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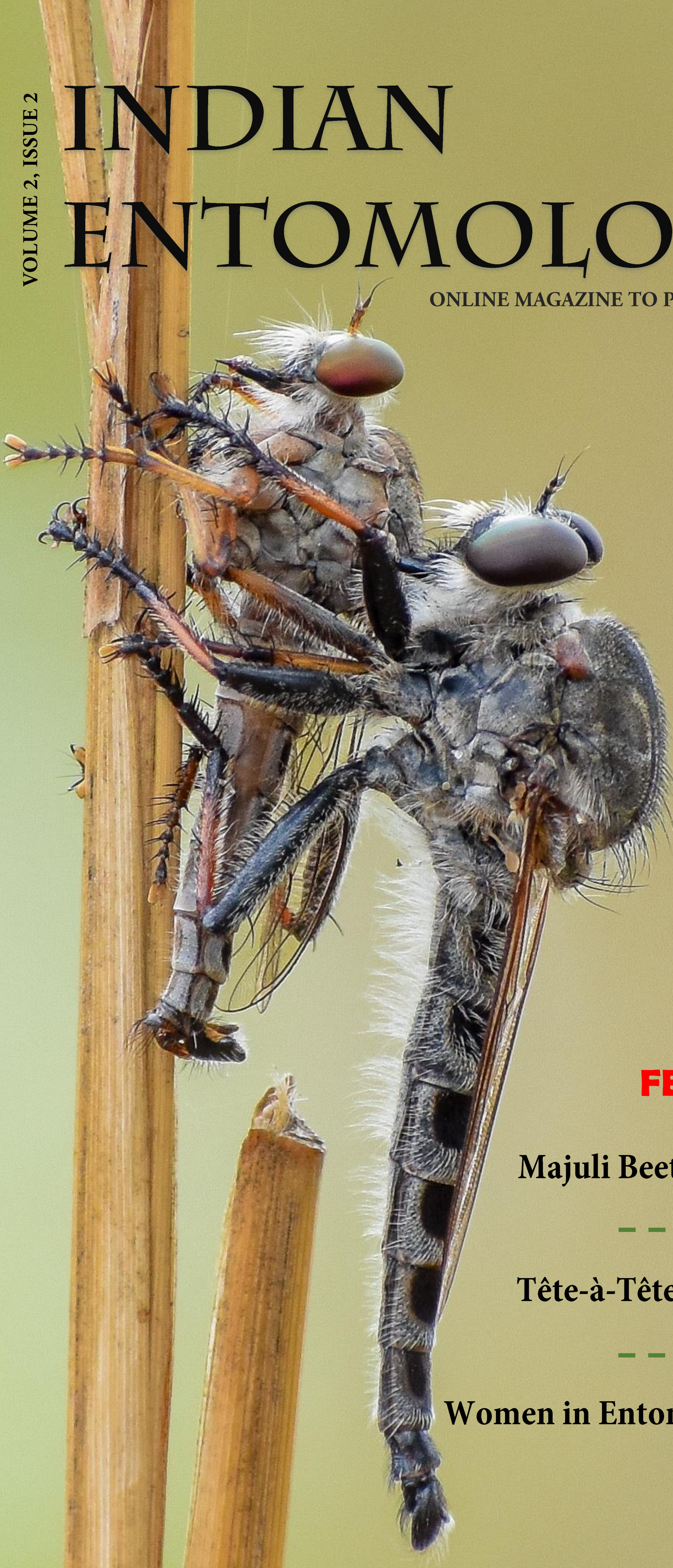

FEATURING

Majuli Beetle - Pest into Cuisine

Tête-à-Tête with Dr. B. V. David

Women in Entomology: Dr. Mayabini Jena

INDIAN ENTOMOLOGIST

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Editorial Board

***Cover page image: Mr. Mohammed Ramees K (Photo taken at Thrissur, Kerala, 24.04.2020) showing cannibalism in robber flies.**

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Entomology and Entomological Society of India: Towards digital transformation

Indian Entomologist is now in its fourth issue! I am fully confident that it is marching past with excellent credentials towards the objectives for which it was created by some young minds a few years back. It stands devoted to the progress of Entomology in India. Similar to the views of entomologists finding their way into this unique medium, entomologists of India put forth their own on the insects, their actions, and more so with their management in forums/ media like journals, magazines, newsletters, blogs, and informal online social media. More recently online webinars have joined these in addition to the conferences and symposia which have become a thing of the past in the recent months due to the Covid 19 pandemic. If an introspection is made, in the midst of these, there are few which stand out forever as immortal and can be easily singled out for their long- standing and humble contributions to Entomology in India. It is also true that amongst such stand-outs and long-standing ones there have been a few, which are unique, handled by stalwarts and doyens in Entomology, with a rich history and rock-solid background. Very few of these remain unparalleled even when compared with those on other such sciences. This is true especially in India, with only one or few remaining as disseminators of Entomological knowledge. Also, there is none which stands as a sole custodian for many decades and with developing aspirations that it will remain so for many more decades to come. No doubt, the Indian Journal of Entomology is one such aspiration, in its 83rd volume and standing out with a rich and memorable past. Its recent reverberations and changes make it fly high as a powerful disseminator of Entomology and its scientific strength. Let me take this opportunity to pen a few words to justify this "change" in this Editorial so that our Entomology fraternity could be more aware of what is on the ground to make this change imminent and responsible to Entomology in India.

If one happens to glance through the pages of the Indian Journal of Entomology issues and that of the website of the Entomological Society of India during the last few years will be convinced about this fact. This confidence will swell if one reads the developments explained below. The Journal is moving in the right direction with the two major global indexing players namely Scopus and EBSCO accepting it for indexing of its contents. This is a long standing aspiration of those running the Journal, which is a step in the right direction and paving the way for its citation prospects. Better late than never!. The Journal is up to date, with many of the authors viewing their papers online published in a matter of six to eight months. All the papers are doi assigned and JATS subjected to enable their digital access, and make them easily accessible for citations. The major development in the immediate offing is it's becoming “open access” from the year 2021 and moving towards state of the art journal management system. The entomologists in India will be able to perceive these changes in the next few months. It will make the dissemination process satisfy global standards, and make Indian Journal of Entomology revive its glory in all respects as required by the scientific fraternity nowadays. Yes, the Journal is continuously striving to meet the standards, and I am sure its attempts for progress will be satisfyingly rewarding. Also, efforts are on to improvise the activities of the Entomological Society of India, the long-standing publisher of the Journal through digitisation in a dedicated website. These improvisations will enable the activities being known at the click of a mouse and reach the homes of Entomologists. Also, specific actions are on to promote Entomology in India with instituting of awards in the next few months. Let’s handhold in all spheres as will be demanded from all of us as Entomologists and enable our aspirations suceed. Nothing succeeds like SUCCESS!

Dr. V.V. Ramamurthy
Editor in Chief, Indian Entomologist

Entomophagy: Success story of Majuli Beetle-Pest into Cuisine

Badal Bhattacharyya and Sudhansu Bhagawati

The white grub, *Lepidiota mansueta* was first detected in October 2005 in the farmers' field of Majuli river island of Assam. Field surveys conducted during 2005-2009 revealed that *L. mansueta* had appeared as an extremely severe key pest in Majuli river island and the most severely affected crops were potato, sugarcane, *Colocasia* and green gram, and the extent of damage varied from 42-48, 15-20, 35-40 and 30-35 per cent, respectively (Bhattacharyya *et al*., 2013). Majuli is the largest fresh water mid-river deltaic island (26° 45 N to 27°12 N latitude and 93° 39 E to 94° 35 E longitudes) and is situated in the upper reaches of the Brahmaputra, 630 km upstream of the Indo-Bangladesh border and 100 km from its mouth and the elevation from the mean sea level is 84.50 meters. Majuli falls under the tropical climate zone; however, the numerous wetlands, streams, etc. endow Majuli with a sub-tropical climate. The average annual temperature is 22.5° C. The average annual rainfall ranges from 200-250 cm with 80 per cent relative humidity. The island is a "Bio-diversity hotspot" and has rich ecology with rare breeds of flora and fauna and is a part of a major path for many species of migratory birds. The government of Assam has also proposed that the island be included in the UNESCO's "World Heritage Site" list because of its unique historic importance, rich biodiversity and co-existence of various cultures.

Realizing the seriousness of the problem, the seasonal life cycle and biology of the white grub beetle, *L. mansueta* were studied in crop fields of Majuli and in the laboratory of All India Network Project on Soil Arthropod Pests, Assam Agricultural University, Jorhat Centre during 2005-2009. *L. mansueta* has a

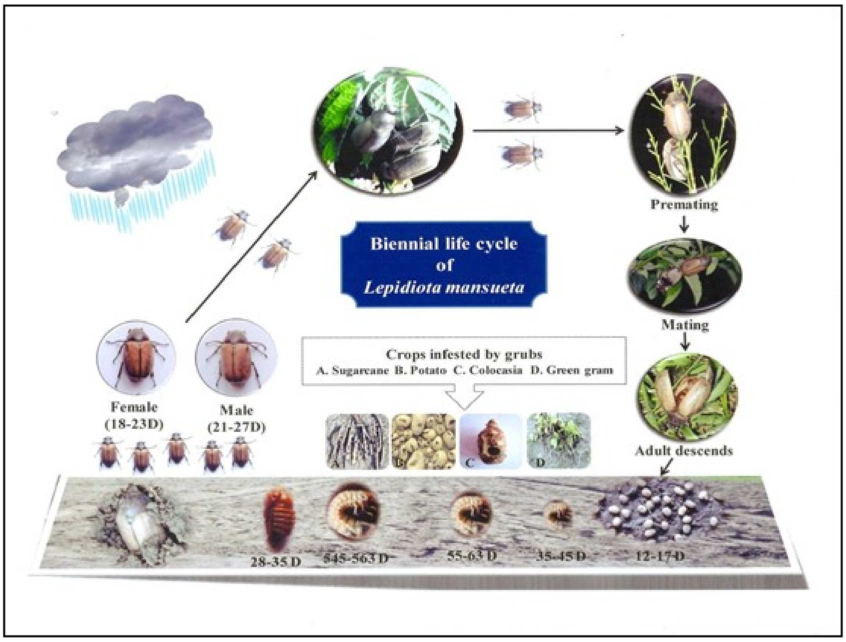

Fig. 1. Biennial life cycle of *L. mansueta*

biennial life cycle (Fig.1), which is the first of its kind from North East India. It is a unique biennial species, spending its entire life cycle under the ground except for a very short period during which adults come out of the ground for mating and oviposition. Grubs are voracious feeders. However, there is no evidence showing that the adults fed on any plants either in the field or laboratory and hence this species has the unique distinction as the first Indian phytophagous white grub species with nonfeeding adults (Bhattacharyya *et al*., 2015). The probable reasons of endemism/outbreak are due to the high organic carbon content of the soil (0.75-1.00%) and presence of abundant thatch zone (dead grass, stems and other organic debris) in the endemic pockets. Other reasons may be nonarrival for last several years, of the migratory bird Siberian crane (*Grus leucogeranus*), a seasonal predator of the grubs in Majuli probably because of the changing climate with erratic rainfall and early onset of summer in the riverine island. Moreover, conversion of virgin low grass lands (sand bars) by the flood and erosion affected people into agricultural farm lands-a potential problem inviting future outbreaks of the species in massive proportions in Majuli. Of late, this species has crossed the geographical barrier of the mighty Brahmaputra and spread to other adjacent riverine areas.

Worrying factors

There were lots of "worrying factors" as far as management of this atypical species of white grub as mentioned below:

a) *L. mansueta* has biennial life cycle which is first of its kind from North East India. Third instar grubs were found to be voracious feeders of roots/tubers/corms of crops and they remained active in the field up to 18 months. As it spends its entire life cycle under the ground except for a short period during which adults come out of the ground for mating, the species was thought to be irregular in occurrence or even migratory; whereas it was very much resident species of Majuli.

b) Application of soil insecticide was effective only against the short-lived 1st and 2nd instar grubs but not against the 3rd instar grubs. Third instar grubs showed typical downward vertical migration into the deeper layer of soil and remained inaccessible to the insecticidal treatments and hence unaffected.

c) It was very difficult to detect the presence of white grubs in both cultivated and noncultivated fields though the grubs were abundantly available in endemic areas (10-15 grubs/sq. m) without showing any detectable above ground symptoms of infestation on the plants.

d) One of the major tactics for managing the adult scarab beetle population that congregated on some preferred host plants during pre-monsoon or monsoon by spraying recommended insecticides during daytime was found to be absolutely ineffective in case of *L. mansueta*. Because, the adults of both sexes were observed not to feed on any plants in the field and hence this species has got the unique distinction of being the "First record of Indian phytophagous scarab beetle with non-feeding adults". Moreover, the adult beetles became over ground during evening hours only for 2-3 weeks in April and hence, managing the huge population of adults within a very short period in the evening over a large area was utterly difficult.

e) Majuli river island is an aspirant for getting the tag of "World Heritage site" from UNESCO. Therefore, there was also an urgent need to ponder about nonchemical approaches of managing this insect pest since the application of chemical pesticides is not allowed in such sites.

Vital tipoffs

After unravelling the seasonal cycle and biology, the investigators learned few vital tipoffs worthy of managing the beetles as mentioned below:

- Rush of adult emergence took place for a short period of time in the evening during April-May. Except for this short aerial life for nuptial activity, the species lives a subterranean life.

- Both sexes of the beetle were positively phototactic.

- Beetles emerged from soil for mating during evening hours and spend almost one hour (6.15pm-7.15pm) for premating flight. Beetles could be collected in huge numbers by operating light traps in endemic pockets during 6.30pm-7pm.

- Scouting for hand collection is also effective since the mated pairs are found abundantly on selected sheltering plants in field during 7pm-8.30 pm.

- Beetles can also be used as animal feed for poultry, pigs, dogs, cats etc.

- Some indigenous tribes also consume the beetles as their food.

- Concept of Social Engineering/Farmers participatory approach could be encouraged for the mass collection and destruction of beetles during the period after premonsoon showers in the endemic areas of Majuli river island. In white grub endemic areas adult collection campaigns are being resuscitated, as farmers do not appear to realise their potential impact on reducing damage; this is because they are not conversant with the life cycle of the white grub. In this regard, the community action programmes aimed at collecting adult beetles as they emerge offer a practical and cost-effective method of management, and should be pursued.

How the Social engineering concept was embraced for the management of Majuli beetle?

Social engineering is a discipline in social science that refers to efforts to influence particular attitudes and social behaviors on a large scale, whether by governments, media or private groups in order to produce desired characteristics in a target population. Adaptive research and development methods, participatory technology development and community involvement are important elements for the desired outcomes. Social engineering means a balance between the competing interests in society, in which applied science are used for resolving individual and social problems. Social engineering is a data-based scientific system used to develop a sustainable design so as to achieve the intelligent management of resources and capital with the highest levels of freedom, prosperity and happiness within a population. A participatory approach, tends to focus initially on small numbers of clients participatory and is location specific in nature. Rather than "passive participation," it is aimed to inspire "self-mobilization", where communities organize and take initiative independently to solve their problems/issues. Community mobilization is the process of engaging communities to identify community priorities, resources, needs and solutions in such a way as to promote representative participation, good governance, accountability, peaceful change and achieving the objectives. Participatory technology development programme with farmers can be done in collaboration with NGOs and extension staff, albeit with training and adjustments to present methods of operation. In case of group approach the main challenge is sustainability of the groups. This concept heavily relies on all the members coming together to achieve a common goal, finding technical solutions and building capacities in the extension system and bridge the gaps in knowledge and technology dissemination.

The underlying principles of social engineering/participatory approaches/community mobilization can effectively and intelligently be explored in solving some crucial constraints related to agriculture and allied sciences. Such type of approaches not only improves crop productivity and livelihood but also tremendously improves overall knowledge contents and capacity building of the farming community. Most of such approaches are ecofriendly, economical and sustainable. The visibility of extension programmes as well as accountability also become more vibrant.

Salient features of the beetle management approach

Field and laboratory studies on seasonal cycle and bio-ecology of *L. mansueta* conducted during 2005-2009 in Majuli and adjacent endemic villages located in different sandbars revealed that the mass collection and destruction of adult beetles by mass campaigning during the period after pre-monsoon showers became inevitable in the endemic areas. During that period, farmers of Majuli did not realised the potential impact of this pest since they were not at all conversant with the biennial life cycle of *L. mansueta* with nonfeeding adults but voracious grubs. Majority of the farmers believed that the grubs were not pests but helpful in increasing the fertility of soil, just like earthworms. Considering farmers wrong perceptions about this notorious pest, a parallel planning was done to carry out both basic research as well as community action programmes/ social engineering/farmers participatory approaches aimed at collecting adult beetles during evening hours (6pm-9pm during April-May) as a practical and cost-effective method of management. These extension activities were initiated from 2010 onwards in collaboration with different stakeholders under the theme "Mass campaigning against *L. mansueta* in Majuli river island and adjacent sandbars through social engineering".

How the "*Lepidiota* Management Groups" were formed?

From the very beginning of mass campaigning against *Lepidiota* beetles, group-based approach for the mass collection and destruction of beetles was given the top most priority. Each village was selected based on the population and extent of damages caused by the grubs, presence of functional farm management committee/self-help groups/gram panchayats and a "*Lepidiota* Management Groups" was formed in each beetle endemic village consisting of 10 active farmers. The year wise numbers of *Lepidiota* Management

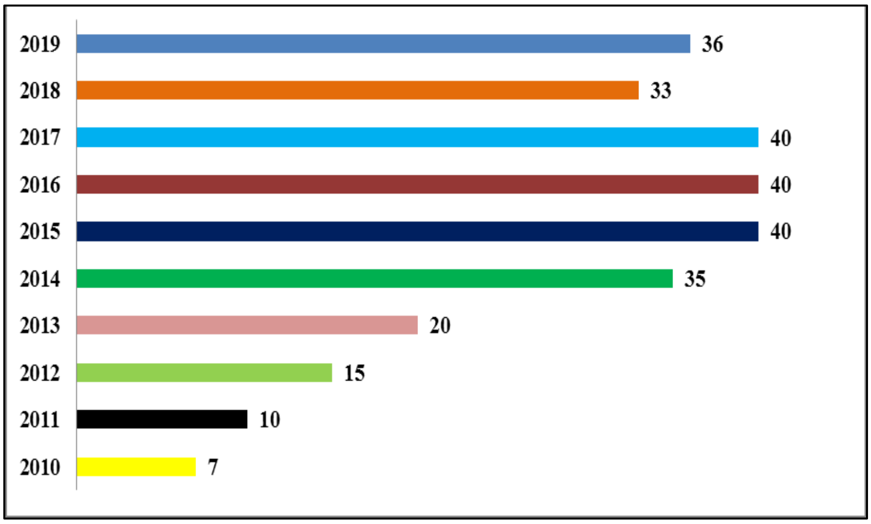

Fig. 2. Year wise (2010-2019) *Lepidiota* Management Groups (LMGs) who received technical knowledge and skill, technical input and other necessary supports from AINP-SAP, AAU- Jorhat Centre

Groups (LMGs) is presented in Fig. 2. These active LMGs since 2010 onwards, who received technical knowledge and skills, technical inputs and other necessary supports from AINP on Soil Arthropod Pests, AAU, Jorhat Centre.

