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***Cover Page: Cuckoo Wasp**
Photo by: Dr. Nagaraj, D.N Senior Scientist
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Insect Environment

(Quarterly journal to popularize insect study, conservation, and watching)

ISSN 0975-1963

IE is back by popular demand as a popular online insect quarterly journal. 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 research notes and essays on all aspects of insects. The journal is published quarterly, in March, June, September, and December. The last issue was Volume 22 (September), 2020.

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 Vol. 22 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.

This journal is unique in that it encourages articles from students to amateurs to professionals! It is hosted in ZooBank, ensuring global coverage.

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EDITORIAL

WFH-Write from home!

I have always been impressed with Francis Bacon (1561-1626) a great philosopher who influenced scientific thinking. He once said “Reading maketh a full man; conference a ready man, and writing an exact man.” It was again he who said “knowledge is power.” I integrate these two: “Knowledge of insects when written, generates, entomological power!” It is the ability to translate observations, reasoning, and interpretations into written matter that makes or sets apart a teacher, scientist or even a student. To talk is average, but to talk and write is scholarship! IE gives the best opportunity to insect lovers the medium to document as they pursue along their passion called insects. We also like to profile achievers as we have done for Dr Sankarganesh in this issue. Our obituary this time is paying tributes to T M Mustak Ali, who has left behind his ‘passion’ as a heritage for Gen X Y Z…

In the context of COVID, I appreciate our authors who have taken to WFH- write from home! COVID has put the brakes on insect lovers too, and expeditions, explorations, field forays, setting traps for collections have all got restricted. Yet, many are using this time for gathering in their data for collation, analyses and writing papers. Thus IE was flooded with articles, that we bring this issue, a month ahead of schedule!

IE has always given importance to ‘speed’. I thank, therefore, all our referees and editorial team for processing each article in 72 hours. Our authors will be able to appreciate the speed with which your articles are returned for corrections and resubmission. We did receive full articles with several tables/figures, etc, which were summarily, but politely returned. We cater to a different scientific genre. We want only short articles, which portray interesting/critical dimensions of entomology, new records essays, current topics, profiles, photographs (under insect lens). We even have a generic announcement on any products which are safe and of human interest.

Fast reports, is yet another niche area for us. Thus, the spread of fall army worm, into Kerala, in a non-conventional ecosystem, by Dr. Gavas Ragesh, was accorded top priority. This note of his, is sufficient, to get new *ad hoc* schemes, local government action, and even a doctoral thesis.

Ticks belong to arthropoda and this time round we are publishing a note by a medical student, S. Sukesh on a tick-transmitted viral disease. IE has wider connotation in terms of other related Arthropoda also. Papers on mites, spiders, etc are welcome.

Thanks to Dr. Nagaraj, D.N., Senior Scientist, Bio Pest Management Pvt. Ltd., for his excellent insect photos for the cover page as well as insect lens.

In this editorial, we are happy to inform that three eminent entomologists have joined our editorial advisory board. They are Dr Abdeljelil Bakri, Former Head, Insect Biological Control Unit, University-Marrakech, Morocco, FAO Consultant and Editor, Fruit Fly News e-newsletter, Canada; Dr. Ravindra Kumar Kodarlal Patel, Vice-chancellor, Sardarkrushinagar, Dantiwada Agricultural University, Sardarkushinagar, Banaskantha, Gujarat and Dr. Zinabhai Paragji Patel, Vice-chancellor, Navsari Agricultural University, Navsari, Gujarat. Incidentally, all the three scientists have been associated with me in international and national fruit fly programs.

I am too happy to inform that ZooBank will be hosting and abstracting Insect Environment. It is the official register of the International Commission on Zoological Nomenclature (ICZN). ZooBank is part of the Global Names Architecture, and is supported by the U.S. National Science Foundation grants DBI-1062441 and DBI-0956415. Thus we have gone global. We have two notes from abroad- West Indies and Saudi Arabia, in this issue.

We have an appeal to all our insect teachers: encourage your students to write, for writing perfects and builds future entomologists. IE is too happy to publish students' notes. Teachers too should write for it shows in your lectures!

Now we have over 2000 subscribers in India and abroad. The number is growing. We welcome all of them to be partners of this mission called Insect Environment, which is part of the Special Insect Interest Group (SIIG).

We will meet next with volume 24 (March) 2021. So here's our Editorial team wishing all of you a COVID-free, and prosperous 2021!

Feedback for volume 22 (September)

I just went through the latest issue of Insect Environment. Indeed the get up of the publication is fantastic with quality contributions and excellent colour pictures. I can feel the enormous efforts put in to bring out this excellent publication which covers wide range of aspects of entomology. Appreciate efforts to revive publication of IE. It was an excellent publication. Running a journal is not an easy task unless one is dedicated to it. God bless you in your efforts.

Dr. B.Vasanthraj David
Chairman, Scientific/Academic Board,
International Institute of Biotechnology & Toxicology, Tamil Nadu

I am happy to know about the revival of Insect environment and the nostalgia from your editorial note. Best wishes for re-success of this prestigious and knowledge bank journal.

Dr.T. Makeshkumar, Ph.D, FPSI
Principal Scientist (Plant Pathology - Plant Virology)
ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram

Excellent issue Dr. Falerio, I will consider sending future articles to this Journal (Insect Environment). Nice that you are member of the editorial Board.

Dr. Hamadttu El-Shafie
Date Palm Research Center of Excellence, King Faisal University
Saudi Arabia

Thanks for your incessant effort to popularize Science, particularly the insect stories.

Jayaprakesh, C.A
Principal Scientist, ICAR-Central Tuber Crops Research Institute,
Thiruvananthapuram

The issue is Awesom sir, I so wanted this journal to be back, it was such a good thing.

Dr. Chitra Shankar
Principal Scientist, ICAR-Indian Institute of Rice Research, Hyderabad

Heartly congragulations sir for reviving and bringing out the IE in most appealing get up with excellent articles of diverse fields of insect world. My sincere appreciation and compliments to the team which worked efficiently under your guidance. Great Job, Proud to be part of IE.

Dr. P.V.Rami Reddy
Principal Scientist, Division of Entomology and Nematology, ICAR-IIHR, Bangalore

Research Articles

Oxygen consumption by *Ancylostomia stercorea* Zeller (Lepidoptera: Pyralidae) larvae: effect of temperature and body weight

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Abstract

The influence of temperature on the respiration rate of *Ancylostomia stercorea* larvae was investigated because of modest research on this serious pigeon pea pest in the region. The respiratory rates of 3rd, 4th and 5th instar larvae were assessed at four temperatures 20, 25, 30 and 35^{0}C. The mean oxygen consumption was greatest at 25^{0}C for all three instars. The highest Q_{10} values were observed for all three instars at the temperature range 20-30^{0}C. There was a negative scaling relationship between oxygen consumption and *A. stercorea* larval body weight.

Keywords: Pigeonpea, *Ancylostomia stercorea,* oxygen consumption, pod borer

Introduction

Pigeonpea (*Cajanus cajan)* (L) is an important drought tolerant grain legume crop grown in developing countries. The crop is ranked sixth in the world in terms of grain legume production with 5.96 x 10^6 tonnes produced in 2018 (FAOSTAT 2020). The major pigeon pea producing countries are India, Burma, Uganda and the Dominican Republic. In the Caribbean region the legume is grown mainly under rain fed conditions by small farmers, to whom the crop represents an important source of income. FAOSTAT (2020) ranked Trinidad, Jamaica and Grenada as 16th, 17th and 18th respectively in terms of pigeon pea production worldwide. The pigeon-pea crop is subject to insect attack throughout its growth; however, the most serious economic pests are those which attack the reproductive structures, including flowers, pods and seeds (Shanower *et al*., 1999; Buckmire 1978). Buckmire (1978) identified a number of pod borers that affect the crop in the Caribbean region. These include *Acylostomia strecorea* Zeller (Lepidoptera:Pyralidae), *Heliothis virescens* F. (Lepidoptera:Noctuidae), *Chalcodermus angulicollis* Fahraeus (Coleoptera:Cuculionidae) and *Fundella pellucens* Zeller

(Lepidoptera:Pyralidae). *Ancylostomia stercorea* was identified as the most serious pod borer throughout the region with seed damage in the unprotected crop being as high as 60% in some countries. This pest is a multivoltine species (Bennett 1960). Oval shaped eggs, 0.6 mm in length and 0.4 mm in width are oviposited on young *C. cajan* pods. There are five larval instars and developing larvae feed on seeds inside pods and later pupate in the soil. The life cycle is completed in 26-32 days (Khan *et a*l., 2003). Insects inside pods would be exposed to a range of temperatures and this would affect their respiratory rate and metabolism (Lal *et al*., 2005; Rosenzweig and Hillel, 1998). Petzoldt and Seaman (2005) noted that climate change resulting in increased temperature will impact the insect population in several ways including increased population size, metabolic and rate food consumption. The current study aimed at evaluating the influence of temperature on the respiration rate and scaling relationships between larval body weight and oxygen consumption of *A. stercorea* 3^{rd}, 4^{th} and 5^{th} instar larvae at different temperatures.

Materials and Methods

Third, fourth and fifth instar larvae of *A. stercorea* were obtained the University Field Station Valsayn Trinidad and kept in pigeon pea pods, in well ventilated plastic containers (15cm width x 20cm length x 10cm depth) with organza covered mesh (250 mesh/cm^2) at the top. Respiration rate was measured using a microrespirometer based on the design by Lee (1995) (Figure 1) which was placed in a constant temperature Thermo Fisher Scientific Precision Controlled 280® series water bath (Model 2849). A mercury thermometer (-20 to 110^0C) was used to ensure that the desired water temperature was achieved. The live larval weight (mg) was taken at the end of each experiment. There were five replicates for each instar and oxygen consumption was assessed at 10-minute intervals over 90 minutes at four temperatures 20ºC, 25ºC, 30ºC and 35ºC. Q_{10} values indicative of temperature sensitivity of metabolic rate were calculated using the following equation: $Q_{10}= (R_2/R_1)^{10}/ (T_2\text{-}T_1)$, where: R_1 and R_2 are the respiration rates at temperatures T_1 and T_2 in ^{0}C. Q_{10} represents the factor by which the metabolic rate increases with a 10^0C change in temperature. Values of $Q_{10} > 1$ indicate an increase in oxygen consumption (metabolic rate) after exposure to increased temperature, while values of $Q_{10} < 1$ indicate a decrease in oxygen consumption after exposure to increased temperature.

Scaling relationships were determined for combined 3rd, 4th and 5th instar larvae at each of four temperatures tested. These relationships were in the form: $R = aW^b$ where: R = oxygen consumption rate, W = bodyweight of larva, a = constant (oxygen consumption at weight 0 = y-intercept) and b = slope of graph of log oxygen consumption vs. log weight.

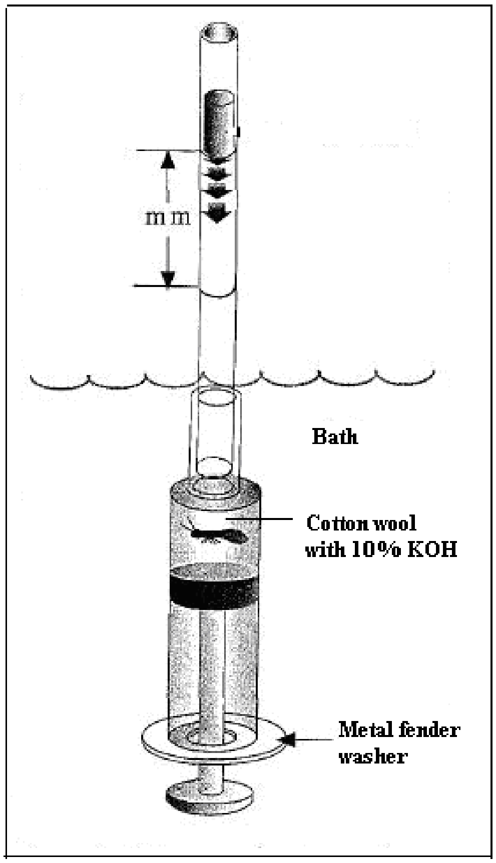

Fig 1: Microrespirometer design (after Lee 1995)

Results

Mean oxygen consumption for 3rd – 5th instar *A. stercorea* larvae was significantly higher ($P<0.001$) at 25^0C for all instars compared to the other temperatures tested. However, oxygen consumption at 20, 30 and 35^0C was not significantly different ($P>0.001$) from each other for each instar examined (Table 1). The 3rd – 5th instar larvae of *A. stercorea* exhibited highest oxygen consumption at 25^0C compared to the other temperatures tested. Oxygen consumption declined rapidly at temperatures higher than 25^0C for all three larval instars (Table 1). Q_{10} values were higher at temperatures between 20^0C and 30^0C compared to 25 and 35^0C (Table 2).

There was a general decrease in oxygen consumption as larval body weight increased as indicated by the negative values of the slope (b) at all temperatures. Comparison of the slopes indicated that they were significantly different from zero ($P<0.05$) however, there was no significant difference ($P>0.05$) between them at any of the temperatures tested (Table 3).

Discussion

The results from the current study indicated that the respiration rate of *A. stercorea* larvae fluctuated with temperature and that maximum oxygen consumption occurred at 25^0C for all three instars. The highest oxygen consumption rate was observed at 25^0C for 5^{th} instar larvae of approximately 1.4µl/mg/h. However, the respiration rate declined steadily at 30^0C and 35^0C. Lee (1995) noted that invertebrates' oxygen consumption is often directly related to temperature over the range of 0-25^0C. He also observed a 40% decrease in respiration rate, using the same microrespirometer technique, to assess the acclimation of diapausing adults of the convergent lady beetle *Hippodamia convergens* Guerin-Meneville (Coleoptera:Coccinellidae) to warmer temperature and holds true for *A. stercorea* 3^{rd}, 4^{th} and 5^{th} instar larvae. Similarly, Bennett *et al.*, (1998) found that lepidopteran larvae could increase respiration rate rapidly with increasing temperatures in the low to mid-temperature ranges (0-20^0C) but at sustained temperatures 30^0C and above, larval respiration rate appeared to level off or decrease and can be physiologically stressful. Similar respiration patterns were observed at 30^0C and 35^0C for the three instars of *A. stercorea*.

In insects there are three periods of respiratory gas exchange referred to as when the spiracles are open, fluttering and closed (Nation 2008, Sláma 1988, Sláma and Karel 1999). He described this process as discontinuous gas exchange and which was evident in *A. stercorea* larvae examined which rapidly increased/decreased respiration rate over a range of time and temperatures and is associated with specific changes in the mechanical pressure within the tracheal system.

The higher Q_{10} values observed at lower temperatures (20-30^oC) may be interpreted as an adaptation of *A. stercorea* that reduces energetic loss at lower temperatures. Studies on the high Arctic wooly bear caterpillar *Gynaephora groenlendica* (Homeyer) (Lepidoptera: Lymantriidae) indicated that Q_{10} value decreased with increasing temperature for both fed and starved larvae

(Bennett *et al*., 1998). Similar results were obtained for larvae of *A. stercorea* in the current study.

The scaling relationship between oxygen consumption and body weight clearly showed that *A. stercorea* larvae oxygen consumption decreased as larval body weight increased, similar to that of Clarke (1957) studying *Locusta migratoria* L. where a high correlation between the trend lines for weight and oxygen consumption in the early instars was observed.

Global temperatures are expected to rise as a result of climate change and have been predicted to adversely affect agricultural crops. Pigeonpea, the host plant of *A. stercorea* can be grown on marginal land with minimal input and has been touted as one of the crops able to withstand the effects of climate change as it has been shown, among other characteristics, to be drought and heat tolerant. This study demonstrated that oxygen consumption by *A. stercorea* larvae was temperature sensitive. While small temperature changes did not negatively affect larval oxygen consumption, elevated temperatures expected as a result of global warming may thus adversely affect this pest despite the favorable outlook for its host plant.

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Table 1. Mean (±SE) oxygen consumption for 3rd – 5th instar *Ancylostomia stercorea* larvae at four constant temperatures.

Temperature (^{0}C)	**Mean (± SE) oxygen consumption (µl/mg/h)***		
	3rd instar	**4th instar**	**5th instar**
20	8.30 ± 0.72 [a]	5.12 ± 1.12 [a]	6.30 ± 1.23 [a]
25	83.94 ± 6.74 [b]	35.92 ± 9.95 [b]	53.37 ± 7.89 [b]
30	7.50 ± 1.42 [a]	20.26 ± 3.91 [a]	9.22 ± 1.65 [a]
35	5.89 ± 1.84 [a]	11.65 ± 2.33 [a]	4.59 ± 1.29 [a]

* Values followed by the same letter along a column are significantly different from each other based on Tukey-Kramer Multiple Comparisons test ($P<0.001$)

Table 2. Q_{10} values for 3rd – 5th instar *Ancylostomia stercorea* larval respiration rates.

Temperature (^{0}C)	**Q_{10} values**		
	3rd instar	**4th instar**	**5th instar**
20 - 30	0.9036	3.9570	1.4635
25 - 35	0.0702	0.3243	0.0860

Table 3. Scaling relationships of *Ancylostomia stercorea* larval body weight (mg) on oxygen consumption at four temperatures.

Temperature (^{0}C)	Scaling equation	Slope b*	95% CI of slope
20	$R = 1.48W^{-0.66}$	-0.66	-1.82, 0.49
25	$R = 6.46W^{-1.62}$	-1.62	-3.58, 0.34
30	$R = 1.66W^{-0.45}$	-0.45	-2.20, 1.25
35	$R = 8.91W^{-1.21}$	-1.21	-2.12, -0.30

* Values followed by the same letter in a column are not significantly different from each other based on Tukey-Kramer test ($p>0.05$)

The parasitoid wasp *Habrobracon hebetor* (Say): a potential biocontrol agent for almond moth *Cadra cautella* in stored dates

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Introduction

The almond moth, *Cadra cautella* causes serious economic damage to stored dates. Post-harvest management of this moth involves the use of chemical fumigants as well as non-chemical alternatives such as heat treatment and modified atmosphere storage. The larval ectoparasitoid wasp *Habrobracon hebetor* (Hymenoptera: Braconidae) is a potential biological control agent for stored-product pests including dates. This article gives a brief overview on the parasitoid biology, behavior and mode of host parasitization.

Morphological and biological characteristics

Adult wasp is small about 2 mm in length and has variable colors ranging from yellowish-brown to dark brown or black. The female body is usually larger than the male body and is characterized by conspicuous black ovipositor that can be easily seen underneath the hyaline membranous wings (Mbata and Warsi, 2019). Eggs of *H. hebetor* (0.52 mm length and 0.12 mm width) are spindle shaped and slightly curved. Pupa is exarate type and protected by a cocoon produced by the last instar larva (Pezzini *et al.*, 2017). The parasitoid wasp, *H. hebetor* is cosmopolitan in distribution (Castaňé *et al.*, 2018) and has a complete metamorphosis with life cycle consisting of egg, larva, pupa and adult stages (Fig.1).

