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Cover Page: Tawny coaster, *Acraea terpsicore*

Photo by: Dr. Nagaraj, D. N, Senior Scientist

Bio Pest Management Pvt. Ltd. Kanakapura Road, Bangalore

Insect Environment

(Quarterly journal to popularize insect study and conservation)

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

Insect Environment subscription is free; articles can be downloaded from the website https://insectenvironment.com/ or anyone requesting by email to IE will receive a copy of the journal.

Author guidelines

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

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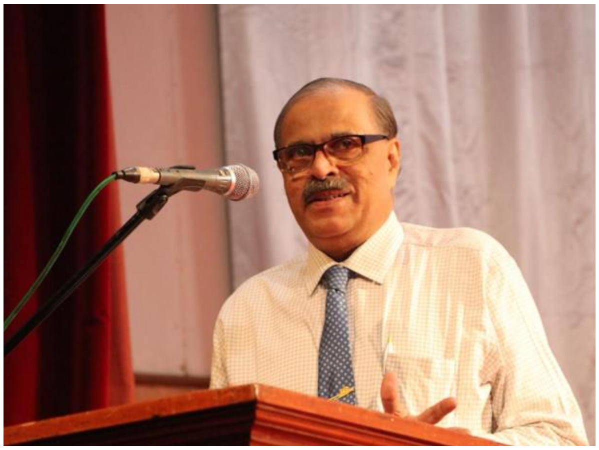
Editorial



Is it climate change or spike?

Of the three times I have been to London, the first two were at bad weather. The city was drizzly, grey and cloudy and never appealed to me. The third time was a short stay, on a return from Lisbon, Portugal. The ride from Gatwick Airport to London, under the morning sunshine, was rewarding with side walkways splattered with trees and shrubs. This was in September, and I knew my visit next day to the city hub would be pleasant. My context is when this July, London had a temperature of 40^{o}C, it was dubbed 'heat wave'! Roads cracked and river Thames warmed. There was chaos! But for us 'Tropicalers,' 40^{o}C is commonplace. When I was in Lucknow, Uttar Pradesh, the temperature in June used to be 43-48^{o}C and the refrigerated *Dashaheri* mangoes kept us cool. And, at this temperature range, eggs of fruit flies fail to hatch on the mango pulp and *Dashaheri* escaped infestation. So much for this natural thermal disinfestation. But when rain comes in July, the temperature dips, the late maturing mango fruits like *Chausa* get infested.

We in India are lucky that we are quite temperature resilient, and for those of us in Bangalore, on the Deccan Plateau, it is always tolerably pleasant. Overall great to be in India!

If heat is one side of the coin, the other has been floods! From most of India, to S E Asia including South Korea and beyond to New Zealand and not to leave out the US of A, floods have been taking a toll, sparing not this time the urban landscapes and business hubs.

From an insect point of view, climate models go haywire in predicting insect infestations in such unpredictable weather spurts. Surely no insects can stand the fury of gale, hale and storm. Climate-spike models on short temporal X-axis should be therefore the new order.

Insect Environment mourns the death of Her Majesty Queen Elizabeth II. Her role as the Patron of the Royal Entomological Society, for the last 70 years is greatly cherished.

Freebies are so much in news; it is however beyond the scope of this humble journal to discuss on this. Our subscription is a 'freebie' as we are a not-for-profit journal! Contextually, I would like to point out that in US, the Inflation Reduction Act, has climate provisions like subsidies for clean power, electric vehicle and for farming practices like no tillage, soil cover crops etc, according to Erik Stostad (*Science*, 16th August, 2022). Something to think on?

Courtesy of the Mendelianum, Moravian Museum, Brno. Noncommercial, educational use only.

This quarter also saw the celebration of the 200th birth anniversary of Gregor Mendel, born 22, July 1822. This Augustinian friars' *principles of inheritance* stood solid for 200 years and laid the foundation of genetics and molecular biology. The sheer dependence on inner Godly Wisdom, to interpret and conceptualize the gene factor manifested in filial pea plants over generations is great. This, without any modern molecular tools, should make every biologist gaze in awe (if they could get to see) at his statue in the Abbey of St. Thomas in Czech Republic.

Insect Environment has been in the ambit of the Internet of Things (IOT) ecosystem from notes/blogs, uploads to referees' connect, to final uploads to various literature search engines and auto-mails. IE is well inter-connected globally. This has enabled us to be the fast, topically relevant information disseminator of insect happenings!. We have already sent an alert blog for *Thrips parvispinus* across south India. Dr. Poorani has blogged in IE the first recovery of the parasitoid *Anagyrus lopezi* post release on cassava mealy bug. There is also a short note in this issue. IE is increasingly becoming relevant, in a time when journals are disappearing! The once acclaimed journals on soil biology, social insects, current biotica, etc are all fossilized. Here I would like to appreciate the efforts put by Dr. V. V Ramamurthy, one of our advisors, in bringing the *Indian Journal of Entomology* on schedule.

The Association for Advancement of Pest Management in Horticultural Ecosystem organized the First Dr. V. G. Prasad Memorial Lecture at IIHR, Bangalore on 29th July 2022. The very memory of Dr. V. G. Prasad is a stimulant to research workers in horticultural entomology. I understand this is going to be an annual feature. A corpus fund for this has been generously donated by Dr Prasad's daughter Mrs. Malvika Khare and family.

IE is a pro-student journal. Short biodiversity accounts for example or small thematic review, who else but IE, with no pretension to 'standards' will publish? We believe in encouraging all dabbling with and watching insects to write, publish and disseminate. That is the only way natural history of insects will grow.

We have literally assimilated two well-known photographers, Drs D. N. Nagaraj and Subramanian Sevgan into the *IE* family. In this issue many of their digital insect captures will enrich the aesthetic dimension of insect diversity. Pictures in lens of IE is again a unique feature. Actually, pictures speak more than words. We thank Mr. Ramesh IFS who permitted us to use a picture he shared in the social media.

The ICAR-National Bureau of Agricultural Insect Resources - Bangalore, a renowned national and globally acclaimed institute, gets a new Director, Dr S N Sushil. IE welcomes him and wishes him an extremely successful stint in his new role.

We sincerely thank all our Editorial Advisors and Team, who have been with us thus far. As per our last executive decisions a litte makeover is being done to bring in newness, freshness as well as diversity in the knowledge pool! Dr S Deepak joins as Associate Editor, and he is a super enthusiastic entomologist. We welcome him. Dr. M A Rashmi, continues to anchor web-author –journal interface with aplomb.

Your notes and news on insects are disseminated fastest through IE blogs. Send in your blogs (100 words+ 1 pictures) for fast publication within a week. Our auto-mailing carries it to thousands of viewers.

We wish all of you a pleasant "insecty" reading ahead, browsing through this issue- 25 (3), September, 2022.

Abraham Verghese

Editor-in-Chief

Research articles

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Field recovery of *Anagyrus lopezi* (De Santis) (Hymenoptera: Encyrtidae), an introduced parasitoid of cassava mealybug, with a note on its hyperparasitoids from Tamil Nadu, India

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Cassava mealybug, *Phenacoccus manihoti* Matile-Ferrero (Hemiptera: Pseudococcidae) is the most dreaded pest of cassava worldwide and it was first reported from Kerala, India in April 2020 (Joshi *et al.* 2020) and soon after found on a larger scale in the cassava growing areas of Tamil Nadu (Sampathkumar *et al.* 2021). *Anagyrus lopezi* (De Santis) (Hymenoptera: Encyrtidae), a specific endoparasitoid of *P. manihoti* of South American origin, has proved to be highly effective in managing *P. manihoti* in more than 25 countries in sub-Saharan Africa (Herren & Neuenschwander 1991) and Thailand in Southeast Asia (Wyckhuys *et al.* 2019). In fact, it is considered to be one of the most outstanding and successful parasitoids ever used in the history of classical biological control of introduced pests. In India too, *A. lopezi* was introduced in August 2021 by the ICAR-National Bureau of Agricultural Insect Resources, Bangalore, in collaboration with the International Institute of Tropical Agriculture (IITA), Republic of Benin. After completion of the mandatory quarantine studies on its biology, safety and host specificity, open field releases of the parasitoid were done in cassava farmers' fields in Tamil Nadu in March 2022 (ICAR, 2022).

Severe infestation of *P. manihoti* was noticed in cassava fields in Karur District, Tamil Nadu, in April-May 2022. In a Frontline Demonstration on cassava mealybug management, ICAR-Krishi Vigyan Kendra, Pulutheri, Karur District, procured about 600 parasitoids from Tapioca and Castor Research Station (TNAU), Yethapur, and released the wasps on 26.5.2022 in three cassava fields at Semparaipatti Village (Pothuravuthanpatti Panchayat, 10.7927° N, 78.3193° E) and two fields at Valayalkaranpudur Village (Renganathapuram South Panchayat, 10.9223°N, 78.1928°E), in Krishnarayapuram

Block, Karur District. Here we report the establishment of *A. lopezi* in the site of release in Karur District, Tamil Nadu, based on field recovery of the parasitoids.

The parasitoid was recovered from the original site of release at Semparaipatti (Latitude 10.788452° Longitude 78.318769°) in fairly large numbers on August 18, 2022 (Fig. 1). Totally 870 adults of *A. lopezi* (Fig. 2a–c) were collected from parasitized mealybug samples of which 425 were females and 445 were males. The sex ratio was slightly skewed in favour of males and males (51.15%) outnumbered females (48.85%). Large number of mummified mealybugs were also recovered.

It indicated that the parasitoid had established well in the areas of release within a fairly short period of about three months. Four hyperparasitoids, *Prochiloneurus pulchellus* Silvestri (Fig. 2d), *Prochiloneurus albifuniculus* (Hayat *et al*.) (Fig. 2e), *Prochiloneurus aegyptiacus* (Mercet) (Fig. 2f) (Hymenoptera: Encyrtidae) and *Promuscidea unfasciativentris* (Girault) (Hymenoptera: Eriaporidae) (Fig. 2g), were also reared from the mealybug mummies. Totally 88 numbers of hyperparasitoids emerged from the mummified mealybugs. Of these, *P. aegyptiacus* (59.09% of the total hyperparasitoids collected) and *P. pulchellus* (14.78%) were more predominant than *P. unfasciativentris* (22.73%) and *P. albifuniculus* was the least collected hyperparasitoid (3.41%). All these four are widely distributed in India. *Promuscidea unfasciativentris* is probably the most common hyperparasitoid of mealybug parasitoids in Indian conditions and it is widely distributed in the Oriental and Afrotropical regions. *Prochiloneurus aegypticacus, P. albifuniculus* and *P. pulchellus* are hyperparasitoids of primary mealybug parasitoids through their hosts such as *Paracoccus marginatus* Granara de Willink, *Coccidohystrix insolita* (Green), *Phenacoccus solenopsis* Tinsley, *Nipaecoccus* spp. and several other mealybugs in India (Hayat, 2006; unpublished data). Two eulophids (*Tetrastichus* sp. and *Aprostocetus* sp. nr. *purpureus* (Cameron)) also emerged from the tangled masses of cassava mealybug in large numbers but their precise role / hosts could not be ascertained.

Agricola & Fischer (1991) reported five hyperparasitoids of *A. lopezi* from Togo, including *Chartocerus* sp. (Signiphoridae), *Prochiloneurus insolitus* and *P. aegyptiacus* (Encyrtidae), *Tetrastichus* sp. (Eulophidae) and *Marietta leopardina*. Neuenschwander *et al.* (1987) reported ten species of hyperparasitoids reared from *A. lopezi* in Nigeria, with *Prochiloneurus* spp. and *Chartocerus* spp. being the most common. In the Universal Chalcidoidea Database, *Prochiloneurus bolivari* Mercet, *P. pulchellus* Silvestri, *P. aegyptiacus* and *P. insolitus* are listed as hyperparasitoids of cassava mealybug in Africa (Noyes 2019).

Interestingly, the population of indigenous predators like *Hyperaspis maindroni* Sicard and chrysopids was low in the mealybug samples collected from the areas of parasitoid release, possibly due to competition for the common food source. No other species of mealybug was found on the cassava plants from which sampling was done and all the hyperparasitoids reported here were associated with *A. lopezi* only. Until now, hyperparasitoids of *A. lopezi* have not been documented from India after its field release. The hyperparasitoids recorded in this study are among the most commonly collected in association with various mealybugs in India.

Prochiloneurus aegyptiacus and *P. pulchellus* have been already recorded as hyperparasitoids of *A. lopezi* through cassava mealybug in Africa (Noyes, 2019) but *Prochiloneurus albifuniculus* and *Promuscidea unfasciativentris* appear to be new associations for this host. At present, the extent of hyperparasitism is low and it is unlikely to have any significant adverse effects on the field efficacy of *A. lopezi* against cassava mealybug.

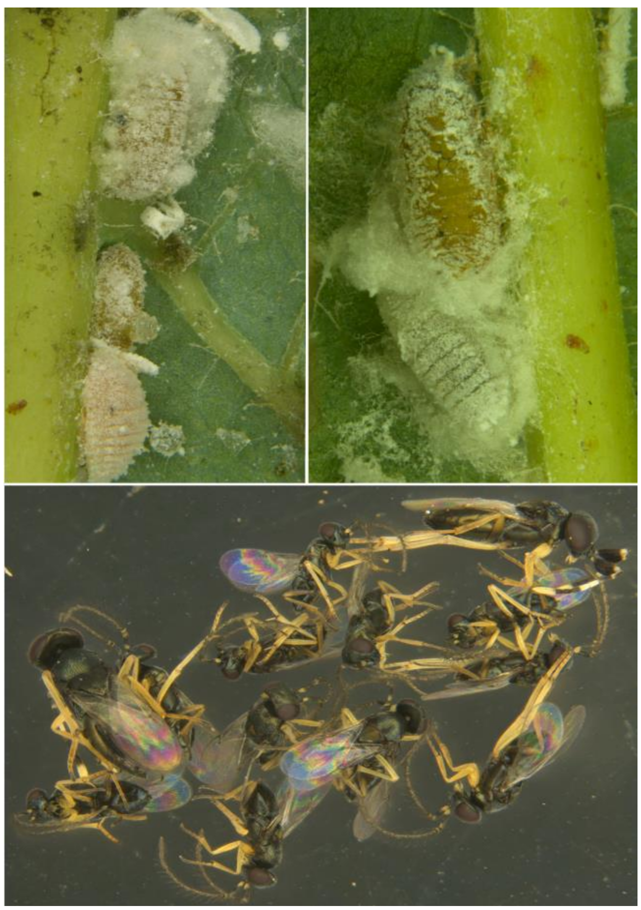

Fig. 1. Clockwise from top: a, b. Mummified cassava mealybugs; c. *Anagyrus lopezi* adults collected from parasitized cassava mealybug samples.

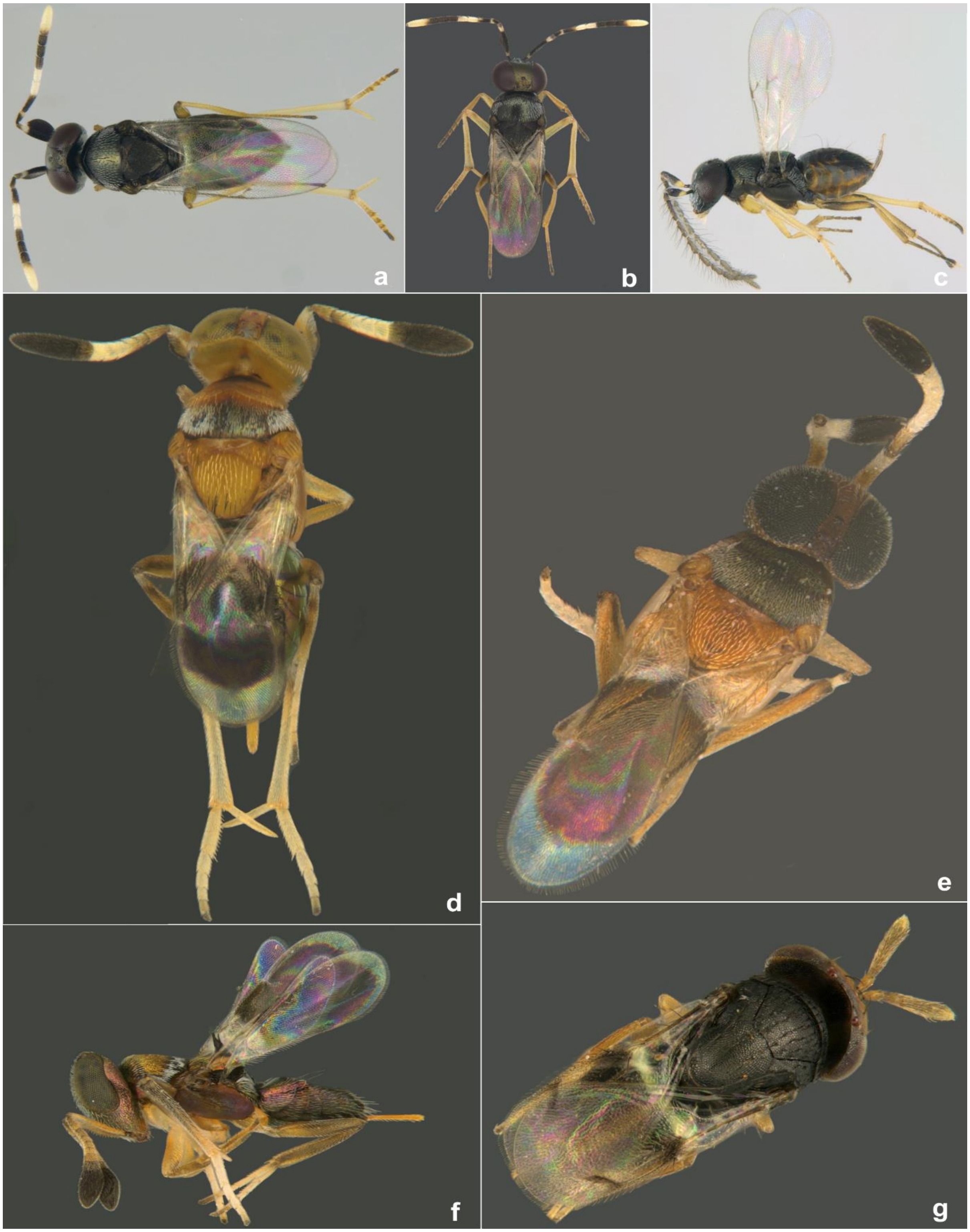

Fig. 2. *Anagyrus lopezi* and its hyperparasitoids: a, b. *Anagyrus lopezi*, female; c. *Anagyrus lopezi*, male; d. *Prochiloneurus pulchellus* Silvestri, dorsal view; e. *Prochiloneurus albifuniculus* (Hayat *et al.*), dorsal view; f. *Prochiloneurus aegyptiacus* (Mercet), lateral view; g. *Promuscidea unfasciativentris* (Girault), dorsal view.

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Status on incidence of invasive thrips species *Thrips parvispinus* Karny in chilli nurseries of Guntur district of Andhra Pradesh: future risk and strategies to mitigate

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Chilli is an important commercial crop being cultivated in Andhra Pradesh, in south India, in an area of 1.8 lakh hectares with a production of 8.36 lakh tonnes (2020-21). The most important districts cultivating chilli are Guntur, Prakasam, Kurnool, Krishna, Ananthapur and East Godavari. Guntur (16.3067° N, 80.4365° E) occupies the first place and contributing to the major share in production and export of chilli from Andhra Pradesh. During 2021-22, due to the incidence of invasive thrips species i.e *Thrips parvispinus* coupled with severe rains in the months of October, November, 2021 most of the chilli crop was damaged. 20-30% of the crops were uprooted and 50-70% reduction in yield was observed. Situation was alarming and all the chilli farmers were in distress. Keeping this in view it was expected that chilli area was going to be reduced drastically for 2022-23 cropping season. But in view of high market price to dried chilli most of the farmers preferred to go for chilli in 2022-23 as well. In this connection Dr. YSR Horticultural University along with the Department Officials and farmers conducted various training programmes to create awareness among the farmers, field level workers including staff in Rythubharosa Kendras and Horticultural officers on pests and diseases management in chilli.

