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Not-for-profit journal promoting Insect Science

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Cover Page:** ***Female Nymph of Letana sp. (Tettigonidae: Orthoptera)

Photo by: Dr. Nagaraj, D. N., Project Head (Entomologist) Ento Proteins Pvt. Ltd., Mangalore, , India

Insect Environment

(Quarterly journal to popularize insect study and conservation)

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

From this issue onwards our publishers are AVIAN Trust and Rashvee- International Phytosanitary Research and Services Pvt Ltd., Bengaluru, India.

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Author guidelines

Short popular insect notes, review essays, new records, profiles, tributes, and views are acceptable. There are no page charges; each article should preferably not exceed 500 words. Authors can refer to back volumes available on the website for writing style. Good photographs are encouraged. A special insect photo gallery "Insect Lens" is to encourage professional and amateur photographers of insects.

The blogs are for quick dissemination of insect "news". These will be published within a week of submission. Blogs should be about hundred words with one photograph, in simple English.

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

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

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Editorial

Urgent need to encourage Indian journals and insect research catering to Natural Farming

Insect Environment has completed 25 glorious years, thanks to authors and readers. This is the only timely and popular insect journal which reaches >6000 readers globally every quarter from India. Our weekly blogs are highly appreciated by several global universities, ICAR, FAO, Plant Quarantine etc. This is the only insect picture journal which publishes a separate LENS section.

Now, to more on research writing. There are many kinds of life sciences research-writers. Some write because they need to get a PDF or an entry into a job or get the next promotion in their careers. These people strain, struggle, sweat and manage to squeeze into an "impact factor journal," mostly controlled by business houses, as promotions are unfortunately based on 'impact factor". The "impact" journals seem to "encourage" mostly bio-molecular studies which demand extensive use of costly chemicals or equally expensive elaborate statistical labyrinthine packages that only make the data knotty, but in both these cases, chemical providers and statistical package creators gain and so perhaps, the paid international publishing business too.

Then there are some who don't write at all. These are the 'post-promotees', now ensconced in comfy chairs. Of course, they tend to lean on students who need to write and thus get authorship.

The above categories of course love and appreciate ***IE***!

Against this backdrop I am happy to say all the authors of ***Insect Environment*** write truly to satiate their insect passions. These entomologists are 'enthu' students, or echt entomologists- the insect-net waving or hand lens carrying type, or amateur insect-watchers or picture capturers. Then there are those who write to inform, educate, or extend to public and farmers, who are also our readers.

Publication of single theme monographs by a single author is a dying art. Today thanks to the huge cost of publishing, especially by business predatory journals, but with "impact", author 'teams' are fast emerging. Such journals, thanks to their "impact" clout, command the publication market. Each paper may thus have five to even 20 authors (!), who share the dollar page price among them. Even those who are unrelated to the subject would be in the 'author' subject line sometimes, of course without "conflict of interest"!- an euphemisim for oneness in scientific mind!! Earlier these 'less related authors' would have found a mention only in the acknowledgments.

This is an interesting and viable 'understanding' of an author guild all of whom would gain the next strata of career advancement.

A paper once published is sold to readers at a high dollar price! While all articles in our journal are free downloads.

Then there are those who publish very useful papers which contextualize on topical science useful to farmers and lay public. These papers have no pretense of elaborate and confusing statistics or machine-generated "chemical profiles" or "sequences". These papers are directly very useful to farmers and stakeholders and their inferences lead to adoptable technologies or products. These plant health studies will perforce be agronomic, field-oriented, and public-useful, ecological, input screening with less jargons and pretense to high-tech that only journals like ours will entertain them. Even if they get published in some of the best Indian journals, but without impact factor, authors don't get to benefit in career advancement. One journal, in point for example, I quote is the *Pest management in Horticultural Ecosystem*. An excellent Grade A journal. Yet it has a NAAS rating of 5+ only and I know it is not the first preference for many serious and young authors. But in this journal "Farmer Impact" papers are several. The need of the hour is to generate scientific basis, products and technologies which will promote Natural Farming as being emphasized by our Prime Minister. Natural Farming requires data generated on scientific field observations with emphasis on traditional plant protection and these research findings bereft of machine generated data and confusing graphs may not find a place in "impact" journals. It is a happy augury, in this context that Dr S K Singh, Director, ICAR-IIHR is embarking on Natural Farming research in horticulture (*ICAR-IIHR Newsletter*, Volume 45, July-December, 2022.) Papers emanating from this research should entail special 'marks' for career advancement, if rejected by "impact" journals or published in non-impact journals.

In fact, our suggestion for promotions and career advancements is that the screening committees should give weightages to papers with high applied science impact, based on usefulness and **immediate adoptability** to the stakeholders like farmers, irrespective of which journal the paper is published. There are several journals in India managed well by scientific societies, universities, institutes, etc., and their standards are high though not impacted by "Impact Factor"- which is a different ball game. This way contribution of entomology/science to farmers and stakeholders or even public would increase, as young researchers can be attracted to such applied sciences. Here I am happy that UGC has taken off the prerequisite of publishing two pre-PhD research papers.

Insect Environment as a concept is evolving into a unique journal with high energy, bracing as it were through the natural history of insects. We, realize that we are indeed an important hub in the documentation of insect history with our web alert blogs and photos. Many have told us that journals like ***IE*** with interactive web, encompassing professionals, college students, amateurs and even the lay public, is the new generation approach in insect journalism. As we begin 2023, we encourage you to be part of this "insect movement", by being writers with passion for entomology who truly wish to communicate for science's sake and inform for knowledge advancement's sake than a self-interest driven portfolio.

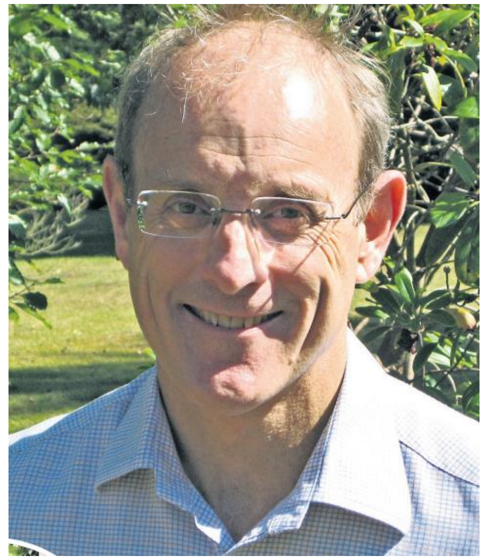
With a sense of pride and team spirit encased in humility, my edit team and I, place Volume 26 (1) March 2023 on your systems. Happy browsing!

Dr Abraham Verghese

Editor-in-Chief

Obituary

Dr. John D. Mumford
1953 – 2022
Editorial Advisor, Insect Environment
Professor of Natural Resource Management in the Centre for Environmental Policy (CEP)
Former Director, Centre for Environmental Policy (CEP)



John Mumford

I first met Dr. Mumford- John to us- and his wife Megan in South Africa in May 2002. We were gathering for the International Fruit fly meet at Stellenbosch[1]. John and Megan had arrived two days ahead and I was to reach the next day. On arrival at the hotel, he sent a message through Late Dr. John Stonehouse that we all would go on a trip to the mountains to see South Africa's most famous flower King Protea (the largest species of Protea and the tag of the South African cricket team).

John hired a self-driven car and took us all to see the amazing giant blooms of Protea, widespread on the mountain top. He was always fascinated by Nature and he wanted us to be the same! This is my first memory of John's loving, caring, friendly and at the same time professional approach to people and science.

That evening, we drove down the mountains, to an Italian restaurant, where John hosted us pizzas and of course with lots of South African wine and dessert thrown in. The conversation on the table veered around John's travel anecdotes, all mixed with science and way forward for IMFFI (Integrated Management of Fruit flies in India) programme. John as the Manager of the Fruit fly program in India, together with Directors from ICAR – first Dr. R N Pal and then Dr. G. Kaloo, and Late Dr. Stonehouse and I, met a couple of times to plan out the IPM programmes for fruit flies in India. It is here, I appreciated John's well studied knowledge of geo-zonation and crop

[1] The Sixth International Symposium on Fruit Flies of Economic Importance, reported on in Proceedings by Brian Barnes. The next symposium in this collaborative consortium, the 12th, will be held 2026 in Morocco.

diversity of India. He chose nine centers across India where a series of eco-friendly fruit fly management treatments would be studied against *Bactrocera* complex in fruits and vegetables.

John's ability to plan research, with a sense of rationale and justification impressed me. The proposal and multi centers were approved by ICAR. John was spearheading the project from UK. I was relating with him the progress of the project, and Stonehouse, who used to visit each centre on longer camping in India, also sought his advice and suggestions on weekly basis.

Next we met at the mid-course workshop for fruit fly identification and progress evaluation in 2004 in Kovalam, Kerala. All of the fruit fly workers came and John insisted that Senior Research Fellow's and students should join in. He stressed that this way students would also imbibe a sense of understanding and commitment to work. This was indeed an eye opener to all of us. Yes, he fostered a great team one-ness in all of us towards achieving the goal. The Kovalam workshop, was a major boost; he offered several tips in finishing off the IPM investigations. Our next meet was in 2005, a review workshop in Goa, with the same participants who had met at Kovalam. The IPM was finalized based on the multi-location results. The whole programme from 2001-2005 was scientifically managed from all dimensions and the recommendations for fruit fly management in mango, guava, cucurbits were forwarded to ICAR for approval and implementation.

IMFFI participants with Prof. J.D. Mumford at Goa (October 2005)

John’s professional and genial mannerism impressed all of us scientists. He mixed well with all, and he and Stonehouse became role models to many in teamwork in science.

I was one of the major beneficiaries of his partnership in India. It was he who mentored me in fruit fly management at Imperial College London and sponsored a training in fruit fly identification with Dr. Ian White at the British Museum in 2004. It was he and Stonehouse who recommended and sponsored my name and paid for the Fellow of the Royal Entomological Society, London. Way back in 2005 it was indeed an uncommon honour! At that time the RES office was just opposite his Imperial College Office in main city London and I could visit the RES library several times

Meanwhile the output of the IMFFI programme was that IPM using para-pheromone traps caught like wildfire across India (and even fetched us the Department of Biotechnology award for commercialization in 2014).

The India – UK team that worked with Dr John Mumford on IPM in fruit fly, 2001-2005

We did celebrate the IMFFI success over a dinner at a Japanese restaurant in Salvador, Brazil in 2006 at the 7th International fruit fly symposium. For the first time I tasted Japanese sushi- a rice fish preparation! Dr Jiji was also with us then. John as usual kept the table alive with his usual anecdotes and excellent insights into entomology, phytosanitary issues, pest risk, etc. (All memories now!)

By 2012-2013, the fruit fly trap spread across India to >40% of the area. When I next met John at Bangkok in 2014 again for a fruit fly symposium (the 9th), he said he was elated at the success of the fruit fly programme, and that he wanted to come to India and see it personally. Thus, John came over to India in 2015. We took him to a few trap manufacturers and farmers' fields. He was delighted in seeing the effort of a team work in 2001-2005, paying rich dividends. He spent a week in India. He and I then met ICAR officials in Delhi and that is the last I saw him physically.

I did work on a project on insect shipment (World Organisation of Animal Health special edition) associating with him in a small way between 2020-2021. Our meetings were over Zoom, and it was great pleasure to be teamed with him and Dr Megan. Fruit fly research and insect shipment all translated in many useful papers (>50).

He was a great supporter of ***Insect Environment*** and we were privileged to have him as our Senior Advisor.

So, it was a real shocker when we heard the news that he was suddenly called to his Eternal Home on 29th December 2022, after Christmas. The entire team of fruit fly workers and IE's Editorial team have expressed shock and have asked me, through this obituary to convey condolences to Megan and their son William.

John, we miss you!

Dr. Abraham Verghese

From the family

Born in Australia, John Mumford immigrated to Indiana, USA with his family when he was seven. After spending his teenage years in Massachusetts, where his father taught restorative dentistry, John's training in entomology began at Purdue University at the level of undergraduate. He completed a PhD at Imperial College through the prestigious Marshall Scholar programme (1975-78), before working at Lincoln University, New Zealand, and then taking up a post back at Imperial College where he worked for over 40 years as an academic and researcher. While always working on a global level, John established his home in Windsor, UK, to be close to the Silwood Park campus yet able to go to the South Kensington, London campus on a regular basis. John lived his life fully up to his unexpected death, at home in Windsor, from an acute pulmonary embolism. He was weeks short of his 70th birthday and but a few months away from his planned retirement from the teaching side of his career. He had spent recent holidays restoring a family home by the Massachusetts seaside as a base for the next phase of life that would have included writing, consulting and relaxation.

John Mumford and Will Mumford (son) peering into the honey extractor after harvesting

John did not divide work from friendships; he lived with consistent integrity, remarkable insight and humour in both realms. John and I met, in fact, at a fruit fly meeting for the Western Hemisphere and three years later were married. I, and later our son too, enjoyed the great pleasure of sharing many years with John and often many travels as well, although unfortunately never to India. Many of John’s numerous students and colleagues kept in touch, seeking his advice, his reaffirming interest and encouragement well past their shared tasks. It is now time for each of us to take up his nurturing role, while at the same time holding each other to the highest standard, in order to reach the best scientific conclusions and advice to make the world a better place. John was so pleased that his contributions made a difference to the everyday life of Indian farmers. We hope that having known John Mumford will inspire you, as it sustains us through the sadness of his early departure.

Sincerely,

Dr. Megan Quinlan (Mrs Mumford) and Will Mumford

Research articles

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Behavioral assays of cotton leaf folder, *Sylepta derogata* (Fabricius) (Lepidoptera: Crambidae) on different host plants

[1]Rakhesh, S. and [2]Mahantesh, S. T.
[1]Agricultural Entomology, University of Agricultural Sciences, Dharwad-580005
[2]Agricultural Entomology, University of Agricultural Sciences, Raichur-584104, India
Corresponding author: mragriinfo@gmail.com

Introduction

The cotton leaf folder, *Sylepta derogate* (Fab.) (Pyralidae: Lepidoptera) mainly distributed in Africa, Australia, Burma, Sri Lanka, Japan, Java, China and India as a minor pest (Mariselvi and Manimegalai, 2016) on different crops like cotton, bhendi, *A. indicum* and other malvaceous plants (Zhou *et al*., 1975 and, Sidhum and Dhawan, 1979). The egg period varies from 2-6 days and a gravid female lays 200-300 eggs on the ventral surface of the leaves. The larval period ranges from 15-35 days and the larvae are glistening green in color with a dark head. The pupation period is 6-12 days and takes place within the roll or ground or fallen leaf. The adult is medium sized cream-colored moth with wavy markings (Kedar *et al*., 2014). The young larvae feed on epidermis on the under-surface for two days, later rolls the leaf in the form of trumpets and remains inside (Dhindsa *et al*., 1980). More than one larva can be seen inside the roll. It is fastened by silken threads in marginal portions. In severe cases, leaves may be rolled or complete defoliation of the plants may occur. (Kedar *et al*., 2014). It is a sporadic pest in India (Sohi, 1964) on cotton but after the introduction of *Bt*-cotton its incidences on cotton has decreased. However, it has been still attacking non-*Bt* cotton, okra and other malvaceous crops. Hence to know the ovipositional and larval preferences on different hosts this study was taken up as an objective for understanding the olfactory and ovipositional response of cotton leaf folder to volatiles from different host.

Methodology

To know the ovipositional and larval preferences of *S. derogata* on different hosts this study was conducted at Dharwad (15.4889° N, 74.9813° E) by using different malvaceous plants *viz*., *A. indicum*, non *Bt*-Cotton, *Bt*-Cotton, okra, hibiscus and wild bendi as different treatments (Table 1).

Table 1: Cotton leaf folder behavioral assay treatment details

Treatments	Hosts
T1	*A. indicum*
T2	Non *Bt*-Cotton
T3	*Bt*-Cotton
T4	Okra
T5	Hibiscus
T6	Wild Bendhi

To study olfactory response of cotton leaf folder to volatiles from different hosts

The eggs of cotton leaf folder were collected from the field and allowed to hatch in the laboratory. An experimental setup was made in such a way that a box was fitted at center with an air tight connection with the different small boxes where we kept different host plants (Fig 1). Then the neonates (young larvae immediately after hatching from the eggs) were individually released into the central box and the observations were recorded as to which host they move towards and which one they feed on. We released twenty larvae for each replication, and each was replicated four times.

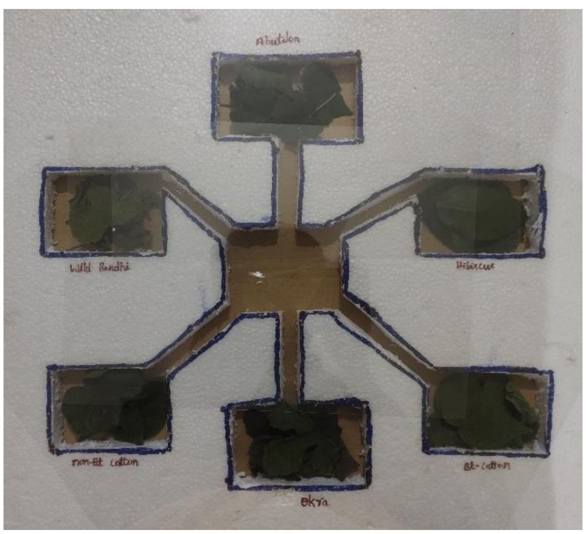

Fig. 1: Experimental setup to know the olfactory response of cotton leaf folder larvae on different host

To study ovipositional choice in cotton leaf folder to volatiles from different host

To study the ovipositional choice test mated female adults were released inside the cage containing all the different hosts (Fig 2). Then the observations were recorded on which host the highest number of eggs were laid. This was replicated four times.

Fig. 2: Experimental setup to know the ovipositional response of cotton leaf folder on different host

Results

Olfactory and ovipositional response of cotton leaf folder neonate and adult to volatiles from different host

The replication data obtained in the experiment under current investigation for various parameters such as larval and ovipositional response were subjected to ANOVA for a completely randomized design in R software (R Core Team, 2016). The cotton leaf folder neonate showed more olfactory response towards the *A. indicum* with an average of 7.5 larvae (Table 2), followed by the treatment T2 containing non *Bt* cotton with an average of 4.25 larvae, which was statistically on par with the treatment T3 containing *Bt* cotton with an average of 4.0

larvae. However, an average of 2.25 and 2.00 larvae moved towards the Okra (T4) and Hibiscus (T5) respectively. Whereas, no larvae showed response towards the wild bendhi leaves. This might be due to the volatiles released from the host leaves does not have any effect on the olfactory response of the cotton leaf folder neonate or the host might not contain volatile stimulants.

