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***Apis cerana* Family: Apidae**
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Insect Environment

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EDITORIAL

Climate, Mango Hopper, World Environment Day…..

Climate change, nay climate turbulence has become the order of the day. From flood/ storm fury in Abu Dabi to West Bengal and North East states in India, the tornadoes in many cities in US, the climate (or weather?) has had havoc on lives, properties and most of all on biodiversity, which includes insects. Add to this the protracted hot (up to $50^{O}C$) dry days for nearly 150 days in much of India, made nature clocks go haywire, and all population dynamics calibrations have gone for a toss!

The mango hopper, *Idioscopus* spp. found breeding normally from December to February on the panicles considerably slowed due to much delayed mango flowering in many parts of India, that with the onset of new flush in April, May, the hoppers roared to high injury levels. May/June saw hopper related sooty mold threatening the commercial value of many varieties like Alphonso, Malika etc. We got some farmers in Hindupur, Andhra to bag their mango cv. Banganapalli with specialty "fruit covers." Thus, these fruits were sooty-free, anthracnose-free and free of fruit fly infestation.

The World Environment Day, 5^{th} June, 2024 saw the Insect Environment team, reaching out to students of a local government school. We showed them how insects helped us in many ways, especially through pollination- all new information for them. Symbolically we planted a jamun tree in their small compound and hoped the tree bear fruits for the future kids. An insect quiz got them all excited, and all were given prizes and gifts.

Every week our blogs draw global attention and they are mailed to over 6000 readers through our auto-mailing.

We heartily welcome Dr. T. V. K. Singh, a great entomologist of many summers into our Editorial Advisory Team. His joining will give fillip to Insect Environment.

Dr Abraham Verghese
Editor-in-Chief,
30 June 2024

Research articles

DOI: 10.55278/IRED2145

New data on distribution of the pleurosticti endemic scarab beetles (Coleoptera: Scarabaeidae: Melolonthinae) and a new pest from Goa, India

Aparna Surechchandra Kalawate[1*] and Tage Lampung Rinya[2]

[1]*Zoological Survey of India, Western Regional Centre, Vidhya Nagar, Sector-29, P.C.N.T. (PO), Rawet Road, Akurdi, Pune, Maharashtra 411044, India.*

[2]*Modern College of Arts, Science and Commerce, Ganeshkhind, Pune - 411016, Maharashtra, India*

Corresponding author: aparna_ent@yahoo.co.in

Abstract

The white grubs are cosmopolitan in distribution and major pest of several economically important crops. A study was conducted to assess the diversity of these phytophagous beetles in and around South Goa in 2023. The adult beetles were collected by installing light traps in the field. The study resulted in new pest record from Goa. The two new records to the state of Goa are *Holotrichia fissa* Brenske, 1894 and *Sophrops karschi* (Brenske, 1892).

Keywords: *Holotrichia*, *Sophrops*, light trap, white grubs, new record.

Introduction

There are several common names for the beetles of the subfamily Melolonthinae. Some of them are white grubs, June beetles and chafers. These are soil-dwelling insects, their larvae causes maximum damage to the roots, rootlets and underground portions of the plant. They damage the root system, which hinders the nutrient and water supply to the aerial parts, consequently drying and wilting the plant. Both adult and larvae feed on the crops. The larvae causes economic losses in maize, wheat, barley, jowar, bajra, oil seed crops like groundnut, sesame, sunflower, soybean, vegetables crops like eggplant, cucurbit, okra, potato, ginger, turmeric, mustard, French beans, and other commercial crops including sugarcane, cotton and tobacco (Kumar *et al*., 2017). In May and June, the adult beetle emerges from the ground and starts feeding on the leaves of neem, ber and acacia (Yadava *et al*., 1995; Sreedevi *et al*., 2017) during the night. In Thrissur district of Kerala these phytophagous scarab beetles (dominant pest was *Holotrichia serrata* (Fabricius, 1781) caused around 10-40% defoliation in mango (Sreedevi *et al*., 2019). Feeding on flowers by *H. serrata* adults resulted in dropping of the flowers and tender pods causing up to 10-20% damage in a single night (Sreedevi *et al*., 2019). White grub damage in an endemic pocket in groundnut ranges from 20-100 per cent (Baloda *et al*., 2021). As per the reports of Yadava and Sharma (1995), one grub/m^2 may cause 80-100 per cent plant mortality in groundnut.

These beetles are difficult to delineate merely based on morphological characters, hence dissection of genitalia is essential. Since, the beginning of the 20th century, taxonomists have relied on genitalia studies most commonly on male genitalia for species identification (Zunino, 2014). It is a known fact that they are species-specific. As these beetles are cryptic, it is mandatory to dissect the male genitalia and study it before concluding the species' identity. Hence, in this study also, the male genitalia have been dissected and studied.

As a part of the survey and exploration in the Bhagwan Mahavir Wildlife Sanctuary and Mollem National Park, these beetles were collected (15.33711N and 74.28468E). The collected beetles were identified and deposited at Zoological Survey of India, Western Regional Centre, Pune.

Materials and methods

The adult beetles were collected by installing light traps using 160-watt mercury bulb as a light source in the field. The collected specimens were then euthanized by ethyl acetate vapours and temporarily dry preserved in the insect envelopes/packets. The specimens were then brought to the laboratory. They were relaxed, pinned, and stored in the fumigated entomological boxes. To identify the beetles, they were examined under Leica EZ4E® with an in-built photographic facility. The male genitalia were dissected by carefully removing it from the abdomen. After removal, it was further boiled in 10% KOH for 5–10 minutes to remove the adhered tissues and soft muscles and then rinsed in distilled water and photographed under the microscope. The adults were photographed using an OLYMPUS Tough TG-6® 12MP digital camera. The specimens were identified by referring to the characters given in identification keys (Frey, 1971). The terminology of the male genitalia is as per D'Hotman and Scholtz (1990) and Zorn (2006). The identified specimens have been deposited at National Zoological Collection, Zoological Survey of India, Western Regional Centre, Pune, Maharashtra, India (ZSI–WRC). The images of the adult beetles and their genitalia are given in Fig.1 & 2.

Results and Discussion

Taxonomy

Order Coleoptera Linnaeus, 1758

Suborder Polyphaga Emery, 1886

Family Scarabaeidae Latreille, 1802

Subfamily Melolonthinae Leach, 1819

Tribe Melolonthini Leach, 1819

Genus *Holotrichia* Hope, 1837

***Holorichia fissa* Brenske, 1894**

(**Fig. 1 A–C**)

Holorichia fissa Brenske, *Mem. Soc. Ent*. Belg. II, 1894, p. 71.

Material examined. 04 ex., Aranyak Nature Camp, Collem, Sanguem taluk, South Goa District, Bhagwan Mahaveer Wildlife Sanctuary and Mollem National Park, 31. v. 2023, A.S. Kalawate (ZSI-WRC-ENT-1/4668); 03 ex., Dhavali, Ponda taluka, North Goa District, 16.viii.2022, K.P. Dinesh (ZSI-WRC-ENT-1/4690).

Diagnostic characters (Fig. 1 A). Length 19mm, width 8mm. Adult beetle Body dark brown. Antennae brown, 10 segmented, with a three segmented club. Clypeus broader than frons, broadly bent upwards, front margin shallowly emarginate, deeply and thickly punctate. Pronotum weakly serrate, bristles in between the serrations; anterior angle strongly acute; hind angle sharply obtuse. Scutellum shallowly punctate, less in the middle. Elytra with four costae, finely and deeply punctate; costal margin with bristles, small serrations from the second thoracic segment till half of the second visible abdominal segment. Foretibiae tridentate, blunt teeth; punctations with setae; single long tibial spur at inner margin of fore tibia, middle and hind tibia with paired spurs, hind tibial spur pointed in male and blunt in female.

Male genitalia (Fig. 1 B–C). Spiculum gastrale Y-shaped with arms longer than stem; slightly narrow, bent at the tip. Phallobase wide at the centre and anterior, relatively narrow at the base, with a pair of symmetrical parameres. Parameres are shorter and darker than the phallobase, each paramere with a chitinized process broader throughout.

Distribution. INDIA: Andhra Pradesh (Kumar *et al*., 2017), Gujarat (Kapadia *et al.*, 2006), Goa (present study), Haryana, Karnataka, Kerala (Verma, 1975; Veeresh, 1975; Abraham and Rajendran, 1978), Madhya Pradesh (Gupta *et al*., 2014), Maharashtra (Shrilakshmi and Patil, 2016), Rajasthan (Jangir *et al.*, 2022), Uttar Pradesh, Chhattisgarh, (ICAR-NBAIR, 2021)).

Host plant. Groundnut (Shrilakshmi *et al*., 2016), Babool (Joshi *et al.*, 1969; Sharma & Shinde, 1970; Theurkar *et al.*, 2012) soybean, maize and paddy (Tippannavar and Patil, 2013) ber (Shrilakshmi *et al*., 2016), *Terminalia arjuna*, *Terminalia tomentosa*, jamun, *Grewia* sp. (Bhawane *et.al*., 2012).

Remark: Endemic to India (Kalawate, 2018).

A B C

Fig. 1. *Holotrichia fissa*: A, Adult, B, Aedeagus, C, Spiculum gastrale

Genus *Sophrops* Farmaire, 1887

Sophrops karschi (Brenske, 1892)

(Fig. 2 A–C).

Holotrichia karschi Brenske, 1892: *Berliner entomologische Zeitschrift*, 37(2): 179.

Material examined. 10 ex., Aranyak Nature Camp, Collem, Sanguem Taluk, South Goa District, Bhagwan Mahaveer Wildlife Sanctuary and Mollem National Park, 27.v.2003, A. S. Kalawate & Pty (ZSI-WRC-ENT-1/4691).

Diagnostic characters (Fig. 1 A). Length 14 mm, width 7 mm. Adult beetle body dark brown. The head and pronotum are darker than the elytra, legs and antennae, light brown. Antennae ten segmented, with a three-segmented club. Labrum deeply notched. Clypeus deeply emarginate, with two lateral lobes formed by it. Pronotal lateral margins are extensively serrated, angulate, thick, and profoundly, densely, and closely punctate. Scutellum deeply and densely punctate, centre smooth. Elytra with costae; serrated costal border. Legs with fore tibiae tridentate, with blunt teeth. Front tarsal segments with short setae; teethed claws; puncture with setae emerging from it. Meso tibia with toothed claws, elongated, thin spurs, and transverse spines. Hind tibia with transverse spines.

Male genitalia (Fig. 2 B–C). Phallobase elongated. Parameres short, sclerotized, linked basally before splitting apart, laterally with a wavy edge that is curved and pointed at the tip, and ventrally joined by a sclerotized area. The stem of spiculum gastrale longer than arms. The arms are arranged widely apart and firmly curved upward.

Distribution. INDIA: Goa (present study), Karnataka, Kerala, Maharashtra, Pondicherry, Tamil Nadu (Bunalski, 2022).

Host plant: Unknown.

Remark: Endemic to India.

Fig. 2. *Sophrops karschi*: A, Adult, B, Aedeagus, C, Spiculum gastrale.

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Bioefficacy of *Steinernema abbasi* and *Heterorhabditis indica* against white grubs (*Holotrichia consanguinea*) in groundnut of Rajasthan, India

Ankita Singh Sajwan

Entomology Branch, Forest Protection Division, Forest Research Institute (ICFRE), New Forest, Dehradun 248006, Uttarakhand, India

Corresponding author: sajwan.ankitasingh@gmail.com

Abstract

White grub (*Holotrichia consanguinea)* is a significant pest that causes damage to all the kharif crops, especially groundnut (*Arachis hypogaea* L.) in Rajasthan's semi-arid region. The bioefficacy of entomopathogenic nematodes, *Steinernema abbasi* (Steinernematidae) and *Heterorhabditis indica* (Heterorhabditidae) was carried out in both *invitro* and *invivo* conditions at Rajasthan Agricultural Research Institute (RARI) Durgapura, Jaipur. Bioefficacy of *H. indica* against white grub revealed that the grub mortality reached up to 64% at a higher concentration of 250 IJs/ml and the plant mortality in field conditions reduced up to 28% at 250 IJs/ml. *Heterorhabditis indica* outperformed *Steinernema abbasi* in terms of white grub infectivity.

Keywords: Groundnut, White grub, *Holotrichia consanguinea*, Entomopathogenic nematodes, *Steinernema abbasi, Heterorhabditis indica*

Introduction

In Rajasthan, white grub (*Holotrichia consanguinea)* is the key pest causing losses to all the kharif crops. It causes damage to almost all vegetables, pulses, oilseeds, and cereals grown in the rainy season (Yadava and Sharma, 1995). Groundnut or peanut (*Arachis hypogeal* L.) is one of the major kharif crops in the semi-arid region of Rajasthan. Its cultivation in Rajasthan has been threatened and as per very conservative estimates, over 1,21,500 hectares of the crop suffer from white grub damage annually (Anon, 1993). Crop losses ranging between 10 to 100 percent, depending upon the pest population level have been reported (Yadav, 1981).

Holotrichia spp. are widely distributed in the Indian Subcontinent. In India, about 300 species of white grubs have been recorded (Shivayogeshwara and Veeresh, 1983). The adult beetles are also polyphagous like grubs and cause considerable damage to economically beneficial trees like neem (*Azadirachta indica),* khejari (*Prosopis cineraria),* ber *(Zizyphus jujube Mill.),* sainjana (*Moringa oleifera* Lam.) in commercial orchards and nurseries. The differential habitat of grub and adult scarabaeids makes them difficult to control. Moreover, being subterranean, the grubs go deep into the soil and are difficult to control by soil application of insecticides. Larvae feed on the roots and fresh legumes of peanuts and other tap root crops, making them more susceptible to infection by soil pathogens and causing decomposition of the injured legumes, finally leading to plant death (Devanda *et al.*, 2021).

Chemical pesticides have been the primary means of managing grubs for many years, but the control of the grubs is often ineffective. There are a lot of limitations to using higher doses of insecticides due to the fear of the development of resistance and threat to human life by entering the food chain (WHO, 2009). Therefore, Entomopathogenic Nematodes (EPNs), especially those that are obligate parasites of insects, possess the desired attributes of a bio-control agent against white grubs and can be important in checking the growth of pest populations in agricultural systems (Neelakanta *et al.*,2023).

Insect pests have been found susceptible to the EPNs of the family Heterorhabditidae and Steinernematidae species in India, resulting in their prospective role as biological agents (Kulkarni *et al.*, 2008, Paschapur *et al.*, 2017). The infective juveniles (IJs) of these families are free-living, non-feeding, and can search out their hosts. They have the potential for long-term establishment in the soil through the recycling of infected insect larvae. EPNs have been studied extensively for the control of white grubs (Sharmila *et al.*, 2023). This study depicts the effectiveness of different EPNs on white grub, under laboratory and field conditions of the semi-arid climate of Jaipur, Rajasthan.