Fig. 1: Life history of the parasitoid wasp *H. hebetor*. Adult female (A); Egg (B); Larva (C) and pupa inside cocoon (D) [Photo: Hamadttu El-Shafie]

H. hebetor displays the arrhenotokous haplo-diploid sex determination mechanism, where haploid male offspring develop from unfertilized eggs through parthenogenesis, while diploid males or females emerge from fertilized eggs (Mbata *et al*., 2019). Females of this parasitoid emerge with a few limited number of mature eggs (synovigenic) and must feed on host or other materials to maintain metabolic activity and egg production (Gündüz and Gülel, 2010). The process of egg laying took only 15 minutes to be completed. It took about 42 minutes from the start of stinging the host larva until the deposition of the first egg. The female lives for 23 days during which it produces about 100 eggs. *H. hebetor* has four larval instars that are completed in only four days (Pezzini *et al*., 2017). Pupation takes place in white transparent silken cocoons spun by the last instar of full-grown larvae. The cocoon protects the developing pupa from physical damage, predators, desiccation and hyperparasitoids (Pezzini *et al*., 2017). Adult wasps emerge five days after pupation and the time of development from egg to adult is about 10-12 days depending on the host and environmental conditions (Pezzini *et al*., 2017). Newly emerged female parasitoid starts searching for host larvae to parasitize by injection of venom (Sanower *et al*., 2017) (Fig 2). The venom of the parasitoid consists of polypeptides that block glutamatergic neuromuscular transmission at the presynaptic nerve terminal, causing the death of host larvae within 15 minutes (Hagstrum and Smittle, 1978).

Fig 2: Females of the parasitoid *H. hebetor* in the act of searching and stinging a fifth instar larva of *C. cautella* [Photo: Hamadttu El-Shafie]

Conclusion

The relatively short life cycle, the ease of mass-rearing, ability to access hidden overwintering host larvae and compatibility with other biocontrol agents make *H. hebetor* an ideal parasitoid for management of pyralid moths in dates storage ecosystem.

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The first report on Fall Armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) as an invasive pest in banana from Kerala, South India and notes on its behaviour

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The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), a notorious pest of maize was recorded from India as an invasive insect pest severely damaging maize crop during 2018 from Karnataka state, South India (Ganiger *et al*., 2018). Native to the tropical region of the western hemisphere from the United States to Argentina, it was reported as the most important pest of corn in Brazil (Shylesha *et al*., 2018) causing 34% reduction in maize grain yield amounting to an annual loss of US$ 400 million (Ganiger *et al*., 2018). Later this invasive pest got introduced into Africa in 2016 (Goergen *et al*.) and to Ghana in 2017 (Ganiger *et al*., 2018) causing severe economic loss, thus warranting decisive management strategies. Its highly polyphagous nature coupled with the potential to spread into the new regions of the globe had lead IITA (2018) to observe, "Further expansion of FAW to countries adjacent to India such as Bangladesh, Nepal, Pakistan, and beyond will put the maize production of the whole Asian continent seriously at risk with dire economic consequences." After its report from India in 2018, FAW had invaded Bangladesh, Thailand, Myanmar, China, Sri Lanka and Nepal (Kushal *et al*., 2020).

FAW had been reported from peninsular Indian states of Karnataka, Tamil Nadu, Andhra Pradesh, Telengana (Venkateswarlu *et al.,* 2018) as a pest that prefer crops belonging to the Graminae family *viz*., maize, millet, sorghum, sugarcane, rice, wheat and other field crops like cowpea, groundnut, potato, soybean, cotton, etc. The conspicuous absence of reports on this pest from Kerala leads to renewed interest in the probable finding of their damage to economically important crops that have yet to record its infestation.

Materials and Methods

Surveys were undertaken regularly for detecting and identifying new and emerging insect pests of banana in Kerala. During 2020, a progressive banana farmer had informed about a severe attack of caterpillars on the banana with a hitherto unseen mode of attack in his field to the notice of the authors. Field visits were promptly conducted and damage symptoms and associated larvae that caused it was documented. As the larvae collected resembled noctuid species, they were brought to the laboratory for detailed observation.

The populations of suspected FAW from Edavaka Panchayat (Lat 1°46'53.2416" N, Long 75° 50.136" E) of Mananthavadi Block (Wyanadu District) were collected and brought to the entomology laboratory at Banana Research Station, Kannara, Thrissur, Kerala for rearing and studies on both morphological and molecular characterization as well as for the presence of natural parasitization.

Results and Discussion

The larvae collected were identified as *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera, Noctuidae) using differentials mentioned in Ganiger *et al*. (2018) and Venkateswarlu *et al.* (2018). The caterpillars had a prominent white inverted "Y" mark on the head (Fig. 1) and with distinct four black spots on the dorsum of 8th abdominal segment that are arranged in a square (Fig. 2). The larvae closely resembled armyworm in the outline. The pupae were reddish-brown in colour with the cremaster having two spines (Fig. 3).

Damage symptoms

The incidence of *S. frugiperda* was observed in a banana orchard having 5000 plants that were planted in June and August, 2020. Young larvae were greenish grey in colour with greyish blackhead were found feeding on margins of the leaf petioles and margins of pseudostems. But 3rd instars onwards the larvae were found feeding into the first 2-3 whorls of the pseudostem in young plants. They showed a marked affinity for the first and second whorls. Large and mature caterpillars with a dark grey head and dull brown body with white sub-dorsal and lateral white lines were found feeding within these feeding holes by inserting their anterior body into it

(Fig.4). Pseudostem of young banana plants of variety Nendran was seen with numerous feeding damages and boreholes 3-5 cm diameter on the surface with 1-3 cm depth (Fig. 5 and 6).

In the controlled condition of the lab, the caterpillars were also seen boring into petioles and making numerous shot holes or windows on the young leaves (Fig. 7). The presence of the larvae was confirmed by the copious amount of fecal pellets in and around the feeding areas. 3rd instar larvae were seen feeding on the spindle leaves by staying in the whorls. The mature larvae pupate inside on the outer whorls of pseudostem (Fig. 8). In a curious observation, the adult moths were found hiding within leaf axils of young plants in the orchard (Fig. 9). The incidence ranged from 1-3 larvae per plant with a maximum incidence of 20% recorded from the orchard.

New record of banana as a host and host range

According to Invasive Species Compendium, CABI (2020), *S. frugiperda* feeds on the leaves, stems and reproductive parts of more than 350 plant species. Shylesha *et al.,* (2018) point to the preference of *S. frugiperda* to crops of the Graminae family including many economically important plants such as maize, millet, sorghum, sugarcane, rice, wheat, etc. and on other field crops like cowpea, groundnut, potato, soybean, cotton, etc. They were reported to infest plants of 27 families (Goergen *et al.,* 2016). A scan through the available literature reveals scant reports on damage to banana plants by FAW, with an exception of the mention of *Musa* (Banana) and *Musa* x *paradisiaca* (plantain) as main and other hosts respectively in Invasive Species Compendium, CABI (2020). In India, FAW is mostly reported from maize and other graminaceous crops and had already spread to most parts of the Indian subcontinent covering maize farms in 20 states. Ganiger *et al.,* (2018) cautioned about the possible spread to other crops and call for a swift survey of the pest and to contain it at the earliest. The present natural infestation of *Spodoptera frugiperda* from banana is the first report of banana as a host plant for this invasive pest from India and points to its high adaptability and potential to spread. Even though maize is not a major crop in Kerala, the present incidence proves its potential to establish and build pestiferous populations in an economically important crop like banana with far-reaching ramifications. Further studies on its molecular characteristics including management options are being undertaken.

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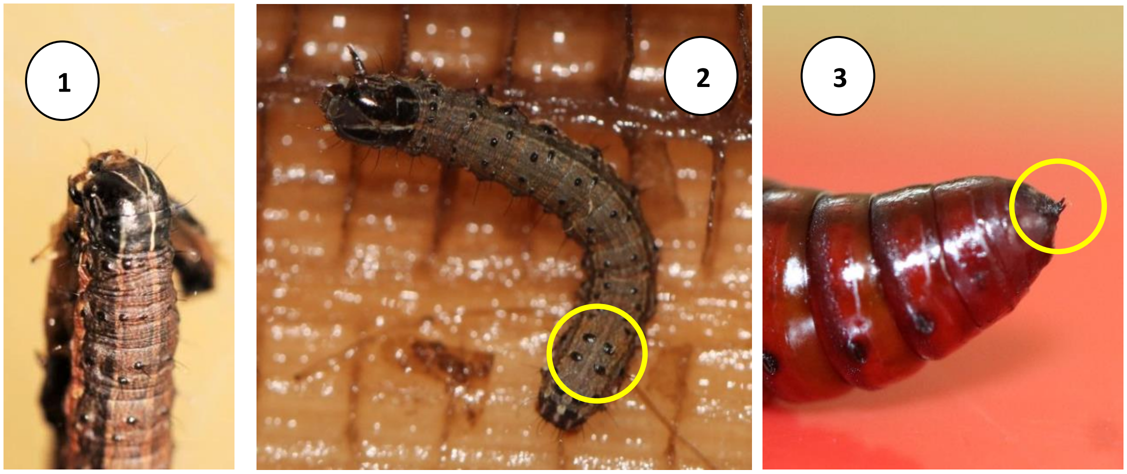
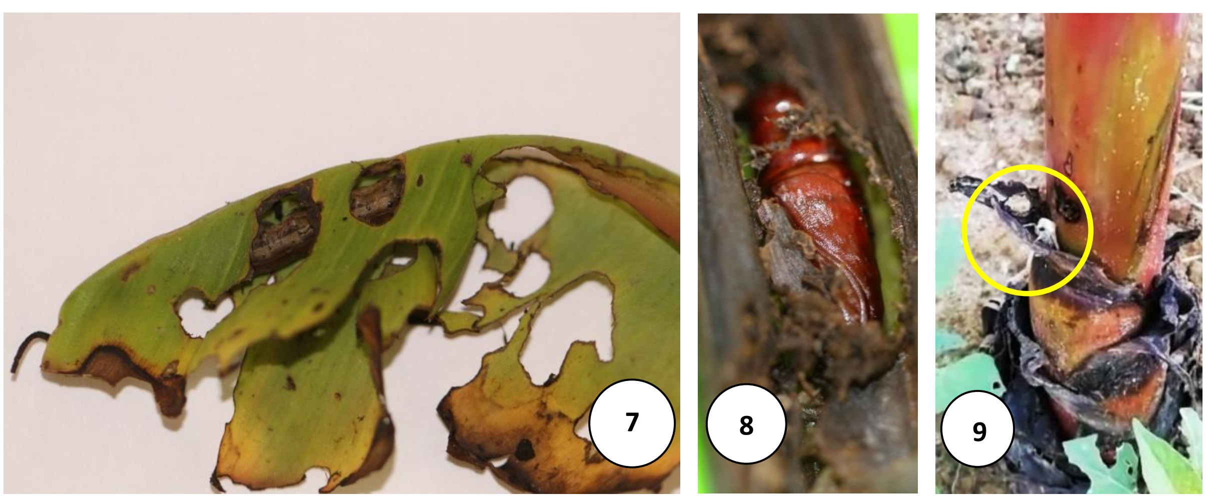


(1) White inverted "Y" mark on the head, (2) Distinct four black spots on the dorsum of *Spodoptera frugiperda* larva (3) Pupal character

(4) Mature larva feeding into the pseudostem, (5) Feeding damage to banana plant (6) *S. frugiperda* larva feeding on the outer whorls



(7) Shot holes on lamina by FAW larva (8) Pupation within pseudostem (9) Adult *S. frugiperda* hiding in leaf axil of banana

A report on the incidence of coconut nut borer in Goa

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Coconut is one of the important crops of the Goa, cultivated in 26,000 ha either as a sole crop or as an intercrop in the *Kulagar* systems (multistoried cropping system). Coconut is in high demand for cooking, tender coconut and coconut oil in the region. Recently virgin coconut oil is becoming popular. Coconut is vulnerable to many major pests *viz*. rhinoceros beetle, red palm weevil, eriophyid mite, black-headed caterpillar, rugose whitefly, etc. However, scales, leaf-eating caterpillar, nut borer, thrips, white grubs, red tree ants, etc. are some minor pests of coconut in Goa.

During our survey in coconut fields of the Don Bosco College of Agriculture (DBCA) farm, Sulcorna, Goa, we observed severe infestation of the coconut nut borer *Cyclodes omma* (Lepidoptera: Noctuidae). Caterpillars were observed feeding on young nuts (buttons) of dwarf coconut variety (Chowghat Dwarf Yellow) in the DBCA coconut plantation. The caterpillar bores into the perianth portion of the nut and feeds voraciously on inner tissues as shown in Fig 1. Later infestation destroys the entire bunch of developing nuts. Caterpillar excreta was also evident on the palm leaf petiole. Lever (1969) reported that the nut borer is dangerous and could potentially emerge as a major pest of coconut.

The caterpillars were collected from the field and reared in the laboratory at DBCA, Sulcorna to identify and further understand its development. Caterpillars (fourth instar) were fed with buttons of the same variety of coconut. It was found that within two days the caterpillar had developed into the fifth instar by moulting (Fig. 2). Further, the pupation period was observed to be 20 days (average) (Fig. 3). Similarly, the pupal stage of *Cyclodes omma* lasted for about three weeks on fishtail palm fruit (Bin, 2015)

Referring to Singh *et al.*, (2014), Hampson (1894) and Hoeven (1840), the adult was identified as *Cyclodes omma*. The adult longevity was found to be three days (Fig. 4). This is the first report of this pest from Goa.

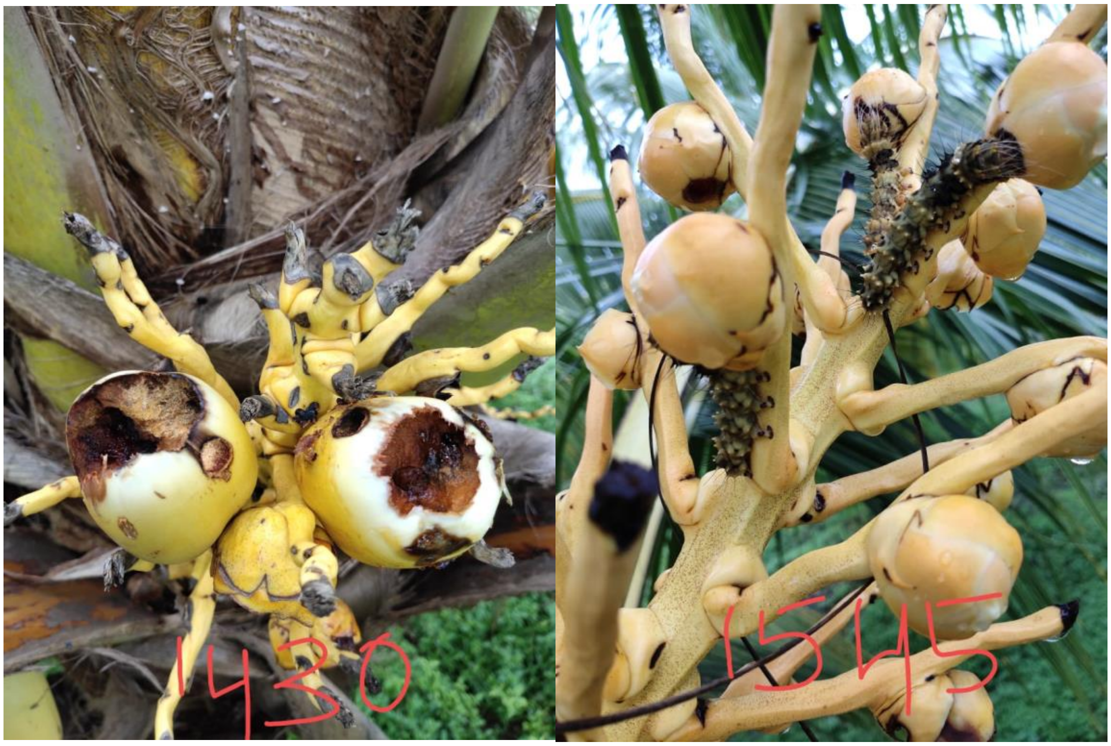

Fig 1: Nature of damage caused by the coconut nut borer *Cyclodes omma* (Hoeven)

Fig 2: Instars of coconut nut borer *Cyclodes omma* (Hoeven).

Fig 3: Pupa of coconut nut borer

Fig 4: Adult of coconut nut borer *Cyclodes omma* (Hoeven)

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Extension of biocontrol techniques in Chhattisgarh particularly in the tribal areas

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In Chhattisgarh, the Biocontrol of insects was very meagre and most of the farmers were unaware of this technique. The main reason behind it was a lack of awareness as no organization was working for providing the natural enemies to the farmers.

After the inception of All India Coordinated Research Projects (AICRP) on Biocontrol in March 2015 at IGKV, Raipur, Chhattisgarh, the work started with the objective, not only to conduct the AICRP trials but also produce natural enemies on a large scale specially *Trichogramma* (at present 4 species *viz. T. japonicum*, *T. chilonis*, *T. pretiosum* and *T. brassicae*), *Bracon* sp., Reduviid bugs, Coccinellid beetles, *Zygogramma* beetles are maintained and most importantly to create awareness through training and demonstration of agriculture extension workers, KVKs of the University and farmers. The funds given by ICAR- AICRP on Biocontrol under TSP has helped a lot to achieve all these objectives.

Chhattisgarh state comprises of three agro-climatic zones, namely, the Northern hills, Chhattisgarh plains in the central region and the Bastar plateau in the South. We are taking demonstrations and training under TSP for the last 3 years in the remote tribal areas of the State especially in Bastar. So far, TSP has been conducted in Jagdalpur, Kanker, Dantewada and Kondagaon were about 393 farmers were directly registered and a large number of other farmers were beneficiaries of the training and demonstration. Biocontrol agents produced in the laboratory of Raipur were distributed to the farmers for release in their fields in different crops. The feedback as received from the farmers are very encouraging, they used and reported these bioagents to be very useful and effective in the management of insect pests and *Parthenium* weed and later on most of the farmers personally visited the laboratory at Raipur or contacted telephonically for the supply of Biocontrol agents for subsequent season.