In this connection survey was taken up in major chilli growing areas of Guntur district viz. Ponnekallu, Garikapadu, Mandapadu, Bandarupalli, Siripuram, Medikonduru, Visadala, Damarapalli, Tadikonda and Tulluru. Nurseries in net house (Fig. 1), open field (Fig. 2), Nurseries surounded by protective barriers like shade net (Fig. 3) and polythene sheet (Fig. 4) were observed for the incidence of *Thrips parvispinus*. In most of the nurseries preferred hybrids by the farmers are SVHM 2222, SVHA 1377, NS 264, NS 275, NS 279, Armor, classic DCH 055, SVHM 9093, Sangam 858, Kundan 284, US 341 and the plant protection measures were regularly followed by the farmers. The commonly used insecticides are Fipronil, Imidacloprid, Pyriproxifen, Tolfenpyrad, Spiromesifen, Diafenthiuron and Afidopyropen to control sucking pests like thrips and white fly. The commonly used fungicides are Copper oxychloride, Tebuconazole + Trifloxystrobin, Captan + hexaconazole to control damping off and coenophora blight. In addition, farmers are also giving micronutrient sprays in the nurseries.

The pests observed are listed in the following table

S. No.	Village	Farmer Name	Area of the nursery	Pests observed
1	Ponnekallu	Palla Srinivasa Rao	2.0 acres	Symptoms of South East Asian Flower thrips incidence was noticed
2.	Garikapadu	Velpuri pavan	0.5 acre	No pest and diseases were observed
3.	Mandapadu	V. Krishna Reddy	0.75 acre	No pest and diseases were observed. 1-2 thrips per blue sticky trap of 15 x 30 cm size
4.	Bandarupalli	H. Ankamma Rao	1.0 acre	No pest and diseases were observed
5.	Siripuram	Y. Paparao	0.5 acre	Whitefly @ 1 to 2 per sq.m area and 1 to 2% leaf curl incidence were observed (Fig 5)
6.	Medikonduru	N. Adinarayana	1.0 acre	No specific pest and diseases were observed
7.	Visadala	V.Buchaih	1.0 acre	No specific pest and diseases were observed
8.	Damarapalli	B. Nageswara rao	0.5 acre	No specific pest and diseases were observed
9.	Tadikonda	K. Venkateswara Rao	0.5 acre	No specific pest and diseases were observed
10.	Tulluru	P. Siva reddy	0.5 acre	No specific pest and diseases were observed

Based on the observations and data collected during survey it can be stated that the present situation is not alarmingand the sticky trap data in Mandapadu village showed very meager incidence of *Thrips parvispinus* (1 to 2 per trap). Though the population of *T. parvispinus* is under low proportions it may increase towards flowering stage i.e during the first week of October, 2022. During the month of October most of the chilli crops transplanted in the third week of August, 2022 comes to flowering stage. The *T. parvispinus* adults especially females which are in large numbers and found feeding on pollen may appear in large number during the pollen dehiscence.

At present farmers are advised to observe for the following symptoms during the vegetative phase:

1) Observe on underside of the leaves near veins for thrips colonization and feeding (Fig. 6)
2) Due to sucking of cell sap from the underside of leaf observe for streaking and blotches on corresponding upper surface of leaf (Fig. 7)
3) Distorted leaf lamina and bubbling (Fig 8)
4) Observe for burning of tips in newly emerging leaves (Fig. 9)

If the above symptoms are observed farmers are advised to take up the following integrated pest management practices on community basis to curtail the pest incidence

- Application of 200 kg neem cake, FYM enriched with *Trichoderma viride,* biofertilizers and VAM may be incorporated in soil during last ploughing.
- Border cropping with 2-3 rows of jowar or maize.
- Before going for transplanting to main field apply Fipronil 5%SC @ 2ml/L on nursery bed.
- If dry weather conditions prevail, nip terminal shoots to reduce pest population.
- Immediately after nipping apply Ccopper oxy chloride @ 3g/L to avoid rotting.
- Seedling root dip with Iimidacloprid @ 0.5ml/L for 15 min may be taken up.
- Avoid close spacing; follow recommended spacing.
- Better to take up mulching with silver colour mulch sheet and follow drip irrigation.
- Application of 0.3G Ffipronil granules @ 8kg/ acre at 15 and 45 days after transplanting under sufficient moisture conditions.
- Frequent intercultural operations to be taken up to destroy soil inhabiting pupae
- Clean cultivation and maintenance of weed-free bunds.
- Installation of blue sticky traps @ 40-50 per acre closer to the plant height on community basis for monitoring and mass trapping of the pest.
- Application of excessive use of nitrogenous fertilizers should be avoided and follow balanced application of fertilizers.
- Spraying of neem oil (Azadiractin) @ 1.25ml/L either alone or in combination with insecticides.
- During severe build up of thrips population apply foliar nutrients viz.19:19:19 , 13-0-45 and micro nutrient mixtures. Light irrigations help to maintain leaf turgidity.

- Application of following recommended insecticides on need basis

Dimethoate 30% EC	2ml/L
Emamectin benzoate 5% SG	0.4g/L
Fipronil 80% WG	0.2g/L
Spinosad 45% SC	0.3ml/L
Spirotetramet 15.31% w/w OD	1ml/L
Spinetoram 11.7 SC	1ml/L
Fipronil 5% SC	2ml/L
Fipronil 40% + imidacloprid 40%	0.4g/L

- Application of entomopathogenic fungi like *Lecanicellium lecanii* @ 5g/L, *Beauveria bassiana* @ 5g/L, *Metarhizium anisopliae* @ 5g/L depending on the availability of quality material. These should be applied under cool weather conditions

Note:

1. Black thrips population on chilli may increase during flowering i.e most probably during the month of October, and during the peak incidence farmers are advised to go for the recommended practices to mitigate the pest incidence.
2. During the year 2021-22 chilli crop in field continued upto the end of March. During the month of March white fly population was very severe on chilli crop (16-20/plant) which continued with green chilli in summer months followed by current season crop. Hence, there is possiblility of increase in the population of white fly i.e *Bemisia tabaci* and incidence of Gemini virus on current crop.

Fig. 1 & 2
Crop in net house & open field

Fig. 3
Nursery surrounded by shade net

Fig. 4
Nursery surrounded by blue polythene cover

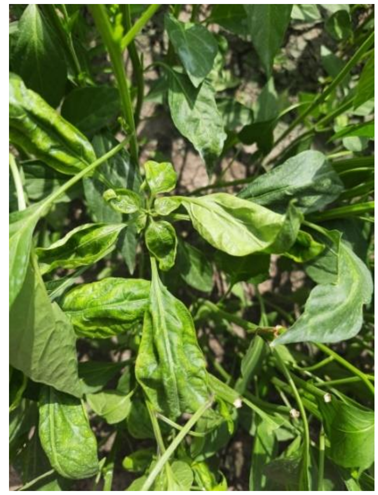

Fig. 5
Gemini virus infection in nursery

Fig. 6
Colonisation of thrips near veins

Fig. 7
Yellow streaking on upper surface of leaf

Fig. 8
Distorted leaf lamina

Fig. 9
Burning of tips of newly emerging foliage

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Screening of tomato cultivars against leafminer, *Liriomyza trifolii* (Burgess) infesting tomato in mid-hills of Meghalaya, India

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Abstract

The present investigation entitled "Screening of tomato cultivars against leafminer, *Liriomyza trifolii* (Burgess) infesting tomato in Mid-hills of Meghalaya" was carried out at the Entomology Research Farm, ICAR Research Complex for NEH Region, Umiam, Meghalaya during 2016 and 2017. Eleven tomato cultivars were screened against leaf miner, *L. trifolii* infesting tomato. The maximum (38.67% and 39.00%) leaf miner infestation were recorded on cultivar Mahy Gotya, while minimum (18.34% and 19.00%) leafminer infestation was recorded on cultivar MT-2 and Selection-1 during the year 2016 and 2017 respectively. None of the cultivars was found to be free from the infestation of leafminer. It was further revealed that MT-2 and Selection-1 were found to be better cultivar against leafminer infesting tomato.

Keywords: Tomato, cultivars, screening, *Liriomyza trifolii*

Introduction

Tomato, *Lycopersicon esculentum* (Miller) is a popular vegetable for its outstanding antioxidant content. It is one of the most important "protective foods" because of its special nutritive value, as the pulp and juice are digestible, mild aperients, promoter of gastric secretion and blood purifier. In India, tomato is cultivated in an area of 882 thousand ha with an average annual production of 18736 thousand tones and productivity of 21.2 t ha^{-1} during 2013- 14 (National Horticulture Board, 2015). Meghalaya is known for production of good quality vegetables among north eastern states (Kumar and Badal, 2004). However, the productivity of tomato is low due to several reasons; the main being the damage caused by insect pests and diseases. Tomato is more prone to insect pests and diseases mainly due to its tenderness and softness as compared to other crops. It is devastated by an array of pests like jassids, aphids, tobacco caterpillar, leafminer, flea beetles, spider mites, and fruit borer (Katroju *et al.,* 2014).

Among the several problems that created obstacles for tomato productivity and quality fruits, insect pests caused heavy losses.

Among them, American serpentine leafminer, *Liriomyza trifolii* Burgess (Diptera: Agromyzidae), a notorious polyphagous pest has recently attained a serious pest status on tomato. The serpentine leafminer is a polyphagous pest feeding on seventy-nine host plants belonging to various vegetables, ornamentals and field crops (Srinivasan *et al.*, 1995). Its severe infestation starts from nursery and continues till fruiting stage resulting in severe yield loss. Its extensive leaf mining activity reduces the photosynthetic rate to about 62% as compared with unmined leaves, leading to adverse effects on young shoot growth and fruit formation which ultimately reduce the yield (Johnson *et al*., 1983). When one fourth of the leaf area was mined, photosynthesis decreased by <1% (Martens and Trumble, 1987). The genus *Liriomyza* contains more than 300 species known in the world. In which, approximately 23 species of *Liriomyza* have been reported as being economically important in which *L. trifolii* is very dominating in vegetable crops like tomato, cucumber, vegetable pea etc. This insect has potential to infest on 250 crop species in India (Sharma and Devindra, 1994). Management of this pest becomes very difficult due to internal mining activity of larvae within the leaf. Nearly 100 per cent leaf miner control is necessary to produce cosmetically marketable crops (Sher *et al*., 2000).

To control these insect pests and to save the crop, pesticides are being used in large quantities. But the continuous and enormous use of same or similar groups of pesticides causes problem of pesticide residues in foodstuff and other environmental contamination. Reducing the chances of chemical residues that may remain in the crop due to excessive use of insecticide is by growing pest resistant cultivars which are effective and environmentally safe component of IPM programme. Host resistance is one of the components in any pest management programme which is economical and safest method for pest management. Hence, development of resistant varieties and their incorporation in IPM schedule is a viable alternative for management of this pest. Keeping the above view in mind, the collected tomato genotypes were screened for their resistance/susceptibility against the leaf miner.

Materials and Methods

To study the response of some promising tomato cultivars against *L. trifolii* a field experiment was conducted at Entomology Experimental field of Indian Council of Agricultural Research (ICAR) Complex for NEH Region, Umiam, Meghalaya during 2016-2017.In this experiment eleven tomato varieties/cultivars were used which were obtained from ICAR-RC for NEH Region, Meghalaya.

Varietal screening

Seeds of eleven varieties, namely, Megha Tomato-2 (MT-2), Megha Tomato-3

(MT-3), H-86, VL-Tomato-4, Selection-1, Selection-2, Selection-3, Arka Vikash, Mahy Gotya, Badshah and Rocky were sown in first week of January in nursery and seedlings were transplanted 45 days after sowing in the main field. Only healthy seedlings were transplanted. The experiment was replicated three times with plot size of 1 m x 3m. No plant protection measures were applied in the experimental field.

The observations were taken by counting the number of infested leaves per plant from randomly selected five tagged plants per plot. The leaf miner infestation was converted into percent infestation by using the formula:

$$\text{Percent infestation (\%)} = \frac{\text{Number of infested leaves}}{\text{Total number of leaves}} \times 100$$

A rating system for fruit damage developed by Kashyap and Verma (1986) was followed for estimating relative resistance/ susceptibility.

Results and Discussions

For the present study, eleven cultivars of tomato *viz*. MT-2, MT- 3, H-86, VL-Tomato- 4, Selection-1, Selection-2, Selection-3, Arka Vikash, Mahy Gotya, Badshah, and Rocky were selected for screening of tomato against major pest of tomato. The data on screening of cultivars against leafminer infestation on number basis are presented in the table below. From the data, it can be seen that none of the cultivars was found to be free from the infestation of leafminer, *L. trifolii*. All the varieties recorded more than 15 percent leafminer infestation for both the years (2016 and 2017) which is similar to the findings of Yadav (2009) who reported that the mean incidence of leafminer *L. trifolii* in different tomato genotypes differed significantly and ranged between 15.25 and 28.51 percent.

During the year 2016, it was found that six cultivars *viz*., MT-3, H-86, Selection-1, Selection-2, Selection-3 and Rocky were moderately susceptible to leafminer infestation with percent damage of 22.50%, 26.33%, 24.67%, 29.34%, 24.00% and 22.67% respectively and four cultivars *viz.*, VL-Tomato-4, Arka Vikash, Mahy Gotya and Badshah were susceptible to leafminer infestation with percent damage of 31.34%, 32.66%, 38.67% and 37.00% respectively. One cultivar MT-2 (18.34%) was found to be moderately resistant to leafminer infestation as shown in table 2. This is similar to the findings of Sarkar *et al*. (2017) who reported that genotype Patherkuchi showed the lowest percentage of leafminer damage with damage percent of 18.11%.

During the year 2017, it was found that four cultivars *viz*., MT-2, VL-Tomato- 4, Selection-3 and Rocky were moderately susceptible to leafminer infestation with percent damage of 23.67%, 29.68%, 26.33%

and 25.68% respectively. This is similar to the findings of Yadav, (2009) who reported that genotypes To - 1831, Swarnalalima and Naina registered leafminer incidence ranging between 25.2 and 28.51 percent. Five cultivars *viz.,* H-86, Selection-2, Arka Vikash, Mahy Gotya and Badshah were susceptible to leafminer infestation with percent damage of 31.33%, 32.67%, 37.67%, 39.00% and 39.34% respectively. Two cultivars *viz*., MT-3 (20.00%) and Selection-1 (19.00%) were found to be moderately resistant to leafminer infestation as shown in table 3. Reddy and Kumar (2004) also reported *L. trifolii* as a major pest of tomato.

From the present study, it can be concluded that none of the tomato genotypes were found to be free from the infestation of tomato leaf miner. However, cultivars MT-2 and Selection-1 were t promising (Tables 2 & 3) and further studies can be initiated to explore their potentiality.

Table 1. Rating system for estimating relative resistance/susceptibility (Kashyap and Verma, 1986)

Sl. No.	Damage level	Rating
1.	No damage	Highly Resistant
2.	0-10.0 per cent fruit damage	Resistant
3.	10.1-20.0 per cent fruit damage	Moderately Resistant
4.	20.1-30.0 per cent fruit damage	Moderately Susceptible
5.	30.1-40.0 per cent fruit damage	Susceptible
6.	40.1 per cent fruit damage and above	Highly Susceptible

Table 2. Screening of tomato germplasm/varieties against tomato leafminer (2016).

Sl. No.	Genotypes/Varieties	Per cent damage (Mean of 10 weeks)	Index of infestation (Plant reaction)
1.	MT-2	18.34	Moderate Resistant
2.	MT-3	21.66	Moderate Susceptible
3.	H-86	26.33	Moderate Susceptible
4.	VL-Tomato-4	31.34	Susceptible
5.	Selection-1	24.67	Moderate Susceptible
6.	Selection-2	29.34	Moderate Susceptible
7.	Selection-3	24.00	Moderate Susceptible
8.	Arka Vikash	32.66	Susceptible
9.	Mahy Gotya	38.67	Susceptible
10.	Badshah	37.00	Susceptible
11	Rocky	22.67	Moderate Susceptible

Table 3. Screening of tomato germplasm/varieties against tomato leafminer (2017).

Sl. No.	Genotypes/Varieties	Per cent damage (Mean of 10 weeks)	Index of infestation (Plant reaction)
1.	MT-2	23.67	Moderate Susceptible
2.	MT-3	20.00	Moderate Resistant
3.	H-86	31.33	Susceptible
4.	VL-Tomato-4	29.68	Moderate Susceptible
5.	Selection-1	19.00	Moderate Resistant
6.	Selection-2	32.67	Susceptible
7.	Selection-3	26.33	Moderate Susceptible
8.	Arka Vikash	37.67	Susceptible
9.	Mahy Gotya	39.00	Susceptible
10.	Badshah	39.34	Susceptible
11.	Rocky	25.68	Moderate Susceptible

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A comparative study of butterfly diversity in varying habitats of urban green spaces

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Abstract

A comparative study of butterfly diversity was conducted in the campus of Dharmaram Vidya Kshetram and Lalbagh botanical garden in Bangalore. The objective of this study was to compare the butterfly diversity between the garden maintained by the campus and a botanical garden. A total of 43 species was recorded belonging to 5 families. Among the recorded families Nymphalidae was found to be higher in number with 20 species. Family Pieridae was found to be the second most abundant with 8 species followed by Hespiiridae (7), Papilionidae (5) and Lyceanidae being the least abundant with only 3 species. The Simpson diveristy index was found to be higher in Dharmaram Vidya Kshetram Campus (0.9) followed by Lalbagh botanical garden (0.8).

Keywords: Butterfly, diversity, Lalbagh.

Introduction

Phylum Arthropoda is considered to be the largest among all the other species in the Animal Kingdom. Arthropods have evolved to survive at very extreme and harsh conditions as they possess characters like high adaptability to changing climatic conditions, living is diverse habitats and a tough exoskeleton to protect them from external harm which allows them to overcome the pressure of natural selection and show high survival rate. Butterflies belong to the Class Insecta and Order Lepidoptera.They are found to be in various colors and patterns. Some of the species exhibit excellent mimicry mechanisms and camouflage themselves among leaves and branches of trees to avoid being attacked by predators. Butterflies play a major role in the process of pollination by helping in the transfer of pollen grains. The technical term given for pollinating butterflies are called Psychophily (Palatty Allesh Sinu, 2016).

Study Area

Site 1: Dharmaram Vidya Kshetram

Dharmaram Vidya Kshetram is an institution for higher education located at DVK road, Bhavani Nagar next to Christ University Hosur Road campus in Bangalore. This campus also is home to various varieties of flora and fauna. It is located at a latitude of 12.5601^0N and a longitude of 77.3624^0E and spread over an area of 100 acres. One of the smallest butterfly and the fifth largest butterfly in the country was recorded in this site. The study area is found to be having flora ranging from small flowering plants to huge coconut trees. The regular watering and maintenance of the greenery invites large number of animals and insect visitors.

Site 2: Lalbagh Botanical Garden

Lalbagh Botanical Garden has a great role in introducing ornamental plants and exotic flowers attracting a wide range of butterflies and insect pollinators. The whole garden serves as a recreational space and attracts tourists from various parts in and around Bangalore. It is located in Mavalli, south Bangalore. The whole area measures to around 240 acres, located a latitude of 12.5707^0N and a longitude of 77.3508^0E housing over 1,000 species of plants. The Band stand area was selected as a region for the study.