Table 2. Olfactory and ovipositional response of cotton leaf folder neonate and adult to volatiles from different host

Treatments	Hosts	Larval response (Number)	Ovipositional response (Number of eggs laid)
T1	*A. indicum*	7.50 [a]	55.50 [a]
T2	Non *Bt*-cotton	4.25 [b]	32.25 [b]
T3	*Bt*-cotton	4.00 [b]	31.75 [b]
T4	Okra	2.25 [c]	17.50 [c]
T5	Hibiscus	2.00 [c]	16.75 [c]
T6	Wild bendi	0.00 [d]	8.25 [d]
S. Em (±)		0.312	0.706
CD @ 1 %		1.369	2.873

The gravid cotton leaf folder moth showed more ovipositional response by laying more eggs on *A. indicum* with an average of 55.5 eggs, followed by the treatment T2 containing non *Bt* cotton with an average of 32.25 eggs, which was statistically on par with the treatment, T3 containing *Bt* cotton with an average of 31.75 eggs (Table 2). However, an average of 17.50 and 16.75 eggs laid on okra (T4) and hibiscus (T5), respectively. The lowest number of eggs (8.25) was laid on the wild bendi leaves. This might be due to the volatiles released from the host leaves that do not have any effect on the ovipositional response of the cotton leaf folder adult female or the host might not contain volatile chemicals for stimulating the oviposition.

Discussion

The cotton leaf folder larva showed high olfactory response towards the *A. indicum* leaves. Similarly, the adult female laid more eggs on it. Our experiment results are in accordance with the findings of Wenbin *et al*. (2020), as they recorded that *S. derogate* female adult showed strong responses to abutilon to lay eggs. Lin *et al*. (2015) documented that the female adults of *S. derogata* significantly laid more eggs on *A. theophrasti* (30.5 ± 3.2) than on cotton (7.8 ± 0.8) and leaf folder attracts more towards abutilon than cotton. This might be due to presence of the volatile chemicals like p-ethylacetophenone and 3-ethylheptane that are more attractive in function.

Conclusion

The behavioural assay of cotton leaf folder, *S. derogata* neonate showed positive olfactory response towards *A. indicum* followed by non *Bt*-cotton, *Bt*-cotton, okra and hibiscus as compared to wild bendi. Similarly, adult female laid more eggs on *A. indicum* followed by non *Bt*-cotton, *Bt*-cotton, okra and hibiscus as compared to wild bendi. Hence, *A. indicum* planted on bunds around the cotton or okra field for attracting cotton leaf folder acts as a cultural/ecological tool in managing the pest.

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First report of cigarette beetle, *Lasioderma serricorne* (Fabricius) infesting domestically stored garlic from Gujarat, India

R. D. Dodiya [1*], R. M. Patel[1], F. K. Chaudhary[2] and P. S. Patel[1]
[1] Department of Entomology, C. P. College of Agriculture, SDAU, Sardarkrushinagar
[2]Centre for Oilseed Research Station, SDAU, Sardarkrushinagar, Gujarat 385506, India
****Corresponding author: ravidodiya1999@gmail.com***

Introduction

Garlic, *Allium sativum* a bulbous flowering plant originated in South Asia, Central Asia, and north-eastern Iran. (Anon, 2023). India stands second after China in area and production of garlic (Anon, 2010). At various phases of the crop's growth, garlic is attacked by a variety of diseases and insect pests. In addition to lowering yield, insect pests have an adverse impact on quality and exportability. Thrips (*Thrips tabaci)*; onion maggot (*Delia antiqua)*; bulb mite (*Rhizoglyphus robin)*; eriophyid mite (*Aceriatulipae)*; red spider mite (*Tetranychus cinnabarinus)*; gram pod borer (*Helicoverpa armigera)*; tobacco caterpillar (*Spodoptera litura)*; cutworm (*Agrotis ipsilon)* are the major pests of garlic (Satyagopal *et al.*, 2014). Apart from these cigarette beetles *Lasioderma serricorne* are also found to infest the valuable crops (Mathew, 2005). The cigarette beetle, *Lasioderma serricorne* (Fabricus) (Anobiidae: Coleoptera) is a cosmopolitan stored pest causing considerable economic damage to stored grains. The beetle prefers to harbor on dried tobacco, cereals, dates, dried fish, ginger, grain, pepper, medicines, raisins *etc*. Adults are also capable of long-distance flight. Additionally, they have the ability to ruin more food consumed (Anon, 2022).

Material and Methods

A roving survey was carried out in Panch Pipalava village (Latitude-20.7907° N, Longitude-70.8298° E, altitude- 15 m above MSL) of Kodinar taluka, Dist. Gir-Somnath, India on domestically (hanging the dried garlic bulb with stem together in a residence area) stored garlic bulb. The damaged samples were collected from domestically stored garlic bulb from ten farmers. To identify the presence of insect pest on stored garlic, collected samples were brought to the laboratory of Entomology, Department of Entomology, C.P. College of Agriculture, S.D.A.U., Sardarkrushinagar, India. The samples were kept in plastic jar with small holes for providing aeration. The sample were observed regularly for presence of any pest. After a week, beetles were seen inside the plastic jar and after second week the presence of small parasitic wasps was also noted. The beetles and wasps were collected from a plastic jar with the help of a mouth aspirator and preserved in 70% alcohol.

Result and Discussion

The pest was identified as Cigarette beetle, *Lasioderma serricorne* (Fabricius) (Coleoptera: Anobiidae) based on the reference key given by Halstead (1986) and Cabrera (2022). From the infested garlic grubs, pupa and adult of *L. serricorne* were collected.

Morphology

Body of grubs were creamy white and yellowish in color with head and mouthparts surrounded by yellowish brown hair (Fig.1A), Exarate pupa (Fig.1B), the adult was quite small, reddish brown in color and tiny hair on elytra with smooth appearance and it has a typical “humpbacked” appearance with serrated antennae (Fig.1 C, D,E,F).

Damage

Grubs of *L. serricorne* caused damage to garlic cloves inside the bulb at the proximal end. Grubs feed inside the garlic clove and a brownish powdery mass appeared at the basal plate of bulb. (Fig.2 A, B). Pupation took place between the damaged cloves. Adults emerged by breaking the papery wrapper of bulb.

A vast variety of hosts of *L. serricorne* include bamboo, beans, biscuits, cassava, chickpea, cocoa, coffee beans, copra, coriander, cotton seeds before and after harvesting, cotton seed meal, atta, cumin, dates, dried banana, dried cabbage, dried carrot, ginger, grain, groundnut, nutmeg, raisins, rice, tobacco, dried fish, fish meal, leather. However, Retief (1988) also recorded this pest on plant specimens displayed in a herbarium at National Herbarium, Pretoria, South Africa. At Bangalore (Karnataka) this pest was first reported by Mathew (2005) on garlic. For the first time in Gujarat this pest was noticed in domestically stored garlic at Panch Pipalava village (Ta. Kodinar: Dist. Gir-Somnath) during *kharif* 2022.

Parasitoid

Primary pupal parasitoid *Anisopteromalus calandrae* Howard (Hymenoptera: Pteromalidae) (Fig. 3 A, B) was also found parasitizing the *L. serricorne* (Dodiya *et al.*, 2022).

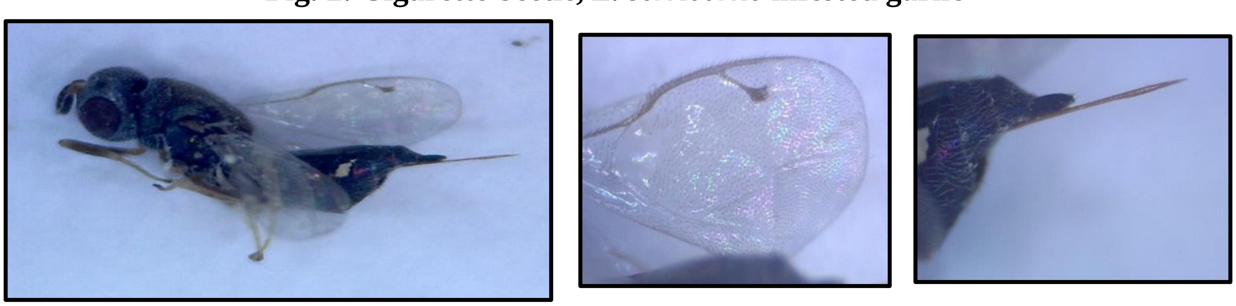
A) Grub B) Pupae C) Adult D) Antennae

E) Dorsal view F) Lateral view G) Ventral view

Fig. 1: Morphology of Cigarette beetle, *Lasioderma serricorne*

A) Damaged Cloves B) Damaged Bulbs

Fig. 2: Cigarette beetle, *L. serricorne* infested garlic



A) Adult of *Anisopteromlaus calandrae* B) Fore wing and Ovipositor of *A. calandrae*

Fig. 3: Parasitoid of cigarette beetle, *L. serricorne*

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First record of black thrips *Thrips parvispinus* (Karny) Thysanoptera: Terebrantia: Thripidae, from Muthalamada, the mango city of Kerala

Syed Mohammed Ibrahim, Malini Nilamudeen*, Berin Pathrose, Karthikeyan K, Anitha N
Department of Entomology, College of Agriculture and RARS, Pattambi,
Kerala Agricultural University, Palakkad, Kerala – 679 306, India
****Corresponding author: malininilam@gmail.com***

Palakkad district is the mango hub of Kerala with an area of 10068 ha and production of 55120 MT (Ecostatkerala, 2020). In Muthalamada panchayat of Palakkad district (10°35'57.3"N, 76°13'01.4"E), mango starts blooming from September and bear fruits by January. This early bearing characteristics give a great share of domestic and export market. However, in recent years untimely rain due to climate variability which affected early bearing character and high incidence of mango thrips on inflorescence posed serious threat to the mango growers.

Twenty mango orchards in Muthalamada panchayat of Palakkad district were randomly selected. A sample of twenty-five mango trees were selected from each orchard and the thrips population from five randomly selected trees in four directions from each orchard was counted. The specimens were collected by CO_2 method (The panicle was gently covered with a plastic bag, and the thrips enclosed within the plastic bag were immobilized with CO_2 released at a gentle flow into the bag for 30 sand immediately tied with a thread. The plastic bags were marked with the date and tree number and transported to the laboratory for further analysis) (Aliakbarpour and Che Salmah, 2010) and were preserved in 70% alcohol and got identified as *Thrips parvispinus, Thrips palmi* and *Haplothrips* sp. by expert taxonomist from NBAIR (ICAR-National Bureau of Agricultural Insect Resource). All these species are being reported for the first time on mango from Kerala.

T. parvispinus, a devastating pest on several agricultural and horticultural crops, is one of the pest species of South East Asia which comes under a member of "*Thrips orientalis* group" (Mound, 2005). The presence of this thrips complex on highly remunerative crop like mango is to be dealt with serious concern as it can create panic among farmers which force them to resort to unscientific application on chemical insecticides. An in-depth study covering the bio-ecology of these pests is the need of the hour to evolve sustainable and eco-friendly management practices for its management.

Fig. 1: Adult *T. parvispinus*

Fig. 2: Adult *Haplothrips* sp.

Fig. 3: Symptoms on panicle

Fig. 4: Symptoms on fruits

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Report of metallic shield bug, *Scutellera perplexa* (Fabricius) (Scutelleridae: Hemiptera) on Phalsa (*Grewia asiatica* L.) from Gujarat, India

N. P. Pathan[1*], R. D. Dodiya[2] and B. K. Prajapati[1]
[1]Department of Plant Protection, College of Horticulture, SDAU, Jagudan, Gujarat 382710 India
[2] Department of Entomology, C. P. College of Agriculture, SDAU, Sardarkrushinagar Gujarat 385505, India
Corresponding author: naziya.p.pathan@gmail.com

Introduction

India and Southeast Asia are home to the indigenous plant phalsa (*Grewia asiatica*, L.; Family: Malvaceae). It is mostly grown commercially in the Punjab and the area near Bombay. Many insect pests attack on phalsa, the major pests are phalsa bug, *Gargara mixta*; mealybug, *Drosicha mangiferae;* bark eating caterpillar, *Indarbela tetraonis;* hairy caterpillar, *Euproctis fraternal*; psylla, *Psylla* sp.; brown beetle *Anomala* sp.; beetle, *Oxycetonia* sp.; phalsa caterpillar, *Giaura sceptica*; aphid, *Aphis craccivora;* root-knot nematode, *Meloidogyne* sp.; spiral nematode, *Helicotylenchus* sp.; soft furred field rat, *Millardia meltada; s*maller bandicoot, *Bandicata bengalensis;* common house rat, *Rattus rattus etc.* attack on phalsa in direct and indirect way (Satyagopal *et al.,*2014). The term "Jewel bugs" refers to members of the Scutelliridae family of insects. These bugs have an expanded scutellum that covers the majority of the abdomen, and the membrane tip is typically visible caudally. The majority of Scutellerinae subfamily species have appealing, colourful bodies. According to Lattin (1994), there are 450 species of Jewel bugs classified into 80 genera described worldwide. Among them, 14 species are known to originate from India (Distant, 1902).

Material and methods

The present study was conducted during 2022 at college farm of College of Horticulture, S. D. Agricultural University, Jagudan (Latitude-23.5134° N, Longitude-72.3998° E, altitude- 95 m above MSL) in Gujarat, India. The collection of the insect was done with two sampling methods *viz*. sweep net and hand picking. The collected samples were killed in killing jar and pinned properly on scutellum. The morphological characters of the said specimens were studied under the microscope in the Entomology laboratory.

Results and Discussion

Based on morphological features and earlier identification on aonla by Pathan *et al.*, 2019 the insect was confirmed as Metallic shield bug, *Scutellera perplexa* (*Scutellera nobilis*). Metallic shield bug causes damage mainly to the leaves.

Nature of damage of *S. perplexa*

Eggs, nymphs and adults were observed on leaves of phalsa (Fig. 1 A, B, C). Nymphs and adults were observed sucking sap from the leaves. These bugs caused direct damage by sucking the sap. Nymphs started sucking sap on the plant parts where they hatched. Nymphs were mostly observed feeding on the lower surfaces of leaves mostly in groups and rarely singly. Adults have been seen sucking sap off young, green branch tips and leaves. The size of the leaves was diminished as a result of the sap being sucked by these bugs. Bugs that feed heavily on the leaves show necrosis symptoms, which eventually causes early leaf fall. Plant leaves turn yellow from bug punctures and shrivelling, which restricts the development and productivity of the plant (Fig. 5). Bug damage results in restricted development and, occasionally, dieback in nurseries, especially when there is a severe infestation when the plants are young.

Morphological characters of *S. perplexa*

Scutellum of the Scutelleridae family is exceptionally lengthy and covers the majority of the body. Underside of body, rostrum, and legs are reddish in colour. The sternum's lateral side and the lateral bands on the abdominal segments are metallic bluish green. Head is triangular, longer than it is wide, and angled downward. A transverse black streak that runs from the prothorax to the centre of the elytra. The insect is oval-shaped and elongated. Its pronotum and scutellum are metallic green in colour, and it has little or big black markings on them. Finely pliable body (Fig. 2 A, B, C). Antennae four segmented. Wings are not visible from dorsal side but appear when insects want to start flying. Forewings are shiny dark blackish in color where hindwings light blackish in color with wing venations seen (Fig. 3 A, B, C). Adult females laid eggs in batches. Eggs were barrel in shaped and observed to be attached on leaves. Freshly laid eggs were white in colour which later on turned light red to bright reddish in colour prior to hatching. Nymphs after hatching were reddish orange in color and observed to remain in groups near the egg cases for some time and later on spread to further places.

Behaviour of *S. perplexa* adult

It passes through four moults and five nymphal instars. The colour of the newly emerging adult is reddish orange. The bugs didn't exhibit any unique precopulatory behaviour. First bodily contact when approaching each other seems to be the stimulation. Mature partners stay close to one another for a while before mating begins. Adults move from one twig or branch to another while they engage in end-to-end copulation (Fig. 4 A, B, C).

Earlier *S. nobilis* was reported for the first time on *Emblica officinalis* in East Forest Division, Chhindwara, Madhya Pradesh causing damage to fruits (Meshram & Garg,1999) and it was also reported as a sucking pest of grapes in Punjab (Singh & Kaur, 2015). *Scutellera perplexa* (Westwood) was also observed as a serious sucking pests of *Jatropha curcas* L. from Delhi (Parveen *et al.*, 2010). Pathan *et al.*, (2019) reported infestation of *S. nobilis* on aonla from Gujarat. But no single report from phalsa crop in Gujarat. So, the present study was the first report of *S. nobilis* infestation on phalsa from North Gujarat region.

The paper deals with one species *viz*. *S. perplexa* (*S. nobilis*) of family Scutelleridae recorded from Research farm of College of Horticulture, S. D. Agricultural University, Jagudan (District: Mehsana). Therefore, new record of host range of Scutelleridae came to light.

<table>
<tr><td></td><td></td><td></td></tr>
<tr><td>A) Eggs</td><td>B) Nymphs</td><td>C) Adult</td></tr>
<tr><td colspan="3">Fig. 1: Life stages of S. perplexa</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>A) Dorsal view</td><td>B) Lateral view</td><td>C) Ventral view</td></tr>
<tr><td colspan="3">Fig. 2: Positional View of S. perplexa adult</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>A) Fore wing of S. perplexa</td><td>B) Hind wing of S. perplexa</td><td>C) Antennae and Stylet of S. perplexa</td></tr>
<tr><td colspan="3">Fig. 3: Different body parts of S. perplexa adult</td></tr>
</table>

A) Moulting	B) Pre copulation	C) Copulation

Fig. 4: Behaviour of *S. perplexa* adult

Fig. 5: Healthy and damaged leaves of phalsa

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Record of South East Asian Thrips *Thrips parvispinus* (Karny) Thysanoptera: Terebrantia: Thripidae, from *Solanum melongena*, Kerala

Ajay P Kumar, Malini Nilamudeen*, Syed Mohammed Ibrahim, Anitha N
Department of Entomology, College of Agriculture, Vellayani, Kerala Agricultural University
Pin: 695522, India
Corresponding author: malininilam@gmail.com

In India, Black thrips (*Thrips parvispinus*), a highly polyphagous species is creating great concern as it being recorded from several different cultivated crop plants. It is an invasive insect species from Indonesia and was first reported in 2015 on a papaya plantation in Bengaluru, Karnataka by Tyagi *et al*., 2015. Rachana *et al*., 2022 has reported *T. parvispinus* on *Chrysanthemum* sp. from Kerala. It has become a major insect pest in recent days on chilli and capsicum crops.

Brinjal is a commercial grown vegetable and occupies an area of 728 ha with a production of 12874 tons (APEDA, 2021). Vegetable productivity is limited mainly by pests inflicting crop losses up to 40 %. Several thrips *viz.*, Melon thrips *Thrips palmi*, onion thrips *Thrips tabaci* Lind., Groundnut thrips, *Caliothrips indicus* Bag., Chilli thrips, *Scirtothrips dorsalis* hood have been found to infest the brinjal leaves (Ghosh, 2020). In an experimental field of brinjal (Variety: Surya) in Instructional farm, College of Agriculture, Vellayani, large number of thrips were found congregating inside the flowers causing severe discoloration, malformation and ultimately dropping of flowers, and the species was identified as *T. parvispinus* with the help of the key published by NPPQS, 2022. Above 90 per cent of the flowers were infested with *T. parvispinus*. Careful examination of flowers showed no thrips species other than *T. parvispinus*. This suggests the possibility of replacement of species and attainment of new pest status. The high population demands extensive study on this invasive pest species.