Materials and Methods

Collection and rearing of white grubs

The grubs were collected from infested groundnut fields of Rajasthan Agricultural Research Institute (RARI) Durgapura, Jaipur (26°50'33.7"N 75°47'27.4"E; 427.63m). Immediately after the collection of grubs, they were maintained in sterile plastic containers at room temperature with some infested groundnuts as food. These plastic containers with grubs were maintained in lab conditions for further *in vitro* and *in vivo* study of EPNs as a biocontrol agent.

In vitro study

Two nematodes *Steinernema abbasi* and *Heterorhabditis indica* strains were procured from RARI, Jaipur as biocontrol agents against white grubs. These biocontrol agents were mixed in the sterile soil and were added to the containers having grubs. The nematode concentrations of 150 and 250 IJs/ml were used in the bioassay. To determine grub mortality, the dead larvae were counted and transferred to a new petriplate containing a moist filter paper. Further microscopic examination was done to observe concerned entomopathogenic infection in dead grubs. Data was recorded after one-week intervals to determine percent mortality. Corrected percent mortality was calculated as per Abbott's (1955) formula.

$$\%corrected\ mortality = \frac{\%\ mortality\ in\ treatment - \%\ mortality\ in\ control}{100 - \%\ mortality\ in\ control} \times 100$$

In vivo study

Similar biocontrol agents such as *Steinernema abbasi* and *Heterorhabditis indica* were used in the field in *in vivo* conditions by following standing crop and seed treatment methods. The experiment was done in the field conditions in white grub endemic areas of peanut crop, at RARI Durgapura, Jaipur. The experiment was arranged in Randomized Block Design (RBD) with 5 replicates per treatment. The plots were $20m^2$ with a 30 cm distance between rows and 10 cm within plants. Five treatments, *viz*. (T1) control (without any strain); (T2)150 IJ/ml of *H. indica*; (T3) 250 J/ml f *H. indica*; (T4) 150 IJ/ml of *S. abbasi*; (T5) 250 IJ/ml of *S. abbasi*.

Results

Bioefficacy of EPNs against white grubs in *in vitro* conditions

The results on mortality of white grub in *invitro* conditions after the application of *H. indica* and *S. abbasi* revealed that the higher dose (250 IJs/ml) caused 64% and 56% grub mortality followed by 150 IJs/ml doses of *H. indica* and *S. abbasi* caused 36% and 28% grub mortality, respectively. Whereas, no mortality was recorded in the control condition.

Bioefficacy of EPNs against white grubs in *in vivo* conditions

The two concentrations (150 and 250 IJs ml^{-1}) of EPNs were used in field conditions where the recorded data revealed that the application of T4(150 IJs/ml) caused 54.66% of plant mortality followed by T5, T2, and T3, which caused 42.66%, 41.30%, and 28.00% plant mortality (Fig.1).T3 was found to be the most effective bio-control agent in comparison to the others.

Conclusions

The two different EPNs *viz*., *H. indica* and *S. abbasi* were tested against white grub, in laboratory bioassay studies and field experiments. Among these two EPNs, *H. indica* was found to be the most effective, recording a maximum of 64% grub mortality at 250 IJs/ml which showed a significant reduction in the grub population. In field conditions, treatment with *H. indica* was found to be most effective recording 28% plant mortality at 250 IJs/ml. The lowest plant mortality showed the most effectiveness of the treatment with *H. indica*. *Heterorhabditis indica* showed a promising effect than *Steinernema abbasi*on in the infectivity of white grubs.

Plate 1 A-C: A. Groundnut field at RARI, Durgapura, Jaipur, B. Collection of white grubs from groundnut filed of RARI, Durgapura, and C. Rearing of white grubs in sterile plastic containers in laboratory conditions.

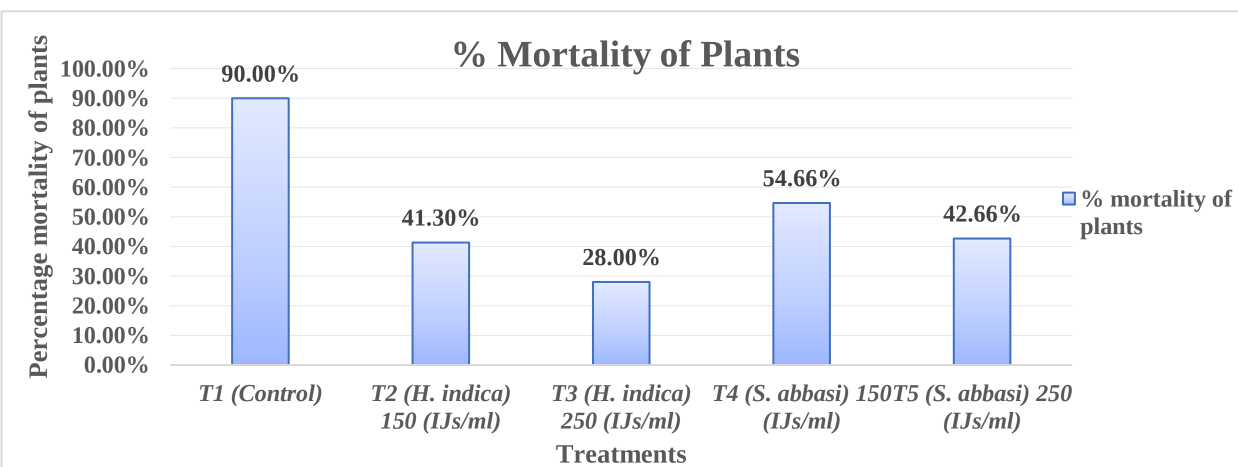

Fig. 1: Graphical representation of plant mortality after application of EPNs in field conditions

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Exploring butterfly diversity: A comparative review of Lalbagh botanical garden and Cubbon Park of Bangalore

Ashalatha B*[1] and Devi Thangam S[2]

[1]*Department of Zoology, Vijaya College, IV block Jayanagar, Bangalore City University, Bangalore 560011, Karnataka, India.*

[2]*Department of Zoology, MES College of Arts, Commerce and Science, Malleswaram, Bangalore 560003, Karnataka, India.*

Corresponding author: ashalathabapuram94@gmail.com

Abstract

Butterflies play a pivotal role as an indicator of environmental health and ecosystem vitality. Their presence often signifies diverse invertebrate populations, which constitute a significant portion of global biodiversity. Butterflies serve as ecological indicators in urban environments, are sensitive to environmental changes, and play a crucial role as pollinators. Butterfly diversity studies are vital for understanding the ecological health of urban green spaces. Lalbagh Botanical Garden and Cubbon Park, two renowned botanical gardens in Bangalore, India, are often compared for their biodiversity. This study aims to compare the diversity of butterflies in these two parks based on the available checklist of species.

Key words: Biodiversity, butterfly, ecosystem, pollination.

Introduction

Butterflies, diurnal insects known for their slender bodies, knobbed antennae and vibrant wings, play a crucial role in ecosystem stability. Among the estimated 1.4 million species in the world, insects dominate with a staggering 53% share. Globally, there are over 17,000 recognized butterfly species. The Indian subcontinent with a diverse terrain, climate and vegetation hosts about 1,504 species of butterflies (Kunte, 2000) (Kehimkar, 2008) (Harisha and Hosetti, 2016).

They play a pivotal role in determining the stability of an ecosystem since their numbers can fluctuate drastically with even slight changes in temperature, weather conditions and environmental pollution (Kakkar, 2018). Their presence not only adds to the biodiversity of an area, but also influences the dynamics of plant-pollinator interactions, ultimately affecting the overall health and balance of ecosystems (Remadevi., 2016). Changes in the population sizes and geographical spread of butterflies have been correlated with several factors, notably habitat loss and fragmentation, shifts in land use patterns and the impacts of climate change (Harish, 2016). Therefore, understanding and conserving butterfly populations are essential for maintaining ecological stability and biodiversity conservation efforts (Mobeen Gazanfar., 2016).

There has been a noticeable rise in recent scholarly works exploring the diversity, habitat utilization and conservation of butterflies (Yates, 1993) (Kunte-2000) (Kehimkar, 2008). This surge in scholarly works, such as those by Yates and Kehimkar has led to a wealth of information becoming available on butterflies in South India. This paper presents a comparative study by investigating the available butterfly diversity between Lalbagh Botanical Garden and Cubbon Park, two distinct urban green spaces, characterized by unique ecological features, and different microhabitats in Bangalore. Through careful reviews and thorough investigation of habitat parameters, this paper aims to expose the distinctions in butterfly communities found in these diverse environments.

This review paper offers a comprehensive synthesis of scholarly research focused on the diversity and distribution of butterflies within the major green spaces of Bangalore city over a decade-long period. Drawing from a diverse array of publications and sources spanning different time periods, the study conducts a comparative analysis of butterfly data. Specifically, the analysis incorporates findings from surveys conducted by Yates, 1993, Karthikeyan, 1999, particularly Kunte and Ravikanthachari, 2020, Rema Devi, 2016 and subsequent studies conducted by various researchers in 2013–14 (Satya Chandra Saga, and Antoney, 2015) (Kunte and Ravikanthachari, 2020) (Remadevi and Vinay Kumar, 2022). The synthesis examines various parameters, such as species richness and abundance to assess butterfly populations between Lalbagh Botanical Garden and Cubbon Park in Bangalore (Remadevi, and Vinay Kumar, 2022) (Remadevi, 2016). By integrating data from various sources and conducting comparative analyses, the paper provides significant insights for conservation initiatives and urban planning strategies in Bangalore city (Kakkar, 2018).

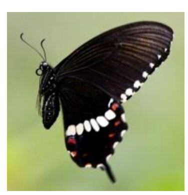
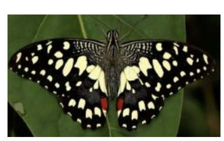
Lalbagh botanical garden, situated in Bangalore (12.950743°N and 77.584777°E), India, is a historic and sprawling garden spanning over 240 acres. The garden supports a wide range of insects including butterflies (Satya Chandra Saga, and Antoney, 2015) (Subhashini, Antony, 2019) (http://www. horticulture.kar.nic.in/lalbagh.htm.)

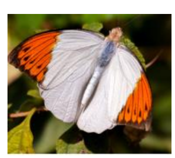
Cubbon Park, also known as Sri Chamarajendra Park (12.9779° N, 77.5952° E), is a landmark 300-acre park located in the heart of Bengaluru's central administrative area. It is a green heaven hosting thicket of trees, massive bamboos, and a diverse array of fauna, including various species of butterflies (https://w.wiki/9yje).

Checklist

A comparative checklist has been prepared by collecting information from published articles (Remadevi, 2016) (Ruchita and Paari, 2022) (Satya Chandra Saga, and Antoney, 2015) and (Remadevi and Vinay Kumar, 2022) (Subhashini and Antony, 2019).

Sl. No.	Common name	Scientific name	Image*	Occurrence	
				Lalbagh	Cubbon park
Family - Hesperiidae					
1	Common Banded Awl	*Hasora chromus*		✓	×
2	Rice Swift	*Borbo cinnara*		✓	×
3	Tamil Grass Dart	*Taractrocera ceramas*		✓	×
4	Dakhan Small Branded Swift	*Pelopidas mathias mathias*		✓	×
5	Giant Redeye	*Gangara thyrsis*		✓	×

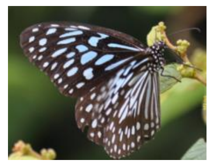
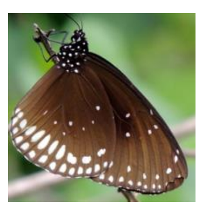
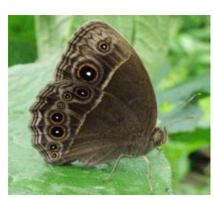
6	Indian Grizzled Skipper	*Spialia galba*		✓	×
7	Grass Demon	*Udaspesfolus*		✓	×
8	Chestnut Bob	*Iambrix salsala*		✓	✓
9	Bush Hopper	*Ampittia dioscorides*		×	✓
Family - Papilionidae					
1	Common Jay	*Graphium doson*		✓	✓
2	Dakhan Tailed Jay	*Graphium agamemnon ssp. menides*		✓	✓
3	Common Mormon Swallowtail Butterfly	*Papilio polytes*		✓	✓
4	Lime Butterfly	*Papilio demoleus*		✓	✓

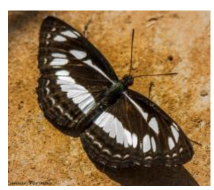
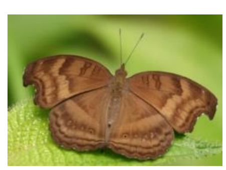
5	Crimson Rose	*Pachliopta hector*		✓	×
Family - Pieridae					
1	Three Spot Grass Yellow	*Eurema blanda*		✓	✓
2	Common Grass Yellow	*Eurema hecabe*		✓	✓
3	Red-line Small Grass Yellow	*Eurema brigitta*		✓	×
4	Common Emigrant	*Catopsilia pomona*		✓	✓
5	Mottled Emigrant	*Catopsilia pyranthe*		✓	✓
6	Yellow Orange Tip	*Ixias pyrene*		✓	✓
7	Great Orange Tip	*Hebomoia glaucippe*		✓	✓

8	Indian Wanderer	*Pareronia hippia*		✓	✓
9	Pioneer White	*Belenois aurota*		✓	✓
10	Common Jezebel	*Delias eucharis*		✓	✓
11	Psyche	*Leptosia nina*		✓	✓
12	Common Gull	*Cepora nerissa*		✓	✓
13	White orange Tip	*Ixias marianne*		×	✓
Family - Lycaenidae					
1	Apefly	*Spalgis epius*		✓	×
2	Slate Flash	*Rapala manea*		✓	×

3	Zebra Blue	*Leptotes plinius*		✓	✓
4	Forget me Not	*Catochrysops strabo*		✓	✓
5	Common Lineblue	*Prosotas nora*		✓	✓
6	Tailless Lineblue	*Prosotas dubiosa*		✓	✓
7	Dingy Lineblue	*Petrelaea dana*		✓	×
8	Common Cerulean	*Jamides celeno*		✓	✓
9	Pea Blue	*Lampides boeticus*		✓	✓
10	Lime Blue	*Chilades lajus*		✓	✓