One of the most successful examples of interest of farmers is that in Village - Badechakwa of Bastar, where one of the beneficiary farmers of TSP, Mr. Kamal Kishor Kashyap

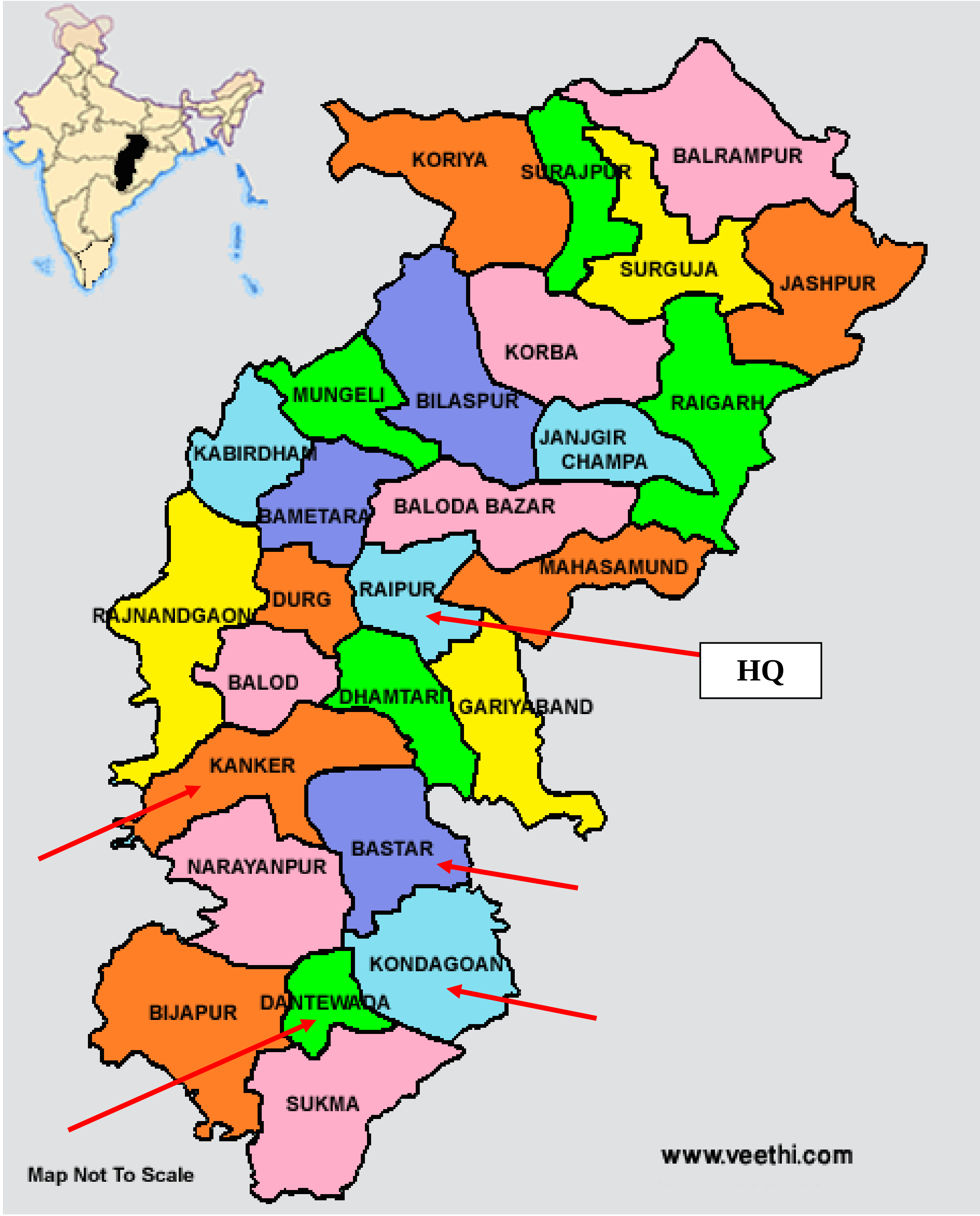
(Rashtrapati Puraskar Awardee) has himself established a small Biocontrol laboratory in his village and taken the mother culture of *Corcyra* and *Trichogramma* from Raipur laboratory. Though the lab is in preliminary stage, nevertheless the keen interest shown by Mr. Kamal Kishor Kashyap ensures that he will take this ahead.

Another important program that helped in the extension and popularization of biocontrol techniques was the “Hamar Chhattisgarh Programme” run by the State Govt. in 2016-17 to 2017-18 under which 16,955 farmers (a documented record) from all corners of the state visited the Biocontrol laboratory. After seeing the live bioagents and their mode of control of insect pests created interest and awareness among farmers.

IGKV and State Government of Chhattisgarh are constantly encouraging and giving support to produce and distribute/sale of biocontrol agents to farmers, KVKs and State agencies. In the National and State-level Kisaan Melas/farmers fairs and in ‘Rajyotsav’, the AICRP on Biocontrol is always provided with an independent stall for exhibition and demonstration of live biocontrol agents, where thousands of farmers visit and show their keen interest in this technology. Various pamphlets in the local language (Hindi) about different bioagents produced and mass multiplied in the lab were published and distributed to farmers in TSP training, Kisan Melas, etc.

Another very important contribution of the Biocontrol lab is the production of human resource experts in Biocontrol as many students of M.Sc. and Ph.D. are doing their thesis research work exclusively on bioagents. Some passed out students are working as Assistant Professors, SMS in University and State Govt. departments, who are also helping to promote and spread the biocontrol techniques. This AICRP on Biocontrol lab is also helping the other Agriculture Colleges in different districts and KVKs in the establishment of new Biocontrol laboratories in their institutes by providing the mother culture, to begin with.

Last but not the least, we acknowledge and thank ICAR-NBAIR, Bangalore for the technical/financial support provided to us, without which the above things would not have been possible.



Map of Chhattisgarh showing 27 districts

Arrow indicating districts where TSP has been conducted

Record of seed borer, *Meridarchis scyrodes* Meyrick (Lepidoptera : Carposinidae) infesting seed of jamun

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Jamun, *Syzygium cumini* L (Myrtaceae) is a common evergreen tree in the Indian continent with dense foliage grown under tropical and subtropical zones. The cultivation of this crop in India is increasing due to its commercial potential. The leaves have antibacterial properties and bark is used against inflammation while the seed has anti-diabetic properties. In Jamun, a large number of major and minor pests infest leaves, bark, flower, fruits, and seed. However, a perusal of literature reveals scanty information except for contribution by Butani (1976). Meanwhile, a survey checklist of insects associated with Jamun from India reported 79 insect species which comprised Lepidoptera 34, Hemiptera 26, Diptera 5, Coleoptera 8 and Thysanoptera 6 (Kumar *et al* 2010). A phytophagous eulophid seed borer, *Anselmella kerrichi* (Naraynan *et al.*1988) was reported to cause immense damage in Jamun. A polyphagous pest of fruit borer, *Merdarchis scyrodes* M. has been reported widely distributed in the country (Butani1979) which commonly occurred in Maharashtra on ber and recently recorded huge damage to tune of 35% fruit damage in jamun (Annonymous,2019). Therefore, the studies on bio management of pests on Jamun (Variety Konkan bahardoli) was conducted during the year 2019-20 and 2020-21 for two consecutive years under AICRP, Arid Zone Fruits, Department of Horticulture, MPKV., Rahuri (at Latitude:19.339171, Longitide: 74.651571) (Fig.1). The observation was made periodically at harvest and fruit damage was recorded based on entry hole and excreta daily up to one week and percent damage was worked out. (Figs.2-3) In the next year two sets of harvested fruits were kept for observation in which one set was washed with water and kept for observation for one month.

In the experimental fruit sample taken for the observation small holes could be seen under the microscope (Fig. 4). The eggs were laid in the rind of young fruits and larvae on hatching feed within the bored tunnel of fruit and enter the seed coat. At the maturity of fruits, larvae were not observed feeding on the pulp of the fruit. It was seen that almost 67 percent of fruits were damaged throughout a fortnight. In infested fruit pale yellow colour larvae feeds on the embryo of the seed. Initially in some fruits larvae were faint violet in colour and some were pale yellow (Figs. 5-7). The adult moth was small,and faint brown in colour (Fig.8).

It was evident that in all the harvested fruits samples kept for investigation, initially no holes could be seen with naked eyes but after 2-3 days fecal matter was seen from tiny depressed fruit rind. Similarly, in the second set of seed samples, Jamun also fecal matter was noticed for a long time. On perusal of literature, none of the research workers reported *M. scyrodes* as a major seed borer besides fruit borer. However, the incidence of Euloophid seed borer, *Anselmella kerrichi* and *Curculio calbum* F was not noticed as reported by Ramegouda *et al*. (2019).

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Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Impact of fruit fly (*Bactrocera dorsalis*) trap on increasing farmers' income in mango cv. Alphonso in Ramanagara district of Karnataka, India

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Bactrocera dorsalis (Hendel) commonly referred to as the Oriental fruit fly (Diptera: Tephritidae) is a very destructive pest of several fruit crops causing severe economical losses to the farmer (Verghese *et al*., 2002, Rashmi *et al*., 2017). It causes pre and post-harvest losses in mango right from the farmer to the consumer via the trader. The extent of damage can vary from 1 to 86 percent in mango and in guava, fruit damage is reported from 19 to 80 percent (Verghese *et al.*, 2004, 2012). In Karnataka mango is grown in an area of 1,40,497 ha. producing 16,07,595 metric tons with an average productivity of 11.44 tons/ha. Out of 29 districts in Karnataka, Ramanagara district (12.7209° N, 77.2799° E) ranks number two in the area and three in production respectively but ranks seventeen in productivity. The productivity of the district was low owing to the incidence of insect pests and diseases. Major pests reducing the productivity in mango were fruit fly. To reduce the menace of these pests ICAR-IIHR developed a male annihilation technique (MAT) of fruit fly using methyl eugenol impregnated fruit fly traps. The present study was conducted in Ramanagara district of Karnataka to assess the impact of fruit fly traps in the mango field on the loss of fruits and its impact on farmers' income.

Impact of fruit fly trap in mango *cv* Alphonso was significant in reducing the menace of fruit fly by reducing the infestation from 8.8% to 4.3 percent in five years. On the contrary, the percent of fruit fly infestation increased from 11.6 percent to 30.6 percent in control plots. Mango fruit loss was estimated at 1,87,878.8 metric tons in five years where the fruit fly traps were not deployed and the loss was 1,34,996.3 metric tons where the fruit fly traps were deployed. The saving in fruits was 52,882.5 metric tons by deploying traps. The estimated savings to farmers was INR 167.9 million to the farmers of Ramanagara district in five years (Table 1).

Table 1. Extent of savings by tying fruit fly trap

Year	Estimated fruit loss without traps (tons)	Actual loss estimated under both conditions (tons)	Saving of fruit from fruit fly (tons)	Economic value of fruits saved (INR) in millions
2008-09	22,631.3	22,177.8	453.5	1.44
2009-10	28,289.1	25,135.4	3,153.7	10.01
2010-11	33,751.9	26,371.7	7,380.2	23.43
2011-12	43,506.7	29,062.9	14,443.8	45.86
2012-13	59,699.8	32,248.5	27,451.3	87.16
Total	1,87,878.8	1,34,996.3	52,882.5	167.9

As India is a major exporter of mango to different destinations across the world were *Bactrocera dorsalis* is an A1 quarantine pest, it's very essential for the farmers to adopt pre and post harvest fruit fly control mearures which involves the methyl eugenol traps, bait sprays and sanitation (Verghese, A. and Devi, S, 1998, Rashmi *et al*., 2014).

Acknowledgment

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Record of four local species of Reduviids from Raipur, Chhattisgarh

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The Reduviidae is a world–wide distributed family of predatory insect which comprise about 7000 species; about 240 species have been described in India (Sahayaraj, 2012), thus forming one of the prodigious families in Hemiptera. Among the harpactorines, *Sphedanolestes* dominates with 20 species, *Sycanus* with 18 species, *Rhynocoris* with 17 species and *Coranus* with 12 species (Ambrose and Kumaraswami, 1992).

Four local species of Reduviid bugs were recorded from different crop eco-system of experimental fields of Indira Gandhi Krishi Vishwavidyalaya, Raipur situated in the central part of the Chhattisgarh state and lies at 21.6^{0}N latitude and 81.63^{0}E longitude at an altitude of 298 meter above Mean Sea Level (M.S.L.) under agro-climatic zone of Chhattisgarh plains. The collected specimens were identified by Dr. Bhagyashree S.N., Scientist, Division of Entomology, ICAR-IARI, New Delhi. The details are as follows:

Table 1. List of identified local Reduviid species collected from IGKV fields

Sl. No.	Species	Sub-Family	Identification Character	Site Of Collection
1.	***Rhynocoris fuscipes***	**Harpactorinae**	Quadrat cell in forewing	Congress grass (*Parthenium hysterophorus*) and okra (*Abelmoschus esculantus*) ecosystem
2.	***Coranus* sp.**	**Harpactorinae**	Quadrat cell in forewing	Soybean (*Glycine max*) ecosystem
3.	***Scadra* sp.**	**Ectrichodiinae**	Forked scutellum	Congress grass (*Parthenium hysterophorus*) ecosystem
4.	***Acanthaspis siva***	**Reduviinae**	Large circular yellow spots on forewing towards the base	Congress grass (*Parthenium hysterophorus*) ecosystem

Fig 1. *Rhynocoris fuscipes*

Fig 2: *Coranus sp.*

Fig 3: *Scadra* sp.

Fig 4: *Acanthaspis siva*

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Sporadic incidence of green stink bug in Kharif paddy

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Paddy is the most important staple food of India and it is cultivated in an area of 266.60 lakh ha. In Telangana State, India, the paddy area during *Kharif* 2020 has been estimated to be 48,46,620 acres as against normal area of 27,25,058 acres (i.e 178% of normal). India’s rice production is estimated at record 102.36 metric tonnes in *Kharif season* of 2020-21 as against 101.98 million tonnes in 2019-20. Telangana State Government has set a target of 1.05 crore tonnes this year as against 66 lakh tonnes last year.

During *Kharif* season 2020, severe incidence of gall midge and stem borer, moderate incidence of panicle mite and brown plant hopper and severe grain discoloration were reported from different rice growing districts of Telangana . Due to continuous rains coupled with cold weather and low light intensity, sporadic incidence of green stink bug (*Nezara viridula* L. Family: Pentatomidae, Order: Hemiptera)) was noticed in farmer’s fields in Warangal (17^{o}57’0’’ Northern latitude and 79^{0}30’0” Eastern longitude, Karimnagar (18^{o}26’18.8’’ Northern latitude and 79^{0}7’43.83” Eastern longitude), Jagtial (18^{o}48’0.00’’ Northern latitude and 78^{0}55’48.00” Eastern longitude) and Nizamabad Districts (18^{o}40 17.54’’ Northern latitude and 78^{0}5’55.6” Eastern longitude) causing considerable economic damage. As per the feedback from affected farmers, the grain damage ranged from 5-10 per cent. Stink bugs cause grain damage between 3 and 15% in the dry season, and 3 and 12% in the wet season (Gupta *et al*., 1993).

Green stink bug is highly polyphagous. Both nymphs and adult bugs suck the sap from rice grains in the milky stage. When grains are ripened the bugs feed on panicle stalks and pedicels. Bug feeding causes partially or wholly stained grains due to infection with bacteria and fungi (Russin *et al*, 1988). Damaged grains are discolored and unfilled. Stink bugs produce a strong odour when disturbed. Severity of the damage depends on the number of punctures in the grain. Discolored grains have lower grade and poor milling quality. They shrivel and become covered with brownish spots and fungal growth (Ito, 1986). The major host plants of this insect pest includes okra, cruciferous crops, cucurbits, sunflower, sesame, cowpea, mung bean, soybean, tomato, black gram etc and wild host plants are Barnyard grass, Cyperus sp, Johnson grass (Kamminga *et al,* 2012).

The body of *N. viridula* adult is bright green and shield shaped and the eyes are usually reddish. Eggs are deposited in tightly packed single layered rafts of about 60 eggs on the leaf surface. These are barrel shaped, cream to yellow, slightly elongate and circular from above. Nymphal colour changes progressively in successive instars (five instars). On hatching the nymphs are mostly black. Nymphs have two rows of white dots on their abdomen. By the fifth instar, a considerable proportion of each is green. Total life cycle is completed in 18-21 days.

Some of the important management practices recommended against green stink bug includes: use of trap crops such as sunflower, triticale, pearl millet, buckwheat *etc* (Mizell *et al.* 2008), utilization of bio-control agents like lacewing larvae, spined soldier bug and birds as predators, parasitoids like tachnid flies (*Trichopoda pennipes*), wasps (*Trissolcus, Anastatus* and *Telenomus*) (Capinera, 2001) and mermithid nematodes and judicious use of insecticides such as thiamethoxam, dinotefuran, imidacloprid, clothianidin, azadirachtin and spinosad (Kamminga *et al.* 2009).

The occurrence of green stink bug during *Kharif* season 2020 in few districts of Telangana State though, sporadic in nature, research studies have to be made on few important aspects such as bio-ecology, diversity of natural enemies *vis-a-vis* bug population, impact of climate change/ weather factors, influence of cropping pattern and cropping sequence, effects of commonly used insecticides, impact of varietal composition and testing efficacy of insecticides etc., and finally evolving integrated management systems. . In addition to research, farmers have to be educated and forewarned about this pest and advocate available management practices to contain the economic damage caused by this bug.


Plate 1. Green stink bug nymphs on panicles

Plate 2. Grain discoloration by green stink bug

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Record of Scarab beetles (helpers and pests) from area adjoining Bannerghatta National Park, Bengaluru, Karnataka, India

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Introduction

Scarab beetles include Coprophagous beetles that comprises of dung beetles, which play an immense role in ecosystems by feeding on dung/fecal matter, thereby involving in nutrient cycling and improving the soil structure. Phytophagous scarab beetles belonging to sub-family Dynastinae, Rutelinae, Melolonthinae and Cetoniinae, are reported to cause economic damage to agri-horticultural crops (Chandra and Gupta, 2011). Dung beetles were previously reported from Bangalore University Campus (Deepak *et.al.* 2014), the present observations are first time report from the site adjacent to the Bannerghatta National Park, Bengaluru.

Study area and methodology

The study was carried out from 9 -12th May 2019 at A Rocha Field Study Centre (12.8136° N, 7.5673° E), Kasserguppe Village, Bilwardahalli (Dakle), Bannerghatta (Post), Jigani (Hobli), Anekal (Taluk) Bengaluru Urban district, Karnataka, India. Scarabaeids are best sampled through light trapping and can be used to assess the quantitative abundance of insect species (Szentkiralyi, 2002). The phytophagous scarabs were collected using light traps and hand picking methods. The light traps were operated between 19:00 to 24:00 hrs. The dung beetles belonging to the subfamily Scarabaeinae were sampled using hand picking method. In this method, the dung pats were located in the field. The pats were overturned with a Hoe and the searched for the presence of dung beetles. After sampling, the beetles were preserved in 70% alcohol for further identification.

Results and Discussion

Ten species of dung beetles (family Scarabaeidae) belonging to three different tribes were identified during the present study (Table 1). The species were identified up to species level using taxonomic descriptions provided by Priyadarsanan Dharma Rajan (ATREE, Bengaluru), India Biodiversity Portal (https://indiabiodiversity.org/)

Table 1: Dung beetles recorded in the study site

Tribe	Type of dung	Species	Functional guild
Gymnopleurini	Elephant dung	*Gymnopleurus cyaneus* Fabricius (1798)	Roller
		Gymnopleurus miliaris Fabricius (1775)	
Onthophagini		*Caccobius meridionalis* Boucomont (1914)	Tunneler
		Onthophagus cervus Fabricius (1798)	
		Onthophagus dama Fabricius (1798)	
		Onthophagus igneus Vigors (1825)	
		Onthophagus kchatriya Boucomont (1914)	
		Onthophagus quadridentatus Fabricius (1798)	
Onthophagini	Elephant dung	*Onthophagus unifasciatus* Schaller (1783)	Tunneler
Oniticellini	Cattle dung	*Tiniocellus spinipes* Roth (1851)	Dweller

Scarab helpers-ecosystem service providers: Dung beetles provide an important ecological service. They feed on the dung of other organisms and thereby cleanse the environment. They breakdown, sort and arrange dung in various ways which favours the germination of seeds contained in the dung and thereby supports pollination. Different species of dung beetles occupying different functional guilds act as a collective cooperative enterprise that helps to sanitize the environment by preventing the spread of disease, decreasing foul odour and maintaining ecosystem health.

Functional guild and resource partitioning: Dung beetles are a great example of how similar species commonly use limiting resources in different ways. It was found that different species of dung beetles competed for the same resources, such as food, nutrients, space or light while cooperating between themselves by occupying different ecological functional guilds. If ‘n’ species attempt to establish themselves in a group of niches numbering less than ‘n’, then after a sufficiently long period, some must perish (Rescigno *et.al.* 1965). In time, natural selection might favour only one species to occupy a given niche at a given time according to the competitive exclusion principle.