Fig. 1: Adult *Thrips parvispinus*

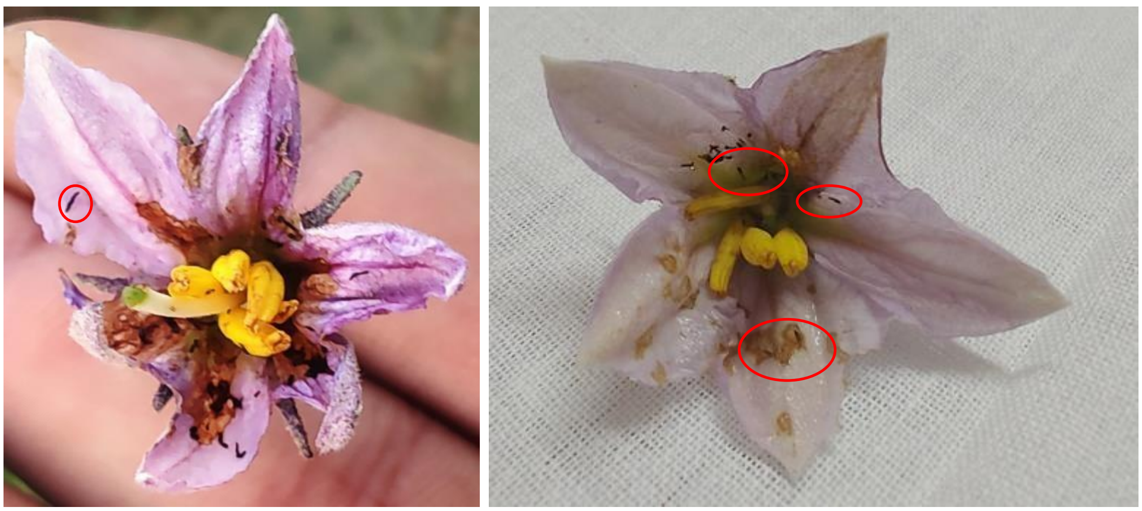

Fig. 2: Malformed flowers

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Hippotion celerio: An unfamiliar guest in our balcony

Latha.V[1*] and Nagashree[1]
[1]Department of Zoology, Maharani cluster University,
Palace Road, Bangalore-560001, India
****Corresponding author: latha.enscience@gmail.com***

Introduction

Hippotion Celerio was described by Carl Linnaeus (1758) in the 10th edition of *Systema Naturae*. It is also called as striped hawk-moth, vine hawk- moth, or Taro hawk moth. It belongs to the phylum: Arthropoda, Family: Sphingidae, Class: Insecta, Order: Lepidoptera, Genus: *Hippotion* and Species: *celerio.* Striped hawk-moth is cosmopolitan, except in the Americas. It is found in Africa, Central & Southern Asia, India and Srilanka. It also migrates to Southern Europe and Australia (Sunitha, 2017).

We observed the hawk moth in our residential building located at Sheshadripuram located at 12° 59′ 0″ N, 77° 34′ 0″ E. The moth was sitting on the balcony wall on 15th Nov 2022. It was immovable for two days and we were curious to know whether it was alive or dead. Upon disturbing also, it resisted to move, but later flew away the following day.

Hence, we decided to learn and report more about striped hawk moth and here is the description of its morphology, lifecycle and ecological significance.

Habitat

Hawk moths are found commonly in gardens but can also be seen in a variety of habitats where flowers are plentiful. They are nocturnal and seen resting on rocks and walls during the day. (Dino *et.al.,* 2009).

Hawk moths in the tropic and subtropics are one group of pollinating insects that have multiple requirements for survival and persistence. But they do have demands like source of nectar, larval host plants, relatively undisturbed sites where their caterpillars can grow and then pupate. As caterpillars, they can sometimes be pests. The caterpillars grow large and need a lot of food to reach full size. Some of the food plants include Grapevines, Rumex etc. (Soumya and Krishnamoorthy, 2020). Hawk-moth exhibit sexual dimorphism (Aldo Catania, 2015).

Description of males

The body is 26.40 mm with big compound eyes and ciliate antenna. The labial palp covered with green and dark hairs. It has a frenulum on hind wing and has an opened fantail.

Fig. 1: Picture of Hawk moth seen in our balcony

Description of females

The body is 29.73 mm long with crescent shaped fantail and filiform antenna. In general a female is larger than the male (Jeenkoed *et.al.*, 2016).

Reproduction

- Oviposition is usually on the underside of the leaves on which the larvae feed.
- Towards pupation they move to the soil and form a cocoon at the surface.
- Adults emerge 2-3 weeks later, fly mostly at night for long distance to feed on nectar and are attracted to light.
- A female produces about 150 eggs, placing them underneath the leave of host plant.
- Egg & larvae are susceptible to low temperature which cause much mortality (Jeenkoed *et al.*, 2016).

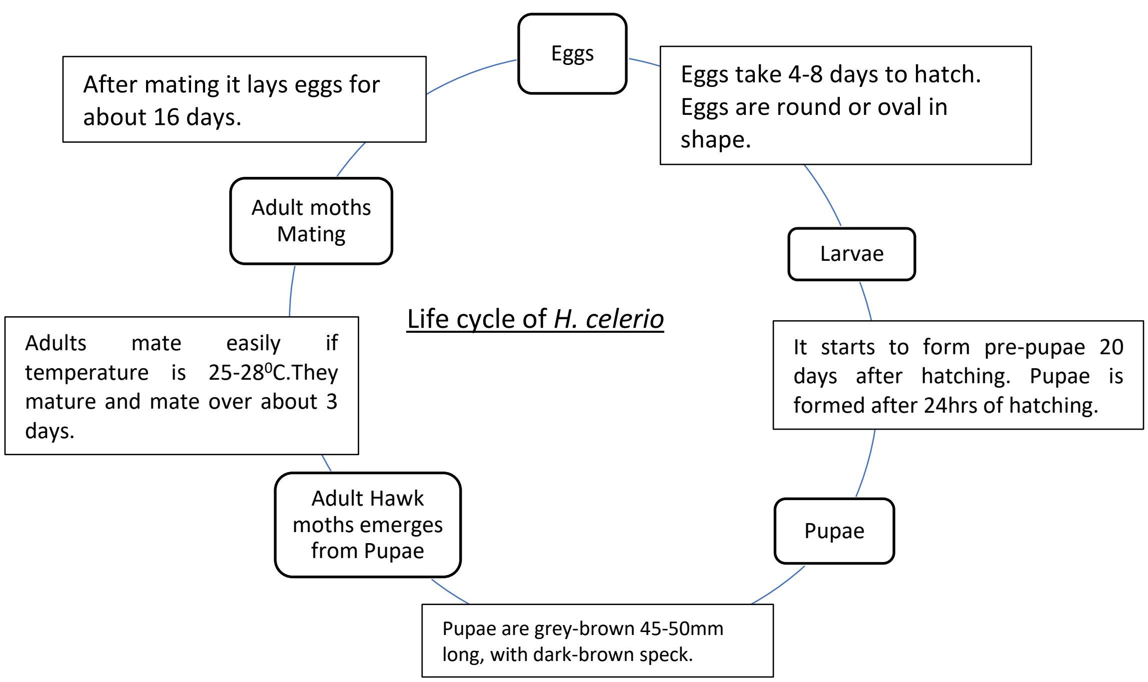

Fig. 2: Life cycle (Schematic representation prepared by Author)

Ecological Significance

They are pollinators because of their extremely long proboscises - straw like tongue. Pollen can be spread more than 18 miles away from source (Jeenkoed *et al*., 2016). *H. celerio* can be important pollinator, they are also a vital resource for garden life, like bats, reptiles, and other predatory insects. Healthy plants can withstand any damage. However, heavy infestations can cause plant die back, stunting growth. However, damage is seldom severe. This species of hawk moth affects papaya crop, grape vine crops the most (Sunitha, 2017).

Conclusion

This article suggests that *Hippotion celerio* is found in Africa, Southern Asia, India and Srilanka. They play significant role as pollinators but they do need host plants, appropriate temperature, nectar source and undisturbed sites where their caterpillars can grow and then pupate. They do not pollinate food crops but they play vital role in saving many native plants.

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Pumpkin spice loving pests, a short study on rearing of *Maconellicoccus hirsutus*

[1]Salome Ruth Jimmy V* and [2] Ruchita. Naidu.D
Department of Biotechnology, Ramaiah Institute of Technology, Bangalore-560054
Department of Zoology, Christ University, Bangalore-560029
*Corresponding author: salomeruthj@gmail.com

Introduction

Maconellicoccus hirsutus commonly known as the pink mealybug is a widespread pest of the order Hemiptera under the family Pseudococcidae. They come under a group of sucking pests as the females possess stylet-like mouthparts which are injected into the plant, sucking the sap out, thus leaving the host to become dry and withered, as the phloem responsible for transporting nutrients throughout the plant gets damaged. The plants begin to have an appearance of lesions, mottling, rotting and complete drying. Mealybugs possess a waxy layer and are therefore known to be resistant to a variety of pesticides and treatments. This pest being polyphagous affects a variety of plants such as hibiscus, chrysanthemum, grapevine, avocado and many others causing significant loss to farmers and small holders. The damage done on these crops results in lesser yield and harvest.

Life cycle

Pink mealybugs (female) usually have a lifecycle that mainly consists of 5 stages, namely: the egg, three nymphal stages of the crawler known as instars and the adult.

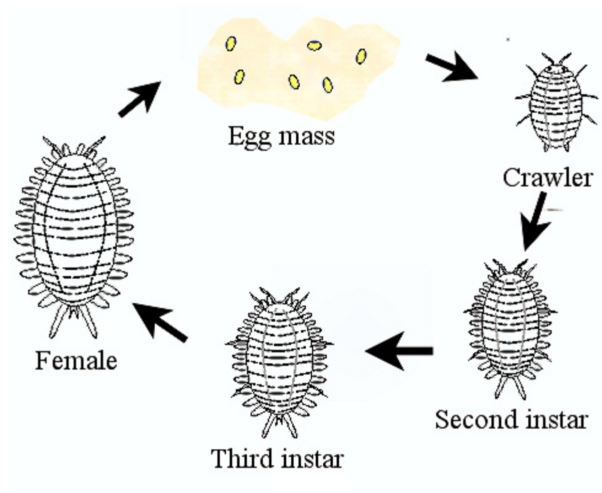

Fig. 1- Life cycle of *Maconellicoccus hirsutus.* Source: https://blog. pestprophet.com/mealybugs/

These pests usually reproduce by means of parthenogenesis or asexual reproduction, on non-availability of adult males. Although the hatching percentage of parthenogenetically produced eggs is quite successful, it has been found that eggs produced as a result of male and female breeding show a slightly higher percentage. (Hakim Ali Sahito et al. 2012)

The females are wingless having reduced legs and antennae and therefore do not move far to longer distances. In the wild, they most commonly settle in the peduncle of plants. The female's body gets converted into an egg sac towards the end of the lifecycle, which gets covered with white mealy matter that protects the eggs from damage due to harsh environmental conditions and treatments applied by humans on the host plant. The adult females subsequently die after the egg sac formation. Adult males possess one pair of delicate wings, well-developed legs, antennae, and no mouthparts. They have a shorter life span than the females.

Materials and Methods

This laboratory study was conducted at Rashvee - International Phytosanitary Research and Services (R-IPRS), Bangalore for a period of two months during January and February 2023.Female egg sacs of mealybugs *(Maconellicoccus hirsutus)* were sourced from ICAR-NBAIR on 23rd December 2022. Pumpkins were selected as the laboratory host in accordance with studies done by Miguel S. Serrano and Stephen L. Lapointe, 2002 and Satish V. Patil *et. al*, 2011. Pumpkins are a great host as they provide ample amount of sap to these sucking pests, they do not degrade quickly and can be used to rear almost 2 generations of mealybugs on a single pumpkin. The pumpkins were first washed with 1% sodium-hypochlorite solution followed by plain water. This was performed in order to remove dust and other micro-organisms which would lead to premature degradation. The pumpkins were then air dried. The egg masses were placed on the pumpkins carefully and these pumpkins were placed in the BOD incubator with a constant temperature of 28°C. The temperature used to rare these pests were found to be similar to the study done by Juang-Horng Chong, Amy L. Roda and Catherine M. Mannion, 2008.The data obtained from the observations was subjected for correlation and liner regression.

Once the egg mass was placed on the pumpkins a new generation of crawlers emerged and began forming colonies which was observed on 2nd January 2023. The colonies were marked and measured length wise using a ruler, and the area of each colony was calculated using the formula Πr^2. The area increase was recorded every 5 days until there was a stagnation and decrease in the area of the colonies on the 25th day. This indicated the end of the first generation and the beginning of the second.

10 colonies were randomly selected, and the number of crawlers were counted. This data was then plotted against the area of each corresponding colony to understand and correlate the two. Linear Regression and correlation were performed using Data Analysis on MS Excel, as shown below in the results.

Fig. 2- First generation of colonized Mealybugs on pumpkin

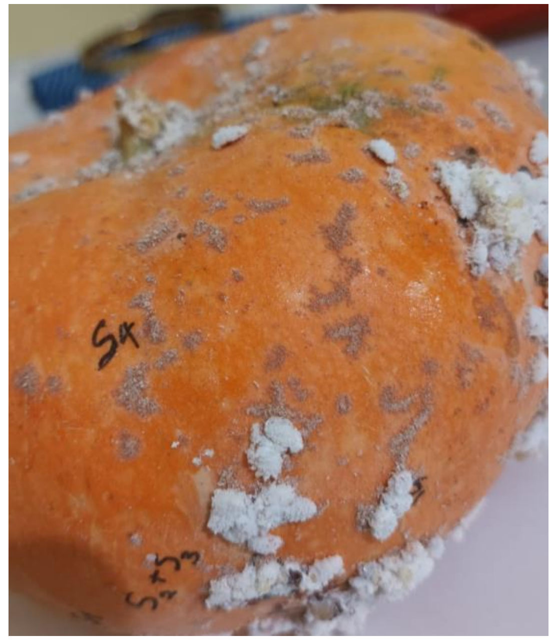

Fig. 3- Light brown colonies of crawlers for second generation

Fig. 4- Crawlers

Fig. 5- Fresh pumpkins used to rare Mealybugs

Results and Discussion

The observations plotted on the graph indicated that there was a gradual increase in area of the colonies till day 10 and there was a drastic increase after day 10. This is considered as the period where the crawlers were increasing in size and transformed into adults. The duration between day 15 and day 20 showed very little or no increase in the area as most of the females had got converted into egg sacs and the eggs were in the incubation period. After the 20^{th} day the area sees a slight fall, as the colonies had started to fall off the host due to the moving away of crawlers after hatching to colonize on new locations of the pumpkin. The total life cycle of the pink mealybug- *Maconellicoccus hirsutus* was completed in a span of approximately 30 days. The graph shows a positive co-relation, with R^2 value of 0.89 indicating goodness of fit of the model.

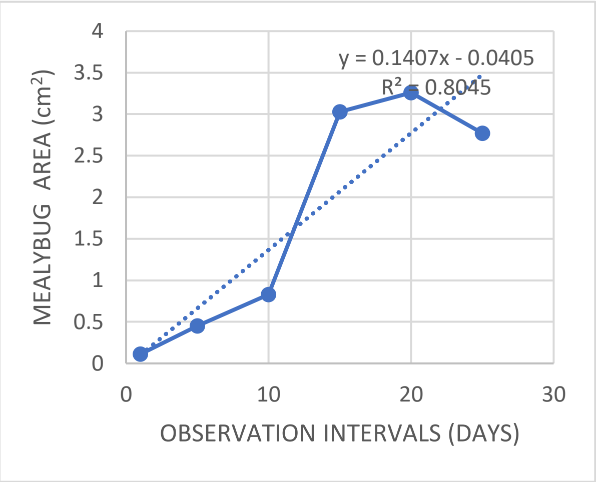

Fig. 6- Mealybug colony growth

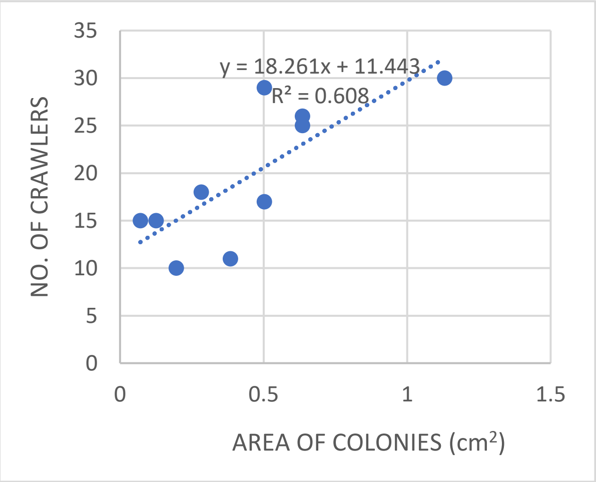

Fig. 7- Relationship between the mealybug crawlers and area of the colony

10 colonies were selected at random and the number of crawlers in each were counted. This data was co-related with the area of each corresponding colony. This plot indicates that greater the area of the colonies, higher are the number of crawlers. There is a positive co-relation with R^2 value of 0.779 indicating that it is statistically significant.

Conclusion

This study provides ample information in understanding the techniques of rearing field pests under laboratory conditions. It urges a researcher to make appropriate arrangements in the laboratory to match the field conditions in order to get good cultures. The duration of a single generation at a constant temperature of 28°C of the pest is very clearly indicated along with the number of days involved in the transformation of the nymphs to the adult stages. These rearing techniques can also be performed to rear very serious pests causing damage to economic crops in the fields so that they can be used to test insecticides or botanicals. Hence one can come up with the perfect formulation which will show mortality. This in turn will aid farmers in gaining great control against these pests to get a good harvest.

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Review articles & Short notes

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Minimise disturbance, maximise control

[1]Neelakanta Rajarushi Chava*, [2]Suresh M Nebapure, [3]Rajna S
Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi-110112
****Corresponding author: chavarajarushi@gmail.com***

Abstract

Biological control is the use of parasitoids, predators, and pathogens in keeping the density of other organisms at a lower average than it would otherwise be. Worldwide, pest suppression from insect natural enemies, such as predators and parasitoid wasps is valued at over US$400 billion annually. Agricultural intensification related disturbances (pesticide use, tillage, fertilizer use, crop harvest, low-diversity agriculture systems & climate change) limit our ability to produce sustainable crop production. These disturbances are caused by crop management practices and they can make agricultural fields more vulnerable to insect outbreaks since natural enemies are more susceptible to disturbances. Considering disturbances that influence natural enemies, conservation practices are discussed that can mitigate or counteract disturbance. The natural enemy's population can be improved mostly by conservation biological control methods like providing alternative food resources, overwintering sites, intercropping methods, maintaining non-crop habitat and reducing the impact of pesticides by screening & selecting the most compatible one to natural enemies (e.g. Spinosad).