11	Gram Blue	*Euchrysops cnejus*		✓	✓
12	Common Hedge Blue	*Acytolepis puspa*		✓	✓
13	Pale Grass Blue	*Pseudozizeeria maha*		✓	×
14	Lesser Grass Blue	*Zizina otis*		✓	✓
15	Dark Cerulean	*Jamides bochus*		✓	✓
16	Tiny Grass Blue	*Zizula hylax*		✓	✓
17	Dark Grass Blue	*Zizeeria karsandra*		×	✓
18	Orange-Spotted Grass Jewel	*Freyeria trochylus*		×	✓

19	Plains Cupid	*Luthrodes pandava*		×	✓
Family - Nymphalidae					
1	Blue Tiger	*Tirumala limniace*		✓	✓
2	Dark Blue Tiger	*Tirumala septentrionis*		✓	✓
3	Striped Tiger	*Danaus genutia*		✓	✓
4	Plain Tiger	*Danaus chrysippus*		✓	✓
5	Common Crow	*Euploea core*		✓	✓
6	Double-branded Black Crow	*Euploea sylvester*		✓	✓
7	Common BushBrown	*Bicyclus safitza*		✓	×

8	Common Four-ring	*Ypthima huebneri*		✓	✓
9	Tailed Palmfly	*Elymnias caudata*		✓	✓
10	Tawny Coster	*Acraea terpsicore*		✓	×
11	Common Leopard	*Phalanta phalantha*		✓	✓
12	Common Sailer	*Neptis hylas*		✓	✓
13	Chestnut-Streaked Sailer	*Neptis jumbah*		✓	×
14	Common Castor	*Ariadne merione*		✓	✓
15	Common Baron	*Euthalia aconthea*		✓	✓
16	Chocolate Pansy	*Junonia iphita*		✓	✓

17	Lemon Pansy	*Junonia lemonias*		✓	✓
18	Peacock Pansy	*Junonia almana*		✓	×
19	Yellow Pansy	*Junonia hierta*		✓	×
20	Great Eggfly	*Hypolimnas bolina*		✓	✓
21	Danaid Eggfly	*Hypolimnas misippus*		✓	✓
22	Common Three Ring	*Ypthima pandocus*		×	✓
23	Common Evening Brown	*Melanitis leda*		×	

*Courtesy - iNaturalist.org

*Note: In the table '✓' indicates presence & '×' indicates absence.

Source:(Ruchita and Paari, 2022), (Kunte and Ravikanthachari, 2020) (Remadevi and Vinay Kumar, 2022)

Discussion

Examination of the data from review papers suggested that the Lalbagh Botanical Garden and Cubbon Park have a rich diversity of butterflies. A total of 62 species of butterflies were recorded in Lalbagh and 49 species were recorded in Cubbon Park, belonging to five families: Hesperiidae, Papilionoidae, Pieridae, Nymphalidae and Lycaenidae (Table 1).

In Lalbagh, Nymphalidae recorded the highest number of butterflies (21), followed by Lycanidae (16), Pieridae (12), Hesperiidae (8) and the least was Papilionidae (5) (Table 2).

In Cubbon Park, Nymphalidae recorded the highest number of butterflies (18), followed by Pieridae (11), Lycanidae (14), Papilionidae (4) and the least was Hesperiidae (2) (Table 2).

Table 2. Family-wise depiction of butterflies in two gardens

Sl. No.	Family	No. of butterflies found in Lalbagh	No. of butterflies found in Cubbon Park
1	Nymphalidae	21	18
2	Lycanidae	16	14
3	Pieridae	12	11
4	Hesperiidae	8	2
5	Papillionidae	5	4

Source: Ruchita and Paari, 2022

Table 2 depicts that although area-wise, Lalbagh Garden is lesser than Cubbon Park, it has more species of butterflies belonging to Nymphalidae, Papilionidae, Lycanidae, Pieridae and Hesperiidae families. This difference in the number of species could be attributed to various factors *viz*., the season of sampling may not be the same, the non-availability of host plants during sampling for them to breed and feed, or the mismatch of breeding season and sampling time. Finally, human interventions like maintaining the gardens with the usage of pesticides could have led to a reduction in the species richness.

Moreover, Lalbagh Botanical Garden, a heritage garden is known for its extensive collection of diverse plant species. A greater variety of plants means a wider range of habitats and food sources for butterflies, attracting more species to the area. In comparison with Cubbon Park, Lalbagh likely presents a more diverse habitat structure, offering various microclimates, soil compositions and densities of vegetation. These diverse habitats can sustain a wide spectrum of butterfly species, each adapted to distinct ecological niches.

Some of the species of Hesperiidae like common Banded Awl, Rice Swift, Oriental Grass Dart, Dakhan Small, Giant Redeye, Indian Grizzled Skipper and Grass Demon were found only in Lalbagh and not in Cubbon Park. Lalbagh's diverse habitat structures and microclimates might provide conditions for skipper butterflies (Hesperiidae). Different skipper species have varying habitat preferences and the presence of suitable microhabitats within Lalbagh could support a greater diversity of skipper butterflies. Lalbagh Botanical Garden may have implemented specific conservation strategies targeted for supporting butterfly populations. These strategies could involve the cultivation of flowers that attract butterflies, establishing habitats conducive to butterfly survival and reducing pesticide usage to safeguard their delicate ecosystem.

Certain species, such as the Bush Hopper of the Hesperiidae family and the Common Three Ring of the Nymphalidae family, are exclusive to Cubbon Park and are absent in Lalbagh. This discrepancy in distribution might be attributed to the consistent upkeep of Lalbagh, which potentially alters their habitat, or it could arise from competitive pressures within Lalbagh's ecosystem. To have a clear understanding of the butterflies, which are specific to Lalbagh and Cubbon Park, requires more systematic studies related to the population dynamics and diversity. These studies are instrumental in conserving these important insects, as they serve as valuable ecological indicators and contribute significantly as pollinators within their habitats.

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First record of Hadda beetle, *Henosepilachna* (*Epilachna*) *vigintioctopunctata* Fab. Coccinellidae: Coleoptera on ashwagandha, *Withania somnifera* L. (Solanaceae) from Tamil Nadu, India

P. Gopinath[1], S. Kavimugilan[2*], P. Manivel[3] and A. Kalyanasundaram[4]

[1]*Department of Plantation, Spices, Medicinal and Aromatic Crops, Horticultural college and Research Institute, Coimbatore, TNAU, Tamil Nadu – 641 003, India*

[2,4]*Department of Entomology, AnbilDharmalingam Agricultural college and Research Institute, Navalurkuttapattu, Tiruchirapalli, TNAU, Tamil Nadu – 620 027, India*

[3]*Department of Plant Breeding and Genetics, ICAR – Central Tobacco Research Institute – Research Station, Vedasandur, Dindigal, Tamil Nadu – 624 710, India*

Corresponding author: kavimugilan2001@gmail.com

The Solanaceae family encompasses both valuable vegetables and medicinal plants, making it crucial to assess the economic impact of hadda beetles on them. Additionally, certain wild plants within the Solanaceae family have been observed as natural reservoirs for hadda beetles year-round (Ganga and Chetty, 1982). Additionally, the pest has been documented on plants belonging to the Cucurbitaceae family (Mandal, 1971, Azam *et al.*, 1974; Verghese, 2012). The prevalence of the hadda beetle fluctuates depending on the specific location and the environmental conditions prevailing each year (Konar and Mohasin, 2002).

For the first time in Tamil Nadu region, Infestation of hadda beetle, *H. vigintioctopunctata* on the leaves of Ashwagandha, *W. somnifera* is reported at ICAR – Central Tobacco Research Institute – Research Station (Latitude 10^0 53ʾN and Longitude 77^0 94ʾE), Vedasandur block, Dindigul district of Tamil Nadu. The Ashwagandha leaves are scrapped (Fig. 5, 6) by hadda beetles.

- **(i) Host plants:** Hadda/Epilachna beetle (*H. vigintioctopunctata*) has been recorded as a serious pest of brinjal, potato, tomato cucumbers, melon, pumpkin, gourds and tobacco etc.
- **(ii) Distribution:** South East Asia, South Canada, USA, Mexico and Africa.

The grubs of the hadda/spotted beetle exhibit a yellowish-red hue and are adorned with six longitudinal rows of spines (Fig.2). They lay their eggs, shaped like cigars (Fig.1), in clusters of 6-7, numbering between 120 and 460 eggs per female, typically beneath leaves. Their egg, larval, and pupal stages span 2-4 days, 10-35 days, and 5-6 days, respectively. These larvae are elongated and elliptical, featuring moderately long legs, a well-developed head with mandibles, and bodies covered in long, branched processes (Scoli) with spines. Pupation takes place either on stems or leaves. In the case of *H. vigintioctopunctata*, each elytron bears 14 spots with deep red pigmentation. The adults measure 5-8 mm in length, displaying a convex dorsal surface and a flattened ventral side (Fig. 4).

The biting and chewing mouthparts of Hadda beetles, both in their adult and larval stages, are responsible for scraping away the chlorophyll present in leaves. A primary visible consequence of their presence on plants is the skeletonization of leaves (Fig. 5, 6). Their damaging population tends to be most active from April to mid-October, with a secondary peak occurring around the second week of September.

Fig. 1. Egg of Hadda beetle

Fig. 2. Grub of Hadda beetle

Fig. 3. Pupa of Hadda beetle

Fig. 4. Adult of Hadda beetle

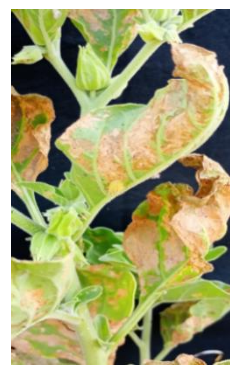

Fig. 5, 6 Ashwagandha leaves Scrapped by Hadda beetle

Fig. 7 Ashwagandha Plant

Ashwagandha (Fig.7) (*W. somnifera*), commonly known as Indian ginseng is an important medicinal plant used in Ayurvedic formulations (Sangwan *et al*., 2004). Due to its robust nature and ability to withstand drought conditions, the plant is cultivated as a rainfed crop across various regions of the country. This widespread cultivation is primarily driven by its high value and potential for export (Chandranath and Katti, 2010).

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First report of *Lipaphis pseudobrassicae* (Aphididae: Hemiptera) on broccoli (*Brassica oleracea* var. *italica*) from Gujarat, India

N. P. Pathan*[1], S. M. Goswami[2], B. K. Prajapti[1] and Mukesh Kumar[3]

[1]*Department of Plant Protection, College of Horticulture, SDAU, Jagudan- 384460, Gujarat, India*

[2]*Department of Entomology, C. P. College of Agriculture, SDAU, Sardarkrushinagar- 385506, Gujarat, India*

[3]*Department of Natural Resource Management, College of Horticulture, SDAU, Jagudan- 384460, Gujarat, India*

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

Broccoli (*Brassica oleracea* var. italica), a member of the Brassicaceae family, is increasingly gaining recognition for its high nutritional value and numerous health benefits. Rich in vitamins, minerals, and antioxidants, broccoli is considered a superfood, contributing to its rising popularity among health-conscious consumers (Baidoo and Mochia, 2016). In India, the cultivation of broccoli is relatively recent compared to traditional vegetables, yet it has seen substantial growth in production and productivity over the past decade. This growth can be attributed to a combination of favorable climatic conditions, advances in agricultural practices and increasing awareness among farmers about the economic benefits of broccoli cultivation. The head of the broccoli plant is a cluster of flowering buds that form a green head. The broccoli plant has many benefits, as it strengthens the immune system; because it contains selenium and zinc, it enhances liver functions, prevents cancer, and facilitates the work of the digestive system. Broccoli is a cool-season crop that can be grown year-round under controlled conditions such as greenhouses. In horticultural crops, sucking insect pests like aphids (Rudani and Deb, 2024), jassids, thrips, and whiteflies are prevalent. Nowadays, the metallic shield bug is also becoming an emerging threat to phalsa (Pathan *et al*., 2023). Broccoli suffers extensively from insect pests and it is attacked by more than 25 insect species. Pests like cabbage butterfly, diamond back moth, mite and aphids cause havoc in North Eastern region of India and also in rest of the country (Boopathi and Pathak, 2012).

Lipaphis pseudobrassicae, commonly known as the turnip aphid, is a significant pest affecting a wide range of cruciferous crops. Belonging to the Aphididae family, this aphid species is known for its detrimental impact on economically important crops such as cabbage, cauliflower, broccoli, mustard, and radish. It lives on the undersides of leaves as well as on inflorescences, young shoots and growing points. In 2006, *Lipaphis pseudobrassicae* (Davis) was recorded in kale area of Brazil (Resende *et al*., 2006). It is originating from the Palearctic region.

The present study was conducted during 2023-24 at College of Horticulture, S. D. Agricultural University, Jagudan, Gujarat, India (Latitude-23°51'34" N, Longitude-72°39'98" E, altitude- 95 m above MSL). The leaves and inflorescence were covered by aphids. Different stages of aphids were collected from the infested leaves and inflorescences of broccoli during the field experiment titled "Effect of fertilizer levels on growth and yield of broccoli". As the aphid observed was different from known aphid species, they were brought to the laboratory of the Department of Entomology, C. P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar for detailed observation. The morphological characters of specimens were examined under the microscope. Several specimens were transferred into glass vials containing 70% ethanol to preserve samples. The collected specimens were sent to the National Bureau of Agricultural Insect Resources, Bengaluru for the identification and confirmation of the species.

The species was confirmed as *Lipaphis pseudobrassicae* by Dr. Sunil Joshi. During the observation, the infestation was noticed on broccoli in the last week of December, 2023 and remained up to 4thweek of February 2024. Broccoli aphids mainly cause damage to the head and leaves. The highest incidence was observed during 3rd week of January 2024.

Morphological characters of *L. pseudobrassicae*

Adult apterae of *Lipaphis pseudobrassicae* are small to medium-sized yellowish green, grey-green or olive-green aphids, with a slight white wax bloom. In humid conditions they may be more densely coated with wax. There are two longitudinal rows of dark bands on the thorax and abdomen which unite into a single band near the tip of the abdomen. *Lipaphis pseudobrassicae* have a dusky green abdomen with conspicuous dark marginal sclerites and dusky wing veins. The turnip aphid was earlier confused with the cabbage aphid, *Brevicoryne brassicae* L. due to its close resemblance, and became well established before it was recognized as a distinct species (Essig, 1948). Moreover, its true identity was not discovered until 1914 when it was described as *Aphis pseudobrassicae* by Davis (1914) (Essig, 1948). The turnip aphid can seriously damage crops by consuming photoassimilates and transmitting at least 16 plant viruses, making it difficult to manage. (Tran *et al*., 2016).