Scarab pests-the foes of the farmers: The scarab beetles belonging to the sub-family Dynastinae, Rutelinae, Melolonthinae and Cetoniinae cause severe damage to crops of agricultural importance (Table 2). The phytophagous scarabs were identified up to species level using taxonomic descriptions provided by Dr. Devanshu Gupta, India Biodiversity Portal (https://indiabiodiversity.org/).

Table-2: Phytophagous Scarab (pest species) recorded in the study site

Sub-family	Species	Host Plants	Collection method
Rutelinae	*Anomala sp.*	*Arachis hypogaea, Psidium guajava, Syzygium cumini* (Bhawane *et.al.* 2012)	Light trap
Melolonthinae	*Holotrichia serrata* (Fabricius)	*Arachis hypogaea*, *Saccharum sp.*, *Nicotiana sp.*(Parasharya, 1994); *Butea monosperma, Careya arborea, Bridelia retusa, Emblica officinalis* (Bhawane *et.al.* 2012)	
	Holotrichia fissa (Brenske)	*Terminalia arjuna, Terminalia tomentosa, Zizyphus jujuba, Syzygium cumini, Grewia sp*. (Bhawane *et.al.* 2012)	
Cetoniinae	*Protaetia alboguttata* Vigors (1826)	*Zea mays, Solanum melongena, Carissa carandas* (Jayanti *et.al.* 2017)	Hand picking
Dynastinae	*Oryctes rhinoceros* Linnaeus (1758)	*Coccus nucifera, Ficus sp*. (Oehlschlager *et.al.* 2007)	Light trap
Dynastinae	*Phyllognathus dionysius* Fabricius(1792)	*Oryza sativa, Zea mays* (Bhawane *et.al.* 2012); *Saccharum sp.*, *Arachis hypogaea* (Sreedevi, 2018)	Light trap

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Nymphal cannibalism in reduviids: a constraint in mass rearing

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Reduviids have been recorded as important polyphagous natural enemies, helping in suppressing several economically important insect pests, especially hemipteran and lepidopterans. Since biological control of insect pests is gaining momentum, conservation and augmentation of this predatory bug are very essential, but nymphal cannibalism is a major constraint in the mass multiplication of Reduviids in the laboratory. No documented evidence is available on cannibalism in reduviids except the nymphal camouflaging on cannibalism (Ambrose, 1986; Livingstone and Ambrose, 1986). Since nymphal cannabalism seems to be one of the major constraints in mass multiplication, knowledge on minimizing it is imperative.

In the present piece of work, the effect of mass rearing density and prey depriviation on the cannibalistic behaviour of Reduviids were observed and it was found that, the 1st nymphal instar exhibited the maximum rate of cannibalism followed by the 2nd and 5th instars, whereas it was comparatively lesser in 3rd followed by the 4th instar. The rate of cannibalism seemed to be directly proportional to the rearing density *i.e*. cannibalism was more when nymphs were reared in more crowded conditions. Prey deprivation (absence of food) was also found as an important factor that seemed to accelerate the rate of cannibalism. Further, cannibalism was more pronounced and commonly observed during molting where the other nymphs attacked and fed upon the one undergoing molting, which could be due to its immobility and softness of new cuticle underlying the exuviae of nymph.

Fig. 1: Photographs showing nymphal cannibalism in *Rhynocoris marginatus.*

Fig. 2. Photographs showing nymphal cannibalism in *Sycanus collaris.*

Thus, from the present observations, the first nymphal instar invariably exhibited maximum percentage of cannibalism irrespective of the rearing density and whether fed or starved, whereas the rate of cannibalism was found to decrease in succeeding nymphal instars. Space had a direct impact on nymphal cannibalism since the reduction in rearing space leads to crowding of nymphs ultimately resulting in increased cannibalism. As far as nymphal cannibalism due to prey deprivation was concerned daily feeding is suggested as a pre-requisite for laboratory rearing. This is in agreement with earlier findings of Ambrose *et al.,* (1980, 1985, 1990 and 1992), Iqbal and Aziz (1976), Sofi and Bhat (1997) and George (2000).

Hence, it can be concluded that space and food are the two limiting factors which need to be taken care of for successful mass multiplication of this potential biological control agent.

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Pod weevil, *Apion amplum* (Faust) (Coleoptera: Apionidae) on green gram

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In recent years, the pod weevil (*Apion amplum*) has gained a major pest status on green gram grown in the transitional belt districts of northern Karnataka, like Dharwad and Haveri. The infestation of *A.amplum* on green gram starts with the appearance of flower buds after 30 to 40 days of sowing. Both grubs and adults causes damage to the crop. The adults feed by remaining on the lower surface of the leaves, causing shot holes. As a result, numerous minute holes could be seen on the severely damaged leaves. Adults feed on tender pods and make numerous punctures with its snout on the pod for egg laying. Eggs are laid individually at the nibbled punctures near the seed. A maximum of 9 eggs are laid on a single pod with the average usually ranging between 4 and 6. Sometimes, adults are also seen feeding on flower buds. On hatching, the grubs feed on the seeds inside the pod hence damaging the embryo of the seed. In case of smaller, the entire seed is more or less eaten up. Pupation takes place inside the pod itself. The adults come out of the pod by making circular holes with their snout. The affected pods exhibit irregular and sunken areas in comparison with healthy ones.

The biology of the pest was studied in detail under laboratory conditions. The incubation period, larval period and pupal period were 3-5, 12-16 and 7-9 days, respectively. Femaleslived for 34.4 days compared to males (24.2 days). The pre-ovipositor period and oviposition period are 5-7 and 3-5 days, respectively. The egg laying capacity of female varied from 9-16.

Studies on the seasonal incidence of the pod weevil on green gram revealed that its peak activity was observed when the crop is sown during first fortnight of July and August. Pod damage varied from 20 to 60 percent. The percent loss in yield due to pod weevil was to the extent of 62.50% in the untreated crop. For control of this pest spraying of insecticides should be done when the crop is at 50 percent flowering. The botanical insecticide, azhadiractin 1 EC @ 2 ml per lit of water and chlorpyriphos 20 EC @ 2 ml per lit of water were found effective for the management of pod weevil in the mungbean.

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Adults feeding on flower buds and pods

Damaged pods with exit holes

Adult weevils under the leaf

Breeding tomato for resistance to South American tomato moth, *Tuta absoluta*

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South American tomato moth, *Tuta absoluta* (Meyrick) (Gelechiidae: Lepidoptera), a serious pest of tomato (*Solanum lycopersicum*) in tropics and subtropics, is rapidly spreading world over. In India, it was first reported in 2014 and since then it has reached all major tomato growing areas in the country causing significant damage ranging from 50 to 100% both under open and polyhouse conditions (Sridhar *et al*., 2014, Sridhar *et al*., 2020).

T. absoluta larvae can destroy the tomato canopy by excavating the leaves, stems and buds; and burrows into fruits causing the quality decline of fresh tomato and yield loss. Multiple generations of the pest coupled with its mining nature of damaging all the parts of the plant at all stages of the crop make it a difficult pest to control. As of now, chemical control methods are being followed. But the feeding habit of the larvae, the increasing number of resistant strains of this pest, together with the negative impact of the insecticides in the environment, makes the chemical control method not sustainable. In addition, mating disruption methods (like sex pheromones) have been used to control *T. absoluta*, but this technique is a lot more expensive than pesticide applications. The biological control methods are still under development for the management of this pest effectively. Due to the various reasons, stated above, exploring wild accession of tomato for new sources of resistance is needed (Bitew, 2018).

Keeping in view the importance of host plant resistance as an important component in the IPM against this pest, twenty one wild/cultivated/advanced breeding lines of tomato were screened for resistance to *T. absoluta* under greenhouse conditions (choice bioassay) at ICAR-Indian Institute of Horticultural Research, Bengaluru during 2017-18. From these screening trials, promising genotypes were evaluated further for their antibiosis activity through no choice bioassay under *in-vitro* conditions. For the *T. absoluta* screening, under field conditions, damage scoring proposed by Maluf *et al*., (1997) was followed. From 21 genotypes screened, six wild accessions *viz., S. pennellii* (LA 1940); *S. chilense* (LA 1963); *S. arcanum* (LA 2157); *S. lycopersicum* (LA1257) and *S. corneliomulleri* (LA 1292, LA1274) were found relatively resistant to *T. absoluta* based on mean per cent damage. Among these six genotypes, *S. pennellii* (LA-1940) showed resistance both under choice and no choice bioassays with a higher number of type IV trichomes, highest total flavonoids and phenols (Sridhar *et al*., 2019). In addition, *S. pennellii* had the highest total phenols (2200 mg/100 g dry weight). In general, glandular trichomes (GTs) (type I, IV, VII) showed negative correlation in different genotypes of tomato with reference to larval number/plant, percent damage and adult activity, whereas type V (non-GTs) showed a negative correlation with number of larvae/plant (Sridhar *et al*., 2019). Trichomes, besides acting as chemical barriers, can also act as physical barriers, limiting pest insect access to the plant surface, due to trichome density and length.

An interspecific hybrid (F_1) between, cultivated line *S. lycopersicum* (TLBER-38-7) and wild genotype identified as resistant to *T. absoluta viz.*, *S. pennellii* (LA 1940) was successfully developed to introgress genes resistant to *T. absoluta*. The evaluation of F_1 progeny revealed clear difference in terms of resistance to the target pest. F_1 progeny has recorded a total phenols of 1637 mg/100 g dry weight and total flavonoids of 1160 mg/100 g dry weight. On F_1, *T. absoluta* took additional time for completing the larval and pupal stages coupled with higher larval mortality, which may be attributed to the antibiosis of the host against *T. absoluta*. On $F_{1,}$ developmental time for larvae and pupae was recorded as 12.33 days and 7.33 days, respectively, as against 9.33 days and 5.33 days, respectively on check cv. Shivam. When *T. absoluta* was reared on F_1 progeny, only 18 per cent of the pest could reach the adult stage. BC_1F_1 and F_2 progenies of SH-3 are being further advanced to study the resistance/tolerance of the lines against *T. absoluta*.

The present attempt to introgress *Tuta* resistance genes to the cultivated tomato lines is very challenging, as the resistance to *T. absoluta* is observed only in wild genotypes and needs different breeding approaches to successfully introduce the resistant genes into the cultivated lines.

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The Record of *Adoretus* sp., (Scarabaeidae: Coleoptera) on okra *(Abelmoschus esculentus* L.) and chilli *(Capsicum annuum* L.*)* crops in Kolar district of Karnataka

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Okra, belonging to the family Malvaceae is an important vegetable crop cultivated for its tender pods. Chilli, belonging to family Solanaceae accounts for 20-30% of total Indian spices exports valuing approx. Rs. 400-500 crores. Oleoresin is important product being exported to European countries. Capsaicin has significant physiological action which is used in many pharmaceutical preparations and ointments for cold, sore throat, chest congestion etc., It is also used in cosmetics like prickly heat powders and skin ointments.

During the survey for the presence of insect pests of horticultural crops in Kolar district (longitude 78^{0}10’25” and latitude 13 00’00”) of Karnataka, the adults of scarab beetles, *Adoretus* sp. (Scarabaeidae: Coleoptera) were recorded to feed on okra and chilli crops. The adults injured both young and matured leaves by skeletonizing with their chewing type of mouth parts. The damaged parts were visible on the plants. Subsequently, the insect specimen was confirmed as *Adoretus* sp. (Scarabaeidae: Coleoptera) by Senior Technical Officer, Regional Plant Quarantine Station, Bengaluru, Karnataka.

Adoretus sp., is a polyphagous beetle, native to parts of eastern Asia, which has been introduced (probably via the plant trade) widely throughout much of Southeast Asia and many Pacific islands, and has the potential to spread further (McQuate and Jameson, 2011b). It feeds on a broad range of plants and can cause severe damage to crops, ornamental plants and trees in places where it has been introduced. Taxonomic identification is problematic. Adults of species in the genus *Adoretus* are similar externally, about 10 mm long and brownish in colour with cream-coloured scales. The scientific literature for identification is scarce (regional publications include those by Péringuey (1902), Arrow (1917) and Baraud (1985), and the form of the male genitalia is considered the best method for identification (McQuate and Jameson, 2011b).

Larvae are white, C-shaped grubs with a conspicuous head and short legs (Mau and Kessing, 1991). Pupae are 6.0-12.0 mm long, and covered with dense, short setae. Eggs are oval, 1.5 x 1.0 mm, and white, becoming duller before hatching (Habeck, 1963).

The unusual mouthparts result in a characteristic interveinal defoliation pattern. The labrum is produced ventrally at the middle and forms a tooth-like process that completely separates the mandible and the maxillae into two independent chewing apparatus that do not meet in the middle. Beetles feed with only one side of the mouth at a time; this produces paired holes in leaves and a narrow strip of leaf is left intact in the middle. McQuate and Jameson (2011b) reviewed the plant hosts of adult *A. sinicus*. They reported that this insect feeds on over 250 species and approximately 56 families of plants according to Habeck (1963), or on over 500 plant species according to Hession *et al.,* (1994). They state, citing Mau and Kessing (1991), Arita *et al.,* (1993) and Zee *et al.,* (2003).

Host plants include many economically important (crop) plants such as broccoli (*Brassica oleracea* var. *italica* Plenck), cabbage (*Brassica oleracea* var. *capitata* L.), cacao (*Theobroma cacao* L.), corn (*Zea mays* L.), cotton (*Gossypium barbadense* L.), cucumber (*Cucumis sativus* L.), brinjal (*Solanum melongena* L.), ginger (*Zingiber officinale* Roscoe.), grape (*Vitis labrusca* Bailey.), green beans (*Phaseolus vulgaris* L.), jack fruit (*Artocarpus heterophyllus* Lam.), okra (*Abelmoschus esculentus*), peanuts (*Arachis hypogaea* L.), star fruit (*Averrhoa carambola* L.), strawberry (*Fragaria chiloensis* [L.] Duch.), sweet potato (*Ipomoea batatas* [L.]), taro (*Colocasia esculenta* [L.] Schott) and tea (*Camellia sinensis* L.)".

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Different stages and damage symptoms of *Adoretus* sp.

Grub Adult beetle

Group of beetles feeding on

Healthy leaf (Okra) Infested leaves (Okra)

Healthy leaf (Chilli) Infested leaves (Chilli)

Drift foraging in the brown ant *Myrmicaria brunnea* in an urban terrace garden

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The brown ant, *Myrmicaria brunnea* Saunders, (Formicidae: Hymenoptera) is mainly distributed in the southern Asian region, including India, Malaysia, Vietnam (AntWeb version 8.41, 2020). It is a soil nesting Formicid, often in large (one to two feet) crater-like mound nests, around base of shrubs and trees. Characteristically, it has a down-curved abdomen, pronounced as it crawls along. It is more of an individualistic or small group forager, so rarely one would find them in large congregations, even around their nests! Food is mainly scavenging dead insects and animals as well as tending Homopterans (Eguchi *et al*., 2011).

In Bangalore, India (12° 57' N, 77° 38' E**)** at an altitude of 965m, this ant species is fairly common in urban and peri-urban gardens (Ali, 1981; Verghese and Veeresh 1981, Viyolla, 2016).

The first formal documentation of ants in India was by Bingham, (1903)- in *Fauna of British India*. Shifting from only faunal to behavioral and ecological studies especially in agro-ecosystems started in the eighties. One of the impetuses of this was a review published by Verghese and Veeresh (1981). This prompted many ant-plant-homoptera-predator interaction studies with quite some implications in sucking insects management.

In a terrace garden, where yard-long bean is being grown, *M. brunnea* was found frequently foraging. On closer look it was found that an ant was attending a tree hopper (Membracidae: Homoptera), literally “milking’ the honey dew excreted by the bug (Fig 1). This was on 30th September, 2020.

There was only one tree hopper on the entire climber. By 5th October, 2-3 ants were attending to the same, single membracid. They seemed to take turns as they shuffled around the bug. After 8th October there was no sign of the Membracid, but the ants, now in small groups of 2-3 (about 7 such groups) were found at the tender leaf/flower axils, probably foraging on the nectaries (Fig 2).

What intrigued me was the fact these observations were on a terrace where no ant nests were present. There were no nests around at least 50 sq m of the place! In an urban park, nearly 100 meters away, these ants are common. These *M. brunnea* ants found on the terrace, seemed to be 'drift foragers', surviving on honeydew and nectaries.

Fig. 1. *M. brunnea* feeding on the honey dew excreted by the bug

Fig. 2. *M. brunnea* found on the flower axils

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Field incidence of foliage feeders in groundnut

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Groundnut (*Arachis hypogaea* L.) is a principle oilseed crop of India also known as peanut, grown in the semi–arid tropic areas (Kandakoor *et al*., 2012). More than 100 species of insects and mites are known to attack groundnut (Nandagopal, 1992). Incidence of foliage feeders was recorded in groundnut in the seed production farm of Krishi Vigyan Kendra, Lunkaransar (Bikaner) during kharif, 2020. Among the various insect pests attacking this crop, the foliage feeders like pod borer (*Helicoverpa armigera*), tobacco caterpillar (*Spodoptera litura*) and hawk moth (*Acherontia* sp., *Hippotion celerio* and *Hyles* sp.), etc cause considerable losses in the production of pod and fodder yield in groundnut. (Fig 1)

The tobacco caterpillar, *Spodoptera litura* (Fabricius) and gram pod borer, *Helicoverpa armigera* (Hubner) are known to inflict direct damage to the crop by consuming the photo-synthetically active foliage. They, cause a 30 to 40 percent loss in pod yield during severe pest outbreaks (Nandagopal, 2004).

Among the defoliators tobacco caterpillar, *S. litura* (Lepidoptera: Noctuidae) is one of the important polyphagous pests, which is widely distributed throughout Asia and causing considerable economic loss to many fields, vegetables and fruit crops. In cases of severe infestation, the entire crop is damaged badly, thus causing 40 percent defoliation of leaf area. (Fig 2)

Pod borer, *H. armigera* (Lepidoptera: Noctuidae) is a most destructive polyphagous pest and it attacks more than 200 plant species including cash crops, vegetables, fruit crops and trees (Manjunath *et al*., 1989; Fitt, 1991). The damage caused by the larvae to groundnut foliage is similar to that caused by the tobacco caterpillar and hairy caterpillars, and they also prefer to feed on flowers and buds. When tender leaf buds are eaten symmetrical holes or cuttings can be seen upon the unfolding of leaflets. (Fig 3)

Hawk moth caterpillars, *Hippotion celerio* and *Hyles* sp. (Lepidoptera: Sphingidae), mainly causes damage to the sweet potato, sesamum, leguminosae like soyabean, *Phaseolus* sp. and beans; other hosts include sunflower, citrus, grapevine, groundnut, etc. The larva of the hawk moth is found on the underside of leaves and defoliated the leaves from the margins. Fig 4 (a and b)

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Fig. 1 Damage caused by the foliage feeders in the groundnut

Fig. 2 Larvae of *Spodoptera litura* on groundnut

Fig 3 Larvae of *Helicoverpa armigera* on groundnut

Fig. 4 (a and b) Larva of Hawk moth on groundnut

Herbivore diversity of a unique, islanded and managed sugarcane agro-ecosystem comprising *Saccharum* germplasm

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The islanded and managed sugarcane agro-ecosystem (11°52' N, 75°25' E, 11m MSL) exists in the heartland of the Kannur District, Kerala state, India as an integral part of the ICAR-Sugarcane Breeding Institute Research Centre (encompasses approximately 20 acres), since 1962. The center hosts the world sugarcane germplasm collection which includes ISSCT (International Society of Sugar Cane Technologists), Indian collection consists of approximately 3500 *Saccharum* and related species. The center is located approximately 200 km from the commercial sugarcane belt to manage the field gene-bank free of pests and diseases. The collection is replanted every year during the January-February planting season and the previous year crop being retained until the current year crop gets established in the field. Thus, the center provides a unique agro-ecosystem with the availability of crops throughout the year in the field which is islanded from the main sugarcane growing area and managed following recommended agricultural practices. The landscape has previously been subjected to paddy cultivation as a wetland before the center came up. The center comes under a humid tropical monsoon climate with precipitation is heavily seasonal where June to September is known as the wettest months with south-west monsoon and the occasional occurrence of localized flooding during the time.