Towards participatory approaches for beetle management

Parallel planning was done to carry out both basic research as well as community action programmes/social engineering/farmers participatory approaches aimed at collecting and destructing the adult beetles during April-May with the help of tribal and other farmers in Majuli from 2010 to 2019. Besides involving farmers, collaboration in this regard was sought from farm management committee, self-help groups, KVK Jorhat, state extension staff, *gram panchayat,* NGOs and district administration, Majuli. To sensitize farmers the following tools of social engineering were extensively used.

a) Smart SMSing to farmers through www.way2sms.com
b) Video-conferencing
c) Use of social networking site
d) Use of print and electronic media
e) Extension trainings
f) Farmer-scientist interaction
g) Field day
h) Exhibition
i) Awareness meeting
j) Documentary shows
k) Posters and banners
l) Distribution of photographs/leaflets
m) Exposure visit
n) Conducting field experiments in endemic areas
o) Visit of Entomologists from other institutes/university
p) *Rongoli* making to depict the life cycle of *L. mansueta*

Fig. 4 (A-H). Collection and destruction of *Lepidiota* beetles through mass campaigning programme conducted at Majuli during 2010-21

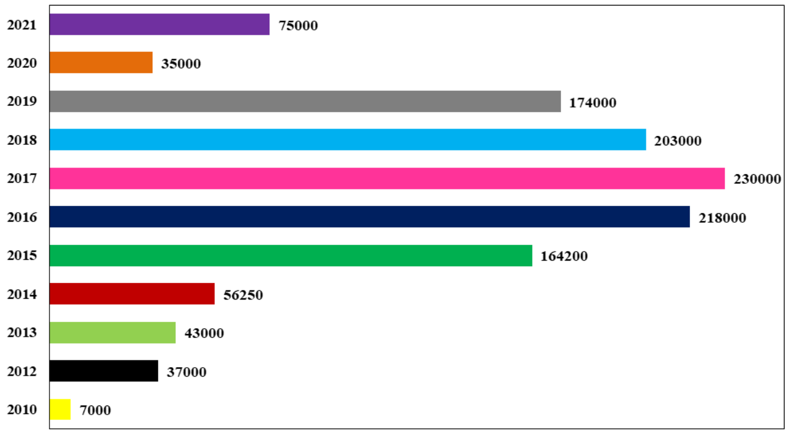

Fig. 3. *Lepidiota* beetles collected and destroyed during 2010-21

(Unsuccessful collection in 2011 due to heavy rain and low emergence of beetles)

q) Demonstration on collection of beetles using Solar LED light traps

r) Demonstration on using *Lepidiota* beetles as human food/animal feed

s) Use of public address system

t) Distribution of extension bulletins

u) Technology showcasing

v) Telephonic discussion

w) Developing interactive mobile app

x) Organizing insect photography competition

y) Distribution of awareness calendar, awareness cup, awareness plate and awareness rain head umbrella

z) Use of drone technology as a means of artificial intelligence for monitoring beetle holes

Mass collection and destruction of beetles

This mass campaigning programme received overwhelming response and was exceedingly successful leading to massive collection and killing of about 12.43 lakhs of *L. mansueta* beetles in Majuli river island during 2010-2021 (Fig. 3 and 4). The major advantages of such approach are -(i) the gravid females are killed before egg laying, (ii) capacity building amongst the farmers in white grub endemic areas and the management approach is ecofriendly and cost effective. It is worth mentioning that some of the local tribal people relished the cooked/fried adults of *L. mansueta* as protein rich food which opens up an avenue of further research on its nutritive/nutraceutical value.

Nutritional profiling of Majuli beetle

Efforts were also made to analyse the nutritional profiling of the beetles for their further exploration as human food/animal feed (Bhattacharyya *et al.*, 2018). The proximate analysis of the beetles revealed a higher amount of crude protein content (76.42%) along with other proximate parameters like crude fat (4.10%), crude fibre (5.16%), total mineral (2.98%), carbohydrate (9.18%) and moisture (2.16%). The energy content was 379.29 kcal/100 g of sample. Elemental analysis revealed the presence of 7 minerals *viz.*, Na (27.76), K (14.20), Ca (33.33), Fe (1.64), Cu (6.52), Zn (15.55) and Mn (1.30) mg/100 g of sample. As antioxidant properties, the phenol and flavonoid content was found to be 4.00 mg catechol equivalent/g and 1.59 mg quercetin equivalent/g, respectively. The DPPH was registered 22.60 per cent whereas tannin (3.24 mg/g) as antinutritional compound was recorded at acceptable level. Fatty acid profiling showed maximum amount of saturated fatty acid (2.24%) followed by mono unsaturated fatty acid (0.57%) and polyunsaturated fatty acid (0.49%). Altogether 10 fatty acids were estimated, of which palmitic acid content was recorded in maximum amount (0.28%). Amino acid profiling registered 17 amino acids, of which 8 were found essential. Considering the immense nutritional value of the beetles, beetle fry dish (https://www.youtube.com/watch?v=ZaTKT_ftT5M) was developed and popularized through community feast. Of late, concerted efforts have also been initiated to explore *L. mansueta* powder for making biscuits and other confectioneries (Fig. 5).

Initially, the tribal populace relished the cooked/fried adults of *L. mansueta* as protein rich food as part of their traditional belief and wisdom. However, of late, nontribal people are also equally showing their interest to explore the beetles as human food/animal feed after knowing the nutritional advantages of the beetles. This effort had tremendous impact in reducing beetle load in Majuli island in terms of protecting the crops, enhancing crop productivity as well as improving both livelihood and nutritional security.

What makes *L. mansueta* beetles as an ideal edible insect?

a) The nutritionals advantages of *L. mansueta* in terms of proximate and elemental composition, antioxidants as well as profiling of fatty acids and essential amino acids have attracted the people to accept the beetles as human food. Demonstration on exploration of the beetles through community feast organized across the island has helped not only to promote entomophagy but also found to build-up confidence on the people as far as safety factor is concerned.

b) As regards to antinutritional compound, the mean tannin content (3.24 mg/g) was recorded at an acceptable level and hence there is no chance of any detrimental effect on health.

c) *L. mansueta* beetles do not feed on any plants and consequently there is no chance of accumulation of toxic chemicals through feeding by the beetles.

d) Both the sexes of the beetles exhibited ever-empty thread like gut that further confirmed the nonfeeding nature of the adults.

e) No toxic glands in the grubs were detected even though the third instar grubs are voracious root feeders.

f) The processing and preparation of beetle fry dish doesn't take much time. Fried beetles are crispy and good in taste. Fried female beetles having eggs were more preferred than the male beetles.

India Book of Records for massive beetle collection

The AINP on Soil Arthropod Pests, AAU, Jorhat Centre has made "National Record" of "Most Beetles collected in 3 hours" by collecting 73700 numbers of white grub beetle, in collaboration with 100 farmers

Fig. 5. Exploration of *Lepidiota mansueta* beetles as "human food/animal feed" A. Fried dish prepared from adult *L. mansueta*; B. Roasted *L. mansueta* beetle dish; C, D. Feast to popularize the "beetle fry" dish; E. Value added products like biscuits, cake and bhujia prepared from *L. mansueta* powders; F, G. Lepidiota beetles using as "animal feed"

of Majuli at Maharichuk Village on 9th April, 2018. This record attempt was made under the ongoing mass campaign against white grub beetles with the following objectives:

a) To destroy the huge breeding ground/ reservoir of white grub beetle in a single strike

b) To create awareness about the beetle menace among the farmers and other stakeholders

c) To show the power of "Social Engineering/Large Community Mobilization" in pest management

It is worthy to mention that a major portion of the beetles so collected were explored as both human food/animal feed to build up confidence amongst the clients. The success story of setting national record was highlighted by most of the print and electronic media of North East India and hence, the zeal for the mass collection of beetles as well their consumption was tremendously increased by many folds.

Impact assessment study on group approach on extension management of white grub

A total of 200 beneficiary farmers belonging to 36 numbers of "Lepidiota Management Group" were randomly selected for the study and interviewed personally through semi-structured pre-tested questionnaire to know the real impact of the group approach on extension management of white grub in Majuli. It revealed that the main logic of the mass campaigning conducted during 2010-2019 for managing the white grub with the help of farmers group was fulfilled to a great extent. The group members perceived that due to formation of the groups, there was reduction in white grub infestation, reduction in occurrence of adult beetles from soil leading to decline in population of grubs in soil. Most of the members also perceived that productivity of different crops such as potato, sugarcane, Colocasia, green gram had increased due to reduction in white grub infestation after the introduction of group approach of extension management. Wide varieties of assistances/material incentives were received by the Lepidiota Management through "Tribal Sub Plan Grant" provided by the Indian Council of Agricultural Research, New Delhi. Social engineering and free inputs to the groups were the major interventions and the immediate output was the formation of groups and this output led to different outcomes such as decrease in population of white grub, decrease in pest infestation/damage, increase in crop production and productivity, increase in farm income, adoption of recommended practices for management of white grub, and above all, the extent of people participation and zeal to work in group also increased. Moreover, impact was also observed in non-project areas due to spreading effect of group approach in a passive way. Majority of the respondents of both group and non- group members had favorable attitude towards group approach of management of white grub. Farmers also readopted the crops that were discontinued earlier due to severe white grub infestation and successfully expanded crop area under crop cultivation after reduction of grub population. Constant efforts of project team to convert this pest as both human food and animal feed also gained popularity among the Majuli populace.

Success stories documented

Success story of the whole mass campaigning programme and the exploration of *Lepidiota* beetles as human food has been highlighted by almost all vernacular daily newspapers and electronic media of Assam and also cited by many national e-journals/Magazines/ conservation and environment sites etc. The lead scientist of this endeavour also received “Fakhruddin Ali Ahmed Award for Outstanding Research in Tribal Farming Systems, 2014” (bestowed ICAR, New Delhi) and “Dr. H. K. Jain CAU Award 2015-16” for “Excellence in Agricultural Research in the North-Eastern States of India” besides other recognition.

Conclusion

The mass campaigning programme explored the group approach of extension mostly targeting the flood and erosion affected farmers in Majuli and had tremendous impact in terms of protecting the crops, disseminating ecofriendly technologies, enhancing crop productivity as well as improving both livelihood and nutritional security. White grub is a dangerous destructive insect which can cause major havoc in almost all cropping systems generally followed in the North Eastern region. Hence ecofriendly management of scarab beetles by embracing “Social Engineering” is extremely important during the peak emergence of beetles, immediately after the first shower of pre monsoon rains. Awareness creation is one of the main requisites to manage this insect, not only in Majuli, but also in other parts of the country.

Edible insects can be considered as a biological treasure in North Eastern region and needs proper exploration to provide both nutritional and livelihood security. To harness the enormous economic value from the edible insects a more holistic approach with multi-disciplinary linkages involving policy makers and other stakeholders needs to be embraced. Due to the high resource efficiency and good nutritional value of insects, insect rearing for entomophagy seems to fit perfectly with a modern food production system. The edible insects could therefore be potential source for human food and animal feed since they exhibited a well-balanced nutrient profile. Extensive study is also needed to explore the edible insect fauna of this region and develop noble bioprospecting models so that they could be explored as mini livestock. Proper roadmaps for promoting insects as human food/animal feed as well as development of supportive and comprehensive legal frame work could pave the way for more investments for making it as a profitable business venture. Recent initiative of the Central Government to implement “Act East Policy” may facilitate international trade with South East Asia Countries, where “Edible Insect Industry” has already flourished.

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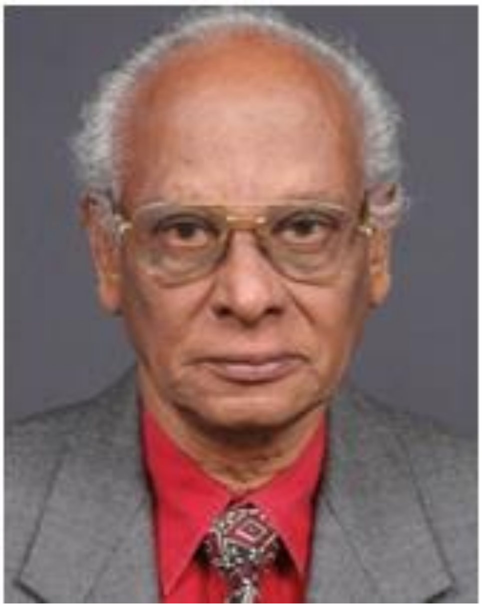
Tête-à-tête with Dr. B. Vasantharaj David

HUMBLE, ILLUSTRIOUS AND DILIGENT ENTOMOLOGIST WHO SERVED ENTOMOLOGY FOR 60 GLORIOUS YEARS



Dr. B. Vasantharaj David, born on 17th November 1935, at Insein (Myanmar) has 60 years' experience in the field of Entomology especially taxonomy and crop protection. He did his B. Sc. (Ag.) from Madras University in 1956 and obtained M.Sc. (Ag.) degree in Agricultural Entomology from the same University in 1961. Later Dr. David obtained his Ph.D. from the Tamil Nadu Agricultural University, Coimbatore in 1972 with Entomology as specialization. He was awarded the degree of Doctor of Science (D.Sc.) by the University of Madras in 1995 for his contributions in the taxonomy of the Aleyrodidae of India, Sri Lanka and Myanmar. He has taught Agricultural Entomology in the Agricultural College & Research Institute, Coimbatore and has served the State Department of Agriculture, TNAU, R & D of pesticide companies, private research organizations, etc.

He has visited various countries such as Japan, United States of America, United Kingdom, the Netherlands, France, Philippines, Singapore, Korea, Sri Lanka, Germany, Mexico, Switzerland, Canada, China, Belgium, Indonesia, Malaysia and Thailand in connection with his official duties and presentation of papers in international conferences.

Dr. David is a Fellow of the National Academy of Agricultural Sciences, the Royal Entomological Society, London, the Academy of Sciences for Animal Welfare, the Entomological Society of India, the Plant Protection Association of India, the Entomology Academy of India, the Society for Biocontrol Advancement, the Applied Zoologists Research Association, the National Academy of Biological Sciences, the Association for Advancement of Pest Management in Horticultural Ecosystems, the Society of Plant Protection Sciences, the Gujarat Science Academy, and the Madras Science Foundation.

Dr. David is recipient of several prestigious awards and recognitions, which include Dr. K. C. Mehta Memorial Award for outstanding contributions in Plant Protection from the National Academy of Agricultural Sciences; "Distinguished Scientist Lifetime Achievement Award in Toxicology" of Society of Toxicology, India; Late Shri Gyan Prakash Memorial Award of the Society of Plant Protection Sciences; Pearl Foundation Outstanding Research Award in Agricultural Sciences 2016; NABS Leadership Award 2016; Life time Achievement Award in Agriculture and Allied Sciences 2016 by the Samagra Vikas Welfare Society, Lucknow; the Friendship Forum of India, New Delhi presented Bharat Excellence Award, Leading Educationist of India Award and Global Arch of Excellence Award on 24th February 2019. He is also recipient of "Outstanding Plant Protection Scientist" Award at the International Plant Protection Congress (IPPC – 2019) held at Hyderabad on 13th November 2019; Bharat Ratna Mother Teresa Gold Medal Award for his outstanding individual achievement in Agricultural Sciences and Taxonomy and Toxicology, and Agri P. Kamalanathan Award for Scientific Contribution in Entomology by Tamil Nadu Agro Technologists' Forum (TANSAF) during its 27th Annual Meet. Dr. David is President of Applied Zoologists Research Association (AZRA) since 1994. Another noteworthy contribution is establishment of "Dr. B. Vasantharaj David Foundation" in 2019 to promote science and green environment.

Dr. Kolla Sreedevi (left) interacting with Dr. B.V. David at Bengaluru

Dr. Kolla Sreedevi, Associate Editor of IE, interacted with Dr. B. Vasantaraj David and the excerpts of the interview are presented below:

Dr. K. Sreedevi (KS): Sir, kindly brief about your journey and the milestones attained in your illustrious career

Dr. B. V. David (BVD): I started my career after obtaining B.Sc. (Ag.) degree in 1956 from Madras Agricultural College, Coimbatore and since then served in various capacities as Agricultural Demonstrator/ Agricultural Extension Officer/ Plant Protection Assistant (Entomology), Madurai 1956-1959; Assistant Lecturer/ Lecturer in

Entomology, A.C.&R.I., Coimbatore 1961-1968; Senior Technical Officer (Agrochemicals), Tata Fison Industries Ltd., Coimbatore 1968-1970; Entomologist, Ciba Agrochemical Research Centre, Koyarambedu, Chennai 1970-1971; Research Officer, Entomology Research Institute, Loyola College, Chennai 1971-1973; Assistant Professor (Entomology), TNAU, Coimbatore 1973-1975; Product Development Manager (Agrochemicals), Voltas Ltd., Mumbai 1975-1981; Director, Fredrick Institute of Plant Protection & Toxicology (FIPPAT), Padappai 1981-1987; Executive Director (Product Development), Rhone Poulenc Agrochemicals (I) Ltd., Mumbai 1987-1991; Director, Coromandel Indag Products (I) Ltd., Chennai and Professor of Entomology, FIPPAT, Padappai 1991-1994; Director, Jai Research Foundation, Valvada (Gujarat) 1994-1999; Director, Coromandel Products (I), Ltd, Chennai 1999-2000; Executive Director, Sun Agro Biosystem Pvt. Ltd., & President, Sun Agro Biotech Research Centre, Chennai 2001-2010; Consultant-GLP, Vanta Bioscience, Gummidipoondi, Chennai 2010-2013; Test Facility Head, Centre for Toxicology, Sri Ramachandra Medical University, Chennai 2010-2013; Consultant – GLP, Rotam Research Laboratory, Kunshan, China 2005-2017; Chairman, Scientific Research & Academic Board, International Institute of Biotechnology and Toxicology, Padappai 2013-2020.

My life time contribution spanning over sixty years has been in the fields of Entomology, crop protection and toxicology which led to enrichment of our knowledge of the bio-ecology and control of several agricultural pests, development of two research institutes, *viz.*, Fredrick Institute of Plant protection and Toxicology, Padappai (1981-1987) and Jai Research Foundation, Valvada, Gujarat (1994-1998), founding of biotechnology companies, Sun Agro Industries India in 1992 and Sun Agro Biosystems Private Ltd. in 2001 and further served as President of Sun Agro Biotech Research Centre for manufacture and marketing of biocontrol products promoting Integrated Pest Management (IPM) concept, taxonomy of whiteflies of India including Andaman & Nicobar Islands, Myanmar and Sri Lanka. Apart from describing around 250 new species, discovered for the first-time occurrence of species of the subfamily Aleurodicinae in India. I have published 24 books and 359 research papers. Two of my books, ***"General and Applied Entomology"*** and ***"Elements of Economic Entomology"*** are widely referred by students, researchers and pesticide industry personnel and prescribed as reference books for civil services examinations. Guided 11 scholars for Ph.D. and 16 for M.Phil. of the University of Madras.

As Director of Fredrick Institute of Plant Protection & Toxicology, Padappai (Tamil Nadu) (1981-1987) and Jai Research Foundation, Valvada (Gujarat) (1994-1998), I developed research facilities for agricultural sciences, toxicology, and product chemistry meeting international compliance of GLP. This facilitated pesticide industry to introduce a number of new pesticides in the country.

My initiative when I was Director, Jai Research Foundation in conducting an International Symposium on Good Laboratory practice in collaboration with DST culminated in establishment of National GLP Compliance Monitoring Authority in 2002, which has become a full member of OECD since March 2011. Today

"Taxonomy is a fascinating field. You derive immense happiness and satisfaction while discovering many new species/genera which remain for ever in posterity"

there are 50 laboratories certified as GLP compliant. I was a GLP consultant to Rotam Research Laboratory, Kunshan, China (2005-2017) and 3 Indian laboratories. Has wide experience in pesticides product development, product stewardship and registration of pesticides in the country and world over.

KS: Can you please narrate about turning points in your journey, if any

BVD: There have been many turning points. The fist was resigning state government job as Lecturer in Entomology, Coimbatore and joining industry R&D of Tata Fison Industries Ltd., Coimbatore in 1968.

The second one was when I lost my job as Entomologist with Ciba Research Centre, Kayarambedu in 1971, Prof. T. N. Ananthakrishnan offered me to join his PL 480 scheme on Thysanoptera in Entomology Research Institute, Loyola College, Chennai. It was during this time I completed my work for Ph.D. thesis on whitefly taxonomy. The most memorable thing was Dr. K. K. Nayar of Kerala University and Dr. Ananthakrishnan requested me to join them in the book project on entomology with Tata Mc-Graw-Hill Co., New Delhi and during the period with ERI the manuscript was completed and submitted to the publisher.

The third occasion has been getting back to TNAU as Lecturer in Entomology (1973-1975) and my decision to get back to industry and served with Voltas Ltd., Mumbai, Coromandel Indag Products (India) Ltd., Fredrick Institute of Plant Protection & Toxicology, Padappai and Rhone Poulenc Agrochemicals (India) Ltd.
The fourth occasion has been an invitation from United Phosphorus Ltd group to head, Jai Research Foundation, Valavada, Gujarat.

KS: Can you please tell us the driving factors/force behind taking up of Agricultural studies and research

BVD: Though I was keen to become a doctor, I was not selected and thus joined B.Sc. (Ag.) course in the Madras Agricultural College Coimbatore in 1951. After completing the course, I was appointed as Agricultural demonstrator, Oddanchatram and after one year, I was posted as Plant Protection Assistant (Entomology), Madurai. As I had passion for Entomology during my undergraduate course joined the first batch of Post graduate course in Agricultural Entomology during 1959-1961 and thereafter posted as Assistant Lecturer in Entomology, AC&RI, Coimbatore. Thereafter though I was with industry and research institutes I have been continuing my research on taxonomy of whiteflies and evaluation, registration and development of new pesticide molecules and toxicology.

KS: How did your professional career started and with what specialization
BVD: Though my career started in agricultural extension after getting qualified with a post graduate degree in Agricultural Entomology, soon my interest shifted

towards taxonomy and toxicology as narrated.