Nature of damage of *L. Pseudobrassicae*

The aphid attacks generally during the 2nd and 3rd week of December and continues till March. Both the nymph and adult suck sap from the plants causing a loss of vigor. Sooty mold develops on excreted honeydew reducing photosynthesis. Honeydew attracts other insects like ants and serves as a medium for fungal growth. Their feeding can cause distorted growth, yellowing of leaves and in severe cases, leads to the death of plants. Aphids feeding on broccoli heads can cause significant damage by sucking the sap from the tender tissues. This can result in a distorted head reducing the quality and yield of the broccoli. *Lipaphis pseudobrassicae* reproduce primarily through parthenogenesis, where females give birth to nymphs without mating. This reproduction strategy allows for rapid population growth under favorable conditions. The mustard or turnip aphid, *Lipaphis erysimi pseudobrassicae* (Davis), is one of the most destructive pests of brassica causing over 50% yield loss (Adhab and Schoelz 2015). Furthermore, aphids of the *L. erysimi* group transmit over 13 different viruses, including important viruses of the Brassicaceae, such as Turnip mosaic virus (potyvirus), Beet mosaic virus (potyvirus), Cauliflower mosaic virus (caulimo virus), and Radish mosaic virus (como virus) (Adhab and Schoelz 2015). The turnip aphid, *L. e. pseudobrassicae* is a serious pest of cruciferous crops that is native to Asia where it has a wide distribution (Tran *et al*. 2016). Consequently, it is noted that prior studies did not document the occurrence of *L. pseudobrassicae* infesting broccoli in Gujarat as observed in this study.

Apterae

Alatae

Fig. 1: Different forms of *L. pseudobrassicae*

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Review articles & Short notes

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The role of citizen science in monitoring forest pests: A collaborative approach

Vidya Madhuri E*[1], Rupali J. S[1], Rajna S[1] and Sagar D[2]

[1]*Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi-110012 India*

[2]*ICAR- National Bureau of Agricultural Insect Resources, Bengaluru- 560024, India*

Corresponding author: evidyamadhuri@gmail.com

Abstract

Forests are complex ecosystems facing threats such as climate change and invasive pests. Climate change increases forest vulnerabilities through droughts and extreme weather, while invasive pests intensify these challenges. Traditional pest monitoring, once limited to experts, is being transformed by citizen science, engaging the public in research and monitoring. Projects like iNaturalist expand monitoring reach, enhance early pest detection, and foster environmental stewardship. Citizen scientists provide valuable data supporting rapid responses and collaboration with plant health specialists. Technologies like drones and environmental DNA empower volunteers and improve data accuracy. Despite limitations like species identification difficulties, comprehensive training and expert validation enhance data reliability. Case studies on tree health surveillance and *Cerambyxcerdo* management show citizen science's effectiveness in increasing surveillance and fostering community-based monitoring. Involving citizens in setting objectives and interpreting data creates impactful conservation outcomes. Integrating citizen and professional efforts ensures thorough monitoring and effective pest management, bridging the gap between research and practical conservation to promote sustainable forests. This article highlights the critical role of citizen science in forest health monitoring, emphasizing clear objectives, appropriate tools, and sustained public engagement.

Keywords: Citizen Science, Forest health, Climate change, invasive pests.

Introduction

Forests are intricate ecosystems offering crucial services but face significant threats from climate change and invasive pests. Climate change causes droughts, windthrow, and other climatic events that weaken trees (Trumbore *et al.*, 2015). Simultaneously, pests and diseases are escalating, with invasive alien species and increasing outbreaks of native species termed "emerging and irruptive pests." Unsustainable logging and new pest introductions further stress forests (Seebens *et al.*, 2017). To safeguard forests, it is essential to enhance monitoring, implement protective measures, and respond promptly to pest outbreaks and invasive species. Forest health involves both the benefits humans derive and the ecological balance essential for stability. In healthy forests, tree mortality due to pests and diseases is natural. However, disruptions such as invasive pests necessitate intervention to restore balance. Effective forest pest management involves early detection, continuous monitoring, species-specific research, and measures to eradicate or manage pests. Examples like the European Spruce Bark Beetle and the Emerald Ash Borer underscore the urgency of addressing forest pests (Vega *et al.*, 2015).

Citizen scientists are members of the public who gather and analyze data about the natural world, usually collaborating with professional scientists on research projects (Bonney *et al.*, 2016). Citizen science is emerging as a valuable tool in forest health monitoring and research. It involves voluntary public participation in scientific activities, from data collection to result dissemination. This inclusive approach engages the public, experts, researchers, small woodland owners, and recreational forest users. Citizen science complements traditional monitoring by foresters and experts, providing valuable data through structured surveys and mass participation initiatives. It significantly contributes to scientific research and monitoring objectives. The article highlights the development and potential of citizen science in forest pest monitoring. It stresses the importance of early pest detection, early warning systems, and monitoring the impacts of emerging and native pests on forest health. Clear objectives, appropriate tools, and methodologies are crucial for the effectiveness of citizen science initiatives. By bridging public engagement and scientific research, citizen science enhances forest health management strategies and promotes sustainable forest ecosystems.

Why citizen science matters

Traditionally, forest pest monitoring was expert-only, but citizen science now involves everyday people, extending monitoring reach and connecting communities to forests. Citizen science transforms monitoring by engaging diverse volunteers, expanding spatial coverage, and fostering responsibility (Roy *et al.*, 2012). It bridges research and conservation, encouraging active participation in ecosystem protection (De Groot *et al.*, 2023). In essence, it democratizes research, enhancing inclusivity, accessibility, and effectiveness.

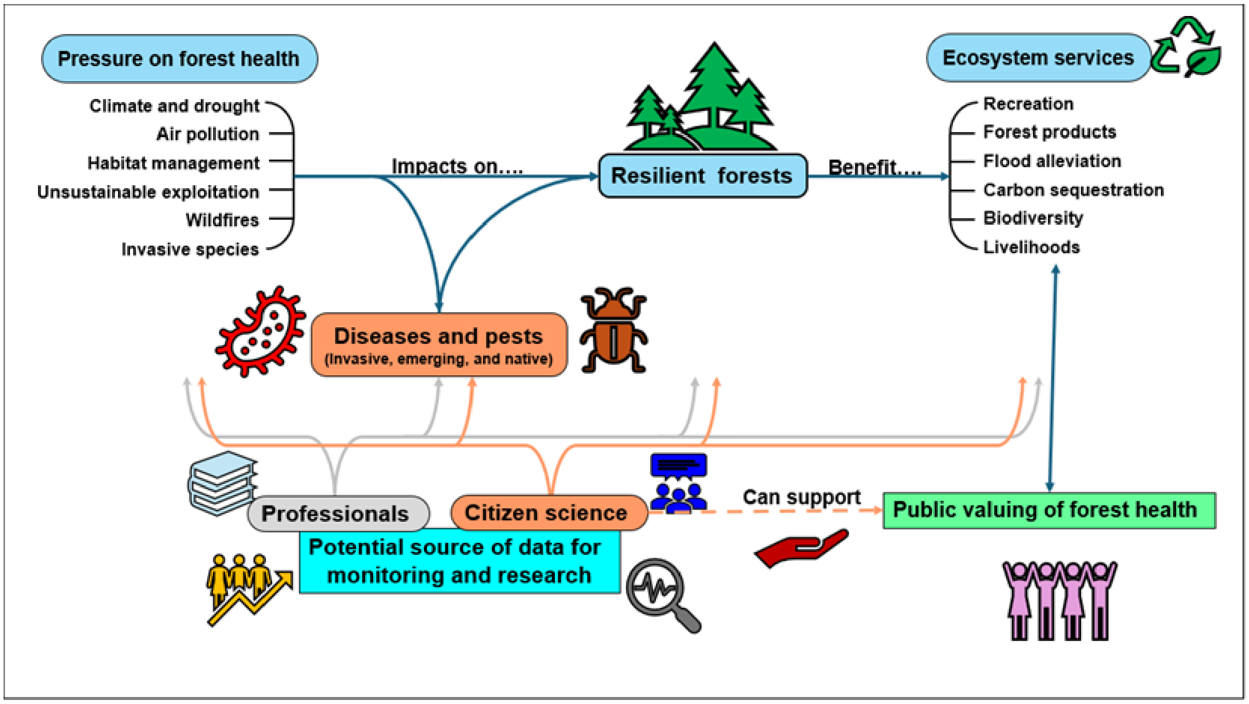

Figure 1: Citizen Science in Monitoring Forest Health: The Role of Public Participation in Tracking Invasive, Emerging, and Native Pests and Diseases (De Groot *et al.*, 2022)

Early warning and early detection of invasive pest species

Citizen science projects utilize various approaches for monitoring forest pests, including opportunistic, structured, targeted species recording, and bioblitz initiatives. Early warning and detection of new and emerging pests are crucial to identify potential risks and pathways of introduction. While professional efforts focus on systematic monitoring, citizen science provides valuable data through platforms like iNaturalist and Observation.org (Rousselet *et al.*, 2013). Engagement of volunteers enhances early detection efforts, supporting rapid response actions and collaboration with plant health specialists. The 'Conker Tree Science' project studied horse-chestnut leaf miner *C. ohridella* parasitism, revealing the highest damage where the moth had been longest (Pocock *et al.*, 2014). 'De Natuurkalender' in the Netherlands tracks oak processionary moth phenology (www.naturetoday.com), while projects like the Sudden Oak Death Blitz identify new hosts for *Phytophthora ramorum* (Garbelotto *et al.*, 2020).

Engaging the public in forest health

Citizen science empowers public engagement in forest health and management through education and training, fostering responsibility and sustainable practices. It extends beyond data collection, raising awareness about tree pests and diseases, crucial for surveillance and research (Andow *et al.*, 2016). Trained volunteers become effective communicators, driving environmental care culture (Pocock *et al.*, 2012). Initiatives like 'The Marri Canker Project' highlight the importance of public-driven efforts in effective citizen science.

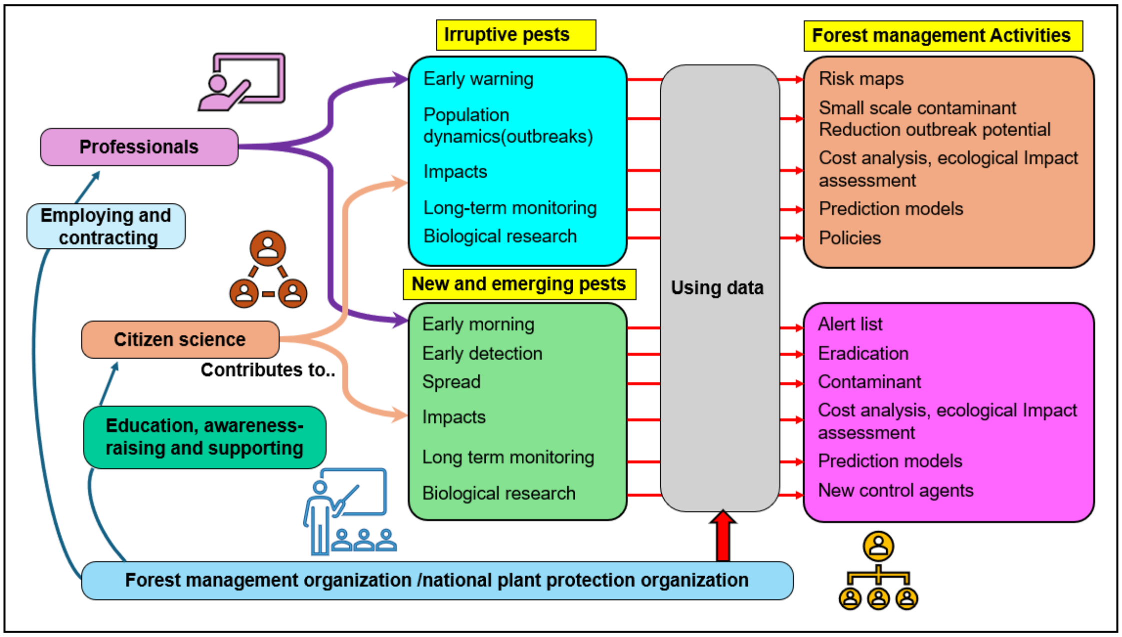

Figure 2: Professionals collect data to meet a wide range of needs regarding irruptive, new, and emerging pests, but citizen science can complement and augment these data with support from relevant organizations, who can use all the available data for monitoring and support forest management activities (De Groot *et al.*, 2022)

Novel technologies, approaches, and how to implement citizen science in data-poor regions

Incorporating novel technologies enhances forest pest monitoring in citizen science initiatives such as drones and environmental DNA (eDNA is genetic material collected from environmental samples like soil, water, or air, rather than directly from organisms) to empower citizen scientists. Standardized designs, repeated visits, and AI-driven image recognition boost data quality (Rani *et al.*, 2024). Collaboration between professionals and citizens optimizes efforts. In data-poor regions, citizen science taps into local knowledge and builds partnerships, offering transformative potential with investment and local relevance.

Table 1: Innovative approaches for citizen science in forest pest monitoring in data-poor regions

Novel Citizen Science Approaches	Description	References
Environmental DNA	Collecting samples of substrate by citizen scientists to use environmental DNA for the detection of pests	(Miralles *et al.*, 2016)
Citizen sensing	Use low-cost sensors to evidence forest pest detection/identification/activity, overseen and monitored by citizens	(Jiang *et al.*, 2016)
Use of artificial intelligence (AI) and image classification	Automated image recognition with the help of AI and image classification increases the potential to recognize new pest insect species and damage to trees.	(Batz *et al.*, 2023)
Standardized citizen science design with repeated visits	Standardise sampling design for the monitoring of forest pest monitoring. Citizen scientists can take a certain area and repeatedly sample the pest insects throughout the year	(Van Strien *et al.*, 2022)
Lures	Physical or chemical lures that may be generalized or specific. Where the lures are species-specific, they do not require additional taxonomic expertise to confirm the forest pest	(El-Sayed *et al.*, 2009)
Augment with professional monitoring	Combining citizen science data with professional surveys, the total survey area will increase significantly with respect to forest health	(Carnegie *et al.*, 2018)
Sentinel trees	Monitor native and non-native tree species for phenology and presence of pests and diseases in botanical gardens and arboreta all over the world as an early warning system for native areas of the tree species	(Paap *et al.*, 2017)
Remote sampling and risk maps-targeted visits	Create risk maps via remote sensing and species distribution models. These maps can be presented to citizen scientists to allow them to target their monitoring.	(Deleon *et al.*, 2017)
Unmanned aerial vehicles (UAVs)	UAVs are used at individual sites (in accordance with local regulations) for automatically collecting aerial images of forests. This can include multispectral imaging using specialist cameras	(Morley *et al.*, 2017)
DNA analysis of mixed samples	New methods like next-generation sequencing are available to quickly sequence large mixed samples. These samples can be collected by citizen scientists using a variety of trapping methods	(Butterwort *et al.*, 2022)

Limitations in citizen science for forest pest monitoring

Citizen science initiatives encounter challenges that hinder their effectiveness in forest pest monitoring. One significant limitation is the difficulty in species identification, especially for non-expert volunteers (Fraisl *et al.,* 2022). This issue can compromise data quality and lead to errors in pest identification and misinterpretation of monitoring results. Additionally, concerns about the validity and reliability of data collected by non-experts arise, impacting the credibility of the information gathered. Uneven spatial and temporal coverage further exacerbates the limitations, as monitoring efforts may be concentrated in specific geographic areas or time periods, resulting in gaps in data coverage (Pernat *et al.,* 2021).