Materials and Methods

The survey was conducted over a period of four months spanning from January 2022 to April 2022. Observations were made by making point transects at the area of survey and observations at each transect lasted for 10 minutes (Sevilleja C.G *et al*, 2019). The study was carried out thrice a week between 12PM to 4PM as Butterflies are found to be the most active at the hottest hours of the day. The butterfly species documented were identified using the field guide 'Bengaluru Butterflies' by O.K. Remadevi *et al*, 2018.

Fig. 1. Dharmaram Vidya Kshetram Campus (PC:Google maps)

Fig. 2. Lalbagh Botanical Garden (PC:Google maps)

Results

The analysis of the data collected on both the sites suggested that the area has a rich butterfly diversity along with other Fauna. There was a total of 3643 individuals recorded at Dharmaram Vidya Kshetram Campus and 1139 individuals at Lalbagh Botanical Garden. 43 species of Butterflies belonging to 5 families were analyzed. Family Nymphalidae was the most abundant with 20 species showing 46.51% of participation, Pieridae (8) was the second most abundant with 18.60% of participation followed by Hespiiridae (7) – 16.27%, Papilionidae (5) – 11.62% and Lycaenidae (3) being the least abundant with 6.97% of participation.

The Statistical Analysis of the data was done by using Simpsons Diversity Index which is given as:

$$D = 1 - \frac{\Sigma n(n-1)}{N(N-1)}$$

Where,

n = number of individuals of each species

N = total number of individuals of all species

The diversity of the species observed and the analysis of the data with the Diversity index suggested that the highest number of Butterflies were found at Dharmaram Vidya Kshetram Campus (3643, 0.9) which was followed by Lalbagh Botanical Garden (1139, 0.8).

Table 1. Checklist of Species

Sl. No.	Scientific Name	Common Name	Family	DVK Campus (Number)	Lalbagh (Number)
1	*Graphium agamemnon*	Dakhan Tailed Jay	Papilionidae	278	2
2	*Grapium doson*	Common Jay	Papilionidae	303	5
3	*Junonia iphata*	Oriental Chocolate Pancy	Nymphalidae	108	7
4	*Papilio polytes*	Common Mormon	Papilionidae	93	8
5	*Junonia lemonias*	Chinese Lemon Pancy	Nymphalidae	736	333
6	*Danaus chrysippus*	Oriental Plain Tiger	Nymphalidae	172	49
7	*Neptis hylas*	Indian Common Sailor	Nymphalidae	36	4
8	*Delias eucharis*	Common Jezbel	Pieridae	20	4
9	*Eurema sp*	Grass Yellow Species	Pieridae	363	35
10	*Hypolimnas bolina*	Great Eggfly	Nymphalidae	93	-
11	*Hypolimnas missipus*	Danaid Eggfly	Nymphalidae	79	4
12	*Papilio polymnestor*	Blue Mormon	Papilionidae	73	-
13	*Pelopidas mathias*	Small Branded Swift	Hespiiridae	4	-
14	*Ariadne indica*	Angled Castor	Nymphalidae	13	1
15	*Ariadne merione*	Common Castor	Nymphalidae	16	3
16	*Melanitis leda*	Common Evening Brown	Nymphalidae	9	-
17	*Belenois aurota*	Indian Pioneer	Pieridae	11	7
18	*Elymnias caudata*	Tailed Palmfly	Nymphalidae	10	-
19	*Chilades pandava*	Plains Cupid	Lycaenidae	603	293
20	*Badamia exclamationis*	Brown Awl	Hesperiidae	1	-
21	*Pothanthus sp*	Dart Sp	Hesperiidae	3	-
22	*Lethe europa*	Bamboo Treebrown	Nymphalidae	1	-
23	*Oriens goloides*	Smaller Dartlet	Hespiiridae	1	-
24	*Junonia orithya*	Blue Pancy	Nymphalidae	2	2
25	*Jamides celeno*	Common Cerulean	Lyceanidae	2	1
26	*Telicota bambusa*	Dark Palm Dart	Hesperiidae	1	-
27	*Gangara thyrsis*	Giant Redeye	Hesperiidae	1	-
28	*Mycalesis perseus*	Common Bushbrown	Nymphalidae	1	-
29	*Spalgis epeus*	Oriental Apefly	Lycaenidae	2	-
30	*Appias albina*	Common Albatross	Pieridae	89	36
31	*Euploea core*	Common Crow	Nymphalidae	53	8
32	*Phalanta drury*	Common Leopard	Nymphalidae	19	47
33	*Ypthima asterope*	Common Three Ring	Nymphalidae	149	-
34	*Hebomoia glaucippe*	Sahyadri Great Orange Tip	Pieridae	64	81
35	*Hasora chromus*	Banded Awl	Hespiiridae	3	-
36	*Junonia hierta*	Yellow Pancy	Nymphalidae	1	11
37	*Acraea terpsicore*	Tawny Coaster	Nymphalidae	1	30
38	*Tirumala limniace*	Blue Tiger	Nymphalidae	10	-
39	*Papilio demoleus*	Lime Butterfly	Papilionidae	4	29
40	*Catopsilia pyranthe*	Mottled Emigrant	Pieridae	207	131
41	*Catopsilia pomona*	Common Emigrant	Pieridae	8	-
42	*Junonia almana*	Peacock Pancy	Nymphalidae	-	7
43	*Pareronia hippia*	Indian Wanderer	Pieridae	-	1

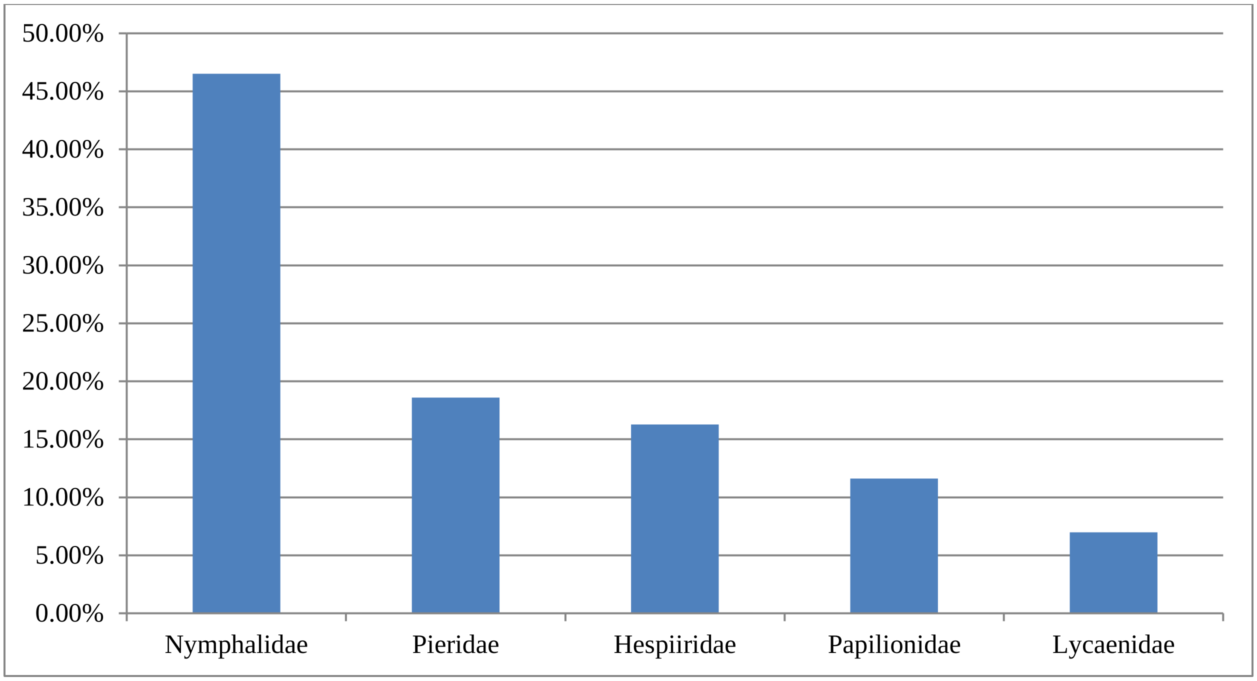
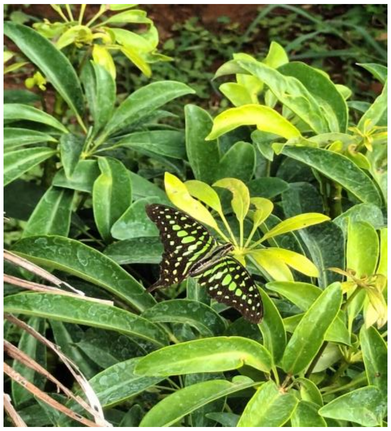
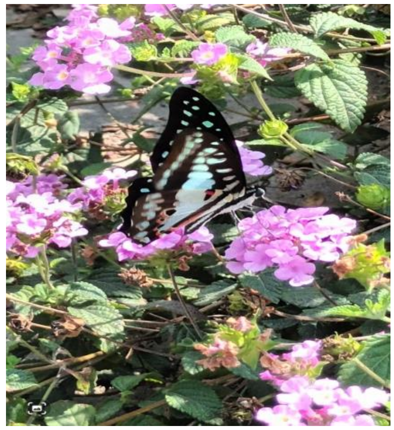
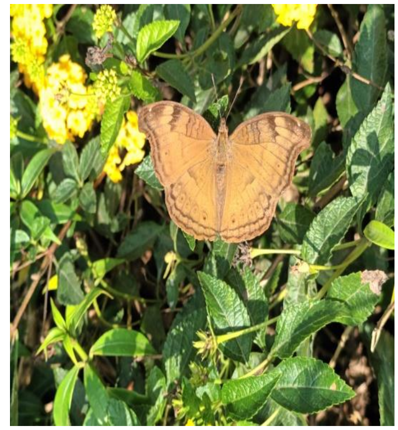


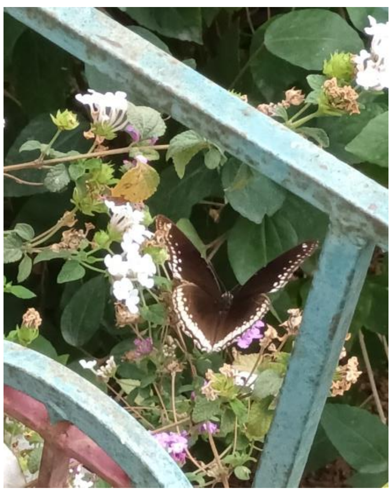
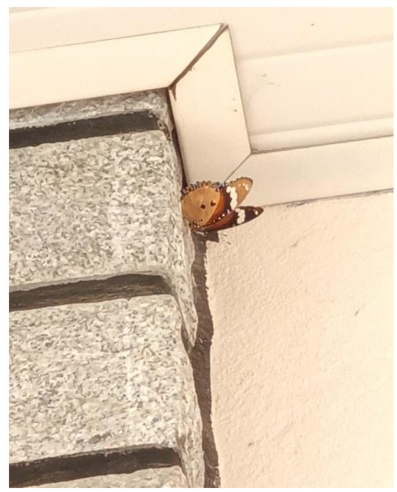
Fig. 3. Graphical Representation of Family comparison

Table 2. Simpson Diversity Index of the Study Area

Sl. No.	Study Area	Total Number of Butterflies	Simpson Diversity Index
1	Dharmaram Vidya Kshetram Campus	3643	0.9
2	Lalbagh Botanical Garden	1139	0.8

Table 3. Pictures of species

 Dakhan Tailed jay	 Common Jay	 Chocolate Pancy
 Common Mormon Male	 Common Mormon Female	 Lemon Pancy
 Plain Tiger	 Common Sailor	 Grass Yellow sp

 Mottled Emigrant	 Common Emigrant	 Great Eggfly Male
 Great Eggfly Female	 Danaid Eggfly Male	 Danaid Eggfly Female
 Small Branded Swift	 Angled Castor	 Common Castor

 Common Evening Brown	 Pioneer	 Brown Awl
 Pothanthus sp	 Smaller Dartlet	 Blue Pancy
 Common Cerulean	 Dark Palm Dart	 Giant Redeye
 Tailed Palmfly	 Plains Cupid	 Common Bushbrown

 Apefly	 Common Albatross	 Common Leopard
 Common Three Ring	 Sahyadri Great Orange Tip	 Common Banded Awl
 Yellow Pancy	 Tawny Coaster	 Lime Butterfly

Discussion

Family Nymphalidae are commonly called brushfooted butterflies and range from being medium to large in size. Each member in the family vary in appearance and are considered to be good fliers. White and yellow butterflies come under the family Pieridae. With the sizes ranging from small to medium the males are brightly colored and females are dull and larger in size. Family Hespiiridae consists of species active during the dawn and dusk. They are commonly called Skippers. Having a small body size, they completely differ from other butterflies in terms of body details. The world's largest butterflies called birdwings come under the family Papilionidae. They are commonly called Swallowtails as they have tailed hindwings with various patterns like forked and sword tails. They are considered to be very fast and restless. Small and blue butterflies come under family Lycaenidae. They have tufts in their hind wings which is a mechanism to protect themselves (O.K Remadevi *et al*, 2018). The Statistical data of the study suggested that the Simpson diversity index was found to be greater in the Dharmaram vidya kshetram campus (3643, 0.9) followed by Lalbagh botanical garden (1139, 0.8). Species belonging to five families were documented during the study. With a distribution of over 6000 species worldwide, Nymphalidae is the most diverse and distributed family In this study since twenty species out of fourty three belonged to Nymphalidae, it is considered to be the most diverse. With other families being moderately distributed, only three species were found under Lyceanidae making it the least abundant. This approves that both the sites that were studied are rich in butterfly distribution. This survey shows that Butterflies are not only found in a botanical gardens but also can be found in very large numbers in an enclosed green space like an educational institution if the greenery and plant population is well maintained. The reduced number of individuals in the botanical garden when compared to the educational institution can be due to continuous cutting down trees and making it a social space for visitors and tourists and conversion of plantation areas into lawns and walking paths.

Conclusion

Butterflies are diurnal and take active participation in the process of pollination. They are not as effective as bees in the pollination process but surely contribute in the promotion of Agriculture and Horticulture. (O. K Remadevi.*et al*, 2018). Continuous cutting down of trees and removal of garden areas to make public amenities are affecting these insect populations. Butterflies long for a green and colorful environment that can provide them with nutrients. Non availability of food and lack of a green atmosphere are causing these insects to decrease in population and migrate to other places in search of proper sources. Taking small steps on daily basis to conserve them will help humans in horticultural activities and also promote the increase of pollinator population (Nicholas

Tew *et al*, 2022) Trees are found to be producing a greater number of fruits by insect pollinators than trees which self pollinate. A large variety of fruits and vegetables in demand are produced by insect pollination. Decline in their number will be a huge pressure to the artificial pollination technology to produce the same amount of horticulture products as that is being produced by insect pollinators. Butterfly gardening and growing of floral plants and trees should be taken up as a small initiative by Educational Institutions and Research Centers. This might promote awareness about pollination and its biological importance. This will help young students and researchers empower the need and significance of greenery conservation. A natural habitat like a butterfly garden can be maintained to allow flowering plants and butterflies to co-exist with eachother. Butterflies can see a greater number of colors when compared to other insects (Kentaro Arikawa, 2017), so a colorful garden with a variety of floral plants will attract these beauties. Using harsh pesticides on these plants should be avoided as they might chase away these butterflies and other useful insects. This type of gardening activities can give the real joy of being a true nature conservationist. (O.K Remadevi *et al.*, 2018).

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Survey of insect pests of summer pearl millet in Gujarat

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Introduction:

Pearl millet is a major cereal crop in northwestern India. The crop is grown in very harsh, arid, dry climatic areas having high temperature and low and erratic rainfall. Its use as food is declining but its use as cattle feed, poultry feed and source of starch in the alcohol industry is increasing. Its fodder is an important source of animal feed particularly in dry months when alternative sources of feed are not available. In the last decade, pearl millet was also grown under irrigation in the summer months. Gujarat state has the highest area under summer pearl millet not only among the northwestern states but also at the all-India level. Yields of summer pearl millet are much higher since it is grown under irrigation and its grain quality is also superior.

It is generally believed that pearl millet, either grown as mono crop or mixed crop or in relay cropping system has hardly had any serious problems. However, perusal of literature on insect pest of this crop gives quite a different picture. Twenty six insects and two non-insect pests were found feeding on pearl millet (Balikai, 2010). Out of these, shoot fly, *Atherigona varia socata,* stem borer, *Chilo partellus* Swinhoe and ear head worm, *Helicoverpa armigera* are comparatively more serious pests attacking the crop. Now a day's fall army worm (*Spodoptera frugiperda*) is also emerging as a new pest in pearl millet (Patange *et al*., 2021) in Aurangabad and Jalna districts of Maharashtra in *kharif* pearl millet. The literature on insect-pest incidence in *kharif* pearl millet is available. However, no study of pest situation in summer pearl millet is available. Sometimes minor pest becomes major pest. Hence, the study was under taken during summer 2021.

Material and methods

The study/survey was conducted in pearl millet at farmer's fields (72 field visits and 8 virtual (video calling), total 80 fields) during summer 2021. It was carried out in 7 districts/blocks *viz.*, Jamnagar, Junagadh, Rajkot, Surendranagar, Kheda, Anand and Banaskantha covering 21 tehsils by the team of scientists consisting of entomologist of Pearl Millet Research Station, Junagadh Agricultural University, Jamnagar, all in Gujarat, India. The survey was conducted at vegetative as well as at ear head stage. The date of survey, name of village, name of tehsil, name of district/block was noted. The area and variety of pearl millet sown by the farmer was also recorded. Incidence of insect-pest was worked out from taking the observations of 20 plants. The population of insect pests infesting pearl millet crop was recorded from 5 randomly selected plants or ear heads per field. For shoot fly, stem borer & fall army worm, per cent damage was worked out. Whereas, for *Helicoverpa armigera* the larval counts were taken into consideration per five ear heads. The grey weevil damage score was done by scaling 0 to 10.

Results and discussion

The details of incidence have been given in table-1.

a. **Shoot fly (*Atherigona approximata*, Malloch):** The shoot fly per cent incidence ranged from 0.0 to 10.00% with an average of 1.93%. The highest incidence was recorded at Aya (Tehsil- Sayla, District-Surendranagar) in pearl millet variety Pioneer at ear head stage.

b. **Stem borer (*Chilo partellus*, Swinhoe):** The stem borer per cent incidence ranged from 0.0 to 10.00% with an average of 0.73%. The highest incidence was recorded at Moti banuagar (Tehsil & District Jamnagar) in pearl millet variety Akshay kranti at ear head stage.

c. ***Helicoverpa armigera*:** The larval population ranged from 0.0 to 5.0 larvae/ 5 ear heads with an average of 0.70 larvae/5 ear heads at ear head stage. The highest larval population was recorded at Mahelav (Tehsil & District-Anand) in pearl millet variety Manglam 252 and at Jhakhar (Tehsil- Lalpur, District-Jamnagar) in pearl millet variety Rasi 502 at ear head stage.

d. **Fall army worm (*Spodoptera frugiperda*):** The FAW damage incidence ranged from 0.0 to 20.00% with an average of 2.28%. The highest incidence (20.00%) was observed at Sunav (Tehsil-Petlad, District-Anand) in variety MP 7333.

e. **Grey weevil [*Myllocerus subfasciatus* (Guerin-Meneville)]:** The grey weevil damage score ranged from 0.0 to 5.0 with an average of 0.84. The highest damage (5.0 Damage score) was observed at Sandesar (Tehsil & District-Anand) in variety Avani 444.