Keywords: Agricultural intensification, farming, natural enemies, organic agriculture.

Natural enemies –Farmer's friends

Important natural enemies of insects and mite pests include predators, parasites and pathogens. The types of natural enemies are

Predators: A predator is an organism that attacks, kills and feeds on several other individuals (its prey) in its lifetime. Immature and/or adult stages can be predatory. Some predators feed on a wide range of species (*generalists*), while others are more specialized in their choice of prey by feeding on only one or a few species (*specialists*). Most of the predator population belongs to the orders like Coleoptera, Hemiptera etc.

Parasitoids: A parasitoid is an insect parasite of an arthropod which is parasitic only in the immature stage and adults are free-living. Around 8.5% of insect species documented till date (*i.e.*, approximately 85,000 species) are parasitoids with Hymenoptera and Diptera being the most common. The larvae can feed both within and outside their host's body species are classified as either solitary with only one parasitoid developing per host or gregarious with many larvae (often hundreds) growing per host.

Pathogens: Pathogens are disease causing organisms (fungi, bacteria, viruses, nematode worms and microsporidia). They can be important to check the growth of pest populations in agricultural systems.

Disturbances in agro-ecosystems and their influence on biocontrol

In modern, high-input farming, several common features limit the potential for natural control to prevent pest outbreaks such as pesticide use, tillage, fertilizer use, and crop harvest. These activities tend to decrease the abundance of natural enemies and the control that they can provide.

Pesticide usage

Pesticides are routinely used as the tool and the first choice to control crop pests. Pesticides can reduce the effectiveness of the natural enemies of arthropods by causing mortality and by influencing their movement, foraging and over reproductive rate (Jepson *et al.*, 1989).

i. **Insecticide use**: Nowadays farmers are going for management-intensive systems and tend to use insecticides preventatively which can limit natural-enemy populations, often resulting in pest resurgence or outbreaks of secondary pest species that can decrease crop productivity. e.g. Synthetic pyrethroids cause resurgence of white fly in cotton.

ii. **Herbicides use**: Herbicides limit the abundance of non-crop plant species in agro-ecosystems and can have direct and indirect effects on natural-enemy populations within crop fields. e.g. *S*-metolachlor was highly toxic having 80–90% mortality on *Phytoseiulus persimilis.*

iii. **Fungicide usage**: Fungicides can disrupt natural control of some insect and mite pest species as many are toxic to entomopathogenic fungi, e.g. Smith *et al.,* 2000 reported an 80% reduced arbuscular mycorrhizal root colonization due to a benomyl fungicide application.

Tillage

Tillage is used as a weed-management tactic and to prepare seedbeds but can have strong influences on soil-dwelling arthropod populations including natural enemies. Tillage for weed control also is physically disruptive to species that enter spaces within the soil for shelter or to pass some stage in their development. Tilled fields tend to have fewer predators than non-tilled fields, whereas herbivorous insects tend to occur equally often in the two types of fields, suggesting that crops in tilled fields may be more vulnerable to pest damage because of an absence of top-down control.

E.g. Carabids often enter earthworm tunnels to seek damper, cooler soil but such tunnels are destroyed by cultivation. Plowing of soil in Swedish crops reduced the emergence of parasitoids of pollen beetles, *Meligethes sp*., by 50 to 100% in spring and winter crops (Nilsson,1985).In Canada, tillage killed 95% of *Tetrastichus julisa* key parasitoid of cereal leaf beetles and it's absence led to the outbreak (Ellis *et al.*, 1988).

Fertilizer usage

Fertilizer use can also disrupt services provided by beneficial organisms. The study showed that even moderate application of phosphorus fertilizer can reduce arbuscular mycorrhizal colonization and spore numbers by 50% (Martensson and Carlgren,1994). This finding indicates that fertilizers that are meant to increase plant growth may actually diminish the natural ability of soils to provide nutrients to plants.

Crop Harvest

Crop harvesting can also be considered as a disturbance, particularly from the standpoint of natural-enemy populations the absence of which can allow pest numbers to grow. e.g. In alfalfa the parasitoid population of aphids *i.e.*, *Hyperapostica* and *Lygus spp.* got killed (Van Den Bosch *et al.*, 1967).

Effect of Elevated Temperature: In the context of global warming scenario induced by climate change, all species will be under strong selection pressures and natural enemies are no exception (Nayak *et al.*, 2020).

i. **Effect on host searching ability:** Parasitoids can sustain a broad thermal range, although exposure to temperature extremes even for short periods is likely to influence parasitoid survival and host searching ability. Studies from 1993 to 1996 correlating climate data with egg parasitism suggest that rate of egg parasitism by *Trichogramma* spp. on European corn borer was drastically reduced to zero owing to extremely dry and hot weather experienced in May 1993 in Slovakia (Cagan *et al.*, 1998). Similar study on tachinid flies in relation to increased temperature suggests reduced range of parasitism up to 51%. Host location falls off sharply at temperatures above 35 ^{0}C of the egg parasitoid, *Trichogramma carverae* Oatman and Pinto (Thomson *et al.*, 2001). In case of predators, it could be different. For example, it has been predicted that coccinellids reduce aphid population more strongly in hot summers than in moderate summers.

ii. Effect on host tracking by natural enemies: It is predicted that a 1^{o}C rise in temperature would enable species to spread 200 km northwards or 140 m upwards in altitude. Herbivore pests having greater mobility are likely to track the expansions. For example, rise in temperature will allow the pink bollworm, *Pectinophora gossypiella* (Saunders) to expand its range to non-traditional cotton growing areas that are presently non habitable (Guiterrez *et al.*, 2006 or 2008). Mobile species such as diamond back moth, *Plutella xylostella* L. and European corn borer, *Ostrinia nubilalis* (Hubner) will track the new areas faster than less mobile species. The probability of hosts escaping their specialist parasitoids will be highest as they may struggle to track the spatial shift of their host. These changes in the distribution of crops and expansion of herbivores range may lead to escape of these pests from natural enemies which may ultimately affect the pest control.

iii. **Phenological asynchrony between natural enemy and herbivore host:** Mismatched phenological asynchrony between a parasitoid and its host has been reported in several of cases. Graben weger *et al.,* 2007 reported lower level of parasitism in the first generation of horse chestnut leaf miner, *Camerariao chridella* Deschka & Dimic, which might be due to emergence of hibernating parasitoids of leaf miners at a time when hosts are not available.

Methods to conserve

Ecological Engineering (EE): It is a new paradigm to enhance the natural enemies of pests in an agro-ecosystem and is being considered an important strategy for promoting Bio-intensive Integrated Pest Management (BIPM). This approach relies on use of cultural techniques to bring about habitat manipulation and enhance biological control. Ecological engineering emerged as a paradigm for considering pest management approaches that are based on cultural practices and informed by ecological knowledge rather than on high technology approaches such as synthetic pesticides and genetically engineered crops. (Gurr *et al.,* 2004). The primary objective of ecological engineering is to make the environment of the agro-ecosystem suitable for better survival of natural enemies of pests. Habitat manipulation aims to provide natural enemies of pests with nectar, pollen, physical refuge, alternate prey, alternate hosts, and living sites. This can be through the plantation of appropriate companion plants like floral trap crops and repellent crops, through which the population of pollinators, predators, and parasitoids can be enhanced to manage the herbivorous insect pests.

Crop-residue destruction should be minimized in Indian sugarcane, several parasitoids like *Epiricania melanoleuca*, *Ooencyrtus papilionis*, *Parachrysocharis javensis* of the sugarcane leafhopper *Pyrilla perpusilla* are eliminated when crop residues are burned. Studies show that if crop residues are left unburned and spread back on the field after burning, parasitoids can be conserved at levels able to control the pest (Joshi and Sharma1989, Mohyuddin 1991).

Plant-flush pest synchronization: A synchronized flush of new growth may follow after some woody plant crops are pruned. Young foliage is often higher-quality food for insects, especially sucking species. A surge in pest population growth rate may follow that exceeds the ability of parasitoids to numerically respond quickly. High pest densities may result from this imbalance. To prevent these events, growers can use alternate-row pruning (which staggers the growth of succulent new foliage, which is attractive as oviposition sites for pests such as whiteflies). This approach prolongs the induction of increased pest populations, allowing more time for parasitoids to respond. Biological control of whiteflies in lemon orchards was improved in coastal California by the use of alternate-row pruning (Rose and De Bach, 1992).

Direct seeding and no-till While not intended as a tool to better conserve natural enemies, no-till agriculture creates a more favorable environment by enhancing soil moisture, reducing soil surface temperature, and preserving soil structure. (Jackson and Pitre, 2004).

Strip harvesting: Strip harvesting rather than cutting whole fields at the same time can help preserve natural enemies in forage crops by preserving both the physical environment and a host or prey supply for natural enemies. Strip harvest of alfalfa, for example, help certain populations of parasitoids of aphids, alfalfa weevil *Hypera postica* and *Lygus spp.* (Vanden Bosch *et al.*, 1967). Nentwig (1988) found that when German hay meadows were strip harvested, predaceous and parasitic arthropods, especially spiders, became more abundant and herbivores decreased.

Semiochemicals: These are the substance released by an organism that affects the behaviour of other organisms. When terminal bud gets infested by maize aphids, *Rophalosiphum maydis* (Fitch), the E-β farnesene (alarm pheromone) is released by herbivores and HIPV'S by plants helps in attracting coccinellids, other predators, and parasitoids for aphid control (Rehman *and* Powel, 2010).

Applying semio-chemicals: Lures may also be used to attract released natural enemies to help them establish themselves. Applying attractants in combination with food sprays may promote the oviposition of released chrysopid predators into the target crop. Hexane extract of corn borer larvae was applied on corn plants to enhance the performance of larval parasitoid *Bracon brevicornis* adults against the corn borers *Ostrinia nubilalis* and *Sesamia cretica*.

Selective use of pesticides: There is an urgent need to develop truly selective pesticides for the conservation of natural enemies by using active ingredients with the least non-target toxicity. Undesired side effects of pesticides on natural enemies could be further reduced by adopting the timing, place and mode of application. Some examples for selective use of pesticides are spinosad, IGR and azadirachtin.

Genetic improvement through selection: Natural selection created populations of pesticide-resistant natural enemies in routinely sprayed crops such as apple. Resistant populations can also be developed artificially in the laboratory. Pesticide-resistant populations of many predatory mites have been discovered (or selected): *Metaseiulus occidentalis*, *Aphytis holoxanthus* DeBach (Havron *et al.*, 1991) and *Aphytis melinus* DeBach (Havron *et al.*, 1991) are scale parasitoids (Rosenheim and Hoy 1986). Endograma is an endosulfan-resistant strain of *Trichogramma chilonis* produced by NBAIR in Bangalore.

Conclusion

Conservation techniques can help to minimise or counter balance perturbations that reduce natural enemies' ability to offer top-down suppression. Non-crop habitat that can assist preserve natural enemies and the natural control they offer may be insufficient in some agro-ecosystems to lower insect populations to economic harm thresholds. So, providing the modified habitat that supports natural enemies sufficiently enough to achieve biological control. The more farmers who can rely on conservation biocontrol the more it will be able to assist shift agriculture toward sustainable intensification by adopting strategies that utilize natural capital more intensively to avoid negative environmental consequences of farming. Some conversation methods provide additional benefits like cover cropping is a conservation method that is extensively supported for its ability to reduce erosion and increase soil quality, nitrogen cycling, and weed control, among other ecosystem services. Cover crops can provide predator habitat and assist raise predator numbers early in the growing season resulting in better pest management. Organic farming reduces neighborhood disruptions and provides better pest management. To conclude this study, we argue to minimize disturbances and maximize diversity of the agro-ecosystem by practicing the suitable conservation methods which will maximize the natural control.

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A review on nano-pesticides in pest management

Balamurugan S*, V Priyadharshini and G Venkatesh
Department of Entomology, Faculty of Agriculture, Annamalai University,
Annamalai Nagar - 608 002, Tamil Nadu, India
****Corresponding author: sbala512945@gmail.com***

Abstract

Nano-pesticides could offer a range of benefits including less environmental contamination through reduction in pesticide application rates; enhanced efficiency of chemical and natural insecticides by controlled release; easy/safe handling with reduced toxicity risks to animals and less toxicity towards non-target organisms compared with bulk. Among other benefits, nano-formulation of many natural insecticides (e.g. neem oil) has protected them from premature degradation in the environment and thus helped in delivering maximum impacts on the target organisms. For insecticide encapsulation, several polymer-based or non-polymer-based nano-formulations, such as nanospheres, nano-capsules, nanogels, micelles, nanofibers, nanometals, and nano-emulsions, have been proposed. Nano-capsules are by far the most extensively utilized of these for controlled release of pesticides. Very recently, a novel concept of hybrid nano-formulation (encapsulation of nano-emulsion or liposome coating) has been suggested for the controlled release of some insecticides. However, the efficacy of the proposed novel approach needs to be tested for a broad-spectrum line of insecticides.

Keywords: nanotechnology, nano-pesticides, hybrid nano-formulation, nano-emulsions, nanogels

Introduction

The word "nano" is developed from the Greek word meaning "dwarf". In more technical terms, the word "nano" means 10, or one billionth of a material. Enhanced properties exhibited by nano sized particles and materials enable widespread potential applications. Nano-pesticides are nearly effective as traditional pesticides at controlling pests (Rani and Sushil, 2018). Biopesticides, plant-derived products and semio-chemicals are replacing chemical plant protection formulations (Sahayaraj, 2014). Non-target organisms are projected to be less harmed by nano-pesticides than by conventional pesticides (Deka et al., 2021).

Scope of nanotechnology

Nanotechnology is a promising field of interdisciplinary research. This includes insect pest management through the formulations of nano-material based pesticides which provide green and efficient alternatives.

Nano-pesticides

One sector where the use of encapsulated nanoparticles is receiving increasing interest is the pesticide sector with the development of a range of plant protection products that are termed "nano-pesticides". Any formulation that purposely incorporates components in the nano-metre size range and/or claims unique characteristics related with these tiny size ranges appears to have been on the market for some years. It is plant protection products where nanotechnology is employed to enhance the efficacy or reduce the environmental footprint of a pesticide active ingredient. It can consist of organic ingredients (e.g. polymers) and/or inorganic ingredients (e.g. metal oxides) in various forms (e.g. particles and micelles). It encompasses a great variety of products and cannot be considered as a single category.

It could offer a range of benefits including increased efficacy, durability, and a reduction in the amounts of active ingredients that need to be in use. It has high efficacy and safety and minimal chemical use. The aims of nano formulations are generally common to other pesticide formulations and consist in increasing the apparent solubility of poorly soluble active ingredient and releasing the active ingredient in a slow/targeted manner and/or protecting the active ingredient against premature degradation.

Nano formulations are expected to have significant impact on the fate of active ingredient. Introducing new ingredients whose environmental fate is still poorly understood (eg. nano silver) is yet a challenge.

Reason for using nano-pesticides

- Great effect with lower chemical use
- Smart treatment system
- Reduce damage by frost
- Decreases toxicity
- Pesticide degradation

Formulation of a nano pesticide

Nano emulsion

Nano emulsions can be defined as oil-in-water (o/w) emulsions with mean droplet diameters ranging from 50 to 1000 nm. Phytochemicals like essential oils face problems of chemical instability in presence of air, light, moisture & high temperature. Incorporation of essential oils into controlled release nano formulation prevents rapid evaporation & degradation, enhances stability & maintains minimum effective dosage. Downsizing of natural oils to form nano emulsions could be effective as larvicidal agents (Anjali et al., 2012).

Nano emulsion produced was thermodynamically stable, optically transparent and of small droplet size. Neem oil with polyethylene glycol sorbitane monostearate at 1:4 ratio produced a nano emulsion with droplet size of less than 200nm. The larvicidal activity of eucalyptus oil nano emulsion (1:2) and bulk emulsion (1:2) was recorded against *Culex quinquefasciatus*. It was observed that at a concentration of 250ppm nano emulsion, 98% mortality in 4h of treatment was observed whereas for the bulk emulsion 100% mortality was observed at 24h. Thus, this proves that the nano emulsion formulation of eucalyptus oil is far more effective than bulk emulsion. Nano emulsion of essential oil (hairy basil oil: vetiver oil, citronella oil at 5:5;10%w/w) prepared using high speed homogenizer had improved physical stability and smaller droplet size of 150-220nm. The nano emulsion had protection against mosquito *Aedes aegyptii* (Sugumar *et al*., 2014). The nano emulsion of DDVP developed for the management of German cockroach revealed that inhibition of acetylcholine esterase was higher in nano emulsion when compared to EC. There was also an increase in the reduction of alkaline phosphatase activity in the nano emulsion when compared to EC (Nuchuchua *et al.* 2009).

Nano suspension

Submicron colloidal dispersions of pure active compounds typically range from 50-500 nm. It is produced by homogenization or milling mechanical forces. It improves the efficacy due to higher surface area. It has higher solubility, higher mobility, induction of systemic activity due to smaller particle size. It has lower toxicity due to elimination of organic solvents. Two kinds of carbofuran formulations, micro suspension and a nanosuspension, were administered to a diamondback moth (DBM) to test their efficacy and stability as a pesticide. The results show that carbofuran has the same effectiveness at a lower dosage in nanosuspension as in micro suspension. The nanosuspension system remained physically and chemically stable over a two-year period, as evidenced by unaltered particle size and specification tests (Chin *et al*., 2011).

Nano encapsulation

Packing of nanoscale active ingredient within tiny envelope is slowly but efficiently released to the particular host for insect pest control. Its size range is around 1-100 nm. In this formulation the active ingredient is encapsulated by a synthetic or biological polymer to allow for prolonged release of a pesticide over a period of time.

Pesticides via encapsulation

Ethiprole

A phenylpyrazole compound affects GABA gated chloride channels and faces problems of photoinactivation. It is a stable polymeric polycaprolactone & polylactic acid nanosphere, encapsulating 3.5% of ethiprole. Initial biological testing was done on cotton aphids which revealed that speed of action &

controlled release was not at par with chemical application. However, it showed enhanced systemicity of active ingredient and improved penetration due to small size.

Avermectin

Insect chloride channel inhibitor faced problems of photoinactivation. Porous hollow silica NPs protect from UV degradation. Porous hollow silica nanoparticles shell thickness of 15 nm & pore diameter of 4-5 nm. Slow release of avermectin reported for 30 days.

Imidacloprid

IMI is photodegradable hence it is nano encapsulated by LbL technique. Photocatalysts like TiO2, SDS/ TO. Ag/TiO2. SDS/Ag/ TIO, constructed for photocatalytic degradation, SDS/Ag/ Tio, has highest photocatalytic activity. Toxicity of 50% nano SDS/Ag/ TiO IMI was higher than 95% IMI in the adult stage of *Martianus dermestoides*.