KS: What made you choose taxonomy as your specialization

BVD: My area of specialization has been taxonomic studies of whiteflies of India including Andaman & Nicobar Islands, Sri Lanka and Myanmar. I also reported on the aleyrodid fauna of Iran. When I registered for my doctoral research, Dr. S. Kanakaraj David, Professor of Entomology, AC&RI, Coimbatore suggested me to consider studying the aleyrodid fauna of India. Taxonomy is a fascinating field. You derive immense happiness and satisfaction while discovering many new species/genera which remain forever in posterity.

KS: Can you narrate about your passion towards biocontrol research

BVD: My passion towards biocontrol developed when I was Plant Protection Assistant at Madurai. There was an outbreak of a hairy caterpillar, *Laelia exclamationis* on guinea grass. When I reared it at my home. I could collect two parasitoids *viz.*, *Hockeria* sp. and *Tetrastichus* sp., and published in *Journal of Bombay Natural History Society*. Then during my post graduate course in 1960, visited Alanganallur in Madurai district to see outbreak of red hairy caterpillar on groundnut when there was large-scale predation of the caterpillar by the pentatomid bug, *Eocanthecona furcellata.* This was published in *Journal of Bombay Natural History Society*.

When I joined Entomology Department after post graduate degree, my main assignment was to maintain cultures of parasitoids of black-headed caterpillar of coconut. I underwent training from August 29, 1962 to September 3, 1962 in mass multiplication technology of *Stomatomyia bezziana* on coconut, which was imported from Sri Lanka, at the Commonwealth Institute of Biological Control, Bangalore and Dr. V. P. Rao was the Head of the Institute.

Another significant contribution was a detailed study by my colleague Clement Peter for his Ph.D. degree under my supervision on the bioecology and parasitoids of the caterpillar *Diaphania indica* on *Coccinia*. Similarly, B. Krishnan studied the parasitoids of whiteflies for his Ph.D. programme. Establishment of Sun Agro Biosystem Pvt. Ltd. and Sun Agro Biotech Research Centre, Chennai was another milestone in commercialization and R&D of biocontrol agents.

KS: What is your vision in the field of taxonomy and other applied research areas?

BVD: My vision is to motivate many young scientists in insect taxonomy. It is essential that the Government of India as well as ICAR ensures further development of laboratories for identification and training of persons in insect taxonomy in the country. Zoological Survey of India, Forest Research Institute, Dehra Dun, Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi and ICAR-National Bureau of Agricultural Insect Resources (NBAIR) must be upgraded with taxonomic wings. As regards applied research, insect physiology, ethology and ecology needs more attention and ICAR and SAU institutes enhance their capabilities by advanced training and encouraging them to focus their research without disturbing them by frequent transfers.

KS: Your book, 'Elements of Economic Entomology' is considered as Bible among Entomologists, can you please narrate the inspiration behind the work

BVD: When I was appointed as Assistant Lecturer in Entomology, AC&RI, Coimbatore, we used to attend the practical classes at 6.30 a.m. and the Lecturers used to assemble the students and conduct the theory class for an hour and disperse for search of pests in the crop. The students were without any reference for study and this prompted me to prepare notes as per syllabus, cyclostyle and provide copies to students since 1964. Subsequently printed copies were made available. In 1975, Mr. Munuswami of Popular depot approached me and he took up publication of the book, "Elements of Economic Entomology" in 1975 co-authored with Dr. T. Kumaraswami. The 8^{th} edition was co-authored with Dr V. V. Ramamurthy Ex. Professor of Entomology, IARI, New Delhi and published in 2016. The book has been a great source of inspiration as it gets updated in tune with latest developments in Applied Entomology.

KS: What are the challenges faced in your professional life?

BVD: Evaluation of aerial spray programmes when I was with AC&RI, Coimbatore in Pollachi for control of red hairy caterpillar infesting groundnut during May 1961, and when with pesticide industry, for evaluation of toxaphene, and dimethoate and combinations against cotton pests in Malaipaatti, near Kovilpatti during 1968-1969; evaluation of aerial spray of phosalone (Zolone) during November-December 1976 at Telav, Bharuch, Gujarat on cotton in collaboration with Navsari Agricultural College and Haffkine Institute, Bombay.

As Director of the Fredrick Institute of Plant Protection and Toxicology (FIPPAT), Padappai, Tamil Nadu during 1981-87 organized and established various unique biological disciplines and undertook safety evaluation of pesticides of Indian and multinational companies, a unique venture in the country as such facilities were not readily available. As a result, many pesticides were introduced and registered by the Government of India and crops were protected from dreaded pests contributing to national economy. I was responsible for introduction of many new molecules of Japanese companies after my visit to Japan, Dow Chemical and Duphar.

The most challenging assignment was Director of Jai Research Foundation. Organized and established unique research facilities such as agricultural science disciplines (Entomology & Nematology, Plant Pathology and weed science), chemistry and toxicology. Secured a soft loan of Rs. 8.4 crores on 1% interest from ICICI, Mumbai to establish GLP facility. The international certification for **Good Laboratory Practice (GLP)** for chemistry (product chemistry including physico-chemical properties and characterization including impurities identification and quantification), toxicology (acute, sub chronic, chronic, and reproductive toxicology), and ecotoxicology (aquatic as well as terrestrial) by the GLP monitoring authority of the Ministry of Health, Welfare & Sports of the Netherlands, was obtained in a record time of 18 months, **an unique achievement**. This has helped the Indian agrochemical companies and multinationals from abroad to utilize the facilities to generate safety data for international registration of their molecules and thus paved way for export of indigenously manufactured products to other countries and earned foreign exchange. Further Indian companies were thus able to compete with multinationals, in addition to providing scientific career and job opportunities to many.

KS: You are the legendary in Entomological research, can you please narrate the most satisfying moments in your long career

BVD: The most satisfying accomplishments in my long career have been: Discovery of whitefly species of subfamily Aleurodicinae in India, description of around 250 new species, a few genera and a book on **Handbook of Whiteflies** (Aleyrodidae: Hemiptera : Insecta) which is in press now; Development of Fredrick Institute of Plant Protection and Toxicology, Padappai and Jai Research Foundation, Valvada, Gujarat to international stature; Establishing, creating infrastructure, training and getting certified for compliance to GLP of Rotam Research Laboratry, Kunshan, China (first laboratory to be GLP accredited in China); ICAR provided me an opportunity to be a member of QRT team for evaluating Tuber crops research institutes during 1995 and RAC of ICAR-NBAIR, Bengaluru during 2010-2013 and ICAR-NRRI, Cuttack during 2014-2017. And serving as President for Applied Zoologists Research Association (AZRA), Bhubaneshwar since 1994.

Participation and presentation of papers in international meetings given below are very interesting:

1. I met Wang in May 2012 in China who has been working on whitefly taxonomy and at the request of Prof. Dr. DU Yu-Zhou, Institute of Applied Entomology & College of Horticulture and Plant Protection, Yangzhou University, Yangzhou. Visited the University on 26thJuly 2012 and delivered two lectures: The Whiteflies (Aleyrodidae: Hemiptera: Insecta): Biosystematics and Pest Species Diversity, and Plant Protection Products: Present Status and Future trend in India.
2. Delivered an invited lecture on “Crop Protection Products in India - The Present and Future Trends” in the IUPAC Sponsored “2nd International Conference on Agrochemicals Protecting Crops, natural environment – Role of Chemistry for sustainable agriculture” held at Delhi on 16th February 2012 and chaired a session on 18th February 2012 at IARI, New Delhi.
3. Presented a paper on “GLP National status and facilities in India for Pesticide Product Registration” at the 5th Chemical Congress of North America, Cancun, Mexico, 14th November, 1997.
4. Presented a paper on “Challenges of implementing GLPs in India” in the 12th International Congress of the International Society of Quality Assurance at Yokohama in Japan, 11th June 1996.
5. Presented a paper on “Future trends in Herbicides usage in India” in the International conference Organized by the Agricultural University, Peradeniya, in May, 1995.
6. Presented a paper on “Sedimentation of Pesticide Residues in the Ecosystem in India” by participation in the poster session of the International Conference of Pesticide Chemistry (IUPAC) held in Washington in July, 1994.

7. Presented a paper on “Pesticide Industry and R & D activities” in the Annual conference of American Chemical Society, New York, 1991.
8. Presented a paper on “*Vitex negundo*, a promising botanical pesticide” organized by East-West Centre, Hawaii at the Agricultural University, Peradeniya in Sri Lanka in 1986.

KS: What is that you look for in young researchers and your advice to them please

BVD: Passion for the area chosen, in depth analysis for improvement, commitment, devotion and hard work. Develop scientific, administrative and leadership qualities.

KS: There are lot of awards and recognitions instituted by you for the cause of science and encouragement to the researchers, can you narrate them please.

BVD: A few of my colleagues insisting me to start a contract research laboratory and I was not interested. Then being Chairman of Prof T. N. Anathakrishnan Foundation I thought of establishing Dr B. Vasantharaj David Foundation which was registered as a Trust and inaugurated on 17th November 2019. The foundation has instituted various awards so far to promote science. Last year notably the foundation instituted three memorial awards *viz.*, T. B. Fletcher Memorial award (Applied entomology), Rao Bahadur Y. Ramaachandra Rao (Ethology, Ecology, Physiology) and Rao Sahib Dr T. V. Ramakrishna Ayyar (Insect and mite Taxonomy) awards.

KS: Can we get an insight into your other activities beyond research and the most favourite activity/stress bursters

BVD: My continued support to AZRA in its activities and conducting annual conferences of Dr B. Vasantharaj David Foundation as long as I am able to do. Presently, engaged in a book project on Agricultural Biotechnology.

KS: Your views on the initiative taken by ‘Indian Entomologist’ magazine and suggestions for improvement

BVD: Running a journal is very difficult. I had bitter experience with Hexapoda. Since publication of Indian Entomologist is part of the activities of Entomological Society of India, its continuance is assured forever. Strive for improving the quality of papers published in the magazine. Ensure timely publication. Avoid notes on pesticides and biopesticides evaluation reports and non-validated IPM recommendations/ suggestions. The editorial board team must be committed to keep up the standard of the journal.

The interview is conducted by Dr. Kolla Sreedevi. She is working as Pr. Scientist at Division of Germplasm Collection and Characterisation, ICAR- NBAIR, Bengaluru. She is working in the field of Insect Biodiversity and Systematics especially Coleoptera; Insect Ecology, biogeography and molecular characteri-sation. She is also an Associate Editor of IE.
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A bizarre Pentatomid, *Phricodus hystrix* (Germer, 1838) (Hemiptera: Pentatomidae) on *Ocimum* spp.

Salini S., Rabbani M. K., Gracy R. G., David K. J. and Sachin K

Abstract: *Phricodus hystrix* (Germer, 1838), a bizarre looking Pentatomid, was found feeding on seeds of various species of Tulsi plants such as *Ocimum tenuiflorum* L. and *Ocimum gratissimum* L. The species is redescribed based on male and female genitalia, which were illustrated along with life cycle of the bug for the first time.

Key words: Parandria, sesamum, samiaceae, pedaliaceae

Phricodus hystrix (Germer, 1838) is a rare pentatomid bug possessing the four segmented antennae unlike the usual five segmented state found in other members of Pentatomidae. Germar (1838) originally described *P. hystrix* from Cape of Good Hope, South Africa. This species is distributed in Saudi Arabia, Yemen, Africa, India, Mauritius and Seychelles (Rider, 2006). Cachan (1952) redescribed this species based on specimens from Madagascar and later, Linnavuori (1975) redescribed *P. hystrix* as a variable species with respect to the length and thickness of antennal segments, denticulation on lateral margins of pronotum as well as the shape of lateral angles of parandria (=paratergites) based on materials collected from an unidentified plant belonging to Lamiaceae.

Distant (1918) recorded *P. hystrix* for the first time from Coimbatore, Tamil Nadu, India while examining the specimens sent to him by Mr. T. B. Fletcher, who collected those from Coimbatore on Sesame plants (*Sesamum indicum* L., F. Pedaliaceae) as well as at light. This is the only species known from India for the genus *Phricodus* Spinola, 1839. This species was recorded from Bangalore, Karnataka for the first time by Salini and Viraktamath (2015). Recently, *P. hystrix* was recorded as a pod feeder of Sesame by Dilipsundar *et al.* (2019) in their checklist of insect pests of Sesame. In this paper, *P. hystrix* was found feeding on seeds of various species of Tulsi plants such as *Ocimum tenuiflorum* L. and *Ocimum gratissimum* L. (Family: Lamiaceae). Besides, the male and female genitalia of this species is illustrated for the first time. DNA barcode sequence of *P. hystrix* is obtained and reported.

Material and Methods

The bugs were collected by sweep net and hand collection from various species of Tulsi plants at NBAIR Attur farm, Yelahanka, Bengaluru during May, 2020. Collected bugs (nearly 55 specimens) were killed using ethyl acetate and were later brought to laboratory for processing. The separated bugs were mounted singly on triangular card points on the right side of the thorax by using Fevicol® to facilitate identification. The procedure to dissect the male and female genitalia was detailed by Salini (2016) was followed. Dissections were done using Leica S8 APO. Photographs were made using Leica DFC 420 camera mounted on a Leica M205A sterozoom microscope and by using the software Automontage® (LAS). Photographs were edited using Adobe Photoshop CS (Version 8.0). The field images were taken using Canon EOS 77D DSLR camera. Terminology of general morphology, male and female genitalia follows Tsai *et al*. (2011), egg structure follows Matesco *et al.* (2014) and those associated with metathoracic scent glands follow Kment & Vilímová (2010). The procedure for DNA extraction and partial gene sequencing of COI follows David *et al*. (2020).

Specimens studied for this research work are deposited in the Indian Council of Agricultural Research- National Bureau of Agricultural Insect Resources (ICAR-NBAIR), Bangalore, Karnataka, India.

Taxonomy

Tribe: Phricodini Cachan, 1952

***Phricodus* Spinola, 1839**

Phricodus Spinola, 1839: 331

Stenotoma (Westwood, 1846): 284 (Synonymised by Signoret, 1849: 327. Type species by monotypy: *Stenotoma desjardinsii* Westwood, 1846 (= *Aradus hystrix* Germar, 1838).

Type species: *Phricodus hystrix* (Germar, 1837) by monotypy.

Diagnosis. Brownish bugs with white peg-like structure uniformly covered all over the body except antennomere I and membrane. Head acuminated apically with a pair of long, acute spinous process in front of compound eyes; base of ocelli partially concealed by anterior pronotal margin. Antennae four segmented with segment I slightly shorter than acute apex of mandibular plates; first antennal segment stout, heavy, pivoted on narrow cylindrical pedicel. Antenniferous tubercle modified into elongate processes. Bucculae slightly longer than the labiomere I, with anterior apex rounded, lacking tooth. Anterolateral margins concave at middle, explanate, slightly reflexed with spinous process; humeri modified into triangular spinous process. Genital capsule almost triangular with ventral side possessing one pair of parandria; paramere minute, club-shaped; phallus with phallotheca moderately sclerotized and constricted towards distal end; dorsoapical emargination of apical part of phallotheca modified into cup-like expansion, encompassing endosoma; valvifers VIII roughly rectangular, with inner lateral margins almost straight; laterotergites IX short not reaching apex of abdomen; spermatheca externally fluted to form a single bulb-like dilation; apical receptacle elongate oval without ductules.

Remarks. Members of this genus possess four segmented antennae. The antenniferous tubercles, lateral margins of head and pronotum modified into long spines.

Göllner-Scheiding (1999) discussed the systematic position of the genus *Phricodus* Spinola and proposed the tribe Phricodini for the genus *Phricodus*. This genus is represented by the lone species, *P. hystrix* (Germer) from India.

Phricodus hystrix **(Germar, 1838) (Figs. 1–31)**

Aradus hystrix Germar, 1838: 134.

Stenotoma desjardinsii Westwood, 1846: 285 (Synonymized by Stål, 1865: 92)

Phricodus fasciatus Signoret, 1861 (Synonymized by Stål, 1865: 92). Lectotype designation by Göllner-Scheiding, 1999: 154).

Phricodus ornatus Villiers, 1952: 1206 (Synonymized by Roche, 1977: 570

Phricodus incisiforceps Linnavuori, 1975: 22 (Synonymized by Göllner-Scheiding, 1999: 154)

Colouration. Brownish coloured with white patches on pronotum, scutellum and hemelytra (Fig. 1). Head disc ochraceous, paler towards outline including spinous process. Antennae brown except pedicel of segment III and IV, small, narrow ring-like mark at anterior apex of segment II, III and IV, black. Pronotal disc brownish, posterior pronotal disc with mosaics of pale white areas and anterolateral margins including humeri pale white. Scutellum with basal gibbous triangular region dark brown, apical 1/3rd and lateral margins pale white. Hemelytra with proximal 2/3rd pale white; membrane whitish with mosaics of dark brown to black markings. Connexivum with alternate bands of pale white and brown.

Ventral side ochraceous with numerous brownish or black small spots scattered uniformly on all ventrites; labium with labiomere III & IV, black. Outline of spiracle and trichobothria black. Legs concolourous to ventral side, apical half of claws black.

Body pilose; whole body including antennomere I, compound eyes and legs, (except antennomeres II–IV and membrane) covered with short, stout white peg-like structure; short, black tubercle-like structure possessing short erect spines, scattered over pronotum, scutellum and hemelytra. Antennae hirsute with nearly erect and moderately elongate setae sparsely distributed on antennomeres II–IV; labium and tibiae and tarsi of all legs covered with short, dense pale setae.

Redescription

Structure. *Head:* (Figs. 7–9) flat dorsally, not declivous, apex and lateral margins reflexed; apex of mandibular plates modified into elongate, acuminate processes (ap), much longer than clypeus, not meeting in front of clypeus, lateral margins of mandibular plates with a pair of long acute processes in front of compound eyes. Apex of mandibular plates on ventral side, provided with additional elongate ridge-like and apically acuminate sclerite (aas), in front of bucculae, enclosing apex of clypeus; ventral ridge like sclerite shorter than apex of mandibular plates. Ocelli situated wide apart at base of head; in dorsal view, the base of ocelli partially concealed by anterior pronotal margin. Antennae four segmented, with segment I slightly shorter than acute apex of mandibular plates, distinctly surpassing apex of clypeus; first antennal segment stout, heavy, pivoted on narrow cylindrical pedicel; segment II longest, proximal 3/4th narrow and thin, gradually swollen towards apex; III longer than IV; each segment III and IV with short, cylindrical pedicel to attach with preceding segments and provided with narrow, indistinct, longitudinal groove both on dorsal and on ventral side; Antenniferous tubercle (at) modified into elongate processes, proximal half of antenniferous tubercle broad and distal half abruptly narrowed towards apex as acuminate processes, but shorter than apex of mandibular plates. Bucculae slightly longer than the labiomere I, with anterior apex rounded, lacking tooth. Labium reaching hind coxae.

Pronotum: Anterolateral margin concave at middle, explanate, slightly reflexed with spinous process; spines adjacent to anterolateral angles longest; posterior and posterolateral margins straight; humeri modified into triangular spinous process. Pronotal disc transversely impressed in anterior half.

Scutellum: Longer than broad at base, 1/3 rd apex narrowed abruptly, scutellar apex obtuse; disc of scutellum basally modified into elevated inverted triangle and continued as a central ridge-like carina to apex.

Hemelytra: Distal 1/3rd of lateral margins of hemelytra explanate, membrane reaching apex of abdomen.

Thoracic pleuron and sternum: Mesosternum with faint, central, longitudinal carina. External scent efferent system with peritreme (p) spout-shaped, reaching mid metapleuron (Fig. 10). Evaporatorium developed as roughly rectangular patch on metapleuron and as short, transverse stripe on mesopleuron, above metathoracic spircle. Metathoracic spiracle long and well developed.

Legs: Femora unarmed, dorsal surface of tibiae with central, longitudinal groove; inner angles of fore tibial apex with stout angulate process possessing short, acute spine; inner lateral margins of foretibial apex with a row of comb-like short setae. All tarsi with segment II shortest, III nearly as long as I.

Pregenital abdomen: Connexivum well exposed and explanate; ventrites smooth, devoid of groove or ridge; posterolateral angles of ventrites III–VII explanate and obtusely angulate.

