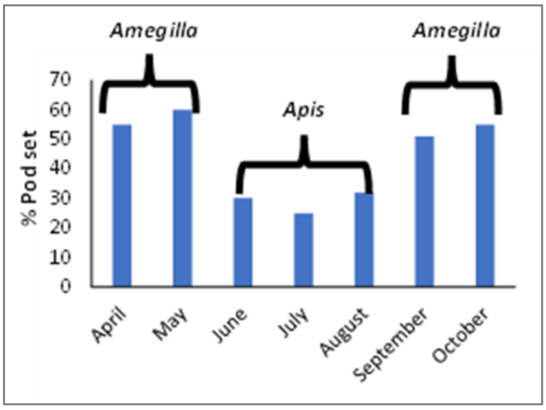

Fig. 5 Per cent fruit set by different flower visitors.

This observation indicated two things – that the blue banded bees (*Amegilla* spp.) are more efficient pollinators than *Apis* spp. and that the population of *Apis* bees may not be sufficient enough to pollinate the available number of flowers in the peak season.

Are blue banded bees better pollinators?

During the peak flowering, measurements of nectar level in the flowers showed that nearly half of the nectar remained unharvested, despite very high activity of honey bees (Fig. 6).

Figure 6: Cardamom flower with 50% nectar remaining after a bee visit.

In the beginning and towards the end of flowering season the nectar level was very much lower, when the blue banded bees will be active compared to the peak flowering time (Fig. 7). Observations on the tongue lengths of these bees and how deep they could access for nectar in the flowers revealed that, despite their shorter tongue lengths of 4.5 and 5.5 mm, the honey bees, could to draw nectar upto 11.5 mm (Belavadi et al., 1997) while *Amegilla* spp. with their longer tongue could exhaust all the nectar available in the flower (Fig. 8). This lead to a hypothesis that *Amegilla* spp. were probably the original pollinators of cardamom. In the wild, the population of cardamom plants will be low and probably *Amegilla* do the job, while under cultivated conditions, the plant population and flower density will be high, and honey bees being opportunistic flower visitors, compete and replace solitary bees, but can take only upto ~50% of available nectar. In the cardamom variety Mudigere- 1, on which most of the observations were made, the corolla length is 23 mm and can hold 4 µl of nectar when the flower is prevented from bee visits. Hence, in each flower, nearly 2 µl of nectar remains which may go waste.

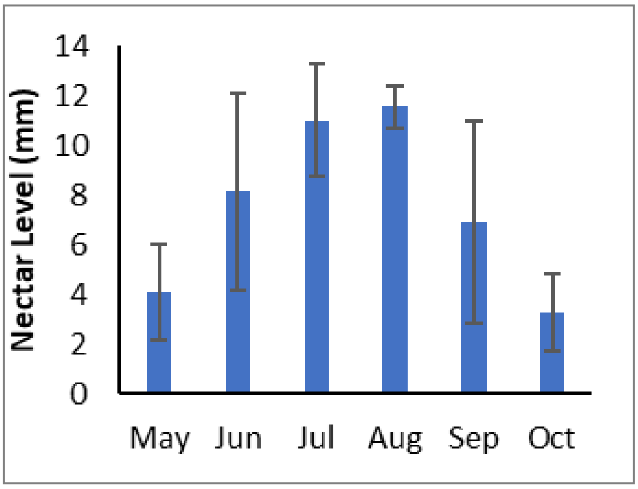

Figure 7: Nectar level in corolla tube.

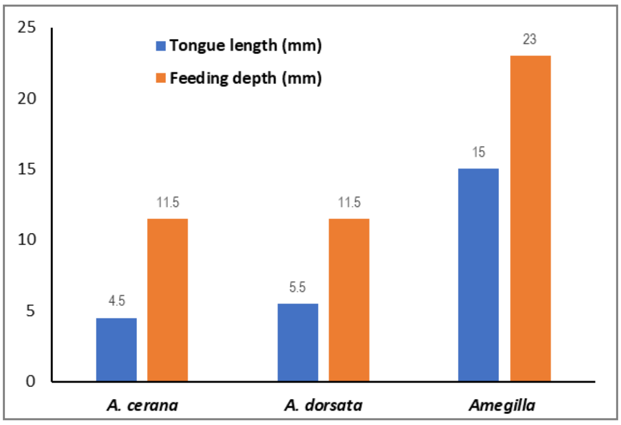

Figure 8: Tongue length and feeding depth by bees.

Nectar production is costly and the plant has to spend lot of energy (Pyke, 1991; Pyke and Ren, 2023). Hemce, one can hypothesize that if corolla length is shorter, the plant may spend less energy in nectar production and invest the saved energy in producing more flowers. Measurement of the corolla lengths of 173 entries in the germplasm collection including the released varieties, at the Zonal Agricultural Research Station, Mudigere, revealed significant variation (Fig. 9). Interestingly, all high yielding cultivated varieties fall to the left of the distribution, indicating that, corolla length can be used as a trait for selection by the cardamom breeders.

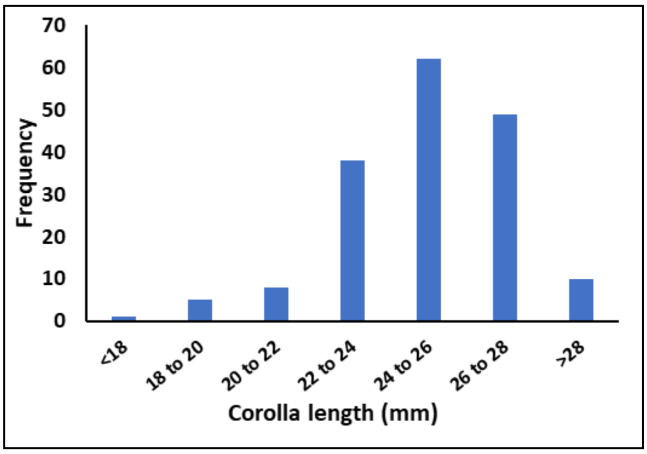

Figure 9: Corolla length of cardamom entries in germplasm collection (n = 173).

Is there a pollinator deficit?

In a study, all flowers produced by ten randomly selected clumps of cardamom were counted from the first day of flowering till the last day and the number of capsules set in each clump was recorded. The number of flowers per clump ranged from 615 to 1700 with a mean of 1170 and the number of flowers setting capsules ranged from 200 to 590 with a mean pod set of 30 per cent (Fig. 10).

If this low pod set is due to pollinator deficit (low population of foragers), can the population of bees be increased and by how much. Based on earlier studies on the foraging behaviour of individually marked *A. cerana* bees (Parvathi et al., 1993), following information was available. a) A single bee visits as many as 130 flowers in one visit; b) A single flower required at least 20 visits to set capsule; c) On an average, there will be 20 flowers/clump every day; d) There are 3000 clumps/ha, e) So, there will be 60,000 flowers in an hectare requiring bee visits and f) Number of visits required per day is 1,200,000. Based on this, it was estimated, that at least 9000 foragers are required per ha (Belavadi and Parvathi, 1998).

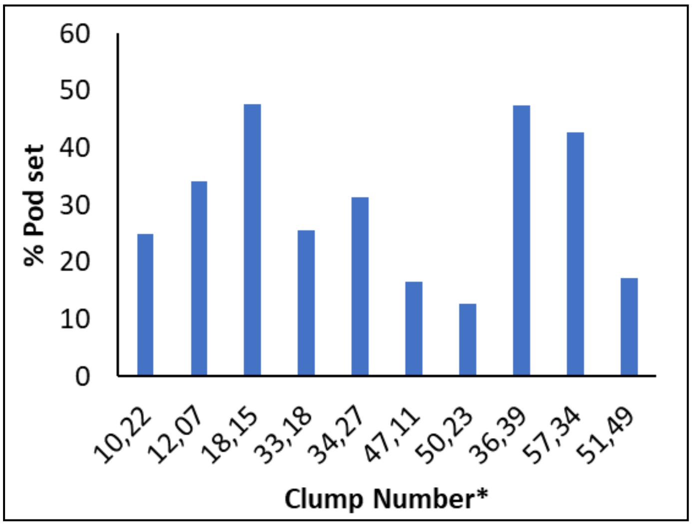

Figure 10: Per cent pod set in cardamom (*first two digits refer to row number and the next two digits to the plant number – 10th row 22nd plant).

Considering the available information on the normal colony size of a 8-frame hive to range between 12,000 to 15,000 workers and about one-third of the workers will be foraging (Inoue et al, 1990; Dyer and Seeley, 1991), a field trial was conducted with two colonies per ha, assuming that there will be at least 4000 to 4500 foragers in a colony. There were three treatments – 1. No flower visitors; 2. Open pollination (feral bees) and 3. Two colonies of *A. cerana*/ha. The results clearly indicated that the cardamom pod set can be more than doubled by introduction of two colonies and the pollinator deficit can be overcome.

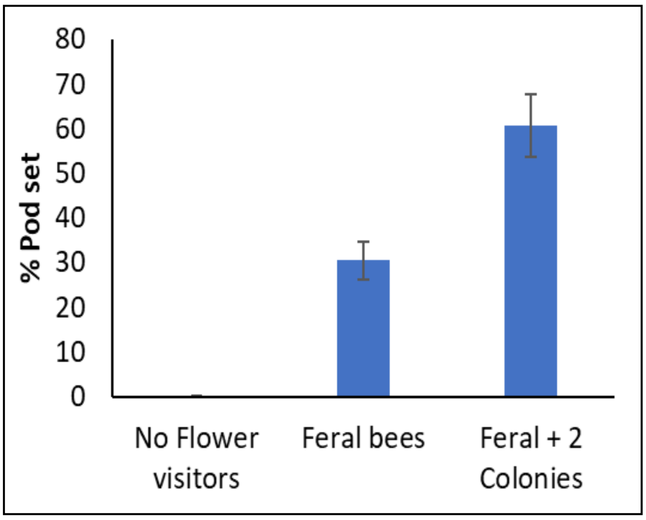

Figure 11: Overcoming pollinator deficit.

Economic value of pollinators in cardamom

Economic value of insect pollination service is determined by multiplying the pollinator dependency index (Pdi) with total economic value of the crop (TVC). TVC is the total production multiplied by the market value per unit. Since pollinators are essential for the pod set in cardamom, the Pdi for cardamom is taken as 0.95. Total production of cardamom in 2023-24 was 25,230 tonne and the lowest market value in 2024 was Rs. 1000/- per kg. The EVIP for cardamom is Rs. 2396.85 crores.

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A DIALOGUE WITH DR. ANANTANARAYANAN RAMAN

A VISIONARY ECOLOGICAL ENTOMOLOGIST WITH AN INTERNATIONALLY RECOGNIZED EXPERTISE IN THE FIELD OF INSECT AND PLANT INTERACTIONS.

It is a proud privilege and an honour to interview a visionary Entomologist Anantanarayanan Raman, who has specialized on gall-inducing arthropods and who works on the mechanisms from both insect and host-plant perspectives, interlinking the ecology and physiology of the interacting organisms. He holds two doctoral degrees and has extensive undergraduate and postgraduate teaching experience in Agricultural Ecology, Forestry, Ecological Entomology, Agricultural and Forest Entomology, Plant Pathology and Nematology. He has been investigating issues related to sustainability and sustainable-land management over last 25 years. He is an internationally recognized expert in the field of insect and plant interactions and the winner of the prestigious Fulbright Award in 1990 and the Deutscher Akademischer Austaush Dienst [DAAD] Award — twice — in 1991 and 2003. He has, to his credit more than 300 research publications documented in international journals, further to a dozen books and monographs. His work and publications demonstrate his independent research capabilities, further to a strong capability to organize and administer teaching and research projects, and critically analyze their outcomes. He has a strong commitment to the development of higher education and pedagogical processes with advanced written and oral communication skills. With all these, he is an effective teacher and a motivated researcher with accomplished leadership, problem solving, and group facilitation skills, which are well supported by an extensive international work experience.

Brief bio-data

He was born to Sri K. P. Anantanarayanan and Srimathi R. Parvathy in Madras (now Chennai), Tamil Nadu. He completed his high-school education from Sir M. Ct. Muthiah Chettiar Boys' High School (now a Higher-Secondary School), Purasawalkam, Chennai. He completed his B. Sc. Degree from Loyola College, Chennai. Later he completed his master's from Presidency College, Chennai.

Soon after post-graduation, he was appointed as a Lecturer at Loyola College and in 1972, joined Dr. T. N. Anantakrishnan's research group. Inspired by Dr. Anantakrishnan, he took up studies on gall-inducing insects and started his PhD on the physiology of galls induced by Phlaeothripidae (Thysanoptera) and the ecology of the inducing Phaleothripidae, which included the extraction of salivary glands of the inducing thrips taxa and their biochemistry for enzymes. He , travelled to Université Louis Pasteur, Strasbourg, France, to work with Odette Rohfritsch at the *Laboratoire de Cécidologie* (LdC), directed by pioneer Cecidologist Jean Meyer. During his several months stay in Strasbourg, he had occasion to be associated and work with other leaders of gall studies, Evelyn Westphal, Roberte Bronner, Françoise Dréger, who were scientists at the LdC. He earned his first doctorate in 1981.

He married Lata née Vaideswaran in 1983. He continued to work with Dr. T. N. Anantakrishnan. In 1990, he was awarded the Fulbright Fellowship by the Fulbright Commission, c/- The Bureau of Educational & Cultural Affairs, U. S. Department of State, Washington, D. C. He was associated with Warren Gene Abrahamson, Burpee Professor of Plant Genetics, Bucknell University, Lewisburg, Pennsylvania and worked on the energetics and nutrient mobilization in gall systems, using *Rhopalomyia solidaginis* (Diptera: Cecidomyiidae)–*Solidago altissima* (Asteraceae). Soon after, he moved to the Universität Heidelberg, Germany winning a *Deutscher Akademischer Austaush Dienst* (DAAD) Fellowship and worked with Rolf Beiderbeck on dual-aseptic culture of insects and their host plants, testing the model system *Trialeurodes vaporariorum* (Hemiptera: Aleyrodidae) and its host plant *Stellaria media* (Caryophyllaceae). He standardized the protocol for the dual culture of a *T. vaporariorum* and cultured shoots of *S. media.* The protocol published in the *Zeitschift für Angewandte Entomologie* (= *Journal of Applied Entomology*) is popularly referred in literature as the Raman–Beiderbeck protocol.

In 1996, he moved to Australia to join the University of Sydney, Orange campus, New South Wales. Notable that this campus changed to Charles Sturt University in 2006. During this tenure, he worked on the tortricid *Epiblema* and a curculionid *Conotrehalus* infesting *Parthenium* in association with Kunjithapadam Dhileepan, Queensland Department of Primary Industries, Brisbane. His average academic productivity in terms of quality-journal publications was from 13 to 18 papers/year.

He submitted his 2-volume thesis staking the claim for the title of Doctor of Sciences of the University Madras and got the title in 2003. During his tenure as a Senior Academic at Charles Sturt University, Orange, he supervised 18 Ph. D students, 12 research-Honours students, and 1 MPhil student. In 2020, he joined CSIRO, Perth, Western Australia as a Senior Scientist.

He has won several research grants and recognitions. He was the recipient of the Agricultural Innovation Research Excellence Award given away by Charles Sturt University & Graham Centre for Agricultural Innovation in 2016. Earlier for three years in succession he won the Faculty of Science Research Excellence Award also by the Charles Sturt University. He was awarded the Australian Academy of Science Visiting Professorship in 2008 to visit a few universities in Japan and Taiwan. The Entomology Academy of India honoured Raman with the M S Mani Centenary Award in recognition of the multiple contributions to Indian Cecidology. Crowning all of these, he was recognized by the Indian National Science Academy, New Delhi, as the Vulimiri Ramalingaswamy Chair in 2018, upon the nomination by Raghavendra Gadagkar and Raman Sukumar of the Indian Institute of Science, Bangalore. During this travel, he lectured and conducted workshops at the Centre for Ecological Sciences, Bangalore, delivered lectures at Tamil Nadu Agricultural University, Coimbatore, Manonmaniyam Sundaranar University, Tirunelveli, Manipur Central University, Imphal, Indian Agricultural Research Institute, New Delhi, and Indira Gandhi National Open University, New Delhi.

Interview of Anantanarayanan Raman (AR) by Dr. Kolla Sreedevi (KS)

KS: Is the study of insects a choice or chance?

AR: Definitely by chance. During my undergraduate days at Loyola College, Madras, I had known of Ananthakrishnan, who was then heading the department of zoology; but my acquaintance with him at that time was casual; the silver lining was that I had chances to meet him often. However after my post-graduation when I joined Loyola College as an academic, our relationship got strengthened. I used to spend more time with him at the Entomology Research Unit, which he directed.

KS: Can I know the inspiring or guiding force behind choosing Entomology?

AR: Ananthakrishnan was a key force. He was a towering personality by his seriousness of purpose and academic productivity. He was the singular recognized specialist of the Thysanoptera throughout the world then. Like any other academic of those days, he spoke English eloquently and charismatically. His oratory power and the high-quality English he wrote was one strong factor that attracted me to him; entomology was --- then --- secondary. He presented himself most elegantly and gracefully, appearing far younger than his real age. All of these, and the power of science brought us close to each other. Moreover during my post-graduate days at the Presidency College, Madras, I was fortunate to have a great Indian biologist, B G L Swamy, as professor and his classes were a deep source of inspiration. He did not teach like everyone. He inspired me by flinging challenges both within the class and outside. That practice stimulated me to think outside the box and importantly unconventionally. This intellectual background of challenging the raw and the apparent must have fostered and cemented the relationship between me and Ananthakrishnan. But I am not sure whether this is correct. Anyhow circumstances came around and I was naturally sucked into exploring the world of insects, starting with the Thysanoptera.

KS: How did the study of gall-inducing insects become your favourite?

AR: While being a post-graduate student at Presidency College, one of my lecturers was K V Krishnamurthy, who spoke to me about insect-induced galls and suggested that we look into their biology. As an MSc student, I helped him out working out the leaf galls on an epiphyte *Aeschynanthus perrottetii* (Lamiales: Gesneriaceae) induced by *Prolasioptera aeschynanthus-perrottetii* (Diptera: Cecidomyiidae). During this investigation, I carried several draft manuscripts for reading, editing, and commenting by Ananthakrishnan in Loyola College. This experience also brought me closer to Ananthakrishnan. This first co-operative work with Krishnamurthy resulted in a journal paper published by a then highly prestigious journal dedicated to study of insect galls and their agents, *viz.*, *Marcellia*, edited and published by Jean Meyer at the Laboratoire de Cécidologie, Université Louis Pasteur, Strasbourg, France. Publication of this paper in *Marcellia* enabled me to know many who were working on galls outside India, the world of galls, and started reveling in those biological marvels. I co-operated with Krishnamurthy and derived some support and guidance from Ananthakrishnan after I joined Loyola College as a lecturer. Krishnamurthy, Ananthakrishnan, and I jointly published papers on galls induced by diverse arthropods, such as, *Aneurothrips priesneri*

(Thysanoptera: Terebrantia), *Baris cordiae* (Coleoptera: Curculionidae), and *Aceria cordiae* (Acari: Eriophyidae) hosted by *Cordia obliqua* (Boraginaceae). This study was published in the *Ceylon Journal of Science*. At this time, I came under the influence of B Vasantharaj David, research officer with Ananthakrishnan. David introduced me to the Aleyrodidae; David and I jointly published the biological details of *Indoalyrodes pustulatus* (Hemiptera: Aleyrodidae) that induces pit galls on the leaves of *Morinda tinctoria* (Rubiaceae) in *Cecidologia Indica* published by Prabha Grover, a Cecidomyiidae specialist of India then, of the University of Allahabad. Once these works were published, I enthusiastically dug my claws deeper into this subject, since this field panned out to me a dynamic discipline of insect—plant interactions, a widely sought-after theme in the 1980s. Moreover I got introduced to paper publishing. Seeing my name in print became an addiction.

KS: Have you faced any challenges in studying gall-inducing insects or the mechanisms involved in gall induction.

AR: Not one; several. During my early days of study not much about galls was known. As I was starting to work on my PhD thesis pertaining to the nutritional physiology of select-species of gall-inducing Phlaeothripidae (Thysanoptera), I needed to learn how the mouth-parts of the miniscule thrips were organized and to dissect the salivary glands aiming to analyze the salivary proteins. I struggled. This was a major, nerve-wrecking challenge. However, I mastered the craft of teasing out the salivary glands in the next few weeks. During field trips determining the identity of the gall-hosting plants was another challenge. Ananthakrishnan would determine the inducing thrips. But knowing the binomial of the plant was a Himalayan task: invariably when I went to the field, I got only galls with plants bearing no reproductive structures: neither fruits nor flowers. I learnt how to ascertain plant identities using only vegetative characters, similar to the practices followed by foresters. Since Loyola College was essentially an undergraduate college, the kind of facilities and equipment I had at my disposal were minimal. I worked with student microscopes. Facilities to carry out physiological work was unthinkable. I had to resort to using elementary paper-chromatography to separate salivary proteins. In the next decade I mastered techniques of histochemistry to qualitatively characterize functional components of both host-plant and insect tissues. What satisfies me most today is that I could interpret my findings and publish them in recognized professional journals in spite of the hiccups and handicaps I experienced.

KS: Can you please elaborate on the significant Raman–Beiderbeck technique for the benefit of readers. Is it related to gall-inducing insects?

AR: First I should clarify that what is generically referred as the Raman–Beiderbeck technique in reality does not pertain to gall-inducing insects and their physiology. Plant-tissue culture was popular in the 1980s and some insect tissue culture was also known. Rolf Beiderbeck of the Universität Heidelberg was a trained plant-tissue and protoplast culturist and he was trialing dual aseptic culture that involved culturing plant tissues and raising the infesting arthropods simultaneously on those aseptically grown plant tissues, which was known as dual-aseptic culture. I was impressed by this and sought training with Beiderbeck in 1991. I used *Stellaria media* (Caryophyllaceae) as the host tissue for aseptically growing populations of *Trialeurodes vaporariarum* (Hemiptera: Aleyrodidae). The main challenge that involved weeks and weeks of trials was to apply the right percentage concentration of sodium hypochlorite to surface sterilize the eggs before placing them on the cultured *S. media* tissue in defined enriched agar medium. Defining the right concentration of the NaOCl solution — the surface sterilant — so that the embryo is not killed because of micropyles was a major challenge. However I succeeded and it eventuated as a protocol paper published in *Zeitschrift für Angewandte Entomologie* (today the *Journal of Applied Entomology*). Micro details of this protocol can be extracted from: Raman, A. and Beiderbeck, R., 1992, Aseptic dual culture of the greenhouse-whitefly *Trialeurodes vaporariorum* Westwood (Hom, Aleyrodidae) and its host *Stellaria media* (L.) Vill. (Caryophyllaceae), *Zeitschrift für Angewandte Entomologie*, **113**: 252–257. Although I did not use a gall-inducing insect in this work, I am aware that many trials involving gall-inducing arthropods have been used by several persons across the world. This protocol has been handy in clarifying the functional aspects of gall-inducing insect and its plant relations.

KS: It's fascinating to hear that you have continued your research work on gall-inducing insects throughout, what made you continue or keep going in the same field.

AR: Thank you for your generous words. When I started work on gall-inducing insects (*sensu lato*, to include species of Eriophyidae (Acarina) as well), my first understanding was that this is an interactive system that intimately involves a plant on the one hand and an arthropod (an insect, mostly) on the other. Therefore I told myself that I needed to be acquainted with every detail of the arthropod I was working on and I needed to possess the same acquaintance with the host plant. An absolute clarity of this understanding made me appreciate the dynamics of their interactions: how the insect exploits the plant and how the plant responds to insect action — producing an enchantingly symmetrical structure, *i.e.*, the gall, and eventually restrains the stress inflicted by the inducing insect. Importantly the gall is an restraining outcome. The alterations induced by the insect action are elegantly restricted to the gall site only. Nothing transcends further, unlike the tumours induced by the Rhizobiales (e.g., *Agrobacterium tumefaciens*). In the Rhizobiales-induced tumours, secondary tumours arise with no *A. tumefaciens* in them. A tumour-principle is transmitted through the plant and secondary tumours eventuate. In arthropod-induced galls nothing of that sort occurs and will ever occur. Gall will materialize where a larva (e.g., Cecidomyiidae) or a population (*e.g*., Phaleothripidae, Adelgidae) will infest. With this clarity I approached insect-gall systems, first using the Phlaeothripidae-induced galls and later with species of the Psylloidea. For a better understanding of galls, I looked into galls induced by the Beesoniidae (Hemiptera: Coccoidea), Eulophidae (Hymenoptera), Curculionidae (Coleoptera), and Tortricidae (Lepidoptera). But works on these insects were not consistent. My consistent work pertained to my exploration of developmental physiology of galls induced by the Phlaeothripidae and the nutritional physiology of the corresponding Phlaeothripidae, when I commenced serious work. From 1985 I shifted to studying the gall-inducing Psylloidea and their galls that were plentifully available in the vicinity of Madras. I worked out the biology and bionomics of an unusual gall-inducing Psylloidea *Phacopteron lentiginoisum* (host plant *Garuga pinnata*, Burseraceae) and published my results in the journal *Phytophaga* in the 1990s. Based on my work on the biology and bionomics and unusual oviposition behaviour of *P. lentiginosum,* Daniel Burckhardt (Basle, Switzerland), a world-Psylloidea authority, moved this taxon from the Pauropsyllidae as indicated by

Ram Nath Mathur of Forest Research Institute, Dehra Dun to a newly erected uni-generic Phacopterinidae.