The overall incidence of various insect-pests was low to moderate. Shoot fly incidence was observed in all the districts and it was highest in Jamnagar district (2.17%) with an average of 1.93%. Stem borer incidence was also observed in all the districts and it was again highest in Jamnagar district. The number of *Helicoverpa armigera* larvae per 5 ear heads was higher in Jamnagar & Junagadh district. During summer 2021, fall army worm was observed at farmer's fields in Anand (5.21%), Junagadh (7.50%) and Kheda (2.08%) districts. The overall average incidence of fall army worm was 2.28%. Grey weevil damage was observed high in Jamnagar district (1.44).

Conclusions

From the above study done on survey of major insect-pests in pearl millet during summer 2021 it was found that there was huge difference in the intensity of different insect pests at different locations. In summer pearl millet, apart from shoot fly, stem borer and *Helicoverpa armigera*, fall army worm and grey weevil damage were observed. Hence, it is important to monitor these pests from time to time in summer season.

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Table-1: Showing the details of District-wise/Block-wise insect-pest situation at farmers fields (Summer pearl millet, 2021)

Districts	**GPS locations**		**No. of Tehsils**	**No. of fields surveyed**	**Shoot fly %**	**Stem borer %**	***Helicoverpa larvae* /5 EH**	**FAW % damage**	**Grey weevil damage score**
	Latitude	Longitude							
1. Anand	22.554029	72.948936	2	24	**2.17**	0.21	0.79	5.21	0.96
2. Banaskantha	24.415827	72.635379	1	1	1.00	1.00	0.00	0.00	0.00
3. Jamnagar	22.470701	70.057732	5	9	1.56	**2.22**	**1.00**	0.00	**1.44**
4. Junagadh	21.515471	70.456444	2	2	1.00	1.00	**1.00**	**7.50**	1.00
5. Kheda	22.750650	72.684669	3	12	1.67	0.25	0.83	2.08	0.17
6. Rajkot	22.308155	70.800705	2	5	1.40	1.80	0.60	0.00	1.40
7. Surendranagar	22.728392	71.637077	5	27	1.92	0.35	0.35	0.00	0.62
			Overall Mean		**1.93**	**0.73**	**0.70**	**2.28**	**0.84**

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Trap catches of *Bactrocera* species in selected urban sites in Bengaluru

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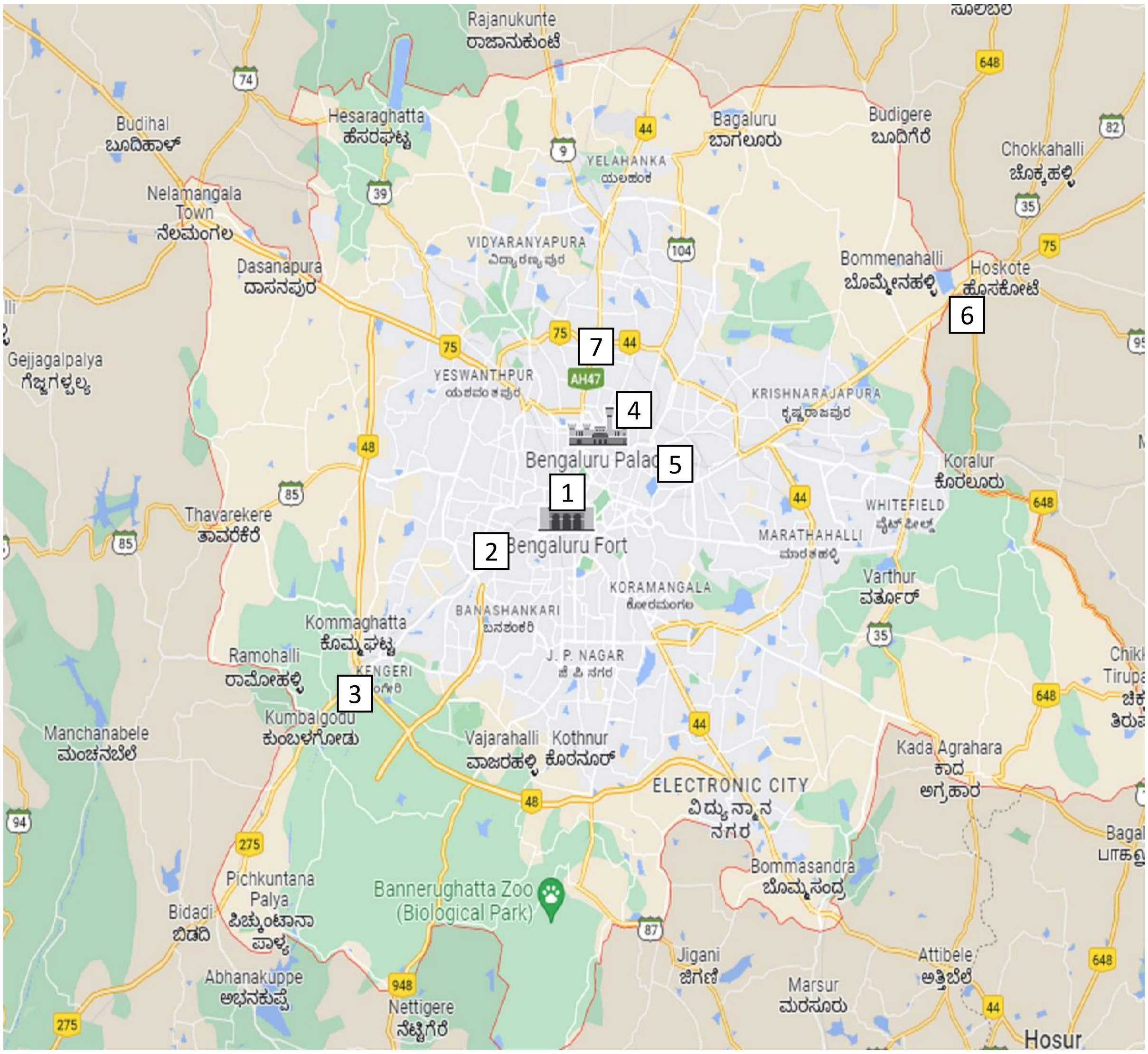
The fruit fly tribe Dacini is a species-rich taxon within Tephritidae (Diptera) and contains around a fifth of all known species in the family, all Dacini members are frugivorous or florivorous and about 10% of the 932 currently recognized species are pests of commercial fruits and vegetables (Camiel *et al*. 2018). The risk of fruit flies especially *B. dorsalis* spread to new areas is mainly through infested fruits facilitated by its concealed nature of infestation, wide host range, high fecundity, food adaptability of the larvae, short life cycle, rapid dispersal ability (can fly50–100 km) and possible influences of climate change (Peng, 2011; CABI, 2013). Fruit fly dispersal may be adventive (the long-distance human assisted transport) or appetitive dispersal by natural means after been transported into previously uninfested areas and how a population disperses after an introduction has occurred (Dominiak, 2012). With the aforesaid eco-biology of the fruit-fly pests an attempt was made to collect flies from different urbanised sites in Bengaluru to assess adventive or appetitive mode of dispersal.

The study was conducted by setting up methyl eugenol fruit-fly traps at different locations *viz*., St Joseph's College (Autonomous) (now St. Joseph's University) 12.92°N, 77.59°E, Chamrajpet 12.95°N, 77.56°E, Kengeri 12.92°N, 77.48°E, Holy Ghost church 13.00°N, 77.61°E, Indiranagar 12.97°N, 77.63°E, Hoskote 13.07°N ,77.78°E and Kaval Byrasandra 13.02°N,77.63°E (Map 1) during February-March, 2021. Methyl Eugenol traps obtained from IIHR (Indian Institute of Horticultural Research), Hessaraghatta were set up at the mentioned locations for a period of three to five days. The traps were set for 5 days at the St Joseph's College campus as it was easily accessible and for 3 days at other locations at a range within 0.5 km of a mango tree.

A total of 71 flies were collected and was identified as *Bactrocera dorsalis* in St. Joseph's College (Autonomous) but the other locations had comparatively less number of flies. *Bactrocera correcta* was found in Kengeri and *Bactrocera zonata* was collected in Kaval Byrasandra (Table 1). Three species of *Bactrocera* were identified among which *Bactrocera dorsalis* was more dominant in number compared to the other 2 species trapped *viz*., *Bactrocera zonata* and *B. correcta.*



Map 1. Trap catch sites, Shanthinagar (1), Chamrajpet (2), Kengeri (3), Holy Ghost church (4), Indiranagar (5), Hoskote (6) and Kaval Byrasandra (7). (Source: https://www.google.co.in/maps) **(PC:Google maps)**

In the order of intensity of damage to various crops, *B. dorsalis*, *B. zonata* followed by *B. correcta* and dorsalis-zonata-correcta complex is an important fruit fly pest complex in India known to attack similar hosts (Kapoor, 2002; Irsad and Haseeb, 2019). All three are reported to cause a considerable yield loss on different crops in and around Bengaluru (Verghese *et al.* 2002: Madhura and Verghese, 2004). Other species like *B. cucurbitae* (Coquillett) too are recorded inflicting damage to horticultural crops (Kumar *et al*. 2006). *B. dorsalis* has the potential to establish adventive populations in various tropical and subtropical areas (Qin *et al*. 2018). Bengaluru Urban district is encapsulated by peri-urban agriculture zones and transition zones between urban and rural areas serving as repositories of biodiversity. Horticulture products to the city are managed *via* market supply avenues like Expand both, supermarkets and through farmers directly or indirectly from across the state. The trap catches in the backdrop of aforesaid factors perhaps indicate both adventive and appetitive modes of dispersal into the city.

Table 1. Trap catches (total numbers) during the study

Sl. No.	Location	*Bactrocera dorsalis*	*B. zonata*	*B. correcta*
1	Shanthinagar	81	-	-
2	Chamrajpet	20	-	-
3	Kengeri	10	-	2
4	Holy Ghost Church	8	-	-
5	Indiranagar	27	-	-
6	Hoskote	4	-	-
7	Kaval Byrasandra	34	2	-

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Bio-efficacy of newer molecules against whitefly (*Bemesia tabaci*, Genn.) infesting cucumber (*Cucumis sativus* L.)

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Abstract

Two field experiments were conducted at the Department of Entomology, College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar during kharif, 2016 and rabi, 2016-17 to evaluate the bio-efficacy of eight insecticides against whitefly, *Bemesia tabaci* Gennadius infesting cucumber *Cucumis sativus*. Both kharif and rabi seasons revealed that 15 days after spraying (DAS) of insecticides, a moderate level of suppression (below 70%) of whitefly population/5 leaves was observed. But all the insecticides evaluated except fipronil (7.67) recorded significantly lower population of whitefly/5 leaves at 15 DAS (3.67-5.67) compared to control (14.56) during kharif, 2016 registering 54.17 to 69.32% reduction over control. On the contrary, Fipronil and Chlorantraniliprole (5.67-7.67) registered significantly higher population of whitefly/5 leaves at 15 DAS compared to other insecticides (3.78-5.33) and control (10.44). The level of suppression in the best treatments viz., Tolfenpyrad, Indoxacarb, Flubendiamide, Spinosad, Cartap hydrochloride and Acephate at 15 DAS during rabi, 2016-17 ranged from 50.21-65.37% over control.

Keywords: Cucumber, whitefly, insecticide, kharif, rabi

Introduction

India being the second largest producer of vegetables in the world next to China cultivates a number of gourd crops. Cucumber (*Cucumis sativus* L.) is one of the important gourd crops grown throughout India. The crop is attacked by a good number of insect pests and mites, of which the whitefly, *Bemesia tabaci* Genn. is one. It attacks the crop during both vegetative and reproductive stages and is a vector of yellow mosaic virus of cucumber crop affecting the vigour and resulting in drastic reduction in yield. Farmers usually rely heavily on the use of conventional synthetic insecticides (Bacci *et al*., 2007; Wafaa and AL-Kherb, 2011; Misra, 2012; Bajpai *et al*., 2014; Golmohammadi *et al*., 2014; Patra *et al*., 2016) for its control, although IPM technologies for its management in other crops are available. Hence, some newer insecticides belonging to different chemical groups have been evaluated in the field against this pest in the present study.

Materials and Methods

Two field experiments were conducted in a randomized block design during kharif, 2016 and rabi, 2016-17 to evaluate the bio-efficacy of some newer insecticides against the whitefly at the experimental farm of Department of Entomology, College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha. It is located at a latitude of 20^{o} 15''N and longitude of 85^{o}52''E, with an altitude of 25.9 m above MSL and 64 kms west of Bay of Bengal. Cucumber variety "Machaar" was grown in plots of size 3.5m x 4m during both seasons with a spacing of 1.5m x 1.5m between pits. The crop was grown with package of practices recommended for the state except plant protection. There were nine treatments replicated three times. The insecticides treatments included, T_1 = Tolfenpyrad 15% EC @ 150 g a.i./ha, T_2 = Fipronil 5% SC @ 50 g a.i./ha, T_3 = Indoxacarb 14.5% SC @ 72.50 g a.i./ha, T_4 = Flubendiamide 480 SC @ 78.70 g a.i./ha, T_5 = Chlorantraniliprole 18.5% SC @ 30.83 g a.i./ha, T_6 = Spinosad 45% SC @ 75 g a.i./ha, T_7 = Cartap hydrochloride 50% SP @ 375 g a.i./ha, T_8 = Acephate 75% SP @ 375 g a.i./ha and T_9 = untreated control. The pesticide treatments were imposed first on appearance of the pest, the second and third sprays were done at 20 days interval with a hand compression sprayer using 500 litres of spray fluid/ ha. Observations were recorded in the morning hours (8.00 A.M.) on the adult population of whiteflies per 5 leaves at random from each treatment plots at 1 day before spraying (DBS) and at 5, 10 and 15 days after spraying (DAS) both during *Kharif* and rabi seasons. The data were subjected to square root transformation before statistical analysis following Gomez and Gomez (1984) to test the significance of treatment effects and arrive at a meaningful conclusion.

Results and Discussion

The whitefly population per 5 leaves did not vary significantly (8.77-11.11) during kharif, 2016 depicting a uniform distribution of the pest throughout the experimental plot on 1 DBS (Table 1). All the insecticides evaluated controlled whitefly up to 15 DAS to some extent compared to untreated control (UTC). Among the insecticides $T_{6,}$ $T_{7,}$ T_8 proved superior in suppressing whitefly population (0.67-1.33/ 5 leaves) compared to other insecticides evaluated and control (12.89/5 leaves) on 5 DAS during kharif, 2016. On 15 DAS the same treatments proved superior in supressing whitefly population (3.67-5.4.33/5 leaves) moderately (65.80-68.07% reduction over control) except Fipronil (7.67/5 leaves) and control (14.56/5 leaves).

The whitefly population per 5 leaves did not vary significantly (10.16-11.06) during rabi, 2016-17 depicting a uniform distribution of the pest throughout the experimental plot on 1 DBS (Table 2). All the insecticides evaluated controlled whitefly up to 15 DAS to some extent compared to untreated control (UTC).

On 5 DAS during rabi 2016-17 only 2 treatments *viz.,* T_7 and T_8 proved superior in suppressing whitefly population (1.33/5 leaves) compared to other treatments (2.67-4.67/5 leaves) and control (9.22/5 leaves). On 10 DAS, all the insecticides (2.44-3.78/5 leaves) except fipronil and flubendiamide (2.89-5.44/5 leaves) registered significantly lower populations of whiteflies compared to control (10.11/5 leaves). On 15 DAS, moderate suppression of whitefly population /5 leaves (50.21-65.37% reduction over control) was observed in tolfenpyrad, indoxacarb, flubendiamide, Spinosad, cartap and acephate (3.89-4.88) compared to other treatments and UTC (10.44).

Superior control of whitefly- a vector of yellow vein mosaic virus was recorded in all the chemicals evaluated except Fipronil, compared to control during kharif, 2016 with moderate level of suppression (54.17 to 69.32%) and rabi, 2016-17 (47.23-65.37%). Bajpai *et al*. (2014) observed maximum reduction of 92.66 to 99.22 and 93.10 to 98.61% control of whitefly in okra during rabi and kharif, respectively with the application of a new molecule tolfenpyrad 150 g a.i./ha which confirms the present finding in cucumber with a reduced magnitude of control during kharif, 2016 and rabi, 2016-17. Bacci *et al.* (2007) reported 80% mortality of whiteflies with the application of Cartap in the sweet potato crop at field rate. Bokan *et al.* (2016) reported spinosad 45 SC @ 135 g a.i/ha was found effective in reducing whitefly population in chilli. Bharati and Shetgar (2016) found spinosad 0.005% to be most effective insecticide in suppressing whitefly population upto 14 days after application in brinjal, which is in line with the present finding.

Thus, it may be concluded from the present study that newer chemicals like Tolfenpyrad 15% EC @ 150 g a.i./ha, Indoxacarb 14.5% SC @ 72.50 g a.i./ha, Flubendiamide 480 SC @ 78.70 g a.i./ha, spinosad 45% SC @ 75 g a.i./ha, along with conventional chemicals like cartap hydrochloride 50% SP @ 375 g a.i./ha and acephate 75% SP @ 375 g a.i./ha could register more than 50% suppression of the whitefly population 15 days after application on cucumber during both kharif and rabi seasons. Fipronil 5% SC @ 50 g a.i./ha and Chlorantraniliprole 18.5% SC @ 30.83 g a.i./ha did not give satisfactory control of the whitefly adults up to 15 days of application.