Efficiency of pyrethroid treated fabrics

Mosquito Repellency Test

Fabric sample (4x4 cm^2) is placed over a person's hand back covered around by a rubber glove. Inserted into a cage (40x30x30 cm^3) (300 *Aedes albopictus*). No. of persons stung during this time (2 min) & textile exposed to mosquitoes were recorded. This method provided better mosquito repellency with higher insecticide retention during washing than the polymeric binder -larger surface area, fine encapsulation and hydrophobicity of vinyl polymer.

Cyhalothrin (Micro encapsulated)

Karate Zeon 5 CS

A quick release microencapsulated product of 2.5 µm size breaks open on contact with leaves provided better rain fastness, improved residual activity. It breaks open to release its contents when it encounters alkaline environments (stomach of insect).

Nanoparticles

Nanoparticles are atomic or molecular aggregates having dimension between 1-100mm. Nanoparticles are loaded with pesticides and released slowly based on environmental trigger. Nanoparticles possess distinct physical, biological and chemical properties associated with their atomic strength.

The application of nano-silica on the resistance of tomato plants, aiming at providing relevant inputs to the management of cotton leaf worm. Nano silica was tested in six doses 100, 180, 200, 350, 300, 350 ppm respectively. Nano silica at various concentrations 250, 300 and 350 caused more than 50% death percentage, it gave 64.18, 68.93 and 78.24%, respectively in comparison to control which gave zero death. Total number of eggs laid per female was affected in all treatments compared with control, the percentage of hatchability was reduced in nano silica treatments compared with control. Thus, it reduces the reproductive potential of females on tomato plants. Therefore, it reduces the insect population density, damages and yield losses to the crop (Bendary *et al.* 2013).

Silver nanoparticles (AgNPs) were synthesized by using aqueous leaves extracts of *Euphorbia prostrata* as a simple, non-toxic and eco-friendly green material. *E. prostrata* and silver nitrate ($AgNO_3$) solution (1mM) and synthesized AgNPs are tested against the control adult of *Sitophilus oryzae*. This is the first report on the pesticidal activity of the plant extracts and synthesized nanoparticles. Silver nanoparticles (AgNPs) using leaf extract of *Euphorbia hirta* (Euphorbiaceae) against the first to fourth instar larvae and pupae of the crop pest of cotton boll worm, *Helicoverpa armigera*. The leaf extract exhibited larval toxicity against the first instar to fourth instar larvae and pupae of *Helicoverpa armigera*. Silver nanoparticles synthesized using an aqueous leaf extract of *Tinospora cordifolia* showed maximum mortality against the head louse *Pediculus humanus* and fourth instar larvae of *Anopheles subpictus* and *Culex quinquefasciatus* (Zahir et al. 2012).

Silica nanoparticles (SNP) and silver nanoparticles (AgNP) act on larval stage and adults of *Callosobruchus maculatus* on cowpea seed. Nanoparticles of silica and silver were synthesized through a solvo thermal method and different concentrations (1. 1.5. 2 and 2.5 g kg ^{1}) of them were tested on *C. maculatus*. LCs value for SiO_2 and Ag nanoparticles were calculated as 0.68 and 2:06 g kg cowpeas on adults and 1.03 and 1.00 g kg on larvae, respectively. Result - both nanoparticles (silica and silver) were highly effective on adults and larvae with 100% and 83% mortality, respectively. The result also showed that SiO2 nanoparticles can be used as a valuable tool in pest management programs of *C. maculatus* (Rouhani et al. 2013).

Second instar larvae of *S. litura* of surface treatment with DNA-tagged gold nanoparticles, at all four concentrations viz., 200, 300, 400 and 500 ppm. As the concentration and days after treatment increased, the larval mortality of second instar *S. litura* larvae also increased. The maximum mortality of 30.0, 57.5 and 75.0 was obtained at 500 ppm on 3rd, 4th and 5th day, respectively. At the highest concentration (500 ppm) of the DNA tagged gold nano particle, feeding was reduced, larvae turned sluggish and were unable to orientate towards the source. It demonstrates that DNA-tagged gold nanoparticle has a devastating effect on the larval tissue of *S. litura*. (Chakravarthy *et al.*, 2012).

Nanogel pheromone

Nanogel pheromones are prepared by using methyl eugenol (ME) low-molecular mass gelator. It is very stable at ambient conditions and works well in rainy season. It lasts for a month.

Microbial products – nano based delivery

Lagenidium giganteum, (aquatic fungus) a mosquito larvicide registered with USEPA (Registration No. 56984-2). It has poor stability during storage & expensive storage requirements. Addition of hydrophobic silica NPs (7-14 nm) to water in oil emulsion reduced desiccation. Thickened formulations are recorded up to 95% efficacy after 12 weeks of storage.

Nano-acaricide

A nano acaricide Allergoff 175 CS composed of permethrin, pyriproxyfen and benzyl benzoate was tested for its efficacy against *Acarus siro*, *Tyrophagus putrescentiae*, *Aleuroglyphus ovatus*. Pesticides were incorporated into the mite diets (10-1000 ug a.i. /g diet). The most effective pesticide Allergoff 175 CS had a range of 463-2453 µg a.i./g (Hubert et al. 2007).

Nano biosensors

A biosensor consists of 2 elements: a biological receptor protein to detect a substance & a sensor, to interpret biological recognition & translate into a measurable signal. "Nano biosensor" properties are modulated because at nanoscale. It has high selectivity, sensitivity, reliability & rapidity. The interaction of target with biosensors are measured by colour, fluorescence or electrical potential.

Nano-biosensor -Pheromone

It is the determination of selectivity/specificity of insect olfactory cells toward odor molecule using whole insect antennae-based micro biosensors. The micro-fabrication of several prototypes of Liquid Ion-Gate Field Effect Transistor (LIGFET) or an array for Organic Field-Effect Transistors (OFET) is as microelectronic readout devices. The synthesis of conductive polymer of nanofibers and semiconducting nanowires produced by using the template method. Functionalization of nanostructures with odorant or pheromone binding proteins results in arrays of nano-biosensors. Testing of nano-biosensor systems with odorants as analytes and comparison with antennae based micro biosensors has been done

Nanosensor-AChE

Immobilization of AChE to MWCNT cross linked cellulose acetate composite, forming stable AChE sensor Carbaryl, a carbamate inhibits action on AChE and causes decrease in oxidation peak current. It is sensitive, rapid, and inexpensive but determines all insecticides which inhibit Ache.

Liposome based nano biosensor

It is unstable AChE encapsulated in internal nano environment of liposomes. OP compounds inhibit hydrolysis of Ach. It produces decreased amounts of acetic acid. Fluorescence of pH sensitive fluorescent indicator pyranine decreases, and there is reduced response related to pesticide concentration. Concentrations down to 100 M can be monitored.

Detection of acetamiprid - aggregation of gold nano particles

Based on the strong interaction of the cyano group of acetamiprid with Au NPs, and the aggregation on AuNPs, its colour changes from red to purple. Concentration is determined by a spectrometer. Rapid and accurate, it eliminates the need for expensive analytical instruments.

Mosquito / Insect repellents

Mosquito repellents are substances that are designed to make surfaces unpleasant or unattractive to mosquitoes. They typically contain an active ingredient that repels mosquitoes as well as secondary ingredients, which aid in delivery and cosmetic appeal. They are available in many forms, from creams to lotions to oils, but are most often sold as aerosol products. The plants used for nano synthesis to control mosquitoes/insects are *Geranium sanguineum, Cymbopogon citratus, Salvia rosmarinus, Allium sativum, Artemisia absinthium, Rubus idaeus, Chromolena ordata.*

Risk involved

ZnO nano particles are toxic to both gram-negative and positive bacterial systems, *Escherichia coli* and *Staphylococcus aureus*. A single high oral dose of nano TiO, caused significant lesions in kidney and liver of female mice. Nano TiO2 is also toxic to algae and water fleas, especially after exposure to UV light. 15 nm Ag nano particles found to be toxic to mouse germ line. Stem cells under in vitro conditions. 50 & 70 nm SiO2 particles taken up into cell nucleus caused aberrant protein formation & inhibited cell growth under in vitro conditions.

Solutions

Early and open examination of the potential risks of a new product or technology. Public and private organization collaboration. Products already in stores, good product management identifying and managing any potential risks.

Conclusion

Nanotechnology in agriculture is in its nascent stage. Nano technological tools are to study the insect physiology & behavior. It has promising results in use of nano materials for delivery of pesticides & fertilizers. Nano particles are used as insecticide, with safety measures. Nano particles can stabilize biocontrol preparations. Nano sensors are effective in detecting pesticides at lower level.

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Treasure out of trash - black soldier fly

Pushpalatha, M. [1]*, Ankush Subhash Gadge[2], Devanand Rajaram Bankar[3]
[1, 3]Mahatma Phule Krishi Vidyapeeth, Rahuri- 413722, Maharashtra, India
[2]Directorate of Onion and Garlic Research, Rajgurunagar, Pune- 410505, Maharashtra, India
Corresponding author: pushpalatham143@gmail.com

Abstract

The Black Soldier Fly (*Hermetia illucens* (Linn.)) is a cosmopolitan tropical fly belonging to the Stratiomyidae family (Order: Diptera) having great economic benefits and environmental potential impact for the processing of various organic waste and by-products into insect-based products. It has a very short life cycle of 40-50 days and a high reproductive potential (nearly 500 eggs/ female). *Hermetia illucens* is the best possible insect species since it can eat and digest a variety of solid organic waste materials. The mature larvae contain fat content of about 20% - 40%. Thus, the black soldier fly larvae can be exploited as the better waste decomposer, protein and lipid feedstock for poultry feed and also for biodiesel production.

Introduction:

The Black Soldier Fly, *Hermetia illucens* (Linn.) (Diptera: Stratiomyidae) is a cosmopolitan tropical fly which is having great economic benefit and environmental potential impact for the processing of various organic waste and by-products into insect-based products. It is a relatively large fly with wasp-like appearance. However, unlike wasps, *H. illucens* have only one pair of wings and lack a sting. Mexico is believed to be the native of black soldier fly with its distribution all over the world (Hauser *et al*., 2015). *Hermetia illucens* is usually found in outdoor environments near livestock or decaying organic matter, including animal waste. The larvae of Black Soldier Fly (BSF) can consume various types of biodegradable materials including food waste, animal manure (pig manure, poultry waste) and much other indigestible organic waste. Therefore, larvae are widely used in manure management and the conversion of organic waste into useful products such as compost (Newton, 2005). The BSF larvae can reduce the accumulation of organic waste by up to 50% in a very short time which makes it ideal for optimal reduction of environmental pollution while the biomass is produced. By this process it can be used as a source of protein for animal feed, fatty acids for biofuel, minerals, chitin and chitosan for production of various types of bio-based products.

Life cycle

Mating occurs two days after adult emergence from the pupal case. Upon successful mating the female begins with the egg laying.

(a) **Eggs:** The female deposits around 500 eggs in a single clutch in decaying matter such as dung, carrion, garbage and other organic waste or in cracks and crevices. Incubation period of the eggs are four days. Each egg is oval in shape, pale yellow or creamy white in colour and measures about 1 mm in length (NCIPMI 1998).

(b) **Larva:** After the incubation period of 4 days, the neonates emerge. The early instar larvae are dull, whitish in colour with a small projecting head, having biting and chewing mouthparts. The larvae can attain a length of 27 mm and a width of 6 mm at their last instar. The insect totally has six instars and require approximately 14-20 days for complete larval development (Hall and Gerhardt 2002). Black soldier fly larvae are insatiable feeders during their larval development, Adults rely on the fats stored from the larval stage and do not feed (Newton *et al*., 2005).

(c) **Pupa:** Before pupation, the fifth instar larva migrates from the feeding site to dry sheltered areas such as ground vegetation to initiate pupation. The exoskeleton (skin) darkens, and a pupa develops within. Pupation will be completed in about two weeks (Hall and Gerhardt, 2002).

(d) **Adults:** Adults are black or blue in colour and have a wasp-like appearance. Soldier flies also have two translucent "windows" located on the first abdominal segment. Adults range from 15 to 20 mm in length. (Sheppard *et al*., 2002). The adults have elongated three segmented antennae and white colorations near the end of each leg. The emerged adults will live for 4-6 days and the total life cycle will be completed within 40-50 days.

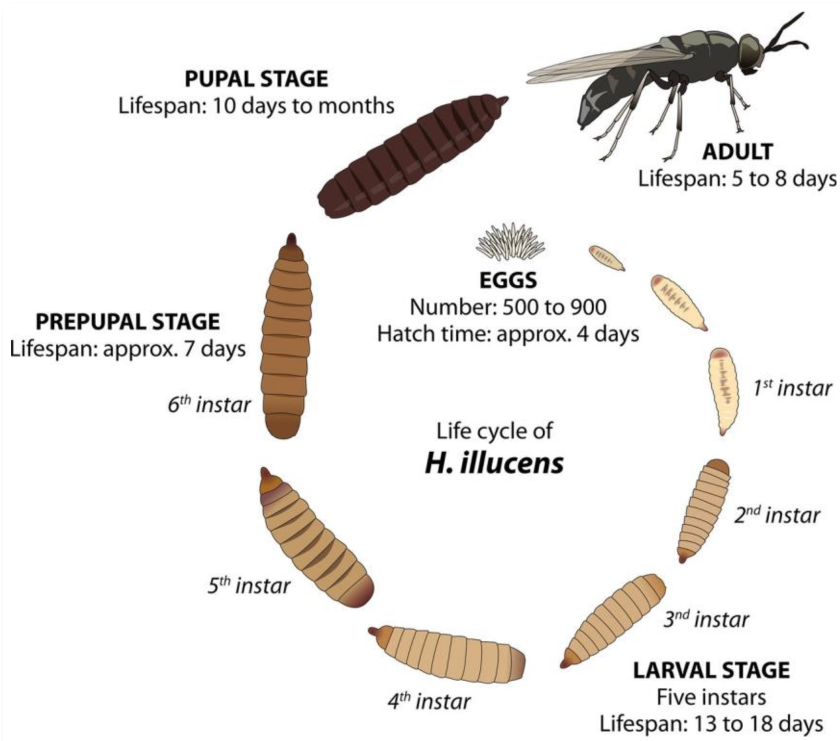

Fig. 1 Life cycle of Black Soldier Fly, *Hermetia illucens* (Linn.)

(Photo courtesy: De Smet *et al*., 2018)

Rearing and breeding under indoor conditions:

Indoor rearing facilities usually consist of cage layered houses under the animal producing waste. Optimum temperature, light intensity and humidity ranges are to be maintained to ensure high yield of *H. illucens* larvae. Temperature of 29–31°C with 50–70% RH is most suitable for larval development. Rearing facilities operate by self-collection of *H. illucens* pre-pupae as they migrate away from their habitat into collection bins or ramp for pupation.

Thus, the collected pupae are then brought into a greenhouse where they will hatch into adults. The size of screen cages for effective rearing of *H. illucens* adults vary. The space required for aerial mating is very large which the rearers can't afford. But 2×2×4m caged house is proved to be good for successful mating of BSF (Sheppard *et al*., 2002). As sunlight and intensity of sunlight influence the mating, it is recommended to keep adult *H. illucens* exposed to sunlight or in artificial light. 24–40°C of temperature, 30-90% of RH and over 200 µmolm^{2}s^{-1} of optimal light intensity are ideal for mating and oviposition. A moist container or corrugated cardboard tray (*i. e*., egg-holding tray) should be provided and placed near decaying organic matter which attracts gravid females for successful oviposition.

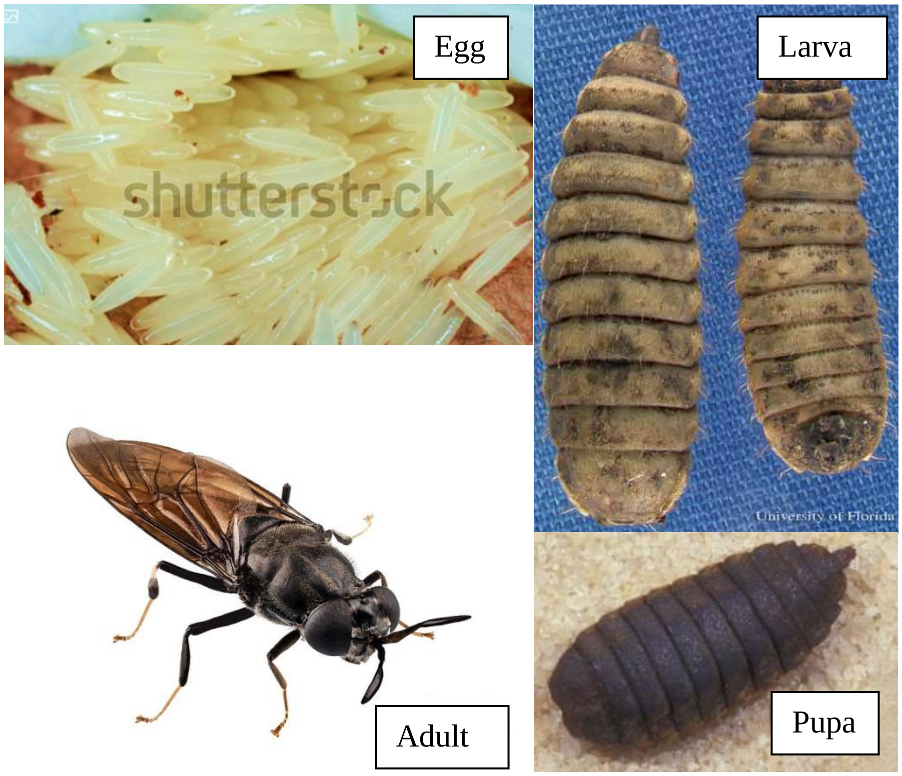

Fig. 2 Different life stages of *Hermetia illucens* (Linn.)

(Photo courtesy: James Castner, University of Florida and Shutterstock)

Blackfly in treatment of organic waste

Food waste is the prime source of organic wastes. Nearly, one-third of food generated is being wasted all over the globe (nearly 1.3 billion tons/year) without consumption (FAO, 2020). Keeping food waste apart, there is one more solid organic waste material *i. e.,* sewage sludge. It is obtained as a by-product from biological wastewater treatment plants. Approximately 2010 million MT of municipal solid wastes is being generated per year across the globe and by 2050 it is presumed to reach 3400 million MT per year (Ellis, 2018). Animal waste manure from farm is another solid organic waste material that is increasing in terms of capacity. Consequentially, 65% of N_2O, 64% of NH_3 and 10% of greenhouse gases are discharged globally because of the various agricultural activities, primarily via production of animal manure (Gómez-Brandón *et al*., 2013).