Every time I completed a work and got a publication ready, I had new questions. Seeking answers to those questions kept me fully engaged and I have felt that a lot more needs to be done in this discipline. What was vital was clarity of thinking and intent of purpose.

I need to clarify here that I have published extensively on the chemical ecology of *Heteronychus arator* (Coleoptera: Scarabaeidae) and biophytic (non-pathogenic) endophytic fungus *Neotyphodium lolii* (Hypocreales: Clavicipitaceae) included in *Lolium perenne* (Poaceae). Once some clarity of these interactions was achieved, then I explored the effect of heterotrophic (pathogenic) fungus *Botrytis cinerea* (Helotiales: Sclerotiniaceae) infecting *Vitis vinifera* (Vitaceae) and *Epiphyas postvittana* (*e.g.*, *Entomologia Experimentalis et Applicata*, **160**, 47–56). In addition my research group has published extensively on the eco-restoration of contaminated land sites (*e.g*., high level metal-contaminated mine sites and salinity-afflicted crop lands) using phytoremediation techniques. The novelty in this effort was that we established diverse phytoremediation possibilities employing plants native to eastern Australia.

KS: Having expertise in teaching and research, which one you enjoyed the most.

AR: Undeniably and undoubtedly I enjoy being a teacher. But my conviction is that to be an effective and contemporary teacher, I need to be an active research person. Research enabled me to keep abreast of scientific and technological developments that enabled me to perform as a better teacher. Importantly, research empowered me with a deep sense of curiosity to know more. That curiosity was a powerful tool useful in my classroom and field teachings.

KS: May I know the turning point in your career?

AR: I cannot think of anything as a critical turning point. But my permanent migration to Australia leaving my homeland was painful. Taking up an academic position with the University of Sydney required me to change many aspects of my professional life. I had to re-train myself in the new ambience I was situated in circumstances beyond my control. Teaching style had to be different because of cultural differences. But the better element was that I could quickly adapt and respond to new needs, thanks to my earlier overseas stints and experiences. Perhaps this can be considered a turning point in my life. New demands, new practices dealing with the new environment. I had to re-invent myself.

KS: In your opinion, what makes an inspiring teacher?

AR: What makes an inspiring teacher? In my thinking one who is able to touch and connect with the hearts of learners while transmitting the information is an inspiring teacher. Learners always remember such a person with passion and a shade of gratitude.

KS: Having worked in India and abroad, can you please throw light on suggestions for the quality research?

AR: In my opinion, honesty and academic integrity are the keys to quality research. Even if we are only able to turn around only ordinary research outcomes (means not necessarily cutting-edge research, trail-blazing research, sexy research) as long as those outcomes are steeped in honesty and integrity then I would consider that quality research. I am highly depressed to read news items that speak of paper retractions by editors of high-class journals on a regular basis based on reasons of plagiarism, lack of academic honesty and integrity. This makes me think whether we have lost our values precluded by and shadowed by the rush for development and technology. Depressing and nauseating.

KS: Can we know the overseas opportunities in Entomology field

AR: Opportunities are aplenty. But it requires constant vigil and serious search. Opportunities are wide and open. However, Indian university training in Entomology and other biological disciplines still follow an examination-oriented training programme (please see my article entitled, 'What is a curriculum, what is its purpose: reflexions on an entomology curriculum for India', *Indian Journal of Entomology*, 2017, **79**, 121–122). This is not desirable. Western universities train their learners (in all disciplines, including entomology) by challenging them and triggering them to seek and learn by themselves. Curriculum cannot be misconstrued for syllabus; it is not simply words and dashes. Curriculum is a complex term that has multiple dimensions and multiple components. University-level learners need to be enabled, empowered, and equipped to seek knowledge by themselves and build problem-solving capability. When this is attained, we will be better practitioners anywhere: within and without. When learners are empowered to seek knowledge by themselves, they will automatically build confidence in the self; a self-confident, yet humble person will be automatically sought by employers in India and elsewhere --- quite naturally.

KS: It's wonderful to know that you have about 100 papers on the history of Madras (Now Chennai), how it's possible to balance the interest in different disciplines (lines/areas)

AR: Elementary, Watson (with apologies to Arthur Conan Doyle: creator of Sherlock Holmes)! Science bores and frustrates me many a time. At those dull moments, reading about and exploring my home town --- Madras, and not Chennai ---- by stretching and applying my scientific thinking and training, I feel rejuvenated. That gives me significant respite from the rigmarole of science. I am able to think as an artist and act as a humanist. Every aspect I explore about the city and state of Madras gives me ample opportunities to appreciate and re-live in the past, which appears glorious to me. In my eyes, buildings and other structures rise and fall, dynasties evolve and degenerate, humans come and go. For example, I have chronicled the lives and works of many medical doctors who had served --- some biased and some unbiased --- humans in Madras city and presidency in diverse ways. In that process they have, or rather should have, enabled longevity and better health by curing peoples' illnesses and chronic diseases. Ironically those medical personnel had died someday that divulges to me: *c'est la vie.* Life is full of education. I learn modesty and humility from writing about the history of Madras, which I see as a matter of reprieve from the occasionally frustrating and boring science including entomology.

KS: Can you narrate your hobbies or interests other than science

AR: I am not sure whether I have any practice that can be listed as a hobby. I have a few alternative interests, such as the one explained above. Other than that I am interested in learning and knowing about India's rich culture, history, and heritage. Proudly I share my thoughts on these aspects when asked to share. Some of my close friends discuss matters relating to these topics with me and I joyfully participate in those conversations. I share what I know and importantly I stand to gain from those conversations. I am deeply interested in the Dravidian stock of Indian languages. I am an ardent fan of Badriraju Krishnamurti (former Vice-Chancellor of Hyderabad Central University), an eloquent authority on Dravidian languages and I speak of his messages on the relationships and individualities of Tamil, Kannada, Telugu, Malayalam, and most importantly Tulu, a minor Dravidian language spoken in pockets of *Dakshina Kannada* and Northern Kerala.

KS: Your advice and suggestions to the young generation.

AR: I am nobody to advice anyone else. But I am a firm believer in truthfulness, honesty, and academic integrity. I am a strong believer that the underpinning element of research in any discipline is sincerity and not greed to win positions, accolades, and awards. These are my personal values. I would not say these publicly to anyone. I am sure every individual can and will take care of him-/herself.

Concluding remarks by KS:

It was a great pleasure and privilege interviewing Dr. Raman and was a great learning experience hearing to his rich experience and expertise. Dr. Raman is an accomplished teacher and a dedicated researcher. I was very much impressed by his perseverance, objectivity, critical thinking and time management. His career journey speaks of his commitment, determination, dedication and devotion. It was a sheer delight and honour interviewing Dr. Raman, which was an edifying conversation. I am sure that this interview and journey of Dr. Raman's scientific approach in understanding and deciphering the mechanisms of gall induction by insects will benefit the readers at large and inspire students and young scientists in particular to pursue their career in gall inducing insects, which is a key area to work upon.

Dr. Kolla Sridevi conducting interview of Dr. A Raman

Dr. Kolla Sreedevi is an ICAR National Fellow and Principal Scientist heading Scarabaeid lab in Division of Germplasm Collection and Characterisation, ICAR-NBAIR, Bengaluru. She has got more than 15 years of experience in taxonomy of beetles.

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FROM CURIOSITY TO INVENTION: INSIGHTS FROM DR. S MOHAN

DR. S MOHAN, POPULARLY CALLED AS 'TRAP MOHAN', IS A WELL KNOWN PRACTICAL ENTOMOLOGIST IN THE FIELD OF STORED PEST MANAGEMENT IN INDIA.

Dr. Sarma Mohan (popularly known as 'Trap Mohan') is well-known figure among all the Indian entomologists and is a regular addition in the syllabus of any student preparing for the competitive exams. Because of his invention of the "probe trap," a novel and still-in-use trapping mechanism for managing stored grain insects at home and farm levels, our generation mostly knows him as *Trap Mohan*. I got the opportunity to interview him for the 'Indian Entomologist' magazine, I felt I was fortunate as I am also working in the field of post-harvest and storage entomology. To begin with his introduction, Dr. S. Mohan (SM), born in 1958. He earned his bachelor's, master's, and doctorate (in-service) degrees from Tamil Nadu Agriculture University (TNAU) in 1980, 1982, and 1993, respectively. He started his scientific career as Assistant professor in 1983, promoted to Associate professor (1997) and Professor (2000) at TNAU exclusively until retiring in 2018. He held a number of positions throughout his career, including Chairman of the Committee to Revamp and Revitalize the Agricultural School Education in Tamil Nadu, Dean of the School of Post Graduate Studies—In charge), Special Officer (Publications and Public Relations), and many more. He taught agricultural entomology to many students, organized various trainings, served in research, extension and education positions. His "TNAU-Stored Grains Insect Pest Management Kit," which featured all his devices, was a success in the 1990s. He published over 60 research publications in peer reviewed national and international journals and most of them are on non-chemical pest management. Dr. SM is a research-extension oriented scientist; he organized several training courses, published numerous popular articles and training manuals, and was awarded with a prestigious Swami Sahajanand Saraswati Outstanding Extension Scientist Award (2010), by ICAR. He has received numerous such honors, including the TNAU Best Researcher Award (2005), the NRDC, GoI's Technology Day Invention Award (2002), the TN government's Award for Stored Grain Insect Trap (1993), and others. In 1994, the Government of TN named the 'Probe Trap' developed by him as 'Mohan Trap' which is a matter of great honour. He is instrumental in successful establishment of five startups through licensing of his technologies and details of it is available at https://www.mohantrap.com/. Even after his retirement, Dr. SM is actively involved in popularizing the non-chemical stored product insect management technologies.

Dr. Guru P. N. (GPN): Sir, on behalf of Indian Entomologist Magazine, I thank you for accepting our invitation to share your experience with the magazine. Can you please tell us how you entered the field of Entomology?

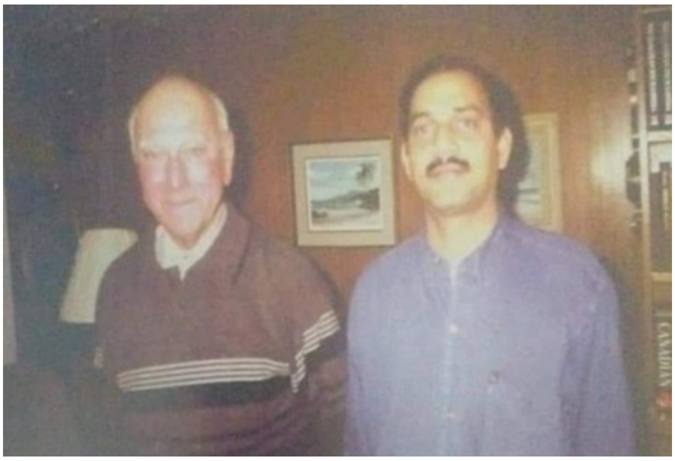
Dr. S. Mohan (SM): When I joined the undergraduate program in Agriculture in 1976, I was a ‘memorising machine’ - reproducing anything by heart as such even the comma (,) or any other symbols. It was an era of multiple-choice tests in agricultural curriculum, and I enjoyed it with my memorising skill. During this course of study, my entomology teacher used to bring one wall chart board with full of insects’ scientific names which were like sweets for me to byheart and reproduce and get full marks. A turning point happened in 1979 when I was studying ‘Pests of crops’ course, where I could get only 17/20 marks. Something went wrong in my memorising machine, my system. Majority in my class got more marks than me, I was so upset and returned to the hostel and took my UG diary and wrote ‘I was born for Entomology, live for entomology and I will die for Entomology’. Still, I remember this event of 1979 even today, which was my 3rd year graduation. In actuality, this marks the start of my path towards the study of "entomology." When we discover our skills, it awakens our inner selves and serves as a reminder of why we were born; in my case, to become *entomologist*.

GPN: How come an ‘Extension Entomologist’ turned into an ‘Engineering Entomologist’ in TNAU?

SM: ‘A miracle…’. My research career in Tamil Nadu Agriculture University (TNAU) started in 1983 and I was posted in ‘National Demonstration Scheme’ of Indian Council of Agricultural Research (ICAR), wherein popularization and demonstration of proven entomological technologies to farmers was the main role. Writing popular articles was one of the components in transfer of technology. As I got good memorising skill, it helped me in writing many popular articles. Interestingly, the first article in my service was on ‘*Storage technologies for Paddy’*. I was unknown at that time in 1983, when I wrote this popular article on grain storage that this would be my research destination. I called it as my research destination (my home coming) i.e., ‘Stored product insect management’. Research is a continuous journey where the path matters more than the destination and, on this journey, the right place of posting also matters a lot. I was transferred in 1986 to Post-Harvest Technology (PHT) Scheme of ICAR in the Agricultural Engineering College (AEC) of TNAU, Coimbatore. Spending 6 to 7 years in the PHT Scheme, ICAR in AEC, TNAU turned me in to an *‘Engineering entomologist’*, and the place where all innovations of my carrier happened and are continuing even after retirement. I continued popularising all my technologies with the support of social media and my friends.

GPN: Sir, we all know you as ‘Trap Mohan', please tell us the story behind it?

SM: It is a beautiful story. After my transfer to PHT scheme of ICAR, TNAU, unlike the present times, back then, we did not have a large-scale resource base as well as access to universal knowledge and information through the Internet etc. TNAU library was the only source of knowledge nd only hard copies of journals were available.



Dr. S. Mohan along with Dr. S.R. Loschiavo in Canada.

I was fortunate togo through the special issues of *Canadian Entomologist* Journal on topics like detection of stored grain insects written by eminent scientists across the world. One research paper I came across was 'Loschiavo S.R, Atkinson J.M 1967. A trap for detection and recovery of insect in stored grain, *Canadian Entomologist,* 99 (11): 1160 -1163'. I was impressed by the research paper and decided to adopt a similar approach for India, so that one day the subject of stored grain insect monitoring and management would be understood throughout the nation. It is a non-chemical method, which turned out to be my area of research. After reading this paper, the first device I developed was 'Probe Trap', a modified version and a suitable form for our country. This is a small gadget to remove insects from the grains for household users. It was merely ₹5 at the time, and TNAU introduced this technology in 1993. It was a fantastic event (I was not present because I was celebrating a festival in my hometown), and to my complete surprise, my guide sent me a telegram informing me that my first device had won ₹5000 and that it was proudly christened "Mohan Trap" and had been granted a government order. This was a great feel of happiness in my research career. It was very popular in my province as well as many parts of India as 'Mohan trap'. Although it was developed in 1993, it was first commercialised in 2000 and made available to various states within country and countries like France, Africa, Thailand and others. Later, many entrepreneurs taken license and started manufacturing and marketing of the device. Most of the people in India especially academicians including students remembered this 'Probe Trap' as 'Mohan trap'. It was an historical event where a technology named after a scientist, and this was a great gesture of government.

GPN: Can you please tell us about other technologies developed by you and your patents?

SM: Prior to discussing technologies, I would like to point out that in 2005, I was assigned to complete a six-month training program at McGill University in Quebec, Canada, as part of the TNAU-McGill Canadian International Development Agency Project on Food Security in South India. There, I received assistance from professors Dr. Venkatesh Sosle and Dr. G.S. Vijaya Raghavan in order to fulfil my goal of distributing the TNAU gadgets developed by me to students around my nation. They helped me fund my idea on developing a "Tool kit" for teaching and training. Thus, all my technologies came to one place, like probe trap, pit fall trap, two-in-one model trap, indicator device, automatic insect removal bin, and UV light trap, and my two patented technologies. The TNAU Kit was launched by Tamil Nadu Agricultural University, Coimbatore on September 15, 2005. Detailing of all these technologies are available at a fingertip on internet.

Secondly, people often asked me if I had patents for my inventions. Until then, I had never given it much thought, as there was little awareness about the importance of patenting. Later, in 2002, the Indian government decided that in order to apply for any invention award for a product / process, patenting is necessary. I got my first patent granted in 2006, and the path guided me towards patented innovation was credited to Dr. Paul Fields, Scientist, CRC, Canada. In 2000, I was deputed to Cereal Research Centre (CRC), Agriculture and Agri. Food Canada, Winnipeg, Manitoba under AHRDP (Agricultural Human Resource Development Programme) scheme of World Bank for training in the area of my specialization in stored product insect monitoring under the mentorship of Dr. Paul Fields. Initially he listened to me and understood my fervent desire and accommodated me to CRC library in 2000 Feb-March gave me an important research paper

(Quentin, M.E, J.L. Spencer and J.R. Miller. 1991. Bean tumbling as a control measure for the common bean weevil, *Acanthoscelides obtectus* (Say). *Entomologia Experimentalis et Applicata.* 60: 105 - 109). This paper was a precursor for my dream turning true. I got my two technologies patented *viz*., A Device to Remove Insect Eggs from Stored Pulse Seeds (IP No. 198434) and a device to monitor insects in bag stacks in warehouse without bait (IP No. 284727).

GPN: Can you please elaborate on the challenges you faced during your career and how you overcome from them?

SM: My journey has often felt like a hurdle race. At every step, I encountered obstacles, and each time I crossed one, I needed to regain stability to prepare for the next. Despite these challenges, my success in this field has helped raise awareness at various levels about the importance of this science. People slowly started discussing green technologies and non-chemical strategies, particularly for stored grain protection. Consumers are gradually accepting these methods, though it took time for my technologies to gain widespread recognition. The driving force behind my journey was motivation, as I firmly believe motivation propels a nation forward, while demotivation hinders its progress. I am deeply grateful to everyone who motivated me, directly or indirectly, as their support laid the foundation for my strong research career. During that time, the focus in pest management was primarily on Integrated Pest Management (IPM) for crops like cotton, sugarcane, vegetables, paddy, and other staples. Many of my peers and fellow researchers mocked me, asking, "Why are you working on such 'useless' technologies?" Yet, I remained determined. In the end, it was my determination, patience, perseverance, and persistence that led to my success. These qualities can help anyone overcome hurdles, just as they helped me.

Dr. S. Mohan with Dr. Paul Fields at TNAU.

GPN: Sir, Storage Entomology in India is very staggered and not collective, additionally I wish to mention that there are very few storage entomologists are there in India. Would you like to say something to them?

SM: Supply Chain Management (SCM) is an important topic everywhere, where we can manage and process the commodities in a scientific way, deliver the processed commodities in a safer way, but notorious insects thrive through SCM.

Dr. S. Mohan with students in 2010 (left) and 2024 (right).

These cannot be managed easily by common methods including chemical methods specially fumigation (most used). However, usage of chemicals also creates lot of problems, especially resistance development. In a country like India, we need sustainable and simpler technologies, which should be non-chemical, work as substitute/ alternative to chemical methods and compatibly integrate with the available management systems. Thus, role of an entomologist is crucial. As I can say, every university has post-harvest and processing division, and in all Indian institutions under ICAR, these divisions are common. I wanted to highlight that every unit of these schemes should have at least an entomologist who can work on post -harvest and storage entomology. At TNAU, I spent six years working in the post-harvest technology scheme, where a position was dedicated to stored product entomology. Unfortunately, that position was later dissolved. Interestingly, if you search online for "non-chemical methods for stored grain insect management," India prominently appears on the first page, with mentions of TNAU, ICAR, and PHT. This reflects the significant work done in the past and highlights the ongoing need for dedicated efforts, particularly by entomologists specializing in processed and stored grain commodities. Today, there is growing interest in organic farming, but the focus shouldn't end with cultivation. It is equally important to store organically produced commodities using non-chemical methods. This underscores the need for the development of tailored technologies, led by entomologists. Collaborative efforts with multidisciplinary teams, particularly involving engineers, are essential to drive a greater revolution in this field. I hope SAUs and ICAR will consider the insights of me and prioritize the development of skilled manpower in this field in India. Storage entomologists are required at many places like quarantine centers, storage agencies, processor level hubs, as many commodities are in import and export. In my case, the journey was tough however youngsters. Although the path was difficult for me, young people in this sector can interact across universities, work with less ego, and foster greater collaboration to accomplish the research goals. Senior brains should train their next lines (the second or third line) since the "journey" is always more significant than merit, status, or achievement. Since you (Dr. GPN) are one of the few persons working in this sector, I bless you. Try to take the initiative to follow the working team's recommendations and receive blessings from seniors.

GPN: Sir, along with training to farmers, you focussed mainly on guiding school and college students, can you mention how it is benefitted the students?

SM: There's a saying from Mahatma Gandhiji, "*If we are to teach real peace in this world, we shall have to begin with the children*". For me, realising this dream of the father of our nation adds a lot of meaning to my life. I went beyond the realm of college students and my outreach finally encompassed school children too. It was a very gratifying experience for me. Besides being useful to the farmers, households and warehouse managers, my TNAU insect trap technologies paved way for kindling scientific temper in school children. For example, a 7th standard student won 2 Gold Medals in the INTEL- IRIS competition and a WIPO Award for young inventor by making TNAU traps using waste materials (Mineral Water Plastic bottles); A student group won a Medal at 10th National Children's Science Congress – 2002, and many like this. The Tamil Nadu government, impressed by the creative talent of the school students and appointed me as the Chairman of the Committee to 'Revamp and Revitalize the

Agricultural School Education in Tamil Nadu' during 2010. The new 11th standard Agricultural Practices-I book has a chapter on the 'Importance of Post-Harvest Technology' in which the TNAU probe trap is highlighted. As the Chairman, I contributed for the significant reforms in Agricultural education in Tamil Nadu schools. The old curriculum structure followed in Tamil Nadu for the past 20 years was revamped in 2010-11 with the introduction of common textbooks, *Agricultural Practices-I* and *Agricultural Practices-II*, for 11th and 12th standard students. This updated curriculum remains in use to this day. Even now, I love teaching and motivating young minds to focus on science for novel inventions and innovations. I fervently hope and believe that my journey to kindle scientific temper among school children will continue ceaselessly.

GPN: What are your suggestions for young students/ researchers for their career in Entomology, especially Stored Product Entomology?

SM: Crucially, in contrast to my time, things have altered since then. Simply said, it is difficult to find employment in the university system as a lone researcher, and it is nearly impossible to work in the same field of study for ten years in a row. My recommendation in this dire circumstance is to, if at all feasible, continue with the research-focused degree program. If we get a research position in any field, then work on that field thoroughly and acquiring knowledge has become easy through internet so explore as much as we can. Try to create some fundamental technologies with real-world applications at the same time. If you are more passionate about the topic, I have no doubt that miracles will occur, just as they did for me. As a theist, I believe that both God and necessity are the sources of invention and innovation. Thus, continue your studies with a clear goal in mind, and you will eventually realize your dreams.

(From left to right) Sh. Sundaram, Dr. S. Mohan, Dr. Guru P. N., Sh. Balaji.

Dr. S. Mohan and Dr. Guru P. N. during a discussion on the UV light trap technology.

Dr. Guru, P. N. is a scientist (Agricultural Entomology) working at ICAR-CIPHET located at Ludhiana, Punjab. He is specialized in storage entomology with focus on developing practical and non-chemical strategies for monitoring and management of insect-pests infesting commodity in storage.

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IN CONVERSATION WITH VEENAKUMARI KAMALANATHAN

A MULTIFACETED ENTOMOLOGIST WHO WORKED ON INSECT BIODIVERSITY IN VARIED ECOSYSTEMS, NPV AND TAXONOMY OF WASPS.

Dr. Veenakumari PhD was born in Kolar, Karnataka and completed her schooling there at the Methodist School. She subsequently joined the University of Agricultural Sciences (UAS), Hebbal, Bangalore where she completed her B.Sc. (Agri), M.Sc., (Agricultural Entomology), and PhD in Agricultural Entomology. Dr. G. K. Veeresh was her guide for both her Master's and PhD programmes. She received the University Gold Medal for securing the highest marks for her PhD.

On completion of her postgraduate studies, she joined the Department of Entomology, University of Agricultural Sciences as a Research Assistant. Resigning from this post she later joined the ARS as a Scientist at the Central Agricultural Research Institute (now ICAR-Central Island Agricultural Research Institute), Port Blair, Andaman and Nicobar Islands in 1989. After a fourteen years stint in the Andaman and Nicobar Islands, she was transferred to the Project Directorate of Biological Control (now the National Bureau of Agricultural Insect Resources), Bangalore from where she retired as a Principal Scientist in 2019.

During her scientific career she worked on various facets of entomology including studies on insect biodiversity in varied ecosystems, the utilization of NPV to manage *Amsacta albistriga* (Lepidoptera, Noctuoidea, Erebidae, Arctiinae), and the taxonomy of Platygastroidea (Hymenoptera). During the course of her studies on Indian Platygastroidea she described four new genera and a number of new species, and revised some genera.

Her book, the 'Butterflies of the Andaman and Nicobar Islands', coauthored with some of her colleagues at CARI, Port Blair was published in both English and Hindi. The latter received the Dr. Rajendra Prasad Puraskar for Technical Books in Hindi in Agricultural and Allied Sciences in 2010.

Post retirement, she continues to be actively engaged in taxonomic studies of the Platygastroidea.