Male genitalia (Figs. 14–21): *Genital capsule:* Almost quadrangular, dorsal rim of genital capsule provided with hood-like convex central emargination occupying most of its margin (Fig. 14); ventral side with a pair of parandria (a pair of expansions of external wall of genital capsule in lateroventral position), parandria (pr) triangular in cross section, as long as or slightly longer than central length of genital capsule (Figs. 14–15), gradually narrowed towards distal end, outer angles of each parandrium ends in acute tooth-like structure at distal end, directed laterad, inner angles rounded. Proximal end of each parandrium with small angulation on inner margin and a bulbous projection on outer margin. Ventral rim concave. *Paramere*: Minute, club-shaped with narrow stem (Figs. 16–17). Articulatory apparatus: elongate, oval capitate processes (cp) attached to trapezoidal plate by a short and narrow dorsal connective. *Phallus:* Dorsoapical emargination (de) of apical part of phallotheca pale and cup-like, encompassing endosoma in inflated form (Fig. 21); 2 pairs of conjunctival process, ventral pair fused into one membranous, pale, moderately sclerotized broad structure, apically truncate with V-shaped notch ventrally; dorsal pair fused medially leaving U-shaped notch on dorsal surface; aedeagus slightly sclerotized, narrow, tubular.

Female genitalia (Figs. 11–13). *Terminalia:* Valvifers VIII (vlf VIII) roughly rectangular, with inner lateral margins almost straight (Fig. 12); posterior margin straight, inner posterior angles angulate; valvifers IX (vlf IX) fused to single plate, with anterior margin slightly concave; antero-lateral angles elongate and strap-like produced laterad; laterotergites IX (lt IX) broader anteriorly and narrowed towards posterior end with rounded apex, short not reaching apex of abdomen, outer lateral margins convex; laterotergite VIII (lt VIII) roughly quadrangular, caudal margin of laterotergites VIII angulate at middle (Fig. 12). *Spermatheca:* Externally fluted to single bulb-like dilation (Fig.13), external wall smooth; proximal and distal spermathecal duct, narrow, tubular; proximal flange one third in diameter of distal flange; apical receptacle elongate oval without any processes.

DNA barcode. GenBank accession number MZ540897 (1♂, INDIA: Karnataka, Attur, Yelahanka, 08.v.2020, N 13° 5' 37.4568", E 77° 33' 38.7252", Rabbani, M. K.)

Bionomy

The adults lay the eggs on seeds or on glumes of the mature floret in 2-3 numbers/floret (Figs. 25–27). Eggs are barrel-shaped with a round, convex operculum (Fig. 28). The aero-micropylar processes (amp) are circularly arranged in a row around the anterior pole, white, short, and clubbed (Figs. 28–29). The freshly laid eggs are creamy in colour (Fig. 28) and later, changed to pink or light purple colour before hatching (Fig. 29). The first instar nymphs are red in colour, resembling red velvet mite (Trombididae) in colour and appearance (Figs. 5–6). Posterolateral angles of abdominal sternites with spine-like projection in nymphs towards later stage (Figs. 3–4). Legs and antennae of nymphs provided with profuse white setae and body with sparse setae. Nymphs and adults suck the sap from the seeds (Figs. 30–31) and the affect the germinability of seeds. The infestation of these bugs were found usually during the later stage of the crop. This might be because of the seed feeding behaviour of the species.

Remarks. These are medium sized bugs (5.00 to 6.70 mm body length). This is the first record that this species is feeding on various species of *Ocimum* (Tulsi) plants (Figs. 22–24). Previously, it was recorded as a pod feeder of Sesamum. Very remarkable species with white peg-like, short and stout structures covering all over the body, which gives a powdery coated appearance to the specimens.

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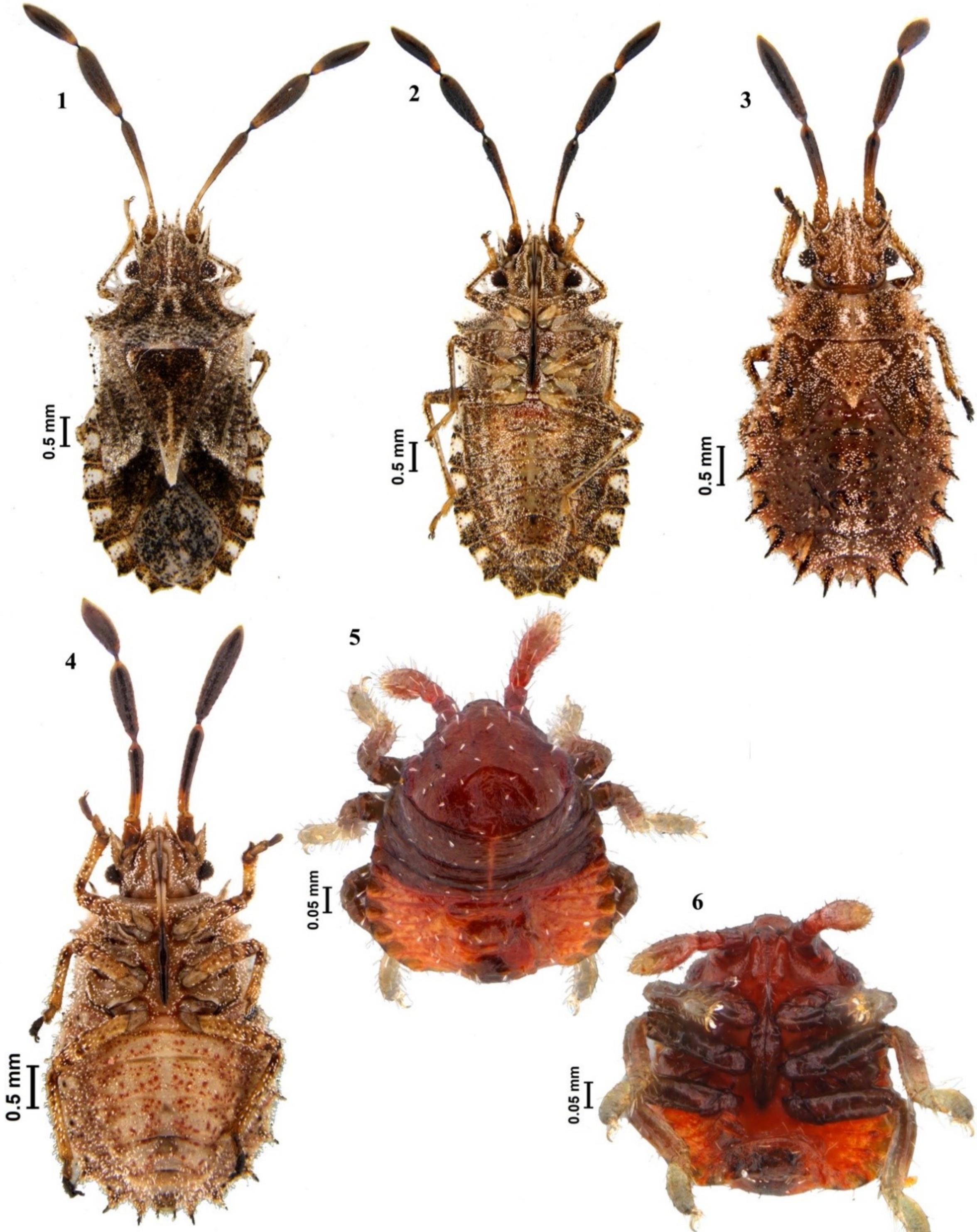
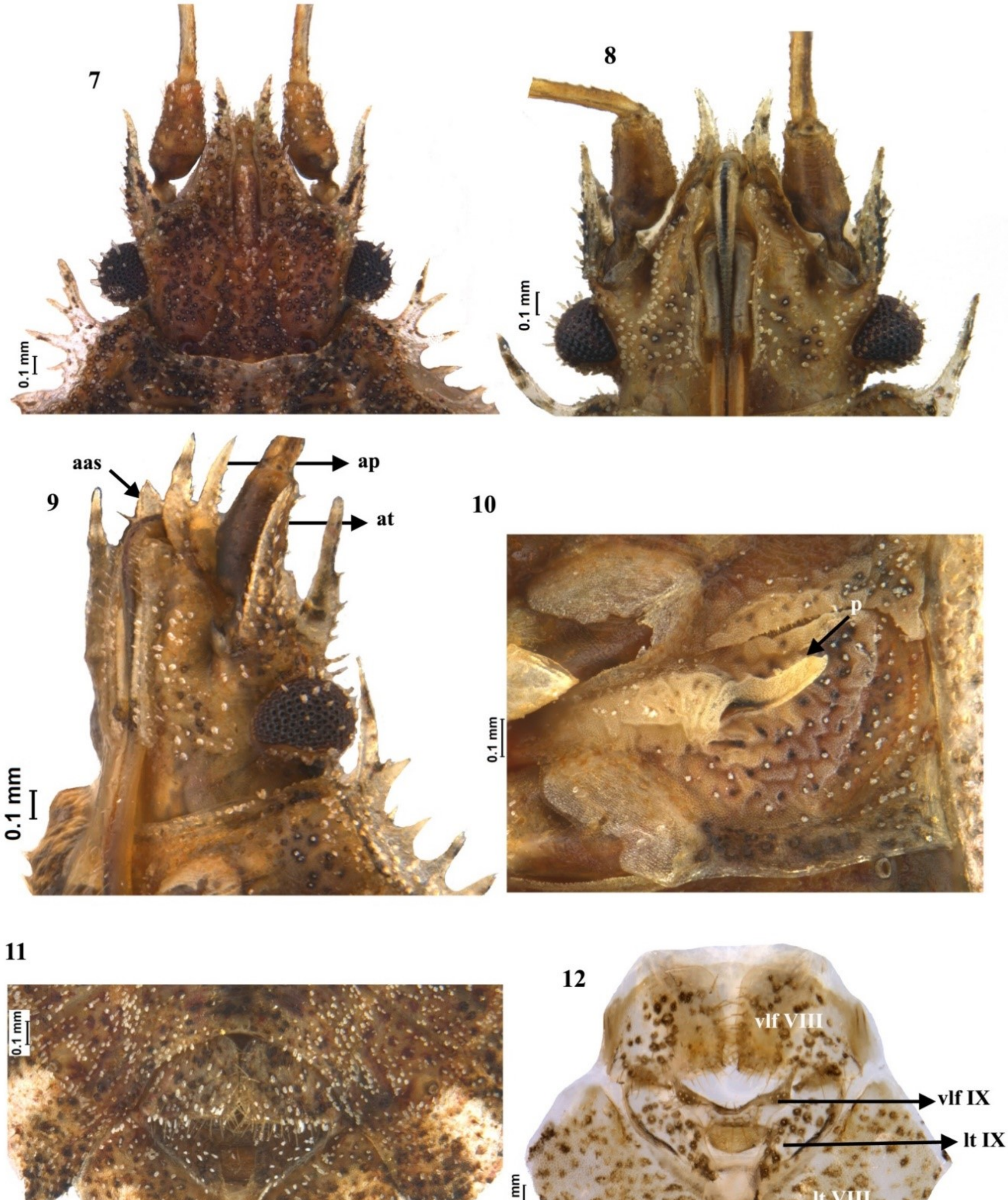


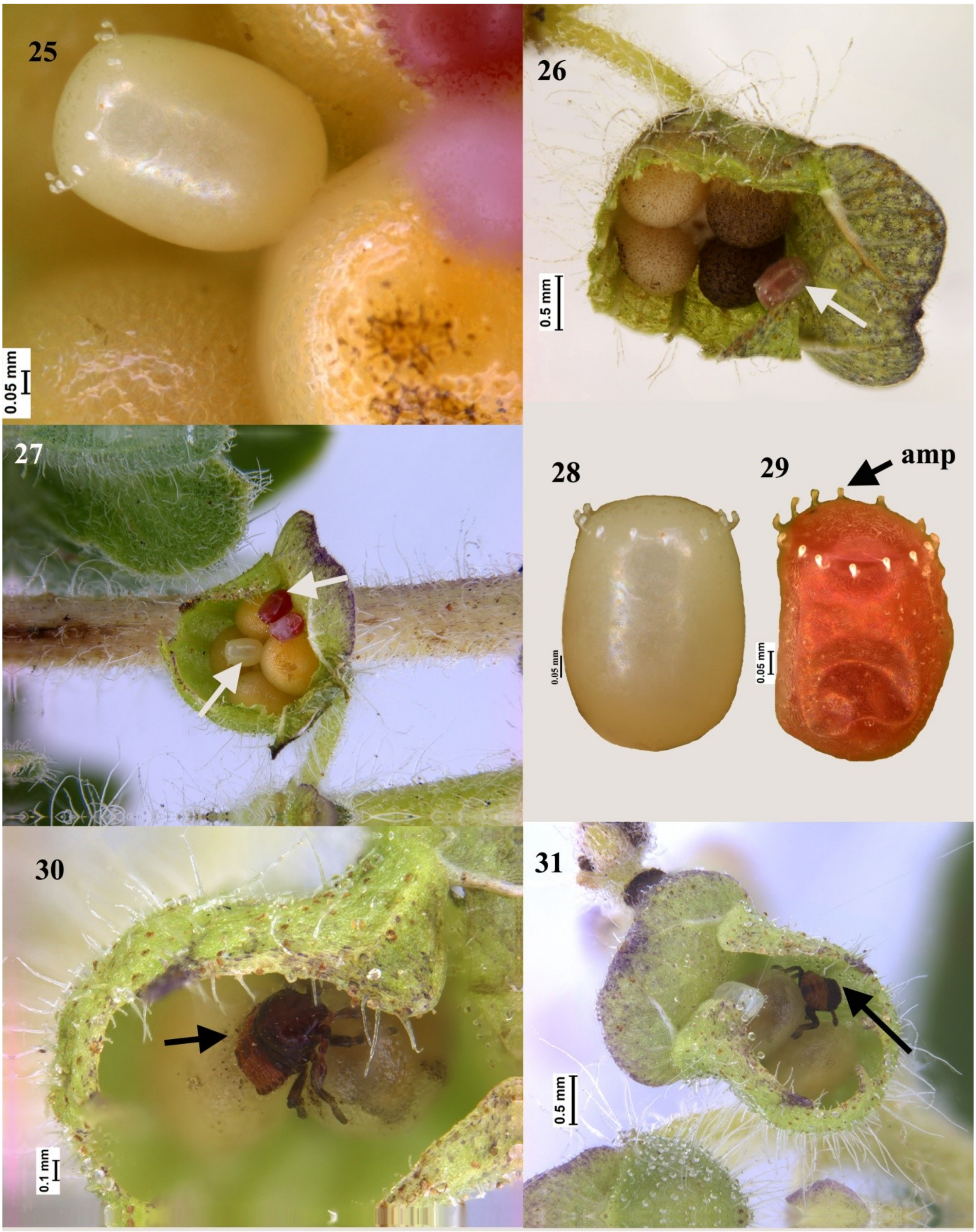
Figs. 1-6 *Phricodus hystrix* (Germer). 1, adult (doral); 2, adult (ventral); 3, later stage instar (dorsal); 4, later stage instar (ventral); 5, first instar (dorsal); 6, first instar (ventral).



Figs. 7-12. *P. hystrix* (Germer). 7, head (dorsal); 8, head (ventral); 9, head (lateral); 10, external scent efferent system; 11, female terminalia before dissection; 12, female terminalia after dissection. Lettering. p- peritreme; ap- acuminte process; at- antenniferous tubercle; aas- apically acuminate sclerite; lt VIII- laterotergite VIII; lt IX- laterotergite IX; vlf VIII- valvifers VIII; vlf IX- valvifers IX.

Figs. 13-21. *P. hystrix* (Germer). 13, spermatheca; 14, genital capsule (dorsal); 15, genital capsule (ventral); 16-17, paramere (differenet planes); 18, articulatory apparatus; 19, phallus (dorsal); 20, phallus (ventral); 21, phallus (lateral). Lettering. ar- apical receptacle; cp-capitate processes; de- dorsoapical emargination of phallotheca; pc-parameral crown; pr- parandria.

Figs. 22-24. Host plant-*Ocimum* spp. 22-23, *Ocimum gratissimum* L. 24, *Ocimum tenuiflorum* L.



Figs. 25-31. ***P. hystrix*** **(Germer)- bionomics. 25, freshly laid egg on Ocimum seeds; 26-27, Ocimum floret showing eggs; 28, freshly laid egg; 29, egg just before hatching; 30-31, first instar nymph feeding on Ocimum seeds. Lettering. amp- aero-micropylar processes.**

Blister beetle triungulins on carpenter bee at Gir National Park, Gujarat, India

Anuj D. Raina, Akshay Chauhan and Dhaval Shukal

During one of our Nature camps (Batheshwar camp) on 4th Feb 2019 at Gir National Park, we observed and photographed a Carpenter bee (*Xylocopa latipes*) with a parasite hitchhiking the host bee. The phenomenon of phoresy was recorded at location 21°01'14.3"N 70°46'28.2"E during 8:80 am, the site adjoining Singodha Dam. The note reports the first record of the host-parasite relationship between the Carpenter bee and Blister beetle from Gir National Park, Gujarat, India.

Carpenter bees belonging to the genus Xylocopa, include 500 species under 31 subgenera (Minckley, 1998), among which 29 species were found in India (Ascher and Pickering, 2016). Carpenter bees, in comparison to honey bees, are more versatile agriculture pollinators due to their capability to buzz pollinate, high thermoregulation abilities, and crepuscular and nocturnal habits. (Heinrich and Buchmann, 1986; Keaser, 2010). Many natural flora and agricultural crops benefit from the pollination of Xylocopa species. (Gerling *et al.* 1989; Raju and Rao, 2006; Keasar, 2010).

Amongst Arthropods phoresy is common, where one organism with limited mobility and in hostile habitat is effectively transported by another organism (Saul and Millar, 2006). The first-instar larvae of the beetle or triungulin use the complex survival mechanism of Phoresy, culminating in the transportation of parasites to the host nest (Saul and Millar, 2006). Hafernik and Saul-Gershenz (2000) first reported the Carpenter bee and Blister beetle-triungulin host-parasitic relationship, where the larval aggregations of blister beetle parasitize the bee. The larval form of blister beetle also called Triungulins (tri-ungulae or 3 claws) have adapted claws to grasp the host such as *Xylocopa* sp. The triungulins aggregate and hold vegetation while simultaneously exploiting the sexual communication system or chemosensory signals of bees by mimicking the sex pheromones of female bees. The luring male bees are attracted by the aggregations of triungulins, and upon contact (pseudocopulation) the triungulins attach to the male bees (Phoresis). Transfer from male to female occur during real mating, which is then subsequently carried away to nest by females. The Xylocopa sp. make tunnels for nesting in solid wood, stumps, logs, or dead branches of trees (Raju and Rao, 2006). The triungulins then consume grubs and pupae of host species.

Only a single bee was observed from the site. As per the direct observation, we were able to see the pale yellowish color, long smooth brush-like hairs, and light color on legs, confirming its sex as male. Through photographs, one can count more than 70 triungulin parasites. The bee was observed dull and uncomfortable compared to its usual active phase. The carrying capacity of the host is important for its survival and

Fig. 1 Snapshots of carpenter bee (*Xylocopa latipes*) parasitized by blister beetle triungulins

parasite survival (Sathe and Margaj, 2001; Vinson, 1976). Suitable parasitic load is an essential factor for the successful transportation of triungulins (Gophane *et al.* 2015). By parasitizing *Xylocopa* sp., triungulins acts as a limiting factor for pollination services (Saul and Millar, 2006).

Many species of the family Apidae which have been reported with host-parasite relation. Further studies and observation are required to understand the intricacies of host-parasite relation and the impact it creates on the ecosystem.

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Occurrence of *Bagrada hilaris* (Burmeister) (Heteroptera: Pentatomidae) on *Parthenium hysterophorus* from India

M. Kaur and V. Kumar

Parthenium hysterophorus L. (Asteraceace: Heliantheae), commonly known as parthenium, white top, congress grass, feverfew or carrot weed, is one of the worst weeds, threatening natural ecosystems and agro ecosystems in over 30 countries worldwide (Adkins & Shabbir 2014). Parthenium has proved a challenge and the conventional means of its control have literally failed due to their innate drawbacks (Aggarwal *et al.* 2014). Many chemical pesticides used for its control have been or being phased out because of potential human health risks, environmental pollution, effects on non-target organisms and the development of pest resistance, (Kaur *et al.* 2014). Still efforts are being made to control this weed by all possible means. As a part of survey conducted during 2012-2015 in the Haryana state (India), a whitish black insect with orange spots was regularly found to be feeding on young as well as mature plants of parthenium, in different parts of the Kurukshetra district of Haryana. The insect was later identified as *Bagrada hilaris* (Burmeister), formerly known as *Bagrada cruciferarum* Kirkaldy or *Bagrada picta* (F.) (Hemiptera: Pentatomidae), is native to Africa, India, and Asia (Howard 1906) and it is known by various names,

Fig.1. a-b) Adult bagrada bug feeding on seeds of parthenium weed; c-d) Foliage feeding by bagrada bug of parthenium weed

including bagrada bug, painted bug. The insect was observed feeding on flowers, leaves and stem of parthenium plant (Fig. 1). *B. hilaris* prefers wild and cultivated mustards and it has been also reported on a wide range of hosts belonging itto various plant families. These includes barley, oats, wheat, artichokes, beetroot, carrot, lettuce, peas (Daiber 1992), rice and sugarcane, and coffee (Rajpoot *et al.* 1996). Among 260 phytophagous arthropods species reported from Parthenium from its native homeland, 144 species actually fed on the weed (McClay *et al.*1995). As per the existing literature scan and to the best of our knowledge, *B. hilaris* reported for the first time on *P. hysterophorus.*

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WOMEN IN ENTOMOLOGY

In conversation with Dr. Mayabini Jena

Simple women yet vibrant, who worked on simple things now making a big difference and setting a unique legacy in crop protection of rice. She shares her journey to IE associate editor Dr. Bhagyashree.