Summary

In a changing world, effective pest monitoring in forests is crucial due to emerging pests. While experts primarily conduct surveys, involving citizen scientists can enhance these efforts significantly. They play key roles in early warning, detecting new pests, and documenting outbreak impacts, providing valuable yet underutilized resources to scientific research. Despite the potential, each field requires tailored projects for effective participation. Currently, citizen scientists are most active in countries with established traditions of citizen science and professional pest monitoring. However, there is substantial potential in countries with less developed forest health sectors, where citizen involvement can expedite the detection and understanding of new pest outbreaks, mitigating future issues.

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Pink bollworm threat: Its management in the Indian cotton industry

Satyabrata Sarangi*[1], Suman Samilita Dash[2], P. Bhavana[3], Aradhana Panda[4], Lipikant Sahoo[5], and Deepali Mohapatra[6]

[1,2,3]Dept. of Entomology, OUAT, Bhubaneswar - 751003, Odisha, India

[5,6]Dept. of Plant Pathology, OUAT, Bhubaneswar - 751003, Odisha, India

Corresponding author: satyasarangi42478@gmail.com

Abstract

Cotton is one of the leading cash crops cultivated all over the world and it provides livelihood to millions of people, due to its higher market value and productive capacity. But the pink bollworm (*Pectinophora gossypiella* (PBW) (Saunders), is one of the key pests among the bollworm complexes in the cotton eco-system, incurring huge damage directly through affecting boll as well as indirectly by heavy crop loss. As the chemical management method has been proven ineffective in many parts of the world due to its internal feeding behaviour, various eco-friendly and sustainable management practices have been undertaken to eradicate the pest upto the level of ETL, to safeguard the farmers from significant economic catastrophe.

Keywords: Bollworm, Cotton, Economic loss, Feeding behavior, Key Pest and Management.

Introduction

With an annual production of almost 6 MTs, India is the world's greatest producer of cotton (*Anon*., 2023). Among the main bollworm pests identified in cotton *i.e.*, Pink Bollworm (*Pectinophora gossypiella* (PBW) (Saunders), Spotted Bollworms (SBW) (*Earias* spp.), and American Bollworm (CBW) (*Helicoverpa armigera* (Hübner)) (Nagrare *et al*., 2022), the most destructive insect pests of cotton (*Gossypium* sp.) is the pink bollworm (PBW), *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae), which is ranked among the top six insect pests globally, resulting in massive crop losses and economic collapse.

Crop loss and economic damage:

PBW Larvae spin webs in flower buds preventing proper flower opening, resulting in "Rosette Flowers," which can penetrate flowers or bolls within 20–30 minutes (Hutchinson *et al*., 1988) or two hours, impacting the boll opening. Before the development of Bt, PBW was the most damaging pest to cotton, reducing seed cotton production by 2.8–61.9%, oil content by 2.1–47.10%, and normal boll opening by 10.70–59.20% (Patil, 2003).

The seed cotton yield was reduced by 61.9%, and 59.2% of the bolls opened normally due to PBW infestation, ranging from 20 to 40% (Amin and Gergs, 2006). In 2015, boll damage by PBW was observed in Bollgard-II, in many regions of Gujarat and some parts of Andhra Pradesh, Telangana, and Maharashtra (Kranthi, 2015), with infestation ranging from 8 to 92% and yield losses between 10 to 30%.

Pest carryover:

Because of internal feeding behaviour, the PBW annoyance leads to severe infestation during the mid-and late phases of cotton without being seen, due to which pesticides are a challenging control measure (Hutchinson *et al*., 1988). The most important causes of PBW's survival and spread in India accounting for over 85% of the pest population on new crops, are ratooning (Sharma and Mohindra 1948), delayed stubble uprooting, and prolonged staking of cotton stubbles.

Management of PBW:

Use of BT-cotton:

The introduction of BT cotton by GEAC in 2002 was a blessing for the Indian cotton sector, due to the superior gene Cry1Ac against PBW. Then, Bollgard II (BG II) was licensed in 2006, after two genes (Cry1Ac + Cry2Ab) were found most toxic to PBW among the resistant transgenic cotton (Choudhary and Gaur, 2010). However, PBW resistance to Bt cotton was demonstrated by the remarkable survival of PBW on Cry1Ac, since 2008 (Mohan *et al*., 2015). Several integrated approaches, including genetic control using sterile insect technique (Tabashnik *et al.*, 2021), SPLAT-PBW Gel, and pheromone-based mating disruption tools like PB rope (Hussain *et al*., 2021), have been employed worldwide.

Chemical control:

According to Prasad and Aswini (2021), there is good control over the percentage reduction of PBW larval incidence and damaged locules per some fully opened bolls with the successive spraying of Profenophos, Spinetoram, and Chlorpyriphos + Cypermethrin. However, pesticide use has been restricted due to its internal feeding habitat and the death of natural enemies. Therefore, the best way to control the pest is to integrate multiple pest management techniques rather than relying solely on chemical management and resistant *Bt* cultivars.

IPM practices: According to Kavitha *et al*. (2008), the use of IPM techniques on cotton has a less detrimental effect than NIPM (non-IPM) methods, on the environment. The implementation of Integrated Pest Management techniques has resulted in low levels of pink bollworm incidence and damage in demonstration plots. The use of different IPM components against PBW has produced positive results in India (Variya *et al*., 2023).

1. Pheromones:

When gossyplure is widely distributed in the cotton canopy at high doses, mating disruption is achieved and modest damage levels may follow. Moth catches in traps are greatly decreased by PB-rope dispensers, which deliver a high dose rate of pheromone release over an extended period (Kavitha *et al*., 2008). Aerial application of a micro-encapsulated pheromone formulation resulted in a progressive reduction in effectiveness, similar to that of insecticide sprays (Lykouressis *et al*., 2005).

2. Botanicals:

Biosafety and environmental safety have bolstered the case for rational and microbial insecticides as appropriate substitutes. Certain botanicals, such as azadirachtin 1500 ppm and NSE 5%, have more of an impact in lowering the number of PBW eggs and larvae (Panickar *et al*., 2003). *Beauveria bassiana, Metarhizium anisopliae*, and *Verticillium lecanii* plant extracts are effective adjuvants and biopesticides (Dougoud *et al*., 2019). Adding these extracts to plant extracts can increase the plant extracts' leaf coverage and persistence, which improves the efficacy of both plant extracts and EPFs when used in conjunction to suppress certain insect pests like PBW (Vashisth *et al*., 2019).

3. Biological control:

The egg parasitoids *Trichogramma bactrae* (Nagaraja) and *Trichogramma brasiliensis* (Ashmead) (Trichogrammatidae: Hymenoptera) seem to limit the egg population of PBW (Chinnababu Naik *et al*., 2018), by reducing the number of exit holes in cotton bolls and by helping in minimizing larval population through reducing locule damage and the number of mines on epicarp. Major parasitoids include *Trichogramma confusum*, *Dibrachys cavus*, *Chelonus pectinophorae*, and *Bracon nigrorufum*; naturally occurring predators utilized against PBW in cotton fields include *Brachinus aeneicostis, Cicindela chinensis*, *Cicindela elisae*, and *Cicindela sumatrensis* (Guo, 1998).

4. Closed season

To reduce the prevalence of pink bollworm, cultural control measures such as the annual requirement that cotton sticks be removed by August 1st were implemented in India as early as 1911. According to Chinnababu Naik *et al*. (2018), one of the main reasons why PBW in North Indian settings remains susceptible to Bt toxins is the "Closed Season." In North India, the cotton season is limited to five or six months to allow for the cultivation of wheat afterward. This creates a closed season, which lessens selection pressure by exposing fewer generations of PBW to Bt toxins.

5. Refugia technique:

However, providing 5–10% non-Bt cotton seeds in a single seed bag as a refuge-in-bag (RIB) has become mandatory in recent years (The Gazette of India: Extraordinary, 2016). However, Bt cotton crops were managed in other countries to cause a lag between the moths' emergence and fruiting bodies. This was achieved through mating disruption technology, refuge planting, the release of sterile insects, and the use of insecticides to control larvae (Nava-Camberos *et al*., 2019). In contrast, in India, the structured refuge strategy was essentially ignored. The other implementable IPM strategies (Jahnavi *et al.*, 2019) include;

- Pupae of pink bollworms exposed to birds and intense sun exposure are caused by deep ploughing.
- Rotating crops might disrupt the pest cycle.
- Encouragement of single-pick, short-duration cultivars (150 days) in high-density planting (HDP) with balanced NPK treatment.
- Premature bolls and dropped squares should be removed and destroyed.
- To prevent the recurrence of other insects or additional outbreaks, wait until the ETLs for PBW before applying synthetic pyrethroids.
- ETLs for three nights in a row, with eight moths per pheromone trap.
- Reducing overwintering larvae can be accomplished through techniques like defoliation, pulling off late-season green bolls, and desiccating the crop at the end of the growing season (Adams, 1995).

Conclusions

The level of scientific and popular opposition to the prolonged use of intense chemical pest control began to rise sharply around the end of the 1960s. The most effective way to control the pest is to integrate several pest management strategies, such as cultural, mechanical, physical, chemical, and biological methods. The use of such methods is a sign of the actual challenges in putting more sophisticated integrated pest management systems into practice. Prioritizing intervention from the start, thresholds have had the unintended consequence of reinforcing growers' customary use of synthetic pesticides due to their apparent effectiveness, rather than encouraging research into potential preventative measures, as advised by IPM principles.

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Review on Insect RNAi - A powerful toolkit for advancing crop protection strategies

***B. N. Balaji**

Department of Agricultural Entomology, College of Agriculture, University of Agricultural Sciences, GKVK, Bengaluru - 560 065 India

Corresponding author E-mail: balajibvn123@gmail.com

Introduction

In crop protection, the battle against insect pests has long been a priority. While biotechnological innovations like Bt proteins have reduced reliance on chemical pesticides, the emergence of pest resistance calls for new strategies. RNA interference (RNAi) has emerged as a promising tool for precise, species-specific pest control without chemicals (Huvenne and Smagghe, 2010). Its systemic action in insects opens up possibilities for RNAi-based insecticides, potentially revolutionizing integrated pest management. RNAi involves RNA molecules suppressing gene expression through ds-RNA, also known as co-suppression, post-transcriptional gene silencing (PTGS), and quelling. This mechanism, illustrated by Fire and Mello in 1998 using *Caenorhabditis elegans* earned them the 2006 Nobel Prize in Physiology and Medicine.

Factors affecting the silencing effect and RNAi efficiency as an insect control method

1. Target gene - Choosing the right target gene is crucial for successful RNA interference (RNAi), as effectiveness varies across genes.

2. dsRNA design - Formulating double-stranded RNA (dsRNA) for gene silencing is precise, but unintended off-target effects may occur if small interfering RNAs (siRNAs) share sequences with unintended genes.

3. dsRNA length - The length of double-stranded RNA (dsRNA) affects its uptake in insects for gene silencing. Longer dsRNAs are typically more efficiently assimilated than small interfering RNAs (siRNAs) (Bolognesi *et al*., 2012).

4. dsRNA concentration - Optimizing the concentration of double-stranded RNA (dsRNA) is vital for effective gene silencing in insects. Surpassing this optimal concentration may not increase silencing (Shakesby *et al*., 2009).

5. Controls - In experiments, including negative controls like empty vectors, cassettes, or irrelevant dsRNAs is crucial to differentiate specific gene silencing from non-specific effects induced by dsRNA exposure. Negative controls validate dsRNA specificity for the target and ensure it doesn't interfere with target expression (Pereira, 2013).

6. Molecular silencing confirmation - It's vital to comprehensively validate RNA interference (RNAi) efficacy, including assessments of target RNA expression, protein quantity, and enzyme activity. Quantitative reverse transcription polymerase chain reaction (RT-qPCR) is preferred for RNA expression analysis due to its sensitivity and accuracy. Careful considerations include selecting stable reference genes and designing efficient primer pairs (Rodrigues *et al*., 2014).

7. Protein stability and phenotype analysis - Proteins with long half-lives can complicate observing phenotype changes in RNA interference (RNAi). Subtle reductions in protein levels may not always lead to observable alterations, especially in haplo-sufficient genes.

8. Insect issues, life stage, nucleases, and gut pH - Considerations before initiating an RNA interference (RNAi) experiment include insect developmental stage and physiological factors like gut pH and nucleases. Silencing effects are often more pronounced in earlier stages.

Insecticidal RNAi and Crop Protection

Insecticidal RNAi shows promise in crop protection against herbivores and pests. It offers specificity and flexibility surpassing other methods like chemical insecticides or protein-coding transgenes (Scott *et al*., 2013). Transgenic plants expressing insecticidal RNAi traits and conventional dsRNA-based insecticides are actively pursued for product development. Efficient delivery methods, such as nanoparticle-mediated RNAi, show promise in increasing dsRNA stability and cellular uptake. Optimization of dsRNA production methods, including bacterial synthesis, holds potential for managing agricultural pests. Although RNAi technology has targeted various crop pests, transgenic plants expressing RNAi traits have primarily focused on Coleoptera, Hemiptera, and Lepidoptera orders (Palli, 2014).

1. Coleoptera

Coleopterans, especially *Diabrotica v. virgifera* (Western corn rootworm, WCR), are targeted by RNAi-plants due to their susceptibility to RNAi. WCR showed larval stunting and mortality when fed on maize expressing hairpin V-ATPase A (Baum *et al*., 2007). Long dsRNAs of Dv V-ATPase C in maize provided effective root protection but did not induce lethal RNAi responses in WCR. Similarly, transplastomic potato plants expressing insecticidal dsRNAs showed potent insecticidal activity against *Leptinotarsa decemlineata*. The absence of RNAi machinery in chloroplasts explains the superior efficacy of dsRNAs from transplastomic plants compared to nuclear transgenics (Zhang *et al*., 2015; Table 1).