Interview of Dr. Veenakumari Kamalanathan PhD by Dr. Rachana R.R.

RRR: Tell us about your childhood and what inspired you to pursue your career in entomology?

VK: Animals caught my fancy from a very young age. Compassion towards all living organisms was inculcated in me by my mother. I loved to listen to stories about sparrows, crows, etc. from the Jataka tales and Aesop's fables. It was easy for me to transition from the worlds of these anthropomorphised animals to living beings in the real world. When the course in entomology was offered during my undergraduate days, it was so exciting that I knew I had found my calling. People tried dissuading me from pursuing my Master's in entomology as it was perceived to be very difficult. But my fascination for living beings was great and I was ready to rough it out.

Migrant butterflies passed in their hordes during certain seasons and the lamps at night were smothered in the most diverse array of nocturnal insects: never before– or after - have we seen such large congregations of Lucanidae and Brentidae at lights.

RRR: Your professional career began at ICAR-CIARI, Port Blair. Was this by choice or by chance?

VK: Unlike the Pandavas who were forced to spend thirteen years and Rama who was forced to spend fourteen years in the forest, I was not forced to serve in the Andaman Islands. My husband Prashanth Mohanraj opted to work at the Central Agricultural Research Institute (now ICAR- Central Island Agricultural Research Institute), Port Blair, and the Indian Council of Agricultural Research (ICAR) readily obliged by changing his posting from the Central Tuber Crops Research Institute (CTCRI), Trivandrum (even before he reported there) to CARI.

We fell in love with the islands from the time we landed. Its people were caring and friendly while its forests were dense and mysterious, and the sea was ever present. Insects were abundant. Migrant butterflies passed in their hordes during certain seasons and the lamps at night were smothered in the most diverse array of nocturnal insects: never before - or after - have we seen such large congregations of Lucanidae and Brentidae at lights. What more could one ask for. Added to this was the historical importance of the islands. It had played such an important part in our freedom struggle; so many who had fought for our freedom had been incarcerated here by transportation across the dreaded waters of Kalapani. Having experienced the islands for a while I could think of nowhere else where I'd like to work. I resigned from my permanent job as a Research Assistant at the University of Agricultural Sciences, Gandhi Krishi Vigyana Kendra (GKVK), Bengaluru - which in fact was the beginning of my professional career - and prepared for the Agricultural Research Service (ARS) examination. I knew that I was taking a tremendous risk as I stood precariously on the threshold of the age limit for entering the ARS. I had only one chance. If I failed, the door would forever be closed to me. Nevertheless, I decided to take the risk and took the plunge, and succeeded, standing first in entomology that year.

RRR: Could you share some memories from your time in the Andaman Islands?

VK: I spent fourteen unforgettable years, both professionally fulfilling and personally satisfying, on these idyllic islands.

When I joined CARI, Dr. A.K. Bandyopadhyay (a soil scientist) was the Director. A dream Director, he gave us free reign to work on aspects of our choice. His only stipulation was that we publish good papers. One of the areas of study I chose was insect biodiversity in the mangroves of the islands - an ecosystem that had been very little studied for their insects, anywhere in the world. The mangroves of the islands though not as extensive as that of the Sundarbans are the most floristically diverse in the country. Among other discoveries of insects in the mangroves, one that stands out in my mind is the discovery of the rare, handsome blue nawab butterfly (*Polyura schrieber*). Only a wing of this species had been found by the British lepidopterist who had worked most rigorously on the butterflies of these islands. As Chief Commissioner of the islands, he had no difficulty in employing prisoners (whom he personally trained) to collect butterflies for him. No one knew if *P. schreiber* was a resident or a vagrant on the islands till I found the eggs and larvae of this butterfly and reared it on its mangrove food plant (*Rhizophora* sp.). Since there was no reference collection of the insects of the islands, particularly those of agricultural importance, we felt that the setting up of one was to be our primary goal. We were told that it would be impossible to set one up owing to the high humidity and warm temperatures that prevailed all year round on the islands. Added to this was the disdain for museums among the non-entomological community and the high cost of installing a dehumidifier. However as luck would have it, we could convince Dr.R.S. Paroda, Director General, ICAR, on the necessity for the establishment of an insect museum during one of his visits to the institute, and he sanctioned the requisite funds for a custom made dehumidifier. The collection continues to be maintained at the Institute, and is a draw to visitors there, both entomologists and lay persons.

We used to take our son, Rekil Prashanth on collection trips from a very early age. The first such trip was to Tarmugli, an uninhabited island off the southeastern coast of South Andaman, when he was a year old. We slept in the open, on mats under a starry sky. From then on, he'd accompany us to many places, and he has collected some interesting insects. He used to bring insects from school too. His desire to become an entomologist or biologist was thwarted by us, for which he continues to blame us. He has now taken up the photography of birds to satisfy the passion for the outdoors and the study of living beings that he developed early in life. That in a way is consolation to us: while we prevented him from taking up biology as a career, we at least developed in him an abiding taste for the outdoors (very unlike many of his peers who have no feeling for the environment and are most comfortable sitting indoors before a computer console).

In spite of all the hardships, even today I feel that [Port Blair] was the best place to work, a sentiment shared by the vast majority of my fellow-scientists who worked there.

RRR: How was life in general on the islands?

VK: In those days (the late 1980s and 1990s), power cuts were frequent. With no electricity we'd have to spend whole nights in the darkness. Large centipedes and snakes (especially the Andaman pit viper) were quite common. It was not uncommon to hear of people being bitten by centipedes (*kankhajuras*, in the vernacular there) that had crept into their mosquito nets. One even found its way up a colleague's leg and bit him high up on his thigh, leading the famed herpetologist Rom Whitaker, who on learning about it, remarked: "how fortunate, it could have wrecked his married life!'.

Public transportation was unreliable and maddeningly infrequent those days. Often one had to return home after having waited for hours for a bus that failed to turn up. Medical facilities were poor and meagre. We were lucky to have found a beloved friend in Dr. Radha Shyamala who took care of all our medical needs including the birth of my son Rekil. Vegetables and fruits were in perpetual short supply. If ships from the Indian mainland were delayed, the prices of onions and potatoes would shoot up. Tomatoes were priceless. Unable to put up with these circumstances many scientists posted to the Andamans were constantly on the lookout for transfers to institutes on the mainland. To me these conditions added a genuine charm to the way of life there. Bangalore (now Bengaluru) then was poised to take wing as the software capital and tech titan of the country. It was fast losing its innocence and metamorphosing into a megalopolis from the warm-hearted garden city and pensioners' paradise that it was justly famous for. At that moment the Andaman and Nicobar Islands turned out to be the perfect counterpoint in my life.

In spite of all the hardships, even today I feel it was the best place to work, a sentiment shared by the vast majority of my fellow-scientists who worked there. Our Director A.K. Bandopadhyay during those days used to encourage us to work. Never imposing his ideas on us, he always found words of encouragement, prodding us to keep working in spite of the hardships.

RRR: Any other memories from your stint as an entomologist in the Andaman Islands?

VK: There are many, though some stand out in my mind. When I first started work as an entomologist in the Andamans I decided that I'd work on dung beetles as I had worked on them for my PhD and so was familiar with the group. But it soon became evident that these islands had a depauperate dung beetle fauna. Then I began work on the insects of mangroves and discovered that the enormous Atlas moth (*Attacus atlas*) fed on species of *Rhizophora*, the dominant plant in the mangroves of the Andamans. A perusal through the literature made it evident that there were other Saturniidae on these islands on which nothing was known about their natural history. Over the years I worked out the life histories of all the saturniids then known on the islands including species of *Actias*, *Cricula* and *Antheraea*. These also turned out to be star attractions to visitors who visited our institute.

We also rediscovered a swallowtail butterfly, *Losaria coon sambilanga* (Lepidoptera, Papilionidae) in Great Nicobar, one that had been collected in the 1880s by William Doherty, and never again. It is not known to occur on any other island in the Andamans or Nicobars. There are many other interesting insects that we collected and studied from Great Nicobar, including some Platygastroidea.

Shortly after I joined CARI, the ICAR began permitting scientists to seek funds for projects from other institutions within the country. Being a new idea, it was viewed by the scientific community there as an unsavoury, additional burden that one would be inviting on oneself. I was the first at CARI to apply for and procure funds for a project on the insects of mangroves from an external source (Ministry of Environment and Forests, Government of India). Others later followed suit.

RRR: How did your shift from ICAR-CIARI, Port Blair to ICAR-NBAIR, Bengaluru change your research interests as an entomologist?

VK: My interests had not changed. But I was not given any choice of alternatives even within the research perspectives of the erstwhile Project Directorate of Biological Control (now ICAR-NBAIR). I was assigned work on the NPV of insects. The ostensible reason being that the current expert on the subject at PDBC would soon be retiring and someone had to take on his mantle. Arrangements were made for me to be trained under Dr. R. J. Rabindra, the foremost expert on the subject then in the country, at TNAU, Coimbatore. By a quirk of fate Dr. Rabindra succeeded Dr.S.P.Singh as the Director of PDBC by the time I began work in earnest on the NPV of *Amsacta albistriga*. Work on this involved extensive field work in villages in and around Pavagada. With able assistance from Srinivas, my enthusiastic and dedicated Research Assistant, I produced large quantities of the NPV of *Amsacta* and successfully created natural epizootics of the disease with its large-scale application in the field. Even when I retired, 20 litres of the concentrate of this virus were still available, which was handed over for further studies in the institute.

Later when the focus of the institute shifted, I began work in insect taxonomy.

RRR: You chose to work on insect taxonomy towards the later phase of your career. We would like to know the motivation behind this bold step that you took.

VK: The chance to study the sheer diversity of insects was what motivated me to pursue entomology for my post graduate studies. My PhD was on the diversity of dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae) in Bengaluru. Taxonomy then appeared too daunting, though my work on dung beetles gave me some exposure to the discipline. Nevertheless, the desire to master it at some time in the future lurked deep down within me. When the opportunity finally offered itself, though late in my career, I took it – with more than a modicum of trepidation though.

RRR: We are curious to know why you selected Hymenoptera from among the several groups of insects for taxonomic studies?

VK: Hymenoptera being an important component of ecosystems in general and agroecosystems in particular – that too at multiple trophic levels – was an important consideration. When I was still undecided about which taxon to take up for my studies it was Dr. H. Nagaraja, the world renowned *Trichogramma* taxonomist (then working at our institute), who suggested that the Scelionidae (Hymenoptera) are an important and interesting taxon that I could focus my attention on. He had collected scelionids that were parasitoids of triatomids for a biological control project that he worked on when employed at the Commonwealth Institute of Biological Control, Bengaluru. He had then got in touch with Dr. L. Masner, the world's most distinguished taxonomist on Platygastroidea, who described the scelionids collected by the CIBC centre, Bengaluru as new species. Nagaraja also gave me a reprint of a paper by Masner from his personal collection. With that I made my choice.

However, my travails began after I made this choice. I found myself floundering rudderless, unable to find my footing and hopelessly lost in the maddening world of microhymenopteran diversity. It was then that Dr. Rabindra agreed to send me to any place in India to familiarise myself with the group. Even a cursory scan of the literature would indicate to anyone that Dr. K. Rajmohana, was the only expert on the taxon in our country. So, it was to her laboratory at the Zoological Survey of India (ZSI), Calicut that I went. She became the beacon to the taxonomy of this group to me. Her warmth and graciousness were boundless; and she gave me unfettered access to her collection while simultaneously sharing her intimate knowledge of the taxonomic subtleties of these little insects. After the fortnight of rigorous exposure to Platygastroidea under her guidance I gained some confidence to set out on my own. Our relationship has continued to blossom with the passage of the years.

I also knew that I could rely on the unstinting and selfless assistance of B.L. Lakshmi and Sasikala (who is sadly no more with us today), two highly motivated and committed people, whom I could count on for assistance in the collection and processing of specimens.

RRR: Have you had role models in your personal life or in your professional career?

VK: My mother was of course my first role model. Her sense of discipline in whatever she did was an aspect of her character that I tried hard to emulate, though not always with the level of success I'd have liked.

Professionally Dr. C. A. Viraktamath is my role model. His single-minded devotion to work is unparalleled. When I was engaged in research while pursuing my PhD, he was the only member on the staff of the Department who'd be working late into the night on most days. It was then that I resolved that I too should try and work like him. After I began work on the Platygastroidea, Dr. Lubomir Masner and Dr. E. J. Talamas, both platygastroid taxonomists, have been added to my pantheon of professional role models.

Jane Goodall, the intrepid primatologist who blazed a lonely trail pioneering studies on chimpanzees in the wild, in the forests of Tanzania was an early role model. Her autobiography had appeared a few years before I began my Ph. D. which I read with awe and admiration. I now think I was at times foolish in venturing out alone to isolated and lonely locales in search of insects inspired by her example. I'd be more careful now and I don't think I'd venture out alone to such places anymore.

RRR: Is there any instance that you value as appreciation from the entomological or taxonomic community?

VK: Though it smacks of immodesty, what I consider the most memorable appreciation (one that I have only shown to a very few people) is an email from Dr. Lubomir Masner, the preeminent platygastroid taxonomist, in response to an e-copy of a paper of mine on Indian *Calotelea* that I sent him in 2022. His email to me is reproduced verbatim below:

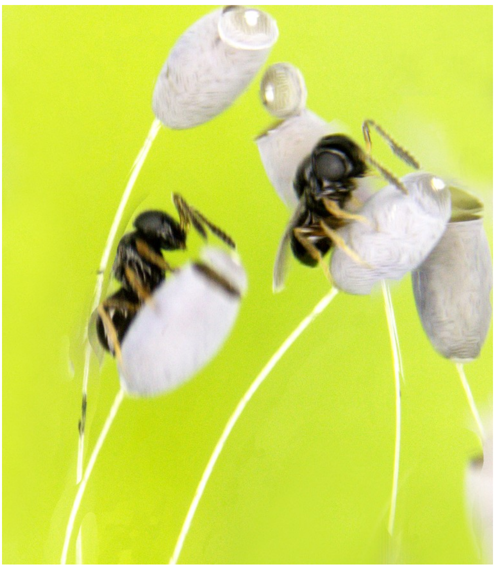
From: Lubomir Masner
Date:Thu, Feb 10, 2022 at 10:55 PM

Subject: Re: Calotelea
To: Veenakumari Kamalanathan

Dear Veena:

Congratulations! Your paper on Indian Calotelea is a real gem! I appreciate both its structure and the high quality of photos, truly a paper that is "user friendly", a model to be followed. In particular I am amazed by your rich material of freshly collected specimens all across India, I can imagine the time and effort to amass this magnificent base. The CNC has only meager amount of Oriental Calotelea which can be perhaps explained by the fact that yellow pan trapping in the past was not frequently used in the Oriental region. By contrast the CNC has tremendous holdings and diversity of Neotropical Calotelea species, though all undescribed. So. e.g. in one single locality at Trinidad (W.I.) we encountered 12 (!) sympatric species of xanthic Calotelea. I am inclined to believe that this is just a tip of an iceberg! May I encourage you to do more pan trapping in the years to come!

With the best regards,
LUBO.



Freshly emerged males of *Telenomus* sp. waiting to mate with females emerging from chrysopid eggs.

Yet another memorable moment was when Peter N. Buhl, a Danish platygastroid taxonomist, named a species after me very early in my foray into the world of insect taxonomy.

RRR: What were the biggest challenges you faced during your career?

VK: Working on the insects of mangroves and inland forests of the Andaman and Nicobar Islands threw up the greatest challenges. To study the insects of mangroves, for instance, one had to wade into the sea, and thread one's way between the slippery prop roots and menacing pneumatophores; while at the same time being ever conscious of the movement of the tides, making sure to get back before the tide rose, so rapidly at times, to cut one off from the shore and leave one stranded out at sea. These were also areas infested with crocodiles which one had to be wary of. Ticks, leeches and venomous snakes had to be contended within the forests depending on the seasons. Once I sank knee-deep into mangrove slush, and my assistants had to drag me out with considerable difficulty.

Travelling to the middle and southern Nicobars was possible only by ship in those days. It took four to five days to sail from Port Blair to Great Nicobar. Although I had rooms booked in advance for the period of my stay at Great Nicobar, I was asked one evening to leave the guest house at very short notice and told to stay in a classroom in a government school with no bed and no toilet, as a foreign dignitary was visiting the island. Food was also a problem on many of the outer islands.

Maintaining the cultures of live insects especially on the long return voyage from Great Nicobar required considerable planning. We had to ensure that we were adequately stocked with the foodplants of the insect herbivores, and the cultures had to be attended to regularly on-board ship. The cabins in which we stayed could heat up considerably making the insects restless and even leading to mortality if they were not temporarily shifted to cooler surroundings. Choppy seas could add substantially to the difficulty of attending to these insect cultures.

And, finally, the challenge of venturing into the taxonomy of Platygastroidea.

...taxonomy is a lonely occupation....the task of cataloguing [the] near limitless diversity [of insects] is gargantuan. That however is the real challenge, but it could also be why not many Venture into this sphere of work.

RRR: You superannuated in 2019. But you continue to be actively engaged in research even now. What impels you to continue working in this fashion?

VK: Having attained expertise in the taxonomy of these insects I find it hard to leave them knowing that there is so much more that has to be done. I often feel it's unfortunate that I had not taken up work on their taxonomy much earlier. The affinity that one feels for the taxon of one's acquaintance, and the immense joy and satisfaction that one gets from working with them is indescribable. When working at the microscope or writing papers I enter another world that makes me forget all my problems and ailments. To my mind no one describes this ethereal feeling better than the renowned author-lepidopterist Vladimir Nabakov. Permit me to paraphrase him at length. He said:

'My work enraptures but utterly exhausts me to know that no one before you has seen a structure that you are examining, to trace relationships that have occurred to no one before, to immerse yourself in the wondrous crystalline world of the microscope, where silence reigns, circumscribed by its own horizon, a blindingly white arena all this is so enticing I cannot describe it.'

RRR: Do you think young entomologists are shying away from pursuing taxonomy as a career? if true, how can we attract more people into this field?

VK: There was a time when taxonomy was considered the quintessential biological science and the best minds gravitated towards taxonomy, as a result of which others flocked to pursue it. There was a feeling that it was possible to catalogue all of life quickly if sufficient manpower and resources were committed to the task. With the passage of time however it is becoming increasingly clear that this is a task much bigger than what anyone ever thought. One reason could be the enormity of the task with no end in sight that deters the faint hearted from taking up taxonomy as a vocation. The other is the birth of disciplines like molecular biology where the money and the prestige are, that is luring the young away.

Traditional taxonomy is a lonely occupation, with very few experts in each group or taxon, and no experts in many groups. There's no one straddling all phyla across kingdoms in the manner in which Linnaeus once did. It takes tremendous courage and optimism to survey the living landscape and not balk when one realizes that the task of cataloguing this near limitless diversity is gargantuan. That however is the real challenge, but it could also be why not many venture into this sphere of work.

Money and prestige are of course the primary forces driving people to choose and pursue careers in a world that has become increasingly materialistic. If there are institutions offering lucrative positions for taxonomists you'd find youngsters clamouring for such positions. But sadly instead of proliferating, such institutions are closing down or downsizing in most parts of the world. Inculcating fascination for nature and its myriad forms at a very early age is a key factor that could motivate the young to later take up studies to document life. I can't help but recall the words of Rachel Carson. '… [G]ift to each child … a sense of wonder [of the natural world] so indestructible that it would last throughout life …'. Sage words that I think offer a surefire prescription to enthuse people to take up taxonomy and keep us from bemoaning the paucity of taxonomists.

RRR: Taxonomists fear that their work gets published in low impact factor publications. Can I have your opinion on this?

VK: This is related to your previous question. It could be one more deterrent to people taking up taxonomy as a research option. Even the best taxonomic papers will by their very nature have low

Two interesting species of phoretic platygastroids. *Sceliocerdo viatrix* (left) and *Trissolcus* sp. (right) hitching rides on a grasshopper and a hemipteran.

impact factors. The metric to judge the performance of taxonomists or the quality of their work should not be based on the impact factor as is being voiced by taxonomists worldwide.

No one judges good literature by the number of people who read a novel or a book of poetry. It is no secret that not many have read Tolstoy's *War and Peace*, or James Joyce's *Ulysses*. How many of us have read, or how many people do we know who have read, the *Ramayana* or the *Mahabharatha*? Yet these are considered classics of world literature. Similarly, any competent taxonomist or scientist can judge the value of a taxonomic work without having to count the number of people who have read or who quote the work. Consider the following example from insect taxonomy. There are many others.

It has become abundantly clear that the neglect of molecular biology would be to the detriment of taxonomy.

Alfred C. Kinsey is recognised as one of the greatest gall wasp taxonomists of the world. In 1937 he was voted by all the leading biologists of the United States of America to be worthy of being a 'starred scientist'. This meant that his name would have a star placed beside it in the list of the '*American Men of Science*'. As his biographer J. Gathorne-Hardy states, this was 'a desperately sought award' by American scientists in every field, and Indiana University where Kinsey worked had only four starred scientists till Kinsey became the fifth. Yet his two master works on the genus *Cynips* (Hymenoptera: Cynipidae) – one, a 577 pages monograph, and the other on the higher classification of this genus – have not been borrowed even once by anyone since the day they were placed on the shelves of the Indiana University library!! [N.B. Both these works were not compendia of previously published papers, but wholly original works being published *in toto* for the first time.]

There is however one subset of taxonomists who'd have had very high, if not the highest, citation indices, but for the conventions that taxonomists themselves follow. Vladimir Nabakov, the famed novelist and lepidopterist of note, whom I quote earlier, was a champion of the minority view. He championed the idea that every time the binomial Latin name is used, the name of the first describer of that species should also be mentioned. Omitting the name of the first describer was a 'deplorable practice' in his view. Just think of the impact if every time you refer to the Latin name of a crop pest, biological control agent, an endangered species or a disease vector you had to mention the original describer and list the publication in which it originally appeared!

RRR: In recent decades, molecular studies have influenced several fields of science including taxonomy. May I have your views on molecular taxonomy?

VK: Molecular taxonomy is an exciting new discipline that is being usefully harnessed to unravel problems encountered by traditional morphology-based taxonomy. It also offers a far quicker method to delimit taxa enabling biodiversity studies at a speed that was impossible before. Speed of documentation of life forms, as you know, has assumed greater significance as ecosystems are being destroyed and species are disappearing even before we know of their existence, at rates much faster than ever before.

I think the ideal situation would be healthy collaboration between morphological taxonomists and molecular biologists.It has become abundantly clear that the neglect of molecular biology would be to the detriment of taxonomy.

RRR: How do you view the work of the new crop of young taxonomists in entomology?

VK: I think there are some very competent and dedicated young taxonomists working in entomology in our country at the moment. It would be unfair to mention names. But two factors continue to plague the field here in our country as well as elsewhere in the world. First the number of those opting for a career in taxonomy is woefully small and inadequate. Second, taxonomy continues to lose its prestige value in the biological sciences in the face of, if I may say so, 'competition' from the newer, more glamorous sciences / disciplines. Decades ago, it was customary for sociologists of science to talk of physics envy among biologists. Today many seem to be suffering from envy of the molecular sciences; by we, I mean taxonomists. This is uncalled for, greater collaboration is what is required.

RRR: Your husband is also an entomologist. How has his association helped in shaping your career?

VK: My husband has been a pillar of strength in my life, both on the personal and professional fronts. He has always encouraged me to work as well as pursue all my other interests. In addition to my mother, he is the most amazing person I have met or seen, who is an altruist to the core, which irritates me at times!

RRR: You are an excellent scientist with remarkable commanding powers. Then, why have you kept yourself away from administrative positions?

VK: During my days as a post graduate student at UAS, Bangalore I noticed that there were people who hankered after administrative positions in my department as well as in other departments. I then noticed that those who shifted to administrative positions in most, if not all cases, dropped significantly in their research output after taking up these positions. I also noticed that people like Dr. C. A. Viraktamath turned down such positions because they felt that it would adversely impact their research work. Imbibing this attitude, I decided even during my student days that I would not take up an administrative post during my research career.

In this context I have an attendant (perhaps discordant) belief. I think that in research organizations it'd always be better to have people trained in the sciences in administrative, decision-making positions. An administrator who is oblivious to the ways in which scientific research is done would ring the death knell of a research establishment. I was aghast to hear the responses of some of my colleagues in this regard when I was undergoing training at NAARM, Hyderabad.When one of our teachers posed the question of whether we'd like the DG, ICAR to be an agricultural scientist or an officer from the Indian Administrative Service, there were those (though in a minority) who said they'd prefer the latter!

It is also pertinent to mention here that the ICAR has taken a very enlightened stance by stipulating that scientists should not be burdened with administrative responsibilities. I know that I appear to be taking a contradictory stance; which however is easily resolved when one sees that in the real world there are many scientists, who at least later in their careers, like directing research in various capacities. And this ensures that research priorities remain in good hands.

Dr. RACHANA R.R. Scientist, works on the taxonomy of thrips in the Division of Germplasm Collection and Characterisation, ICAR- National Bureau of Agricultural Insect Resources, Bengaluru. Dr. Rachana R.R. talked to Veenakumari about her life in the Andaman and Nicobar Islands and her views on the current status of taxonomy as a field of study, while tracing the meandering trajectory of her career terminating in her taxonomic studies of the Platygastroidea (Hymenoptera).