The existence of the manmade ecosystem for more than five decades since the establishment subjected to continuous interaction with the dynamic surrounding and urban environment and provided shelter to the various arthropods including herbivores, omnivores and carnivores.

The plant diversity of the ecosystem highly differs from that of mainland sugarcane (Monocropping of *Saccharum spp*. hybrids) with the growth of various *Saccharum spp* viz., *S.officinarum*, *S.barberi*, *S.sinense*, *S.robustum* & *S. edule* and *S.spontaneum;* hybrids of Indian and foreign origin *(Saccharum spp.* hybrids*)* and sugarcane allied genera such as *Erianthus, Narenga*, and *Sclerostachya* which fundamentally created a heterogeneous habitat in the ecosystem (approximate area of the each germplasm grown mentioned in Table 1).

Table 1. Area of the *Saccharum* germplasm in the ecosystem

Germplasm	Area (in ac) (Total area= 20 ac approx.)
S.officinarum	2.5
S.barberi	0.2
S.sinense	0.2
S.robustum and *S. edule*	0.4
S.spontaneum	2.0
Indian hybrids	3.3
Foreign hybrids	3.2
Related genera	1.0
Other clones	2.0
Fallow grassland; Irrigation channels; openwells; farm buildings etc.	5.2

Herbivore diversity recorded in the ecosystem

The observational studies were done over three years from 2017- 2020 and details were collected on herbivorous arthropods/pests in the ecosystem (listed below). The abundance and the diversity of habitat vegetation provided numerous herbivores to survive in the ecosystem and some of them are essentially new to the sugarcane and unfamiliar as pests in the mainland sugarcane growing areas.

List of herbivores recorded in the ecosystem

1. Internode borer, *Chilo sacchariphagus indicus* (Kapur)
2. Sugarcane planthopper, *Pyrilla perpusilla* Walker
3. Pink stem borer, *Sesamia inferens* (Walker)
4. Sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner
5. Leaf scraper, *Callispa vittata* Baly
6. Leaf beetle, *Monolepta signata* (Olivier)

7. Flea beetle, *Altica sp.*
8. Leaf miner, *Aphanisticus aeneus* Kerremans
9. White grub, *Heteronychus annulatus* Bates,
10. Rice leaf folder, *Cnaphalocrocis ruralis* Walker
11. Flat grass scale, *Aclerda takahashii* (Kuwana)
12. Sugarcane scale insect, *Melanaspis glomerata* (Green)
13. Pink sugarcane mealybug, *Saccharicoccus sacchari* (Cockerell)
14. Sugarcane whitefly, *Aleurolobus barodensis (Maskell)*
15. Rugose spiralling whitefly (RSW) *Aleurodicus rugioperculatus* Martin
16. Sugarcane aphid, *Melanaphis sacchari* (Zehntner)
17. Rice grasshopper, *Hieroglyphus banian* (Fabricius)
18. Black leafhopper, *Proutista moesta* (Westwood)
19. Sugarcane web mite, *Schizotetranychus sp.*
20. Rice thrips, *Stenchaetothrips biformis* (Bagnall)

Conservation of pollinators is vital for the sustainable cultivation and conservation of Indian sandalwood (*Santalum album* L.)

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Pollination is a biological phenomenon for gene recombination in flowering plants that plays a key role in making a healthier and more genetically diverse plant population that is indirectly responsible for environmental consistency, community persistence, and ecosystem stability. Wind, insects, and birds, and in some instances bats are the major pollinating agents. Entomophily or insect pollination is a form of pollination whereby pollen of plants, is dispersed by insects. The insects especially the bees accomplish 80% of the pollination and hence we fully understand the overwhelming importance of bee diversity and our reliance on these insects for sustaining agricultural and natural habitats worldwide (Engel, 2017). But widespread declines in insect pollinators are a key example of a critical ecosystem service being lost due to the degradation of natural habitats.

Indian sandalwood *Santalum album* is one of the economically important tree species in Indian forestry, known for its world-famous "East Indian sandalwood oil" used in cosmetics, medicines, and perfumes. This tree is self-incompatible and adapted for cross-pollination by insects and dispersal of fruits by birds and bats. The freshly opened dull green flowers to one day old pale pink flowers are receptive to pollination. The inherent range of phenotypic and genotypic variations in terms of morphology, size, and colour of heartwood, growth rate, and years of initiation of the heartwood is mainly due to its strict cross-pollination phenomena (Bhaskar, 1992). Studies revealed that the pollinator guild of *S. album* consists of 82 species of insects which includes 6 species of Diptera, 20 species of Hymenoptera, 55 species of Lepidoptera, and a species of Odonata. Among the pollinator guild the visit of honeybees viz. *Apis cerana indica* (Fig. 1) and *A. florea* (Fig. 2) were dominant and in abundant and hence they might be playing the role as key pollinators of sandalwood. Hence, we have the greater responsibility to conserve these pollinators for sustainable cultivation and conservation of sandalwood.

The decline of mobile ecosystem service providers, such as pollinators is threatening food security and natural capital as global agriculture has become more pollinator-dependent. The health of landscapes and the health of pollinators are integrally linked and the land-use change is a primary driver of declining of pollinators due to a loss of floral diversity and abundance (Hall and Martins, 2020). An estimated five billion people may experience losses in crop production due to insufficient pollination (Chaplin-Kramer *et al*., 2019). The intimate tie between flowering plants and their bee (Fig. 1) pollinators is also among the most critical of such affiliations, forming the foundation for healthy ecosystems worldwide (Michener, 2007). All bees forage on a mixture of both flowering plants and tree species (Eastburn *et al*., 2017). Honeybees have a detectable preference for foraging on trees as they offer a great wealth of pollen and nectar in one stop. Bees and flowers have co-evolved together for millions of years by the mutual relationship in which bee is provided with food and the plant gets to disperse its pollen to other plants of the same species.

In such specialized interactions involving a specific bee or plant species, the bee behavior or bee biology, as well as the plant morphology or phenology are guiding the mutual relationship (Alves-dos-Santo and Machado, 2017). Plants have developed flowers with increasingly specialized features to attract visiting bees that, in turn, would distribute pollen grains and optimize the plant's reproductive capabilities. Concurrently, bees underwent physiological, behavioral, and structural adaptations to take advantage of the nutritional benefits presented by flowering plants. In contrast to this relationship, detrimental pruning of sandalwood trees (Fig. 3) in combination with extensive applications of agrochemicals will have a negative effect on the foraging ability and lifespan of adult bees and their resilience which will lead to colossal loss of pollination in the cultivation of sandalwood and apiculture. Cross-pollination is vital for sustainable cultivation (Fig. 4) and conservation of sandalwood and apiculture (Fig. 5) is obligatory as we don't understand the art of making honey.

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Fig (1) Fig (2)

Figure: (1) *Apis cerana indica* (Fig. 2) and *A. florea* visiting flowers of sandalwood tree

  

Fig (3) Fig (4) Fig (5)

Figures: (3) Sandalwood tree disfigured due to pruning; (4) Unpruned sandalwood tree supports Honey Beehive; (5) Sandalwood tree based apiculture

Record of leaf cutter bees inside bamboo leaf rolls at Raipur, Chhattisgarh

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Introduction

Leaf-cutter bees also known as leaf-cutting bees, (Order- Hymenoptera Family- Megachilidae) are important pollinators that differ from most other bees in that they collect pollen on their abdomens rather than on their hind legs. They use cut-leaves to construct nests in cavities (mostly in rotting wood). They create multiple cells in the nest, each with a single larva and pollen for the larva to eat. These are important pollinators of wildflowers, fruits, vegetables, and other crops.

Distribution and diversity

Leaf-cutter bees are a diverse group of stingless bees known for cutting oval pieces of green leaves to line their nests. With over 1,500 described species worldwide, this is one of the most species-rich groups of bees. (Ascher and Pickering 2014). They are effective pollinators, and interest in these bees has increased in recent years due to widespread declines of honeybees (*Apis mellifera*) and some native pollinators. (Burkle *et al.* 2013, Vanbergen *et al.* 2013). These bees are present on all continents except Antarctica. Although more species occur in the tropics than elsewhere, leaf-cutter bees can be found almost in all places where flowering plants grow.

Biology

Most leaf-cutting bees are moderately sized (around the size of a honey bee, ranging from 5 mm to 24 mm), stout-bodied, black in colour. The females, except the parasitic *Coelioxys*, carry pollen on hairs on the underside of the abdomen rather than on the hind legs like other bees. When a bee is carrying pollen, the underside of the abdomen appears light yellow to deep gold. Leaf-cutting bees, as their name imply, use 0.25 to 0.5-inch circular pieces of leaves they neatly cut from plants to construct nests. They construct cigar-like nests that contain several cells. Each cell contains a ball or loaf of stored pollen and a single egg. Therefore, each cell will produce a single bee. The larva hatches from the egg and after molting a few times, it spins a cocoon and pupates. Leaf-cutting bees construct these nests in soil, in holes (usually made by other insects) in wood, and in plant stems.

Host plants

Leaf-cutting bees visit numerous flowers for pollen and nectar. For nest building, they prefer plants with petals and leaves that are not thick or stiff. They also pollinate fruits and vegetables and are used by commercial growers to pollinate blueberries, onions, carrots, and alfalfa. These bees use the leaves of almost any broad leaf or compound leaves of deciduous plants to construct their nests. Some species of leaf-cutting bees use petals and resin in addition to leaves. These bees will commonly cut circles from ornamental plants such as roses, azaleas, ash, redbud, bougainvillea, and other plants with thin smooth leaves. This decreases the aesthetic value of these plants.

In the present studies, leaf-cutter bee, *Megachile* sp. was recorded inside leaf rolls made by Bamboo leaf roller, *Crypsiptya coclesalis* in the Agro-forestry field of IGKV, Raipur (C.G) during September 2020. On opening the rolls, the bee *Megachile* sp. was recorded forming a nest made from compound leaflets of some tree species. Grubs and pre-pupal stages were also recorded. On an average, 5-6 cells were observed in a single nest loaded with pollen and each cell resembles a cigar butt of 1 inch depth. There was only a single tunnel shaped nest per bamboo leaf roll with a mixture of coarse sawdust at the entrance of each cell. The size of the tunnel was about 6-7 cm.

Fig 1: Damaged leaves and adult of *Megachile* sp.

(A) (B) (C)

Fig. 2. (A) Pre-pupa inside cell (B) and (C) Cells of leaf-cutter bee (*Megachile* sp.)

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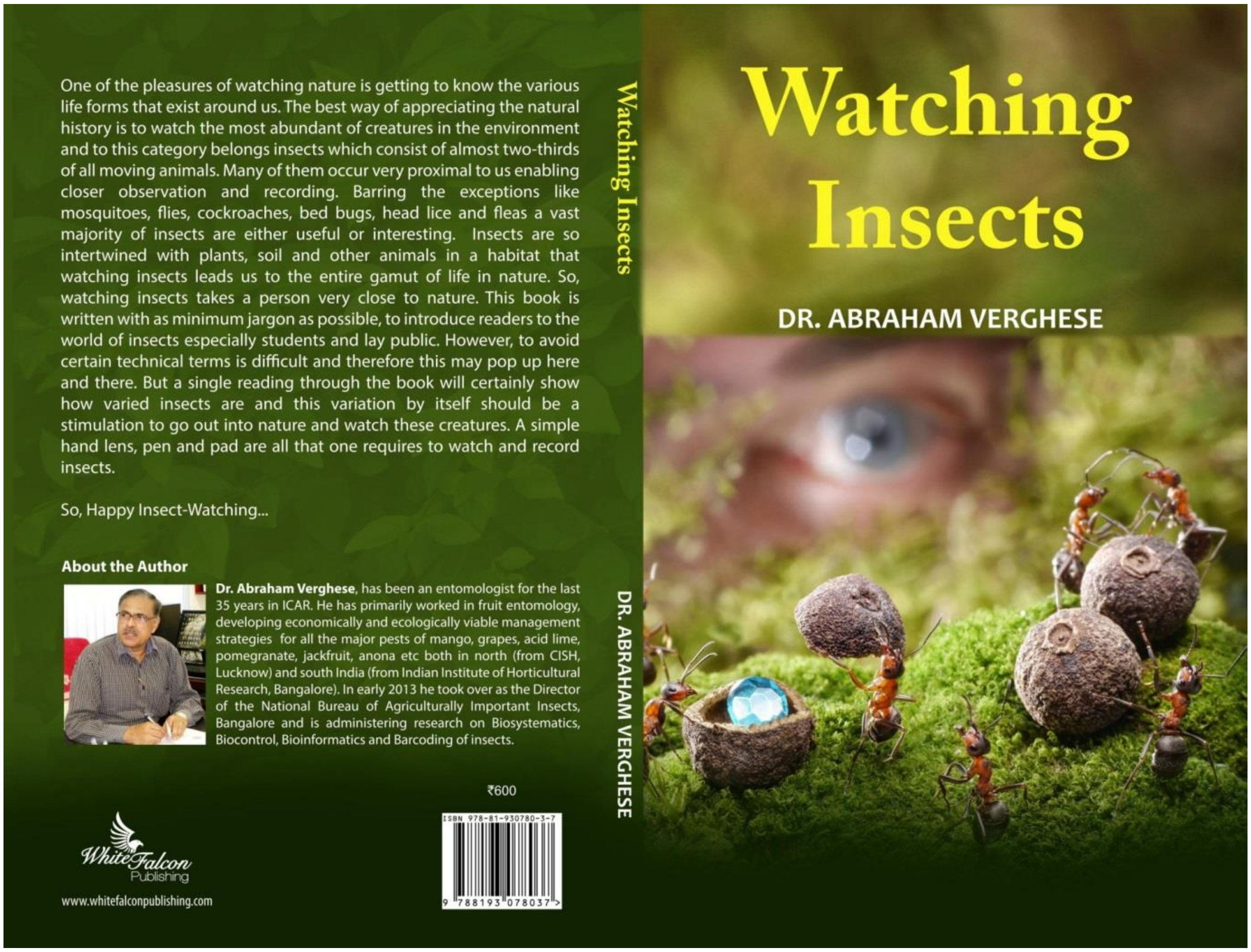

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Review Articles/ Short Notes/ Essays

Crimean-Congo Hemorrhagic Fever: A zoonotic disease transmitted by the tick, *Hyalomma* sp.

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The Crimean-Congo Hemorrhagic Fever (CCHF), also known as the Congo fever, is a tick-borne viral disease in humans. The first report of the tick-borne hemorrhagic fever dates to 12th century (Ergönül, 2006). Since then many outbreaks of CCHF have been reported. It is endemic in parts of Africa, the Middle East and Southeastern Europe with sporadic cases reported from Russia, Pakistan, and Afghanistan (Maltezou and Papa, 2010; Leblebicioglu, 2010; Mertens, Schmidt, Ozkul, Groschup, 2013). The notable outbreak of CCHF was reported from Agago, Uganda in 2013, and the Eid-al-Adha associated 'super spreader' event of Pakistan in 2016. The virus made inroads into India in 2011, with an outbreak at Sanand, Gujarat, claiming four lives (Patel *et al*., 2011). The disease had a sporadic reemergence in the same city during 2015. Currently, the Palghar district of Maharashtra is on high alert over fears of a fresh CCHF outbreak during October 2020 amidst the COVID19 pandemic. Clinically, CCHF symptoms are indistinguishable from the ones of COVID-19, hence raising the possibility of misdiagnosis.

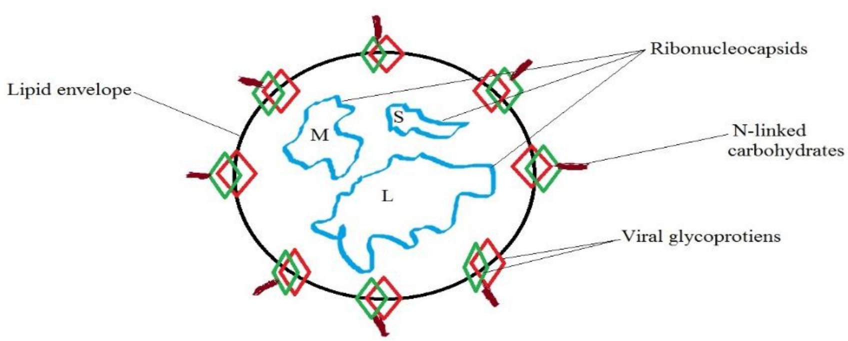

Fig 1. Schematic representation of the Crimean-Congo haemorrhagic fever virus

The CCHF virus belongs to genus *Nairovirus*, family *Bunyaviridae* (a family of RNA viruses). The nairoviruses are characterized by their exclusivity to tick hosts. The CCHF virus distinguishes itself from other bunyaviruses by presence of large L-segments in their genome (Bente *et al*., 2013).

The association of ticks with the disease was a casual observation during the early part of 12th century. Later, Butenko *et al*., (1968) inoculated mice with serum of patients suffering from CCHF and tick extracts and observed the occurrence of CCHF symptoms in mice. Among the ticks, the genus belonging to *Hyalomma* spp. (Family Ixodidae) are common vectors for transmission of CCHF virus to humans (Ergönül, 2006). Immature ticks feeding on infected small vertebrates later transmit the virus to larger ruminants that are viremic for a week before being infected. The virus ingested, along with the blood meal by the tick, colonizes the midgut lining of the vector and continues to replicate. It eventually spreads to other organs of the tick, with high titers noted in the salivary glands.

Fig 2. *Hyalomma* ticks the vectors of CCHF

Photo source: http://www.emro.who.int/health-topics/crimean-congo-haemorrhagic-fever/index.html

Humans acquire the CCHF virus through tick bites or contact with infected body fluids and tissue. The disease is a threat to farmers, agricultural workers, veterinarians, and health workers. The infected ticks transmit the CCHF virus to humans during the tick bites. The frequency of transmission rises during summer. The ticks are attached to their vertebrate hosts for weeks that raises the chances of viral transmission from the tick to the host or from the viremic host to the virus-naïve ticks. Large part of the blood feeding phase occurs in cattle and sheep, thus obviating the vulnerability of persons involved in occupations requiring direct contact with livestock (Bente *et al*., 2013). Human-to-human transmission of the virus can occur on contact with the infected patients body fluids and secretions, thus raising the possibility of the disease gaining a nosocomial dimension.