2. Lepidoptera

Initially, transgenic plants producing Bt proteins effectively managed many lepidopterans, but their sustainability is now uncertain due to increasing resistance. Instances of evolved Bt resistance rose from one in 2005 to five in 2010, with four resistant species in the Lepidoptera order (Tabashnik *et al*., 2013). Despite being potential RNAi crop targets, lepidopterans pose challenges in gene silencing, with higher dsRNA concentrations needed compared to Coleoptera (Kolliopoulou and Swevers, 2014). The first successful RNAi plant targeting lepidopterans, specifically *Helicoverpa armigera*, demonstrated effective gene silencing of CYP6AE14, crucial for detoxifying gossypol from cotton (Zhu *et al*., 2012; Table 1). These findings suggest potential cross-species effects, highlighting the risk of impacting non-target insects.

3. Hemiptera

Hemipterans, known for their piercing/sucking feeding, are significant agricultural pests causing direct damage and transmitting viruses. Systemic chemical insecticides are commonly used due to feeding on the phloem. The lack of effective Bt toxins against hemipterans prompts interest in RNAi-based transgenic crops expressing dsRNAs in the phloem. RNAi could be a promising strategy to control the invasiveness of this hemipteran pest (Arya et al., 2020). Early reports showed reduced gene expression and fecundity in *Myzus persicae* feeding on transgenic *Nicotiana benthamiana* and *Arabidopsis thaliana* targeting gut and salivary gland genes (RACK1 and MpC002) (Pitino *et al*., 2011). Similar effects were seen when *M. persicae* fed on *A. thaliana* and tobacco plants targeting serine protease (MySP) and hunchback genes, respectively, without lethal outcomes. Recent studies demonstrated *Bemisia tabaci* mortality on tobacco plants expressing dsRNA of v-ATPaseA (Thakur *et al*., 2014; Table 1). These findings suggest that plants expressing effective dsRNA levels targeting crucial genes could resist Hemipteran pests.

RNAi Risk Assessment and Regulation

As RNAi-based technologies advance in crop enhancement and pest management, evaluating associated risks is crucial. These risks, concerning molecular characterization, food/feed, and environmental assessment, need systematic evaluation (Alamalakala *et al*., 2018).

1. Molecular Characterization: Understanding the effects of off-target gene silencing is crucial in assessing risks associated with RNAi-based technologies. Off-target silencing can affect both genetically modified plants and organisms consuming them, including target pests and non-target organisms (NTOs) (Casacuberta *et al*., 2014).

2. Food/Feed Risk Assessment: The evaluation of genetically modified (GM) plants involves a comparative approach to identify both intended and unintended changes. This assessment includes proximate analysis, toxicity, allergenicity, and nutritional traits, aligning with global regulatory standards (US EPA, 2014).

3. Environmental and Ecological Risk Assessment: This aspect examines harm to non-target organisms, tracks environmental impact, and studies resistance in pests. It uses tiers: lab tests first, then field studies. Lab tests show no harm to non-target organisms, even at expected exposure levels (Bachman *et al*., 2016).

Table 1. Recent publications on the use of plant-RNAi against different insect pests

Species	Order	Crop	Target Gene	Remarks	References	Place
Diabrotica v. virgifera	Coleoptera	*Zea mays*	V-ATPase	Mortality	Li *et al*. 2015	USA
Leptinotarsa decemlineata	Coleoptera	*Solanum*	β-actin, shrub	Mortality	Zhang, *et al*. 2015	Germany
Helicoverpa armigera Spodoptera exigua	Lepidoptera	*Nicotiana tabacum*	Nuclear receptor complex of 20hydroxyecdysone (HaEcR)	Molting defect and larval lethality	Zhu, *et al*. 2012	China
Helicoverpa armigera	Lepidoptera	*Nicotiana tabacum*	Molt-regulating transcription factor gene (HR3)	Developmental deformities and larval lethality	Xiong, *et al*. 2013	China
Helicoverpa armigera	Lepidoptera	*Arabidopsis thaliana*	HaAK	Developmental Deformities and larval lethality	Liu, *et al*. 2015	China
Myzus persicae	Hemiptera	*Arabidopsis thaliana and Nicotiana benthamiana*	MpC001, Rack1	Progeny reduced	Pitino, *et al*. 2011	UK
Bemisia tabaci	Hemiptera	*Nicotiana rustica*	V-ATPase	Mortality	Thakur, *et al*. 2014	India

Conclusion

Despite significant progress in RNAi applications in agriculture, particularly in virus control, its efficacy against insect pests in real-world field conditions is still under full validation. Currently lot of work has been carried out on RNAi in India mainly in the orders Hemiptera and Lepidoptera. RNAi presents a promising avenue for developing pest management solutions against insect herbivory, with studies targeting various insect pests across different orders (Coleoptera, Lepidoptera, Hemiptera). However, while RNAi acts through gene suppression, field efficacy data for many targets and species remain limited, often showing sublethal phenotypes. Recognizing the species and target gene dependency of dsRNA effects is crucial for refining regulatory frameworks and addressing challenges for future commercial deployment of RNAi. Advanced technologies like BioClay hold promise for enhancing RNAi spray efficiency and warrant further investigation.

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Pink bollworm management in cotton: Challenges, innovations, and sustainable solutions

Pooja Dalal[1], Mandeep Redhu[*2], Arvind Mor[1]

[1]Department of Entomology, CCS Haryana Agricultural University, Hisar, 125004, India

[2]Department of Plant, Soil and Agricultural System, Southern Illinois University Carbondale, IL, 62901, USA

Corresponding author- mandeep.redhu@siu.edu

Abstract

Pink bollworm (*Pectinophora gossypiella*) poses a significant threat to cotton production worldwide. Despite the initial success of *Bt* cotton, resistance has emerged, necessitating alternative management strategies. Integrated Pest Management (IPM) approaches, including mating disruption and the sterile insect technique (SIT), offer promising solutions. The SPLAT (Specialized Pheromone and Lure Application Technology) technique utilizes wax-based formulations to disrupt pink bollworm mating behaviour, reducing population growth and damage to cotton crops. Meanwhile, SIT utilizes radiation to induce sterility in pink bollworm populations, reducing reproductive rates and mitigating infestation levels. Embracing these innovative strategies collectively ensures sustainable cotton cultivation, safeguarding farmers' livelihoods and reinforcing resilience against the persistent threat of the pink bollworm.

Keywords: *Pectinophora gossypiella*, Cotton, IPM, SPLAT, STI

Introduction

Cotton known as the "King of Fibres," serves as a crucial cash crop, extensively grown globally and renowned for its reputation as a "sustainable fiber". Besides a natural source of fiber, cotton serves as an oilseed crop, by supplying raw materials to both the oil and textile industries. It is commonly cultivated in subtropical and tropical parts of America, Africa, Asia and Australia. However, the production faces significant challenges, primarily from insect pests and diseases. Around 162 species of phytophagous insects affecting the cotton crop have been recorded. Out of which 24 were identified as pests and nine were classified as key pests in various cotton-growing regions of the Indian subcontinent. One of the serious threats to cotton production is pink bollworm. In 2015, severe damage caused by pink bollworms ranged from 40 to 95% in Maharashtra (Rakhesh *et al.,* 2023). In 1843, W.W Saunders first identified it from damaging cotton specimens and named it as *Depressaria gossypiella*. Presently, it is known as the Pink bollworm, belonging to the family *Gelechiidae* of order Lepidoptera. It's life cycle can be categorised into eggs, larvae, pupae and adult developmental stages (Bhute *et al*., 2023). The eggs are deposited individually or in groups of 4 to 5, looking like a flattened oval shape with a pearl-white colour. Hatching occurs within 3-4 days, and the eggs measure around 0.5 mm in length and 0.25 mm in width. During the early stages until the second instar, young larvae appear as small, white caterpillars with dark brown heads. By the fourth and final instar, they transition to a pink hue. The intensity of the pink colour is influenced by their diet, with the consumption of matured seeds resulting in a darker pink shade. The larval phase lasts for 10-14 days, and fully developed larvae measure 10- 12 mm in length with horizontal bands of red coloration on their bodies. The pupal stage lasts for seven to ten days, with the pupa measuring approximately 7 mm in length and displaying a light brown colour. Adult moths are nocturnal and conceal themselves in soil, waste, or holes during the day. They have a length of about 7-10 mm and a lifecycle lasting 3-6 weeks. Mating takes place 2-3 days after emergence.

The pink bollworm population exhibits a noticeable increase after 100 to 110 days of crop emergence, and consequently, the infestation reaches its apex around 140 days (Sarwar, 2017). Stained lint within open bolls and rosette flowers are usually clear indicators of damage. The presence of stained lint within open bolls serves as a clear indication of damage, typically observable in subsequent crop growth stages when the harm has occurred. Rosette flowers refer to a condition where the flower fails to fully open and becomes twisted. The pink bollworm damage to cotton bolls frequently gives rise to secondary bacterial infections, causing the external blackening of the boll rind. Green bolls exhibiting black spots are frequently regarded as an indication of pink bollworm damage. Exit holes, measuring 1.5 to 2 mm in diameter, on green bolls unmistakably indicate the insect's emergence from the boll. The damage to the lint is extensive, often causing farmers to abandon the crop for harvesting because poor-quality seed cotton is not valued in the market. The estimated losses include around 2.1 to 47.1% in oil content, 10.7 to 59.2% in normal boll opening, and 2.8 to 61.9 percent in seed cotton production (Patil, 2003). Prior to 2002, India faced lower cotton production and productivity despite its larger cultivation area, primarily attributable to a substantial bollworm infestation. Following the Genetic Engineering Approval Committee's (GEAC) authorization of *Bt* Cotton (Miracle Bean) cultivation in India in 2002, the country ascended to become the leading global exporter of cotton and the second-largest producer worldwide, surpassing both the USA and China.

***Bt* cotton**

Genetically modified organisms (GMOs) known as *Bt* cotton produce a toxin designed to prevent bollworm infestation. Resistance against lepidopteran pests is conferred by the Cry1Ac protein sourced from

Bacillus thuringiensis. This case involved the introduction of toxic crystal-encoding genes into cotton seeds to develop *Bt* cotton. Ingesting the *Bt* toxin exposes insects to a stomach poison that targets the alkaline gut. The cry protein activates the toxin, which adheres to the cadherin site on the brush border cells of the midgut epithelium. Once bound, the toxin breaks down cells and creates pores, allowing the body haemocoel to enter the gut, contaminating it and disrupting pH, leading to interference with homeostasis. Ultimately, the populations of worms perish.

Bollgard containing the Cry1Ac protein was introduced in 2002, followed by the release of Bollgard II in 2006, incorporating both the Cry1Ac and Cry2Ab proteins. The cultivation of *Bt* cotton in farmers' fields in 2002 resulted in a substantial increase in cotton production, rising from 2.3 million metric tons in 2002–03 to 5.4 million metric tons in 2007–08. This growth was noteworthy, especially considering that the cultivation area only marginally expanded from 7.7 million hectares to 9.4 million hectares. Throughout these years, the yields increased from 302 kg/ha to 567 kg/ha, and the cultivation area for *Bt* hybrids surpassed 80% of the overall cotton area (Karihaloo and Kumar, 2009). The key techniques for addressing resistance against bollworms involved two different strategies such as refuge and gene diversification or pyramid. A "refuge" refers to a border of non-*Bt* plants planted around a *Bt* field, serving as a feeding area for bollworms. Unfortunately, most farmers have not prioritized refuge planting. The *Bt* plant field exerts selective pressure on bollworm populations, promoting the survival and dispersal of naturally resistant worms, potentially leading to the spread of the resistance trait. In refuge plants, it is anticipated that *Bt*-sensitive worms will thrive, mate with resistant worms, and diminish the level of resistance. Thus, this strategy hinders insect resistance and enhances Cry1Ac expression in transgenic cotton. As the refuge percentage rose, so did the Cry1Ac expression levels in various parts of the plant such as lower leaves, sepals, boll bracts, and upper leaves. The maximum yield was attained with a combination of 75% *Bt* and 25% refuge, demonstrating increased Cry1Ac expression (Srikanth *et al.*, 2019). On the other hand, Mahyco-Monsanto developed Bollgard-II, employing a "pyramid strategy" using Cry1Ac and Cry1Ab to target a single pest with two or more toxins. To prevent the development of resistance in the target pest, gene stacking or pyramiding was utilized, involving the production of two or more insecticidal proteins in the plant (Sheikh *et al.*, 2017). The examples of gene pyramided *Bt* cotton include Bollgard II (Cry1Ac and Cry2Ab) and Widestrike (Cry1Ac and Cry1F) (Karihaloo and Kumar, 2009). The strategic incorporation of these genes into cotton aimed to provide long-term resilience to pest control technology.

Since *Bt* genes were present in a heterozygous form in one copy per cell in *Bt* hybrids, approximately 25% of seeds from Bollgard I hybrids and 6% from Bollgard II hybrids are devoid of *Bt* toxin. This accelerated resistance emergence and diminished the efficacy of bollworm control. A research study conducted by the Central Institute for Cotton Research (CICR) Nagpur, has scientifically confirmed the resistance of the pink bollworm population to the toxins Cry1Ac and Cry2Ab (Naik *et al*., 2018). that's why, cotton production has experienced setbacks in India during the previous decade. Due to the increasing resistance of the pink bollworm, the livelihood security of farmers cannot be guaranteed in the present scenario. Globally, it has become the most economically notorious pest of cotton presenting a formidable challenge for both farmers and scientists, demanding a comprehensive strategy for successful control.