The conventional mishandling of organic wastes is contributing to a wide range of environmental hazards and economic misery (Ferronato and Torretta, 2019). Therefore, proper groundwork for waste disposal is required to cast out the huge amount of waste in a safe and sustainable manner with limited or no discharge of greenhouse gases. In this view, *H. illucens* is a perfect insect species as it can feed and breed on a variety of solid organic waste materials. Leaving apart the role in decomposition, the mature larva contains about 20% - 40% of fat. Therefore, the larval biomass can be used as lipid and even as a protein feedstock in the production of biodiesel and as poultry feed respectively (Oonincx *et al*., 2015). Furthermore, the adults of BSF have the ability to control houseflies that can affect human and animal health by preventing them from oviposition. Moreover, adults are not pests and the larvae are saprophagous which are capable to feed on various and large amounts of solid organic wastes (Čičková *et al*., 2015).

Fig. 3 Larvae of Black soldier fly engaged in decomposition of manure
(Photo courtesy: Lyle J. Buss, University of Florida)

Feeding substrates for BSF larvae

Single substrate

Feeding substrates of the larvae are particularly carbohydrates and protein contents which remarkably affect the larval growth, its bioconversion efficiencies, pre-pupal weights and the nutritional contents of the mature larvae (on a dry weight basis) (Kinasih *et al*., 2018). Among all the single substrates, chicken manure feed achieved the shortest larval development time followed by animal manure, waste from the restaurant and vegetable and fruit residue (Spranghers *et al*., 2017). Increased total larval biomass is directly correlated with chicken manure feed. The sludge from secondary waste water can also be used as a single substrate. But it lengthens the development time of the pre-pupa to emerge and the emerged pre-pupa will be smaller compared to other feeds. To overcome this drawback, the employment of undigested sludge is suggested.

Blended substrate

The common organic wastes administered for the nurturing of larvae of black soldier fly are waste coconut endosperm, dairy manure and sludge as these wastes have been produced in vast amounts as an outcome of various agricultural and industrial activities. The valorization of wastes by the sole utilization of the BSF larvae is very slow and not promising as the dairy manure comprised of hemicellulose, cellulose and lignin which makes it difficult for the BSFL to digest even though the manure has a good buffering ability (Mata-Alvarez *et al*., 2014). Therefore, there is a need of blending dairy manure with SCR for larval co-digestion as dairy manure is generally high in water insoluble nutrients *i.e.*, proteins and fats. Waste coconut endosperm is also blended with SCR at 3:2 ratio which helps the larvae to gain the highest weight (twice the mass of the larvae fed with only coconut endosperm waste). Reduced growth weight of the larvae due to the insufficient nutrients in sewage sludge is the main drawback which in turn leads to a small attainable larvae and a short period of pupation. Therefore, chicken manure or wheat bran is recommended for mixing with sludge to obtain maximum larval yield.

Microbial fermented substrate

In order to increase the nutritional composition of the feeding substrates of larvae prior to their administrations, the microbial modification method is employed by accomplishing fermentation in waste biomass. However, the occurrence of mazy organic waste materials such as lignocelluloses from plant-based products in larval feed is generally hard to ingest and digest since the larvae need to engulf the epidermis layer of the plants prior to ingesting. Thus, fermentation via microbes is viewed as a necessary work to bring down the complex ingredients via hydrolysis into simple molecules (Wong *et al*., 2020).

Various kinds of microorganisms are employed in the process and the fermentation thus, is categorized into two types based on the inoculation modes:

a) In-situ fermentation:

When the micro-organisms are inoculated to execute the fermentation process simultaneously with the valorization of waste organic substrates by the black soldier fly larvae it is referred as in-situ fermentation. *Saccharomyces cerveciaea*, *Bacillus subtilis*, *Lactobacillus buchneri* are employed in in-situ fermentation (Wong *et al*., 2020).

b) Ex-situ fermentation

The fermentation is referred to as ex-situ when the waste organic substrates are fermented by the microorganisms prior to feeding by the black soldier fly larvae. In this case, fermentation is an ongoing process throughout the larval feeding period. *Saccharomyces cerevisiae* for rice straw at 37 °C for 48 hours, *Aspergillus oryzae* for fermented maize straw, waste coconut endosperm fermented by mixed-bacterial powder (Reckitt Benckiser, UPN:1920080310) for 28 days prior to feeding the BSF larvae are some of the examples of Ex-situ fermentation (Mohd-Noor *et al*., 2017).

Future prospects

Valid and sound figures on environmental requirements of black soldier fly and the complete biological processes of the treatment is need to be provided in order to increase the performance which contributes in increasing the financial output is one of the significant prospects in future. This will empower the flexibility of the waste management plan along with the treatment plant in which the black soldier fly unit is established. This research needs to take an account on the effects of up-scaling and finally coming up with a refinement of design and operation for the facility for optimized profit. Such kind of research needs to occur constantly, involving researchers, plant operators and regional planners with closely bound information exchange networks. This is to make sure that there are immediate responses to emerging new developments and challenges.

Conclusion

Hermetia illucens with its high reproductive capacity and short life cycle has a great waste management potential as it can add value to various organic wastes and transform into its biomass. It can recycle waste into clean energy and reduce environmental pollution of the manure. It is an exceptionally resistant species and has a capacity to deal with demanding and changing environment such as oxygen deficiency, drought, food shortage etc. With respect to their robustness, survival of the species as a whole will not be endangered within a region. But increased heavy metal concentrations, temperatures reaching lethal values or a waste source turning anaerobic, exceeding a certain threshold level may prove detrimental to the larval population. The small sized larval harvest is usually associated with unavailability of essential nutrients in the food substrates. Hence, mixing with other substrates and fermentation by microbes has been suggested to hasten the nutritional values of larval feeding substrates. Overall, BSF larva is a good example for 'Treasure Out of Trash'.

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Migratory beekeeping: a boon to both farmer and beekeeper

Swapna Rani K[1], Samrat Saha[2*] and Jawahar Reddy A[3]
[1]Department of Entomology, Sri Krishnadevaraya College of Agricultural Sciences, Anantapur-515001, Andhra Pradesh, India
[2]Department of Agricultural Entomology, Uttar Banga Krishi Viswavidyalaya, Pundibari- 736165, Cooch Behar, West Bengal, India
[3]Department of Entomology, Sri Krishnadevaraya College of Horticultural Sciences, Anantapur-515001, Andhra Pradesh, India
***Corresponding author: isamratsahamtb43@gmail.com**

Abstract

Migratory beekeeping is a modern concept of commercial beekeeping that improves the yield of honey by many times. In this type of beekeeping, honey bee boxes are transported from one nectar-exhausted area to another nectar-rich area. It is not only beneficial for the beekeeper but also increases the crop yield through pollination and thus provides an additional income to the farmer. There are many plants that depend on honey bees for pollination for which migratory beekeeping is a blessing in disguise. In many developed countries migratory beekeeping has already been considered as a remunerative venture and has a significant contribution to the economy of that country.

Keywords: Migratory beekeeping, honey bees, pollination, Global scenario, Indian scenario

Introduction

People often mistakenly believe that the production of honey and other associated products like wax, propolis, royal jelly and bee venom is the only role of honey bees. But is it true? Answer is a big no, because honey bees play a pivotal role in pollination of several agricultural and horticultural crops. In fact, the pollination service provided by bees is ten times more valuable than the honey. Entomophily is the second important source of pollination after anemophily and among all insects, bees are the most dominant pollinating agents. Migratory beekeeping is one such practice that deploys bee pollinators in action when the plants are in need i.e., during the blooming period. The concept of migratory beekeeping is gaining popularity day by day and is now recommended by researchers due to its economic importance in all developed agricultural systems.

Bees in pollination

It is needless to state that pollination is the primary objective of migratory beekeeping whereas continuous and increased honey production is the secondary objective. Also, to cater the needs of increasing population, deployment of managed bee pollinators is essential for achieving higher food production. All over the world insect pollination has an annual valuation of more than 153 billion Euro for agricultural production (Gallai *et al*., 2009). Among several pollinating insects, bees (Hymenoptera: Apiformes) are the most important one and responsible for pollinating about 80% (Michener, 2007) of all flowering plants of which majority are agricultural crops.

From an experimental study it has been estimated that nearly 17% increase in seed yield was observed in onion and 35% fruit yield increase in pomegranate by deployment of managed bee pollinators. Different plants having different level of dependency on pollinators viz., in the plants like cocoa, pumpkin, squash, vanilla and watermelon artificial bee pollination is essential whereas others like cardamom, cashew, coriander, cucumber, and cross pollinated varieties of strawberry regarded as highly dependent on bee pollination (BEEINFOrmed, 2018). Hence, there is huge scope for mobile beekeeping in tropical regions where these plant species grow abundantly.

Migratory beekeeping in ancient Egypt

Migratory beekeeping is actually an age old practice mentioned in the history, where ancient Egyptians moved their cylindrical clay hives in floating rafts along the river Nile to catch bloom and nectar flow season by moving north towards Cairo during summers and similarly towards southern direction in winters. This practice exposes bees to longer blooming seasons thus more conversion of nectar into honey which is more profitable to the beekeeper (Abou-Shaara, 2009).

Migratory beekeeping: The global scenario

Though earlier several attempts have been made to bring migratory beekeeping to commercial level, they were proved to be non-practical until the 19th century. In the 1920's roadways started improving in developed countries led to use of trucks for mobile beekeeping. By the end of World War I, beekeepers had started providing commercial pollination service to the growers of the United States (USA) (Cheung, 1973).

The concept of mobile beekeeping is very much popular in developed countries like USA and Germany, where a huge eighteen-wheeler truck carrying many bee colonies is senton a rental basis for pollination of fruit trees which blooms only once in a year such as almond plantations, kiwi, cherry and apple orchards. As most of these tree species are self-incompatible, bee pollination is essential not only for achieving good yield but also for better quality of produce.

The California almond is the most notable example of the role of bee pollination service. In the USA, every year approximately 1.5 million commercially managed beehives migrate to the Central Valley of California for pollination of the almond crops. This value accounts for over 60% of total commercially managed beehives in the USA (Glenny *et al*., 2017). It is not an exaggeration that each almond they eat is produced by the pollination service provided by honeybees. The net value of the almond crop is 2.2 billion USD and it adds an estimated amount of 21.5 billion USD to the economy of California and also generates employment for 104,000 people in different sectors from production to marketing (Sumner *et al*., 2016). In the USA, the managed honey bee pollination service generates an annual estimated revenue of approximately 17 billion USD (Calderone, 2012).

Fig. 1: A mobile bee keeping truck containing stacked honeybee colonies (Source: Complete Beehives, 2022).

In Southern Europe, rape seed starts blooming during the early spring for which bee colonies are migrated following the bloom (EIP-AGRI, 2019). In the European Union (EU), the estimated insect pollination service revenue accounted for 14.6 [±3.3] billion Euro annually, that equivalent to 12 (±0.8) per cent of the total annual crop production value (Leonhardt *et al*., 2013).

A mutualistic relation between beekeeper and farmer

Migratory beekeeping creates a mutualistic environment between beekeeper and farmer where both the participants get benefitted. The pollination service provided by the bees allow the land owner to earn additional income due to the higher yield obtained, whereas the surplus nectar collected from the crops has been converted by the bees into honey that generate good income for the beekeeper. Moreover, beekeepers can earn additional income by renting out their hives to farmers at the rate two per acre to install in their farms for a three to four weeks period of blooming to fetch additional income besides the income from honey. Even sometimes the beekeepers pay the farmer for allowing bees to feed on their land.

Transportation of bee hives

After exhaustion of floral nectar in one area the beekeeper usually packs their hives during night times stacked onto pallets and placed inside the truck. The whole process of packing and shifting into the trucks need to be done during nights only because moving the hives in daytime when bees engaged in forging activity will lead to loss of their home. The beekeepers select new locations where plants containing ample amounts of nectar present in their sweet scented blooms as the next destination and the entire travelling carried out in the night time only. Upon reaching the destination, the beekeepers carefully open the hive and stack additional supers by wearing hand gloves and face veils on the top. This practice encourages bees to yield maximum honey and it can be gathered after three weeks.

Old bus to mobile beehive centre:

The large and lavish trucks are not always necessary for mobile beekeeping. For example, recently in 2020, an innovative beekeeper named Karlen Tchagharyan of Armenia, USSR showed his immense love to his honey bees and successfully converted three old Soviet era tourist buses into mobile bee center and each bus containing 40 bee boxes, set up with luxurious rooms splendid for bees (Katy, 2020).

Migratory beekeeping in Indian context:

Now the question is, how can migratory beekeeping influence the Indian beekeeping industry? In India, mobile beekeeping by using *Apis mellifera* colonies allows the beekeeper to go for 4–5 harvests every year that provide an average annual honey yield of approximately 50–60 kg/hive generating a significant income (Sharma *et al*., 2013, Kishan Tej *et al*., 2017). In addition, the strength of the colonies also improved due to migration (Brar *et al*., 2018). In small scale intra-state migration and in large scale inter-state migration is practiced. In North India, transhumance is carried out between plain lands and hilly areas, thus exploiting the flowering crops like lychee orchards and mustard, rapeseed or sunflower fields. In South India, the rubber and tamarind blooms are exploited for honey production (Kishan Tej *et al*., 2017)

Recently in India, mobile honey processing vans have been launched by Khadi and Village Industries Commission (KVIC) which can process nearly 37 kg of honey per hour. These mobile processing vans move to different apiaries to process honey which has proven to be beneficial for small beekeepers that save their expenses on transportation of honey to processing units (GOI, 2022). But still the improper condition of migratory routes, lack of awareness regarding the role of bees in pollination, small land holdings of farmers making the migratory beekeeping challenging for the beekeepers of our country.

Migratory beekeeping always lucrative?

Just like every coin, migratory beekeeping also has two sides. Though people always focus on the positive side without giving much attention to the negative side. Studies revealed that migratory beekeeping has an influence on the lifespan of honey bees. The travelling bees generally spend a shorter life than the stationary bees. Those travelling bees face a greater level of oxidative stress that results in quick aging of travelling bees and may also reduce their ability to escape disease and parasites (Simone-Finstrom *et al.*, 2016). But there are many complications on how migratory beekeeping impacts health and aging of honeybees, whereas new environmental conditions may show more influence on their health (EIP-AGRI, 2019).

Even during transportation in trucks the hives are kept side by side very closely which can cause easy spreading of mites and diseases. Migratory beekeeping also requires good road conditions, otherwise bees will face shaking and uncomfortable situations during transportation.

Conclusion

Though migratory beekeeping has some constraints, if they are managed properly, it will be a blessing for both the beekeeper and farmer. Particularly, in countries like India where tropical and subtropical climatic conditions exist without severe cold weather during winters and blooming occurs throughout the year, there is more scope for migratory beekeeping which can be more profitable compared to temperate countries. Although precautions need to be taken when warm and dry weather persists and by taking proper care and maintaining hygiene of bee colonies, one can derive good profits by venturing into mobile beekeeping.

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Honey Crystallization – Myth and Concept

Rakesh Das[1, 2]*, Amit Layek[2] and Kaushik Pramanik[2]
[1]School of agriculture, Swami Vivekananda University, Barrackpore, WB- 700121, India
[2]Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, WB-741252, India
Corresponding author: rdas6907@gmail.com

Honey crystallization, also called granulation, is a process where the liquid honey turns into a semi-solid state. But the people consuming honey are unaware of this fact, and often misjudge the crystallized honey as adulterated or unnatural one. Pure, crude or unheated honey appears to crystallize over time, as it is a spontaneous natural phenomenon. In actuality, crystallization guarantees the honey authenticity. It is well known that, crystallization does not influence the honey quality, only affect the colour and appearance.

Why does honey crystallize?

Honey is a supersaturated solution, mainly composed of a complex mixture of carbohydrates (Saxena *et al*., 2010). This supersaturated nature of honey is responsible for spontaneous crystallization. Fructose (levulose) and glucose (dextrose) are the two main sugars found in honey, which differ in amount from one to another type of honey. Generally, the fructose ranges from 30 - 44 % and glucose from 25 - 40 %. The combination of these two major sugars is the main reason that allows the honey to crystallize, and the relative percentage of each decides whether it crystallizes quickly or slowly (Hamdan, 2010). Glucose, which is less soluble than fructose, precipitates out of the supersaturated solution and forms glucose monohydrate crystals. Therefore, glucose crystallization reflects crystallization of honey (Gleiter *et al*., 2006). As the process progresses, the liquid state of honey transforms into a saturated thick or crystallized form.

Crystallization may be uniform or uneven and in uneven type two layers exist, lower with crystallized layer and upper with liquid layer formed. This uneven type of crystallization affects the shelf life, as the non-crystallized portion of honey will contain higher moisture content, which makes it vulnerable to yeast growth, resulting in fermentation. Crystals also vary in size and quick crystallization resulting in fine texture. Generally crystallized honey appears as lighter or pale in colour due to presence of pure white glucose crystals. But the darker honey shows a brownish appearance.

Factors imparting rapidness of crystallization:

Crystallization rate or speed varies from one type to another, some crystallizes immediately after harvest, whereas some retains liquidity for longer period. Different aspects like sugar composition, preservation temperature, presence of impurities etc. accelerate the crystallization rate in honey.

The main factors that influence crystallization are fructose, glucose, moisture content and sugar ratio (Escuredo *et al*., 2014). The fructose to glucose ratio (F/G) indicates how quickly the honey granulates. Honey with a higher F/G ratio (i.e., containing less than 30% glucose), resulting in less or slow crystallization and vice-versa. Honey crystallizes quickly when the F/G ratio is 1.14 or less; honey with an F/G ratio exceeding 1.58 does not have a crystallization propensity (Venir *et al*., 2010); and honey with an F/G ratio of 1.3 crystallizes slowly (Dobre *et al*., 2012). Simultaneously, the rate of glucose crystallization depends on glucose to water ratio (G/W). Honey with higher G/W ratio is expected to granulate rapidly and vice-versa.

Temperature during storage also has an impact on crystallization rate. The optimum temperature for crystallization is between 10 - 15°C, whereas it is restricted at temperatures greater than 25 ºC (Zamora and Chirife, 2006). Low temperatures (4 - 10°C) resulted in slowing down of crystallization; because of an increase of honey viscosity (thickness), it reduces the glucose diffusion making it more difficult for crystals to move (Costa *et al.*, 2015).

Apart from honey composition, presence of foreign entities like pollen grains, pieces of bee wax and other impurities accelerate the crystallization rate. Basically, all these impurities present in honey serve as nuclei or centres for crystallization. A study revealed that degree of crystallization was positively correlated with absolute pollen count (Grégrová *et al*., 2015). Thus, raw unprocessed or unfiltered honey crystallizes faster than processed or filtered honey.

How to liquefy crystallized honey?