Dr. Mrs. Mayabini Jena hails from Balasore, Odisha, has nearly 4 decades of dedicated research experience in Rice, presently working as an ICAR-Emeritus Scientist at National Rice Research Institute (NRRI), Cuttack and she superannuated as Head, Crop Protection Division, NRRI, Cuttack on 2018 with more than 200 publications and worked in more than 17 externally funded projects of national and international importance as PI and Co-PI with high scientific output.

Dr. Jena worked on persistent toxicity of more than 50 insecticides against brown planthopper and other insect pests of paddy *viz.*, yellow stem borer, gall midge, leaf folder, case worm, swarming caterpillar or cutworm; Residual toxicity of selected insecticides on rice plant was correlated with insect mortality for quantification, particularly in rice–fish ecosystem. She started working on Botanicals from 1988, evaluated the neem (oil, seed, leaf, bark) and about 19 neem-based chemicals against BPH and other rice pests. Validated efficacy of ITK-based botanicals such as *Cleistanthus collinus*, *Sachharum spontaneum*, *Strychnos nuxvomica*, *Polygonum hydropiper*, *Calotropis gigantia*, *Pongamia pinnata*, *Madhuca longifolia*, *Vitex nigundo* etc against rice insect pests.

She also worked on on-station Package development and on-farm validation of IPM on scented rice, Irrigated rice, Rain-fed shallow favourable lowland, Bio-intensive IPM with emphasis on botanicals. Integrated management of BPH along with other pests was also demonstrated successfully in farmers' participatory seed production programme at a large scale in farmers field from 2013 to 2017, till their full acceptance. She studied effect of weather parameters on the occurrence and severity of rice pests through proper surveillance, both at on-station and on-farm condition to know the shift of population, if any. Factors leading to brown planthopper resurgence were studied in detail. Contributed to the development of an alternate energy light trap which got patent during 2021.

Work on host plant resistance was Started during 2000 against BPH. Screened about 5000 rice genotypes against BPH and about 100 highly resistant donors have been identified. Two donors, purified Salkathi and Dhoba numberi are registered under NBPGR, New Delhi and are actively used in rice breeding programme. The resistant gene/QTLs have already been identified from these two donors by different teams. Highly resistant and high yielding breeding lines, CR 2711-76 and 3006-8-2 are also identified which were evolved from the donors and stood unaffected in BPH endemic areas of Odisha. Similarly, varietal screening was conducted with traditional rice varieties against gall midge and YSB to identify multiple resistant traits. She contributed to the development of six NRRI rice varieties - CR Dhan 503, CR Sugandha Dhan 907, CR Basana Dhan 902, Nua Kalajeera, Nua Dhusura and Nua chinikamini.

She enjoyed training farmers on new technologies and imparted training on "rice pest management with emphasis on botanicals/biointensive IPM" to rice farmers of Odisha, Bihar, Madhya Pradesh, Gujrat, West Bengal, Jharkhand, Meghalaya, assam, Tamil Nadu. Training was also imparted through Trainers' training programme to agricultural officials of Odisha, Maharashtra, Kerala. She also recognised by contributing to the rice mobile App, the 'riceXpert' for rice farmers which is available in English (2016) and Odia (2017).

Even with the dedicated research for nearly 40 decades, she never showcased herself by applying to awards and recognitions; she kept her life simple with immense dedication only to research. Still her institute recognised her as best worker by Best worker Award, NRRI- Principal Scientist category – 2013 and CROPSAP, Govt. of Maharashtra recognised with **Prime Minister's Award** with gold medal in e-governance category by GOI during 2016-17.

Dr. BSN (Bhagyashree S.N.): Dear madam, thank you for accepting our consent and speaking to "Indian Entomologists" we are really happy to interact with you. Can you please tell me what made you to pursue career in entomology and how did you choose working especially on Rice crop protection?

Dr. MBJ (Dr. Mayabini Jena): My M.Sc. was from the pure science stream of subject Zoology with special paper Entomology at Utkal University, Vani Vihar, Bhubaneswar, Odisha. The dissertation work on a small research topic, "Life cycle of the aphid, *Aphis nerii* on local *Calotropis gigantea*" under the guidance of renowned professor, late Dr. B.K. Behura and Prof. Ms. Kalyani Bohidar aroused my interest in research. After M.Sc., I was selected for ICAR research scholarship at the National Rice Research Institute, Cuttack (Former Central Rice Research Institute) where I joined during November 1979 and my Ph.D. work on rice started under the able guidance of Dr. I. C. Pasalu, the then Sr. Scientist of CRRI. The Institute gave me the opportunity to know different facets of rice research and also of insect pest management options in Rice crop. My Ph.D. topic was on toxicological aspects of insecticides, "Toxicity of selected insecticides against rice insect pests in relation to their persistence and residues." I joined as an ARS scientist at the same Institute on 31st January, 1985 and I continued the subject, not by choice but by the decision of the Divisional SRC for the necessity of farmers. And I adhered to it because I had experience in working with pesticides, both at controlled and field condition.

Dr. BSN: How would you like to see rice pest management science in future? What are the management practices which you wish to remove and incorporate?

Dr. MBJ: The science of rice pest management is very important to reduce the future loss of the crop since it holds the key to food security in a global perspective. But, *"Interest in research and hard work is the main trait or attitude to be a successful scientist, both for men and women"*

at the same time, it is very delicate because it is the staple food for a major population. Therefore, human safety should be of greater emphasis in future pest management strategy which can be attained by incorporating available non-pesticide management options such as host plant resistance, biological control, botanicals, cultural control etc. to the judicious use of insecticides leading to IPM. Though we know insecticides are the major culprit for environmental pollution and human health hazard, it is not possible to remove them from the system at present without a suitable alternative. But, absolute dependence on it for pest management can be minimised by following IPM.

Dr. BSN: What are the traits or attitude, do you think that can help women to be successful as scientist?

Dr. MBJ: Interest in research and hard work is the main trait or attitude to be a successful scientist, both for men and women. But according to my feelings, women prove better researchers if they are provided proper environment to work. Devotion to work has made me an achiever, and I have never thought it as a burden but an enjoyment. For example, I have tested more than 50 insecticides in detail in controlled as well as in field condition which was supposed to be risky. But to see their reaction on different insect pests is more satisfying than the risk. Likewise, the screening of different rice genotypes or application of botanicals or ITKs where the quest for a better one continues for the larger interest of farming community, definitely it leads to knowledge gain in practical and it never remains un-noticed by others. Farmers listen to practical solution and follow. Only you have to be patient enough to understand their problem and also to make them aware of the solution. Overall, patience, practical knowledge from research and respect to your stakeholder can make you a successful scientist.

Dr. BSN: A change you would like to see in young agricultural entomologists?

Dr. MBJ: The young agricultural entomologists should be more oriented towards field problems. Controlled condition research findings have to be validated through on farm testing. They should be in touch with rice farmers and their mode of application of technologies so that proper correction can be made for better adoption. But, before applying the technology, all the basic data must be generated on the subject for proper knowledge and implementation.

Dr. BSN: Do you think your research dimensions are narrowed down because of working in crop specific institute?

Dr. MBJ: No. Rather it has been intensified. Rice science is so vast and rice pest management itself has so many dimensions that after more than 3 decades of research, I still have the notion that many more remained unattended. One crop will provide opportunity for more in-depth study.

Dr. BSN: So many scientists worked on botanicals still it's not attaining the commercial status of what it deserves in terms of percent share in plant

protection, what may be the reason and how to overcome this?

Dr. MBJ: Whether botanicals attained a commercial status substantially or not, one cannot deny their role in pest management in a country like India. Synthetic pyrethroids and neem-based chemicals are the examples of commercial success that were evolved from the botanicals. But, when hundreds of insecticides were paving their way to market by different national and international agencies, it is difficult for one neem or a pyrethrum-based pesticide to exist commercially for a long time. Therefore, we have looked into the rich traditional history of pest management of rural and tribal India and identified many pesticidal plants along with validation of their efficacy. There is a need to identify the active ingredient/s quickly through vibrant laboratory facilities dedicated for the purpose so that botanical pesticides can be formulated within stipulated time. Again, some botanicals have behavioural changing trend for insect like wild sugarcane which attract the spiders to multiply on them and control rice case worms, leaf folders effectively. These technologies should be promoted among the farmers.

Dr. BSN: Now that rice is holding the highest share in insecticides consumption, what needs to be done to change this scenario?

Dr. MBJ: IPM is to be strengthened through knowledge based interventions, emphasizing incorporation of resistant varieties and ITK-based botanicals, the two alternatives of pesticides which are at farmers hand practically. In addition, rice trading inside the country should be monitored strictly for pesticide residues because there are rice pockets which dump pesticides to the crop irrespective of proper recommendation, dose and timing. Such pockets are to be identified and policy decisions should be taken for residue analysis in rice in these areas. Trading should be stopped on detection of pesticide residues above MRL. Lastly, awareness among the farmers should be created on negative effect of insecticides.

Dr. BSN: Since nearly 3 decades you are working in rice, do you think organic rice cultivation is possible, to reduce the chemicals residue? And do you find any difference in indigenous and hybrid rice IPM?

Dr. MBJ: Organic rice cultivation is possible, because any product with market demand, gives more benefit to the grower. The present world has recognized the immense value of human health, bonded with environment and food for which organic rice has great demand nationally and internationally. Another scenario also exists in our country particularly in tribal and many rural areas where the organic rice cultivation is continuing as such in virgin farming lands unexploited by modern agricultural technologies for their own consumption. The experienced as well as young agricultural entrepreneurs are gradually coming forward to grow organic rice in both the situations and seeking pest management advisory time to time during my Headship at NRRI, Cuttack and up till now. Definitely it will reduce chemical load once it gets full momentum. Many hybrids rice attract more pests as compared to indigenous rice. But, proper implementation of IPM should not make any difference except putting always an effective insecticide in the hybrid rice IPM for emergency action, if needed.

Dr. BSN: What were the challenges you have faced being in Women cell and PME cell?

Dr. MBJ: I was chairman of Women cell for two terms. Problems were social, administrative and also the ignorance of women workers of their own right to get proper facilities at their work place. As a committee, we took our suggestions for the problems to the authority and they were suitably sorted out. Authority being co-operative and grievances being within the rules and suggestions being proper, I have faced no challenge during my tenure.

But as PME cell chairman and Secretary, IRC, I had greater responsibility at NRRI. It was both for research and administration. I had to help the Director in conducting IRC, monitoring publications, annual reports of the scientists according to their work plan and maintaining the documents in PME cell. It was a huge job in addition to my job as the Head, Crop Protection and demanded more of my time and energy. But at the same time, I was fortunate to work under two dynamic, sincere and sensible Directors, Dr. Trilochan Mohapatra and Dr. Himansu Pathak, that transformed my job from challenge to pleasure. I was also blessed in the home front as my husband and son were not only co-operative, but very encouraging towards my work.

Dr. BSN: You are one of those, who are championed in rice Pest Management right from 1980s, how was it then and how is it now?

Dr. MBJ: In 1980s, the work on pest management in rice was pesticide-based but farmers based. A few insecticides were at farmers' arena. As an entomologist, first I used to generate detail data of commonly used insecticides in controlled condition against insect pests so that their efficacy was known in relation to their mode of application with timing and dose. Then, I was visiting farmers field through lab to land programme or as a resource person of the state agricultural departments to make them aware of the effective insecticides against particular pest. I still remember perusing the farmers not to apply Phosphamidon against BPH which was the most popular insecticide. It took more time but we succeeded.

Now, there is great improvement over the past years. Surveillance has been brought to the lime light to educate the rice farmers on identifying insects with their time of occurrence through different techniques to which I was also a part. It has curtailed unnecessary use of pesticides and also use of unwanted pesticides. The system is linked to weather parameters, other pest management techniques and residue analysis of hazardous insecticide residues within the form of IPM which has created an awareness among the farmers to reduce pesticide use. Now, there is a need for frequent interaction with farmers at field level to accelerate the implementation of the IPM strategy.

Dr. BSN: Role model/the person you admire/follow in your life as well as in professional life?

Dr. MBJ: My father Sri. Manamohan Jena is always my role model from whom I have learnt sincerity and honesty to my job. In professional life, I have acquired qualities from many seniors but particularly, I follow my Ph.D. guide Dr. I.C. Pasalu, who taught me precision, integrity, hard work and respect in research. He inspired me by his devotion to the duty and at the same time, for his mentorship to the young ones, encouraging them to be a very good human being which I tried to impart to my juniors.

Dr. BSN: How to tackle the shift in pest's scenario? is it going to be a big challenge?

Dr. MBJ: Shift in pest scenario is due to many reasons. the major factors responsible for the change in insect pest scenario are - change in weather parameters to suit their multiplication and feeding, change in cultivation practices, extensive cultivation of high yielding varieties without pest resistance, intensive rice cultivation throughout the year, imbalanced use of fertilizers and indiscriminate use of pesticides.

But, with the present-day techniques, particularly keeping surveillance in the front, the problems can be tackled.

Dr. BSN: What working women should possess to have balanced and healthy life?

Dr. MBJ: A working woman is also a home maker and it is no less a responsibility than professional research life. Balance between these two arena keeps a woman healthy and happy. I am fortunate to join the ARS as it does not have frequent transfer to disturb the household which is very difficult in research life. Patience, hardworking and understanding the problem of self as well as others, help to maintain a healthy balance and also brings in co-operation from family members and from professional front.

Dr. BSN: Your suggestions/views and opinion on "Indian entomologist" magazine?

Dr. MBJ: The magazine is one of its kind which can reflect the inner talent, knowledge and aspiration of Indian Entomologists, particularly, providing a platform to the young and dynamic ones for free communication of knowledge. The general articles arouse much interest and a pleasure to study. The section "remembering the legends" gives a chance to know the achievements of such veteran entomologists. Overall, the magazine expresses many aspects of popular as well as educative scientific Entomology, including the interview with Women Entomologist where I am going to be a part. My utmost regards to Dr. V.V. Ramamurthy whose able guidance has shaped the magazine so nicely, with varied topics. I profusely thank Dr. Shashank and you for selecting me and conducting the interview. I wish all the best for a dazzling future of the magazine.

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An architectural marvel of a potter wasp, binding water to bide

Unnikrishnan M.P.

The brilliance of scintillating sunshine was so radiant and scorching that there was considerable drop in the availability of water, at this juncture what else could we think of? except for survival instincts? It always remains as a question, but on the other hand only who senses it could recognize the activity of other organisms around us which exactly coincides with the theme of this year's Biodiversity Day i.e., "OUR SOLUTIONS ARE IN NATURE" this is explicitly true as during lockdown, I happened to unearth the fact that my homestead is rich in biodiversity.

There was a sight, which surprised me a lot. A wasp like creature was flying around the wet clothes kept for drying. It flew away in a matter of seconds after sucking water from them. Though I don't know its whereabouts but it was revisiting the same spot over again and again, the next day, there were no clothes left for drying. Surprisingly I saw it flying around the well! the only source of water. It was sucking the water content from the rope which was used to draw water. While reaching the rope, it's wings were still and after the intake, a sudden flight was noticed. Finally, I found it in my house.

Figs 1-4: 1. Adult wasp, 2. Nest, 3. Eggs, 4. Larvae

There was also a mud nest nearby. After seeing the mud nest, I understood that it is potter wasp.

The potter wasp uses the water for building this nest. While reaching the water source, they suck the water inwards and release them on reaching a place where they could get good granular soil by the process of regurgitation. After mixing the water with the soil, they would make a mud ball and will carry it to the construction site. The potter wasp entered my house though a window which was kept open. The nest was also nearer to the window, where in Interestingly, I could spot a green caterpillar inside. Afterwards, the potter wasp closed the opening of the cell. I waited for the construction of the next cell so that I could understand their nesting behaviour from the beginning. After a long gap the mason brought small balls of mud from backyard and started construction, It is very interesting to see how it built the house by moving the yellow head with two large black shiny compound eyes forward with the help of a pair of front legs. There is an ivory like part at the bottom of the head, near mouth, i.e the mandibles, with which it digged the soil. The next two pair of legs help them to stand firm. The movement of the head will surely doubt us whether they are telling something to us. Their thorax is half yellow half reddish brown and the abdomen is reddish brown and yellow, with a black stripe in middle, by the time I noticed the architectural beauty of the wasp construction of the second cell was also completed. After that, I saw it folding its abdomen into the cell. Now I understood it was about to lay the eggs. Soon after laying eggs, she disappeared and returned, but wasn't alone this time, astonishingly was holding a caterpillar which she placed in her nest.

I wondered why the caterpillar was unable to escape through the hole in her absence?

A wonderful feast by the mother wasp for her beloved ones. I took a glimpse towards their life. The main food of an adult potter wasp is flower nectar. Once they undergo mating, the female potter wasp collects the sperms from the male. Later it is all the female who are actually seen in the scenario. After mating, the females search and finds a suitable place for building nest. Now she starts to build the nest. Once she completes the work, it’s time to lay the eggs. She can decide the sex of eggs they lay. That is, if the egg is fertilised with the sperm which was collected during mating, it will be a female. If it is unfertilized, then the eggs will be males. After laying eggs, her duty shifts into finding food for the larvae that comes after hatching. Their major preys are lepidopteran caterpillars and spiders. After stinging the caterpillars, she takes them with her. After putting them inside the cell, she closed the opening of the cell. Then the cell is covered once again with mud. This is because other wasps could enter inside the cell and destroy the eggs and lay their own eggs. Now she has no role left with that cell. She starts to build the next one. Finally on completion of the nest, she leaves.

They belong to order Hymnoptera, Eumeninae subfamily of the Vespidae family. The potter wasp which visited my house was *Delta pyriforme*. They do not lead a social life. Generally, wasps are very violent. But potter wasps are not violent as others. We could observe them without panic making sure that it is does not harm us. We need to understand that it is not very easy for a potter wasp to build it's nest. Finding a suitable place, building nest, laying eggs, search for prey, paralyzing them, putting them into the cell creates thousands of questions in our mind. The honeybees understands a place through waggle dance. But how does a potter wasp find the correct position of her nest, water source, soil source etc. The answer is when they start to fly, there is a zig zag movement at the beginning. They consider some signs to keep the position in mind. We can always see this test flight before they start flying. Many days passed by the eggs inside the nest hatched. The larvae ate the reserved food. The adult potter wasps came out of the cell with the help of secretions from mouth. When *Delta pyriforme* left, the next guest came to the same nest. It was a mud dauber was in the genus *Chalybyon*. Afterall, it is very exciting to observe them. The joy of finding them is indescribable.

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Programmed cell death: A destructive and constructive process in insects

Jabez Raju B, Karthik S, and Anil G

Abstract: Programmed Cell Death (PCD) is a basic phenomenon which can be seen in plants, animals and even some unicellular organisms. In insects, events of post-embryonic development such as metamorphosis occur. During metamorphosis, the insect loses several of its body components during larval-pupal, pupal-adult transition. Response of how the body components disintegrate in insects reclines on the concept of PCD. When we talk about programmed cell death we discuss two important phenomena i.e., Apoptosis and Autophagy. PCD can be seen in insects during embryogenesis, metamorphosis where juvenile tissues are destroyed in order to form adult body parts. Current article is an attempt to provide an insight into mechanism of programmed cell death in insects and to promote cytological study of insects to understand basic cell biology, topics concerned with human health such as cancers.

Key words: Programmed cell death, insects, apoptosis, autophagy, cancer

Post-embryonic development is a gradual process occurring in insects after embryogenesis, and it is under hormonal control. The process of post-embryonic development starts from the eclosion of the egg and proceeds until the final adult is formed through a process called metamorphosis. During the course of post-embryonic development, an insect undergoes many structural changes *viz.* development of segmentation, moulting, growth and metamorphosis, accompanied by a non-structural change *i.e.*, development of reproductive maturity (Gillot, 2005; Minelli and Fusco, 2013).