Various studies emphasize the effectiveness of Integrated Pest Management (IPM) as a sustainable and holistic strategy for addressing pink bollworm infestations in cotton, ensuring increased yield and ecological balance. Due to the increasing pest's tolerance to insecticides and cry-toxins, its impact intensifies, becoming more troublesome and challenging to control using existing management methods. Due to its concealed feeding behavior inside cotton bolls, direct insecticide contact proves highly challenging and ineffective. This brings an advantage for their survivability and poses a challenge for growers as neonates are less vulnerable to insecticide exposure. Therefore, the pest's resilience has become a frustrating issue. There is a compelling need for non-chemical approaches to alter the behavior of pink bollworms. Consequently, farmers are compelled to explore cutting-edge, sustainable, and environmentally friendly alternatives for pest control, with the innovative mating disruption-based technology known as Specialized Pheromone and Lure Application Technology (SPLAT) and sterile insect technique (SIT) offering a promising glimpse of hope in mitigating the threat posed by the pink bollworm (Acharya *et al.*, 2023). The SPLAT is a wax-based formulation designed for slow and sustained release of pheromones, specifically gossyplure, disrupting the mating behaviour of pink bollworms and controlling the population growth. The mating process of the pink bollworm relies on female pheromone release, intercepted by synthetic pheromones in the SPLAT formulation, trapping male moths before mating. The SPLAT formulation includes gossyplure ((ZZ/ZE) 7,11-hexadecadienylacetate - as the active ingredient) blended with wax and water, with an application of 125 g per acre at 30, 60-65, 90-95 and 120-125 days after sowing (Acharya *et al.*, 2023). In the absence of females, copulation is hindered, affecting fertilization and reproduction, thereby, protecting fields from pink bollworm attacks and reducing long-term damage. PB-ropes facilitate high-rate releases of sex pheromones, making mating disruption the most effective method for pink bollworm control in cotton crops (Mohamed *et al*., 2016). This approach will raise cotton production per acre while reducing the need for pesticide sprays. Pheromones being harmless for beneficial insects, offer a complete replacement for conventional insecticides in pink bollworm management. Hence, the SPLAT technology stands as a boon to the farming community. On the other hand, SIT is an environmentally friendly and highly targeted method that utilizes radiation to disrupt the reproductive system of sexually reproducing pests. By reducing reproduction, SIT aims to create a high proportion of sterile matings within a natural population. Successful eradication of pink bollworm populations in the southwestern United States and northern Mexico was achieved through a combination of SIT, mating disruption, and transgenic technologies.

Conclusions

Addressing pink bollworm challenges in cotton requires a multifaceted approach. While *Bt* cotton initially triumphed, resistance threatened its efficacy. This led to an unprofitable situation for farmers, as the damage caused by pink bollworms increased, along with a rise in production costs due to resistance issues and the necessity for multiple insecticide sprays. Integrated Pest Management proves pivotal, and innovative techniques like SPLAT and SIT offer promising, environmentally friendly alternatives. Embracing these strategies collectively ensures sustainable cotton cultivation, safeguarding farmers' livelihoods and reinforcing resilience against the persistent threat of the pink bollworm.

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Avian predators in cocoon market on the Uzi fly *Exorista bombycis* Louis.

Ravi Kumara R*[1] and Harishkumar J[2]
[1]*CSB - Muga P-3 Seed Station, Kobulong, Nagaland, India*
[2]*CSB - Silkworm Seed Production Center, Berhampore, West Bengal, India*
Corresponding author email: ravisilkstar5@gmail.com

The Tachinid fly *Exorista bombycis* Louis, popularly known in India as the 'Uzi fly,' is an endoparasitoid of the mulberry silkworm *Bombyx mori* (Mukerji, 1919), referred to as a menacing pest of silkworms. The female Uzi fly lays eggs on the body of silkworm larvae, which hatch into small maggots that pierce the host's integument and devour its body contents, ultimately resulting in the host's death (Datta and Mukherjee, 1978). The primary distinguishing features of an infestation with Uzi flies are a black scar on the larval body and an emerging hole in the cocoons. After the death of the host, the maggots inside the silkworm's body emerge and metamorphose in the outside environment, completing their life cycle by 28 to 42 days. Depending on the situation, the Uzi fly can cause losses up to 75 % but generally causes 10-15 % losses. These Uzi flies cause 100 % mortality, as seen in the case of silkworm larvae before spinning cocoons when the larvae were infested in the III instar or IV instar. The larvae infested in the V instar manage to spin the cocoon, but the maggot emerges by piercing a hole in the cocoon, resulting in pierced cocoons (Fig. 1) (Chakraborty *et al*., 2023). These Uzi flies are observed mostly on the cocoon market floors when farmers spread their cocoons in the allotted slots of the market. This poses a threat to the ecosystem as the maggots become gravid female flies. A single Uzi fly can infest by laying eggs on 300-400 silkworms, affecting half a kilogram of cocoon, which poses a significant threat to the farmers (Chakraborty *et al.*, 2023).

The effective measures recommended and undertaken by farmers include creating enclosures with nylon net or wire mesh to prevent adult flies' access to silkworms, spraying 1 % Benzoic acid solution (Uzicide) to kill parasitoid eggs on silkworm larvae, and dusting 10 % Dimilin on maggots and puparia to suppress adult reproduction. While these methods help reduce Uzi infestation, economic loss may not be completely avoided. Exclusion methods are using wire mesh/nylon nets on doors and windows, providing doors with automatic closing mechanisms, and maintaining sanitary conditions. Physical methods include dissolving Uzicide tablets in water for trays inside and outside the rearing house and using Uzi traps after spinning. Biological methods such as releasing *Nesolynx thymus*, a pupal parasitoid, and proper disposal of silkworm litter after cocoon harvest.

Silkworm litter should be separated, packed in plastic bags for 15-20 days, or buried or burned to prevent Uzi fly emergence (Kumara *et al*., 1993). Despite farmers employing various methods mentioned above, the Uzi fly population remains severe in cocoon lots brought by the farmers in cocoon markets, where they re-enter silkworm rearing houses. Moreover, the Uzi fly can travel a distance of 2.7 km for effective parasitization of silkworms (Narayanaswamy *et al*., 1994).

In the present study, we conducted observations in 2023, once a week (2 months), on the predation of Uzi fly pupae by birds in Asia's largest cocoon market, Ramanagara Govt. Cocoon Market. It is located in the district headquarters of Ramanagara, Karnataka, and 40 km from Bengaluru towards Mysuru. In this market, averages of 40,000 to 50,000 kg of cocoons are sold each day. The predatory birds such as House Sparrow (*Passer domesticus)*, Myna *(Acridotheres* spp.), Domestic Pigeon (*Columba livia domestica)*, and Crow (*Corvus* spp.) were observed (Fig. 2). Although there are a large number of people in cocoon markets, the birds display fearlessness in their desire to feed on Uzi pupae and maggots (Fig. 3). It was noted that the bird's activity is more intense in the morning from 6:00 a.m. to 9:00 a.m. in the cocoon market. Most of the Sparrows, Mynas, and Pigeons were nested and stayed within the market buildings, and Crows were nested outside the market buildings. The range of individual bird visits per day was maximum in Sparrows (92-156 nos./day), followed by Crows (44-67 nos./day) and minimum in Mynas (25-38 nos./day) and Pigeons (15-20 nos./day). It was estimated that 50 to 70 percent of the Uzi pupa were eaten by the birds per day. These remarkable birds, often overlooked in the grand tapestry of nature, play a crucial role in keeping Uzi fly populations in check. Moreover, these birds do not prey on the cocoons. Insects are important food resources for birds, irrespective of their feeding mode. Hence, 80 % of birds are reported to include insects in their diet (Morse, 1975). The species of insect consumed often depends on the bird species and its stage in life. In terms of nutritional value, the insect diet is adequate; because it is rich in easily digestible protein and fat, although the digestibility of various parts largely depends on their chitin content (Klassing, 2000). With a keen sense of detection, avians target Uzi fly pupa, offering a natural and sustainable solution to the age-old problem of pest control to some extent.

This natural pest control mechanism not only showcases the complexity of ecological relationships but also holds some potential implications for sustainable sericulture practices. Hence, these birds need to be encouraged in the cocoon markets to check the Uzi fly by providing open space in buildings, windows, and doors for easy fly, non-disturbing or non-destructive of their nests, and non-hunting birds.

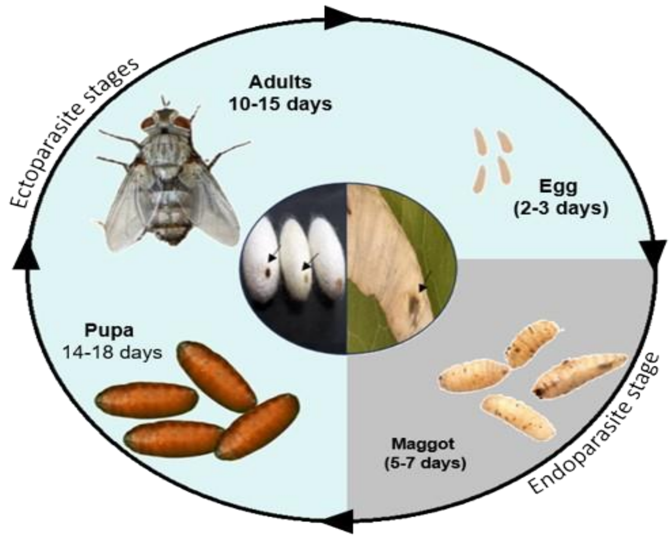

Fig. 1. The life cycle of Uzi fly

(Source: Chakraborty *et al*., 2023)

Fig. 2. Predatory birds in the cocoon market

(Source: https://www.birdsofindia.org/)

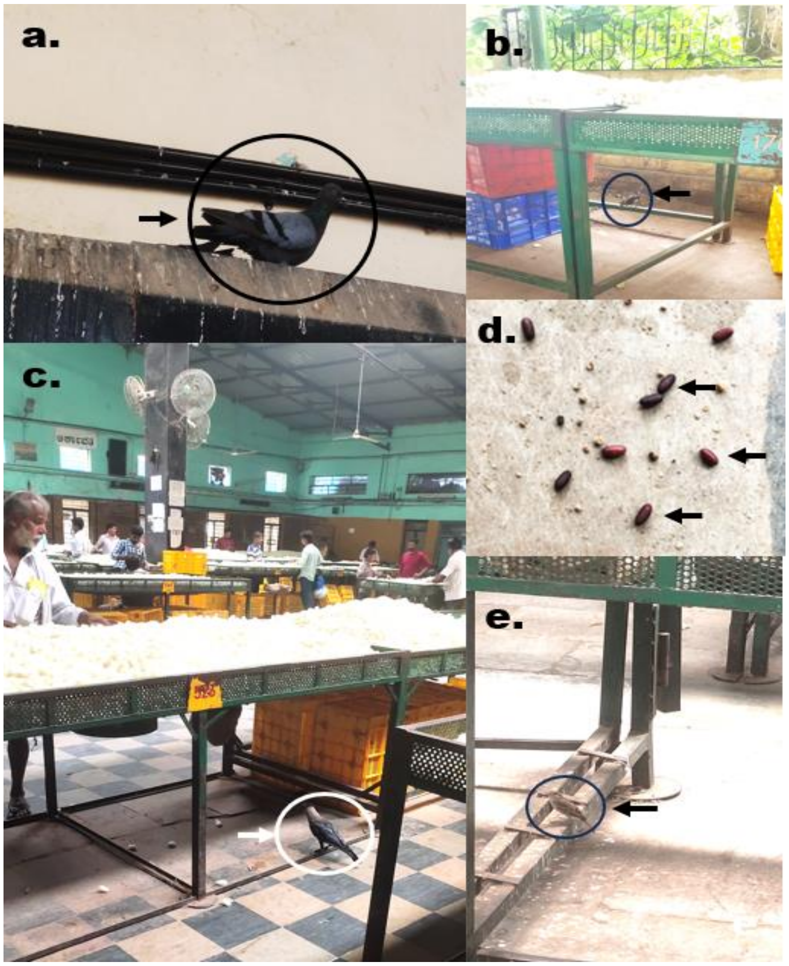

Fig. 3. Birds predating in the cocoon market

(a. Pigeon; b. Myna; c. Crow; d. Uzi pupa; e. Sparrow)

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Pterochloroides persicae (Cholodkovosky): A threat to peach economy of Himachal Pradesh?

Chander Singh*, SC Verma, PL Sharma, RS Chandel, VGS Chandel, Nikita Chauhan, Anshuman Semwal, Vibhuti Sharma, Lalit Kalia, Aryan Bhandari, Pankaj Sharma

Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni (Solan), HP – 173230, India

***Corresponding author: thakurchandersingh008@gmail.com**

Peach is an important temperate fruit crop worldwide and is grown in an area of 4812 ha in Himachal Pradesh with production of 2897 MT in 2022-2023 (Anonymous, 2023). *Pterochloroides persicae* (Cholodkovsky) (Hemiptera: Aphididae: Lachninae) also known as peach black aphid, peach trunk aphid, giant black aphid, clouded peach stem aphid, peach stem aphid and clouded peach bark aphid was found infesting peach and nectarine orchards at Nauni (Solan) 30°51'19.725"N 77°10'27.148"E in Himachal Pradesh (Fig. 1). In India along with Himachal Pradesh this pest is reported to infest peach trees from Kashmir and Punjab. A wide range of hosts has been associated with this pest due to its polyphagous nature (Table 1). It is a significant pest of peaches and similar fruits, especially in the Middle Eastern countries. Continuous attacks by this aphid caused the death of trees in Armenia and Georgia for over ten to fifteen years. A severe infestation has been recorded in Afghanistan, Iraq and Pakistan (CABI. 2022).

Large colonies of *P. persicae* were found infesting on stems and primary branches in peach and nectarine plantations and small colonies were also found on secondary branches. The colonies appear well camouflaged along with the bark and can be seen only if properly observed. It feeds on sap by sucking it from phloem, which leads in overall weakening of the fruit trees, withered branches and ultimately decreased yields. *P. persicae* has not been recognised as a vector of viruses so far, but large populations cause early fruit loss, curling of leaves, an uneven curving of branches, stunted development and growth of sooty mold (Mahendiran *et al*. 2018).

Pterocholoroides persicae excretes an excessive amount of honeydew in the form of rain/shower of honeydew leading to the development of sooty mould due to which the whole stem and branches along with the basin turns black. This excessive honeydew production attracts ants, honeybees, wasps, syrphids etc.