Crystalized honey can be brought into liquid state simply by heating, but heat should be given indirectly, not directly. One must also remember that the heating temperature should be in a particular range, otherwise overheating as well as direct heating will reduce the honey quality by means of destroying its enzymes, loss in flavour and aroma etc. Similarly, the overheated honey appears dark in colour, hence both loss in nutritive value and physical appearance make the honey unmarketable. Generally, the normal or average bee hive temperature is 30-35^{0}C, though sometimes it raises up to 40^{0}C during the hot summer period and in this temperature range honey remains still liquid in the hive throughout the period. So, it is best to heat the crystalized honey at 35-40 ºC for liquefying it and heating with excess temperature should be avoided to prevent overheating damage. One of the important negative impacts of overheating is formation or increase of 5-Hydroxymethyl furfural (HMF), which deteriorates the honey quality.

The best method for liquefying the crystallized honey through heating is hot water bath method. Here the heat is provided indirectly through water *i.e.* the honey containing jar is placed in warm water for liquefying the honey. In large scale or in industrial use where the bulk amount has to be liquefied the hot water bath machine is used. On the contrary, in small or individual purpose simple household water heating technique is used. In this technique at first one large container with water is heated allowing the temperature up to 35-40 ºC, then the honey containing jar has to be placed into this hot water container and kept it for at least 30 minutes until the honey came in liquid state. Sometimes, stirring of honey is required during liquefying period to evenly distribute the heat, as the crystallized honey is a poor conductor of heat. But if the water cools rapidly, heating should be done in the same way or by replacing the hot water if needed. In this process of honey heating the following precautions should be taken, viz., (i) avoiding overheating of honey and (ii) honey must always be taken in a glass jar, and plastic ones must be avoided

Methods to prevent crystallization

Several issues starting from honey harvest to storage accelerate the honey crystallization, hence proper care should be taken to prevent this process.

Honey harvest should be done from the comb having 2/3 part or 75% of honeycomb cells sealed *i.e.* the sealed ripen honey. Generally, the sealed honey having moisture less than 20% keeps or maintains the honey in good quality, as the excess moisture leads to deterioration of honey quality.

Harvested honey should be filtered properly before storage. During harvesting, the impurities like bee broods, comb wax, pollen grains etc. are also mixed with honey in the extractor machine and all these form the nuclei of honey crystallization and accelerate the crystallization process during the period of storage. Hence, harvested honey should be filtered properly by one or more sheets of fine nylon cloth to remove all these crystallization centres (Amariei *et al.*, 2020).

Honey always must be stored in closed container and never kept in open. Honey kept in the open or in earthen pots leads to accumulation of moisture in honey as it is hygroscopic in nature and absorbs the air moisture. Excess moisture leads to loss in honey quality as it is fermented easily.

Honey storage should be done at room temperature of 25-30^{0}C and one must avoid the cold temperature of 10-15^{0}C which is ideal for crystal formation. Similarly, storage of honey in high temperature (>40^{0}C) for longer period also leads to the deterioration of quality as the high temperature causes breakdown of enzymes.

Processing of honey

Honey processing denotes the post-harvest management of honey, which also sometimes includes bottling and labelling. But mainly moisture reduction and filtration are the main aspects of post-harvest management of honey during processing. It must always be remembered that no chemical addition or any such type should ever be done during the honey processing. Excess moisture and external impurities are the major causes of quality deterioration; hence moisture reduction and filtration have to be done prior storage properly. In industrial or large-scale honey processing, processing machines of various capacities (5qt, 10qt, 50qt etc.) are used, where both moisture reduction and filtration process occur simultaneously in a single unit. But individually one can process his/her honey by means of separate household methods, where moisture reduction can be done by hot water bath method and filtration by repeating sieving through nylon sheets.

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Entomotherapy- a renewed healing technique

Penuballi Swathi* and Haseena Bhaskar
Department of Agricultural Entomology,
College of Agriculture, Kerala Agricultural University, Thrissur-680656, India
****Corresponding author: swathipenuballi108@gmail*.com**

Healing of human ailments by using medicines prepared from different insects or insect derived by products is called as Entomotherapy. The ancient Mayan, Egyptian and Brazilian societies have long since understood the powerful biochemical properties of insects. In traditional medicine, different insects are used as live, cooked, ground, in infusions, in plasters and as ointments, both in curative and preventive medicines (Shrivastava and Prakash, 2015).

The discovery of antimicrobial peptides (AMP's) in insects and animals during 1980's, has led to the development of promising alternative sources of today's antibiotics (Nguyen *et al*., 2011). The anticancer, antimicrobial and antiviral properties of peptides isolated from insects have been widely documented (Chernysh *et al*., 2002). Nearly 64 different arthropod species from 14 orders are used medicinally across five continents. Lepidoptera, Coleoptera, Orthoptera, Hemiptera, Hymenoptera and Diptera feature most prominently in entomotherapy in human therapeutic practices. Insects can be either directly used as live insects in human treatments or indirectly as their products.

Live, medical grade fly larvae of the blowfly, *Lucilia sericata* are used in maggot debridement therapy (MDT) for fast and effective treatment of non-healing wounds. Maggots remove dead or decaying tissue, their secretions promote faster wound healing and reduce spread of infection through blood. Recently lucifensin, a novel larval defensin isolated from *Lucilia sericata* (Calliphoridae) has been identified as one of the antibacterial agents of medicinal maggots involved in MDT. The maggots can be applied on wound surface either by directly releasing onto the wound and then retaining within a special dressing system, or as biobag dressing, where the maggots are sealed within a dressing of finely woven net pouch containing foam (Pickles and Pritchard, 2017).

Insect products in human medicine are honey bee products such as honey, propolis, royal jelly and bee venom (apitherapy) as well as cantharidin, venom, silk and anticoagulants. Honey is a powerful antimicrobial agent with a wide range of effects. Many commercial firms have registered medical grade honey by enhancing certain antibacterial components like hydrogen peroxide and methyl glyoxyl contents. Two popular sources of medical grade honey commercially exploited around the world are Manuka honey and Revamil honey. Propolis is proven to be a safe immune-stimulant and a potent vaccine adjuvant, as it induces an earlier immune response and provides a longer protection period. Royal jelly has a hepatoprotective effect by stimulating liver tissue regeneration. The antimicrobial, antiviral, anti-inflammatory and anti-cancer activity of bee venom may be attributed to its main component, melittin.

Fig. 1. Applying maggots on the wound surface

(Source: https://www.sciencephoto.com/contributor/lmu/)

Cantharidin, a terpenoid extracted from the blister beetles, *Mylabris cichorii* and *Epicauta hirticornis* acts as a vesicant (Moed *et al.,* 2001). Huan *et al*. (2012) reported that cantharidin promotes secondary necrosis and COX-2 over-expression in human bladder carcinoma cells and stimulate cystitis through c-Fos and COX-2 overexpression in rat. Recently, analogues of solenopsin, an alkaloid present in the venom of fire ants of the genus *Solenopsis* have been explored for the treatment of human psoriasis.

Silk fibroin hydrogels developed from the silk proteins of Bombycidae and Saturniidae prevents infection during wound healing process (Nguyen *et al.,* 2011). Blood sucking arthropod saliva possess wide range of bioactive compounds with therapeutic qualities. The most potent vasodilator known to science, maxidilian was found in the saliva of biting sand flies. The salivary anticoagulant, anopheline isolated from *Anopheles* sp. possess distinct thrombin inhibition mechanism which has implications for the design of novel anti thrombotics to combat immune response during organ transplantation (Figueiredo *et al.*, 2012)

Fig. 2. Blister beetle (family: Meloidae)

(Source: https://www.thailandnatureproject.com/mylabris-cichorii)

Insects provide inexhaustible resources for pharmacological research, representing a feasible substitution to many medicinal drugs. Hence it is imperative that insect diversity be conserved so as to identify new sources of pharmacological exploration in the coming years.

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Understanding how *Apis cerana* and *Apis mellifera* keep *Varroa destructor* away-a brief review

Salome Ruth Jimmy V.
Department of Biotechnology, Ramaiah Institute of Technology (MSRIT), Bangalore-560054, Karnataka, India
Corresponding author: salomeruthj@gmail.com

Abstract

It is a well-known phenomenon in the field of apiology that honey bees have developed adaptive behaviours in displaying resistance against the *Varroa destructor* mite, since its widescale emergence and the host-jump displayed from *Apis cerana* to *Apis mellifera*, in the last few decades, allowing it to be found in almost every part of the world rearing honey bees. This brief review attempts to understand the mechanisms and general behaviours displayed by both species.

Introduction

Honey bees are one of the smartest of the class Insecta existing on the planet. Known as highly complicated superorganisms, honey bee colonies possess a variety of social immunity traits that can help shield them from dangers like disease and parasite infestations.

Honey bees are eusocial creatures. They work together to ensure the survival of the entire community, and not just their individual selves, and display characteristics such as social apoptosis. (Kate E Ihle, Lilia I de Guzman, Robert G Danka,2022). With regard to this, as evolution has taken place, honey bees have shown to adapt at a rapid rate to protect themselves against threats, the biggest one being the *Varroa destructor*, a parasitic mite that attacks two species of honey bees namely *Apis cerana* and *Apis mellifera.* It is responsible for transmitting viral infections that eventually lead to colony fatality if mite populations continue to grow without check. To combat this, honey bees display certain traits which have been studied for their gene expression and heritability such as allogrooming, brood cell recapping and hygienic behaviour.

Brood cell recapping

A study published (Gabel Martin et al., 2023) on heritability and genetic correlations for suppressed mite reproduction (SMR) and recapping (REC), in two populations namely Carnica and Buckfast of *Apis mellifera*, distinguishing between recapping of infested cells (RECinf) and all cells (RECall), found that both traits showed promise in further selection. They showed that the traits SMR, RECinf and RECall can be made greater by targeted selection and are also being adopted in few breeding generations. They concluded that these traits alone do not guarantee complete resistance to the mite. During artificial selection it must be noted that, there must be, in addition to these desirable traits, other adaptive features to the respective environment as well. Another study (Melissa A.Y. Oddie *et al.*,2021) compared surviving and susceptible colonies of *Apis mellifera* and demonstrated that there was higher recapping efficacy in surviving populations that had mite infestations.

Genetic mechanism behind grooming behaviour

Allogrooming is a common trait displayed by honeybees in resisting the parasite and it has been found that *Apis mellifera* shows lesser resistance than the host *Apis cerana* (Dorian J. Pritchard, 2016) in which it was first discovered. In relation to the paper by Gabel et. al., another study (Nuria Morfin et al., 2023) was published where the honeybees were bred for low *Varroa destructor* population growth (LVG) and high *Varroa destructor* population growth (HVG) and the 2 genotypes were classified as light and heavy groomers, thus giving a total of 4 groups that were evaluated (HVG light, HVG intense, LVG light, LVG intense). Approximately 20 mg of wheat flour was applied to the thorax with the help of a paintbrush. The flour acted as an irritant, and the self-grooming behaviour of the bees was observed for a span of 3 minutes each, to see how fast or slow the bees would be in removing the irritant off their thorax. The observer was not made aware of the genotype of the bee. After this was completed, the brains of 50 randomly selected bees were taken and RNA was extracted. Analysis was done using a Pearson correlation test where the grooming of bees in different categories (LVG-intense, LVG-light, HVG-intense and HVG-light), viral abundance and transcript abundance were analysed. They found that there was a much greater number of intense to light groomers in both genotypes. They were able to identify 19 different pathways, odorant binding proteins and a gustatory receptor responsible. Given that both genotypes of bees had higher proportions of intense groomers than light groomers, this particular trait of intense grooming cannot prove to be the sole reliable way of distinguishing between LVG and HVG bees. This study however does provide valuable information by showing molecular mechanisms of behaviour traits of these honey bees. The study on viral levels enables scientists and breeders to understand the subsequent effect of pathogenicity and its role in behavioural immunity without human intervention. The results of this study give a great head-start to further delve into studying genomic assisted selection tools to improve breeding.

The switch between old hosts to new hosts

It is now common knowledge that this parasitic mite is found in both hosts viz. the Western (*Apis mellifera*) and the Eastern honey bee (*Apis cerana*). Wenfeng Li et. al. (2022) wanted to explore if the parasite *Varroa* *destructor* had a cell preference between the old and new hosts. They demonstrated through cell invasion bioassays that there indeed was a preference for the new host- *Apis mellifera.* When analysed for levels of cuticular hydrocarbons (CHCs) a significant difference between the two species was shown. They found that methyl-alkane amounts were higher in *A.mellifera* and alkene amounts were higher in *A. cerana*. They then placed a dummy glass with larval CHCs of *A.mellifera* and found the mites favouring it. This study therefore indicated the role of these larval CHCs as one of the reasons for the parasite's preference. Another study (Zheng et. al., 2023) aimed to identify the genetic factors behind the reproduction of the mite if any, between those infesting the old and new hosts and separated them into two groups. They artificially infested both the hosts and performed transcriptome sequencing to find differentially expressed genes (DEGs). Firstly, they found that there was an upregulation in oogenesis of the mites in *A. mellifera* and the DEGs were associated with 9 genes partially responsible for oogenesis. Although the key mechanism still needs to be researched, they were able to determine the genes responsible in the reproductive process of these mites.

Discussion and Conclusion

Latest research and information obtained has opened exciting new avenues with respect to resistance against *V. destructor*, but there is significantly a greater amount of data available regarding the resistance behaviours in *A. mellifera* to the parasite, in contrast to its counterpart *A. cerana.* Although genetic studies using high-throughput sequencing have become common in recent years, being also affordable, there are still a number of gaps in the research available, especially with respect to resistance in *A. cerana.* There is therefore a great need for researchers to study this as it may prove to be useful in selective breeding, and thereby assist beekeepers and breeders to combat the parasite. Resistance to the parasite is a sum of all factors such as environmental factors and not just the ones discussed in this review. Since variations continually take place in both the parasite and host populations, and breeding of new generations takes place at a rapid rate, attesting only a few known and discovered factors to resistance cannot be considered, although playing an absolutely crucial role in our understanding of this area.

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Inflorescence looper *Perixera illepidaria* (Guenee) Lepidoptera: Geometridae on mango

Malini Nilamudeen*, Sumiya K V, Karthikeyan K, Syed Mohammed Ibrahim
Regional Agriculture Research Station, Pattambi, Kerala Agricultural University
Pincode- 679303 India
****Corresponding author: malininilam@gmail.com***

Mango orchards which came to bloom in the first fortnight of November 2022 in Kollengode block of Palakkad district (10° 37' 0" N, 76° 42' 0" E.) recorded serious infestation of *Perixera illepidaria*. The looper caterpillars were found feeding voraciously on mango flowers. More than twenty larvae were collected from a single inflorescence on slight shaking. The damaged inflorescence presented a dried appearance and flowers became brittle. In India, the pest has been reported for the first time from Bihar from *Litchi chinensis* by Kumar *et al*., 2014. Nayanthara and Narayanan, 2020 recorded *P. illepidaria* as an inflorescence looper from mango orchards of Kolengode, Kerala. Soumya *et al*.,2021 stated that *P. illepidaria* can be a major threat to commercial cultivars of mango in the southern India. They reported it from the states of Andhra Pradesh, Karnataka and Tamil Nadu and observed that population was high during the peak flowering season of mango (January–March) and found it feeding on mango inflorescence with set fruits, resulting in yield loss. Poorani and Mohanasundaram, 2022 reported the migration of the looper caterpillars to banana for pupation. In Muthalamada panchayat of Palakkad district, the mango starts blooming from September and bear fruits by January and the infestation by *P. illepidaria* is severe during this year also. Ecofriendly management protocol is to be developed for the management of this pest as their population is flaring up in every subsequent flowering season.

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Fig 1: *Perixera illepidaria*-larva and pupa

Fig 2: *Perixera illepidaria* Adult

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Natural parasitoid species of silk moth in Cameroon Afromontane ecosystem

Ouaba José [1], Tchuinkam Timoléon [1], Niassy Saliou [2], Meutchieye Félix [3*]
[1]Department of Animal Biology, Faculty of Science, University of Dschang, Cameroon. PO Box 067 Dschang, Cameroon
2Department of Plant health; International Centre of Insect Physiology and Ecology, Nairobi, Kenya. PO Box 30772-00100, Nairobi, Kenya
[3]Department of Animal Science; Faculty of Agronomy and Agricultural Sciences, University of Dschang, Cameroon. PO Box 188, Dschang, Cameroon
**** Corresponding author: fmeutchieye@gmail.com***

Lepidopterans form one of the largest orders of the insect class with high economic importance in Cameroon. In addition to their role in pollination and food web, larvae (caterpillars) of some species are agricultural pests, while others serve as food for many populations (Meutchieye, 2019; Ngute *et al*., 2019; Ouaba *et al*., 2020). Collection and trade of charismatic butterflies are also recorded in many localities of Cameroon, as is the trade of silk cocoons of some lepidopteran species (Malzy, 1955; Ouaba *et al.*, 2020). Given their essential role in the food system and community livelihood, sustainable management of beneficial species (e.g., through domestication), harmful and sustainable species control. However, this requires a better knowledge of the biology and ecology of these lepidopterans (Dongmo *et al.*, 2023).

Natural enemies play an important role in the bioecology of lepidopterans and commonly control their population numbers and influence their survival (Hassel, 2000). However, very little is known about the presence and diversity of parasitoids developing in these caterpillars in Cameroon. We report here a hymenopteran parasitoid affecting silk cocoons of *Epanaphe* sp. (Lepidoptera: Notodontidae**)** in the Cameroon Afromontane ecosystem.

This wasp (Figure 1) was found ovipositing in wild silk cocoons gathered from an avocado tree. It belongs to the family Ichneumonidae and has the following characteristics: The head is black, as are the antennae, which measure a little more than half the length of the whole body. The size of the body is 1.8 cm. The thorax is black with white markings on the pronotum and a white spot on the mesossculletum. There is also a white mark on each side of the metapleuron. The abdomen is mainly dark red, with the posterior segments partly black. The ovipositor is black and measures a little more than half the whole body's length. The femur of the fore and middle legs is orange, with the rest of the legs being black. All parts of the hind leg are dark red except the femur and the coxa, which are black.

This parasitoid used its antennae to check the appropriate place to oviposit before inserting its ovipositor inside the cocoon to oviposit. Eggs were laid successively in 6-7 cocoons.

This is an unusual observation of a silk cocoon parasitoid in this part of the country. Specific identification using advanced tools is required in Cameroon.