Table 1. Bioefficacy of different chemicals against whitefly at Bhubaneswar during kharif, 2016

Tr. No.	Treatments	Dose g/ml, a.i/ha	No. of whitefly/ 5 leaves, *Kharif*, 2016				Reduction over control (%) At 15 DAS
			1 DBS	5 DAS	10 DAS	15 DAS	
T_1	Tolfenpyrad 15% EC	150	9.77 (3.20)	3.33 (1.96)	4.67 (2.27)	5.33 (2.41)	58.37
T_2	Fipronil 5% SC	50	10.44 (3.31)	6.66 (2.68)	7.00 (2.74)	7.67 (2.86)	43.94
T_3	Indoxacarb 14.5% SC	72.5	9.77 (3.20)	3.77 (1.22)	4.44 (2.62)	3.33 (2.41)	58.37
T_4	Flubendiamide 480 SC	78.7	9.33 (3.14)	3.85 (2.09)	4.78 (2.80)	5.44 (2.44)	55.51
T_5	Chlorantraniliprole 18.5% SC	30.83	9.44 (3.15)	5.77 (2.50)	6.33 (2.61)	5.67 (2.48)	54.17
T_6	Spinosad 45% SC	75.0	9.66 (3.19)	0.67 (1.08)	2.44 (1.71)	4.33 (1.20)	65.80
T_7	Cartap hydrochloride 50% SP	375	9.40 (3.15)	1.33 (1.35)	2.78 (1.81)	3.78 (2.07)	69.32
T_8	Acephate 75% SP	375	8.77 (3.04)	1.00 (1.22)	2.00 (1.58)	3.67 (2.04)	68.07
T_9	Control	Water spray	11.11 (3.41)	12.89 (3.66)	13.07 (3.76)	14.56 (3.88)	
SE(m)±			(0.09)	(1.11)	(0.15)	(0.15)	
CD (P=0.05)			NS	(0.33)	(0.46)	(0.44)	
C.V (%)				9.41	11.28	10.24	

Figures in the parentheses are $\sqrt{(x+0.5)}$ transformed values, DBS = Day Before Spraying, DAS= Days After Spraying

Table 2. Bioefficacy of different chemicals against whitefly at Bhubaneswar during rabi, 2016-17

Tr. No.	Treatments	Dose g/ml, a.i/ha	No. of whitefly/ 5 leaves, rabi, 2016-17				Reduction over control (%) at 15 DAS
			1 DBS	5 DAS	10 DAS	15 DAS	
T_1	Tolfenpyrad 15% EC	150	10.58 (3.33)	3.33 (1.96)	3.78 (2.07)	4.67 (2.27)	56.54
T_2	Fipronil 5% SC	50	11.06 (3.40)	4.67 (2.27)	5.44 (2.44)	7.67 (2.86)	31.71
T_3	Indoxacarb 14.5% SC	72.5	10.24 (3.28)	2.67 (1.78)	2.89 (1.84)	4.88 (2.31)	53.07
T_4	Flubendiamide 480 SC	78.7	10.54 (3.32)	2.67 (1.78)	2.89 (1.84)	4.88 (2.31)	50.21
T_5	Chlorantraniliprole 18.5% SC	30.83	10.58 (3.33)	2.89 (1.84)	3.78 (2.07)	5.67 (2.48)	47.23
T_6	Spinosad 45% SC	75.0	10.16 (3.25)	2.89 (1.84)	3.33 (1.95)	4.78 (2.30)	53.67
T_7	Cartap hydrochloride 50% SP	375	10.54 (3.32)	1.33 (1.35)	2.67 (1.78)	3.78 (2.07)	64.69
T_8	Acephate 75% SP	375	11.06 (3.40)	1.33 (1.35)	2.44 (1.71)	3.89 (2.10)	65.37
T_9	Control	Water spray	10.28 (3.28)	9.22 (3.12)	10.11 (3.26)	10.44 (3.31)	
SE(m)±			(0.11)	(0.06)	(0.06)	(0.08)	
CD (P=0.05)			NS	(0.18)	(0.18)	(0.24)	
C.V (%)				9.19	10.93	9.56	

Figures in the parentheses are $\sqrt{(x+0.5)}$ transformed values, DBS = Day Before Spraying, DAS= Days After Spraying

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Mycophagy in Coccinellidae: A review

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Introduction

Coccinellids commonly known as lady bird beetles are the most familiar insects to everyone from their childhood. It is well known that these fascinating insects are voracious predators of sternorynchous hemipterans. They even have a history of the first successful classical biological control involving the introduction of the vedalia beetle, *Rodolia cardinalis* (Mulsant), to control cottony cushion scale, *Icerya purchasi* Maskell), on citrus plants in California during the late 1880s (Caltagirone and Doutt, 1989). Despite the stereotype of the family Coccinellidae as zoophagous few of them are phytophagous (Epilachnini and genus *Bulaea*), a lesser-known fact that certain coccinellids are mycophagous feeding on various fungi either as facultative or obligate feeders. The term mycophagy refers to a wide range of nutritional modes adopted by insects in which fungi are selectively favored as a food source (Murrin, 1996).

Origin of mycophagy in coccinellids

The evolution of Coccinellidae includes feeding transitions that span kingdoms of life (plant, animal, and fungus) and trophic levels (e.g., herbivore and primary carnivore). Phytophagy within the Epilachninae and mycophagy (both facultative and obligative) within the Coccinellinae have evolved from a common coccidophagous ancestor (Giorgi *et al*., 2009) that, in turn, may have been derived from an ancient mycophagous group, the Cerylonid series, from which all coccinellids are descended (Sasaji, 1968; Leschen, 2000; Giorgi *et al*., 2009; Sutherland and Parrella, 2009). Several others believe that the mycophagy may have been associated with the early evolution of aphidophagy (Lawrence and Hlavac, 1979; Crowson, 1981; Thomas, 1993). The ancestral ladybird beetles first consumed the sooty molds of ascomycotina developed on the honey dew excreted by hemipteran insects and later evolved as the predators of hemipteran insects (Leschen, 2000).

Coccinellids feeding on fungi

Facultative feeders

Mycophagy is known to occur in many clades of Coccinellidae. Facultative feeders largely are observed in the aphidophagous coccinellids of tribe Coccinellini where they feed on fungi as non-prey foods in their diet. Many researchers reported the presence of fungal spores in the gut analysis of coccinellids. The first establishment of consumption of fungi by coccinellids was by Forbes (1881, 1883) who examined the gut contents of agricultural coccinellids. Together with the pollen, the gut contents comprised approximately half of the estimated volume of fungal material in all the eight species of coccinellids examined. About 90% of food observed in the guts of *Coccinella novemnotata* was *Ustilago* and *Helminthosporium* spores. Triltsch (1997) reported the frequent occurance of the *Alternaria* (80%) and *Puccinia* (20%) fungal spores in the gut contents of *Coccinella septumpunctata* adults. Molecular analysis revealed the presence of powdery mildew fungal spores in the guts of *C. septumpunctata* when fed either on powdery mildew or on a mixed diet of aphid and powdery mildew revealing the utilization of fungus in their diet (Radonjic *et al*., 2018).

The polyphagous coccinellids of tribe Tytthaspidini with two genera, *Tytthaspis* Crotch and *Bulaea* Mulsant often feed on fungi and compliment their diet with pollen and some plants. Turian (1969) gave the first detailed information on food of *Tytthaspis sedecimpunctata* revealing that it feeds on Erysiphaceae and proposed the term "micromycetophagy" to describe the feeding behavior on lower fungi (micromycetes). Ricci (1982) discovered the fungal spores of *Alternaria* and *Cladosporium* Link ex Fries, along with pollen, Acari, and Thysanoptera remnants, in the gut contents of *Tytthaspis sedecimpunctata* (L.).

Obligate feeders

The obligate mycophagous species of the genera *Psyllobora*, *Vibidia*, *Illeis* and *Halyzia* belong to the tribe Halyziini feed on lower fungi, especially those belonging to Erysiphales (Vandenberg, 2002; Ślipiński & Tomaszewska, 2010). Both the grubs and adults are known to reduce the spore load on the leaves of crop plants by feeding on the fungal patches (Fig. 1). Turian (1969) also observed *Psyllobora vigintiduopunctata* larvae and adults feeding on various Erysiphaceae. However, Culik *et al*. (2011) published the first report of *Psyllobora rufosignata* feeding on the rust fungus *Phakopsora euvitis* which was also the first record of any Halyziini species feeding on any species of Basidiomycota.

Morphological adaptations

The morphology of the mandibles in coccinellidae varies with the feeding habit (Kovar, 1996; Samways *et al*., 1997). Most mycophagous species exhibit morphological feeding adaptations that facilitate the collection, scraping and consumption of spores from fungal material, similar to those rakes and combs used in pollinivory (Lawrence, 1989). Specifically, the members of the Halyziini possess a series of secondary teeth on the ventral apical tooth which varies with the species. The prostheca of the mandibles extends ventrally from the base of the mandibles and fringed with setae which are well developed in *Tytthaspsis sedecimpunctata* (Ricci, 1982; Kovar, 1996; Samways *et al*., 1997). Other facultative feeders lack these morphological adaptations to fungal feeding, yet this does not negate the importance of fungus in their life histories.

Fungus as olfactory cues

Mycophagous ladybirds are attracted to the "moldy" odorants which are the fungal volatiles emitted by the powdery mildew infected plants and these cues can play important roles in ladybird foraging behavior. *P. vigintimaculata* beetles showed strong preference to characteristic odors released by squash plants infected by powdery mildew especially to 1-octen-3-ol, which was the most abundant of the characteristic fungal compounds identified (Tabata *et al.,* 2011). Olfactometer bioassay of powdery mildew affected barley plants evoked a positive behavioral response in *C. septumpunctata* compared to the odor of uninfected controls (Radonjic *et al.,* 2018).

Fungus as nutrition to coccinellids

Fungus is a highly nutritious food source for many entomophagous coccinellids and fungal specialists. The most abundant constituent in most fungal tissues is water (85% by weight) except spores. Carbohydrates and proteins in fungi are the abundant source for the insect growth and development. Lipids, sterols, vitamins and other inorganic compounds of the fungi are also utilized by these insects (Mueller *et al*., 2001; Chang and Miles, 2004). However, the entomphagous coccinellids when fed alone with fungus may be lethal for their survival as they lack the digestive enzymes required for the digestion of cellulose and lignin and are unable to acquire sufficient nutrition (Lundgren, 2009). Fungus when fed as mixed diet along with aphids can increase their survival rate. In *C. septumpunctata*, 56% mortality was observed when fed with fungus alone on third day while the survival increased to 80% when fed along with aphids on sixth day (Radonjic *et al*., 2018).

Fungal Benefits from coccinellids

Mycophagous coccinellids aid in the mechanical transmission of fungus. Adherence of fungal strands and spores to the body of coccinellids aid in their dispersal. It's also worth noting that being eaten by coccinellid isn't always fatal for spores as they pass undigested due to lack of sufficient digestive enzymes and acts as vector for transmission. *Hippodamia convergens* carry the spores of the fungal pathogen, *Discula destructive* on their bodies and also consumes the fungus, thereby the spores are passed in their frass infecting new hosts (Colby *et al*., 1995, 1996; Hed *et al*., 1999). However, the coccinellids of Halyziini use powdery mildew fungi as a nutritive source and thought to be digested (Sutherland and Parrella, 2009).

Feeding potential of mycophagous coccinellids

The obligate mycophagous coccinellids have a great potential in the control of powdery mildew diseases. A handful of studies were carried out on the feeding potential of various mycophagous coccinellids in different crops speculating the possible utilization of these biocontrol agents in the control of powdery mildew diseases. *Psyllobora bisoctonotata* grubs cleared 92 per cent of the conidial density of *Erysiphe cichoracearum* infested okra leaves when fed to the beetles (Soylu and Yigit, 2002). The efficiency of *I. cincta* and *I. bistigmosa* was evaluated against the fungus *Phyllactinia corylea* causing powdery mildew in mulberry, where the infection decreased with the release of 5 pairs of adults per each plant. In addition, the beetles were efficient in controlling the disease when compared to fungicides (Krishnakumar and Maheswari, 2004). Sutherland and Parrella (2006), used a linear model to determine the consumption of powdery mildew by a single larva of *Psyllobora vigintimaculata*, where the model estimated that an average larva was able to clean 6.32 ± 3.3 cm^2 of leaf area of spores and hyphae during its development. The observations of Illahi *et al*. (2011) indicated that the five beetles of *Halyzia tschitscherini* have the potential to consume 96.40 cm^2 of powdery mildew infection in mulberry within 60 hours. Thite *et al*. (2013) reported the incidence of *I. cincta* on powdery mildew of *Dalbergia sisso* and *Xanthium strumarium* and also found that the larval stages were more voracious feeders of powdery mildew anamorphs than adult beetles. The strong association of powdery mildew of sunflower and the occurance of *I. cincta* has been established as the severity of disease incidence increased in India (Jagadish *et al*., 2006). The feeding potential of *I. cincta* was evaluated against *Erysiphe cichoracearum* causing powdery mildew of sunflower (Dharshini and Jagadish, 2018). Adult and third instar are the efficient feeders where they were able to clear mycelial area upto 4-8cm^2 within 36-48 hrs. Thus, by considering the feeding potentiality of adults and grubs of mycophagous coccinellids, the beetles may be employed effectively in biological control of powdery mildew diseases.

Sutherland *et al*. (2010) evaluated the effect of five fungicides used in grape vineyards of California and biocontrol agents *Bacillus subtilis*, *Stretomyces lydicus* on *P. vigintimaculata* under laboratory and field conditions where fungicides like wettable sulfur, trifloxystrobin and myclobutanil showed significant mortality in both the adults and larvae of the insect while the biocontrol agents proved to be nontoxic. Choudhury *et al*. (2020) reported the tritrophic movement of the systemic insecticide (imidacloprid) from the roots of a treated plant, into a plant pathogenic fungus, and these proved to be lethal to the mycophagous beetles when consumed. Various pesticides used in the cucumber cultivation of Korea for the control of pests are found to be toxic to the *I. koebele* which is a widely distributed and potential biocontrol agent against powdery mildew diseases in Korea (Lee *et al*., 2017). These pesticides also affected the pupation rate and fecundity of the adults. Hence, it is important to consider the effects of pesticide applications on mycophagous coccinellids to promote their utility in potential biological control of fungal diseases.

Considering the rapid spread of the disease and profuse sporulation of powdery mildew fungi, biological control using Halyziini alone may not be adequate for intensive agriculture. It may be possible to integrate these mycophagous coccinellids involving augmentation and conservation of these natural enemies along with the usage of compatible and safe fungicides and adopting cultural practices to control disease as part of an integrated disease management (IDM) program.

Conclusion

Mycophagy has evolved as a feeding transition in coccinellids. Fungi are consumed as a part of non- prey foods or as primary foods. Members of Halyziini have special morphological adaptations to rely on fungal feeding. Although numerous instances of fungal feeding in coccinellids are reported, still a deeper understanding is required in many aspects such as nutritional ecology, phylogenetics, mechanical transmission, chemical ecology and in particular, the possible utilization of the coccinellids for the biological control of fungal diseases.

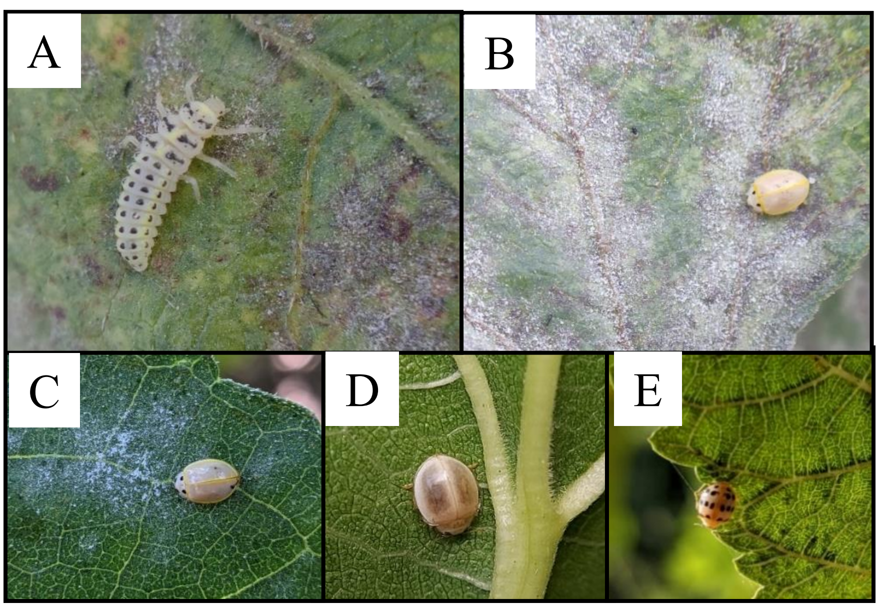

Fig. 1: A) Grub and B) Adult of *Illies cincta* feeding on powdery mildew of green gram and C) sunflower D) Adult of *Illies* sp. and F) *Psyllobara* sp. in mulberry

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Sperm dimorphism in lepidopteran insects

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Introduction

One of nature's most diverse cell types is the sperm, which plays a prominent role in sexual reproduction in animals. Sperm is the only fundamental reproductive unit in the male reproductive system that is transferred from male to female. A gamete (sex cell), also known as a sperm cell or spermatozoa, is formed in the male reproductive system. It is a cell that moves about with only one purpose: to fertilize a female egg.

Sperm dimorphism in insect is scientifically a process known as dichotomous spermatogenesis; in all the males of a species produce two main types of contemporaneous spermatozoa with distinct differentiation paths, structures, and DNA compositions. The usual haploid sperm that fertilizes the eggs is one type. It is conceptually comparable to the generalized type of spermatozoa seen in most animal species (Baccetti, 1991). The other kind, sometimes referred to as parasperm (Jamieson, 1987), is different in form and function, either being anucleated or possessing an imbalanced set of chromosomes. This type of spermatozoa does not fertilize the egg, and its function in many systematic groupings is unknown. There are only these two types of spermatozoa produced by dichotomous spermatogenesis; there are no intermediate morphs.

The structure of insect sperm (as ancestral type of hexapod sperm) consists of an elongated cell with a three- or two-layer acrosome on top of the nucleus and a posterior functioning flagellum with an unmodified 9+2 axoneme. Two mitochondria are found in the flagellum in addition to the axoneme (Dallai *et al.*, 2016). The condition of male ejaculates containing two or more different types of sperm is known as sperm polymorphism. Insect species belonging to the orders Diptera, Hemiptera, Hymenoptera, Lepidoptera, and Coleoptera have four different types of sperm polymorphism (Jamieson *et al.*, 1999; Presgraves *et al.*, 1999; Swallow and Wilkinson, 2002; Chawanji *et al.*, 2005).

Differences in the sperm structure among insect orders

The research conclusion, is based on phylogenetic interpretation of sperm characteristics and their constituent parts, indicates that structural differences have been seen in the sperm of various insects, which are arranged according to acroneme and axoneme of flagellum. Order-wise the number of axoneme varies in flagellar portion *viz.*, Collembola (9+2 axoneme), Diplura (9+9+2 axoneme), Paraneoptera (9+9+2 axoneme), Ephemeroptera (9+9+0 axoneme), Strepsiptera (9+9+2 axoneme) and Polyneoptera (9+9+2 axoneme) (Dallai *et al*., 2016).

Sperm polymorphism in different insect orders

The polymorphism is occurrence of various forms within a population, colony, or within a single organism's life cycle. In almost all taxa, sperm exhibit strikingly different evolutionary morphologies. Some organisms that reproduce sexually have variations in their male solitary sperm. Sperm polymorphism is a specific sort of variation or polymorphism found in special group of insects. The phenomena of male ejaculates containing two or more different types of sperm are known as sperm polymorphism.

Four different forms of sperm polymorphisms, which vary depending on different reproductive and chromosomal features, have so far been identified in several insect orders. Sperm polymorphism is a type of physiologically adapted behaviour. Below is a list of the different types of sperm polymorphism.

1. *Drosophila* fruit flies (Beatty & Burgoyne, 1971), Diopsidae stalk-eyed flies (both Diptera) (Presgraves *et al*., 1999), and cicadas (Chawanji *et al*., 2005) (Hemiptera) are examples of the first kind. Some species of these insects produces spermatozoa in more than two sizes wherein they differ only in the length of the sperm head and/or tail but not in terms of ploidy (i.e. number of chromosomes).

2. Some pentatomid insects (Hemiptera) and carabid ground beetles (Coleoptera) are examples of the second kind, in which a typical haploid and enormous polyploid spermatozoa are documented (Schrader, 1960; Bouix, 1963; Jamieson *et al*., 1999; Swallow and Wilkinson, 2002), although additional studies are necessary to confirm the presence of sperm polymorphism in carabids because a different result also is reported (Takami and Sota, 2007).

   Other insect species have not been found to exhibit the same kind of sperm polymorphism as like *Scarites terricola* ground beetle. Unlike other instances, *S. terricola's* sperm dimorphism is unusual with the heads of multiple spermatozoa are "glued" together while the tails are free to move in one form. The other form is free as single spermatozoa and has an extended tail and an abnormally huge head. In Ringer's solution, both types are motile (Sasakawa and Toki, 2008).

3. A hymenopteran species that has multiple forms of spermatozoa, including two that differ only in the spiral orientation of the

spermatozoa's helical structure, represents the third type (Lee and Wilkes, 1965).

4. Lepidoptera, which includes butterflies and moths, is the fourth kind. In this type, anucleated shorter spermatozoa (apyrene) are produced in addition to usually nucleated spermatozoa (eupyrene), making up the most well-studied group in terms of sperm polymorphism. (Swallow and Wilkinson, 2002)

Sperm dimorphism in lepidopteran insects

The Lepidoptera is the group of animals with dichotomous spermatogenesis that is most well-known. Meves (1903), in a stunning work hypothesized at the very beginning of the twentieth century, accurately and in great detail the process at the cytological level. He was the first to disclose that moths and butterflies produce two types of sperm. Katsuno (1977) claims that Toyama's (1894) study of spermatogenesis in the commercial silk moth, *Bombyx mori* was the first publication to note the dichotomous spermatogenesis of lepidoptera, but a careful examination of the text and figures of Toyama's paper shows no evidence that he recognized the distinction between eupyrene and apyrene meiosis or the resulting presence of two kinds of sperm.