Fig. 1: Colonies of *Pterochloroides persicae*, (A) Large colony (B) Camouflaged small colony (C) Syrphid larvae feeding on *P. persicae* colonies

Table 1: Various hosts of *Pterochloroides persicae* (Gaikwad. 2020; CABI. 2022)**.**

S. No.	Common Name	Scientific Name	Family
1.	Almond	*Prunus dulcis*	Rosaceae
2.	Apple	*Malus domestica*	
3.	Apricot	*Prunus armeniaca*	
4.	Blackthorn	*Prunus spinosa*	
5.	Citrus	*Citrus* sp.	Rutaceae
6.	European Pear	*Pyrus communis*	Rosaceae
7.	Japanese Plum	*Prunus salicina*	
8.	Mediterranean Willow	*Salix pedicellata*	Salicaceae
9.	Nectarine	*Prunus persica* var. *nucipersica*	Rosaceae
10.	Peach	*Prunus persica*	
11.	Plum	*Prunus domestica*	
12.	Quince	*Cydonia oblonga*	
13.	Sour Cherry	*Prunus cerasus*	
14.	Weeping Willow	*Salix babylonica*	Salicaceae

Various natural enemies like coccinellids and syrphids were observed feeding on nymphs as well as adults of *P. persicae*. The generalist predator *Coccinella septempunctata* grubs as well as adults were the most abundant predator feeding on *P. persicae*, besides coccinellids, sryphid flies, *Eupeodes* sp. and *Episyrphus balteatus* larvae were observed feeding on *P. persicae* colonies and adults were foraging on honeydew. Other coccinellids *viz. Adalia tetraspilota*, *Hippodamia variegata*, *Oenopia conglobata* and *Priscibrumus uropygialis* were also found associated with this aphid in Kashmir (Mahendiran *et al*. 2018). The presence of these natural enemies along with the colonies of this aphid indicates the ability of various natural enemies *viz.* coccinellids and syrphids to control *P. persicae* through biological control.

Since the sporadic occurrence of *Pterocholoroides persicae* in Himachal Pradesh, it is not recognized as an important pest, but considering its global scenario, this pest has been found causing severe infestations in other countries and this may become a pest of economic importance in Himachal Pradesh as well. However, further studies are required before reaching a conclusion.

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INSECT LENS

Mango Stem Borer, Batocera rufomaculata (Cerambycidae: Coleoptera)

A serious pest of mango orchards in India. The borer can damage the wood structure of trees and threaten their health. A formulation called "Thavee Gel Tree Swab" developed Rashvee International Phytosanitary Research and Services, Bangalore can be used for effective management of this borer.

Author: *Satyabrata Sarangi and Suman Samilita Dash, OUAT, Bhubaneswar – 751003.*

Location: *Agronomy field, College of Agriculture, OUAT (20.26°N, 85.82°E)*

Email: *satyasarangi42478@gmail.com / jubly09@gmail.com*

Common Sailor, Neptis sp. (Nymphalidae: Lepidoptera)

Common Sailor adults are sun-loving and fly in a slow "sailing" fashion. Common Sailor is highly polyphagous with its early stages feeding on leaves of various plant species in the families: Leguminosae, Malvaceae and Tiliaceae.

Author: *Ruchita Naidu D, Project Assistant, ICAR – National Bureau of Agricultural Insect Resources, Hebbal, Bangalore, India.*

Location: *R. T. Nagar, Bangalore, India*

Email: *naiduruchita2000@gmail.com*

Chrysalis of Common Crow Butterfly, Euploea core (Nymphalidae: Lepidoptera)

It can be metallic silver or gold in colour and often hangs from the underside of a leaf of the food plant. The shining effect is the result of being covered in a number of transparent layers of skin.

Author: *Satyabrata Sarangi, OUAT, Bhubaneswar, Odisha*

Location: *ICAR-NRRI, Cuttack, ODISHA, Pin – 753006 (20.5°N, 86°E).*

Email: *satyasarangi42478@gmail.com*

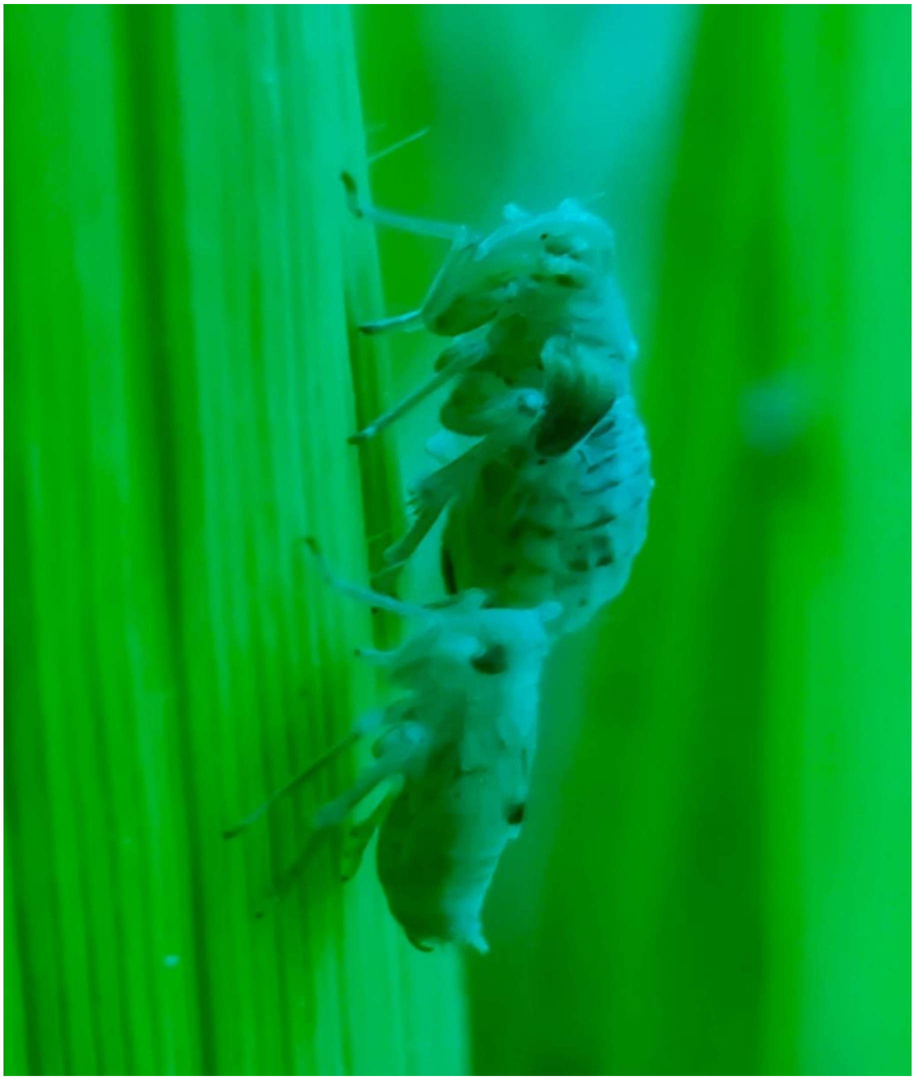
Larvae of Citrus butterfly, Papilio demoleus L. (Papilionidae: Lepidoptera)

Primarily feed on all species of citrus plants. Caterpillars prefers on light green tender leaves, feeding voraciously and leaving only the mid-ribs of the leaves. The larval population density will be high during October to December months and July to December.

Author: *Satyabrata Sarangi, OUAT, Bhubaneswar, Odisha*

Location: *Malkangiri, Odisha - 764048 (18.34°N, 81.88°E)*

Email: *satyasarangi42478@gmail.com*



Nymph of Brown Plant Hopper, Nilaparvata lugens (Delphacidae: Hemiptera)

Nymphs of the brown plant hopper are similar in appearance as that of adults have different colours, and lack functional wings. They damage plants by sucking sap from the mesophyll and affected plants become chlorotic. Older leaves turn progressively yellow from the tip to the midpoint of the leaf, then gradually dry up and die. This feeding damage is commonly referred to as hopper burn.

Author: *Satyabrata Sarangi, OUAT, Bhubaneswar, Odisha*

Location: ICAR-NRRI, Cuttack, Odisha – 753006 (20.5°N, 86°E)

Email: *satyasarangi42478@gmail.com*

Chrysopid eggs

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

Preying Mantis

The two large compound eyes of mantis are used to detect movement and depth, which gives panoramic vision of its surroundings.

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

Location: *Bangalore*

Email: *nasoteya@yahoo.co.in*

Carpenter ant*, *Camponotus parius (Formicidae: Hymenoptera)

Camponotus parius is a captivating ant species known for its unique characteristics and behaviours. This species belongs to the Monogyny colony type and has single queen. Colony size ranges from 2000 to 5000 workers. C. parius are highly populous and efficient in their activities.

Author: *Dr. Abraham Verghese*

Location: *Bengaluru, India*

Email: *abraham.avergis@gmail.com*

Man faced stink bug and Hitler bug, Catacanthus incarnates (Pentatomidae: Hemiptera)

Catacanthus incarnates masses in dense groups of several hundred on fruit trees and are considered as a pest as they feed on the young shoots and sap of valuable crops such as Cashew trees, corn and cotton. The bright colour is said to warn predators of its toxicity.

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

Location: *Bangalore*

Email: *nasoteya@yahoo.co.in*

Eurybrachid

They are remarkable for the sophistication of their auto mimicry.

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

Location: *Bangalore*

Email: *nasoteya@yahoo.co.in*

Cuckoo Wasp (unidentified)

Author: *Rushikesh Rajendra Sankpal, Assistant Professor, Department of Biotechnology, Abasaheb Garware College (Autonomous), Pune*

Location: *Pune, Maharashtra*

Email: *rushisankpal@gmail.com*

Lady bird Beetle, Cheilomenes sexmaculata (Coccinellidae: Coleoptera)

Cheilomenes sexmaculata is an important predator of many insects such as aphids, thrips, whitefly, coccicids and psyllids with a worldwide distribution and common aphid feeding species being found in Pakistan, India, Borneo, Jawa Indonesia, U.K. Philippines, Islands of Bali, France, Sumatra and South Africa.

Author: *Harish G, Senior Scientist, Agricultural Entomology ICAR-Directorate of Groundnut Research, Junagadh, Gujarat-362001*

Location: *Junagadh, Gujarat*

Email: *hari4065@gmail.com*

Violet Carpenter Bee, Xylocopa violacea (Apidae: Hymenoptera)

After mating, the gravid females of Violet Carpenter Bee bore tunnels in dead wood, hence is known as "carpenter bee." It is not particularly aggressive, and will attack only if forced to.

Author: *Dr. V. C. Gadhiya, Assistant professor department of Entomology*

Location: *College of agriculture, Junagadh Agricultural University (Mota-bhandariya), Amreli, 365610*

Email: *drvcgadhiya@jau.in*

IE EXTENSION

World Environment Day, 2024 celebration by IE and AVIAN Trust at Government School, Kempapura on 5th June 2024

Conducting quiz and prize distribution to students on account of World Environment Day celebrations, 5th June 2024

Student's participation in environment conservation posters, 5th June 2024

Visit to dragon fruit and litchi fields at Doddaballapura, Karnataka, India, May 2024

Field visit and farmers training at Dinnur, Devanahalli, April, 2024

With Dr. N. Loganandhan, Head ICAR- Krishi Vignana Kendra (KVK), Hirehalli, Tumakuru, May 2024

Demonstration of latest fruit fly management technology with Rashvee-non insecticidal liquid lure to Scientists at ICAR- Krishi Vignana Kendra (KVK), Hirehalli, Tumakuru

Pomegranate field visit, Chikaballapura, Karnataka, India, May 2024

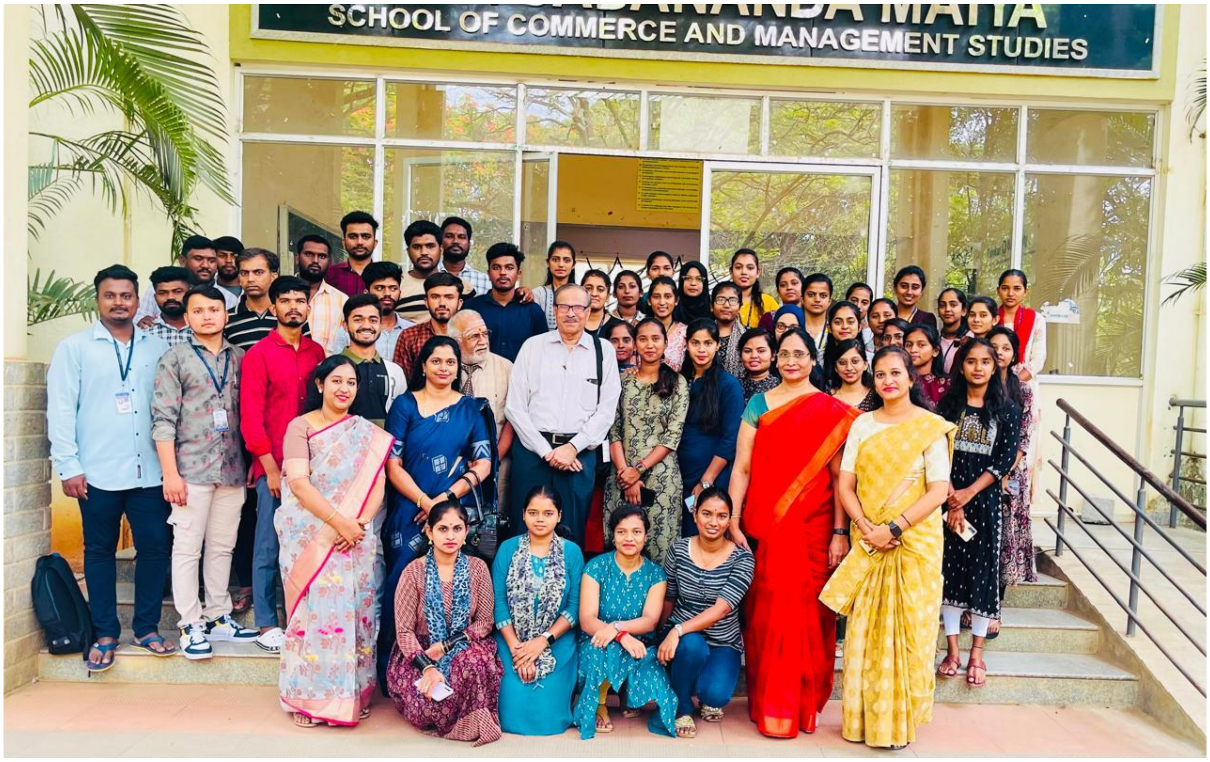
With Dr. S.C.V. Reddy, Former Additional Secretary, Department of Agriculture, GoK, April 2024

IE team with Dr. Rahul Dhanuka and Dr. Hemantheshwa, Dhanuka Agritech Ltd. April 2024

Visit to farmers field and nursery at Kaivara, Chintamani, Karnataka, India, June 2024

Demonstration of latest fruit fly management technology with Rashvee-non insecticidal liquid lure to DEASI students at ICAR- Krishi Vignana Kendra (KVK), Chintamani, Karnataka, India, June 2024

Mango filed visit at Srinivasapura, Kolar, Karnataka, India, June 2024



IE team training MBA students to become entreprenurs in workshop "Today's Entrepreneur's tomorrow's corporate Leaders" organised by University of Tumakuru, Karnataka, India, May 2024