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Reviving the Legacy: Indigenous Silkworm Races of West Bengal

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Abstract

West Bengal, a state known for its vibrant culture and diverse landscapes, holds treasure trove of natural wealth and historical significance within its boundaries. From the majestic Himalayas in the north to the pristine beaches along the Bay of Bengal in the south, West Bengal's geographical diversity is matched only by its rich cultural heritage. In this heritage lies the tradition of sericulture, an ancient practice that has shaped the lives and livelihoods of countless generations in the region. Sericulture, the art and science of rearing silkworms for silk production, has been practiced in West Bengal for centuries. The state's conducive climate, fertile soil, and abundant mulberry plantations make it an ideal location for silk production. Over the centuries, sericulture emerged as a thriving industry in West Bengal, providing employment and economic opportunities to rural communities across the state. Silk produced in West Bengal became renowned for its quality and craftsmanship, fetching high prices in domestic and international markets. The silk industry played a crucial role in the economic development of the region, contributing significantly to its prosperity and growth.

Keywords: Silkworm ,West Bengal and Sericulture.

One of the distinguishing features of sericulture in West Bengal is the diversity of mulberry silkworm races found in the region. These indigenous silkworm breeds have adapted to the local climatic conditions with their unique characteristics and qualities. All races of domesticated and most races of wild silkworms found on the mulberry belong to the first two classes such as European silkworm (*Bombyx mori)*, Barapalu (*B. textor)*, Nistari or Madrasi or Canary Silkworm (*B. craesi*), Deshi or Chhotapalu silkworms (*B. fortunatus*:), Cheenapalu (*B. sinensis*) (Mukerji, 1919). However, as time marched forward and modernization swept across the land, these indigenous silkworm races faded into obscurity, their delicate threads lost amidst the clamor of progress. Yet, in the quiet corners of West Bengal, a gentle breeze of change whispers of their return.

Landraces of West Bengal (Table 1 and 2):

1. Chhota polo/ Chhotapalu:

Chhotapalu silkmoth thrives in colder seasons, making it particularly well-suited for regions with harsher climates. Despite this difference, like Nistari, Chhotapalu exhibits polyvoltinism, enabling multiple generations within a year. However, one notable distinction lies in the developmental timeline of its larvae. Chhotapalu larvae undergo a longer maturation period, lasting approximately 22 days in summer and extending to 57 days in winter. This prolonged duration translates to a slightly longer spinning time for its cocoons compared to Nistari. Chhotapalu silk is valued for its strength and durability, making it ideal for the production of high quality silk fabrics.

2 . Bara polo / Barapalu:

Bara Polo was reared in Assam and Bengal, but its cultivation has declined due to challenges in cocoon production. While Barapalu follows a univoltine pattern, completing its life cycle within a single year. The peculiarity of Bara polo is a ten-month hatching period, hence it called 'lehemia or slow' during which eggs are carefully nurtured until the emergence of young worms. On the other hand, it showcases unique adaptations to spring seasons, where European races struggle. Additionally, different races of cocoons, such as dhali and bulu, serve various purposes in textile production. Barapolo silk stands out for its robustness, with longer filaments and higher tenacity, making it ideal for specialized textile applications requiring strength and resilience. The silk's value reflects its rarity, fetching high prices in the market.

3 . Cheena polo/ Cheenapalu:

Cheenapalu silkmoth shares polyvoltinism with Nistari but presents distinct characteristics of its own. Cheenapalu silk production requires a longer spinning time compared to Chhotapalu.

4. Nistari:

Nistari traditional multivoltine silkworm race originating from West Bengal, and utilized in the silk industry for over a century, particularly in the Gangetic plains region. Despite being known for relatively lower silk productivity and fiber quality compared to some other breeds, Nistari has been valued for its adaptability to adverse climatic conditions and specific regional requirements. These races thrive in warm and rainy seasons, exhibiting polyvoltinism and reared 8 times in a year. The fecundity ranges from 457 to 492, the total larval period from 22.00 to 22.87 days, and the weight of 10 mature larvae ranges from 6.29 to 6.49 grams. Additionally, the effective rate of rearing varies from 23.53 to 26.05, while single cocoon weight ranges from 7.704 to 8.738 grams. The number of cocoons per kilogram (Chitt) varies from 934 to 1028 (CSGRC, Hosor). These ranges reflect the diversity among nistari silkworm strains and the importance of understanding their variability in cocoon characteristics for effective silk production and breeding programs.

Efforts have been made to enhance the productivity and quality of Nistari through various breeding programs. For instance, productive multivoltine breeds like LMP, LMO, DMR, and PO were isolated through line breeding approaches by crossing females with larval markings and males without crescent markings from the Nistari race. Additionally, Nistari has been utilized in the development of other multivoltine breeds with improved characteristics, such as MY, RD1, P2D1, B2D, and HS2B. These breeds have evolved by utilizing indigenous races like Nistari, Pure Mysore, and Sarupat. In recent years, Nistari has continued to play a role in the development of new breeds and hybrids. CSR & TI, Mysore, has evolved breeds like BL_{67} and BL_{27} from multi x bi-hybrid crossings involving Nistari. (Kumaresan *et al.,* 2004). Furthermore, new productive hybrids such as Sharavati, Cauvery, and Tippu have been developed by crossing Nistari-derived breeds like BL_{67} with other races. Overall, Nistari remains an important contributor to the genetic diversity and breeding programs in the multi-voltine silkworm industry, despite its inherent limitations in silk productivity and fiber quality.

Other landraces:

There are other races of silkworms Naya polo called *B. Arracanensis* reared in Burma, and

Table 1: Comparison of Silk Characteristics among Different Land Races of Silk Worms (Mukerji, 1919).

Land Races of West Bengal		Nistari	Chhotapalu	Barapalu	Cheenapalu
Local names		Madrasi / Canary/ Purani	Deshi	Lehemia	China worm
Scientific names		*Bombyx croesi*	*Bombyx fortunatus*	*Bombyx textor*	*Bombyx sinensis*
Suitable seasons		Warm and rainy seasons	Cold season	Spring	Warm and rainy seasons
Months of cultivation		April, June , July, September	March, April, June, July, October, November	February and March	Janvary , Febravary, march, April, may
No. of crops		8	8	1	8
Egg Duration		8 to 16 days	8 to 16 days	annual race	8 to 16 days
Voltinism		Poly	Poly	Uni	Poly
Cocoon colour		light -coloured cocoons		Sivery white , Greenish to blue (Race called Bulu Palu	light -coloured cocoons
5th instar		2-3 days than cheenapalu	2-3 days more than Nista-ri	4-5 days more than chota palu Longest duration	5-12 days Shortest
Larval duration	**Summer**	20	22	Spring 30	18
	Winter	55	57	-	53
Spinning	**Summer**	2-3 days			
	Winter	4-5 days			
Avg filament length		210	215	270	
Weight of reelable silk in each cocoon in milligrammes		36	45	60	-
Weight 6f unreelable portion in each cocoon in milligrammes·		16.5	16	20	-
Proportion of reelable silk in the fresh cocoon per cent		6	7.5	8	-
Diameter of the bave in milimeter		20	20.5	16.5	-
Denier		1 3/5	2	2 1/3	-
Tenansity		4	6.4/5	6 ½	-
Elasticity		12	2	2 ½	-
Bill of loss		25	30	24	-

Table 2. Characteristics of Nistari Silkworm Strains and Cocoon Parameters (Saha *et al*., 2011)

Sl. No	Nistari strains	Larval marking	Cocoon Shape	Cocoon Color	Fecun-dity (по.)	5th stage	Total lar. pe-riod (day)	Wt. of 10 mat. lar. (g)	ERR by wt. (Kg)	Single cocoon wt. (g)	ERR (No.)	Cocoon weight (g)	Shell weight (g)	Shell (%)	Chitt (No. of cocoon/ kg)
1.	**Nistari (Mark)**	Mark	Spindle	Yellow	457	94.91	22.30	6.33	23.53	7912	7.963	0.989	0.13	13.15	1028
2.	**Nistari (Chalsa)**	Mark	Spindle	Yellow	485	95.90	22.77	6.45	26.05	7849	8.651	1.077	0.145	13.42	953
3.	**Nistari (Balapur)**	Plain	Spindle	Yellow	490	96.32	22.00	6.29	24.23	8150	8.419	1.019	0.134	13.10	998
4.	**Nistari (Shibnivas)**	Mark	Spindle	Yellow	492	95.12	22.87	6.49	25.68	7947	8.487	1.054	0.158	14.98	970
5.	**Nistari (Debra Mark)**	Mark	Spindle	Yellow	469	96.22	22.83	6.48	24.85	7807	7.704	1.012	0.146	14.39	1008
6.	**Nistari (Debra Plain)**	Plain	Spindle	Yellow	487	95.17	22.62	6.43	24.38	7390	8.230	1.028	0.150	14.63	988
7.	**Nistari (Plain)**	Plain	Spindle	Yellow	485	95.29	22.37	6.35	25.79	7481	8.738	1.085	0.156	14.32	934

another race called Barapat reared in Assam to belong to the *B. Textor* race. The silkworms reared in Manipur are also Barapalu or *B. textor.* Indeed, there is a tradition in Bengal that the Barapalu originally came from Manipur. In Midnapore, there is a race of silkworms called Bulu or Blue with small greenish-white cocoons. Bulu and Chhotapát of Assam seem to belong to the *B. Sinensis*. Among the landrace of mulberry cocoons, the Theophillas make good reelable cocoons, while Ocinara, Trilocha, and Rondotia spin very inferior cocoons which are called *Bombyx arracanensis* (Mukerji, 1919).

Challenges Faced by Indigenous Silkworm Races

Despite their historical significance, indigenous silkworm races in West Bengal have faced numerous challenges in recent years. The rapid industrialization and urbanization of the state have led to the loss of traditional silk-producing areas, as land is converted for other uses such as real estate development and infrastructure projects. Additionally, changing weather patterns and the spread of diseases have affected the health and productivity of silkworms, leading to a decline in silk production. Another challenge faced by indigenous silkworm races is the competition from exotic breeds that are often favored for their higher silk yield and faster growth rates. The silk fabric contained in Bengal cocoons was also inferior in quality. The average weight of a cocoon and average weight of reelable silk contained 1800 and 200 milligrams respectively, Bengal cocoons were only 600 and 40 milligrams. The average length of each fibre was 600 and 200 metres respectively. As a result, many farmers have switched to cultivating exotic silkworm races of *Bombyx mori*, leading to a decline in the population of indigenous breeds. Although the yield attributes of multivoltine silkworms are very poor, because of their resistance to various stresses under the tropical conditions of West Bengal, the majority of the silk production is multivoltine-oriented. Hence, maintenance of multivoltine silkworm breeds in original is highly essential to meet desired objectives of the breeder for effective commercial exploitation.

Efforts towards Conservation and Revival

Despite these challenges, there is renewed interest in conserving and reviving indigenous silkworm races in West Bengal. Various, research institutions like entral Sericulture Germplasm Resurce Center and Central Sericulture Research and Training Institute, Berhampore are maintaining some of the Indigenous breeds and preserving their genetic diversity i.e., Nistari Plain, marked, Chalsa and Debra. These centers also conduct research on indigenous silkworm races, with aim of developing new breeds that are resistant to diseases and environmental stresses. Although other productive breeds are developed across West Bengal and major breeds are Nistari Parentage breeds i.e., Nistari X (Sk_6 x Sk_7), Nistari X M12W and reciprocals. In recent days two Silkworm seed production centers (SSPCs) and 3 Basic Seed Farm of Central Silk Board, Department Of Textile (Sericulture) and 165 Registered seed producers (RSPs) recognized by CSB to manage the conservation and production of DFLs to supply to the farmers of West Bengal. Additionally, government is striving to raise awareness among consumers about the value of indigenous silk fabrics and the importance of supporting local sericulturists.

Conclusion

Conservation and revival of indigenous silkworm landraces in West Bengal are essential for preserving the state's rich cultural heritage and promoting sustainable rural development. By supporting local sericulturists and investing in research and conservation efforts, we can ensure that future generations continue to benefit from the beauty and craftsmanship of indigenous silk fabrics. Together, revive the legacy of West Bengal's sericulture industry and ensure its prosperity for years to come. Further, diverse mulberry silkworm races found in West Bengal are a testament to the region's rich biodiversity and cultural heritage. These indigenous breeds have been cultivated and cherished by generations of sericulturists, contributing to the state's economic prosperity and cultural identity.

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Insects immunity: types and mechanisms

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Abstract

Insects, despite lacking an adaptive immune system, have powerful ways to fight infections. They can phagocytose bacteria and encapsulate parasites, and secrete antimicrobial peptides into the hemolymph. They recognize foreign pathogens using specific receptors like peptidoglycan recognition proteins (PGRPs) and β-glucan recognition proteins (βGRPs). These receptors activate signalling pathways that activate genes that encode antimicrobial peptides. This article discusses the innate immunity of insects, including both cellular and humoral responses to bacteria, fungi and parasites, and discusses recent advances in insect antivirus immune responses .

Keywords: Immunity, Phagocytsosis, Haemocytes, AMPs.

Immunity is a host defense system comprising many biological structures and processes within an organism that protects against disease. Insects have evolved cellular and molecular defense mechanisms against infections, primarily innate and adaptive immunity. Innate immunity is an immunological subsystem that comprises the cells and mechanisms that provide the first line of defence from infection in a non-specific manner. Adaptive immune system, also known as the acquired immune system or specific immune system, that is composed of highly specialized, systemic cells and processes that eliminate pathogens or prevent their growth. Insects does not have this immune system.

The innate immune system of insects consists of

1. Physical barriers
2. Cellular response
3. Humoral responses

1. Physical barriers: The integument and peritrophic membrane serve as physical barriers against abrasive food particles and digestive pathogens in insects. However, these membranes are semipermeable, making them inefficient for viruses. They protect the hemocoel and midgut epithelium against microorganisms, activating humoral and cellular immune responses when they enter these barriers.

Upon infection, haemocytes immediately engage in cellular immune responses (Hemocytes) upon hemocoel infection, followed by humoral response sseveral hours later. These defense mechanisms do not work independently from each other (Cao *et al.,* 2015).

2. Cellular response: In insects, phagocytosis, encapsulation, and nodulation are examples of cellular immune responses. Granular cells, crystal cells, oenocytoid cells, and plasmatocytes are examples of hemocytes, which are in charge of defense reactions. For example, three hemocyte types—crystal cells, plasmatocytes, and lamellocytes—have been more thoroughly defined

Table 1: Difference between innate immunity & adaptive immunity (Fig.1).

Sl. No.	Characteristics	Innate immunity	Adaptive immunity
1	Presence	Innate immunity is something already present in the body	Adaptive immunity is created in response to exposure to a foreign substance
2	Specificity	Specific for pathogen associated molecular patterns	Highly specific even it can discriminate minor difference in molecular structure of microbial molecules
3	Response	Fights any foreign invader	Fights only specific infection
4	Inheritance	It's generally inherited from parents & passed to offspring	Adaptive immunity is not passed from the parents to offspring
5	Response time	Faster response Minutes/hours	Slower response Days
6	Major cell type	Plasamtocyte, granulocyte	T-cell, B-cell
7.	Example	Insects	Mammals

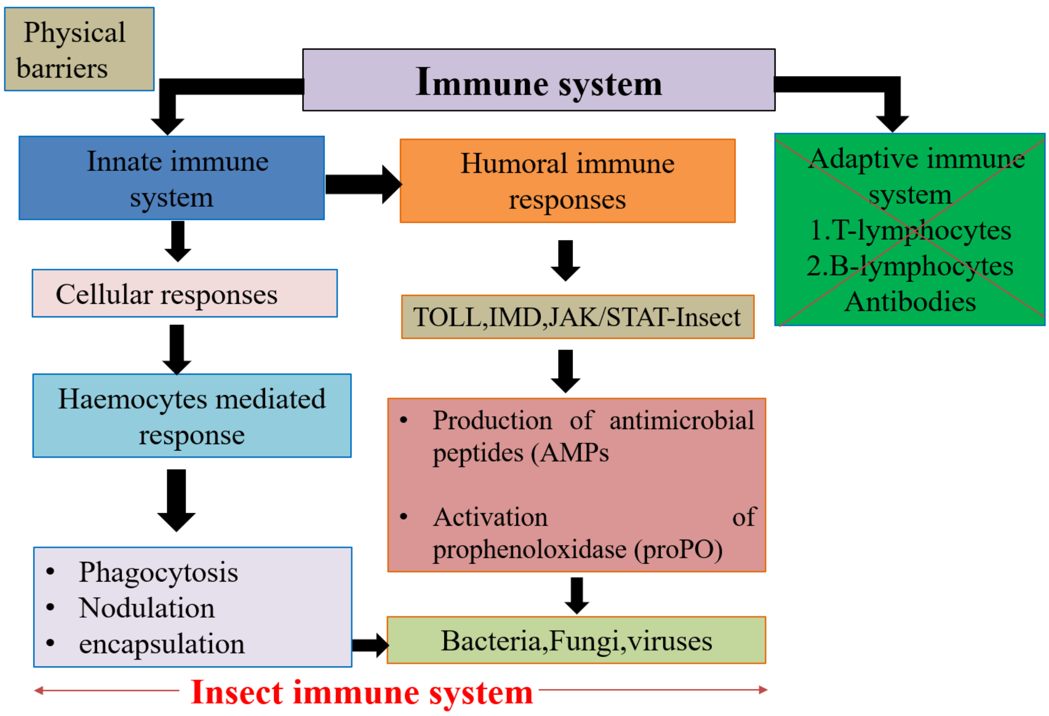

Fig 1: General immune system classification in insects.

in *D. melanogaster* (Parsons and Foley, 2016). Crystal cells have crystalline inclusions and are comparatively large cells. Prophenoloxidase, the zymogen they manufacture, is triggered during melanization (Fig. 2). Granular cells called plasmatocytes make up around 90% of all hemocytes. They have phagocytic receptors and use nodulation or phagocytosis to get rid of the majority of the invasive bacteria (Fig.2). Only when the larvae are infected by parasitic organisms can the flat cells known as lamellocytes be identified (Fig. 2). These hemocytes are mainly responsible for encapsulating the parasitoid wasp egg (Fig.2).

2.1 Phagocytosis: The process by which cells identify, attach to, and absorb big particles by tight contact with their plasma membrane, pinocytic vesicles, or pseudopodia is known as phagocytosis.

In Diptera and Lepidoptera, professional phagocytes are granular hemocytes and plasmatocytes, respectively. The primary phagocytic cells in the majority of insects are either granulocytes or plasmatocytes (Rosales, 2011).

2.2 Nodulation: When the initial phagocytic immune response is inadequate, hemocytes initiate methods to regulate infections, such as creating nodules to deal with high bacterial loads. Multicellular hemocyte aggregates are created during nodulation, trapping a lot of germs. Bacteria are encircled by hemocytes, which then develop into tiny clumps and eventually huge nodules. Bacteria are successfully isolated from the hemolymph by the melanized and flattened hemocytes covering these nodules (Fig. 3). For many insect species to develop nodules, certain chemicals like proPO, eicosanoids, and dopa decarboxylase (Ddc) are essential. Two proteins, Nodular and Reeler1, respectively, were shown to be crucial for mediating nodulation against *Escherichia coli* K12 and *Bacillus subtilis* bacterial challenges during screenings for novel immune genes from Indian saturniid silkmoth (*Antheraea mylitta*) larvae and *Bombyx mori* larvae. (Gandhe *et al.,* 2015).

2.3 Encapsulation: Hemocytes (lamellocytes) operate as effector cells, encasing bigger pathogens such as parasites, protozoa, and nematodes in a capsule. They create a melanized capsule by

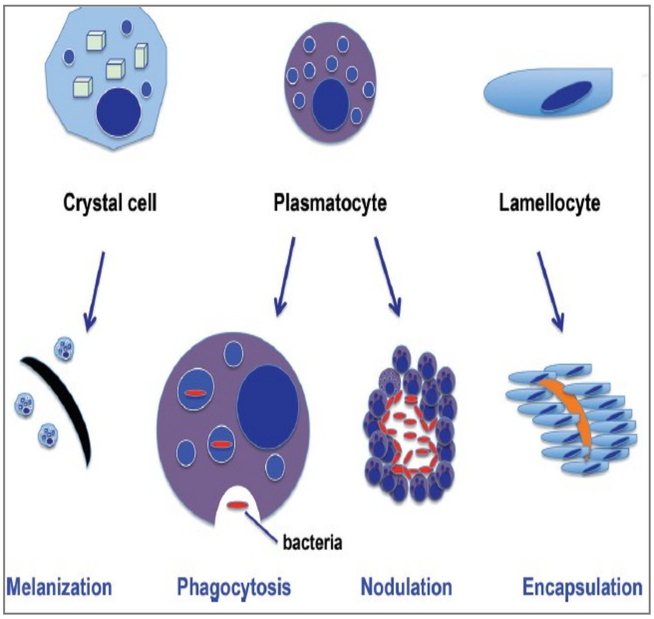

Fig 2: General immune system classification in insects.

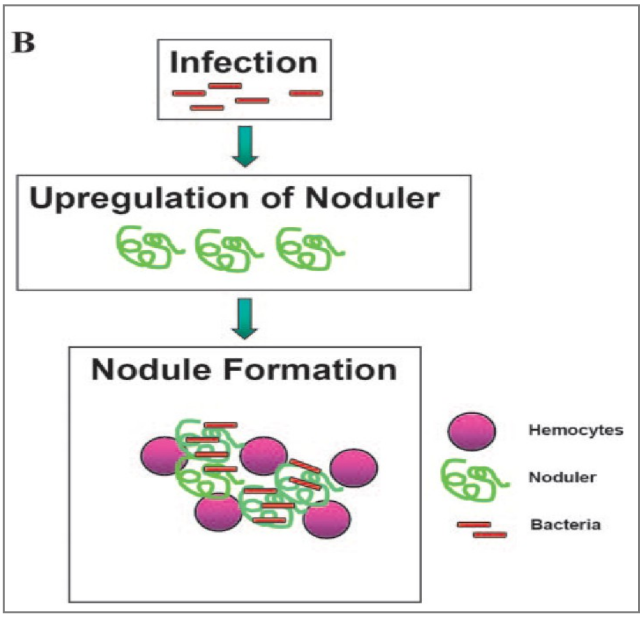

Fig 3: General immune system classification in insects.

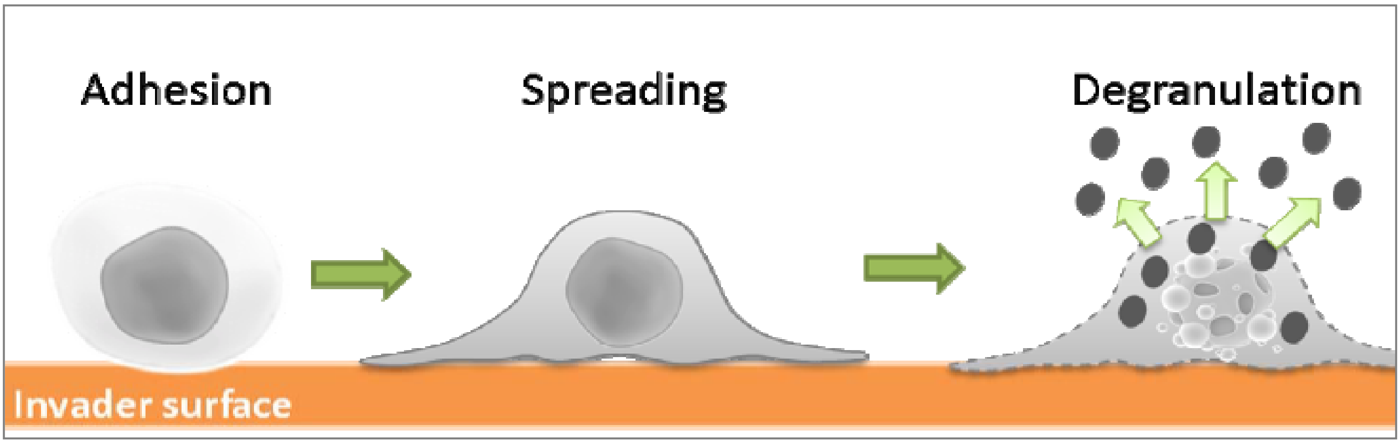

Fig 4: Haemocytes adhesion, spreading and degranulation during encapsulation of parasites inside insects (Dubovskiy *et al.* 2016).