Sperm polymorphism in lepidopteran leads to formation of two kinds of sperm *viz*., eupyrene (nucleate) and apyrene (anucleate) spermatozoa. Sperm dichotomy is present in all species of lepidoptera with an exception in two species of primitive Micropterigidae (Sonnenschein and Hauser, 1990). In the lepidopteran order, dimorphism with eupyrene and apyrene sperm is distinctive. The former have a prolonged glycocalyx made up of blade-like structures termed laciniate appendages and are functional (eusperm). These appendages and the nucleus are absent in apyrene parasperm. Sperm polymorphisms were described in snails as early as 1836 by von Siebold which was described by Sakai *et al*. (2019) and have subsequently been reported in invertebrates and vertebrates.

Eupyrene sperm bundles have needle-shaped sperm nuclei that are placed in the anterior section of the elongating cells and contain the normal haploid spermatozoa to fertilize eggs. These bundles extrude cytoplasm by a process called "peristaltic squeezing." Sperm bundles from apyrene are shorter and entirely devoid of nuclear material. In the final stages of spermatogenesis, the cytoplasm and spherical micronuclei in the center of the apyrene sperm bundles are squeezed out (Chen *et al*., 2020).

Role of apyrene sperm in fertilization

Eupyrene and apyrene sperms are produced in the same testicular follicles, but eupyrene spermatogenesis occurs before apyrene spermatogenesis. The major function of nucleated eupyrene sperm is to fertilize eggs. Different functions of apyrene sperm is being proposed including their role in improved fertilization during sperm competition; defense against spermicidal conditions; assisting the eupyrene sperm in spermiation or transport; regulation of sex ratios and the provision of nutrients for females or other sperm; facilitating dissociation of eupyrene sperm bundles; serving as a source of nutrients for the eupyrene sperm, the female, or the zygote (Higginson and Pitnick, 2011) But in many animals, there is still insufficient evidence to support their functions. In addition, it was observed that the apyrene sperm carry out a number of unique functions. Apyrene sperm delayed female remating in *Pieris napi*, protecting male reproductive investments and contributing to improved fertilization success in the context of sperm competition.

Predictive pathway for the formation of eupyrene sperm and apyrene sperm

Both nucleated fertile eupyrene sperm and anucleate non-fertile parasperm, also known as apyrene sperm, are produced during spermatogenesis in lepidopteran insects (moths and butterflies). Sex lethal gene (*Sxl*) mutants were used in genetic investigations, which demonstrated the gene's essential role in the correct morphogenesis of apyrene sperm. Similarly, using *Sxl* mutants clearly demonstrates that apyrene sperms are necessary for eupyrene sperm migration from the bursa copulatrix to the spermatheca.

The formation of apyrene sperm occurs after the formation of eupyrene sperm. According the explanation quoted by Sakai *et al*. (2019) the alternative splicing isoforms *Bm-Sxl*-L and *Bm-Sxl*-S are produced during transcription of *Bm-Sxl* gene. 336 amino acid protein, *Bm-Sxl*-L encodes eight exons and an open reading frame (ORF). Contrarily, *Bm-Sxl*-S lacks the second exon and encodes an ORF that is truncated at the N terminus by 46 amino acids. Apyrene sperm meiosis begins prior to the spinning stage, which corresponds to 5- to 6-day-old fifth instar larvae in this strain, and continues throughout the pupal stage, whereas meiosis for eupyrene sperm primarily occurs during the early fifth instar in *Bombyx mori*.

High expression of *Bm-Sxl*-S was observed immediately before the spinning stage (pupal stage), corresponding well with the developmental stage for the transition from eupyrene to apyrene spermatogenesis. Apyrene sperm are considered an apomorphic trait in advanced lepidoptera. Moreover, expression patterns of *Sxl* in five representative lepidopteran species from different families showed that *Bm-Sxl*-S is mainly expressed at the pupal stage (i.e., the apyrene sperm formation period). Therefore, *Bm-Sxl*-S is likely involved in apyrene sperm formation.

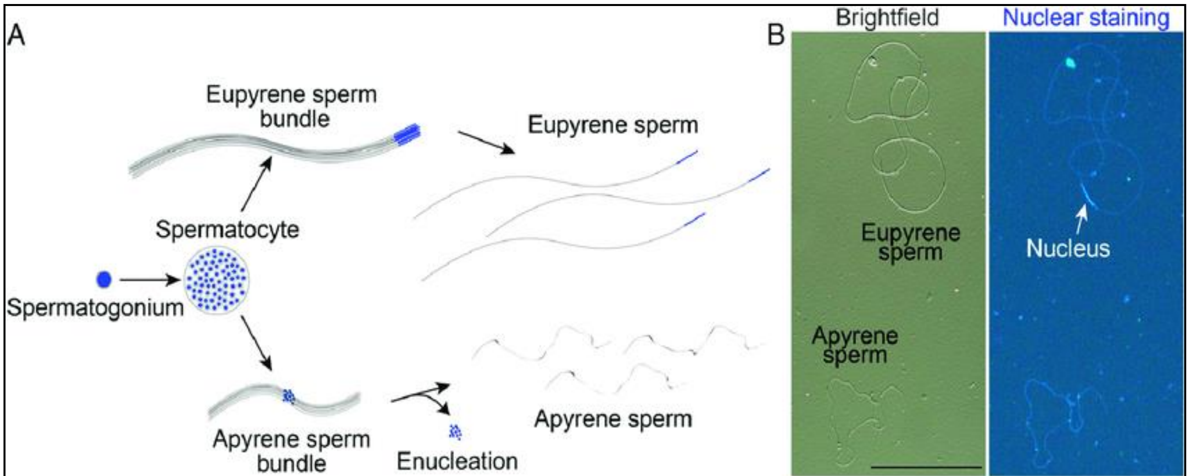

Fig. 1 Formation of Eupyrene and apyrene sperm bundle (Sakai *et al*., 2019)

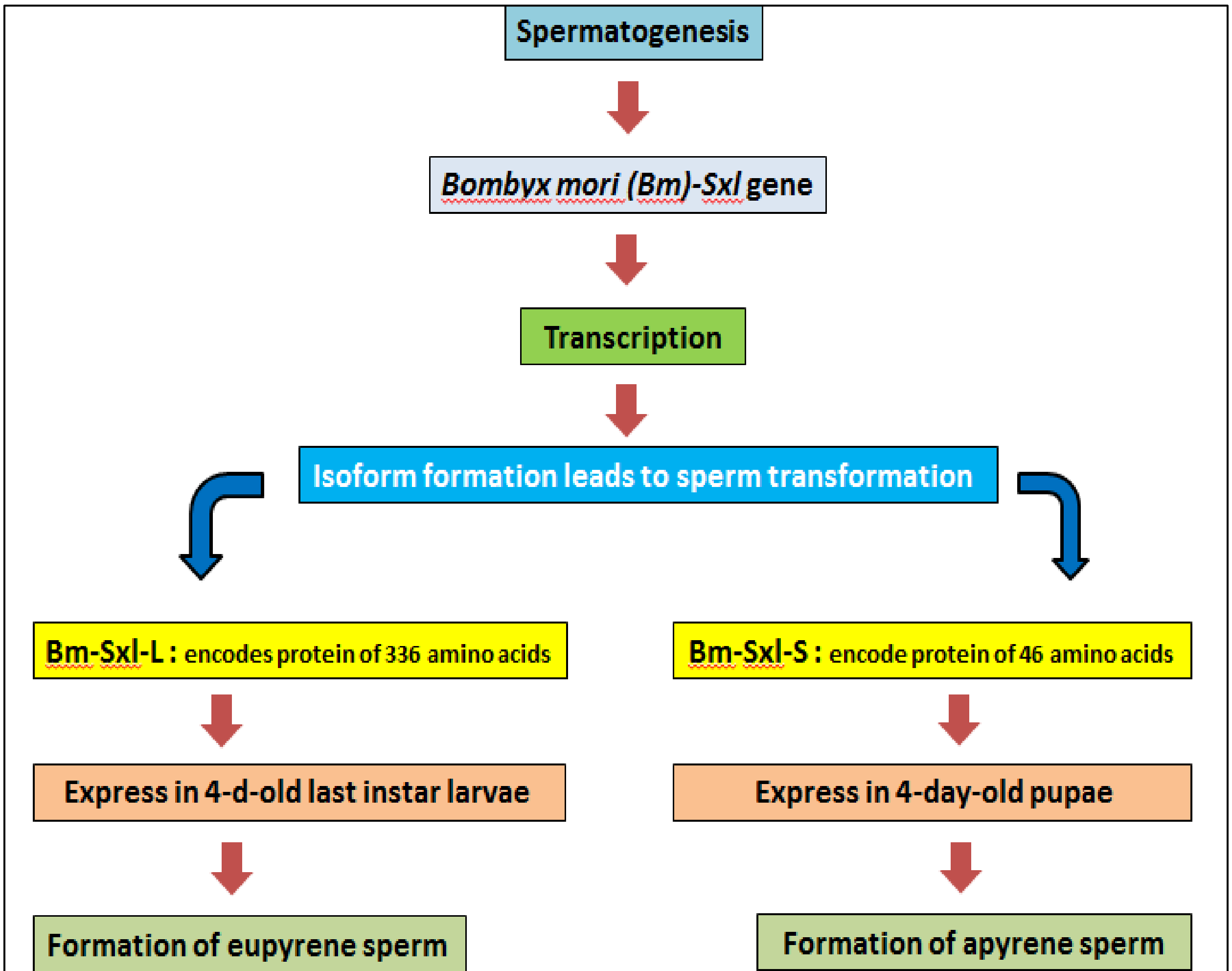

Fig. 2 Formation of Different sperm bundles in *Bombyx mori* (Derived: Sakai *et al*., 2019)

Some research finding says that the formation of Eupyrene sperm bundle depends upon another gene called as *BmPnldc1* (*B. mori poly (A)-specific ribonuclease-like domain-containing 1*) which regulates the development of eupyrene sperm. When a binary transgenic CRISPR/Cas9 system was employed to create a representative line of BmPnldc1 from BmPnldc1- sg12× nos-cas9, although the generation of apyrene sperm was unaffected, the disruptions of BmPnldc1 were accompanied by a decrease in BmPNLDC1 protein expression in BmPnldc1 testes and deformation of eupyrene sperms (Chen *et al*., 2020).

Evidences of interrelationship between apyrene and eupyrene sperm

A test was carried out using the *Bombyx mori, Bm-sxl* gene. Additionally, mutants were created utilizing the TALENS genome editing method (Sakai *et al*., 2019). The findings showed that, firstly, the eupyrene and apyrene spermatozoa had morphological differences that were not visible in spermatogonia but that can be seen in primary spermatocytes and were clearly visible at the meiotic metaphase. Secondly, *Bm-Sxl*-S may control the transition from eupyrene to apyrene spermatogenesis in primary spermatocytes because it is expressed in these cells' capacity to differentiate into either apyrene or eupyrene sperm.

Thirdly, the male-specific sterility of *Sxl* mutants with defective apyrene sperm was reversed by the insertion of functional apyrene sperm, indicating that apyrene sperm is required for fertilisation in *B. mori*. Additionally, it was shown that *Sxl* mutants ejaculated eupyrene sperm into the bursa copulatrix but none of these sperm appeared in the spermatheca. According to these findings, eupyrene sperm must migrate from the bursa copulatrix to the spermatheca with the help of apyrene sperm.

Another experiment was conducted by the Mongue *et al.,* (2019) by taking the monandrous Carolina sphinx moth and the highly polyandrous monarch butterfly based on population genetic analyses evidence to check the adaptive evolution in fertilizing sperm and results revealed that; Initially, instead of directly influencing the outcome of female remating, non-fertilizing sperm may be utilized to postpone it and lessen the likelihood of sperm competition. The majority of the proteins that were discovered were shared by the two cell types (Apyrene and eupyrene sperm cells), the set of proteins were exclusive to eupyrene sperm, and finally the smallest set of proteins that were only present in apyrene sperm and by delaying female remating, apyrene sperm may play a passive role in lowering the risk of competition.

Conclusion

The physiology of reproduction in lepidopteran insects depends on sperm cell dimorphism in addition to sperm structure. Both of these two sperm cells, eupyrene and apyrene work together in the reproductive system. Although apyrene sperms do not have the role of fertilizing, they are necessary for the long-term fertilisation of eupyrene sperm, which is why they have an impact on the mobility and survival of eupyrene sperm.

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Insect-world's best kept secret: A tale of silk and webspinners

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Introduction:

The fascinating world of insects never fails to amaze us. The reason lies in the interesting behaviour of various insects and the amazing substances they secrete during their life cycle. Among the various beneficial products known to be produced by insects, silk enjoys a prominent position. When anybody says "silk", generally most people tend to connect it with spider silk or the cocoon silk of the domesticated silkworms (*Bombyx mori*), which has been coveted for textiles for millennia. It is from this species that we have learnt themost about silk manufacturing. But as interesting as it sounds, the production of silk can be found in 17 insect orders having 23 lineages based on their production, phylogenetic relationships, and molecular structures of the proteins they contain (Sutherland *et al*., 2010). It is secreted by the insects at some point in their life cycle for various purposes, such as bristletails (sperm transfer), caddisflies (foraging), lacewings (egg stalk production), lepidopterans, and hymenopterans (cocoon and nest building). Apart from these, the webspinners remain a very unique group which can produce silk both in the nymphal and adult periods, unlike others.

Webspinners (Order: Embioptera):

Webspinners belong to the taxonomic order- Embioptera (Greek. *embios*: "lively", *pteron*: "wing"). They are a tiny group of primitively social, poly-neopteran insects, comprising nearly 300 known species from a possible 2000 existing species worldwide (Ross, 2009). They build nest-like galleries on or under the tree bark, rocks, and logs, and sometimes in leaf litter, which serves as a habitat in addition to giving protection against impending predators. They show parental care, which can be classified as "sub-social" and they dwell mostly in the tropics. They have a flexible, thin body that allows fast movements and U-turns in narrow areas. The flexible antennae that avoid tangling in silk and the wings with few veins that fold along a crease running perpendicular to their length also act as adaptations for the life beneath silk walls (Ross, 1970).

Silk glands and sexual dimorphism:

The characteristic feature of Embioptera is the enlarged fore tarsus, which contains numerous silk glands that manufacture fine, strong silk. Because of their location and position beneath the epidermis, the glands are also called dermal glands. Another distinctive feature in Embioptera is the phenomenon of sexual dimorphism. Males and females of this order are visually distinct and can be distinguished morphologically. While nymphs and adult females have normal orthopteroid mandibles, adult male's mandibles are modified considerably to be elongated forceps like those used for clinging females during copulation. The compound eyes can also vary between the sexes, which are sharply curved and larger in males as compared to females. The cerci present at the terminal end of the abdomen are asymmetrical in males as an adaption to their reproductive behaviour.

Silk spinning mechanism:

Embioptera's spinning machinery is made up of a huge number of separate glands that secrete silk into the reservoirs they surround. A secretory channel transports the secretion to the basitarsus' ventral surfaces, from where it is released by silk ejectors. There is a significant positive relationship between body length and the volume of silk reservoirs, as revealed from the analysis of contrast scores of body length and silk gland measurements (Busse *et al*., 2015). It is interesting to note that the silk spinning process in Embioptera is "passive" *i.e*.- pressure-driven and produced by external mechanical stimuli, as there is no special internal organ or musculature for ejecting the silk (Busse *et al*., 2019). The process is supported by specialised behaviours like avoidance of contact with the substratum during forward locomotion. Further, the intricate spinning processes can also be differentiated between males and females, as seen in the case of *Aposthonia ceylonica* when documented with ethograms and discriminant analysis of time spent on various behavioural actions (Edgerly *et al*., 2012).

Properties of silk:

Thanks to their tropical habitat, the silken colonies of webspinners are exposed to the rain on a daily basis, which warrants investigation of their properties upon reaction with water. Studies on interactions between silk and water revealed that silks with larger fibre diameters had greater contact angles when they interacted with water. After being exposed to water, a greater number of hydrophobic amino acids showed permanent changes in hydrophobicity and water adhesion capabilities, transforming silk into film and ultimately slipping off the water particles (Stokes *et al*., 2018). Their molecular architectures might be used to inspire the creation of a material having a hydrophobic property that alters its physical characteristics when wet.

Conclusion and future prospects:

Silk refers to protein filaments secreted by a variety of arthropod lineages. It has reawakened attention in recent years, to duplicate its extraordinary mechanical qualities using modern biotechnology. Though many insects secrete silk, Embioptera stands out for its eccentric characteristics. In Embioptera, silk spinning is performed by a complicated behavioural mechanism with relatively simple anatomy. Webspinners spin around their bodies in a highly characteristic spinning step, releasing silk that is nature's "finest known insect silk". Technological advancements have prompted a renewed interest in producing finer fibres for application in nanoscale medical and optical devices. The webspinners remain one of the least understood orders within the class "Insecta". Discovering a suitable method for understanding the complex behaviour of silk-spinning in this order in a simpler manner is still a great task, which can add tremendously to the scant information that exists in the literature at present. A growing interest in creating bio-nano materials in recent years has also paved the way for the disclosure of many more secrets of this order, which has remained nature's "best-kept secret".

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Limb regeneration in coccinellids

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Ladybirds (Coleoptera: Coccinellidae), also called ladybugs and ladybird beetles, are considered as beneficial because they are predators of aphids, mites, whiteflies, scale insects *etc*. Worldwide, nearly 6,000 species of ladybirds are known. Eggs of ladybird beetles are elongate-ovoidal in shape. Larvae are mobile and in some species are protected by waxy secretions. Cannibalism of eggs, larvae and pupae is common, especially when prey is scarce. Pupae are adecticous obtect type. Adults are oval shaped that can be yellow, pink, orange, red, or black in colour. They are usually marked with distinct spots. Their length ranges from about 0.8 mm to over 18 mm depending upon species. Females are generally larger than males (Anon., 2014).

Limb regeneration

Limb regeneration is the process of re-growth of lost body parts in an organism (Saxena *et al.*, 2016). It is reported in 36 genera of 11 orders of insects, including Blattodea, Phasmatodea, Ephemeroptera, Odonata, Orthoptera, Hemiptera, Diptera, Lepidoptera, Coleoptera *etc*. Regeneration in arthropods can occur only during the process of moulting when the epidermis separates from the cuticle. Wound healing takes place just immediately after amputation, while full regeneration will take place during the moult.

Types of regeneration

(1) Physiological regeneration: In which replacement of constant loss of many kinds of cells due to wear and tear caused by day-to-day activities**.** (2) Reparative regeneration: During reparative regeneration lost parts are repaired or replaced. (3) Autotomy: Self multiplication of body part which is broken off on being threatened by a predator. Wu *et al*. (2015) reported three phenotypes in leg regeneration *viz*. (1) no regeneration (2) partial regeneration and (3) complete regeneration. Maruzzo and Bortolin (2013) reported four levels of regeneration potential *viz*., (1) lack of regenerative potential (mite) (2) poor regenerative potential (scorpion) (3) good regenerative potential (black widow spider) and (4) very good limb regenerative potential (cockroaches).

Modes of regeneration

Das (2015) described two modes of regeneration: epimorphosis and morphollaxis. Epimorphic regeneration involves the formation of a specialized and transient structure called a blastema. The regenerating blastema is a mass of dedifferentiated cells, obtained through the loss of cellular specialization, with the ability to proliferate and re-differentiate into all cellular components of the lost structure. During morphallaxis, insect regenerates by reorganizing the remaining tissues following an injury or loss of body parts, requiring little or no cell division.