Figure 1: Ichneumonidae A&B=dorsal and lateral view; C=oviposition D=infested silk cocoon cluster

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Incidence of *Papilio demoleus* Linnaeus (Lepidoptera: Papilionidae) in Kinnow

Rajendra Nagar[1*], Balbir Singh[2] and Dayanand[1]
Krishi Vigyan Kendra (SKRAU), Abusar, Jhunjhunu-333001 (Rajasthan) India[1]
Krishi Vigyan Kendra (SKRAU), Chandgothi, Churu-331305 (Rajasthan) India[2]
****Corresponding author: rajendranagar86@gmail.com***

Citrus fruits are grown all over the world. Early records indicate that citrus fruits such as, orange (*Citrus reliculata* Blanco), limes (*Citrus aurantifolia* (Swingle) and lemons (*C*itrus *limon* (L Burm.) were being cultivated in South China, Malaya and Sub-Himalayan parts of Assam. From there, they spread to the tropical and sub-tropical parts of the world. The third most important fruit crop of India after mango and banana is citrus fruits. Citrus trees are attacked by a wide variety of pests.823 species of insects damaging citrus in various countries were reported, 175 of them occurred in India (Ebeling, 1959). The reported pest is a serious citrus pest in India (Pathak & Rizvi, 2002). Citrus tree in India is attacked by a very large number of insects and mites causing appreciable loss in yield. Among all the insect pests, lemon butterfly (*P. demoleus* L.) is an important pest of citrus causing severe damage at sapling (nursery) and young stage in the orchard. Looking at the apparent importance of the pest and the little information available on seasonal abundance of lemon butterfly. Studies were carried out on newly established kinnow orchard at Krishi Vigyan Kendra, Chandgothi-Churu, Rajasthan (Latitude = 28.57737 and Longitude = 75.52049). The *P. demoleus* pest population was recorded at weekly interval on ten randomly selected new grown kinnow plants. Lemon butterfly attacks kinnow at the vegetative stage defoliating the whole plant. The appearance of the *P.demoleus* on kinnow plant were noticed on the first week (0.33 /10plant). The caterpillar population started to decline during the latter fortnight (5.0 /10 plants) which continued up to first week of next month (0.66/10 plants) and thereafter completely disappeared.

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Fig. 1 Damage of *Papilio demoleus* (Linnaeus) in Kinnow

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INSECT LENS

***Leaf webber*, Eretmocera impactella (Scythrinidae: Lepidoptera)**

Sporadic pest and widely distributed in the Indian sub-continent. The larvae feed on various plants of Amaranthaceae species and other food plants. Caterpillars web leaves with white silken threads and remain hidden in folds feeding from inside.

Author: *D. N. Nagaraj, Project Head (Entomologist) Ento Proteins Pvt. Ltd., Mangalore*

Location: *Bengaluru, Karnataka*

Email: *nasoteya@yahoo.co.in*

Ant-mimicking flower beetle, Anthicus sp. (Anthicidae: Coleoptera)

Yet another interesting mimic of ants. Adults generally found on flowers and foliage and larvae are usually found on or in the soil, leaf litter, rotten wood, under stones, logs or debris, water banks and littoral zone, grasslands, deserts, etc. Larvae feed on decaying vegetation.

Author: *Sevgan Subramanian*
Location: *Karura Forest, Nairobi, Kenya (December 2022)*
Email: *ssubramania@icipe.org*

Stingless bee, Tetragonula iridipennis Smith (Apidae: Hymenoptera)

Stingless bees are important pollinators of crops in tropical and subtropical parts of the world. In addition to pollination, honey produced by them has higher medicinal value compared to honey of other bees and costs rupees 1000–10,000 per liter.

Author: *Rakshitha T. N., PhD. Scholar (Agril. Entomology)*

Location: *College of Agriculture, Hanumanamatti, Ranebennur, India*

Email: *tnrakshitha@gmail.com*

Dirt-coloured Seed Bugs, Metadieuches sp. (Rhyparochromidae: Hemiptera)

Their name was derived from the Greek words 'Rhyparos' and 'Chromus' which mean dirt and color respectively. Hence, these groups of bugs are often referred to as dirt-colored seed bugs. These dirt-colored seed bugs are typically seen in human households hiding under debris or in wall cracks. However, in the wild, these bugs are seen around trees like pine trees or even small shrubs and bushes.

Author: *Sevgan Subramanian*

Location: *Karura Forest, Nairobi, Kenya (January 2023)*

Email: *ssubramania@icipe.org*

Clown Beetle or Hister Beetle, Hister sp. (Histeridae: Coleoptera)

Interesting group of predatory beetles with over 3,900 species known worldwide. Biologically they feed on dung, decaying tissues, vegetations and eggs, larva and adult insects that feed on dung such as houseflies.

The term Histeridae was given by Leonard Gyllenhaal, a Swedish military officer and entomologist. These beetles are called as clown beetles due to their amazing thanatosis behaviour (Feigning death) when disturbed or under threat. In Latin the term "Hister" refers to actor. The term "Hister" could also mean someone living in a filthy environment.

Author: *Sevgan Subramanian*

Location: *Karura Forest, Nairobi, Kenya (January 2023)*

Email: *ssubramania@icipe.org*

Ape-faced pupa of Lemolea harvester, Spalgis lemolea (Lycaenidae: Lepidoptera)

This is among the best sculptures of nature. Just reminds the Vanar Sena warrior characters in Hindu Epic, Ramayana. The larval forms of this species are excellent predators of mealybugs. However, unfortunately communities consider the ape face of the pupa as a bad omen and try to destroy them rather than the mealybug.

Author: *Sevgan Subramanian*
Location: *Karura Forest, Nairobi, Kenya (January 2023)*
Email: *ssubramania@icipe.org*

Bee Mimicking Robber fly, Laphria thoracica (Asilidae: Diptera)

A large species of robber fly that is very hairy and has bee-mimicking coloration, including black and yellow stripes on its abdomen. They prey on a variety of insects, including other robber flies, bees, wasps and beetles. They use proboscis to penetrate the body of their prey and inject enzymes which dissolve the tissues.

Author: *Naresh Talari*
Location*: Tirupati, Andhra Pradesh, India*
Email: *drtn_ahs@vignan.ac.in*

Ant-mimicking predatory thrips, Franklinothrips megalops (Aeolothripidae: Thysanoptera)

These are predatory thrips that feed on other pest thrips, small insects such as white flies, psyllids and insect eggs. Some of these thrips belonging to Franklinothrips have been commercially used for biological control in greenhouses in Europe and US. Adult thrips are ant-like with few abdominal segments constricted and pale and they are fast moving. They have an interesting pupation behaviour among thrips as they pupate within a silken cocoon.

Author: *Sevgan Subramanian*

Location*: ICIPE, Kasarani, Nairobi (January 2023)*

Email: *ssubramania@icipe.org*

Indian honey bee, Apis cerana indica (Apidae: Hymenoptera)

Indian honey bee plays a very significant role in pollination in both natural environments and for crops. Indian honey bee is highly attracted to high densities and numbers of flowers. Hence, in the wild, it makes them especially important pollinators for canopy trees in tropical forests with supra-annual flowering schedules. This trait also makes them great pollinators for crop monocultures in agriculture, and it has also led to them becoming highly adapted to human-dominated landscapes, both urban and agricultural.

Author: *Rakshitha T. N., PhD. Scholar (Agril. Entomology)*

Location: *Hi-tech Horticulture, Saidapur farm, University of Agricultural Sciences, Dharwad, India*

Email: *tnrakshitha@gmail.com*

Cicada, (Cicadidae: Homoptera)

Cicadas are loud singers. The song is a mating call produced by the males only. Each species has its own distinctive call and only attracts females of its own kind even though rather similar species may co-exist. Cicadas are the only insects to have developed such an effective and specialized means of producing sound.

Author: *Rakshitha T. N., Ph.D., Scholar (Agril. Entomology)*

Location: *Sullia (Tq.), Dakshina Kannada (Dist.), India*

Email: *tnrakshitha@gmail.com*

Tobacco capsule borer, Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae)

It is a pest of paramount importantance for tobacco seed production due to its feeding preference on seed capsules.

Author: *Nimish A Bhatt, Assistant Research Scientist, Anand Agricultural University, Dharmaj Gujarat, India.*

Location: *Tobacco Research Station, Anand Agricultural University, Dharmaj Dist. Anand (Gujarat) 22.4153° N, 72.7895° E*

Email: *nimishanil@gmail.com*

Blue milkweed beetle, Chrysochus cobaltinus (Chrysomelidae: Coleoptera)

In the blue milkweed beetle, Chrysochus cobaltinus (Coleoptera: Chrysomelidae), males remain stationary on females' backs for prolonged periods after a brief copulation.

Author: *Rakshitha T. N., PhD. Scholar (Agril. Entomology)*

Location: *Sullia (Tq.), Dakshina Kannada (Dist.), India*

Email: *tnrakshitha@gmail.com*

Plume moth, Exelastis atomosa (Pterophoridae: Lepidoptera)

Plume moth is named for the deep wing divisions that resemble plumes or lobes. The clefts in the wings divide them for about half their length, with the forewings usually divided into two plumes and the hind wings into three. Plume moths are active at night and usually rest in plants during the day, with their wings stretched out and rolled into the shape of a rod, rather than folded back. Larval habits include rolling leaves, leaf mining, boring in stems, or feeding in exposed situations.

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

Nymph of the armoured bush cricket/corn cricket, Acanthoplus discoidalis (Walker) (Tettigoniidae: Orthoptera)

These are sporadic pest of cereals, maize, sorghum and millets in sub-Saharan Africa. Grown up crickets do also get consumed as edible insects by several communities.

Author: *Sevgan Subramanian*

Location: *Salima, Malawi Kenya (January 2023)*

Email: *ssubramania@icipe.org*

Soldier fly, Sargus sp. (Stratiomyidae: Diptera)

Adults are almost found on flowers and lap up nectar to fuel their amorous activities. Larvae are aquatic, feeding on decaying organic matter.

Author: *D. N. Nagaraj, Project Head (Entomologist) Ento Proteins Pvt. Ltd., Mangalore*

Location: *Bengaluru, India*

Email: *nasoteya@yahoo.co.in*

Stalk-eyed fly, Diopsis sp. (Diopsidae: Diptera)

Minor pest of sorghum. The damage is similar to that caused by Atherigona soccata and results in "dead hearts". Diopsis will appear later in the season. During the dry season, the population of Diopsis decreases rapidly.

Author: *Sevgan Subramanian*

Location: *Maize farm, Mount Makulu Agricultural Research Station, The Zambia Agriculture Research Institute, Chilanga, Zambia (February 2023)*

Email: *ssubramania@icipe.org*

Lauxaniid Flies (Lauxaniidae: Diptera) feeding on honeydew excreted by Red Gum Lerp Psyllid, Glycaspis brimblecombei (Psyllidae: Hemiptera)

An invasive pest of Eucalyptus in Africa. Most species inhabit in forests, where the adults usually are found sitting on leaves of the understory. They are far less common in open land, such as grassland habitats

Author: *Sevgan Subramanian*

Location: *Karura Forest, Nairobi, Kenya (February 2023)*

Email: *ssubramania@icipe.org*

Common jezebel, Delias eucharis (Pieridae: Lepidoptera)

Delias eucharis has bright colouration to indicate the fact that it is unpalatable due to toxins accumulated by the larvae from the host plants. The common jezebel can be distinguished by the shape of the orange red spots on the hind wing. These spots are arrow head shaped in common jezebel.

Author: *D. N. Nagaraj, Project Head (Entomologist) Ento Proteins Pvt. Ltd., Mangalore*

Location: *Bengaluru, India.*

Email: *nasoteya@yahoo.co.in*

A Carpenter Bee, (Genus: Xylocopa)

The tropical carpenter bee, is a species of carpenter bee widely dispersed throughout Southeast Asia. As its name suggests, this bee inhabits forests in warm tropical climates and constructs nests by burrowing into wood.

Author: *Mr. Rushikesh Rajendra Sankpal, Assistant Professor: Biotechnology, Department of Biotechnology, Abasaheb Garware College (Autonomous), Pune, Maharashtra*
Location: *Warananagar, Dist- Kolhapur, State- Maharashtra*
Email: *rushisankpal@gmail.com*

EXTENSION

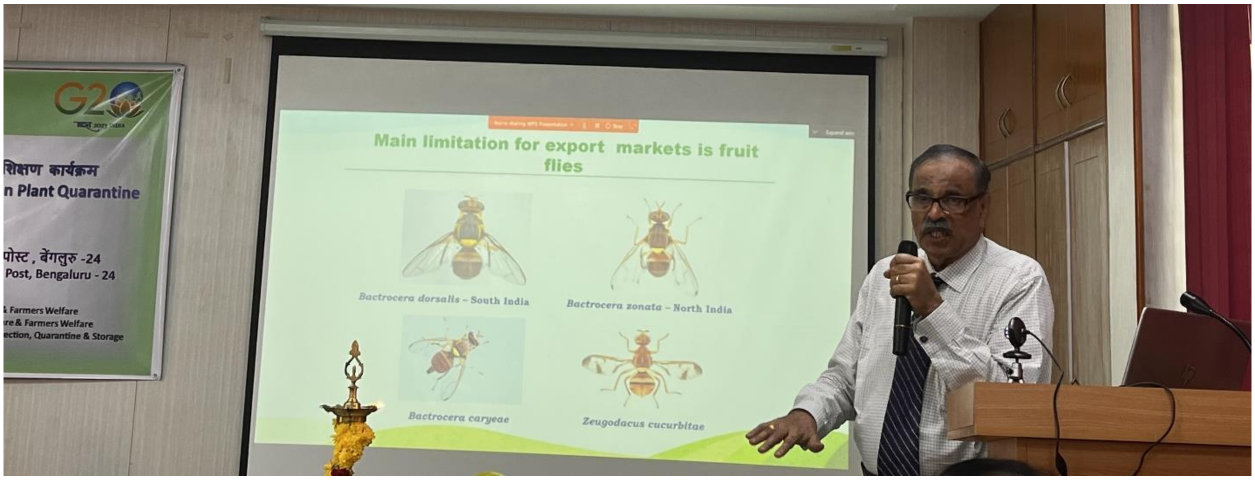
OUTREACH BY RASHVEE-IPRS AND AVIAN TRUST

Integrated pest and disease and nutrition management in mango recommendations video by Dr. Abraham Verghese, https://www.youtube.com/watch?v=S9UX3o4mr9s&t=5s

Interacting with farmers at plant health clinic

Visit of interns to Regional Plant Quarantine Station, Bengaluru

Dr. Dr. Abraham Verghese, with Sh. Gyaneshwer Banchhor, DD (E), CBU, DPPQS, Faridabad and Dr. D.K. Nagaraju, DD (E), In-charge, RPQS, Bengaluru at Regional Plant Quarantine Station, Bengaluru



Dr. Abraham Verghese delivered a lecture on Good agricultural practices (GAP) in relation to mango fruit flies in Capacity Building Training on Plant Quarantine on 25 February, 2023 at RPQS, Bengaluru

Dr. Abraham Verghese Dr. S. Gnanasambandan, JD (PQ), PQD, DPPQS, Faridabad in Capacity Building Training on Plant Quarantine on 25 February, 2023 at RPQS, Bengaluru

Participation of IE team in Capacity Building Training on Plant Quarantine on 25th & 26th February, 2023 at RPQS, Bengaluru

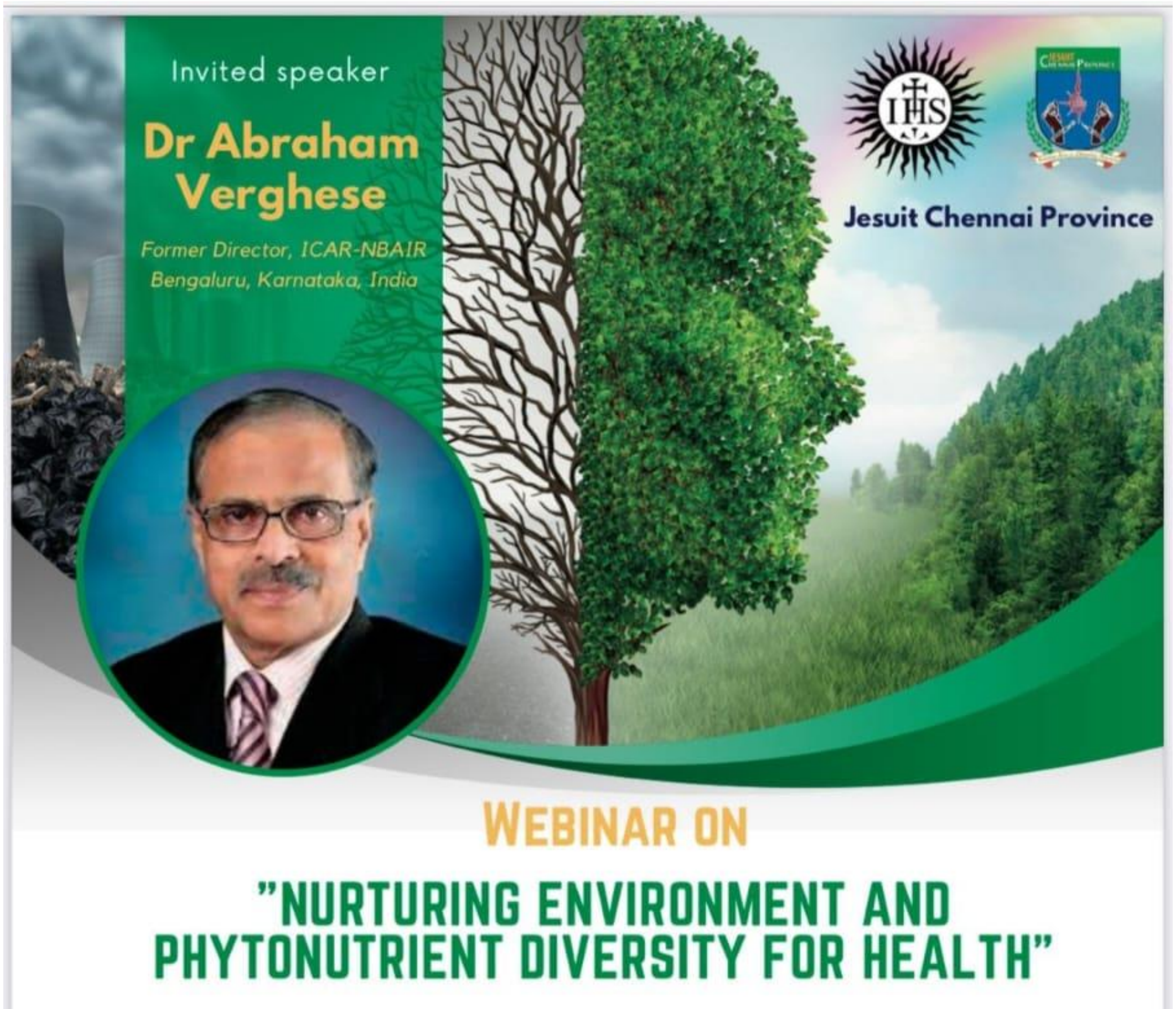
Distribution of Thavee gel to farmers for protection from borers, fungal and bacterial wilt

Field visits – Encouraging farmers to follow integrated pest and disease management

Integrated farming

Consultants in floriculture

Grape orchids- Regular consultation with quality inputs from experts



Dr. Abraham Verghese delivered a lecture on "Nurturing environment and phytonutrient diversity for health" in a webinar organized by Higher Education Commission and Ecology Commission, Chennai on 02 February, 2023

"Pros and Cons of Agri-input and farmer consultancy services"-Guest lecture by Dr. Abraham Verghese at the webinar organized by Horticulture College and Research Institute (Periyakulam) Alumni Association on 10th Jan 2023.

YouTube link for the lecture: https://youtu.be/FQML3jnn4yw