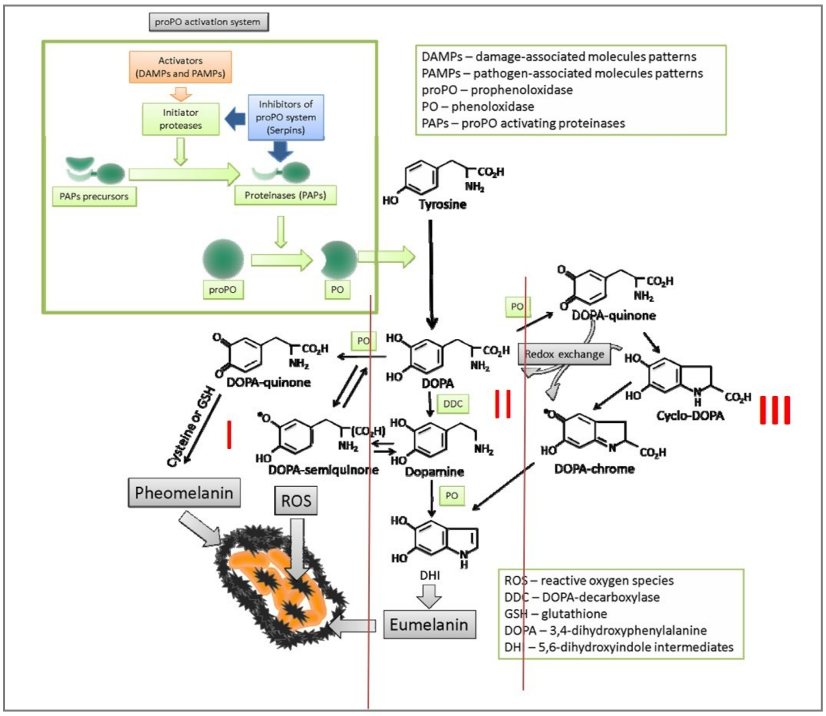

Fig 5: Activation of proPO system and melanogenesis in insects (Dubovskiy et al., 2016).

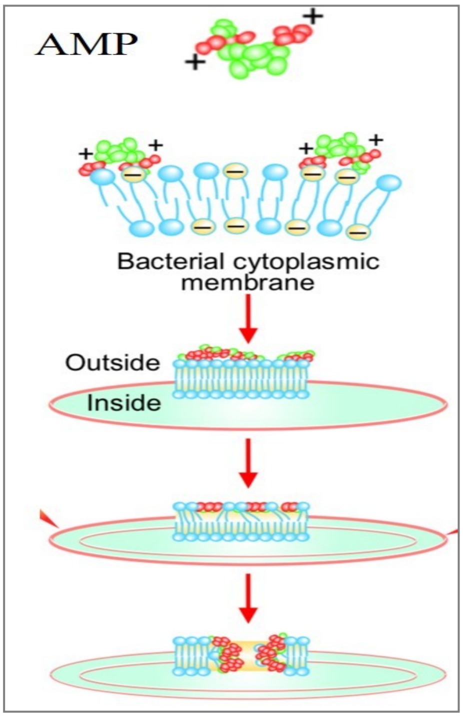

Fig 6: Mode of action of antimicrobial peptides (Haine *et al.*, 2018)

adhering to the target in several layers. After the hemocytes recognize the invader, they connect and begin to spread, killing the invading organism inside the capsule either by suffocation or reactive cytotoxic chemicals. (Fig. 3). Haemocyte destruction (degranulation), which releases effector molecules and immunomediators, is the next step in the cellular immune response (Fig. 3).

2.4 Melanization: Melanization is the process of melanin formation, activated during wound healing and nodule formation against pathogens or parasites in insects. The enzyme phenoloxidase (PO) is crucial in this process, which requires pattern-recognition proteins like PGRP or βGRP. PO binds to foreign surfaces, initiating melanin formation. PO converts tyrosine to dopa, which can be decarboxylated to dopamine or oxidized to dopaquinone and later may metabolized to eumelanin and melanin (Fig.5).

3. Humoral responses:

3.1 Antimicrobial peptides

Insects have a defense mechanism through the production of antimicrobial peptides (AMPs), which are released into the hemolymph after microbial infection. Mode of action of antimicrobial peptides: First they will attack the outer cell membrane of bacteria and it will cause ion imbalance and eventually cell wall lysis and death of bacteria will occur (Fig. 6).

These peptides are highly inducible and can vary in levels from undetectable in uninfected animals to micromolar concentrations in infected individuals' hemolymph. The first identified antimicrobial protein was the lysozyme from *Galleria mellonella*, which is structurally similar to chicken C-type lysozyme and can degrade bacterial cell wall including peptidoglycans of Gram-positive bacteria. It also has some activity against Gram-negative bacteria and some fungi. Biochemical analysis of hemolymph of the fruitfly *Drosophila melanogaster* and some other Dipterans has led to the discovery of seven groups of AMPs in insects (Haine *et al.,* 2018).

a. Defensins: Insect defensins, consisting of α-

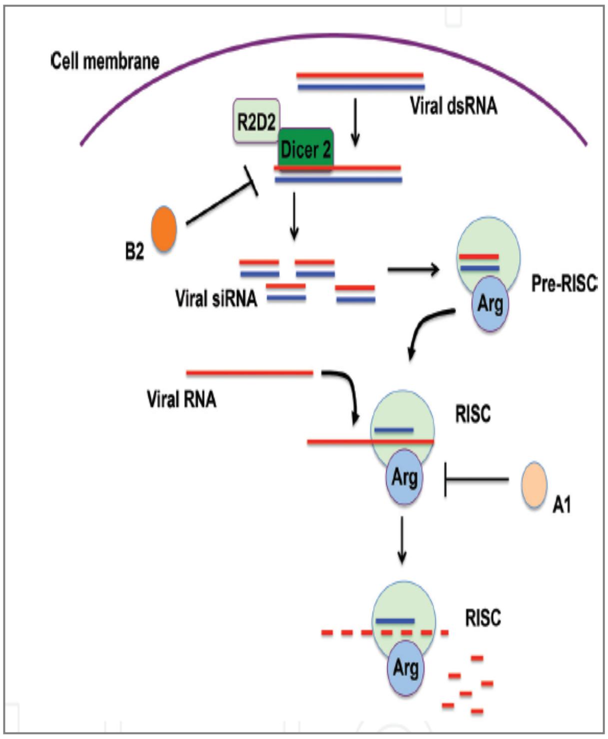

Fig 7: Steps involved during the RNAi pathway (Rosales and Vonnie, 2017).

helix/β-sheet mixed and triple-stranded antiparallel β-sheets, have been reported in many Lepidopteran species for their antibacterial and antifungal activity.

b. Cecropins: Cecropins are small, amphipathic peptides with 31-37 amino acid residues, found in the hemolymph of the silkworm *Hyalophoracecropia.* They act on antimicrobial activity by damaging pathogen cell membranes, inhibiting proline uptake, and causing leaky membranes.

c. Drosocin: Drosocin, a 19-mer cationic antimicrobial peptide from *D. melanogaster,* which has been found to possess an O-glycosylated threonine residue that is crucial for its antimicrobial activity.

d. Attacins: Attacins, 20 kDa AMPs, were isolated from *Hyalophora cecropia* hemolymph. Two isoforms, one acid and one basic, have been cloned and increase bacterial outer-membrane permeability, primarily binding to lipopolysaccharide.

e. Diptericin: Diptericin is an AMPs rich in glycine synthesized by insects in response to bacterial injections or injuries. It is active against a limited range of Gram-negative bacteria and disrupts their cytoplasmic membrane. Diptericin has been reported to inhibit bacterial growth and protect against oxidative stress, potentially trapping free radical anions and attenuating oxygen toxicity by increasing antioxidant enzyme activities in *D. melanogaster.*

f. Drosomycin: Drosomycin, an inducible antifungal peptide with 44 residues, was initially isolated from *D. melanogaster* but has shown potent antifungal activity against bacteria, with recent research showing it antiparasitic and anti-yeast properties.

g. Metchnikowin: Metchnikowin, a 26-residue proline-rich peptide in *Drosophila*, is an antimicrobial peptide that is active against both Gram-positive bacteria and fungi. It has been shown to protect transgenic plants from fungal pathogens, such as powdery mildew and *Fusarium* head blight, by expressing the metchnikowin gene in transgenic barley.

3.2 Antivirus insect response

Insects are infected by viruses, some of which are pathogenic to them and others are transmitted to mammals through biting. Understanding the insect innate immune response against viruses is crucial for medical and economic purposes. The RNA interference (RNAi) pathway, which produces tiny, interfering RNAs (siRNAs) in response to virus-derived double-stranded RNA (dsRNA), is the main antiviral defense mechanism. In turn, these siRNAs target viral RNA for destruction, so inhibiting the spread of the virus. Dicer-2 and the protein R2D2 both detect double-stranded viral RNA. The ds RNA is subsequently broken down by Dicer-2 into tiny duplex DNA fragments of 21 nucleotides. The guide strand is chosen based on complementarity once the duplex is unwound. After that, the siRNA guide strand is inserted into the RNase Argonaute-containing RNA-induced silencing complex. When a target viral RNA pairs with the guide strand, Argonaut breaks it down (Fig.7).

Additionally, insect antiviral responses involve innate antimicrobial pathways like Imd, Toll and JAK-STAT. The JAK-STAT pathway functions similarly to the mammalian interferon system, activating in uninfected cells when a virus-infected cell sends a signal. Also, the autophagy pathway is suggested to be important in some viral infections (Rosales and Vonnie, 2017).

Emerging viral infections that pose a concern to public health include dengue and chikungunya fevers, as well as Zika virus infection. The bite of an *Aedes* mosquito is how their aetiologic agents are spread. Vector control is the primary method of stopping the spread of these diseases in the absence of viable treatments or vaccinations. the chitin necessary for *Aedes* mosquito larval survival structures. *E. coli* HT115 was used to express dsRNA molecules that target five distinct locations in the CHS A and B transcript sequences. These molecules were then created both in vitro and in vivo and tested by being added directly to larval breeding water. When exposed to dsRNA that targets the CHS catalytic sites, both immature and adult larvae exhibited markedly reduced viability, which was linked to a decrease in CHS transcript levels. In association with diflubenzuron, this bioinsecticide exhibited insecticidal adjuvant properties (Lopez *et al*., 2019).

4. Conclusion

Cellular and humoral responses to pathogens involve phagocytosis and encapsulation of bacteria, respectively, while humoral responses involve secretion of antimicrobial peptides into the hemolymph. Recognizing foreign pathogens involves specific receptors like PGRPs and βGRPs, which activate signaling pathways for gene expression of antimicrobial peptides and antiviral activity. However, the specific pathway activated by each pathogen and its outcome, especially for viral infections, is still unknown. Insects lack antibodies and their immune system is non-specific, making future research in insect immunity is promising.

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'Entomophilately' – Collecting Insects without a net

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Philately is the collection and study of postal stamps. Philately is 'King of hobbies'. Entomophilately is the study and collection of postage stamps that features insects (Baig et al., 2020). This specialized area within philately attracts enthusiasts fascinated by the incredible diversity and beauty of insects, as well as their ecological significance. Insects possess intricate relationships with plants, animals, and other living organisms on earth, providing valuable insights into the natural world. These stamps serve not only as a means of postage, but also as tools for education and awareness about the vital roles insects play for healthy ecosystem (Miller and Miller, 2022; Turienzo, 2018). Engaging children and students in entomophilately can significantly enhance their interest in insects and the natural world. This help in highlighting the diversity and importance of insect species, conservation efforts needed against numerous threats, including habitat loss, climate change, and pesticide use (Hamel, 1990).

After independence in1955, the first stamp on an insect (a malaria stamp featuring a mosquito, *Anopheles culifacies*) was released. The first stamp featuring lepidopteran insects was issued in 1981 (Butterfly: *Teinopalpus imperialis*, *Cyrestis achates*, *Cethosia biblis*, *Stichophthalma camadeva*). In the year 2008, four stamps endemic butterflies from Andaman and Nicobar Island were released, which include *Papilio mayo* (male and female) and *Pachliopta rhodifer* (male and female). In the year 2017, four stamps featuring lady bird beetles (Coccinellidae) stamps were issued (Baig *et al.*, 2020).

Way for Connecting with Entomophilately:

Connection with entomophilately helps to turn simple hobby into an educational tool that encourages environmental awareness and scientific curiosity. Collectors not only preserve a unique piece of cultural and natural history, but also contribute to the broader effort of educating others and promoting conservation (Miller and Miller, 2022). Following are the ways for this:

1. Hands-On Learning: Collecting and studying stamps is a tactile, interactive activity that engages individuals in research, organization, and problem-solving (Hirwade and Nawlakhe, 2012). As collectors handle and arrange insect stamps, they also acquire knowledge about the species, their habitats, behaviours, and importance in ecosystems. This hands-on engagement is not only fun but educational, as collectors may look up facts about insects and their role in nature, developing an appreciation for biodiversity (Turienzo, 2018). Example: A collector could research the life cycle of a species featured on a stamp and then use that information to create a detailed presentation or even a report about the insect.

2. Sense of Responsibility: The act of collecting and preserving stamps creates a sense of ownership and responsibility in maintaining the condition of the stamps while also preserving knowledge about

Indian Stamp featuring a malaria mosquito, *Anopheles culifacies* released in 1955.

Indian Stamp featuring Lepidopteran insects released in 1981.

Indian Stamp featuring ladybird beetles released in 2017.

Endemic butterflies of Andaman and Nicobar Islands released in 2008.

India Post released stamps featuring the silk from Silkworm (*Bomybx mori*).

Lepidopterans on Postal stamp of different Countries.

the insects they represent. In a broader sense, it can encourage a sense of environmental responsibility—collectors may become more invested in protecting endangered species or promoting conservation efforts as they learn about the species shown on their stamps (Gupta, 2010). Example: Collectors may become aware of the threats facing certain insect species and, as a result, support conservation efforts or advocate for the protection of insect habitats.

3. Skill Development: Engaging with entomophilately can help develop a variety of skills:

- Skill for identifying the insects on stamps and learning about their zoological classification, behaviour, and conservation status.
- Skill for Sorting, categorizing stamps, managing collections, and maintaining records.
- Skill for Examining the artwork and design of stamps, understanding their historical or cultural context, and interpreting how they reflect the relationship between humans and the natural world (Yadav *et al.,* 2023).
- Collectors may engage in conversations with other enthusiasts, write about their collections, or share knowledge through blogs, presentations, or social media platforms.

4. Citizen Science Engagement: Entomophilately can foster engagement with the scientific community by encouraging collectors to learn more about the insects depicted on stamps, which may relate to topics in entomology, biodiversity, or conservation. Many stamps feature rare or endangered species and this could serve as an entry point for individuals to learn about and participate in citizen science projects. For example, stamp collectors might be inspired to contribute to local biodiversity surveys, track insect populations, or participate in citizen science platforms like iNaturalist, where people document species sightings. Example: A stamp depicting the Monarch Butterfly could prompt a collector to participate in a tagging program to track Monarch migrations, a citizen science initiative.

Collecting and Cataloging of Stamps

a. **Specialized Catalogs:** Collectors use specialized catalogs that insect-themed stamps; by insect type, country of issue, and date of release.

b. **Thematic Collections:** Collections are typically organized thematically, focusing on particular insect groups, regions, or specific scientific themes.

c. **Philatelic Exhibitions:** Enthusiasts participate in exhibitions and competitions, showcasing their collections and sharing knowledge with others.

Some examples of Insect-Themed Stamps

1. Butterflies: Butterflies stamps are most popular, due to their colorful and aesthetically pleasing appearance. India Post released series of stamps on butterflies which includes the Common Jezebel, Striped Tiger, Blue Mormon, and Indian Jezebel etc. They have been featured prominently on Indian postal stamps, celebrating their vibrant beauty and ecological importance.

2. Bees: Bees, especially honey bees, are commonly featured on stamps to highlight their crucial role in pollination and agriculture. Honey Bee featured Stamps emphasize the importance of bees in ecosystems and the need for their conservation.

3. Beetles: Beetles play significant roles in ecosystems, from pest control to decomposing organic matter. There diverse forms and colors make them interesting for collectors specially ladybugs, stag beetles etc.

4. Dragonflies: Dragonflies are indicators of healthy aquatic ecosystems. These insects are known for their striking appearance and aerial flight. They are featured for their beauty and ecological role as predators of smaller insects.

5. Silkworms: Recognizing the significance of sericulture in India's economy, India Post has released stamps featuring the silkworm (*Bombyx mori*). These stamps emphasize the importance of silk production and the cultural heritage associated with it (Baig *et al*., 2020).

Importance of insect featured postal Stamps

a. **Diversity of Insects:** Insects are most diverse group of animals on earth surface. Entomophilately encompasses such a wide variety of insects, including butterflies, beetles, bees, dragonflies, ants, grasshoppers, and many others. Collectors often focus on specific types or groups of insects (Hamel, 1990).
b. **Educational Value:** Stamps featuring insects can serve as educational tools, providing information about different species, their habitats, and their roles in the ecosystems. They can raise awareness about the importance of insect conservation (Turienzo, 2018).
c. **Artistic Appeal:** Many stamps featuring insects are beautifully designed, showcasing the intricate details and vibrant colors of these creatures. This makes them appealing not only to entomologists but also to art lovers (Yadav *et al.,* 2023).
d. **Cultural and Scientific Themes:** Stamps may depict insects in various contexts, such as their cultural significance, scientific discoveries, or their roles in agriculture and pollination. Insects are often associated with beauty, transformation, and the natural heritage of India, making them an appealing subject for philately (Yadav *et al.,* 2023).
e. **Conservation Awareness:** These stamps not only enhance the aesthetic appeal of postage but also play a crucial role in promoting environmental awareness and conservation efforts across India. By featuring insects on stamps, India Post helps raise awareness about the conservation challenges these species face, such as habitat loss and climate change.

Conclusion

Philately connects in a friendly way to the world's flora and fauna which faces crisis and we need to conserve them. This effective tool can educate and provide awareness to the society towards conservation.

Entomophilately is a fascinating niche within philately that combines the beauty of insects with the art and history of postage stamps. It offers a unique way to explore the natural world and promotes awareness of the vital roles insects play in our ecosystems. Whether for educational purposes, artistic appreciation, or scientific interest, collecting insect-themed stamps provides a rewarding and enriching hobby. In India, insects have been featured on postal stamps to highlight their ecological importance and cultural significance.

Future Perspective

By harnessing entomophilately, we can evolve, a powerful tool for education, conservation, and community engagement, ultimately inspiring a new generation to cherish and protect the intricate world of insects. Entomophilately serves as a unique and engaging gateway for individuals, particularly children and students, to explore the diverse world of insects. By collecting insect-themed postage stamps, enthusiasts not only appreciate the beauty and variety of insects but also gain insights into their ecological roles and cultural significance. This hobby can foster a deeper understanding of entomology, encouraging curiosity and respect for biodiversity. As we face increasing environmental challenges, promoting awareness about insects through entomophilately can inspire the next generation to advocate for conservation efforts.

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Pollinator Health: Balancing Agricultural Practices with Conservation Efforts

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Abstract

Pollinators are vital for food production and ecosystem health, yet their populations are declining due to agricultural practices, habitat loss, and pesticide use. Around 40% of invertebrate pollinators and 16% of vertebrate pollinators are at risk of extinction. This article examines the impact of agricultural practices and pesticides on pollinator health and highlights conservation strategies such as habitat restoration, reduced pesticide use, and pollinator-friendly landscapes. It also emphasizes the importance of policies like pesticide -free zones and expanded protected areas. By adopting these strategies, we can improve ecosystem resilience, support biodiversity, and ensure food security, underscoring the need for global action to protect pollinators and promote sustainable land use .

Keywords: pollinators, pesticides, toxicity, pollinator-friendly habitats.

Pollinators play a vital role in worldwide food supply and ecosystem health by facilitating the reproduction of flowering plants, including many crops that humans rely on for food. Around the globe, pollinator populations have been experiencing a concerning decline in recent decades (Potts et al., 2010; Goulson et al., 2015; Nath et al., 2022). It is estimated that about 16% of vertebrate pollinators, including birds and bats, and 40% of invertebrate pollinators, such as bees and butterflies, are currently at risk of extinction. This article explore the complex interactions between agricultural practices, pesticide use and pollinator populations, emphasizing the status of conservation efforts and the promotion of pollinator-friendly landscapes.

Interactions Between Agricultural Practices and Pollinator Health

The dynamics among agricultural practices and pollinator health are complex and multifaceted. Modern agricultural intensification, characterized by monoculture farming and widespread pesticide use, poses significant threats to pollinators. Monoculture reduces floral diversity, limiting food sources for pollinators, while pesticides, including insecticides and herbicides, can directly harm them or impair their reproductive success and immune systems. These factors contribute to failures in pollinator populations worldwide, impacting biodiversity and agricultural productivity. To mitigate these effects, conservation efforts focusing on habitat restoration, minimized pesticide application through Integrated Pest Management (IPM), and educational programs are crucial. Such measures will promote pollinator-friendly landscapes that support diverse floral resources and reduce pesticide exposure, thereby safeguarding pollinator health and ensuring their vital role in global food production (Goulson 2013).

Conservation Efforts to Protect Pollinator

Populations

Recognizing the critical role of pollinators, conservation efforts have been increasingly prioritized worldwide. These efforts include:

1. Habitat Restoration and Enhancement: Conservation efforts to protect pollinator populations prioritize habitat restoration and enhancement, focusing on creating diverse landscapes with native flowering plants. These habitats provide essential resources like nectar and pollen, crucial for the survival and reproduction of pollinators. Recent studies emphasize the success of such restoration projects in bolstering pollinator numbers and diversity. For instance, research highlights the positive impacts of restoring pollinator-friendly habitats on enhancing ecosystem resilience and supporting agricultural productivity through improved pollination services (Garibaldi *et al*., 2015). These efforts are crucial for mitigating pollinator declines and ensuring their vital role in global biodiversity and food security. Habitat restoration within protected areas is essential for supporting and conserving insect populations, especially in the face of climate-driven changes (Thomas *et al.,* 2012). By focusing on the restoration of degraded habitats—such as planting native vegetation, creating water sources, and removing invasive species—Protected Areas can offer crucial refuges for both pollinators and other beneficial insects. These efforts, combined with targeted monitoring and conservation strategies, help maintain insect biodiversity, safeguard essential ecological functions, and enhance the resilience of ecosystems. Effective habitat restoration ultimately ensures that insects continue to thrive, supporting broader biodiversity and ecosystem health.

2. Reduced Pesticide Use: Pesticides, particularly insecticides and herbicides, pose significant threats to pollinators through direct toxicity and sublethal effects such as impaired foraging behavior and reproductive success. Recent research underscores the detrimental impacts of pesticide exposure on pollinator health and populations, highlighting the need for alternative pest management approaches that minimize pesticide use. Implementing such practices, promoting organic farming methods and establishing pesticide-free zones near pollinator habitats are crucial steps towards conservation of pollinators and enhancing ecosystem resilience (Woodcock *et al.,* 2016). Insecticide selectivity, the best option to safeguard pollinators. Selectivity in the context of insecticide use can be classified into two main categories: ecological and physiological selectivity (Maredia, 2003).

3. Educational Programs: Educational programs are obligatory in protecting pollinator populations by raising awareness and promoting informed conservation practices among farmers, landowners, and the general public. These initiatives educate about the importance of pollinators, the challenges posed by habitat loss and pesticide use, and effective actions individuals can take to create pollinator-friendly environments (Dicks *et al*., 2016).

4. Policy and Regulation: Policy and regulation are critical in protecting pollinator populations by establishing guidelines that limit pesticide use and promote habitat conservation. Recent initiatives focus on creating pesticide-free zones near pollinator habitats and implementing sustainable agricultural practices. Such measures aim to mitigate the impacts of pesticides and ensure the long-term viability of pollinator communities (Simon-Delso *et al*., 2015). To conserve beneficial insect pollinators and biodiversity, it is vital to strengthen policies on pesticide use, habitat protection, and climate change mitigation. Key recommendations include expanding protected areas, improving integrated pest management (IPM) practices, and promoting sustainable land use. Governments should prioritize reducing fossil fuel use, curbing short-lived pollutants, and committing to ecosystem restoration. Policies must also support plant-based diets, ecological economics, and population stabilization. International agreements like the Paris Agreement should set ambitious, time -bound goals with strong accountability. Additionally, land-use policies should preserve natural areas and reconsider land allocation for agriculture and urban development, ensuring long-term biodiversity sustainability (Harvey *et al.,* 2023).

Importance of Pollinator-Friendly Landscapes

Pollinator-friendly landscapes play a crucial role in maintaining biodiversity and agricultural productivity. By providing habitats and food sources for bees, butterflies, and other pollinators, these landscapes support the pollination of crops essential for food production. This ecosystem service is invaluable and decline in pollinator populations threaten global food security and ecosystem stability (Klatt *et al*., 2014). Creating and preserving pollinator-friendly spaces, such as wildflower meadows and native plant gardens, not only enhances the resilience of ecosystems but also promotes sustainable agriculture and enhances urban green spaces. These efforts are pivotal in safeguarding both natural biodiversity and human livelihoods against future environmental challenges.

Conclusion

The symbiotic relationship between pollinators and agriculture underscores the urgent need for concerted conservation efforts. As pollinator populations face unprecedented threats from intensive agricultural practices and pesticide use, the imperative to promote pollinator-friendly landscapes become3 clear. By restoring diverse habitats with native plants, reducing pesticide exposure through Integrated Pest Management (IPM), and fostering public awareness through education, we can safeguard pollinators and ensure their vital role in global food security and ecosystem resilience. Embracing these strategies not only protects biodiversity but also sustains agricultural productivity and enhances urban green spaces. As stewards of our environment, prioritizing pollinator conservation is indispensable for a sustainable and thriving future.