The pathogenesis of the virus has not been clearly delineated. However, majority of its effects tend to arise from the infection of hepatic cells and endothelial cells, thus negatively impacting the body's ability to produce and effectively use clotting factors and platelets, leading to the hemorrhagic sequelae. Another possible reaction that is suspected is the body's hyperimmune response to the viral pathogen, which may lead to the destruction of normal tissues. The disease has an incubation period ranging from 1 to 3 days. The course of the disease is divided into 4 distinct phases- incubation, pre-hemorrhagic, post hemorrhagic and convalescence. Life threatening complications arise in the hemorrhagic phase with patients developing frank bleeding and bruising tendencies, along with the phenomenon of disseminated intravascular coagulation (DIC), which may eventually progress to acute kidney failure and respiratory distress. The clinical diagnosis of CCHF is supported by genomic RNA analysis, antiviral antibodies detection by the enzyme linked immunosorbent assay (ELISA), and viral cultures of the patient's serum (Shayan *et al*., 2015). The mortality rate ranges from 5% to 30% (Ergönül, 2006), with death occurring usually in the second week of illness. The patients that make a full recovery usually do so in about nine to ten days (WHO CCHF Factsheet, 2013).

Vaccines or treatments have not been developed for CCHF yet. However, the broad-spectrum antiviral drug Ribavarin, a nucleoside inhibitor, has shown some inhibitory effect on viral replication *in vivo* and *in vitro* (Watts *et al*., 1989). The other modes of treatment involve the suppression of the hyperactive immune response with corticosteroids and supportive procoagulant therapy with fresh frozen plasma (Erduran *et al*., 2013).

Preventive methods in endemic areas is to avoid visiting areas infested with ticks. If work exposure is inevitable, then regular examination of clothing and skin for tick's presence and removal is essential along with application of repellents (neem oil) on skin. Regular examination and elimination of ticks on animals and stables are to be done. Veterinarians and slaughterhouse personnel should use protective clothing while handling animals in endemic areas. The animals infested by ticks are to be treated with pesticides two weeks prior to slaughtering. The health workers should use protective gear while handling CCHF infected patients.

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Sound production in insects

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"Insect sounds" (Haskell 1961) was defined as "any mechanical disturbance which is potentially referable by the insect to an external and localized source". Sound-producing mechanisms in insects are involved in identifying the potential mates. For these, insects have evolved behavioral strategies and communication systems, largely visual, chemical, or acoustical, to ensure effective mate finding (Capinera, 2008). Many groups have specialized mechanisms of sound production and hearing organs, which are used in intraspecific acoustic communication (Claridge, 2005). Ewing (1989) described a most recognized classification compiling five categories of sound producing mechanisms. These are vibration, percussion, stridulation, click mechanisms, air expulsion. Sound emissions that result from vibrations of relatively unspecialized body parts of the insect are generally oscillations of the abdomen, either dorso-ventrally or laterally. The oscillatory movement of the wings of an insect sets up regions of compression and rarefaction and a vibrational sound is produced. Tremulation sound is transmitted through the legs to the substrate on which the insect is walking or standing. Percussion is striking one part of the body against another as a communication system for pair formation, as known for example, in the Australian moth (Lepidoptera). Stridulation consists of sounds produced by frictional mechanisms, involving the movements of two specialized body parts against each other in a systematic patterned manner (Claridge, 2005). Air explosion sounds depend on the deformation of a modified area of cuticle, generally by contraction and relaxation of specialized musculature within the insect body.

Haskell (1961) defined a hearing organ as a receptor that mediates an adaptive behavioral response to sound. Insects have specialized receptors that detect external vibrations as airborne and substrate transmitted emissions (Claridge, 2005). There are five main types of hearing organs in insects, Hair sensillae, scattered chordotonal sensillae, Johnston's organ, Tympanal organ, Subgenual organ. The sensory neurons are bipolar and monodendritic, bearing one single distal dendrite and a proximal axon. Mechanically sensitive ion channels mediate a vast array of different cellular and organismic sensations, ranging from the most basic that must occur in all living cells, such as osmoregulation, to the highly specialized, such as hearing and touch. Members of the Transient Receptor Potential (TRP) family of ion channels have been implicated in a wide variety of mechanical transduction processes in diverse organs and species.

No Mechanoreceptor Potential C (NOMPC = TRPN1) NOMPC (localizes to the tips of chordotonal sensory neurons and forms a mechano-gated ion channel. In addition to NOMPC, two sun units' members of the *TRPV (vanilloid receptor–related TRP)* subfamily, Nanchung (Nan) and Inactive (Iav) ion channels, were surmised to mediate insect sound transduction.

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Insects in space- a peep into exploration of cosmic journey

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Introduction

Space is a limitless dimension to be explored in search of existence of life Since ages it has been a fascinating whim to experience that untouched part of the world, Many aspire to explore the boons and banes faced by mankind, to unleash the possible means of sustenance, ethology, metabolical mechanisms, operation of biological clocks in space when compared to mother earth, as it is a potential future avenue for generations to come.

Studies globally indicate that spaceflight alters both cellular and humoral immune responses in humans, Moreover; impaired immunity in humans may be impediment for short and long-term exploration missions. Hence keeping this in mind, space explorations were carried out using several animals including insects. Office of Naval Research reported that in the year 1947, February 20, V-2 (space flight) was loaded with fruit flies which traveled 67 miles (109 kilometers) into the air in less than 200 seconds and these were the first insects that were ever chosen for the expedition (www.nasa.gov).

Why were fruit flies chosen for space expeditions?

About 75 per cent of all the disease causing genes present in *Homo sapiens sapiens* have analogues in the fruit fly's genetic code, Studying fruit flies helps us to better comprehend the cellular and biological systems as they resemble with that of the humans, apart from this the small size and multiple generation production within single space mission helps to monitor the adverse effects of space flight travel on entire life stages of the fruit fly, making them particularly good models for biomedical research in space, which in turn can be correlated with the alterations and impacts on immune system of human beings during and after space travel.

On the V-2's (spaceflight) descent back to earth, scientists of NASA (1958) observed an astonishing finding that mammothic living beings like hamsters, mice and monkeys sent into space couldn't make it back alive to earth, on the other hand tiny fruit flies were still alive and concluded that the exposure to cosmic radiation brought no mutational after effects on them. (Mark mancini, 2018). Based on the previous observations obtained, The National Aeronautics and Space Administration (NASA), U.S. launched a Fruit Fly Lab (FFL) to the International Space Station (ISS) way back in 2014 as part of a mission to assess the effects of microgravity and other aspects to understand how long-term prolonged space flight that might probably affect humans during their journey of space expeditions. (https://www.nasa.gov/ames/fruit-fly-lab)

The FFL features include NanoRack centrifuges that allows flies to be exposed to variable gravity conditions ranging from 1 *g* (Earth gravity) to fractional *g* (moon or Mars gravity) to 0 *g* (weightlessness or microgravity). This enables the use of an in-space group of flies. (Monica Harrington, 2014) as well in another expedition led by Ocurr, (2015) identified the changes in expression of genes associated with the cardiovascular system of fruit flies in space.

The Fungus, Immunity, Tumorigenesis (FIT) microgravity experiment

FIT is the first flight experiment conducted by Katherine Taylor *et al.* (2014) to investigate µg effects on *Drosophila* immunity, the hyper g work, with infection of *Drosophila* genotypes proceeding in space where in the flight duration (12 days) allowed production and return to Earth of a small population of flies that had undergone their entire development in space (space flies). Upon return this population was divided into three groups and used for transcription profiling without infection and after infection with *Beauveria bassiana* or *Escherichia coli*. The fungal spores and *E. coli* used were grown on Earth. Earth-reared flies, grown at Kennedy Space Center, were used as controls (Earth flies). Recordings relayed from the shuttle ensured similar growth conditions for the space and Earth flies other than the change in g force. The experiments thus encompass humoral immunity in response to Toll and Imd mediated fungal and bacterial infections through transcriptional profiling after development in space. The uninfected space flies showed an altered transcriptional profile and data indicate that Toll mediated responses to *B. bassiana* are impaired in space flies and in particular the failure of *Drosomycin* and *Metchnikowin* activation indicated that the space flies were severely immune compromised.

The Imd pathway is activated normally in adults raised in space

As a part of altered transcriptional profile study in adults fruitflies by scientists where in six genes associated with apoptosis are up regulated: *starvin*, which is a cochaperone associated with heat shock protein 70 (Hsp70) Arndt 2010; the caspase *Damm*, which can trigger apoptosis when overexpressed Harvey2001; and *Rab3-GEF*, a Ras superfamily member predicted to regulate the cell cycle and apoptosis Stenmark 2001, Together these transcriptional alterations indicated severe stress associated with protein unfolding during development of the flies which was observed under microgravity (µg) and concluded that the extracellular space is more susceptible to protein unfolding in stress conditions than the intracellular environment. Thus in the µg conditions experienced by the space flies, the more complex extracellular induction events associated with Toll activation (recognition, activation of SPE, cleavage of Spz and binding to Toll) are more susceptible to disruption than those associated with activation of the Imd pathway.

Huang (2010) stated and proved that hyper g may stabilize proteins against unfolding or affect heat shock protein interaction with Toll receptors. Effects on the stability, folded status or function of endocytotic components may be particularly important both at hyper g and µg since endocytosis is essential for Toll; a further possibility is that most common stresses such as sleep deprivation, physical activity and ageing affect immune responses via these proposed routes. Oana *et al*., 2011 observed that *Drosophila* larvae reared in space are smaller and have fewer plasmatocytes. Plasmatocyte phagocytic activity is impaired in space-reared larvae and also found hemocyte cultures from larvae that developed from egg to 3rd instar in space had a significantly smaller percentage of cells engulfing bacteria at the early 15, 25 and 35 minutes post-infection and finally concluded saying that the population of mature hemocytes is affected in space-reared larvae, Pattern recognition molecules are downregulated in spaceflight larvae, The constitutive expression of genes involved in humoral immunity is down regulated in space-reared larvae. Likewise Charroux and Royet (2009) also observed that more pupae died in space than on ground and so it is possible that larvae with poor immunity did not survive metamorphosis.

EPILOGUE: As interest in space travel grows for both research and commercial aims it is increasingly important to understand the after effects a microgravity environment can have on the human heart for the traveler and these molecular change prediction beforehand could help to protect and treat cardiovascular disorders as human immune responses are weakened in space, with increased vulnerability to opportunistic infections and causing further challenges to health. To understand these issues better we need to resume design of space entomology as countermeasures including insects in space which will be a new avenue of hope in coming future.

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Biosurgery by Dipterans: a kind of maggot debridement therapy for healing wound

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Introduction

Physical damage to the tissues leads to the formation of wound. Wound healing is the process by which skin or other body tissue repairs itself after trauma. Wound healing process is divided into four phases: blood clotting (hemostasis), inflammation, tissue growth (proliferation) and tissue remodeling (maturation). Any impairment in this wound healing process leads to chronic wound formation which can be debilitating to the affected individual, decreases the patient's quality of life and places a massive financial burden on patients. Such chronic wounds are leg ulcers, venous ulcers, pressure ulcers, diabetic foot ulcers, post-surgical wounds etc. Debridement is defined as the removal of dead, damaged, infected tissues to improve the healing potential of healthy tissue. If debridement doesn't take place, wound repair is significantly damaged. Maggots selectively consume only necrotic tissue and debride the wound.

Maggot debridement therapy or biosurgery by maggots

A biofilm is an any group of microorganisms in which microbial cells stick to each other and adhere to surface of injured site. It acts as barrier for wound healing. Regular clinical approach for chronic wound with biofilm includes, physical debridement and antibiotic treatment. However, limitations of these debridement include, low efficacy, high morbidity and secondary infection. It is realistic to say that maggot excretions/ secretions, salivary gland extract and its physical action prevent the formation, inhibition and breakdown of biofilm. This therapy is called as maggot debridement therapy (MDT) or biosurgery by maggots. It is type of biotherapy/biosurgery in which live, disinfected maggots (fly larvae) are placed into the non-healing skin and soft tissue wounds of humans or animals to clean out the necrotic (dead) tissue within a wound (debridement) and to disinfect the same.

History of maggot debridement therapy

Australian Aborigines used maggots to clean wounds for thousands of years. The French surgeon, Ambroise Pare (1510-1590), was the first doctor who observed the cleansing action of maggots in wounds. He noted the beneficial effects of myiasis in wounds of soldiers on the battle of St. Quentin. In 1917, William S Baer (founder of maggot therapy), a military surgeon in France, reported his treatment of open fractures and stomach wounds with maggots. He in fact went on to call maggots as “viable antiseptics.’’ The Lederle pharmaceutical company commercially produced "Surgical Maggots", larvae of the green bottle fly, which primarily feed on the necrotic tissue of the living host without attacking living tissue. More than 300 American hospitals employed maggot therapy during the 1940s. The extensive use of maggot therapy prior to World War II was curtailed when the discovery and growing use of penicillin caused it to be deemed outdated. However, with the advent of antibiotic-resistant bacteria, Dr. Ronald Sherman, re-introduced maggot therapy into the armamentarium of modern medical care in 1989. The therapeutic maggot used by Sherman *et al.*, (2000) is a strain of the green bottle fly *(Phaenicia sericata)* and marketed under the brand name “medical maggots’’. In 2007 preliminary trial, maggots were used successfully to treat patients whose wounds were infected with MRSA, a bacterium (*Staphylococcus aureus*) with resistance to most antibiotics, including methicillin. There are over 800 health care centers in the United States that have utilized maggot therapy. Over 4,000 therapists are using maggot therapy in 20 countries.

Commercial medicinal maggot flies

The infestation of live human and vertebrate animals with dipterous larvae, at least for a certain period, feed on the host’s dead or living tissue, liquid body-substances, or ingested food is called myiasis. There are mainly three Dipteran families which cause myasis *viz.*, Calliphoridae, Sarcophagidae, Oestridae (Figure 1, 2 and 3). The fly lays around 150 eggs in a single time. Hatches in 18-24 hours to maggots, 1-2 mm in length. The maturing first larvae continue to feed for 4-5 days. Enters pupation stage within 5 days. Adult fly emerges from pupa in 5 days. Eggs are harvested immediately and are washed several times with specific solutions (70% alcohol) and distilled water. After hatching maggots are again washed three times with 70% alcohol and distilled water. Maggots are ready for commercial use. Each vial contains approximately 2,000 eggs. Each vial also contains sterile food (containing soy protein and yeast).

Maggots can be removed easily by wiping them off the sides of the vial with a gauze pad moistened with sterile saline or water.

Regulation regarding use of medicinal maggots

In January 2004, the U.S. Food and Drug Administration (FDA) and in February 2004, the British National Health Service (NHS) granted permission for maggot debridement therapy in chronic wounds such as, debridement of non-healing necrotic skin and soft tissue wounds, diabetic/neuropathic foot ulcers, pressure ulcers, venous ulcers and non-healing traumatic or post-surgical wounds.

Application of maggots

The MDT procedure is given in figure 4. Special type of dressing called creature comfort dressing, made up of polyester netting is assembled with other dressing material most commonly hydrocolloid pad to create a confining “cage dressing” which allows air to enter, drains out necrotic tissue. Primarily the wound boarder is drawn on a film and the template are used for the wound “opening” in a hydrocolloid dressing. The skin wound surroundings are protected by a barrier film (i.e. Cavelon No Sting). The opening in the hydrocolloid is placed exactly on the wound edges to protect the wound surroundings. The maggots are removed from the container by using of few mL of saline. The maggots are placed on the net which is included in the maggot’s shipment should use 10 maggots/cm2 surface area of the wound. The net is turned to place the maggots into the wound cavity. The net is fixed with water safe wound tape on the hydrocolloid surface. A nonwoven gauze slightly moisture by saline is then placed on the surface of the net to give humidity to the maggots, which is needed to survive in the initial phase. Later the maggots produce the humidity by their own secretion. Then, more (dry) nonwoven gauze is placed on the top of the moisture gauze and fixed by gauze bandage and patient is then mobilized without pressure on the maggots. The compression bandages are not allowed in the MDT procedure.

Mechanism of action: The maggots have four principal actions:

1. Debridement: Maggots selectively consume only necrotic tissue and debride wound in two days. Each maggot is capable of removing 25 mg of necrotic material within 24 hours. They have modified mandibles, called “mouth hooks,” and they have some rough bumps around their body which scratch and poke the dead tissue. This probing and maceration of wound tissue with maggot mouth hooks enhance debridement, but these hooks are used during feeding to disrupt membranes and thus facilitate the penetration of proteolytic enzymes. Maggots are covered by minute spines which scrape along the wound base as the maggot’s crawl about, loosening debris as does a surgeon’s rasper. The mandibles, in the form of “mouth hooks,” are used to help pull the maggot’s body forward as it crawls and to probe every nook and cranny for food or shelter. The physical action of the maggot over the wound is a primary reason given by the FDA for classifying medicinal maggots as a medical device and not a simple drug. The maggot does not “bite off” pieces of tissue, but it rather secretes and excretes its digestive enzymes. They derive nutrients through a process known as "extracorporeal digestion" by secreting a broad spectrum of proteolytic enzymes that liquify necrotic tissue, and absorb the semi-liquid, i.e. metalloproteinase and aspartyl proteinase and arich soup of digestive enzymes while feeding, including carboxypeptidases A and B, leucine aminopeptidase, collagenase and serine proteases (trypsin-like and chymotrypsin-like enzymes). The latter shows excellent degradation of extra cellular matrix components like laminin, fibronectin and collagen types I and III, and may therefore plays a significant role in the digestion of wound matrix and effective debridement. This all can liquefy necrotic tissue. In an optimum wound environment maggot moult twice, increasing in length from 1-2 mm to 8-10 mm. within a period of 3-4 days, they ingest necrotic tissue, leaving a clean wound free of necrotic cells.

2. Disinfection: Greenberg hypothesized that antimicrobial compounds might be produced in the gut by symbiotic microbes such as *Proteus mirabilis*. In 1986, Erdmann and Khalil identified and isolated two antibacterial substances (phenylacetic acid and phenylacetaldehyde) from the *P. mirabilis* that they isolated from the gut of a related blowfly larva. *P. mirabilis* is the commensal gut bacteria having ability to produce high level of urease which hydrolyze urea to ammonia which is necessary for increasing p^H and inhibiting bacterial growth. Allantion, phenylacetic acid, phenylacetaldehyde, calcium carbonate and proteolytic enzymes, ammonia etc. are the secretions of maggots inhibits the growth and development of bacteria, i.e. *Staphylococcus aureus* and Group A and B *streptococci,* Methicillin-resistant *Staphylococcus aureus* (MRSA) group A and B *streptococci* and *Pseudomonas.*

3. Biofilm inhibition: Biofilm is a structured community of one or more species of bacterial cells, living closely in an enclosed, protective, self-produced polymeric matrix, and adhere to living surface. Antibiofilm activity is valuable because biofilm is highly resistant to penetration and successful activity of human immune system. Maggots excretions and secretions is capable of dissolving biofilm and inhibiting growth of new biofilm. The example are *Staphylococcus aureus* and *Pseudomonas aeruginosa* biofilms.

4. Stimulation of healing: Proliferation of fibroblasts (cells found in connective tissues that synthesize collagen which is responsible for muscle cells connection required for wound healing) and endothelial tissue increases. Angiogenesis (formation of new blood vessels) takes place.