Now, have you ever wondered what happens to body parts in immature insects which are lost during metamorphosis? Consider a lepidopteran larva which is way heavier than its adult moth and how it changes its structure during metamorphosis. A phenomenon called Programmed Cell Death (PCD) occurs during the events of metamorphosis. When we talk about cell death, it is a basic part of life and maintaining homeostasis in living organisms. Cells die due to several factors both external and internal such as physiological stress, invasion of pathogens, toxins, ageing etc. But in the case of PCD, cells die due to an internal triggering mechanism that activates the cytolysis and disintegration of tissues. Apoptosis and autophagy are the two significant phenomena of PCD in insects.

PCD was first described in the silk moth, *Bombyx mori* intersegmental muscles during metamorphosis by Kuwana in 1936. From then on scientists have documented the occurrence of PCD in insect muscular system, nervous system, ovarian follicles, salivary glands, midgut of lepidopteran larvae (Terashima *et al.*, 2000; Gaino and

Rebora, 2003; Tettamanti *et al.*, 2007; Fahrbach *et al.* 2012; Lee and Park, 2020).

Physiological changes during PCD

As mentioned earlier, PCD is under the control of endocrine regulation. Certain enzymes called caspases (cysteine aspartate-specific proteinases) are present in insects as well as in many plants and animals. They are responsible for the initiation and execution of apoptosis (Cooper *et al*. 2009). However, PCD is not compulsorily caused by caspases. The Programmed cell death is classified into two types *viz.*, caspase-dependent and caspase-independent (Iga *et al*. 2007).

During PCD, several changes including structural and physiological changes take place. The hormonal concentrations in the body of insects vary accordingly with PCD. The cells undergoing apoptosis show distinctive modifications. Apoptosis is characterized by caspase activation, cell shrinkage, cytoplasmic blebbing, nuclear and DNA fragmentation and phagocytosis of the dying cells (Tracy and Baehrecke, 2013). In contrast, autophagy is characterized by formation of an isolation membrane separating cytoplasmic materials, followed by the formation of a double membrane vesicle called autophagosome. Lysosomes fuse with the autophagosome’s outer membrane, release the lysosomal enzymes which digest cellular material and organelles (Poyraz *et al.* 2021).

Role of haemolymph in PCD and its regulation

The haemocytes of insect haemolymph are of prominence for insect immunity. However, they are also known to be involved in PCD during metamorphosis. It was found out that a certain type of haemocytes called granulocytes was increased during metamorphosis. These granulocytes enter the tissues to be degraded like fat bodies and transform into macrogranulocytes which undergo apoptosis in target tissues, releasing Cathepsin L which degrades the target tissues like fat bodies. The transformation of granulocytes into macrogranulocytes is regulated by 20-hydroxyecdysone and the expression of Cathepsin L (Zhai and Zhao, 2012). It was also found that Cathepsin B is associated with the programmed cell death (PCD) of the fat body cells, and Cathepsin B, D, and O are involved in metamorphosis (Pan *et al.* 2021).

Genetic signals involved in PCD

Drosophila melanogaster is used as a model to understand the process and mechanism of PCD. In *Drosophila,* Dronc is primary apoptotic caspase apart from Dredd and Strica (they are also initiator caspases) which is homologous to mammalian caspase-9. It is the initiator caspase that activates effector caspases like Drice, Dcp-1, Decay and Damm. The initiator caspases are activated following the transmission of cell death signal. After the perception of death signals from cells, genes coding for proteins such as Apaf-1/Ced-4 are expressed followed by their production triggering a cascade of caspase activity. The genome of *Drosophila* codes for proteins such as IAPs (Inhibitors of apoptosis proteins) which reduce the activity of caspases by binding to them thereby terminating Apoptosis. IAP antagonists such as Reaper, Hid, and Grim inhibit the IAP binding with caspases, thereby promote apoptosis (Cooper *et al*.

2009; Fahrbach *et al.* 2012). The schematic regulation of apoptosis in *Drosophila* is depicted in Fig 1.

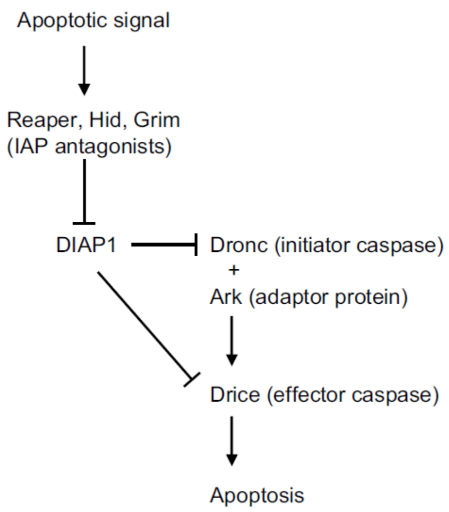

Fig. 1. Regulatory mechanism of Apoptosis (Fahrbach *et al.* 2012)

Other factors responsible for PCD

PCD occurs in all insects during metamorphosis however, there are several other factors which could lead to PCD in insects. Inducing oxidative stress in Sf9 cells by application of H_2O_2 produced apoptosis in cultured cells (Hasnain *et al.* 1999). Midgut cells of citrus psyllid (*Diaphorina citri*) undergo apoptosis when exposed to *Candidatus Liberibacter asiaticus* by an unknown mechanism (Ghanim *et al.* 2016). Harmine an alkaloid derived from *Paganum harmala* induced apoptosis in the cultures Sf9 cells (Cui *et al.* 2020). Alphaviruses are known to cause cell death in their mosquito vectors and the cell death was found to be important the propagation of the viruses in the vector (Cappuccio and Maisse, 2020). It was reported that Acetylcholineesterase promotes apoptosis of insect neurons (Knorr *et al.* 2020). It was showed that *Wolbachia* induces apoptosis of nurse cells in the ovaries of *Laodelphax striatellus* and it is associated with increase in fecundity (Guo *et al.* 2018). It was also reported that Phytohaemagglutinin induced apoptosis in the epithelial cells of *Sitobion avenae* gut, the cells showed the hall marks of apoptosis after the insects were fed with diet containing Phytohaemagglutinin (Sprawka *et al.* 2013). The presence of Zinc in higher concentrations in the diet induced the apoptosis of haemocytes in the larvae of *Spodoptera litura* (Xia *et al.* 2005).

Reports of PCD

a. Ametabolans:

It was reported that apoptosis, autophagy and sometimes necrosis will occur in the degeneration of midgut epithelium during molting in a proturan *Filientomon takanawanum* (Rost-Roszkowska *et al.* 2010a). In *Lepismachilis notata* and *Machilis hrabei* (Thysanura), the midgut epithelial cells surrounded with cisterns of endoplasmic reticulum form the autophagosomes and degenerate by necrosis. Necrosis intensifies just before each moult. Degenerating cells' basal lamina persists as a covering over the underlying regenerative cells. Apoptosis also occurs where condensation of chromatin takes place, nucleus assumes a lobular shape and fragmentation occurs. The apoptotic cells eventually separate from the basal lamina and are secreted into the lumen of midgut where they disintegrate (Rost-Roszkowska *et al.* 2010b). Also, in *Atelura formicaria* (Ateluridae), necrosis is the most common form cell death in midgut during metamorphosis however apoptosis also occurs (Rost-Roszkowska, 2010c). In *Allacma fusca* (Collembola) apoptosis is common in younger forms but however as the insects age, apoptosis becomes less frequent and at the end of their life, necrosis occurs in the midgut epithelial cells (Rost-Roszkowska, 2008).

b. Paurometabolans:

In *Acheta domesticus* (Gryllidae), the midgut epithelium in the posterior region degenerates as the cells undergo necrosis. They are discharged into the lumen of the midgut where they disintegrate. The cell organelles are destroyed by autophagy (Rost-Roszkowska *et al.* 2010d). The Til pioneer neurons in a grasshopper, *Schistocerca americana* embryo undergo programmed death which is found to be triggered by the change in ecdysteroid titres in the haemolymph (Kutsch and Bentley, 1987). It was proved that the antennal cells during embryonic development undergo apoptosis in *Schistocerca gregaria* (Boyan *et al.* 2018).

c. Hemimetabolans:

It was reported that the follicular epithelial cells undergo apoptosis in nymphs of *Ecdyonurus venosus* (Ephemeroptera) during the developmental phase characterized by pale wing pads (Gaino and Rebora, 2003). Studies on the female accessory glands of *Aeshna juncea* and *A. grandis* (Odonata) revealed that PCD is initiated at the early reproductive phase and is almost disintegrated at the late reproductive phase by apoptosis (Abro, 2005). The labial musculature of *Anax junius* (Odonata) was degenerated during metamorphosis (Maloeuf, 1935).

d. Holometabolans:

Extensive studies on PCD were conducted in holometabolous insects like Lepidopteran caterpillars and *Drosophila*. In Lepidopterans, caspase-1 is the first caspase and was first identified in *Spodoptera frugiperda* and triggers apoptosis which is regulated by 20-hydroxyecdysterone and Juvenile Hormone. Both apoptosis and autophagy occur simultaneously however, there might be a cross-talk between apoptosis and autophagy. In *Drosophila*, Dronc is the initiator caspase and can trigger apoptosis. In *Apis mellifera*, autophagy and apoptosis are activated in tandem for destruction of salivary glands, larval gut and malpighian tubules during larva-pupa transition (Tettamanti and Casartelli, 2019).

PCD in Insects

PCD occurs in insects not only during growth and metamorphosis but there are several other instances like when cells which fulfilled their function undergo PCD. Also, insects use apoptosis as a defense against viral pathogens invading them (Clarke and Clem, 2003). In symbiotic association between aphid (*Acyrthosiphon pisum*) and the endosymbiont *Buchnera aphidicola*, modified host cells called bacteriocytes serve as the habitat for the symbiotic bacteria. These bacteriocytes are degenerated by a novel mechanism which is non-apoptotic and non-autophagic whereas, the endosymbionts are killed by a lysosomal-dependent mechanism in the adults (Simonet *et al.* 2018). In *Sitobion avenae*, the winged adults migrate to new host plants. It was reported that the flight muscles are degenerated after the migration through apoptosis (Feng *et al.* 2019).

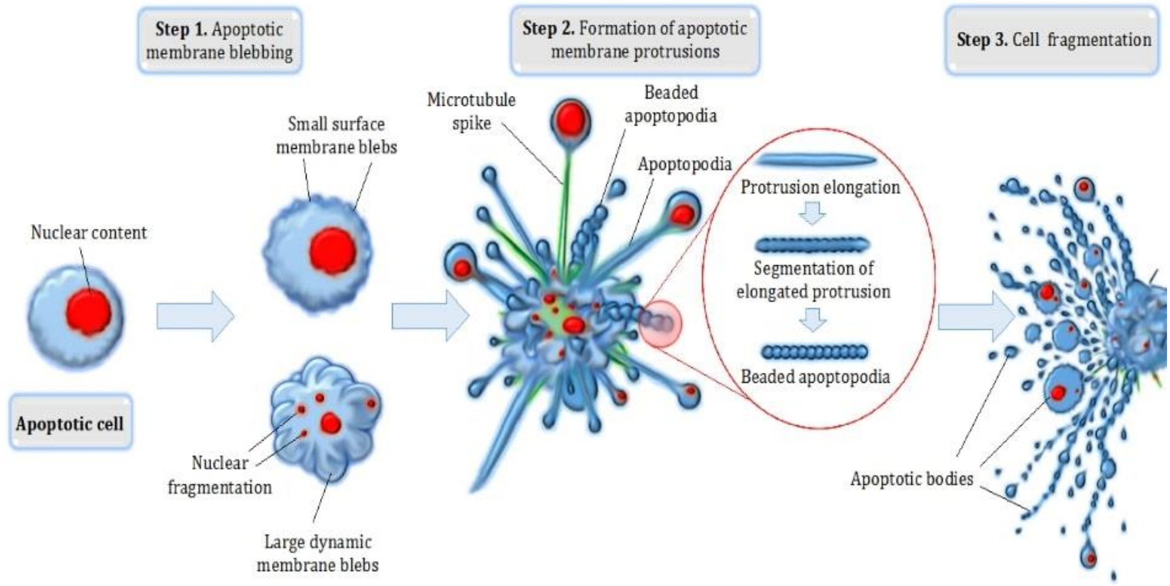

Fig. 2. Plasma membrane blebbing or zeosis (Smith et al. 2017)

Apoptosis

Apoptosis is a process where the cells will not grow and divide, but the cells and their contents undergo programmed death without any spillage of the cell contents (D'Arcy, 2019). During apoptosis, cells shrink and form plasma membrane blebs. The cytoskeleton structure of the cell is disrupted and the cytoplasmic content flows through these disruptions and forms outward bulges known as blebs carrying cytoplasm (Van der *et al.* 2016). These apoptotic blebs (Fig 2) are consumed by the phagocytes. The nucleus of apoptotic cells condenses, and electron dense chromatin gets aligned along the inner margin of the nuclear envelope (Fahrbach *et al.* 2012).

Autophagy

Autophagy is a process where the contents of the cells are sequestered into lysosomes for degradation which are then digested and then reabsorbed (D'Arcy 2019). Unlike apoptosis, cells undergoing autophagy do not from electron dense chromatin and instead they form autophagosomes. The Autophagosomes eventually fuse with lysosomes and the contents of the cell are recycled (Xie *et al.* 2007). Autophagy plays an active role in PCD in several tissues in *Drosophila* including the salivary gland and ovary (Fahrbach *et al.* 2012). Programmed cell death always has been a topic of interest and is studied in various organisms ranging from unicellular organisms, invertebrates to mammals. Among insects, exclusive studies were conducted on *Manduca sexta, Drosophila melanogaster*, *Bombyx mori* and *Helicoverpa virescens* (Table 1).

The *Manduca* model: *Manduca sexta* (Tobacco hornworm) attracts the attention of insect neurobiologists and endocrinologists because of its large size and ease of rearing and facultative diapause in their lifecycle. The Inter Segmental Musculature (ISM) of *M. sexta* is studied for elucidating PCD of muscles during metamorphosis. ISMs are prominent abdominal muscles found in larva, pupa and pharate adults. They are divided into separate pairs of bilaterally symmetric bundles, each of which attaches to the cuticle at inter segmental boundaries. The ISMs are helpful in hatching and subsequent larval locomotion. After pupation, the muscles in the 1st, 2nd, 7th and 8th abdominal segments die and rapidly disappear. The muscles in the middle four segments persist throughout metamorphosis and are used for the defensive and respiratory movements of the pupa. Following adult eclosion, the remaining ISMs undergo PCD during the subsequent 30 hours. Under laboratory conditions, metamorphosis in *Manduca* is complete in 18 days, with adult eclosion taking place late on day 18. On day 15 of adult development the mass of the ISMs begins to decline, and during the next 3 days ISMs lose 40% of their mass. Ultra structural studies revealed that autophagy is the mode of PCD of ISMs (Fig 3).

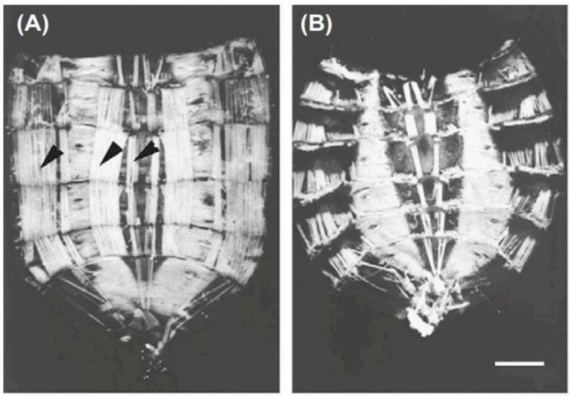

Fig. 3. ISMs in the abdomen of newly eclosed adults (A) and 30 hour-old adults (B) (Fahrbach *et al.* 2012)

The *Drosophila* model: PCD studies on *Drosophila melanogaster* (Diptera) indicated that the steroid hormone 20-hydroxyecdysone influences the PCD during metamorphosis. PCD is studied in the midgut and salivary glands of *Drosophila.* Three death genes have been identified in ~300kb region in its genome. There is two-way mechanism to control the apoptosis using the death genes *rpr*, *hid*, *grim* which trigger apoptosis mediated by caspases and a death regulatory gene baculovirus p35 gene which inhibits caspase activity. Besides this several baculovirus IAPs (Inhibitors of Apoptosis) are discovered in *Drosophila* genome. Titer changes in the ecdysone concentrations trigger the metamorphic events. At the end of larval development, a pulse of ecdysone triggers the formation of puparium and prepupal development, followed by another pulse after 10 hours signals for pupation. The salivary glands are degenerated by ~ 15 hours after puparium formation (Fig 4). PCD in the salivary glands of larva is ecdysone-triggered and is genetically regulated using early and late genes defined by the puffing pattern of salivary gland polyene chromosomes (Jiang *et al.* 1997).

The Silkworm model:

The salivary glands of the silkworm larvae are of prominent importance as they are used to spin silk. However, they are specific structures seen only in larvae. They are lost during metamorphosis from last instar larva to adult. The silk gland consists of an anterior, middle, and a posterior division. The anterior silk gland is a duct surrounded by a single layer of approximately 300 large, flat cells and lined with a thick cuticular intima at the internal surface. As in case of *Drosophila*, the PCD in *B. mori* is also triggered by the hormone 20-

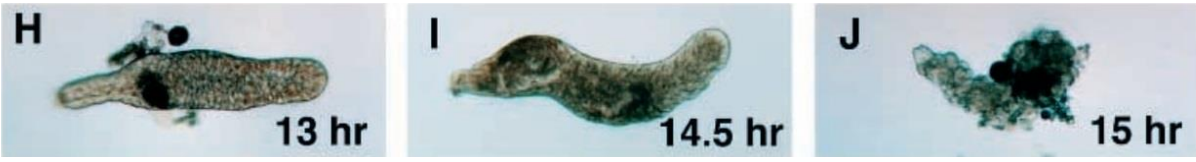

Fig. 4. PCD in salivary glands of Drosophila pupa. (H) Normal salivary glands seen in 13 hour pupae, (I) degenerating salivary glands in a 14.5 hour pupae, (J) completely degenerated salivary glands after 30 min (Jiang et al. 1997)

hydroxyecdysterone. The anterior salivary gland began to exhibit signs of PCD in vivo 2 days after gut purge and completed PCD by 48 hours as shown in Fig 5. Posterior silk glands are degenerated by apoptosis and autophagy (Montali *et al.* 2017).

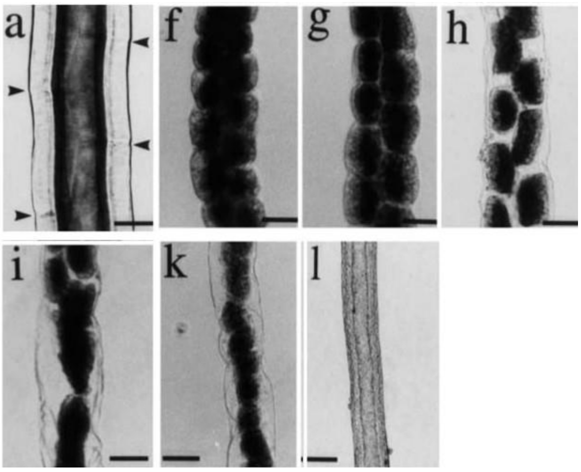

Fig. 5. In vivo progression of PCD in *B. mori* anterior salivary gland (a) salivary gland of last instar larvae, (f) at pupation, (g) 12h after pupation, (h) 24h after pupation, (i) 36h after pupation, (k) 42h after pupation, (l) 48h after pupation. (Terashima *et al.* 2000)

The *Helicoverpa* model: In the tobacco budworm (*Helicoverpa virescens*), the larval midgut epithelium undergoes a renewal process in pre-pupae. During this process of renovation, the old larval epithelium is destroyed by PCD mechanisms meanwhile the regenerative cells (Nidi) proliferate giving rise to a new epithelium. The old larval midgut undergoes PCD through co-occurrence of apoptosis and autophagy. For ease of study the larvae from 5th instar to pupa are arranged in phases1, 2, 3 and pupal phase, where phases 1, 2, 3 are from ecdysis to digging, digging phase, pupal cell formation to pharate pupa. The changes in nuclear structure attributable to apoptosis occur at late phase 1 especially in goblet cells and few columnar cells of the monolayered epithelium. The autophagic events occur in early phase 2 where feeding stops, so as to supplement halted food intake and continue throughout phase 3 (Tettamanti *et al.* 2007).