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Advancements in Pesticide Application Equipment

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Abstract

The rapid advancements in pesticide application equipment are reshaping pest and disease management practices across agriculture, horticulture, and allied sectors. With increasing demands for sustainable farming and stricter regulatory standards, technologies such as precision sprayers, electrostatic sprayers, and drone-based systems are offering promising solutions to the limitations of traditional pesticide application methods. These innovations enhance application accuracy, minimize pesticide use, and reduce environmental impact, thus promoting more sustainable agricultural practices. Precision sprayers utilize GPS and sensor technologies to target specific areas, optimizing pesticide distribution and reducing wastage. Electrostatic sprayers improve coverage and adherence to plant surfaces, while minimizing drift and chemical runoff. Drone-based spraying systems, with their ability to cover large areas rapidly and uniformly, enable precise and efficient pesticide delivery, even in difficult terrains. Despite challenges, such as high initial costs, operational complexity, and the need for specialized training, these technologies contribute to improved crop health, enhanced productivity, and reduced ecological footprint. This article highlights the significance of these advancements in transforming pest management practices and their role in ensuring food security, environmental sustainability, and the long-term viability of agricultural and horticultural production.

The rapid evolution of agriculture, horticulture, and allied sectors has necessitated innovative approaches to pest and disease management. Pesticides play a vital role in safeguarding crops, enhancing productivity, and ensuring food security. However, their effectiveness depends significantly on the precision, efficiency, and sustainability of their application. This highlights the importance of advancements in pesticide application equipment, which aim to optimize resource utilization while minimizing environmental and health risks. Modern pesticide application technologies address the limitations of traditional methods, such as uneven distribution, overuse, and wastage. Innovations like precision sprayers, drone-based application systems, and electrostatic sprayers are transforming how pesticides are applied in fields, greenhouses, and orchards (Fig. 1). These advancements are particularly critical for horticulture, where high-value crops demand meticulous pest control, and for allied sectors like forestry and floriculture, which face unique pest challenges. The need for advanced equipment is driven by several factors: the rising costs of agricultural inputs, the push for sustainable farming practices, and stricter regulatory standards regarding pesticide usage. By reducing chemical residues, improving application accuracy, and enhancing operator safety, these technologies contribute to producing safer, higher-quality agricultural and horticultural products while preserving natural ecosystems.

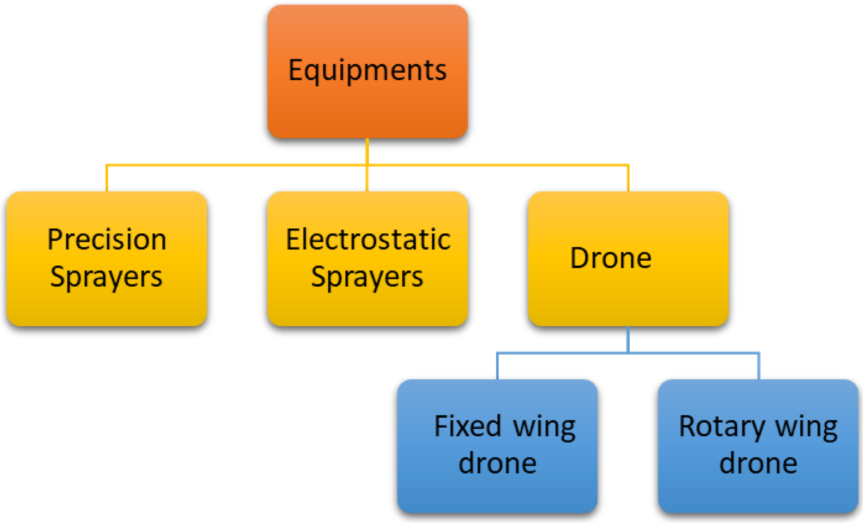

Fig 1: Advanced pesticide equipments.

Principle and working

Precision sprayers (Fig. 2) are designed to apply pesticides more accurately and efficiently by using advanced technology to control the rate, pattern, and placement of chemicals. The basic principle behind precision sprayers is the use of sensors, Global Positioning System (GPS) systems, and variable rate technology (VRT) to target specific areas of a field, reducing wastage and ensuring that pesticides are only applied where needed (Fig. 2). By detecting real-time field conditions, such as pest infestations or plant health, sensors enable the sprayer to adjust the amount and distribution of pesticides dynamically. GPS ensures precise field mapping, while automated nozzles control spray patterns and droplet sizes. This targeted approach minimizes pesticide use, reduces environmental impact, and improves pest control efficacy (Giles & Slaughter, 1997).

Advantages and disadvantages

Precision sprayers offer several advantages, including reduced pesticide use, which leads to cost savings and minimizes adverse environmental impact. By applying pesticides only where needed, they decrease the risk of over-application and chemical runoff. This targeted approach improves crop health and yield potential by avoiding unnecessary chemical stress on plants. Additionally, precision sprayers enhance efficiency by covering large areas quickly and accurately, ultimately supporting more sustainable and cost-effective farming practices. However, they require a significant initial investment in technology and equipment, which may not be feasible for all farmers. The complexity of operation demands skilled labour and regular maintenance, adding to operational costs. Additionally, precision sprayers can be sensitive to adverse weather conditions and may experience reduced effectiveness if GPS signals are lost or if the sensors malfunction. These factors can limit their practicality in some farming situations and increase reliance on technological infrastructure.

2. Electrostatic Sprayer: Maximizing efficacy and minimizing drift

Principle and working

The principle of electrostatic sprayers (Fig. 3) is based on charging the pesticide droplets with an electric charge as they are sprayed. In this system, pesticide droplets are generated through atomization and then passed through an electric field or near an electrode, which imparts a strong

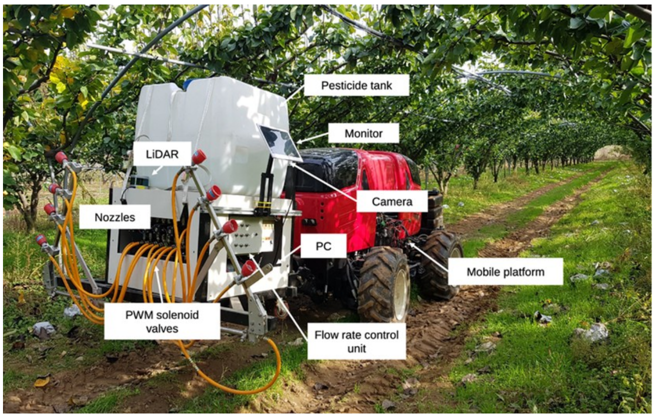

Fig 2: A precision sprayer (Seol et al., 2022)

Fig 2: Electrostatic sprayer (Thorat et al., 2022)

positive or negative charge to the droplets. Once charged, these droplets are sprayed into the air towards the target plant. These charged droplets attract the target (e.g., plants, crops) due to the electrostatic force between the charged droplets and the neutral or oppositely charged plant surfaces. This attraction ensures that the droplets wrap around and adhere to all surfaces of the plant, including hard-to-reach areas such as the undersides of leaves and within the canopy, increasing the deposition and coverage of the pesticide

The main difference between electrostatic sprayer and electrodyne sprayer is that electrostatic sprayers charge liquid droplets to enhance coverage and adhesion, while "electrodyne sprayer" is a less common term, potentially referring to similar or specific electrically enhanced spraying technology.

The electrical charge on the droplets results in mutual repulsion between them, preventing the formation of larger droplets and promoting the creation of small, uniform droplets. This minimizes the potential for overspray and reduces drift, thereby decreasing environmental contamination. The electrostatic sprayer thus offers a highly efficient and environmentally friendly means of applying pesticides, optimizing both chemical use and resource management in agricultural practices. (Thorat et al., 2022).

Advantages and disadvantages

One key benefit is their ability to achieve better coverage of difficult-to-reach targets, such as the undersides of leaves, where conventional spraying often falls short. This results in higher bio-efficacy, ensuring that pests are more effectively controlled. The technology also allows for longer-distance coverage, making it suitable for larger fields. In terms of resource savings, electrostatic sprayers reduce pesticide usage and overall cost per acre by 25 and 20%, respectively. Water consumption with electrostatic sprayers is ~10 times less water than conventional methods, further conserving resources. Overall, this method not only increases the effectiveness of pesticide application but also helps mitigate environmental pollution, making it an eco-friendly and cost-efficient solution in agricultural spraying. However, electrostatic sprayers come with certain challenges, one of the main drawbacks being their high initial cost. Additionally, the maintenance and repair of these sprayers can be quite complex and challenging, making it difficult for operators to address technical issues. Another limitation is the uncertain coverage in dense, thick crop canopies, where the sprayer's effectiveness may be compromised. The system is also more intricate compared to conventional methods, requiring specialized training for proper use. The nozzles need to be positioned at a precise distance from the plant canopy for optimal performance, adding another layer of complexity

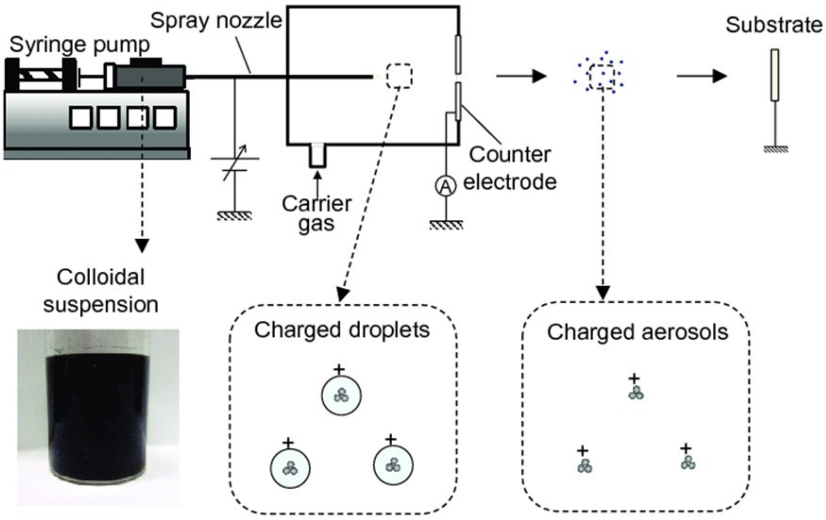

Fig 4: A schematic diagram of electrostatic-assisted spray and deposition system (Gen *et a*l., 2014).

to the operation.

Drone-based Spraying Systems: Unmanned Precision and Flexible action

(a) Fixed-wing drone

A fixed-wing drone features a rigid, aerodynamic wing design that generates lift as it moves through the air. It closely resembles a conventional aircraft but operates without a pilot on board (Fig. 5). These drones are powered by either one or two internal combustion engines or an electric motor, which is connected to a propeller that provides forward thrust. The wings are constructed with a specialized air foil that creates a pressure difference between the front and rear surfaces of the wing. The wings are constructed with a specialized air foil that creates a pressure difference between the front and rear surfaces of the wing. Control surfaces such as ailerons, elevators, and rudders on the wings are used to adjust the drone's flight path. Fixed-wing drones offer several advantages, including the ability to cover long distances, reach high altitudes, and fly with minimal noise. They are commonly employed for surveillance purposes due to their endurance and quiet operation.

(b) Rotary-wing drone

Rotary wing drones generate lift through rotating blades, known as propellers. These drones come in two main types: Single Rotor Drones and Multi-Rotor Drones (Fig. 5). Single Rotor Drones, which resemble helicopters, use a single large rotor to achieve lift and are primarily employed in the construction industry for surveillance tasks. On the other hand, Multi-Rotor Drones are the most prevalent type in the market. They achieve propulsion and control their movements by adjusting the speed of individual rotors, coordinated by a flight controller. Based on the number of rotors, multi-rotor drones are further classified as Tricopters (three rotors), Quadcopters (four rotors), Hexacopters (six rotors), and Octocopters (eight rotors). Among these, quadcopters and hexacopters are the most widely used.

Principle and working

A quadcopter drone operates on the principle of generating lift through four equally spaced rotors, each powered by brushless DC (BLDC) motors. The propellers attached to these motors create thrust, which serves as the lift force. The motor speed, regulated by a flight controller and an electronic speed controller (ESC), determines the amount of lift generated, allowing the drone to

Fig 5: Different types of drones.

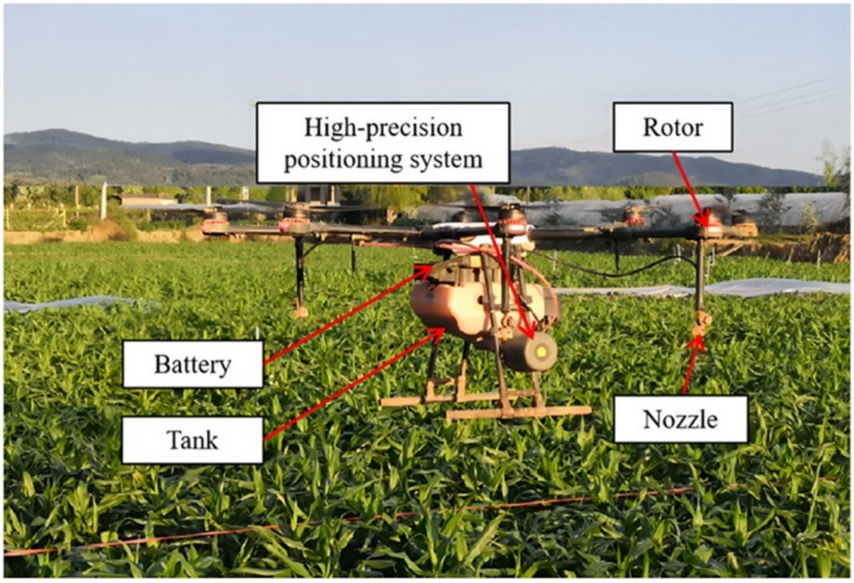

Fig 6: Labelled diagram of a drone.

ascend or descend (Fig. 6). To achieve various manoeuvres, the drone manipulates the lift force produced by the rotors. Take-off occurs when the lift force exceeds the drone's weight, while hovering is achieved when the lift force equals the weight. During stable hovering or climbing, all four rotors rotate at the same speed to maintain balance. Forward or backward movement (pitch) is achieved by adjusting the speed of the front and rear rotors, while sideways movement (rolling) is controlled by varying the speed between rotors on either side. Yawing, or rotating the drone around its vertical axis, is accomplished by altering the speed of diagonally opposite rotors. This coordination of rotor speeds allows for precise control of the drone's movement and stability in the air.

Advantages and disadvantages

One of the primary benefits of using drones for pesticide application is their ability to cover large agricultural areas quickly and uniformly, ensuring precise application where needed. This reduces wastage, as drones can apply targeted treatments with greater accuracy than traditional methods, minimizing the overall use of chemicals and promoting sustainable farming practices. Drones can also access difficult terrains and dense crop canopies, providing better coverage in hard-to-reach areas, a challenge for ground sprayers. Additionally, flying at lower altitudes improves pesticide deposition on plants while reducing drift, thus limiting environmental contamination. The high degree of automation in drones facilitates efficient scheduling and monitoring of pesticide application, saving both time and labour costs.

However, there are some disadvantages to consider. The initial cost of purchasing and maintaining drone technology can be high, particularly for smaller farms. One primary concern is that batteries need to be changed or charged for every acre of spraying. connected to a propeller that provides forward thrust. The wings are constructed with a specialized air foil that creates a pressure difference between the front and rear surfaces of the wing. The wings are constructed with a specialized air foil that creates a pressure difference between the front and rear surfaces of the wing. Control surfaces such as ailerons, elevators, and rudders on the wings are used to adjust the drone's flight path. Fixed-wing drones offer several advantages, including the ability to cover long distances, reach high altitudes, and fly with minimal noise. They are commonly employed for surveillance purposes due to their endurance and quiet operation.

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Rotary wing drones generate lift through rotating blades, known as propellers. These drones come in two main types: Single Rotor Drones and Multi-Rotor Drones (Fig. 5). Single Rotor Drones, which resemble helicopters, use a single large rotor to achieve lift and are primarily employed in the construction industry for surveillance tasks. On the other hand, Multi-Rotor Drones are the most prevalent type in the market. They achieve propulsion and control their movements by adjusting the speed of individual rotors, coordinated by a flight controller. Based on the number of rotors, multi-rotor drones are further classified as Tricopters (three rotors), Quadcopters (four rotors), Hexacopters (six rotors), and Octocopters (eight rotors). Among these, quadcopters and hexacopters are the most widely used.

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One of the primary benefits of using drones for pesticide application is their ability to cover large agricultural areas quickly and uniformly, ensuring precise application where needed. This reduces wastage, as drones can apply targeted treatments with greater accuracy than traditional methods, minimizing the overall use of chemicals and promoting sustainable farming practices. Drones can also access difficult terrains and dense crop canopies, providing better coverage in hard-to-reach areas, a challenge for ground sprayers. Additionally, flying at lower altitudes improves pesticide deposition on plants while reducing drift, thus limiting environmental contamination. The high degree of automation in drones facilitates efficient scheduling and monitoring of pesticide application, saving both time and labour costs.

However, there are some disadvantages to consider. The initial cost of purchasing and maintaining drone technology can be high, particularly for smaller farms. One primary concern is that batteries need to be changed or charged for every acre of spraying. Drones also have payload limitations, restricting the amount of pesticide they can carry, which may require multiple flights for larger fields, potentially increasing operational time. Compliance with aviation regulations can be complex, often requiring permits and adherence to guidelines specific to pesticide application. Weather conditions such as strong winds or low visibility can affect the accuracy and effectiveness of drone operation. Moreover, technical expertise is needed to operate drones effectively, necessitating training to ensure proper handling and application techniques. Lastly, the risk of pesticide drift, where chemicals may affect non-target areas, raises environmental and safety concerns. One of the primary benefits is their ability to cover large agricultural areas quickly and uniformly, ensuring that pesticides are applied precisely where needed. This capability minimizes wastage, as drones can apply targeted treatments with greater accuracy than traditional methods, reducing the overall quantity of chemicals used and promoting more sustainable farming practices. Additionally, drones can access difficult terrains and dense crop canopies, allowing for better coverage of hard-to-reach areas, which is often a challenge for ground sprayers. The ability to fly at lower altitudes enhances the deposition of pesticides on plants while reducing drift, thereby decreasing environmental contamination. Drones also operate with a high degree of automation, allowing for efficient scheduling and monitoring of pesticide application, which saves time and labour costs.

The effectiveness of modern pesticide application technologies compared to traditional methods has been the subject of various studies (Giles and Slaughter, 1997. These studies emphasize the improved efficiency, accuracy, and environmental benefits offered by new sprayers, drones, and electrostatic equipment. Here’s a summary of key findings from some of these studies:

Precision vs traditional sprayers

Precision sprayers, which use GPS and sensors, reduced pesticide use by 30-50% compared to traditional methods (Zheng et al., 2023; Thorat et al., 2022; Giles and Slaughter, 1997). These sprayers also minimized the risk of chemical runoff by applying pesticides only where necessary, based on real-time data from the field. This is a big improvement over traditional sprayers, which often lead to over-application and waste by spraying the same amount of pesticide everywhere, regardless of pest levels. Precision sprayers not only help control pests more effectively but also lower long-term costs by cutting down on pesticide and labour use. However, their high initial cost and the need for skilled operators remain challenges for wider use (.

Electrostatic vs conventional sprayers

A study by Thorat et al. (2022) compared electrostatic sprayers with traditional sprayers, highlighting the advantages in coverage, effectiveness, and environmental impact. Electrostatic sprayers reduced pesticide use by up to 25% and water consumption by almost 90% compared to conventional methods. The charged droplets in electrostatic sprayers stick to plant surfaces, improving coverage, especially on the undersides of leaves, which are harder to reach with traditional sprayers. The study also found that electrostatic sprayers produced much less pesticide drift, helping to prevent environmental pollution. On the other hand, traditional sprayers often suffer from drift and uneven coverage, which wastes chemicals and contaminates areas that shouldn't be sprayed. Although electrostatic sprayers have these advantages, their high upfront cost and limited effectiveness in thick crop canopies are challenges.

Drone-based vs ground-based sprayers

Zheng et al. (2023) compared drone sprayers (quadcopters) with tractor-mounted sprayers in terms of coverage, efficiency, and pesticide use. Drones were more accurate, applying pesticides at lower altitudes, which improved deposition and reduced drift. In comparison, traditional sprayers often lead to pesticide loss due to wind drift and uneven application. The study also showed that drones could cover larger areas more quickly than ground sprayers, saving on labour costs and reducing the need for multiple passes. Drones can access difficult areas such as dense crop canopies and uneven terrains, offering better coverage where ground sprayers are less effective. However, drones have some drawbacks, such as their limited payload, which means multiple flights may be needed for large fields, increasing operational time. Additionally, drones require specialized training and have high maintenance costs, which can be barriers to widespread adoption.

Conclusion

The advancements in pesticide application equipment are revolutionizing pest management practices in agriculture, horticulture, and allied sectors, offering solutions to the challenges of traditional methods and aligning with the goals of sustainable farming. Innovations such as precision sprayers, electrostatic systems, and drone-based technologies provide enhanced accuracy, reduced chemical usage, and lower environmental impact, contributing to optimized resource use, improved safety, and higher-quality crop production. While challenges like high upfront costs, operational complexity, and the need for specialized training remain, growing accessibility through supportive policies, training initiatives, and technological advancements is facilitating their adoption. As food security demands increase and environmental regulations become more stringent, these advanced systems are critical for achieving efficient and sustainable pest control. By embracing these transformative technologies, the agricultural sector can enhance productivity, preserve environmental integrity, and build a future defined by sustainable and resilient farming systems.

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Nature's Guardians: Exploring Biopesticides and the Impact of Entomopathogenic Fungi

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Abstract

Biopesticides are natural or biologically derived agents used to control pests, offering an eco-friendly alternative to chemical pesticides. They include microorganisms, plant extracts and natural toxins that target specific pests without harming non-target organisms or the environment. Among these, entomopathogenic fungi play a crucial role in pest management. These fungi infect and kill insect pests through infection, providing a biological control solution for a wide range of agricultural crops. Entomopathogenic fungi are particularly valued for their effectiveness against insect pests, their ability to target specific species and their environmental sustainability. In India, biopesticides like Entomopathogenic fungi are gaining attention as part of integrated pest management (IPM) strategies to reduce reliance on chemical pesticides, although challenges related to formulation consistency, storage and awareness still need to be addressed for wider adoption.

Keywords: Biopesticides, entomopathogenic fungi, IPM.

Biopesticides have garnered considerable attention for their eco-friendly nature and efficacy in pest management (Pretty & Bharucha, 2015). Biopesticides, derived from natural sources such as plants, microorganisms and minerals, offer an effective alternative to conventional pesticides. They harness the power of nature's own mechanisms to target and manage pests, providing a sustainable and environmentally friendly approach to pest management. Among the diverse array of biopesticides, entomopathogenic fungi have emerged as promising biocontrol agents in managing insect pests.

Entomopathogenic fungi are naturally occurring microorganisms that have evolved to infect and kill insect pests. They possess innate predatory capabilities, which they utilize to invade the bodies of target pests, ultimately leading to their demise. This natural mode of action makes entomopathogenic fungi highly effective in controlling pest populations while minimizing harm to non-target organisms and the environment. The utilization of entomopathogenic fungi in pest management represents a significant advancement in the field of biopesticides. Their ability to provide targeted control of specific pest species, along with their minimal environmental impact and compatibility with integrated pest management strategies, makes them an attractive option for sustainable agriculture. (Butt et al., 2016).

Types of biopesticides (Isman, 2006):

A. Microbial pesticides: These are based on microorganisms such as bacteria, viruses, fungi, and protozoa that infect or otherwise interfere with the physiology of pests.

B. Plant-incorporated protectants (PIPs): These are pesticidal substances that plants produce from genetic material that has been added to the plant. They can protect the plant from pests or enhance its resistance to diseases.

C. Biochemical pesticides: These are naturally occurring substances that control pests by non-toxic mechanisms, such as pheromones, plant extracts, or insect growth regulators.

D. Botanical pesticides: These are pesticides derived from plants or plant extracts that have pesticidal properties, such as neem oil, pyrethrum, or garlic extract.

Advantages of Biopesticides (Kumar *et al.*, 2018):

A. Biopesticides are typically less toxic to non-target organisms, including humans, beneficial insects and wildlife. They also degrade more rapidly in the environment, reducing their impact on ecosystems.

B. Many biopesticides have narrow target ranges by minimizing harm to beneficial organisms and reducing the risk of pest resistance.

C. Biopesticides leave little to no harmful residues on crops or in the environment, reducing the risk of pesticide contamination in food and water sources.

D. Biopesticides are compatible with integrated pest management (IPM) approaches, which emphasize the use of multiple pest control methods to minimize reliance on chemical pesticides and promote long-term sustainability.

Entomopathogenic fungi

Entomopathogenic fungi are microorganisms capable of infecting and killing arthropods, making them an eco-friendly option for pest control. These fungi are extensively utilized as biopesticides, especially in ecological farming, where they serve as a sustainable substitute for harmful chemical insecticides (Lovett & Leger, 2017). Entomopathogenic fungi are found amongst the families of Zygomycota and Ascomycota and in the class of Hyphomycetes in Deuteromycota. They are natural biological control agents for many insects and other arthropods and frequently behave as epizootics that significantly decrease host populations (McCoy, 1990).