Advantages and Disadvantages

Maggots separate the necrotic tissue from the living tissue which make a surgical debridement easier. The offensive odour emanating from the necrotic tissue and the intense pain accompanying the wound, decrease significantly using MDT. More proximal amputation could be avoided and septicaemia can be prevented. MDT seems to be an effective and environmentally friendly treatment of complicated necrotic wounds that are resistant to conventional treatment. It takes about 15-30 minutes to apply. It is simple enough for even non-surgeons to use it. Effective against both gram-positive and gram-negative bacteria, *viz.*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and MRSA. It promotes healing of diabetic foot wound by up-regulating endothelial cell activity (Sun *et al*., 2016). Its use could prevent amputations and minimize the need for prophy lytic antibiotics to avoid kidney and liver toxicity (Tantawi *et al*., 2007). The disadvantages include, patients and doctors may find maggots unpleasant. The limited availability of medical maggots. Maggots have a short shelf life which prevents long term storage before usage. Sometimes the therapy can be painful, especially in the first few treatments after 24 hr due to increased size of maggots and due to crawling over exposed nerve ending.

Conclusion

MDT therapy is increasing worldwide because of its safety, efficacy, simplicity mainly in chronic wounds infected with multidrug resistant bacteria and significant comorbidities with surgical intervention. MDT benefits patient by rapid debridement, disinfection, odour elimination, prevents major chances of amputations and decreases massive financial burden on health care system. As antibiotic resistance becomes increasingly prevalent, this ancient therapy may once again be at forefront of human and animal survival. By studying biochemistry and mechanism of action, it can have huge impact on medical industry with respect to ability of maggots to trigger angiogenesis.

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Fig. 1. Common green bottle fly, *Lucilia sericata* Family Calliphoridae (Photograph by Joseph Berger, Bugwood.org.)

Fig. 2. Spotted flesh fly, *Wohlfahrtia magnifica* Family Sarcophagidae (Photo from PARASITIPEDIA.net)

Fig. 3. Human botfly, *Dermatobia hominis* Family Oestridae (Photograph by Lyle J. Buss, University of Florida)

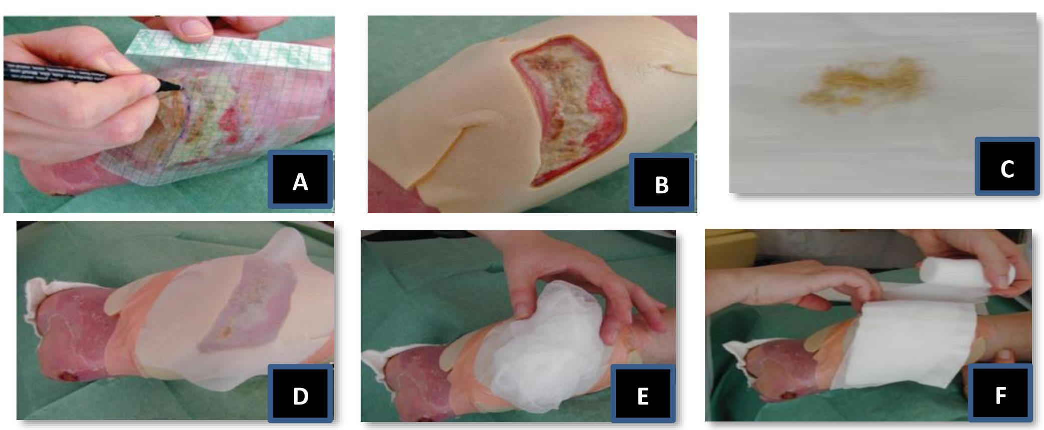

Fig. 4. MDT procedure (Gottrup and Jørgensen, 2011); (A) Drawing the mound, (B) Film template cut of hydrocolloid, (C) Maggots on net, (D) Net with maggots placed in the wound, (E) Non-woven gauze placed on net and (F) Fixation by gauze bandage.

Scent gland in Lepidoptera: Coremata

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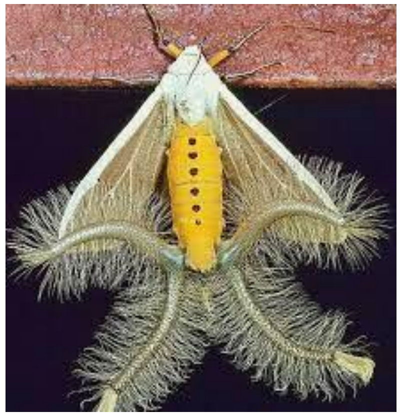


"There is nothing more frightful than ignorance in action."(Johann Wolfgang Von Goethe)

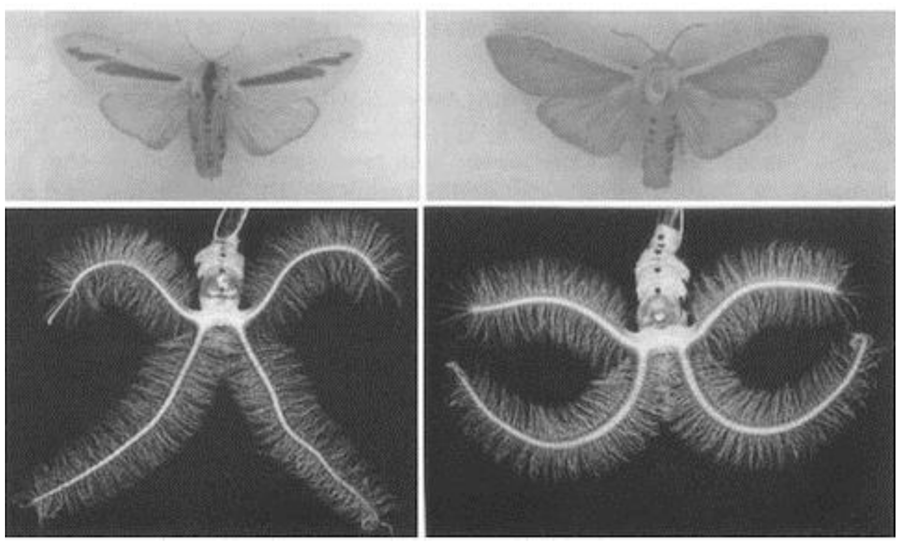
In insects, the most extended communication mechanism is chemical communication. It involves the process in which the emitter scatters chemical substances in the environment and the receiver detects these chemicals and responds. These chemical substances are pheromones (for finding a mate), allele-chemicals (as alarm signals, as a defensive system) etc. Insects have specialized receptors either located on their antennae, legs, etc. for the reception of these chemicals.

Majority of research have focused on the female attractants of pest species due to their economic importance (Carde and Minks, 1997; Blomquist and Vogt, 2003; Carde and Millar, 2004; El-Sayeed, 2011; Ando, 2012). The females mostly produce species specific sex pheromones in specialized glands that constitute the ovipositor (Raina *et al.,* 2000). Percy-Cunningham and Mac Donald (1987) identified and studied the structural characteristics of female moths representing 16 families. But the male courtship pheromones, structures and behaviours associated with their release is of prime importance. The males in many species of Lepidoptera are provided with scent organs situated on the structures such as abdomen, thorax, legs, wings etc. These vary from being simple scales, hair tufts to complex structures that can be everted from the body. Male scent structures consist of hypertrophied trichogen cells and their associated scent scales or hairs. Cells of the glands occur in groups. Scent cells or hairs form a brush or pencil which is concealed within a pocket and can be everted by means of sclerotized levers. Such glands include coremata (inflatable tube-like organs), androconia and hairs. These are also known as androconial scales/ scent fans/ costal hairs/ brushes/ hair pencils/ coremata. The diversity of male scent disseminating structures is highest in families Gelechiidae, Torticidae, Pyralidae, Notodontidae, Erebidae and Noctuidae (Brown *et al*., 2011).

Corema (pl. of Coremata) are defined by De la Torre- Buneo (1950) as "specialized scent tufts near the end of the abdomen of certain males in order Lepidoptera". Either functions of scent producing or scent disseminating, whether internal or external, under control or voluntarily has not been explained. These are in fact glandular, internal and apparently voluntarily eversible. In some species, volatile chemicals are emitted from these organs when the female is in close vicinity but in few species these have been proved to have pheromonal function. Pheromones are important in speciation and all aspects of organism's behaviour.

In tiger moths, there is profound lack of species specificity in male courtship pheromones. The coremata emerge from pockets between the seventh and eighth abdominal sternite or in the genital valves. It is twice the size of the body in *Creatonotos gangis.* Coremata consists of a basal bladder and four tubes. Its scent hairs (scales) produce and release the hormone hydroxydanaidal, which attracts both sexes. Pyrrolizidine alkaloids (PA) ingested by the larva with its food not only accounts for the precursors of the pheromone but also acts as a morphogen, which quantitatively controls the growth of coremata in pupal stage and finally its final size and number of hairs. These alkaloids trigger a pronounced morphogenetic effect and the males that feed on high levels of alkaloids develop large sized coremata than those which feed on lower levels or no alkaloids have smaller and less robust coremata. Boppre and Schneider (1985) demonstrated that more PA ingested, the larger is the scent organ. It is a remarkable morphogenetic effect on PA's in *Creatonotos* species. The molecular mechanism by which the PAs exert their morphogenetic effect is unknown. The alkaloids transferred to females during courtship temporarily protect the female from predation.

Coremata arises from epidermal anlagen at the anterior border of the eighth abdominal sternite. Scent hairs originate from trichogen cells which arise together with their associated tormogen cells. Both the size of the organ and its pheromone content depend on the ingestion of pyrrolizidine alkaloids (Boppre and Schneider, 1985). Before mating, the males form aggregations and inflate their coremata which attracts more males and females for mating. Depending on the nature of mating system, they are deployed in two ways. In most of the species, coremata is inflated for a brief period prior to coupling (Birch 1974). In *Creatonotos gangis* and *Creatonotos transiens*, males congregate during evening and inflate their coremata (Figure. 1) for extended periods and this behaviour is termed as lekking (Wills and Birch, 1982; Wunderer *et al.*, 1986; Alcock, 2001). Both sexes are attracted to the leks. The males join in display and females mate with males. The occurrence of lekking depends on the availability of PAs in the habitat. In genus *Creatonotos*, the females do not show selective specification for males or the biggest coremata (Spangler *et al.*, 1984; Schneider, 1987). The concept of origin of scent glands and their diversification can be clearly defined with the aid of characteristics like sexual dimorphism and diet dependency.



Males and artificially inflated Coremata in *C. gangis* (left) and *C. transiens* (right) (Sarah, 2017)

The females adopt alternative mating strategies depending upon the PA. If it is deficient in PA content due to larval diet, it prefers the lek to attain PAs from males. But if during larval feeding it gets sufficient Pas, then it avoids the search for lek by remaining stationary and attracting males.

Thus, the source of male courtship pheromones is more diverse than originally thought (Birch 1970a, 1970b, Birch *et al.* 1990) and reflect the selective advantages of their use. These species act as an excellent model for the study of chemically mediated lekking behaviour in insects.

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Antlion pits: pinnacle of predatory strategy

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Antlions (Neuroptera : Myrmeleontidae) prey primarily on ants showcasing red-queen effect of prey-predator interaction. The massive mandibulate antlion larvae are metaphorically referred, a "lion" among ants. Other than being a subject of curiosity to entomologists, these "doodlebugs" or "sand dragons" have been an attraction to children (Arnett and Ross, 1985). There are approximately 2,000 species of antlions that are distributed throughout the world, primarily in the warmer regions (Grzimek, 1979) preferring sheltered, sandy areas such as wooded dunes, open forest floors, and dry, tree-lined river banks (Mark, 2007). Most species of antlion larvae dig a shallow cone-shaped pit and wait at the bottom for an ant or other insect to slip on the loose sand and as soon as the an ant falls in, the antlion quickly flips out more sand, thus deepening the pit causing miniature landslides along the walls which knock the struggling ant to the bottom only to be immediately devoured. Often the struggling victim is pulled beneath the sand as its body fluids are gradually siphoned out. After consuming all the contents, the lifeless, dry carcass is flicked out of the pit, and the pit is readied for a new victim. (Arnett 1985; Armstrong, 2007). The average life span of these adult neuropteran is 20 to 25 days. After mating, female antlions will stick their abdomen into the sand to deposit eggs. Antlions go through complete metamorphosis, but have an extended life cycle where one generation may take 2 to 3 years (https://utahpests.usu.edu/uppdl/files-ou/factsheet/beneficial-insects_lacewings-and-antlions.pdf).

There are very few records on the eco-behaviour and distribution of these psammophilus bugs in India (Kailash *et al.*, 2014). Yeshwanth *et al.*, (2011) had reported on the natural history observations of antlion pits in the premises of the Department of Zoology, Bangalore University.The present study undertaken in February 2019 is a more elaborate follow-up of antlion pits in four other locations in the University campus *viz*., Ladies hostel (road leading to Mariyappan palya) , adjacent to the library, Behind the Department of Zoology and Behind the Life science and Psychology Department. The total number of pits was counted and they were checked as active or inactive by simply dropping an ant into the pit. The depth and circumference of the pits under observation was recorded on a centimetre scale. The response time to the introduction of bait was recorded and tabulated. A total of 129 pits were counted in four different spots in the study area. Twenty pits were sampled and their morhphological measurements were recorded and tabulated. The depth of the pit as well as circumference has been tabulated including the total number of nests and its occupancy status (Table 1).

Table 1: Nest dimensions in the study sites

Study sites	Latitude/ Longitude	Mean Depth (cm)	Mean circumference (cm)	Total number of nests	Nest status	
					Active	Inactive
1	12.9464436, 77.5065879	1.19	7	36	25	11
2	12.9483976, 77.5080742	1.08	6.25	22	18	4
3	12.9482856, 77.5063673	1.56	7.65	43	14	29
4	12.9575363, 77. 607482	1.23	7.18	28	10	18

The rate of prey capture using bait was also studied (Table 2). The time taken to respond, capture, point of capture and sinking of prey into the nest was noted. Escape attempts as well were recorded (Table 3). 8 specimens two from each site were observed. Doodlebugs can eat for two years and will molt three times before becoming full grown. The larvae eventually make a cocoon of sand and silk to pupate (Hodgson and Trina, 2008). In the present study taxonomic evaluation of the species was not undertaken.

Table 2: Time budget of antlion predatory response

Study site	Antlion No.	Trial 1	Trial 2	Trial 3	Trial 4
1	1	2s	2s	0.6s	No response
	2	1s	0.8s	No response	No response
2	3	1.3s	No response	No response	1.42s
	4	2.3s	2s	1.8s	No response
3	5	3s	2.7s	3s	3.8s
	6	4s	3.5s	3.8s	4.3s
4	7	3.5s	2.8s	No response	3s
	8	3s	2.6s	2.8	No response

Table 3: (T-r = Time taken to respond to the bait, T-c = Time taken to capture the prey, T-s = Time taken for prey to sink, EA= escape attempts)

Study site	Antlion	T-r	T-c	Point of capture	T-s	EA
1	1	2.2s	18s	Hindlimbs	3.35s	22s
	2	0.8s	43s	Hindlimbs	10.10s	1.20s
2	3	1.5s	23s	Hindlimbs	8.58s	Nil
	4	2.4s	19s	Abdomen	15.45s	Nil
3	5	3.4s	10s	Hindlimbs	8.25s	36s, 1.18s
	6	4.6s	14s	Abdomen	10.35s	43s. 1.00s, 1.28s
4	7	3s	36s	Forelimbs	14.48s	Nil
	8	3.4s	29s	Hindlimbs	17.20s	56s

The pit diameter increases with the increase in larval body width (Anila and Francy, 2016). Antlion 5 and 6 were found to have the lowest time required to capture the prey and they also had the lowest time required for the prey to sink into the pit (Table 1 and 2). Owing to the fact that they were also found to be highest in the depth average and circumference average, Antlion pits that are larger have a tendency to capture and sink prey sooner, but when studied with respect to their time of response, they had a very slow rate of response.

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Fig. 1. Antlion pits in the study site

An -'army'- invading the -'cob kingdom'- is cleverer than the anticipated!!!

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Fall armyworm, is scientifically referred as *Spodoptera frugiperda*. They are so voracious feeders wherein a single larva leaves no plant unfed if left unchecked. They are crazy and bounce on more than 300 species of plants approximately. (Montezano *et al*., 2018). Adults make trips travelling hundreds of kilometers searching for suitable hosts and get halted to continue for the next generation.

Different methods and chemicals were initially experimented on this worm after its appearance in the year 2018. As the days passed, farmers were acquainted with one major and popular chemical i.e., Emamectin Benzoate, locally called as *shaavige* owing to its 'vermicelli' like resemblance. This shaavige has become popular with many maize growers in and around shivamogga.

Maize growers in Karnataka are advised to use this chemical, Emamectin Benzoate, which are available in various and attractable trade names like Robot, Cylinder, Pencil etc.. @ 0.5g per liter. Farmers are acquainted with this chemical and favour it over other insecticides.

So how long will the single chemical work?

The power begins to diminish when the insect has smartly mastered the fighting back techniques. In a span of year, this chemical which is being used extensively to control armyworm, is speculated to have gained resistance.

During the course of my laboratory study in August 2019, 100% mortality of the larvae was obtained when they were exposed to a very low dosage immediately after few hours rather than waiting for a day. The pattern was the same for few months in which bioassay were carried out in laboratory.

In the era of Covid 19 i.e., in August 2020, larvae showed zero percent mortality for the same concentration. The mortality was unsatisfactory even though a higher dose compared to the previous year's dose was used. This is because the physiology of the insect becomes reluctant to respond to cause its demise, -the Resistance!

Once the annoyance reaches its peak, certain external weapons has to be applied to gain control and these weapons should be soldered very well and replaced with other effective ones. Here the weapons are other agents (insecticides and alternate control measures) which tries to bring down the pest load.

A TRUE WARRIOR IS NOT THE ONE WHO FIGHTS BUT WHO ESCAPES!

Fig. 1: *Spodoptera frugiperda* feeding on maize

Fig. 2: Final instar of fall armyworm

Invasive insect species: A bane to agricultural biodiversity

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Insects are the most abundant and diverse group of organisms on earth, playing a major role in the biological foundation for all terrestrial ecosystems. With the glorifying truth that life would cease to exist without insects as they are considered the heart of every kind of ecological process, yet at the same time some insects are a threat to agriculture and its produce. Indian agriculture encounters a lot of challenges ranging from the production of sufficient produce to feed its population to the protection of crops from pests. Apart from all these, a new challenge in the form of invasive species has come to play which threatens the agricultural economy.

Alien species are non-native species introduced outside its natural distribution. It becomes invasive when it arrives, survive and thrive in the given environment. Invasive species can be plant, animal, insect or micro-organism. According to the Global Invasive Species Program (GISP), "Invasive alien species (IAS) are non-native organisms that cause, or have the potential to cause harm to the environment, economies, or human health"

Globalization has created a situation in which even the most thriving nation in the world is now economically dependent on the goods and services provided by other countries (Bright, 1999). Globalization has brought the utmost benefits socially and economically all over the world but alongside it has also brought new challenges, and IAS (Invasive alien species) is among the most significant. Invasive alien species are considered the second biggest threat to biodiversity after habitat loss. Invasive species are given so much priority in the present scenario that, article 8(h) of the Biodiversity Convention asks for measures to prevent the introduction, control or even eradicate those alien species which threaten ecosystems, habitats or species. In most cases, the translocation of biological organisms does not pose an issue as the chances of survival in their new environment is very low unless with deliberate care, or their populations are small and easily controlled (Mack *et al*., 2001). However, about 1 out of every 1000 organisms introduced into a new environment thrives and becomes invasive (Williamson and Brown, 1986).