Future prospects in pest management:

The phenomenon of PCD could be a potential target for pest management as it is required for growth and development during metamorphosis. As of now pesticides were developed as growth regulators, molting disruptors but in the near future there is scope to develop novel pesticide molecules which actually target the PCD phenomenon in insects. For example, fenoxycarb a growth regulator inhibited PCD and remodeling of the fat bodies in *Galleria mellonella* (Poyraz *et al.* 2021). Similarly, novel molecules could be developed to act specifically on the PCD during metamorphosis. Also, harmine based molecules could be developed as pesticides as harmine induced apoptosis in Sf9 cells as shown by Cui *et al*. 2020. As reported by Xia *et al*. 2005, breeding for resistance to *Spodoptera litura* could be done by elevating Zinc levels in crop plants. Gene silencing of iap (Inhibitor of apoptosis proteins) genes using RNAi could be a potential pest management strategy (Yoon *et al.* 2020).

Conclusion

Programmed cell death in insects can be triggered during growth and development of insects. Although having several genes which regulate PCD, insect hormone ecdysone triggers PCD during metamorphosis in almost all insects. PCD is also seen during embryogenesis of the insects. In insects PCD occurs through apoptosis, autophagy and necrosis, sometimes they co-occur simultaneously. The larval structures are destroyed and recycled during metamorphosis using PCD. Further exploration of PCD in insects can pave ways to understand basic cellular biology, explore new targets at molecular level for insect pest management and prepare new formulations of insecticides which target the PCD during growth and development of insects, study cancers in insects, and devise strategies for molecular therapeutics which can be used against cancers in humans.

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Table 1. Programmed Cell Death (PCD) studies in different Insects

Insect	Location of PCD	Mechanism of PCD	References
Manduca sexta	Inter Segmental Musculature	Autophagy	Fahrbach *et al.* 2012
Drosophila melanogaster	Salivary glands	Apoptosis	Jiang *et al.* 1997
Bombyx mori	Silk glands and Salivary glands	Apoptosis and Autophagy	Terashima *et al.* 2000; Montali *et al.* 2017
Helicoverpa virescens	Larval midgut	Apoptosis and Autophagy	Tettamanti *et al.* 2007
Filientomon takanawanum	Midgut epithelium	apoptosis, autophagy and necrosis	Rost-Roszkowska *et al.* 2010a
Lepismachilis notata and Machilis hrabei	Midgut epithelium	Apoptosis and necrosis	Rost-Roszkowska *et al.* 2010b
Atelura formicaria	Midgut	Apoptosis and necrosis	Rost-Roszkowska *et al.* 2010c
Allacma fusca	Midgut	Apoptosis and necrosis	Rost-Roszkowska *et al.* 2008
Acheta domesticus	Midgut	autophagy and necrosis	Rost-Roszkowska *et al.* 2010d
Schistocerca gregaria	Embryonic antennal cells	Apoptosis	Boyan *et al.* 2018
Ecdyonurus venosus	Follicular epithelial cells	Apoptosis	Gaino and Rebora, 2003
Aeshna juncea and *A. grandis*	Female accessory glands	Apoptosis	Abro, 2005
Apis mellifera	Malpighian tubules, Larval gut, Salivary glands	Apoptosis and Autophagy	Tettamanti and Casartelli, 2019
Acyrthosiphon pisum	Bacteriocytes	Non-apoptotic and non-autophagic mechanism	Simonet *et al.* 2018
Sitobion avenae	Flight musculature	Apoptosis	Feng *et al.* 2019

Rugose spiraling whitefly: An invasive pest of coconut in Bastar plateau of Chhattisgarh

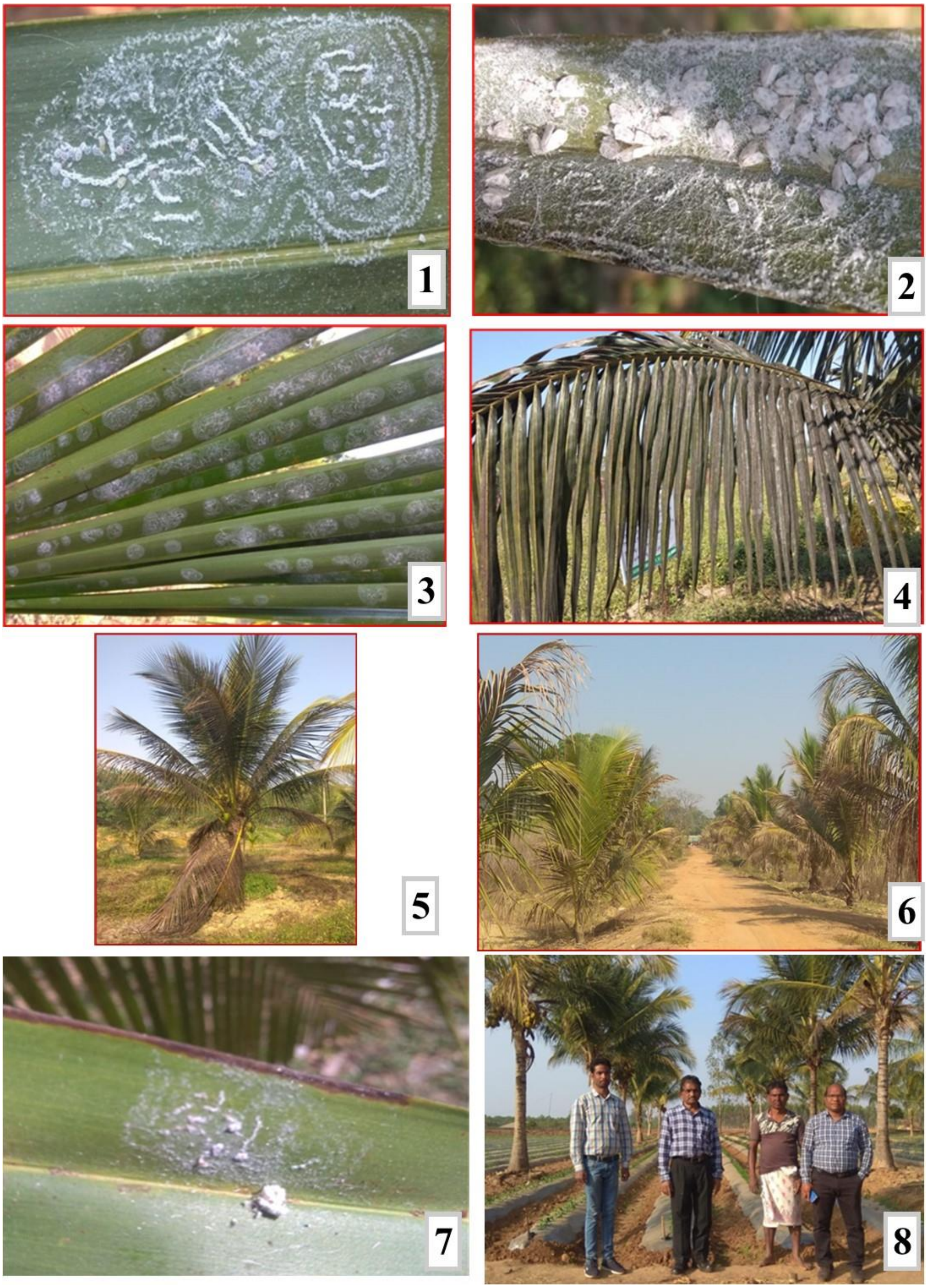
Rajesh Kumar Patel, Beena Singh P. K. Salam and Maheswarappa H. P.

Whiteflies belong to the order Hemiptera and the suborder Sternorrhyncha with a single superfamily, Aleyrodoidea, within the whitefly genus *Aleurodicus* Douglas. It comprises of 35 species of which only the spiraling whitefly (*Aleurodicus disperses* Russel) was so far known to occur in India. The Rugose Spiraling Whitefly (RSW) was first described from Belize on coconut during 2004 (Martin, 2004). So far in India the infestation of RSW on coconut has been reported in Tamil Nadu (Sundararaj and Selvaraj, 2017), Kerala (Sundararaj and Selvaraj, 2017), Karnataka (Selvaraj *et.al,* 2017), Assam (Chandrika, *et. al,* 2020), Gujarat (Jethva, *et. al,* 2020) and Chhattisgarh (Patel *et. al,* 2020). This pest is polyphagous devouring wide range of hosts including palms, ornamentals, fruits and weed flora. Bio mortality factors of RSW are the aphelinid parasitoid, *Encarsia guadeloupae* and the sooty mould feeding Leiochrinid beetle, *Leiochrinus nilgirianus* that are mostly used as conservatory biological control.

Occurrence of RSW in Bastar

A survey and monitoring for rugose spiraling whitefly in coconut were carried out in AICRP on Palms, S. G. College of Agriculture and Research Station, Jagdalpur and farmers field of Kondagaon and Dantewada districts of Chhattisgarh. The survey was based on typical characteristics of the pest i.e., spiraling pattern and concentric circular egg laying which is covered with white woolly waxy matter underside of the leaflets and fruit along with the presence of their nymphs and adults. The nymphs are light to golden yellow in colour that produces a dense, cottony wax as well as long, thin waxy filaments. The adults are lethargic, larger in size than other common white flies. These usually have a pair of irregular light brown band across their wings. Males have a pair of long pincers like structure at the end of their abdomen. They remain congregated on abaxial surface of leaves. The upper side of the leaflets show development of black sooty mould due to the secretion of glistening liquid *i.e.* honey dew.

The rugose spiraling whitefly was first time observed on coconut palm (*Cocos nucifera* L.) from Bastar plateau of Chhattisgarh during month of September, 2020. During the survey occurrence of this pest was not observed in the farmer's field of Bakawand, Kondagaon and Dantewada. Based on the present study the average population of the pest on different coconut cultivar revealed that it varied from 14.2 to 30.6 RSW / cm^2. The highest population was recorded in Gautami Ganga (30.6 / cm^2) followed by Kera Bastar (23.2 / cm^2) while the minimum population in Kalpa Raksha (14.2 / cm^2) (Patel, *et. al*, 2020). The invasive pest, *A. rugioperculatus* has already been reported to cause significant damage in India. Currently, this pest has invaded the



Figs 1-8: 1. Eggs and Nymphs of RSW, 2. Adults of RSW, 3. Spiral Pattern of Egg Laying, 4. Sooty Mould Development, 5. View of Infested tree, 6. View of Infested field 7. Lace wing grub feeding on nymphs, 8. Survey of farmers field (Sh. Somaru Ram)

coconut fields of Bastar region in Chhattisgarh. In order to manage its further spread in the experimental area; guidance and help was taken from the Project Coordinator, AICRP on Palms and scientists of NBAIR, Bengaluru. The culture of *Isaria fumosorosea* was procured from NBAIR, Bengaluru. Apart from the use of *Isaria* formulation; installation of yellow sticky traps and regular spray of water as well as Azadiractin was carried out. As this pest is polyphagous in nature the current incidence in Bastar is alarming as it has a great potential to extend its host range and spread to other coconut growing areas in the Chhattisgarh State.

Symptoms of Damage

- Egg spirals of rugose spiraling whitefly on the underside of leaves.
- Presence of heavy white, waxy material with silky filaments.
- Presence of sticky honeydew.
- Black sooty mold formation on upper side of leaves.

Suggested Management Practices

- Avoid transportation of planting materials from affected area to non affected area to check the spread of the pest.
- Spray Azadiractin 1% @ 1 ml per liter of water with 10 gms detergent 2-3 sprays at 15 days interval.
- Forcibly spray water or detergent + water on leaves to washout sooty mould as well as various life stage of RSW at fortnight interval.
- Installation of yellow sticky traps smeared with castor oil on palm trunk to attract adult of RSW. Castor oil should be applied after 7 to 10 days interval.
- Release of *Dichochrysa astur* @ 100-150 eggs / palm in case of low incidence and upto 300 eggs / palm during medium incidence for at least 10 % of the infested palms.
- Release and augmentation of *Encarsia guadeloupae* in affected palms for satisfactory pest suppression.
- Foliar application of entomopathogenic fungi *Isaria fumosorosea* @ $1x10^8$ spores/ ml (5gms/ liter of water along with sticker 1 ml/ liter).
- Avoid application of chemical pesticides to reduce the chances of resistance and pest resurgence problem.

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Conserving natural enemies in crop ecosystem

G. R. Hithesh, Sachin S. Suroshe and P.R. Shashank

Biological control is the regulation of pest populations by the activity of natural enemies *viz*., predators, parasitiods and pathogens. It consists of three principles introduction, augmentation and conservation among which, conservation is widely practiced as it is easy to understand by the growers. It is defined as modification of the environment to protect and enhance or increase specific natural enemies to reduce the effect of pests. It takes the advantage of resident natural enemies (predators and parasitoids) and involves management strategies which conserve their populations to uplift ecosystem services they provide. Generally, there are two general approaches that are followed for conserving the natural enemy population. The first one involves habitat manipulations to increase the abundance and activity of natural enemies (Landis *et al.*, 2000) and the second one involves the use of semiochemicals to attract predators and parasitoids, thus helps in reducing the use of pesticides, that may harm natural enemies. The biodiversity of natural enemies depends on two components *viz*., species richness and evenness. The different approaches that are used for conservation of natural enemies in vegetable crops are vegetation diversity, semiochemicals, insectary plants, food sprays, oviposition sites and shelters, mixed diet food, banker plant, trap crops, beetle bank and flower strips.

Vegetation diversity: The conventional method is used where no manipulation of habitat leads to high pest numbers and few natural enemies are entering into the crop from the surrounding fields. In this case, as there is no habitat manipulation, it is impossible to conserve the natural enemies in the field conditions. Addition of intercropping, cover cropping and supplemental food sources in an agroecosystem may lead to increase in natural enemies abundance and addition of lures Herbivore Induced Plant Volatiles (HIPV'S) may attract natural enemies into crop ecosystem to enhance the biological control. In okra crop, when coriander was used as an intercrop and maize as border crop, it enhanced the coccinellid population when compared with the sole crop.

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

Fig. 1. Corn pollen as a natural food supplement to enhance natural enemies. Photo credit: G. R. Hithesh

Food spray: Artificial or natural food supplements that can be sprayed or dusted on to the crop to enhance natural enemies in field conditions, where the nectar and pollen is not available or only present at low quantities. For predatory mites, pollen sprays can serve as a food and augment the biological control of thrips and whiteflies on cucumber (Rijn *et al.,* 2002). Narrow leaf cattail, *Typha angustifolia* L. pollen commercially sold as 'Nutrimite' are being used to increases population of pollen feeding predatory mites. It is commercially used in roses, poinsettia and in pepper before flowering and in cucumber with no pollen. The dosage that should be applied in the field is 500 g/ha. It is available in dust formulation and has to be applied once in 2 weeks. Maize or Corn pollen is also used for enhancing the populations of *Amblyseius swirskii* (Athias-Henroit) (Adar *et al.,*2014)

Plant providing food: Plants provide nectar, pollen and plant sap as food resources for natural enemies. Most of the natural enemies are omnivores feeding on both plant and prey. Adults of parasitiods, syrphids and gall midges increases their longevity and oviposition by feeding on nectar (Bozsik, 1992). The flowering plant like sweet alyssum, *Lobularia maritima* (L.) provide resource subsidies for the maintenance of the predatory bugs, *Orius laevigatus* (Fieber) during the scarcity of prey in cabbage crop.

Mixed diet food: The reproduction of predators can be increased by providing mixed diets of prey or mixture of different prey and non-prey food sources (corn pollen). It has been reported that the survival and reproduction of the predator, *Orius insidiosus* (Say) was enhanced, when the combination of aphids and thrips were supplemented as a prey source in soybean (Butler and Neil, 2007). The red velvet mite predator, *Balaustium sp.* developed better on a mixed diet of whitefly eggs and spider mites than on a diet of each prey alone in tomato crop.

Oviposition sites and shelters: The suitable oviposition sites are crucial for the reproduction of predators. Predatory mites prefer plants with trichomes to attach their eggs. However, not all trichomes are favourable for natural enemies. Tomato plants produce glandular trichomes which strongly hamper the movement of predatory mites as well as Flower bug, *Orius sp* (Koller *et al.,* 2007). Sweet pepper plants have tuft of domatia in the vein axils that are used by predatory mites for oviposition. It reduce cannibalism and increase survival by providing a suitable micro climate.

Banker plant method: It is used to breed the predators within a crop and also when the crop is not favourable for natural enemies to establish. The example of banker plant grass species, *Leersia sayanuka* (L.) is planted adjacent to rice fields to attract a planthopper, *Nilaparvatha muiri* (Muir). It does not attack rice plants, but is an alternative host for an egg parasitoid, *Anagrus nilaparvatae* (Pang et Wang), which is the main natural enemy of BPH (Zheng *et al.,*2017).

Flower strips: Flower strips such as *Fagopyrum* sp., *Lobularia* sp. and coriander produce nectar, pollen and provide shelter to natural enemies like hover flies etc.

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

Trap crop: A plant species able to attract simultaneously both pests and their natural enemies can be used in a trap cropping system for conservation biological control program. Trap plant, Borage, *Borago officinalis* (L.) (Boraginaceae) has been found to attract aphids and its parasitoid, *Aphidius colemani* (Viereck) and Chrysopids in tomato crop (Zhu *et al.*,2005).

Beetle banks: Beetle banks are grassy ridges in the center of the field that provide shelter to hide, and overwintering habitat for more rapid colonization by predators. It can be constructed as means of raising a ridge (≈0.5×2.0 m; H×W) by carefully conducting two directional plowings. A mixture of perennial grass seeds should be sown along with dense shelter seeds of perennial flowers in order to attract and provide shelter for natural enemies such as syrphids, parasitoids, lady beetles, spiders and ground beetles. It is used in wheat crop in Europe.

Pest in first techniques: It is the riskiest method which requires intensive crop monitoring and the release needs to be in time. The predatory mite, *Phytoseiulus persimilis* (Athias- Henriot) is applied after the detection of hotspots of spider mites in the sweet pepper crop. It can also be posssible to inoculate plants with a low level of spider mites early in the growing season and release the predators shortly. Thus, allowing the low levels of the pests without risking crop damage for the conservation of predators.

Considering all of the advantages rendered by Conservation Biological Control (CBC), it must be accommodated in IPM programmes for the management of dreaded insect pests.

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Importance of stingless bees as alternative pollinators in crop pollination

Rakesh Das and Gautam Kunal

For fruit and seed set, most of the crop plants depend on pollination and insect pollination of crops is a critical ecosystem service. More than 75 % of the 115 major crop species directly depend upon animal pollination, whereas only about 28 % crop species depend on wind and self-pollination worldwide (Klein et al., 2007). It is well reported that one third of the total human food supply relies on insect for pollination (Jivan, 2013; Said et al., 2015). The insect pollination value for agricultural production in worldwide is estimated to be € 153 billion, representing 9.5% value of the world agricultural production used for human food in 2005 (Gallai et al., 2009). As far as India is concerned, the total value of Indian agriculture is 1291369.63 crores at 2012-13 prices or USD 258.27 billion and the proportion of animal pollinated crops is 422827.52 crores ($ 84.57 billion), representing 32.74%. Whereas, the direct contribution of insect pollination to Indian agriculture is staggering 112615.73 crores (USD 22.52 billion) annually, representing 8.72% (Chaudhary and Chand, 2017). Co-evolution between flowering plants and their pollinators started about 225 million years ago (Price, 1975). Insects from the orders of Hymenoptera, Lepidoptera, Diptera, Coleoptera, Thysanoptera, Hemiptera and Neuroptera reported as major pollinators of different crops (Mitra et al., 2008). Among different insect group, bees are the most important and constitute more than 80% of the total. Effective pollination results in increased crop production, quality improvement, and more seed production. Many of fruits, vegetables, edible oil and nuts are highly dependent on bee pollination (Irshad and Stephen, 2014).