Novel applications of entomopathogenic fungi

- **Encapsulation:** Microencapsulation and nanoencapsulation involve enclosing entomopathogenic fungi within tiny polymer capsules, providing protection against environmental challenges like UV radiation and desiccation. Production of nano and microcapsules incorporating entomopathogenic fungi like *Metarhizium anisopliae* (Metchnikoff) Sorokin *and Beauveria bassiana* (Bals.-Criv.) Vuill. is predominantly achieved using alginate (Shah *et al.,* 2023). Additionally, starch and chitosan have been utilized for developing capsules containing *Beauveria* (Fernando *et al.,* 2020). Numerous patents have been registered for alginate-based formulations used as bioinsecticides. For example, US Patent 9808768B2 outlines an alginate-based formulation incorporating entomopathogenic fungi for managing agricultural pests. Algibio is the commercially available alginate-based formulation which has been used for the control of various insect pests, such as the citrus blackfly (*Aleurocanthus woglumi* Ashby) and the coffee berry borer (*Hypothenemus hampei* Ferrari).

- **Secondary metabolites:** *Beauveria* spp. possess more than 10 metabolites with insecticidal activity, including beauvericin, allobeauvericin, isariin, isoisariin, isarfelin, cyclosporine and bassianolide. Efrapeptins are the peptides found in *Tolypocladium spp.* (W. Gams)., target mitochondrial ATP synthase in insects, leading to energy depletion and mortality. They infest a wide range of pests, including root-feeding insects (Niu *et al*., 2024). Cordycepin is ubiquitous among *Cordyceps* spp. (Fr.) It exhibits immunosuppressive action against *G. mellonella* and can cause high mortality .
- **Endophytes:** Endophytic insect pathogenic fungi (EIPF) play a vital role in enhancing plant resilience to various stresses and promoting soil nutrient distribution. *Beauveria bassiana* and *Metarhizium anisopliae* have emerged as promising endophytic fungi, capable of colonizing internal plant tissues asymptomatically. As endophytes, these fungi exhibit dual functionality by directly suppressing insect pests and indirectly benefiting plants through enhanced growth, improved tolerance to abiotic stress, and increased resistance to pathogens (Dara, 2021).

Mode of action of Entomopathogenic fungi:

Entomopathogenic fungi employ a multi-stage mode of action to target and control insect pests effectively. Initially, specialized structures such as spores or conidia attach to the cuticle, the outer surface of the insect (Figure 1). Subsequently, enzymes and toxins are produced to aid in penetrating the insect's cuticle, facilitating the fungi's entry into the insect's body. Once inside, the fungi colonize and proliferate, utilizing the insect's internal tissues as a nutrient source. During this

Table 1: Different Entomopathogenic fungi and their target pests

Fungal strain	Target insect pests	Mode of action	Application	Reference
Beauveria bassiana	Whiteflies, aphids, root grubs, caterpillars	Penetrates cuticle, produces toxins and kills	*Helicoverpa armigera* in cotton and *Spodoptera litura* in vegetables.	Sharma & Gupta, 2018
Metarhizium anisopliae	Termites, root grubs, locusts	Germinates on insect cuticle, releasing toxins	Fall armyworm (*Spodoptera frugiperda*) in maize.	Gurung & Prakash, 2021
Lecanicillium lecanii (R. Zare & W. Gams)	Aphids, whiteflies, thrips	Infects insect surface and sporulates inside host	Greenhouse whitefly (*Trialeurodes vaporariorum*) and aphids in vegetable crops.	Inglis *et al*., 2001
Hirsutella thompsonii (Pat)	Mites	Enzymatic degradation of mite exoskeleton	Effective against coconut eriophyid mite (*Aceria guerreronis*), reducing damage in South India.	Mishra *et al*., 2015
Cordyceps militaris	Caterpillars, grasshoppers	Produces bioactive compounds to kill insects	Proven potential against tea mosquito bug (*Helopeltis* spp.) in tea plantations.	Charnley & Collins, 2007
Isaria fumosorosea (Wize)	Whiteflies, aphids	Spores attach to and germinate on insect surface	Controlled *Bemisia tabaci* (whitefly) in cotton and vegetables, mitigating viral disease spread.	Manisegaran & Babu, 2019
Paecilomyces lilacinus (Bainier)	Nematodes, root-infesting pests	Parasitizes eggs and juvenile stages of nematodes	Widely used to control root-knot nematodes (*Meloidogyne spp.*) in vegetable and fruit crops.	Gurung & Prakash, 2021

Subsequently, enzymes and toxins are produced to aid in penetrating the insect's cuticle, facilitating the fungi's entry into the insect's body. Once inside, the fungi colonize and proliferate, utilizing the insect's internal tissues as a nutrient source. During this stage, they may also secrete secondary metabolites that weaken or kill the insect. As the fungi continue to grow, they eventually produce spores or conidia, which are released into the environment to infect other susceptible insects, completing the lifecycle. Overall, entomopathogenic fungi employ a combination of mechanical penetration and biochemical degradation to effectively target and control insect pests (Ma *et al,* 2024).

Impact of climate change on the effectiveness of entomopathogenic fungi

- Rising temperatures can exceed the thermal tolerance of many fungal strains, reducing their viability and effectiveness.
- Changes in rainfall patterns and prolonged dry spells negatively impact fungal spore germination and infection processes.
- Climate-induced changes in pest distribution may expose fungi to pests for which they are less effective, requiring the development of new strains.
- Existing fungal formulations may not perform reliably under fluctuating climatic conditions, necessitating improved stabilization techniques.
- Changes in soil properties, host-plant dynamics, and microbial communities due to climate change can further affect fungal performance.
- Enhanced genetic and biotechnological tools are required to develop strains that can withstand extreme environmental conditions.

Incorporation of entomopathogenic fungi into Integrated Pest Management (IPM) practices (Chandler et al., 2011):

- Monitoring pest populations and setting action thresholds, entomopathogenic fungi can be strategically applied when pest levels exceed tolerable limits.
- Cultural practices such as crop rotation and habitat manipulation can create favorable conditions for these fungi to thrive, complementing biological control efforts.
- Selective use of chemical pesticides that are compatible with entomopathogenic fungi further enhances pest management outcomes.

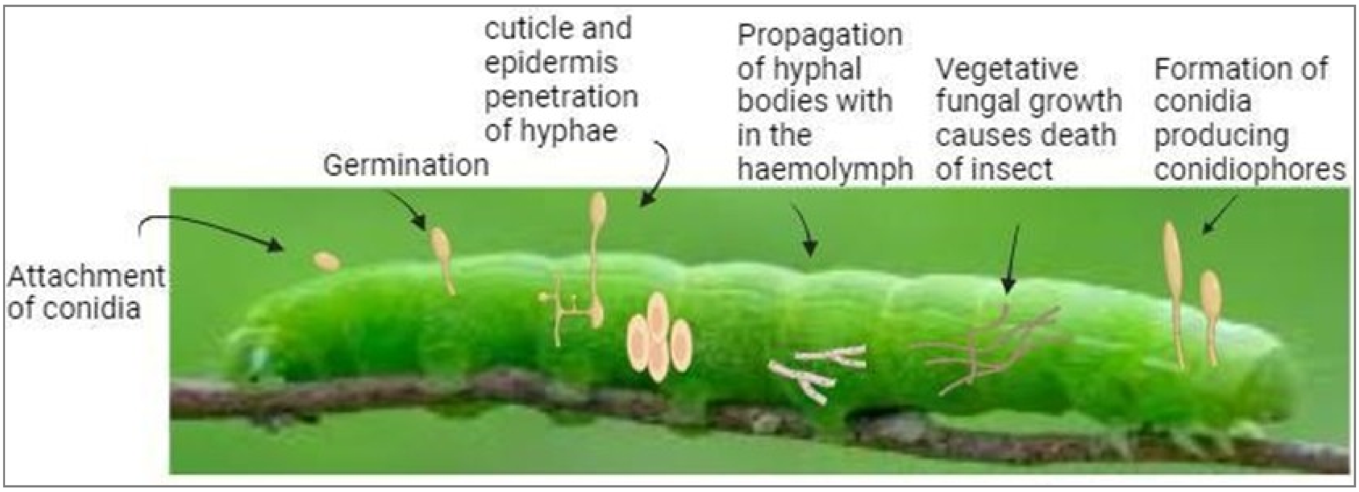

Figure 1: Mode of action of Entomopathogenic Fungi (Senthil-Nathan, 2014)

- Optimal application techniques, resistance management strategies, and ongoing education and training ensure the effective utilization of entomopathogenic fungi within IPM programs.

Case studies: Success stories of entomopathogenic fungi in pest control

In a study conducted in Karnataka, India, researchers evaluated the field efficacy and safety of indigenous strains of *Beauveria bassiana* against the pink bollworm (*Pectinophora gossypiella,* Busck), a major pest of Bt cotton crops. Using different formulations of *B. bassiana* applied via standard spraying techniques, the researchers observed significant reductions in pink bollworm populations in treated plots compared to untreated ones. Moreover, *B. bassiana*-treated plots showed lower levels of pest infestation and damage to cotton bolls, with the efficacy of *B. bassiana* biopesticides comparable to synthetic chemical pesticides commonly used for pink bollworm control. Importantly, the study found that the use of *B. bassiana* biopesticides was safe for beneficial insects and non-target organisms, highlighting its potential as an environmentally friendly pest management strategy in Bt cotton cultivation (Prasannakumar *et al.,* 2016).

In a study conducted in the southern United States, particularly Louisiana and Mississippi, researchers investigated the efficacy of *Metarhizium anisopliae* in controlling the southern pine beetle (*Dendroctonus frontalis,* Zimmermann), a destructive pest of pine forests. Laboratory experiments demonstrated high mortality rates of southern pine beetles exposed to *M. anisopliae* spores, indicating the pathogenicity of the fungus to the target pest. Field trials further confirmed the effectiveness of *M. anisopliae* formulations in reducing southern pine beetle populations, with beetle mortality rates increasing with higher concentrations of fungal spores. The successful suppression of southern pine beetle populations by *M. anisopliae* in both laboratory and field trials highlights the potential of this indigenous fungus as a biocontrol agent for managing forest pests in the southern United States (Goble *et al.,* 2007).

Limited popularity of entomopathogenic fungi in the Indian market:

The adoption of entomopathogenic fungi in India has been limited, despite their eco-friendly nature and potential to reduce chemical pesticide use. One of the primary challenges is the inconsistency in product quality. Many commercially available formulations suffer from low spore viability, inadequate concentrations, and contamination with non-target microorganisms. These issues often stem from poorly regulated manufacturing processes and a lack of adherence to quality control standards. Additionally, fungal biopesticides are sensitive to environmental conditions, and improper storage during distribution reduces their effectiveness. Farmer awareness is another significant barrier. Most farmers are unfamiliar with EPF products or lack trust in their efficacy due to previous experiences with substandard products. The limited availability of extension services to educate farmers about proper application techniques and the benefits of EPF further hinders their acceptance.

Education and awareness: Farmers and consumers:

- Education and awareness efforts play a crucial role in facilitating the adoption of entomopathogenic fungi by farmers and consumers. Farmers and agricultural stakeholders require access to accurate, science-based information regarding the benefits, efficacy, and application methods of these fungi.

Dissemination of knowledge through extension services, training programs, and outreach initiatives is essential to build capacity among end-users. Furthermore, on-farm demonstration trials and case studies showcasing the effectiveness of entomopathogenic fungi can increase confidence and trust among farmers, motivating adoption and encouraging sustainable pest management practices. Additionally, raising consumer awareness of the environmental and health benefits of biopesticides is vital for driving demand for sustainably produced food products. Marketing campaigns, eco-labeling initiatives, and consumer education programs can effectively raise awareness and promote the adoption of biopesticide-treated crops in the marketplace.

Strategies to Strengthen the Value Chain for Entomopathogenic Fungi

- A comprehensive approach involving policy, research, and market support is essential.
- Regulatory frameworks must enforce stringent quality control standards for production, ensuring formulations meet minimum spore viability, purity, and efficacy benchmarks.
- Subsidies and tax incentives for manufacturers adhering to these standards could encourage compliance.
- Investments in research and development should focus on creating resilient fungal strains that are effective under diverse agro-climatic conditions, along with user-friendly formulations.
- Government-backed training programs and extension services are needed to educate farmers about the benefits and proper application techniques of EPF.
- To streamline distribution, public-private partnerships can establish cold chain networks to maintain product integrity during storage and transportation.
- Financial support schemes such as micro loans for smallholder farmers to adopt biopesticides, coupled with awareness campaigns, can boost market demand.

Conclusion

Entomopathogenic fungi represent a promising solution for sustainable pest management, offering numerous advantages over conventional pesticides. Their targeted control of specific pest species minimizes harm to non-target organisms and reduces the risk of pesticide resistance. Their biodegradability and minimal impact on humans, animals, and beneficial insects make them environmentally friendly options. With their efficacy and versatility, entomopathogenic fungi can be utilized across various agricultural settings, integrating seamlessly with integrated pest management strategies. Moreover, by preserving natural enemies of pests and reducing reliance on chemical pesticides, they contribute to biodiversity conservation and ecosystem health. To realize the full potential of biopesticides like entomopathogenic fungi, collaboration and investment in research, regulatory support, education, and awareness are essential. By embracing biopesticides, we can pave the way for a healthier and more sustainable future in agriculture, ensuring the well-being of both current and future generations.

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From Dung to Decay: The Unusual Diets of Butterflies

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Abstract

Butterflies are often known for feeding on nectar, but it doesn't provide all the nutrients they need for growth and reproduction. During an expedition in Arunachal Pradesh, India, we observed species feeding on alternative sources like dung, carrion, and ash. These unusual diets supply essential nutrients such as amino acids and minerals, allowing butterflies to thrive in nutrient-poor environments. Species like the Paris peacock (*Papilio paris*) and Orange oakleaf (*Kallima inachus*) displayed these behaviors. By feeding on decaying matter, butterflies play a role in nutrient recycling and ecosystem health. This study highlights their adaptability and calls for further research into their ecological roles .

Keywords: Butterflies, coprophagous, saprophagous.

Introduction

Butterflies are often known for their vibrant colours and delicate beauty, captivating enthusiasts and researchers alike. While nectar provides butterflies with essential sugars and some nutrients, it does not supply all the nutrients required for their growth and reproduction. Hence, nectar seekers often engage in a behaviour known as mud-puddling, where they gather in large groups to use their proboscis to absorb fluids from sources like soil, dung or carrion. In response, some butterflies have evolved to exploit alternative food sources to meet their nutritional needs (Beck et al. 1999). Dung and decaying organic matter offer valuable nutrients, such as amino acids, salts, and minerals, which are often absent from nectar. These diets may also help them to establish intestinal microbes. Understanding these atypical feeding behaviours provides insight into the survival strategies and ecological roles of butterflies.

Study area and observations

From July 31, 2024 to August 10, 2024, during the monsoon season, we conducted an expedition for butterflying and mothing in the Upper Siang and Dibang Valley regions of Arunachal Pradesh, India. This region, renowned for its rich biodiversity and varied topography, offered a unique opportunity to observe and document a wide range of butterfly and moth species. The expedition took place across diverse elevations, ranging from approximately 700 to 2000 meters above mean sea level. The varying altitudes provided access to different ecological zones, from subtropical to temperate, which are crucial for understanding the distribution of butterfly species in this region.

During the expedition, several notable butterfly species were encountered. Photographs were taken using a Canon 70D camera to aid in identification. Field identification was initially carried out using standard butterfly and moth field guides and an online database about butterflies in India (Kunte et al., 2024). For

Figure: 1 & 2 Green Commodore butterfly exhibiting coprophagy; 3 Red Admiral butterfly exhibiting coprophagy; 4 Orange oakleaf butterfly exhibiting saprophagy on dead snake; 5 Lycaenid butterfly exhibiting mud puddling; 6 Red Helen butterfly exhibiting mud puddling; 7 Indian Nawab butterfly exhibiting ash feeding; 8 Vagrant butterfly exhibiting ash feeding .

accurate identification, we consulted experts Mr. Sanjay Sondhi, a Dehradun-based naturalist and Mr. Fahim Khan, a lepidopteran enthusiast. During the expedition, several notable butterfly species were encountered, including Paris peacock (*Papilio paris*), Yellow Gorgon (*Meandrusa payeni*) and White Dragontails (*Lamproptera curius*) belonging to the family Papilionidae, Orange oakleaf (*Kallima inachus*), Amber jungle queen (*Stichophthalma sparta*), Blue duke (*Bassarona durga*), Vagrant (*Vagrans egista*), Indian Nawab (*Charaxes bharata*), Cruiser (*Vindula erota*), Sailor (*Neptis hylas*) and Large Yeoman (*Cirrochroa aoris*) belonging to the family Nymphalidae and many others. We observed them feeding on unusual diets. While most butterflies are known for their reliance on nectar, many species in this region were seen feeding on alternative sources like animal dung (Fig. 1, 2, 3), dead animals like snakes (Fig. 4), mud puddling (Fig 5, 6), and even ash (Fig. 7, 8).

Dung feeding/coprophagous butterflies: Feeding on dung is an adaptation observed in a few butterfly species (Hewavitharana et al. 2013). By consuming dung, butterflies gain nitrogen and other minerals that are otherwise scarce in their typical nectar sources. This adaptation enables them to thrive in environments where nectar is not readily available or is of poor quality (Molleman et al. 2005; Ravenscraft & Boggs 2016). Species like *Hermeuptychia hermes* and *Colobura dirce* have been documented feeding on dung and decomposing organic matter. These butterflies are typically found in tropical and subtropical regions, where dung is more accessible and decomposition processes are more prevalent (Krenn et al. 2010). The ability to utilize dung as a food source allows these butterflies to supplement their diet and enhance their survival and reproductive success.

Feeding on dead animals/ saprophagous butterflies: Butterflies feeding on dead animals, including reptiles such as snakes, is an even more unusual behaviour. While there are few documented cases of butterflies consuming dead snakes, species like the *Nymphalis xanthomelas*, *Kaniska canace* and *Vanessa indica*, are known to visit carrion and decaying matter for nutrient supplementation (Ômura, 2001; Ômura & Honda, 2003). Butterflies feeding on dead reptiles may be more common in environments with scarce nectar sources. In such cases, alternative food sources, including dead animals, become crucial for meeting their nutritional requirements such as amino acids, salts, and minerals, which are not readily available from their usual nectar sources (Laxmisha & Ramesh, 2023). This behaviour is particularly prevalent in tropical and subtropical regions, where the decomposition of large animals is more common, providing an accessible source of essential nutrients.

Conclusions

The study of butterfly feeding behaviours, particularly those involving dung and decaying organic matter, reveals a remarkable adaptability and their resilience in the face of environmental challenges. While nectar remains the primary food source for most butterflies, the ability to utilize alternative food sources such as dung and dead animals highlights their ecological flexibility and survival strategies. By breaking down and recycling organic waste, these butterflies contribute to the health and functioning of their habitats. Their feeding behaviour aids in the decomposition process, returning essential nutrients to the soil and supporting plant growth.

Further research is needed to explore the full extent of these unconventional feeding behaviours and their implications for butterfly ecology. Investigating the nutritional benefits of feeding on dung and dead animals, as well as the specific environmental conditions that drive such behaviours, will enhance our understanding of butterfly adaptations and their roles in ecosystem processes.

In summary, the diverse feeding behaviours of butterflies, from nectar to unusual diet, underscore the complexity and adaptability of these fascinating creatures. Their ability to utilize a range of food sources highlights their critical role in maintaining ecological balance and provides valuable insights into their survival strategies.

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Tasar silkworm rearing on kusum: A new approach

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Abstract

This study showcases the viability of rearing tropical tasar silkworms (*Antheraea mylitta* D.) on Kusum (*Schleichera oleosa*) trees, traditionally used for lac cultivation. The rearing process, from coupling to harvesting, spanned approximately two months, yielding 31 cocoons per tree. In future integration tasar rearing with lac production on Kusum trees presents a lucrative opportunity for rural and tribal communities, with added benefits like silkworm excreta-based dye extraction. This eco-friendly approach fosters a circular economy, generating a new income stream for farmers.

Keywords: Tasar silkworm, Kusum, lac cultivation, sustainable agriculture, sericulture, rural development.

Tropical tasar silkworm, *Antheraea mylitta* D., is a key source of tasar silk. Traditional rearing relies on specific primary food plants, but the search for alternative host plants could increase production and sustainability.

Tasar Silkworm Food Plants

Tasar silkworms feed on a variety of plants, categorized into primary, secondary and tertiary. Primary food plants include *Terminalia arjuna* (Arjun), *Terminalia tomentosa* (Asan), *Lagerstroemia speciosa* (Jarul), and *Shorea robusta* (Sal), which silkworms prefer. Secondary and tertiary plants are those where silkworms can survive but are not typically the first choice.

Exploring Kusum for Tasar Silkworms

Kusum (*Schleichera oleosa*) is a versatile tree traditionally valued for lac cultivation, but its benefits extend far beyond this. It holds significant

Table 1: The lifecycle of tasar silkworm on kusum.

Stage	Date /Stadium
Date of Coupling	01.11.2023
Date of hatching	11.11.2023
Incubation	10 Days
I Instar	5 Days
I moult	16.11.2023
II Instar	5 days
II moult	21.11.2023
III Instar	7 days
III moult	28.11.2023
IV Instar	9 days
IV moult	07.12.2023
V Instar	12 days
Spinning	7 days
Harvesting	10.01.2024

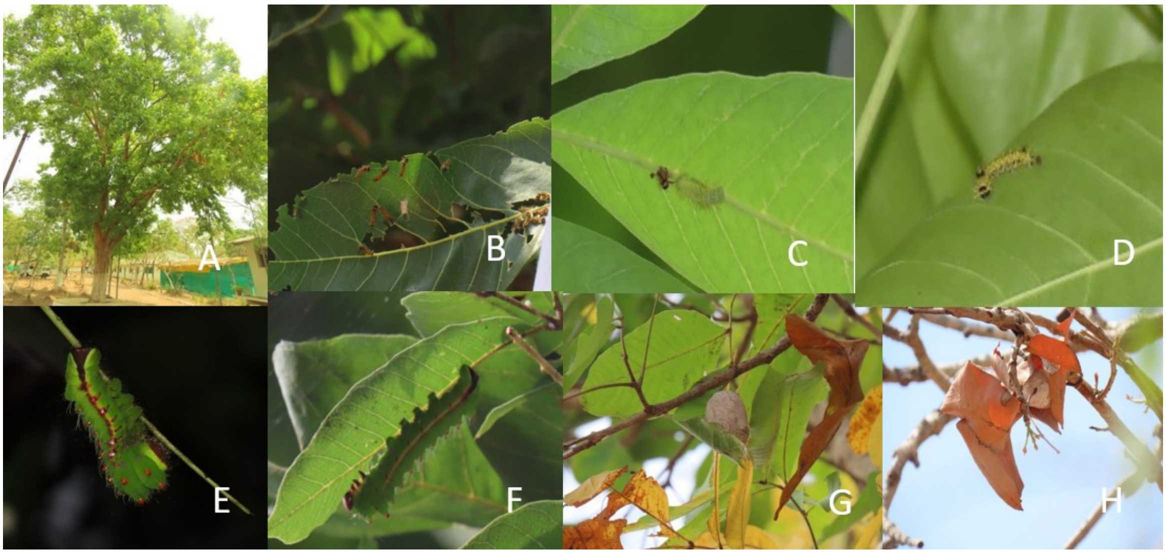

Figure 1: Tropical Tasar Silkworm rearing on Kusum Tree (A. Kusum tree, B. Brushed worms, C. Molting process of worms, D. Chawki worm E&F. Mature worms, G&H. Cocoons intact with kusum leaves.)

pharmacological potential, exhibiting anticancer, antioxidant, and antimicrobial properties, which could lead to new medical applications. In addition, Kusum offers promise for biodiesel production, with its biodiesel having a higher cetane number than petroleum diesel, positioning it as a viable alternative fuel. Moreover, its low tannin levels make it safe for use as livestock feed, further demonstrating its wide-ranging utility.

Nadaf et al. (2022) reported that lac cultivation could be integrated with tasar culture, given that *Ziziphus mauritiana* serves as a common host plant for both lac insects and tasar silkworms. However, Kusum (*S. oleosa*) had not been considered a food plant for the Daba ecorace of tropical tasar silkworms. This perception changed when the Basic Seed Multiplication and Training Centre (BSMTC) in Bastar, operating under the Basic Tasar Silkworm Seed Organization (BTSSO) of Central Silk Board, conducted rearing trials with tasar silkworms on Kusum for the first time.

Integrating Tasar Silk and Lac Production

Kusum has long been a host plant for lac insects. Its potential as a food plant for tasar silkworms has been studied by the Basic Seed Multiplication and Training Center (BSMTC) in Bastar where the 2 disease free layings (DFL) were bushed on 11.11.2023 on 20 year old tree.

Observations

It was observed that the first instar (larval stage) lasted for 5 days, from 11.11.2023 to 16.11.2023, followed by the first moult on 16.11.2023. The second instar also lasted 5 days, from 16.11.2023 to 21.11.2023, ending with the second moult on 21.11.2023. The third instar had a longer duration of 7 days, from 21.11.2023 to 28.11.2023, with the third moult occurring on 28.11.2023. The IV instar stage lasted 9 days, from 28.11.2023 to 07.12.2023, followed by the fourth moult on 07.12.2023. The fifth instar was the longest, lasted 12 days, from 07.12.2023 to 19.12.2023 and it was the final larval stage before the silkworms began spinning cocoons which lasted for 7 days, from 19.12.2023 to 26.12.2023. The fully formed cocoons were harvested on 10.01.2024 (Table).