Mechanism of limb regeneration

Epimorphosis mode of limb regeneration has been divided into 4 general stages, which involved (1) wound healing (2) blastema formation, (3) blastema proliferation and (4) subsequent re-patterning of the de-differentiated tissue (Wu *et al*. 2015).

Effect of limb regeneration on coccinellids

Growth parameters

Wu *et al.* (2015) observed that the regeneration frequency in *Coccinella septempunctata* (seven spotted ladybeetle) was greater in half ablation as compared to complete ablation and it decreased with increasing instar, but it was unaffected by the thoracic location of the ablated leg and the side of the body to which the leg was attached. Wang *et al*. (2015) reported that regenerated *Harmonia axyridis* (Asian ladybeetle) adults spent more time during pupation and male as well as female were heavier than unregenerate and control adults. Saxena et al. (2016) revealed that the site of amputation influenced the degree of regeneration in *Menochilus sexmaculatus* (Zig-zag ladybird) adults. Distal amputation of forelimb led to more regeneration than proximal ones, and amputation in the fourth instar led to more regeneration than the third instar. Abdelwahab *et al*. (2017) revealed that regenerated beetles (*H. axyridis*) spent longer time in pupation, and fresh body weight of emerging females was lower than that of controls.

Reproductive parameters

Wang *et al.* (2015) found that *H. axyridis* females preferred to mate with regenerated males as compared to unregenerated and control males in choice tests. They further found that females mating with regenerated males produced more fertile eggs than unregenerate and control males. Abdelwahab *et al*. (2017) reported that reproductive parameters of *H. axyridis* were unaffected by different pair wise crosses of control and regenerated adults. However, Wu *et al*, (2018) reported that the *C. septempunctata* females paired with leg-regenerated males laid a significantly high number of eggs as compared to that paired with normal male.

Effect on progeny

Wang *et al*. (2015) observed that progeny of female mated with leg regenerated male had higher immature survival rate as compared to unregenerated male in *H.*

axyridis. Abdelwahab*et al*. (2017) did not find a significant difference for the incubation period, pupal period and male fresh weight in the progeny of *H. axyridis* produced by different pair-wise crosses of control and regenerated adult beetles. Whereas, female fresh weight of progeny was significantly higher, if any one or both of the parents had regenerated as compared to that of control parents.

Cost of limb regeneration

According to Wu *et al*. (2018) costs of limb regeneration are: (1) high pupation period (2) decrease foraging ability (3) decrease grasping ability (4) decrease sensory capability (5) decrease consumption rate (6) decrease competitive ability.

Conclusion

Regeneration is a developmental process of re-growth of lost body part. Reparative type of regeneration takes place in coccinellids through epimophosis mode. Regeneration increases pupation time, pupal weight, fecundity and egg viability (in some cases). Females prefer to mate with limb regenerated males over un-regenerated and control males. Female fresh weight of progeny of limb regenerated coccinellid was higher as compared to that of control parents.

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Forensic entomology: what insects tell about crime?

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Forensic entomology is a branch of forensic science, which utilizes insects and their arthropod relatives that dwell in decomposing remains, as scientific evidence to aid in legal investigations. Medicolegal, urban and stored product forensic entomology are the three branches of forensic entomology. Medicolegal forensic entomology focuses on utilising arthropod evidence on human remains in solving crimes (Hall, 1990). The insect fauna present on the corpse can be very good evidence in criminal investigation. Vertebrate corpses are excellent food sources for a more or less specialized insect community. Insects are attracted to the corpse immediately after death (Smith, 1986; Haskell *et al*., 1997) and lay eggs on it, and these insect evidences may shed light on different aspects of the crimes. In order to interpret a crime scene, it is important to know which species of insects are infesting the body and about their habits and environmental requirements. Hence, proper identification of insect and other arthropod species of forensic importance is the most crucial part in the forensic entomology

Many insects are attracted to certain stages of decomposition of animals and they will not occur simultaneously on a cadaver, but in a more or less predictable chronological sequence, known as insect succession (Megnin, 1894). Diptera and Coleoptera are the main groups of insects associated with the decomposition process (Carvalho and Linhares, 2001). Dipterans are the primary decomposers to arrive at a dead body, the most common being the species belonging to families Calliphoridae (blow flies) (Fig. 1), Sarcophagidae (flesh flies) and Muscidae (house flies). However, Coleopterans are generally encountered during the later stages of decomposition (Anderson, 2015). Other insect orders having forensic importance include Lepidoptera, Hymenoptera, Anoplura and Dictyoptera. (Goff, 1991). Corpse-associated arthropods can reveal many forensically important facts *viz*., post mortem interval, presence of drugs and toxins in the corpse, genetic profile of an unknown body etc.

Post-mortem interval (PMI) refers to the time between death and discovery of a corpse. By determining the age of developing insects on a body (Fig. 2), it is possible to estimate the time when insects first colonized the body, rather than the actual time of death. This determination would become possible with precision, as each developmental stage in insects has its temperature requirement, and each species has its own defined number of accumulated degree days (ADD) or accumulated degree hours (ADH) to complete its development. Bala and Sharma (2016) successfully demonstrated the accuracy of accumulated degree hour method in estimating the PMI of the mummified body of a female with the immature stages of *Chrysomya megacephala* (Diptera: Calliphoridae), obtained from the corpse.

Insects are used as substrate for toxicological analysis for detecting drugs and toxins present in the corpse, when conventional medium such as blood, urine or internal organs are no longer available. Qualitative assessment by thin-layer chromatography showed the presence of morphine in maggots of blowfly, *Chrysomya albiceps*, fed on the carcass of rabbit administered with morphine (Salimi *et al*., 2018).

Isolating human DNA from gastrointestinal tract of maggots and analysing its genetic profile for the identification of an unknown body is a molecular approach in forensic entomology (Introna *et al*., 2005). In particular, researches demonstrated that, after ingestion of human tissue, during the digestion process, the hydrolysed host tissues are normally stored in the maggot's crop. Therefore, it is possible to sample the host tissue residues from the crop, subject it to STR analysis and generate a genetic profile for the identification of an unknown body. This kind of analysis is suggested if the food source of the larvae sampled at the scene is in doubt and no corpse is present but larvae are found. But this kind of studies are rare (Amendt *et al*., 2011). If necessary, the identity of the person can be determined by forensic STR typing, by comparing it with existing genetic profiles.

Cases of children and elderly neglect by relatives or nursing staff can be solved by blowfly larvae. Wounds and circumstance of bad hygiene in elderly and very young person will attract certain species of flies. Blowflies are valuable as forensic indicators in cases of abuse, rape and neglect. Insect evidence represents how long a person was abused/neglected. When sexual assault has occurred prior to death, blowflies will be more likely to get attracted and oviposit in these regions (anus and penis or vagina), and investigators can start to suspect a sexual crime.

Many species of fly prefer to specific geographic region and different environments. One species general in city centre may not be obtained in rural areas and vice versa. If city species identified from the dead body obtained in rural area may also show that the body has been moved to a rural site after death (Sumadon, 2002).

Forensic entomology, though not the last word in all death investigations, the evidence from insects, if investigated with the right techniques, can undoubtedly complement and supplement conventional procedures in forensics.

Fig. 1. Blow fly (Family Calliphoridae)

(**Source**: https://inaturalist-open-data.s3.amazonaws.com/photos/150885/large.jpg)

Fig. 2. Collecting insect samples from corpse

(**Source**: https://www.sfu.ca/content/sfu/fass/meaning/better-future/bad-guys-good-bugs.jpg)

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Crater mound nests of the ant, *Camponotus* sp. in a terrace garden in Bangalore

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As Himalayas are to us humans, so must be the nest mounds of their own making to an ant. In the last three months, we were fascinated by the mound making of the *Camponotus* ant, on a terrace in Bengaluru (12.9784°N, 77.6408°E) in all probability the *Camponotus parius* Emery, a native to India and Oriental. Except for mainly regional records, habitats and perhaps a casual mention of seasonality, much of this ant's bioecology is not known.

The ant caught our attention when we found a crater nest adjacent to a brick (Fig. 1) on a levelled heap of soil bed on a terrace, on which vegetables are grown. This was the month of June, 2022. The mounds seemed to have come up in a few days. Soil was excavated and thrown out so geometrically circular, all round, that a funnel shaped crater was formed up to about a height of 5-7 cm with a diameter of 14-16 cm (Fig. 1). A hole in the centre leads perhaps to the nest cavity. That the crater is 'live' is evident only by the workers moving on and around the crater. It is not sure whether the brood is raised in about 20 days times, but, after that the nest looked abandoned. At Bengaluru, the rains between June and August, have been between 100 to 150 mm and the nest building activities, seemed to coincide with the rains. The second and the third nests in July and August, respectively, were in two different earthen pots in which plants were already growing. The second nest was like the first one with a single funnel like opening. However, the third nest had three openings and one is not sure whether these were three colonies or a single colony. The bigger crater of the third nest seemed to be the 'mother' nest (Fig. 2). Unless excavated, which we did not want, one cannot be sure if the excavations were temporary shelter or brood rearing chambers.

The nest building by itself was interesting. Ants 'painfully' bring small blobs of soil (size of their head!) and release it outside the excavated hole. Gradually these blobs of mud fall on either side, and craters are formed all around and when tunnelling is complete, the crater formation (at about 7-8 cm height, based on two nests of observed) stops.

The blobs are formed as small mustard sized particles, perhaps mixed in a "sticky" saliva, for the crater soil were mild cement-like and when removed and spread, it hardens. Once the colony abandoned the nest, evident by the absence of ant activity, the funnel became a 'saucer' shaped (Fig. 3) depressions, the only tell-tale evidence of a once thriving ant colony, albeit, though for a short while.

In urban terrace gardens, when such active crater nests are found, care should be taken to avoid watering over them, avoiding sprays and manuring or any form of disturbance for about three weeks to encourage ant conservation.

Fig. 1. A typical nest

Fig. 2. Three nests, workers and blobs of soil clearly seen

Fig. 3. Abandoned nest- a saucer-shaped depression

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Earwigs as potential pests of groundnut

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Earwigs belong to insect order Dermaptera and are characterized by the presence of pair of sclerotized forceps-like cerci on the last abdominal segment and membranous hind wings tucked beneath short hardened forewings. These are tiny insects which live in chambers 1-inch deep inside debris or soil crevices. Unusual among non-social insects, mother earwigs care for their eggs and nymphs. Earwigs are abundant in America and Eurasia and are mostly scavengers but some species are omnivorous feeding on plants as well as preying on arthropods.

Earwigs species infesting groundnut in India are, *Euborellia (=Anisolabis) annulipes* (Lucas), *E. plebeja* (Dohrn), *Forcipula quadrispinosa* (Dohrn) and *E. stali* Dohrn (Barwal, 1985; Anitha, 1992; Nandagopal and Prasad, 2004). The former three earwig species are widely distributed across groundnut growing regions of India while, *E. stali* is mainly reported from Tamil Nadu (Burr, 1910; Thangarajan, 1939; Cherian and Basheer, 1940; Senguttuvan and Dhanakodi, 1997; Das and Ray, 1988; Srivastava, 2003).

Adults are elongated, dark brownish to black insect measuring 30-35 mm in length. Female earwigs lay 20-100 eggs in clusters on pods or in the soil. Eggs hatch in 3-11 days and nymphs pass through five instar stages to become adults. Nymphal period lasts between 30-60 days. Adults survive as long as 250 days and one generation takes 56-101 days. Both nymphs and adults of *E. stali* bore holes into tender groundnut pods and feed on the developing kernels/seeds and fill the pods with soil and/or excreta (Purushothaman *et al.*, 1970; Amin, 1988; Senguttuvan and Dhanakodi, 1997). On mature pods, earwigs fail to bore holes but can cause orange to brown colored superficial pits.

The earwig, *E. stali* on groundnut was observed from the pod developmental stage till harvest (Sahayaraj and Raju, 2003). Cherian and Basheer (1940) first recorded infestation of *E. stali* on groundnut pods and kernels at Coimbatore and South Arcot districts of Tamil Nadu. Senguttuvan and Dhanakodi (1997) also identified *E. stali* as a predominant pod borer of groundnut in Tamil Nadu. However, *E. stali* was also noted infesting groundnut pods in Bombay and Manipur (Barwal, 1985). At Tindivanam, Tamil Nadu, around 47% of pods of an introduced groundnut cultivar, Asiriya Mwitunde were earwig damaged wherein, 44% of matured pods and 52% of immature pods were found with bored holes (Purushothaman *et al.*, 1970). However, at Pudukkottai, Tamil Nadu both earwigs and wireworms caused pod damage ranging from 1.2 to 11.5% (Senguttuvan and Dhanakodi, 1997). Giridharan et al. (1985) reported that earwigs preferred Virginia bunch varieties (0.8-6.7%) over Virginia runner varieties (0.3-4.3%) of groundnut.

Since 2016, *E. stali* infestations were observed on groundnut in Saurashtra (21.4843°N, 70.4405°E), peninsular region of Gujarat. Pod damage by earwigs ranged from 2 to 25% in *Kharif* groundnut while in rabi-summer groundnut it ranged from 2 to 5% (Harish, 2021).

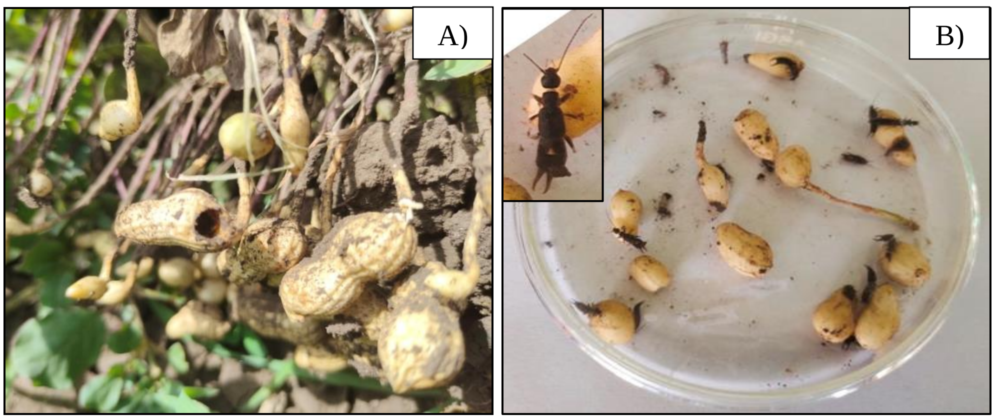

Fig 1. Characteristic earwig damage observed on groundnut. A) Hole bored on an immature pod; and B) Earwigs feeding on immature pods (**Inset:** Adult earwig).

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Report of *Anisopteromalus calandrae* (Howard) (Hymenoptera: Pteromalidae) as a potential biocontrol agent of cigarette beetle, *Lasioderma serricorne* (Fabricius) (Coleoptera: Anobiidae) infesting tobacco seeds under storage condition from Gujarat, India

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Introduction:

The cigarette beetle, *Lasioderma serricorne* (Fabricius), gets its name from attacking stored tobacco (Cabrera, 2007). It is a stored product pest throughout the world. The adult beetle is small in size (2 to 3 mm) with light brown color. The head is bent down and barely visible from above, which gives the beetle a rounded or "humped" appearance. The wing covers are not striated, and the antennae are the same thickness from base to tip. Grubs are yellowish white with three sets of thoracic legs and a brown head capsule. The larvae are about 0.1 inch long when fully grown. (Chaitanya *et al.,* 2016).

Materials and Methods:

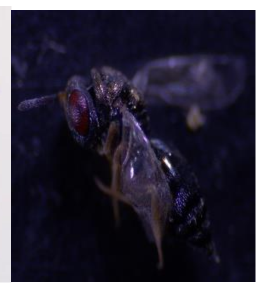
To study the natural enemies of *L. serricorne* prevailing in Middle Gujarat agro climatic zone, the seeds of tobacco (*Nicotiana rustica* L.) brought to entomology laboratory of Bidi Tobacco Research Station and were kept without any insecticidal treatments. After 15 days, *L. serricorne* was observed along with small parasitic wasps. Wasp specimens were collected with an aspirator and placed in 70% alcohol in glass vials for further studies. Specimens were sent to Zoological Survey of India, Calicut, Kerala for identification.

Results and Discussion:

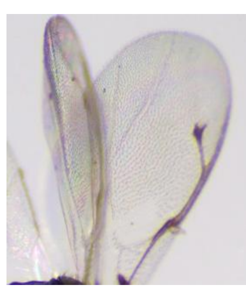
The parasitoid identified was *Anisopteromalus calandrae* Howard (Hymenoptera: Pteromalidae) and was pupal parasitoid of *L. serricorne* infesting seeds of Culcutti tobacco. Head was transverse in shape with bluish black colour and compound eye dark – reddish in color (Fig.1A), Antennae with scape not reaching median ocellus (Fig. 1D). Thorax was brownish black with green metallic shine and legs are short with femur and base of tibia are black and all tarsi were yellow in colour. (Fig. 1A). Forewing with one recurrent vein (Fig. 1E). The ovipositor was short and split (Fig. 1F). The adult male insects resemble with female in colour but differed by a measurement in length, and there were a white-yellowish coloured 3-4 segments on abdomen of female. Abdomen of male is smaller than female in size (Fig. 1B, C).

In India, it was observed earlier in Haryana and Karnataka (CABI, 2022). The parasitic wasps of the genus *Anisopteromalus ruschka* (Pteromalidae) prey on coleopterous insect pests that primarily attack stored grains (Noyes, 2013). The Pteromalidae is one of the biggest families of Chalcidoidea (Hymenoptera) and has been reported from various stored grains and pulses beetles like *Stegobium paniceum*, *Sitophilus oryzae, Sitophilus granarius, Tribolium castaneum, Athesapeuta cyperi, L. serricorne, Oryzaephilus surinamensis, Pempherulus affinis, Rhizopertha dominica and Callosobrochus* spp. (Sureshan, 2003). The results of Yafei Guo *et al* (2021) reported that the female *A. calandrae* preferred to parasitize mature larvae and pupae of *L. serricorne*, and has great potential for controlling *L. serricorne* infestation. Our report explores the possibilities of a parasitoids, *Anisopteromalus calandrae* Howard as a potential biological control component in Integrated Pest Management of cigarette beetle.





(A) Adult of *Anisopteromlaus calandrae* **(B) Female** **(C) Male**


(D) Antennae **(E) Forewing** **(F) Ovipositor**

Fig. 1: External morphology of *Anisopteromlaus calandrae*

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Yafei Guo., Jianhua Lüa., Jianhu Guob., JiaqinXi and Chao Guoc 2021. Control potential of *Anisopteromalus calandrae* (Howard) (Hymenoptera: Pteromalidae) against *Lasioderma serricorne* (F.) (Coleoptera: Anobiidae). *Journal of Stored Products Research,* **93:** pp 101820.

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First host record of false chinch bug, *Nysius inconspicuus* (Hemiptera: Lygaeidae) on sesame in Anand (Gujarat, India)

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Sesame [*Sesamum indicum* L.] also known as Til, Gingely, Ajonjoli, Simsim and Benniseed and belongs to family Pedaliaceae. Sesame is the "Queen of oil seeds". A general survey was carried out during summer season of the year 2022 to document insect pests and their natural enemies under the aegis of All India Coordinated Research Project (AICRP) on Biological Control of Crop Pests. During the survey, a hemipteran pest was found infesting sesame crop in the field located in Agronomy (Lat. 22.53955 & Long.72.98093) and Medicinal Research Farm (Lat. 22.53659 & Long.72.98227), Anand Agricultural University, Anand, Gujarat. The bugs were collected in a plastic container (5.5 × 4.5 cm) and brought to the laboratory. The collected bugs were observed using Olympus SZX 10 binocular microscope. The bugs were identified as *Nysius inconspicuus* (Hemiptera: Lygaeidae). Moreover, this is the first instance of false chinch bug infesting sesame crop in Anand (Gujarat, India). The pest was found sucking the sap from the foliage and flower buds (Fig. 1).