Invasive introductions occur in two ways, one with the intention to do well (e.g. classical biological control) while the other arrives unintentionally mainly through hitchhiking on people and products.

The outcome of IAS can have grave and long term ecological effects on the invaded environments. There is lack of natural enemies in the new environments, which enable them to quickly increase their abundance and spread. IAS can carry diseases, outcompete or prey on native species, alter food chains, and even change ecosystems. These impacts can lead to local and global extinctions of native species and eventually cause ecological devastation. IAS have invaded and affected native biota in virtually every ecosystem type on earth.

India is not new to invasive insect species as it has witnessed invasions leading to degradation of natural habitat and imbalanced ecosystems as well as direct economic loss of many millions of dollars annually. Therefore to avoid future implications caused by invasive insect species, meticulous efforts to prevent its entry into new environment should be made as it is the cheapest, most effective and most preferred option.

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Mating mystery of Mecoptera

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Introduction

Mecoptera derived from Greek word means, mecos-long, ptera-wings are an order of insects in the Endopterygota with about 686 species in forty families worldwide (Penny, 1997). Mecopterans are sometimes called scorpionflies after their biggest family, Panorpidae, in which the males have dilated genitalia that look similar to the stingers of scorpions, and long beak-like rostra. The Bittacidae, or hangingflies, are another exuberant family and which are efficient predators. Mecopterans are small to medium-sized insects with long beak-like rostra, membranous wings and slender, elongated bodies. They have moderately simple mouthparts, with a long labium, long mandibles and fleshy palps, which resemble those of the more primitive true flies. Scorpionflies usually live in broad-leaf woodlands with bountiful damp leaf litter. Adult mecopterans are mostly scavengers, feeding on decaying vegetation and the soft bodies of dead invertebrates. Most mecopterans live in moist environments, in hotter climates; the adults may therefore be active and visible only for short periods of the year (Penny, 1997).

Reproductive organs of Mecoptera

Functionally, the male genitalic structure can be divided into interconnecting and grasping structures. The former is used to connect to the female genitalia during copulation. The latter is used to grasp particular part of the female during copulation. The genital bulb of the male *Neopanorpa longiprocessa* consists of the epandrium (tergum IX), hypandrium (sternum IX), and genitalia. The genitalia consist of paired lateral gonopods and the central valved penis. The gonopod is two-segmented comprising the basal gonocoxite and the distal gonostylus. The elongated gonostyli are claspers, grasping the female terminalia during copulation. The genitalia of the female are located on the abdominal segment IX, consisting of a subgenital plate and a genital plate. The subgenital plate is emarginate distally in a V-shape, implying its paired origin and curves dorsally from each side to form a shallow genital chamber, in which the genital plate is situated. The genital plate is a heavily sclerotized structure, consisting of the main plate and the axis. The main plate extends backward, forming paired posterior arms. In the axis, the spermathecal duct is fixed in the midventral groove and the irregular shaped copulatory pore is situated medially at the posterior end. The genital plate can stretch out to connect her copulatory pore to the phallotreme of the male penis (Zhong and Hua, 2013).

The notal organ is an extremely elongated posterior process on tergum III, extending to the halfway of tergum-V of male mecopterans and is used to clamp the wings of the female together with the raised post-notal process on tergum IV during copulation. The ventral surface of the notal organ is densely furnished with pointed long setae, inversed and directed antero ventrally. The post-notal process of tergum IV is raised dorsad and is densely set with thick antero-dorsal directed setae. The anterior half of tergum IV is weakly sclerotized, and sparsely covered with numerous microtrichia. The forewings of the female bear microtrichia on the upper surface and setae along the veins. These setae interlace with the setae on the notal organ, and impede the female from escaping (Zhong and Hua, 2013).

Mating behaviours in Mecoptera

There are different mating behaviours adopted by mecopterans based on the availability of food (Thornhill *et al.*, 1991).

1. Salivary secretions as nuptial gift in Panorpidae

The salivary glands are tubular labial glands, opening at the bottom of the salivarium between the labium and hypopharynx. The salivary glands exhibit spectacular sexual dimorphism between the sexes, simply bifurcated and short in the female, but well developed and multiple-furcated in the male. The male feeds female with a salivary mass that it secretes. These hard, typically pillar shaped masses are attached to a leaf during their secretion. After saliva secretion, males stand near the saliva mass and disperse a distance sex pheromone from an eversible sac in the genitalia which chemically constitute of (2E,6Z)-nona-2,6-dienal and (E)-non-2-enal in the ratio of 1: 10. The pheromone is attractive to conspecific females at distances up to eight meters. A female attracted by the pheromone, feeds on the saliva, while male holds female forewing with notal organ and continue to copulate, which may last a few hours in some species (Kock *et al.*, 2007).

2. Dead arthropod as nuptial gift in Panorpidae

In this case, a male locates a dead arthropod, feeds on it briefly; 89-97% of scorpionflies diet comprises dead insects of which, Dipterans share 47-69% and then male disperses sex attractant while standing adjacent to the dead arthropod. During both alternatives, males display with wing movements and abdominal vibrations to females attracted to the pheromone. Males defend nuptial offerings of both types from other males that attempt to grab them through aggression. Aggressive interactions between males may involve non-contact wing-lifting and abdominal vibration similar to courtship. Belligerent interactions often escalate, however, into either ramming an opponent with the head or body or rapidly lashing out the slender, flexible abdomen and striking an opponent with the massive genital bulb. The male genitalia are large and muscular. On the distal end of the genital bulb is a pair of sharp claspers. Males often clasp an opponent's wing or leg during aggressive interactions. Males only resort to forced copulation when the two other alternatives cannot be adopted because of resource scarcity, which may stem from low absolute resource abundance or from increased male-male competition, or both. Also, male body weight determines a male's success in male-male competition for resources, and the larger the male, the more it employs alternatives resulting in greater relative mating success (Thornhill, 1981).

3. Prey arthropod as nuptial gift in Bittacidae

Bittacids are major predators on soft bodied insects like tipulids, aphids and house flies. They dangle on vegetation to hunt the prey which comes in its vicinity, immediately after catching the prey, males release pheromone at that instant a female arrives in the immediate vicinity of a male in response to his pheromone and female lowers her wings. At this time the female is hanging directly in front of the male and usually less than 10 cm away. Wing-lowering is seemingly the cue males use for presentation of the prey to the female. The male retains a grasp on the prey with both hind legs and one or both middle legs during prey presentation to the female and during feeding by the female. After initiation of feeding on the prey, the female may or may not raise her wings this does not influence male behaviour. The male attempts to couple his genitalia with those of the female as the female feeds on the nuptial prey. However, the female initially keeps her abdominal tip pulled away. Ultimately, the male engages the female's genitalia, but only after she has evaluated the quality of his nuptial offering.

4. Sexual coercion in Panorpidae

Sexual coercion is forced insemination or fertilization. A sexual coercion attempt involves a male without a nuptial offering (i.e. dead insect or salivary mass) rushing toward a passing female and lashing out his mobile abdomen at her. On the end of the abdomen is a large, muscular genital bulb with a terminal pair of genital claspers. If the male successfully grasps a leg or wing of the female with his genital claspers, he slowly attempts to reposition the female. Then he secures the anterior edge of the female's right forewing in the notal organ, a clamp-like structure formed from parts of the dorsum of the male's third and fourth abdominal segments. Females escape from males without nuptial gifts. If grasped by such a male's genital claspers, females fight vigorously to escape. When female wings are secured, the male attempts to clinch the genitalia of the female with his genital claspers. The female attempts to keep her abdominal tip away from the male's probing claspers. The male retains hold of the female's wing with the notal organ during copulation, which may last a few hours in some species.

Conclusion

Food is the major limiting resource for Mecoptera as they share food web with different groups of insects and the aim of every organism on this earth is self-perpetuation which is also true with Mecopterans. This is the major driving force for this group to adopt diverse mating behaviours even in unsafe and perilous situations.

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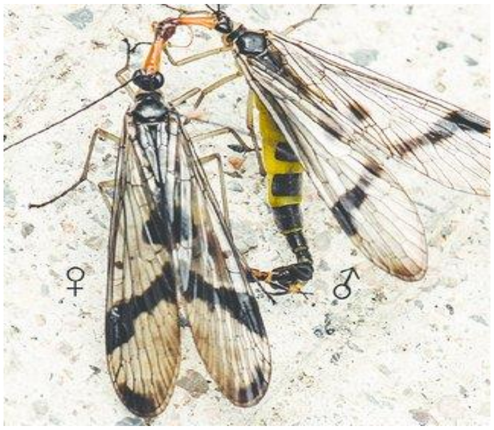

Fig: 1 Copulation in Scorpionfly (Image courtesy: Zhong *et al.*, 2015)

Fig: 2 Copulation in Hangingfly (Image courtesy: Thornhill *et al.*, 1986)

Webinar report on "Biocontrol of Parthenium"

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Society for Biocontrol Advancement (SBA) and Indian Council of Agricultural Research-National Bureau of Agricultural Insect Research jointly organised a webinar on 'Biocontrol of parthenium' as a part of National Bureau of Agricultural Insect Resources parthenium awareness week on 21 August 2020 from 11.30 – 13.00 hrs. The webinar was chaired by Dr. N. Bakthavatsalam, Director, Indian Council of Agricultural Research-National Bureau of Agricultural Insect Research, Bengaluru. In his introductory remarks he briefed on the menace caused by parthenium and the evolving methods to manage it. He urged that adoption of community level approach will aid to contain the spread of the weed. Dr. K. Dhileepan Principal Entomologist, Biosecurity Queensland, Australia who had supplied the parthenium seed feeding weevil, *Smicronyx lutulentus* (Permit No. 33/2017-18) as a part of Material Transfer Agreement between Australia and India delivered a talk on 'Biocontrol of parthenium'. The work churned out by group on the potential biological agents in containing the parthenium menace was discussed by him. He called upon the Indian researchers to look for biocontrol agents attacking different parts of the parthenium as additional agents that would ease in control of parthenium in India along with the *Zygogramma bicolorata,* in a long run. The webinar was attended by former Directors of ICAR – NBAIR, Dr. N.K Krishna Kumar, Dr. Abraham Verghese and Dr. Chandish. R. Ballal. There were 107 participants from ICAR institutes, All India Co-ordinated Research Project on Biological Control (AICRP-BC) centres, State Agricultural Universities and research scholars. The webinar was organized by Drs. Kesavan Subaharan, G. Sivakumar, (Secretary, SBA), M. Sampath Kumar, (Treasurer, SBA), Amala Udaya Kumar, M. Pratheepa and M. Mohan.

A screenshot of the webanair on parthenium

Insect Lens

Desert Locust, Schistocerca gregaria color variation in desert locust

Author: Keshav Mehra, Krishi Vigyan Kendra, Lunkaransar, Bikaner, Rajasthan (Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan),

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Japanese Silk Moth, Antheraea yamamai

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Syrphid Mango Pollinator, Eristalinus arvorum

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Beetle

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Red cotton bug's mating

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Place: Location: Indian Institute of Science Campus, Bangalore

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Granite Ghost Dragonfly, Brodinopyga

Author: Dr. Abraham Verghese

Place: Bangalore

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Paper Wasp

Author: Dr. Nagaraj DN

Place: Bangalore

Email: nasoteya@yahoo.co.in

***An ant mimic, Odontomantis sp*.**

Author: Dr. Abraham Verghese
Place: Bangalore
Email: abraham.avergis@gmail.com

***A** Camouflaged Praying Mantis on the forest floor*

Author: Satyajeet Gupta

Place: Agumbe rainforests, Karnataka

Semilooper

Author: Dr. Nagaraj DN

Place: Bangalore

Email: nasoteya@yahoo.co.in

Profile

SANKARGANESH E. has been awarded with the Best Post Graduate Researcher Award 2020 by the Society for Biotic and Environmental Research (SBER), Tripura in recognition of his outstanding research and quality of master thesis. His thesis title was "Development of DNA barcodes for major insect pests and natural enemies of solanaceous crops ecosystem in mid hills of Meghalaya". Dr G. T. Behere, Principal Scientist, ICAR-Research Complex for NEH Region, Umiam, Meghalaya, was his major Guide.

As a part of his thesis work, he has published two peer reviewed research papers in International Journals having NAAS rating 9.03 and 7.02. He has contributed for the detection of invasion of ***Tuta absoluta*** in Northeastern India and the infestation of ***Helopeltis cinchonae*** on chilli for the first time in India. During his master's degree research, he has contributed to the identification of 86 insect species associated with solanaceous crops in Meghalaya and has developed 50 DNA barcodes from the study of which 20 DNA barcodes were submitted to the International; GenBank (NCBI) for the first time.

He has also received the Best Master thesis award from Agricultural and Environmental Technology Development Society (AETDS), Uttarakhand 2019 and Best paper award in International Conference on Biocontrol and Sustainable Insect Pest Management (ICBSIPM-2018) held at Tamil Nadu in Jan 2018. He has presented his thesis work in International Conference on Biocontrol and Sustainable Insect Pest Management-ICBSIPM-2018 (held at TNAU during Jan 2018), 7th India Biodiversity Meet-IBM-2019b (held at Indian Statistical Institute, Kolkatta during Nov 2019) and International Conference on Global Perspective in Agricultural and Applied Sciences for Food and Environmental Security- GAAFES 2019 (held at Uttarakhand during Dec 2019)

Mr Sankarganesh is currently pursuing Ph.D with JRF fellowship in the Department of Agricultural Entomology at Bidhan Chandra Krishi Viswavidyalaya (BCKV), Mohanpur, West Bengal. He has completed Bachelor's degree in Agriculture from Tamil Nadu Agricultural University (TNAU) in 2015 and Master's with specialization in Agricultural Entomology from Central Agricultural University (CAU), Imphal during 2017 and has qualified ICAR-ASRB National Eligibility Test in 2020. GAAFES 2019.

Dr G. T. Behere

OBITUARY

T.M. Musthak Ali (22nd September 1945-11th October 2020)

Musthak Ali was a friend for more than four decades. We first met in an IPM practical class; him a teacher and me a student. Musthak, as I called him, joined the millet scheme as Research Assistant first in Raichur soon after his B.Sc (Agri) in 1968. He was then transferred to Bangalore in 1975, when I joined my Masters. He taught us IPM for the range of millets, with élan and zeal that could stem only from an entomologist who is involved in field-level actions. None of us in the junior M.Sc (Agri) ever felt he was only a graduate, but he never masked that fact. But his systematic dispensation of knowledge, articulated with field and agricultural anecdotes, endeared him to me. He strode into my life. The year was 1975.

I have been a birdwatcher, since my undergraduate days. Musthak knew about it and suggested that I visit the hills of Kemmanagundi in Chikmagalur (Karnataka). So one weekend he suggested I go there as he would be there for a week in a relative's place. Two co-birders and I agreed. He left a week early and we planned to catch up with him the weekend. Our bus to Kemmanagundi from Bangalore would reach the destination by 3 am and we told Musthak to receive us only by 7 or 8 am, for we thought we will hang on in the bus station. But Musthak Ali sacrificed his sleep, and was waiting for us from 2.30 am. We were surprised to see him at that unearthly hour. That was the sincerity and concern he had for his friends. He brought his cousin's Ambassador car and took us to the hill guest house. That day, I saw for the first and last time, the Scimitar babbler at Kemmanagundi and that sight I dedicate to Musthak!

It was in 1976 that the University of Agricultural Sciences, under the aegis of UNDP/Ford Foundation, hosted the soil biology symposium to stimulate interest in soil arthropods. Dr. G.K. Veeresh asked me, a postgraduate student then, to prepare a review on 'Ants of India' and present it at the symposium. I prepared and did present. Musthak, who was in the audience, came to me during the break and with a genuinely appreciative smile said "Abu (as he has always called me) you did well." I never knew that he would take ants as his topic for M.Sc thesis, five years later. In 1981, he submitted his thesis on the theme 'Ant fauna of Bangalore' with notes on nesting and foraging habits. This anchored him well in entomology, and after his thesis, he continued in the Division of Entomology, as millet entomologist, UAS, but alongside pursued his passion: myrmecology-the world of ants.

While then, he was promoted in 1988 and became Principal Investigator of All India Project on white grubs, in which he continued till he superannuated in 2005. Apart from ants, his collections in Scarabaeidae are also noteworthy. They are part of the repository at the UAS(B), Bangalore. Each beetle looks almost polished, systematically stretched and pinned. It was ditto for the Formicids too.

Musthak Ali was a much-contended man, from the time I met him. He nursed no ambitions but strode along as God ordained for him. This had two great impacts on him. One, he never was a "group-man" and never indulged in facetious mud-slinging. Two, posts and positions were an apathy to him. So he was nobody's competitor, but an everybody's scientist, and a beloved one at that.

Tyrannomyrmex alii a species of tropical ant named after Musthak Ali

I know, he trained 100's in ant taxonomy and I too was a beneficiary in 1989 of one such workshops. His enthusiasm for ants kindled in me interest in ant-predator-homoptera interspecific interactions. The outcomes were one DBT scheme and another student's Ph. D thesis on ant-diversity. Musthak was a helpful collaborator in both.

Musthak was an authority on the ant fauna of Karnataka, Peninsula India and beyond. His faunistic data are available in about two dozen papers. This data also resulted in some secondary papers. He was a magnanimous person, indeed.

I've had many interesting moments with him. Across the coffee table at the University canteen, we shared anecdotes and laughed our hearts out. He had a keen sense of humour. One of our outings in the eighties was to a Taaj hotel in Shivajinagar to eat biryani! This hotel served hot piping biryani for budget costs. These memories are etched green in me.

Musthak's relatives owned mango orchards, especially *Badami*, the famous Alphonso variety. He was a connoisseur of fresh fruit mangoes. He said people eat Badami the wrong way- slice and gobble! He told me that he will visit me during the season at the Indian Institute of Horticultural Research (ICAR-IIHR) where we have orchards, and demonstrate to me the right way of eating a mango, especially the Alphonso! A little intrigued, I still invited him during the season. It was the year 2005, when he retired. He came with Mrs. Ali and two heavy containers of excellent biryani. We ate in our laboratory- to our hearts content. Then I had the Alphonso brought in. He selected a few real round pulp ones as would a connoisseur. He held the mango horizontally, gave a neat central cut, all round the circumference. He then gently squeezed, and out popped the seed, with two halves of the mango in his hands. He gave me one half, and told me to scoop and eat the flesh. We did that till we scrapped the rind. That was royal eating indeed! We enjoyed that afternoon to the hilt -food, fun, and Formicidae. Now on, every mango season, till I am permitted, I will raise a toast to my dear friend Ali with a Badami split fruit!

Musthak, if you can hear me, I am missing you- you a cool, joyous personality, a person without any guile or dissatisfaction, a scientist and naturalist, who has left behind thousands of invaluable collections of named six-legged crawlies- a rich heritage for posterity and science. We are poorer without you, but the other world is richer indeed!

Dr. Abraham Verghese

With inputs from Dr.V.V. Belavadi, Dr. Vijay Kumar, K.T., and Dr. Yeshwant, H.M
Photographs contributed by Dr. M A Rashmi