The key observations were as follows:

- Incubation period was observed from 01.11.2023 to 11.11.2023 (10 days) while the larval development spanned approximately 38 days, culminating in the spinning stage.

- The longest instar was the fifth, lasting 12 days, while the first and second instars were the shortest, each lasting 5 days.
- After the spinning stage, harvested the cocoons when matured.
- Successful trials yielded 31 cocoons from a single tree.
- Cocoons were intact with kusum leaves.
- Further excreta of worms were used for the dye extraction studies. Need to draw a proper time schedule for the both the crops (Lac and Tasar).

Conclusion

The study demonstrated that Kusum trees (*S. oleosa*) are a suitable food source for rearing tropical tasar silkworms (Daba ecorace), with the entire rearing process, from coupling to cocoon harvesting, taking approximately four months. The larval development lasted about 38 days, with the longest instar (fifth) lasting 12 days and the shortest (first and second) each lasting 5 days. Successful trials yielded 31 cocoons from a single Kusum tree, confirming the feasibility of this approach. Typically, primary food plants produce a yield of 45-50 cocoons per DFL. While kusum's yield may be lower, it offers supplementary income without incremental input costs. Furthermore, when integrated with lac cultivation, kusum demonstrates significant profitability for rearers. These results suggest that integrating tasar rearing with Kusum-based lac production could provide a sustainable and profitable model for rural and tribal communities, with the added potential for innovative applications such as using silkworm excreta for dye extraction. Further research and larger-scale trials are needed to optimize conditions and assess the broader socio-economic impact of this method.

Future Scope

Given the success of this study, several future research directions can be considered like conducting larger-scale trials in different regions to validate the results and understand any geographical variations, exploring factors like tree density, climate conditions, and leaf quality to maximize cocoon yield and quality, investigating the potential to integrate tasar rearing with lac cultivation on the same Kusum trees, providing farmers with multiple revenue streams, further study into the potential uses of silk streams, further study into the potential uses of silkworm excreta for dye extraction and other applications, promoting a circular economy and assessing the socio-economic impact of introducing this cultivation method to rural and tribal communities, with a focus on sustainable income generation.

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Anar butterfly, *Deudorix isocrates* (Fab.) found feeding on kusum fruits

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The Kusum tree (*Schleichera oleosa*) is a highly valued species, offering a wide range of benefits that span economic and agricultural contributions, medicinal applications, and environmental sustainability. Its cultivation supports the production of lac (Non-Timber Forest Products) a valuable resin used in varnishes, adhesives, and other products secreted by the species of *Kerria*. The lac produced from the kusum tree is commonly called *kusmi* lac with two crop cycles Jethwi and Aghani, and is a significant source of income for rural communities in India.

Apart from lac cultivation kusum tree provides fruits that are edible and consumed locally, low tannin levels in leaves and fruit residues make it a good animal fodder, oil extracted from Kusum seeds can be converted into biodiesel, fuel-wood, timber, and medicinal benefits with anticancer, antioxidant, antimicrobial properties and is used in traditional medicine to treat ailments such as skin diseases, digestive issues, and fever for both humans and livestock, it also provides habitat and food for various wildlife species, contributing to biodiversity conservation. Its multifaceted uses make it integral to rural livelihoods and ecological balance (Sarkar et al., 2022). The *kusum* trees generally flower during the onset of the dry season (January-February) and fruiting takes place during March-April and fruits ripen during the month of July-August. The seeds are the major source of propagation and are viable mostly if sown freshly after collection (Saha et al., 2010).

The butterfly species *Deudorix isocrates* (Fab.), commonly referred to as the pomegranate/ anar butterfly or common guava blue, is a significant pest of fruit-bearing trees, causing substantial damage to its host plants. (Anonymous 2024; Gundappa et al., 2017; Singh and Kaur 2016; Homkar 2009; Tiwari et al., 2008; Haseeb and Sharma 2007; Rao 1992). The primary damage is caused by the larvae by boring into the fruits, which leads to secondary infections and causes deformed fruits, fruit decay, premature fruit drop and ultimately feeding on seeds will also cause reduction in its viability, sometimes it may cause of germination failure which has negative impact on future plant propagation efforts.

Anar butterfly has wide range of larval host plants such as, *Tamarindus indica* (Fabaceae). *Strychnos nux-vomica* (Loganiaceae). *Punica*, *Punica granatum* (Lythraceae). *Psidium guajava* (Myrtaceae). *Eriobotrya japonica, Malus pumila*, *Prunus dulcis*, *Prunus persica*, *Pyrus communis* (Rosaceae). *Catunaregam nutans*, *Catunaregam spinosa*, *Gardenia gummifera*, *Gardenia latifolia*, *Randia*, *Tamilnadia uliginosa* (Rubiaceae). *Citrus*, *Citrus x aurantium*, *Citrus sinensis*, *Limonia acidissima*, *Limonia elephantum*, *Naringi crenulata* (Rutaceae) (Bell 1920; Wynter-Blyth 1957; Robinson et al., 2010; Nitin et al., 2018).

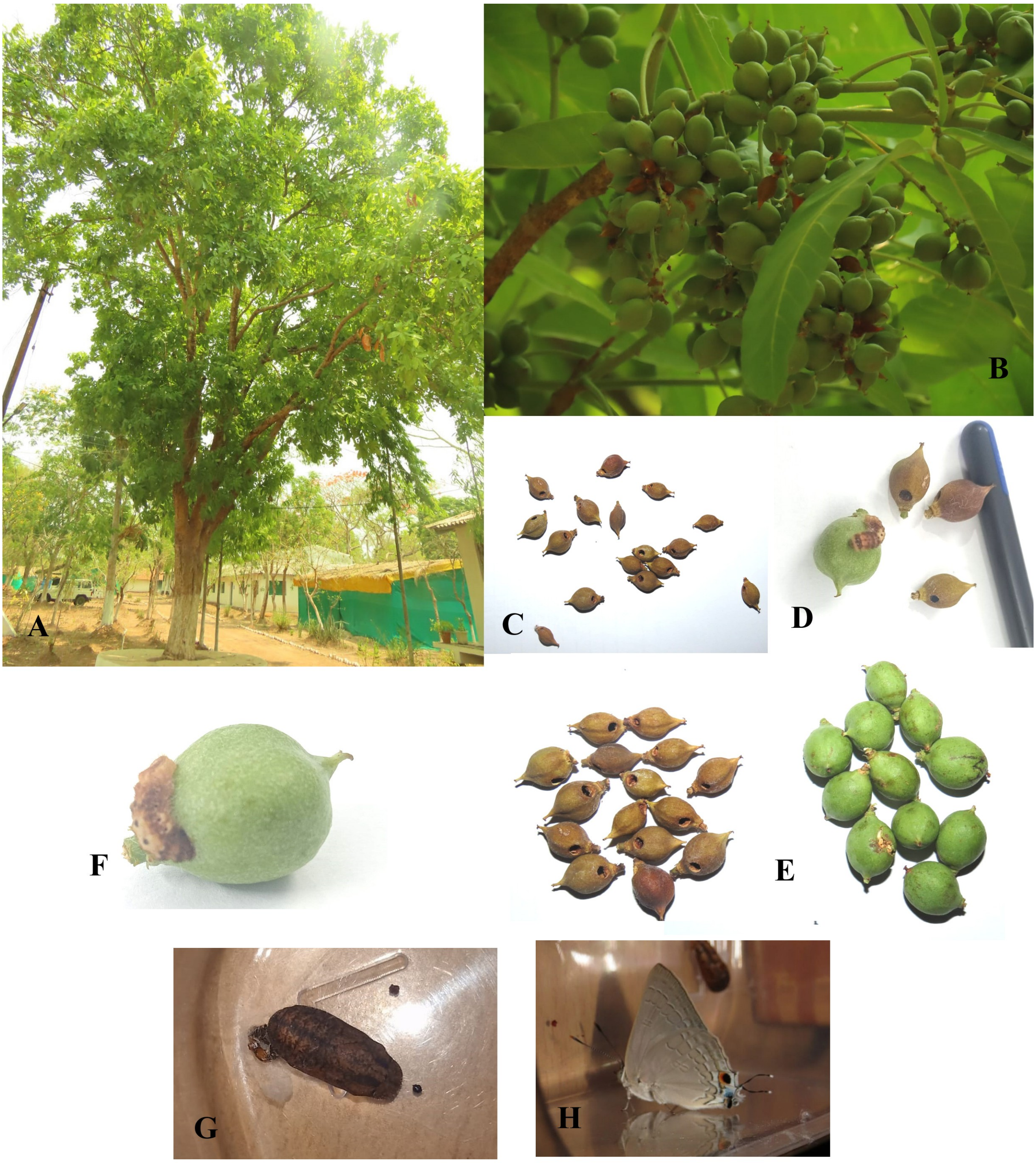

Fig. 1: A. *Kusum* tree. B. Fruit bunches with infested fruits; C. Damaged fruits with characteristic circular bore holes; D. Larvae feeding on healthy fruit; E. Comparison of healthy and damaged fruits; F. Larva feeding on internal contents; G. Pupa; H. Freshly emerged adult.

In the month of April, 2024 during field observations at the Basic Seed Multiplication and Training Centre, Central Silk Board, Bastar, Chhattisgarh. We observed *anar* Butterfly larvae (*Deudorix isocrates*) feeding on immature *kusum* fruits. Some fruits exhibited signs of damage, with larvae feeding on them, circular bore holes, premature drying and dropping of the fruits. The damage was characterized by complete feeding of the internal contents or seed/ kernel by the larvae, leaving behind circular exit holes on the outer rind of the fruit (Fig. 1). Each fruit was affected by a single larva. When the larva fully penetrates the fruit, it seals the entry hole with its anal end. The field laboratory photographs of the different life stages and damaging symptoms were captured.

The larvae were collected and reared in plastic jars and upon adult emergence the species was identified based on photographs. Here in the present study, we observed the feeding of anar butterfly larvae on fruits of the kusum for the for the first time. Damage leads to premature drying and dropping of the fruits and loss of viability which may leads to difficulty in propagation of kusum.

Acknowledgment: Authors thankful to the Dr. P. R. Shashank, Senior Scientist, National Pusa Collection, Division of Entomology, ICAR-IARI, New Delhi, India for the identification of the species and thankful to Central Silk Board for giving necessary support.

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11th INDIAN ENTOMOLOGIST PHOTO CONTEST

The Indian Entomologist Photo Contest aims to promote insect photography among photographers, professionals, amateur entomologists, and laymen. The theme for the ninth edition of the photo contest was "Insects and aspects related to insect life." The contest was open from the 23rd of October until November 23rd, 2024. Each participant was asked to submit one good photograph that meet a few specified formats, as well as a filled-in application form in which he or she must include his or her details, caption, description, photograph specifications, and a declaration of the ingenuity of the photograph. We received an overwhelming response from 90 participants, who submitted a total of 101 images. The photos were initially screened by Bug Studio associate editors for the prescribed standards and overall image quality and further sent to three independent and anonymous external reviewers to judge the best three photos. Based on the reviewer results, the final evaluation was done by a committee of independent members under the oversight of the three editorial board members. During the complete review process, the entries were assessed based on the following criteria: quality (clarity, lighting, depth of field, composition), relevance of the subject matter (theme, rareness of subjects), creativity and originality. To ensure a blind review, the details of the photographer were hidden, and the evaluators were only presented with the photograph, caption, description and technical specifications.

The following are the winner for 11th Indian Entomologist photo contest

- The first place was won by Shailesh S Deshpande (H2-703, Vanaraji heights, Rambaug colony, Paud Road, Kothrud, Pune-411 038), who captured incredible photo of Hummingbird-Hawk moth on flowers.
- The second place was won by Dharmendra R. Padiyar (C-83, Laxmi row house, At. Delad, Po. Sanyan, Ta. Olpad, Dist.Surat-394130), for his incredible close up photo of Membracid hopper.
- The third place was won by Suresh Khaire, Shivam, C187, Sandalwood Society, Opp Kochartech Sales India, Manjalpur, Vadodara-390011) for capturing a photo of Common Mormon caterpillar.

Congratulations to the winners, and we acknowledge all the participants who took an interest in 11th Indian Entomologist photo contest and sent their entries!!

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First place

Hummingbird-Hawk moth on flowers submitted by Shailesh S Deshpande from Pune, Maharashtra.

Second place

A close up shot of Membracid hopper by Dharmendra R. Padiyar from Surat, Gujarat.

Third place

A Common Mormon caterpillar by Suresh Khaire from Vadodara, Gujarat.

KEERTHANA A.

PH.D. SCHOLAR (ENTOMOLOGY)
TNAU, COIMBATORE

Keerthana A. is currently pursuing her doctoral programme in Entomology on "Investigating the insect gut microbial communities for plastic degradation" under the guidance of Dr. V. Balasubramani, Professor Agricultural Entomology & Controller of Examinations, TNAU, Coimbatore. She did her masters from Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar and research on "Morpho-molecular characterization and assessing the effect of sowing time on aphid incidence in wheat" under the guidance of Dr. M. S. Sai Reddy, Assistant Professor, RPCAU, Bihar. She had identified the six aphid species in wheat through molecular characterization and resulted that aphid populations were more abundant on early -sown wheat and decreased with delayed sowing dates which are the key outcomes of her master research. She shared the expected outcome of her current research work that characterization of plastic degradation and identification of key microbial communities in *Galleria mellonella* and *Corcyra cephalonica* larval gut and generation of transcriptomic data highlighting the genes and metabolic pathways involved in plastic degradation. She emphasized that it will provide eco-friendly solutions for mitigating plastic pollution through microbial or enzyme-based approaches. She detailed her interest in entomology that hands-on experiences in labs and fieldwork deepened her curiosity, inspiring her to pursue research that combines understanding insect behavior with solving real-world challenges. She was granted JRF and SRF scholarship in her master and doctoral programmes. She strongly stated that she wishes to pursue postdoctoral research to deepen her expertise and contribute to innovative advancements in her field after completing Ph.D. programme and her long-term goal is to establish a career in research, making meaningful contributions to science and agriculture. She had published several research papers, reviews, popular articles etc. with respect to entomology.

VIVEK ADHIKARI

PH.D. SCHOLAR (ENTOMOLOGY)
IARI-CICR, NAGPUR

Vivek Adhikari is doing his doctoral research on “Simulating cotton yield loss by coupling pest damage with crop growth model” under the guidance of Dr. Babasaheb B. Fand, Senior scientist, ICAR-CICR, Nagpur. He did his masters from Anand Agricultural university, Anand, Gujarat and research on “Bionomics of lesser grain borer, *Rhyzopertha dominica* Fabricius and its management through nano-emulsions in stored wheat” under the guidance of Dr. M.V. Dabhi, Assistant Professor, AAU, Anand. He enlisted the key outcomes of his master research such as GW 513 and GW 1 which are the resistant wheat varieties exhibited the least damage to *R. dominica*, neem oil and karanj oil nano-emulsions were the most effective significantly outperforming conventional oils and nano-emulsions reduced population growth of R. dominica and germination loss of wheat significantly compared to oils, with neem oil nano-emulsion which had a uniform particle size and better efficacy as grain protectants, demonstrating superior pest control and seed preservation. He shared the memories during his master research that “During my M.Sc. research, I experienced several remarkable and memorable moments that deepened my understanding and passion for science. One of the most fascinating discoveries was observing how oil transforms into an emulsion and, through ultrasonication, the particle size is downscaled to form nanoparticles. Witnessing this process firsthand was truly captivating, and I was amazed to realize that nano-emulsions outperform regular emulsions in terms of functionality.” He shared the insect pest and disease photographic data with Cropmint (Farmitopia Pvt. Ltd.), supporting the development of a pest detection tool. These experiences solidified my passion for entomology and motivated him to pursue it for his higher studies. It made the remarkable interest in the field of Entomology. He secured the ICAR NTS scholarship in his UG and PG programmes followed by IARI scholarship in his doctoral programme. He had received the Best poster award at 1st Entomology Students Conclave (ESC) by Entomological Society of India (ESI) in 2024. Interestingly, he has Instagram page “Insectagram_am” and YouTube channel “Entomo communication” about red ants. Besides, he is very much interested in insect photography.

SANGEETA DASH

PH.D. SCHOLAR (ENTOMOLOGY)
ICAR-IARI, NEW DELHI

Sangeeta Dash is presently pursuing her Ph.D. in Entomology from ICAR-IARI, Pusa Campus, New Delhi. Inspired by her teachers at OUAT, Bhuvaneswar where she completed her Bachelors, she developed a keen interest in the field of entomology, which offered her a chance to explore an incredibly diverse and essential part of the natural world. She completed her Masters in Agricultural Entomology from University of Agricultural Sciences, GKVK, Bengaluru, where she worked on mango fruit fly, *Bactrocera dorsalis* for the validation of suitable genetic loci as targets for genetic population control using CRISPR/CAS9 technology. Her research resulted in the successful restriction of yellow gene in *B. dorsalis*. Currently, she carries out her doctoral research under the guidance of Dr. Amalendu Ghosh, Senior scientist (Entomology), Division of Plant Pathology, ICAR-IARI, Pusa campus. Her research focuses on functional validation of key genes in the whitefly, *Bemisia tabaci* associated with begomo-virus transmission using the RNAi technology and in evaluating the spray-induced gene silencing for the management of whitefly begomo-virus complex. Silencing of key genes can induce mortality and impair the virus transmission by *B. tabaci*. Further, conjugating the dsRNA with regenerative polymer can improve the environmental stability of dsRNA for the better application of RNAi in pest management. Her academic achievements include securing ICAR-JRF fellowship (AIR-10) during her M.Sc. and ICAR-SRF fellowship (AIR-11) and ASRB- NET during her Ph.D. program. Her publications include several research, review and popular articles and book chapters. Besides her interest in research, she finds strength and peace in dancing, especially all forms of Indian classical dance. Sangeeta aspires to become a scientist, to continue contributing to the research field of entomology.

CHANDANA C R

PH.D. SCHOLAR (ENTOMOLOGY)
UAS, RAICHUR

Chandana C R, a Ph.D. scholar (Entomology) from University of Agricultural Sciences, Raichur has always been fascinated by the intricate relationship between insects and environment. Her interest in the field of entomology stems from its incredible relevance to agriculture, ecology and human wellbeing. The potential to contribute to sustainable agricultural practices and environmental conservation has solidified her passion for the field of entomology. She has completed her M.Sc. degree from Assam Agricultural University where her research led to successful biosynthesis of silver nanoparticles from Polygonum hydropiper which when evaluated for its efficacy showed significant control against major insect storage pests. She recalls witnessing the transformation of oil to nanoparticles through the process of ultrasonication for the first time and describes it as one of most memorable moments during her days of research. At present she is pursuing her doctoral research on the topic of mining and expression analysis of ABC transporters for their role in insecticide resistance in legume pod borer, *Maruca vitrata*. Her research is being conducted in collaboration with ICAR-National Bureau of Agricultural Insect Resources (NBAIR) under the guidance of Dr. Sushila Nadagouda (Assistant Professor, UAS, Raichur) and Dr. M. Mohan (Principal Scientist, Division of Genomic Resources, ICAR-NBAIR). Besides, providing insights into the role of ABC transporters in insecticide resistance, she also aims to utilize RNAi technology for the management of *M. vitrata*. The outcomes of her research can pave the way for developing resistant cultivars and novel insecticides. The genomic data obtained can further be used in toxicological and physiological studies for the development of effective pest management strategies. Chandana has been awarded, Rastrapati guide (The Bharat Scouts and Guides, Government of India) in 2014, best poster presentation award at the International Conference on Plant Protection in Horticulture (ICPHM) and Entomology Students Conclave (ESC) in 2024 and has cleared ASRB NET. Currently, she is awarded University Merit Scholarship by UAS, Raichur. Besides her studies, she enjoys reading literature, exploring nature and engaging in creative activities like writing and painting. After receiving her doctorate, Chandana plans to pursue postdoctoral research to deepen her knowledge and contribute to innovative advancement in the field of entomology.

SABA TANVEER

PH.D. SCHOLAR (ENTOMOLOGY)
GBPUA&T PANTNAGAR

Saba Tanveer is doing her doctoral research on “Eco-Friendly Strategies for Pigeon Pea Pests management: Harnessing Habitat Manipulation strategy” under the guidance of Dr. Ruchira Tiwari (Professor), GBPUA&T Pantnagar. She did her masters from GBPUA&T Pantnagar and research on “Study on the dynamics of Insect Pests of Sugarcane in the Tarai region of Uttarakhand and evaluation of various Sugarcane germplasm against major insect pests” under the guidance of Dr. R. P. Maurya (Associate Professor), GBPUA&T Pantnagar. She enlisted the key outcomes of her master's research, including the finding that the germplasm CoPant 12221 was the least susceptible to the borer complex and sucking pests of Sugarcane. Additionally, the study identified that host plant resistance, characterized by specific biophysical and biochemical traits, contributed to resistance. Germplasm exhibiting these traits showed narrower leaf width, fewer leaves, wider leaf angle, higher antioxidant and phenol content, as well as reduced total carbohydrate content, all of which resulted in decreased insect pest infestation of sugarcane. The expected outcomes and practical utility of her current research are to develop an Integrated Pest Management (IPM) package that incorporates habitat manipulation, the use of biopesticides and novel insecticides, as well as fostering host plant resistance by screening pigeon pea germplasm accessions for their biochemical and biophysical characteristics.She reflected on her experiences during her master's research, saying, "Throughout my M.Sc. research, I had several unforgettable and significant moments that enhanced my understanding and passion for science. One of the most fascinating aspects was working with the egg parasitoid *Cheiloneurus* pyrillae and the nymphal adult parasitoid *Fulgoraecea melanoleuca* of *Pyrilla perpusilla*." Since the first year of her undergraduate program, she has been deeply fascinated by entomology, with a particular interest in working with live insects which has become her passion.In addition, she has a strong interest in playing badminton and chess, as well as writing and reciting poems in both English and Urdu.

MADEVU SAI KUMAR

PH.D. SCHOLAR (ENTOMOLOGY)
ANGRAU, BAPATLA

Madevu Sai Kumar is currently pursuing his doctoral programme in Entomology on “Studies on floral calendar and evaluation of various pollen substitutes on the growth and development of Apis mellifera L. (Hymenoptera: Apidae) ” under the guidance of Dr. S. R. Koteswara Rao Professor & Head, Department of Entomology, Acharya N.G. Ranga Agricultural University, Bapatla. He did his masters from College of Agriculture, Assam Agricultural University, Jorhat and research on “Exploration of Jasmonic Acid induced resistance in Chilli (*Capsicum annuum* Linnaeus) against Aphid (*Aphis gossypii* Glover),” under the guidance of Dr. Shimantini Borkataki (Assistant Professor) Assam Agricultural University, Jorhat. The results of his master research clearly demonstrate that the exogenous application of jasmonic acid (JA @ 315 ppm) twice, once at 20 days after transplanting and again at 60 days after transplanting, holds potential for further exploration in the commercial cultivation of chilli to boost yield and production. Additionally, jasmonic acid (JA@ 210 ppm) can be used to enhance resistance against insect pest attacks. He shared the expected outcome of his current research work that during periods of scarcity, these pollen substitutes will serve as an additional supplement for *Apis mellifera*, supporting their growth and the development of brood characteristics. He emphasized that a study on the floral calendar will provide insight into which flowering plants are suitable near apiculture boxes and which ones are good sources of nectar and pollen. He expressed his enthusiasm for entomology, emphasizing how hands-on lab and fieldwork experiences sparked his curiosity and motivated him to explore research that integrates insect behavior studies with addressing practical challenges. He was granted Non JRF fellowship from ICAR in master’s degree programme. His long-term aspiration is to build a career in research, contributing significantly to science and agriculture, with the aim of becoming an ARS Scientist.

Indian Entomologist is a biannual on-line magazine and blog site that publishes articles and nformation of general, scientific and popular interest. The magazine publishes letters to the editor, columns, feature articles, research, reviews, student opinions and obituaries. The magazine accepts articles on all aspects of insects and terrestrial arthropods from India and worldwide. Short field notes and observations are also welcome. This magazine is intended to provide a broad view of topics that appeal to entomologists, other researchers interested in insect science, and insect enthusiasts of all stripes.

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Articles submitted should not have been published elsewhere and should not be currently under consideration by another journal/ magazine. Interested authors are advised to follow the author guidelines of Indian Journal of Entomology for reference citations and to follow as closely as possible the layout and style, capitalization and labelling of figures. All papers are subject to peer review and may be returned to the author for modification as a result of reviewers reports. Manuscripts are acknowledged on receipt and if acceptable proofs are sent without further communication. Minor editorial alterations may be made without consulting the author. Make sure to submit the photographs of high quality in .jpg format. For those who want to contribute commentary and feature articles please contact editors before submission.

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Student corner – students working on interesting topics of entomology to share their views and opinions about their research work. Can submit with personal photograph; it should not be more than 1,000 words in length. We encourage entomologists to contact us if you have any interesting story to share about insects. Contributions to be sent to the Managing Editor, in digital format (MS Word) as an e-mail attachment to indianentomologist@gmail.com

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