Citing earlier reports of this pest in India, Distant (1903) described false chinch bug (FCB), *N. inconspicuus* (Hemiptera: Lygaeidae) from BhorGhat and later reported the same from Mysore. A severe infestation of sesame by *N. inconspicuus* Distant was reported from Tindivanam in the Indian State of Tamil Nadu (Thangavelu *et al*., 1989). In Gujarat, *N. inconspicuus* and *Nysius ericae* (Schilling) (Lygaeidae), a hemipteran pest was found feeding on pearl millet and muskmelon for the first time (Gamit *et al*., 2022; Zala *et al*., 2013). *Nysius inconspicuus* is a highly polyphagous and occasional pest. Greyish brown small sized bug has transparent wings (Fig. 2). They suck the sap from the foliage and flower buds (Milliken, 1918).

Fig. 1. False ching bug, *Nysius inconspicuus* infesting sesame

Fig. 2. Adult of *Nysius inconspicuus*

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First report of C*helonus* sp. (Hymenoptera: Braconidae); an egg larval parasitoid of fall armyworm, *Spodoptera frugiperda* (J. E. smith) (Lepidoptera: Noctuidae) in Anand, Gujarat, India

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A new invasive pest fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) has invaded India and reported in Andhra Pradesh, Gujarat, Karnataka, Maharashtra, Tamil Nadu, Telangana states infesting maize crop (Shylesha *et al.*, 2018; Sisodiya *et al.*, 2018). It is a serious maize pest that is native to the tropical and subtropical regions of America and is also known to target more than 100 hosts. It is a well-known pestiferous insect pest, making it one of the most serious economic pests due to its great dispersal capacity, broad host range, and high reproduction. In maize, yield losses from *S. frugiperda* may reach up to 70% of total production (Ayala *et al*., 2013).

General survey was carried out during *kharif* season of the year 2021 to document the natural enemies of fall armyworm infesting maize in Kanisa (22º23'2'' N 72º41'13'' E), Sandeshar (22º31'7'' N 72º52'47'' E) and Sihol (22º30'53'' N 72º52'22'' E) Anand district of Gujarat, India. During the survey, few larvae were found less active with reduced feeding. Initially these larvae were suspected of Nuclear Polyhedrosis Virus (NPV) infection (Raghunandan *et al.,* 2019). Later, these suspected larvae were collected in ventilated plastic container (5.5 × 4.5 cm) and brought to the laboratory. The haemolymph of the collected larvae were observed for NPV occlusion bodies and found negative. After 3-4 days, creamish white larvae were found emerging from the infected FAW larvae. It was confirmed as egg larval parasitoid *Chelonus* sp. (Hymenoptera: Braconidae). Hence, we documented egg larval parasitoid *Chelonus* sp. (Hymenoptera: Braconidae), which has a potential for biological control of fall armyworm, *S. frugiperda*. The egg larval parasitoid *Chelonus* sp. attacks the egg stage and completes its development in the larval stage of the host. The larva of *Chelonus* sp.was creamy white in colour and cylindrical or spindle in shape (Christa *et al.*, 1994) (Figure 1). The cylindrical shaped cocoon was constructed of fine white silken threads secreted by the silk glands of the last instar larva and later stage turned into brown colour (Hafez *et al*., 1980) (Figure 2).

Fig. 1. *Chelonus* sp.: A potential egg larval parasitoid of fall armyworm, *S. frugiperda*

Fig. 2. Pupa of *Chelonus* sp.

Fig. 3. Adult of *Chelonus* sp.

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Occurrence of *Cotesia* sp. (Hymenoptera: Braconidae): A larval parasitoid of *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) in castor

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Castor (*Ricinus communis* L.) locally known as 'Arandi' is a non-edible oilseed crop which belongs to the family of Euphorbiaceae. More than 107 species of insects and mite pests have been listed on castor at different stages of crop growth (Lakshminarayana and Raoof, 2005). One of the most significant insect pests infesting castor in Asia is the castor leaf eating caterpillar, *Spodoptera litura*, which is widespread throughout tropical and temperate Asia, Australia and the Pacific Islands (Kranz et al., 1977). Parasitoids are important biocontrol agents that are used in biointensive pest management programmes. In recent days, these bioagents have gained great attention because of their incredible ability to suppress the pest populations. The utilization of biocontrol agents assures the reduced use of synthetic chemical pesticides and hence helps in minimizing the environmental pollution and hazards (Bhadane et al., 2016).

During *rabi* season of the year 2021-22, general surveys were carried out under All India Co-ordinated Research Project (AICRP) on Biological Control of Crop Pests, Anand Agricultural University (AAU), Anand (Gujarat) for documenting biocontrol agents. The castor fields of Agronomy farm at AAU, Anand was found infested with *S. litura* and few larvae were found less active with reduced feeding. The larvae suspected of parasitization were collected. The collected larvae were kept in the laboratory and observed for emergence of parasitoid. After 2-3 days, small off-white larvae were found emerging from *S. litura* larvae. The parasitoid was identified as *Cotesia* sp. Larvae of *Cotesia* sp. were soft skinned and soon after emergence from the host started spinning a tight white silky cocoon. Adults of *Cotesia* sp. were small with short ovipositor that aid in parasitizing neonate larvae.

Fig 1. Larvae of *S. litura* parasitized by *Cotesia* sp.

Fig 2. Black marks indicating the exit hole of parasitoid *Cotesia* sp. in *S. litura*


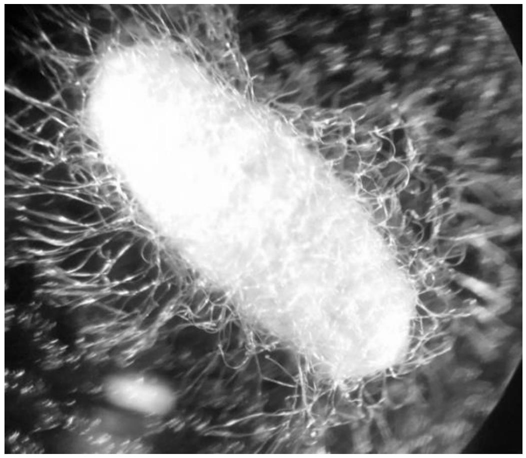

Fig 3. Cocoon of *Cotesia sp*.

Fig 4. Adult of *Cotesia* sp.

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Webniar Report

Firefly, Ecology and Environment: A webinar report

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Introduction

Fireflies are beetles belonging to Order: Coleoptera, Super family: Elateroidea, Family: Lampyridae. Globally there are about 2400 described species in 11 sub-families (Martin *et al* 2022, and Riley *et al* 2021). In India, about 45 species have been described. Fireflies are known by names such as forest star, lighting bugs, fire devils, flying embers, moon bugs, glow flies, blinkers, etc. Fireflies are two types: those that produce light and those that do not.

Fireflies are indicators of climax vegetation, found in tropical as well as temperate regions. Fireflies produce cold light with no infrared or other harmful frequencies. At times, adults serve as pollinators and predators and are essential for stable ecosystem functioning. Adults are generally identified by pronotum dorsally extending forward covering head, head, without median ocellus and base of antennae separated on head. Adults are with leathery dorsal elytra and luminous organs in ventral side of abdomen, generally more pronounced in males than females. Larvae are generally flat, cylindrical or worm-like with distinct segmentation and lateral expanded pleurae. Larvae in aquatic species are often with reduced sclerites and might have gills. Adults are found in moist grassy patches, verges, hedge banks and larvae under soil, stones, etc. Life stages may be in terrestrial or aquatic habitats, arboreal or subterranean. Larvae are carnivorous feeding on snails, slugs, earthworms, ants, termites, gastropods and decaying organic matter (Riley *et al* 2021).

The Webinar

The Environmental Management and Policy Research Institute (EMPRI), Bengaluru organized an **International Webinar** on the occasion of World Firefly Day on 22 July 2022 from 11:00 AM to 07:00 PM IST. Participants from 11 countries – Australia, Cuba, Japan, Malaysia, Vietnam, Pakistan, Philippines, Sri Lanka, the USA, Bangladesh and Singapore –attended the day-long webinar. This is the first webinar on fireflies conducted on **'World Firefly Day'** 22 July 2022 in India.

EMPRI has undertaken a study from January 2022 to document the firefly species found and their abundance in Karnataka. The populations of fireflies are believed to be declining globally. The webinar provided an opportunity to young researchers and learners to interact deliberate and share their experiences on firefly ecology, threats, mitigation and conservation.

Director General EMPRI Dr Jagmohan Sharma IFS inaugurated and addressed the webinar. He highlighted the intention to develop a breeding protocol for fireflies that will help in establishing of a **Firefly Park** on the lines of Bannerghatta Butterfly Park in the state. This will be first of its kind in the country and will promote nature awareness and tourism.

The distinguished speakers to the webinar included Dr Lesley Ballantyne, Charles Sturt University, Australia, Prof. Sara Lewis, Firefly Specialist Group – IUCN, USA, Dr Dammika Wijekoon, University of Ruhuna, Sri Lanka, Dr. Devanshu Gupta, Zoological Survey of India, Dr Anurup Gohain Barua, Gauhati University and Dr Nada Badruddin, Forest Research Institute Malaysia (FRIM), Malaysia. The daylong event also included an interaction and a quiz session for the participants.

The select highlights of the webinar included establishment of a portal for fireflies in India, a Field Guide and an *Asia-Pacific Network of Fireflyers,* which is likely to get recognition as an adjunct network to the IUCN Firefly Group. In India and several other countries fireflies are not legally protected. IUCN SSC Group on Fireflies can take up the initiative with governments to accord legal protection. Dr. Sara Lewis, the co-chair IUCN Firefly Group agreed to help the workers and governments in this regard. Concerted efforts at all quarters should be initiated to attract young researchers and enthusiast to study and conserve fireflies. Dr. Lesley Ballantyne, Charles Sturt University, Australia is ready to help and guide youngsters on firefly taxonomy, ecology and behaviour.

The Western Ghats

In Western Ghats of Karnataka, congregating populations of fireflies exist which should be conserved because these insects are ecologically and economically vital for the functioning of the ecosystem in Western Ghats. This comes in the wake of the Central government's Western Ghats notifications which declared 20,668 Sq. Km of area in Karnataka as eco sensitive area. People in Western Ghats may not be aware of the importance of preserving the habitats of these charismatic beetles and other creatures. The lives and livelihoods of rural people in and around Western Ghats are closely linked to the sustenance and perpetuation of keystone species such as the firefly beetles. This webinar and other initiatives by EMPRI will contribute to the awareness creation activities among people in the region.

Scientific information and studies on fireflies in India have not been conducted systematically so far. The scientific community, foresters, administrators, naturalists, and others have not paid the attention to fireflies they deserve. People in different countries are attracted to fireflies because of their synchronous switch-on and switch-off lights in massive numbers, thousands or millions. To the general public fireflies are associated with eco-tourism. Foresters and local people celebrate the event as firefly day, firefly count, firefly walk, and so on. For instance in the Western Ghats region of South India, in the evergreen tropical forests of Kerala, Karnataka, Tamil Nadu and Maharashtra Firefly Day are conducted at a few sites during monsoon and winter depending upon the rains. India should be concerned about fireflies because they are ecologically and economically vital, populations are declining and not much is known even on the basics of fireflies like species diversity, bio-ecology and behaviour.

Threats

- Habitat loss, pesticide use, invasive species, climate change.
- Artificial lights at night.
- Unplanned urbanization.
- Human interferences and habitat fragmentations.
- Water pollutions

Mitigation

- Should be declared as protected species-group by law.
- Large scale *in-situ* conservation.
- More research and outreach activities to create awareness.
- Firefly habitats having tourist potential should be declared ‘Protected habitats’.

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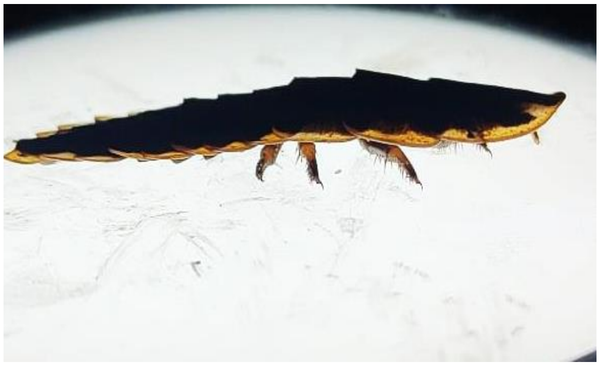
The webinar was live-streamed on EMPRI website (https://empri.karnataka.gov.in/news/Fireflies,%20Ecology%20&%20Environment%20webinar%20recordings/en)

YouTube page - (https://www.youtube.com/watch?v=7-SlWJjWMBA).

Firefly eggs



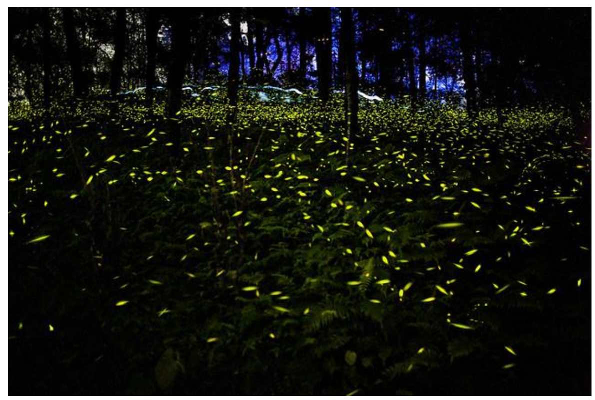
Firefly larva

Firefly adults (ventral side showing light organ, white in color)

Firefly adult (lateral side)

Firefly adult (dorsal side)

Firefly larva feeding on snail



Congregation population of fireflies at night (http://indiasendangered.com/say-no-to-firefly-festival-period/)

All photographs are by the authors except otherwise stated.

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INSECT LENS

Spined assasin bug nymph, Sinea diadema (Reduviidae: Hemiptera)

Sinea diadema is bivoltine, preys on small bugs and beetles, and overwinters in the egg stage. They are considered valuable biological control agents. They are also reluctant cannibals – newly hatched nymphs will attempt to feed on their siblings only after several days of starvation, but they seem to prefer other prey.

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Net-winged beetles, Lycostomus sp. (Lycidae: Coleoptera)

Net-winged beetles have a cosmopolitan distribution with over 4000 species. Apparently, they are a difficult group to tease out taxonomically based on morphological characters alone. There are more species undescribed.

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Yellow fever mosquito*, *Aedes aegypti (Culicidae: Diptera)

Yellow fever mosquitoes are widespread throughout the tropical and subtropical regions of the world. Yellow fever mosquitoes are considered the vectors for diseases like chikungunya fever, dengue fever, and Zika.

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Stem gall fly, Cecidochares connexa (Tephritidae: Diptera)

Stem gall fly was introduced from Indonesia into India in 2002 for the control of Chromolaena odorata. Stem galls formed by Cecidochares connexa result in reduction of stem growth, seed production and carbohydrate storage, often leading to reduced plant growth and even plant death.

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Hairy caterpillar, Eupterote mollifera (Eupterotidae: Lepidoptera)

Eupterote mollifera is a destructive and specific pest of drumstick in South India. Caterpillars feed gregariously by scrapping bark and gnawing foliage. Severe infestation results in complete defoliation of the tree.

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Hadda beetle with parasitoid, Henosepilachna vigintiopunctata (Coccinellidae: Coleoptera)

It is commonly known as the 28-spotted potato ladybird or the Hadda beetle. It feeds on the foliage of potatoes and it is major pest of solanaceous crops like brinjal, tomato etc. In this image we can see the grub of hadda beetle along with its larval parasitoid.

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Tree hoppers, Oxyrachis tarandus (Membracidae: Hemiptera)

Tree hoppers can be observed in a variety of colors. Their pronotum extends beyond the abdomen and encloses the wings. The pronotum is armed with spines and needles to use as a defense mechanism. Some species of tree hoppers have a distinctive 'humpbacked' appearance. They are herbivores, and can be seen feeding on shrubs and grass blades. Similar to Cicadellidae, they also deposit their eggs into the tree branches, doing considerable damage.

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Blue banded bee, Amegilla cingulate (Apidae: Hymenoptera)

Blue banded bee is solitary, non-aggressive and active forager which helps in buzz pollination. Unlike females, male blue banded bees don't live in the ground they roost in small groups on stem or things of the plants. Male bee hangs to the stem with the help of its mandibles, tucking its legs under their own body.

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Egg raft of an Assassin Bug, Epidaus famulus (Reduviidae: Hemiptera)

Accidentally found this beautiful egg raft of an assassin bug on all-spice plant leaf at spice unit of UAS Dharwad while searching for insects. We kept it for adult emergence and we were expecting for Assassin bugs nymphs to emerge out from it but, surprisingly some adult parasitoids emerged out of it.

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Bihar hairy caterpillar, Spilosoma obliqua (Erebidae: Lepidoptera) on sunflower

Polyphagous pest feeds on approximately 126 plant species including pulses, cereals, vegetables, oilseeds, mulberry, turmeric, fibre crops. Young larvae feed gregariously on chlorophyll mostly on the under surface of the leaves, due to which the leaves look like brownish-yellow in colour. In later stages, the larvae eat the leaves from the margin. The leaves of the plant give an appearance of net or web.

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Grub and pupa ***Mature pupa*** ***Skeletonized leaves of brinjal***

Hadda beetle, Henosepilachna vigintioctopunctata (Coccinellidae: Coleoptera)

Both adult and grubs scrap the lower epidermis of leaves in characteristic manner leaving behind stripes of uneaten areas. The leaves give a stifled appearance. In severe infestation all leaves may be eaten off leaving only the veins intact (skeletonization) and plants may wither

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INSECT ENVIRONMENT EXTENSION

Dr. Abraham Verghese, Chairman, Rashvee International Phytosanitary Research and Services, Editor-in-Chief, Insect Environment With Principal Bishop Cotton Boys School at their Science Festival. He was the Chief Guest of the festival.

Farmer's training program on plant protection practices in Pomegranate on July 8th 2022 at Vijayapura, Devanahalli organised by Rashvee International Phytosanitary Research and Services, (IPRS) & Insect Environment, Bengaluru.

Dr. Abraham Verghese was awarded Karnataka Science and Technology Academy Fellow 2022, on 2nd August 2022.

Farmer's training program on plant protection practices in Grapes on September 17th 2022 at Vijayapura, Devanahalli organised by Rashvee International Phytosanitary Research and Services, (IPRS) & Insect Environment, Bengaluru.

Farmers getting a profit of 5 lakh per acre with Rashvee International Phytosanitary Research and Services, consultancy

Dr. Abraham Verghese at Research Advisory Committee, Central Plantation Crops Research Institute (CPCRI) -ICAR Kasargod 4th July 2022

Keynote address on sustainable research on 20th September by Dr Abraham Verghese for the staff and students of St Joseph's College Alappuzha Kerala

Dr. Rashmi, M.A delivered a lecture on Integrated Pest Management for students of the Diploma in Agricultural Extension Services for Input Dealers (DAESI) Program at GKVK, Bengaluru.

Rashvee International Phytosanitary Research and Services, and Insect Environment team with Dr. S. Ayyappan, Former Secretary (DARE) & DG (ICAR)

Dr. Rashmi, M.A delivered a lecture on Quality certification for exports on 6th September 2022 at VTPC, Bengaluru for Agri Exporters in association with KAPPEC