Stingless bees

Stingless bees are the smallest honey producing bees belong to the family Apidae, subfamily Apinae and tribe Meliponini. Rearing or beekeeping with stingless bees is called meliponiculture. They are eusocial like true honey bees and live in perennial colonies, consisting of hundreds or thousands of workers (Wille, 1983). They are widely known as dammar bees in India, since dammar is a kind of resin collected from dipterocarp trees for construction of their nest along with wax produced from their body (Rasmussen, 2013). They differ from *Apis* species in terms of biology and nesting characteristics. In stingless bee the larval feeding process is termed as mass provisioning, whereas in *Apis* spp., progressive feeding with royal jelly and bee bread during growth and development of the larvae can be seen (Heard, 1999). On the contrary, in nest architecture, numerous elliptical/spherical pots can be seen to store honey and pollen, made by "cerumen", a mixture of wax secreted from wax gland and resins collected from plants (Quezada-Euán, 2018). They prefer to make their nests in dark places like empty logs, cavities in tree trunks, cracks and crevices in old walls etc., where the nest entrance mostly projects as an external tube (Wille, 1983). In India, Danaraddi (2007) reported that the *T. iridipennis* was found to be nesting in tree cavity and wall cavity at Dharwad. Roopa (2002) and Gajanan et al. (2005) found the similar nesting behaviour of *T. iridipennis* in Bangalore and Muthuraman (2006) in Tamil Nadu. Also in a recent study, Kunal et al., (2020) reported nesting of *T. bengalensis* in tree-cavities, concrete wall, mud wall, iron pipe and wash basin from West Bengal, India. The name stingless bee implies due to having no or vestigial form of sting. Hence, they protect their nest from intruders very effectively by biting with their stout mandibles and also get into the hairs, ear and nose of the intruders (Muthuraman et al., 2013).

Diversity and distribution

Stingless bees evolved around 80 million years, before - longer than *Apis* bees and assumed to be emerged first in African continent and later spread across the rest of the world (Crane, 1992; Wilie, 1983). The inefficiency of controlling nest temperature, especially when the temperature is low, limited their distribution to tropical and subtropical areas and they are found in Australia, Asia, Central and South America (Muthuraman et al., 2013). Meliponinae includes 8 genera with 15 subgenera and having more than 500 species worldwide (Wille, 1983). Similarly three genera viz., *Tetragonula*, *Lepidotrigona* and *Lisotrigona* with eight named species of stingless bees are found to be distributed throughout the Indian subcontinent (Rasmussen, 2013) and among the different species, *Trigona* (*Tetragonula*) *iridipennis* most commonly seen in India (Raakhee and Devanesan, 2000).

Why alternative pollinators?

Though the group bee is widely diversified (wild and managed bees), the managed bees of *Apis* spp. (*Apis mellifera* and *Apis cerana*) appear as major crop pollinators across worldwide due to its manageable property. But threats include habitat destruction or alteration, overuse of pesticides, parasites and diseases, and the introduction of alien species resulting rapid declining of both managed and wild bees' population, causing global concern for pollination services (Buchmann and Nabhan, 1996).

Additionally, honeybees are not always the most suitable pollinators due to various factors, e.g. a miss-match in body size and flower size, low in nectar production and specialized pollen release mechanisms in some plants, including those with poricidal anthers (ex. solanacceous plants) (Kearns and Inouye, 1997). Hence, diversification of crop pollinators would help to achieve pollination services when the commonly used pollinator (specifically honeybees for most crops nowadays) is not available in sufficient numbers.

Stingless bee as an alternative pollinator

Sometimes the wild or non-Apis bees effectively complement honey bee pollination in many crops, including the solitary bees Nomia and Osmia (for orchard crops), bumble bees (for Solanaceae crops e.g. tomatoes), Megachile bees (for alfalfa) and more recently, stingless bees (Free, 1993; Heard, 1999). But most of these non-Apis bees have limitations, such as solitary bees have limited life span of annul cycle, bumble bees only found in higher altitudes etc. and in this context diverse group of stingless bees (Meliponini) can be appeared as future potential pollinators (Heard, 1999). Though distribution throughout the tropical and subtropical parts of the world with significant variation in colony size (from a few dozen to tens of thousands of individuals), body size (from 2 to 14 mm; compare to 12 mm for honeybees), and foraging strategy (some species recruit nest mates to high quality food sources, like honeybees, whereas others forage mainly individually like bumble bees) give adaptive advantages to stingless bees as alternative pollinators over non-Apis bees (Roubik, 1992; Michener, 2000). In addition, colonies are naturally long-lived and perennial; don't die after reproducing, unlike *Bombus* (Slaa, 2006), thus can forage year-round. Similarly, like true honey bees, they are domesticated and can be manipulated in relatively small hives. Their small size allows them to co-exist peacefully with other commercial bees as they can access many kind of flowers, whose openings are too narrow to permit penetration for other bees (Abrol, 2012). Being true generalists and perennial, they can collect nectar and pollen from a vast array of plants throughout the year (Roubik, 1989; Biesmeijer et al., 2005).

Lacking of functional sting and having smaller foraging range than that of the honey bees, they can be efficiently used as pollinators in confined spaces such as cages and greenhouses (Katayama, 1987; Kakutani et al., 1993). In contrast to the honey bee (*Apis* spp.), stingless bee colonies are typically long-lived (Roubik, 2006; Quezada-Euán, 2018) and have low absconding behaviour. Unlike honey bees, they are not affected by the various diseases (bacterial, viral or fungal) and parasites (mites), however, they have their own natural enemies but neither shared with honey bees nor very serious (Abrol, 2012). More importantly, certain larger species of the genus *Melipona* are capable of buzz pollination, where pollen is released through vibration or sonication i.e. buzzing from poricidal anthers of solanaceae plants (e.g. tomato and eggplant) (Buchmann, 1983).

Crops pollinated by stingless bees

Stingless bees can act as pollinators of a wide range of plants including vegetables, pulses, oilseeds, fruit trees, plantations etc. throughout the tropical and subtropical parts of the world, few list of plants presented in table 1. Apart from these (tropical and subtropical crops), there are certain plants that are visited by stingless bees but pollination occurs occasionally or partially, examples are fruits like Peach, Pear, Plum etc.; although there are many crops for which stingless bee pollination has not been thoroughly investigated (Heard, 1999).

Limitations of stingless bees

The major disadvantage of stingless bees as pollinator use is their distribution. They are limited to the tropical and subtropical regions due to their inefficiency of controlling nest temperature, especially when the temperature is low. Although attempt has been made to maintain colonies indoors in colder climates, using temperature-controlled rooms and/or hives (Amano, 2004). Apart from this, study also showed that stingless bee, *Trigona fulviventris* affect the pollination of plants by damaging the flowers, where they cut anthers to access pollens and often styles, during their lengthy visits on *Eriocnema fulva*, a threatened Melastomataceae of the Atlantic Forest, Brazil (Rego et al., 2018).

Conclusion

The characteristics like eusociality, colony perenniality, floral constancy, polylecty, harmlessness etc. enhance the importance of stingless bees as effective crop pollinators for both cultivated and wild floral diversity. But the lack of proper knowledge about meliponiculture as well as insufficient study of pollination effect of stingless bees on different crops should be considered for better improvement in future aspect.

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Table 1. List of plants pollinated by stingless bees

Sl. No.	Plant group	Plants
1.	Pulses	Pigeon pea
2.	Vegetables	Cucumber, Water melon, Squash, Bitter gourd, Sweet pepper, Eggplant, Onion, Ash gourd (Chauhan et al., 2019)
3.	Oil seeds	Sun flower, Castor, Niger
4.	Spices	Cardamom, Coriander
5.	Fruits	Peach (Cortopassi-Laurino et al., 1991), Plum & Pear (Boonithee et al., 1991), Guava, Citrus, Litchi, Strawberry, Jack fruit, Bread fruit
6.	Trees	Indian jujube, Subabul, Soap nut, Kapok, Tamarind, Sago palm, Rubber, Eucalyptus

Source: Abrol, 2012

Life lessons to be learnt from social insects (Ants) – A take away for managing pandemic situations

K. Murugasridevi, P. Logesh Kumar and K. Hari Priya

Over the years, disease has ravaged mankind, sometimes the course of history has changed and at times the ends of whole civilizations are signaled. Of which, coronavirus is an important disease attacking both human beings and animals. In 2019, a novel coronavirus was identified and became a pandemic throughout the world due to its rapid spread. In February 2020, the World Health Organization (WHO) designated the disease COVID-19, which stands for coronavirus disease 2019. The virus that causes COVID19 is designated severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). In this situation, to contain the spread of COVID-19 within the communities and help human societies, we shall find some clues from the social insects.

Social insects, in general, adore group-level defense mechanisms *viz.*, avoidance behavior (Cotter and Kilner, 2010), hygienic behavior (Wilson-Rich *et al.*, 2009), collection of antimicrobial resin (Simone *et al.*, 2009), spread of metapleural gland secretions (Yek and Mueller, 2010), behavioral fever (Starks *et al.*, 2000) and allogrooming (Walker and Hughes, 2009). Ants are one of the social insects living in large colonies, most often in close quarters. Their colonies, usually ruled by one or more queens depending on the species, are highly organised with each ant having a specific job to do. While the queen lays the eggs, worker ants forage for food, care for the queen's offspring, work on the nest, and protect the community. We, humans have many lessons to learn from the ants to escape ourselves from this pandemic crisis.

1. Social distancing

Until the COVID-19 epidemic, social distancing was primarily a strange concept to modern people. Nevertheless, it is a habit with deep evolutionary roots that is found in animals all throughout the world. The foraging ants that confront potentially fatal fungal pathogens outside the colony socially separate from the queen ant, her immature stages and nursing worker ants. Ants are extremely altruistic, therefore they want the colony's entire population to thrive. Black garden ant, *Lasius niger* was evolved to reduce the risk of disease transmission in colonies where the ants live in close proximity (Pull and Cremer,2017).

The older ants become foragers, which means they leave the nest to seek for food or defend their territory and they are less essential to the colony because they're already much older and on the verge of dying. Inside the colony, ants will take additional precautions to ensure that the younger nurse ants and the valuable queen are not vulnerable. Immediately after pathogen contamination, *L. neglectus* stop brood care and leave the brood chamber. When ants, *Camponotus aethiops* and *Temnothorax unifasciatus* are close to death due to disease or old age, they reduce their interaction rates with others, sometime by decreasing food sharing behavior and then leave their nests to die. The importance of these behavior to disease transmission remains unaccountable, but can offer an interesting parallel to the phenomenon, which preserves the organism's health of inflammatory and non-inflammatory programmed cell death (e.g., pyroptoses and apoptosis).

Stroeymeyt *et al.* (2018) placed a barcode-like QR labels on the backs of ants to observe how they reacted when a potentially infected individual returned to the colony, allowing a camera-equipped computer to monitor their activities. When few ants become infected by the pathogen, among the healthy ones inside the colony, there was an increase in social distancing between the nurses and the foragers. An extreme version of this happened when the ants were infected with fungal pathogens, as they were ill, they abandoned the colony in order to safeguard it.

2. Self isolation

Generally, moribund ants leave their nest and die in isolation and some reports also have found that infected ants spend less time with the brood. The carpenter ant, *Camponotus aethiops* when infected with generalist insect pathogenic fungus, *Metarhizium brunneum* shown that afflicted ants change their behavior dramatically over time to minimize the threat of colony infection. Infected individuals seemed to have reduced social interactions, did not communicate with brood and spent the majority of their time outside the nest from after three days of infection until death. Furthermore, infected ants were also more hostile towards non-nestmates. Eventually, infected ants' cuticular chemical profiles did not change, implying that sick individuals do not communicate their physiological status to their nestmates (Bos *et al.*,2012).

3. Nest hygiene

The importance of a clean nest environment for colony success can always be underlined. When their nest gets excessively polluted, social insects may selectively choose pathogen-free breeding locations, restrict nest entrances that are close to a pathogen source, or even relocate the entire nest to a different location. Social insects often collect and line their nests with antimicrobial chemicals gathered from the environment, *viz.*, resin or even venom. Wood ants, *Formica paralugubris* employ conifer resin in their nests to prevent further spread of infection, which serves as a prophylactic defense rather than a curative defense. When the colony is affected with a pathogen, worker ants do not increase collection, yet nests with resin have lower microbial contents than nests without resin (Brütsch *et al.*,2017).

4. Waste and corpse removal

The elimination of waste that poses a sanitary threat is essential for nest hygiene. Leaf-cutter ants must frequently replace the fresh leaf substrate in their fungus gardens, resulting in a continual waste stream. In this case, waste removal is especially crucial, since the fungal food source may be threatened by the fungus *Escovopsis*, a specialized garden pathogen. Parasitism by this fungus inhibits food production and leads to colony extinction. To safeguard their fungus garden from infection, the ants weed their garden by dumping the contaminated fungal food and old substrate into trash heaps or middens. Spatial separation prevents transmission from the waste dumps to the clean garden in the nest center, which is strengthened by behavioral separation. Fungus garden workers do not enter the midden; instead, they deposit the waste along the periphery, where garbage workers pick it up. This means that only indirect contact exists between the two working classes, lowering the risk of infection and pathogen transmission. If a garbage worker penetrates the clean nest site, her conspecifics will fight her ferociously, probably to prevent sickness from spreading to other parts of the colony (Diez *et al.*,2012; Zelagin *et al.*,2018).

Infection hazards arise from physical contact with deceased conspecifics. Both insect and human communities deploy sanitary burial techniques to avoid disease transmission concerns. The relevance of such practices is obvious during disease outbreaks where transmission occurs through direct contact. For example, during the 2014 Ebola outbreak in West Africa, the adherence of WHO-recommended burial customs suggesting limited contact with the dead lowered disease transmission and likely shortened the epidemic's length.

Social insect societies have developed intricate corresponding protocols to deal with their deceased colony members. Many ant species bury their dead in specialized nest chambers (such as graveyards) or outside the nest, a process known as necrophory (Maák *et al.*,2020). Furthermore, ants will disembowel the carcasses and deposit them in nest building material. These activities, in general, enhance spatial separation from potential pathogen sources, lowering the likelihood of pathogen exposure and infection among colony members.

5. Sanitary response

Despite these widespread hygiene practices, contamination of colony members cannot always be evaded, demanding thorough cleaning methods targeted at exposed individuals to prevent infection after pathogen exposure. To cope with infection of their colony members, social insects have evolved mechanical removal of infectious particles by grooming and chemical disinfection with antimicrobials. Both defenses frequently coexist with one another.

5.1. Pathogen Avoidance

The first line of defense for an individual or a colony is parasite or pathogen avoidance. Although absolute avoidance is rare due to the possibility of disease contamination in food sources *viz.*, flowers and insect remains, there is evidence that ants shun contaminated food sources. Shared resources like flowers can act as a transmission hotspots. Hence, the ecology of insect species may play a role in its avoidance behavior.

Leaf-cutter ants, *Atta cephalotes* have evolved sophisticated mechanisms to avoid parasite and pathogen intake into the colony. Workers of this species collect plant material and carry it back to their nests where it serves as a substrate for their fungus gardens, which provide food for the entire colony. At specific periods of the year, parasitic flies cluster around ant foraging sites to lay their eggs on the ants. The worker ants are beheaded after emergence of the adult fly. To avoid parasitism by these flies, the ants change their foraging times from diurnal to nocturnal to avoid parasitism. Likewise, *Atta* ants have a small worker caste that rides on the leaf parts as they return to the nest. The small workers weed the cut leaves, cleaning them of infectious particles and inhibit the phorid flies from parasitizing their sisters. This small worker caste is an especially a great illustration of a caste that is specialized for parasite avoidance (Cremer *et al.,*2018).

5.2. Grooming

Pathogen-infected colony members use self-grooming and evoke allogrooming from their fellow colonists. Workers lick the pathogen-exposed colony members and remove infectious particles from their body surface. Ants employ allogrooming to remove the infectious conidiospores of fungal entomopathogens, which adhere to and subsequently penetrate the insect host's cuticle. This behavior is quite effective and increases the chances of contaminated individual's survival. Allogrooming is more efficient than self-grooming because it targets body regions that the individual would otherwise be unable to reach. In addition, it is typically carried out by a group of nestmates. The groomed-off debris is gathered in infra-buccal pouches in the groomer's mouth, where it is compacted, treated with antimicrobial gland compounds, and then discharged as pellets.

5.3. Antimicrobial treatment

Allogrooming can be used in conjunction with the use of self-made antimicrobial chemicals. Specialized glands actively produce or squirt these chemicals. In the Formicine ants, poison gland secretions contain formic acid, a potent antimicrobial that is effective in inhibiting fungal germination and bacterial growth. When workers of *L. neglectus* groom their fungus-contaminated nestmates, they extract poison from their poison gland located at their posterior and store it in their mouth. Then, they smear it over the cuticle of the infected individuals while grooming. This greatly reduces the germination of the fungal conidiospores that were not eliminated during grooming. Antimicrobial use is both preventive and induced in response to pathogen exposure, implying that chemical disinfection works in combination with mechanical removal to protect colony members from being infected.

5.4. Removing the source of infection

After establishing an infection in a host, a pathogen goes through multiple rounds of replication, improving its potential of dissemination to other members of the colony. When *L. neglectus* fails to prevent fungal infections of *Metarhizium* spp. from establishing in their pupae despite early grooming and disinfection, these fatally infected pupae evoke a modified chemical signature (*i.e.,* cuticular hydrocarbon profile) several days after infection. This is comparable to contaminated cells in a vertebrate body emitting "find me – eat me" signals that attract immune cells (cytotoxic T cells) to begin their elimination. The ant's action is triggered by a change in the chemical pupal signature, which is referred to as "destructive disinfection". Workers first remove the silk cocoon that surrounds the pupae, then bite holes in the cuticle and spray poison directly from their acid pore onto the afflicted pupae. This behavior causes the fatally infected pupae to die prematurely during the incubation period and totally eliminates the pathogen lifecycle by blocking fungal proliferation and sporulation, similar to how antigen recognition by cytotoxic T cells in vertebrates kills the pathogen lifecycle. Pathogen propagation in individual vertebrates and the super-organismal colony is prevented by both antigen recognition by T cells and destructive disinfection (Pull *et al.,* 2018).

6. Building immunity through vaccination

Successful disease transmission involves not just the eradication of an infectious source, but also the reduction of host susceptibility. Susceptibility to pathogens might vary depending on previous exposure. Immunity can be acquired by immunological memory (vertebrates) or immunological priming (Invertebrates). At the colony level, a similar phenomenon known as social immunization might occur. Immunization happens at all levels of an organization when a previous pathogen exposure gives protection against a subsequent exposure to the same disease. Social immunization provides colony level protection, because social contact with a pathogen-exposed individual reduces susceptibility and increases survival of conspecifics after re-exposure to the same disease. Ants display social immunization against both fungal and bacterial infections, implying that it is a regular phenomenon in social insects.

In particular, social insects may provide passive immunization to their colony members through the transfer of immune effectors, similar to the treatment with antibodies given to humans following an acute rabies infection. The protection of nestmates of carpenter ants, *Camponotus pennsylvanicus*, injected with heat-killed bacteria, *Serratia marcescens*, has been postulated as a technique of passive immunization by transfer of protective chemicals dispersed to its colony members by the infected person (Hamilton *et al.*,2010). Injected individuals had higher antimicrobial activity in their guts than controls, and they regurgitated their gut contents to their naive nestmates, who had better survival after being exposed to live bacteria.

Social immunization against fungal pathogens (*Metarhizium* spp.) occurs via an alternative mechanism: active immunization of colony members by immunological activation caused by low-level pathogen transmission. This is similar to inoculation, an early kind of vaccination that employed a low dose of live pathogens, as compared to modern immunizations that employ dead or attenuated infectious agents. In *L. neglectus*, individuals exposed to infectious particles of the *Metarhizium* are allogroomed extensively by their naive nestmates, who thereafter get low-level fungal infections. Low-level infections do not cause sickness or death, but they do activate the immune system, resulting in increased antifungal and immunological activity (i.e., upregulation of antimicrobial peptides and the phenoloxidase cascade, involved in melanization of fungal pathogen in the body). In the past, inoculation with a sublethal dosage of the smallpox virus had a similar protective effect in people when reinfected with the virus, dramatically lowering the death rate from the terrible disease. In eusocial insect societies, such a response may be adaptive since they are likely to meet the same disease several times while performing foraging tasks, therefore carrying a low-level, protective infection may be beneficial to colony fitness.

7. Resisting antimicrobial resistance

The world is facing an antibiotics crisis. Antibiotics are in short supply around the world. Many once-effective medications have become ineffective against some strains of deadly microbial infections as a result of overuse. As a result, scientists are looking for novel strategies to combat dangerous microorganisms. In a recent study, antibacterial activity of 20 ant species with populations ranging from 80 to 220,000 inhabitants was reported (Penick *et al.*, 2018). External secretions were tested against *Staphylococcus epidermidis*, against which 60 percent of the ant species produced antibiotic secretions. Amazingly, 40 per cent of the people didn't come up with an antibacterial that might kill the bacteria. Furthermore, species in bigger colonies were no more likely than those in small colonies to have antibacterial action. This is surprising because it is commonly assumed that disease spreads faster in larger colonies. Whereas, the 40 per cent of ants that do not have antimicrobial activity have different ways of regulating bacterial spread. This supports the notion that ants could be a promising source of novel drugs. Ants not only create their own antimicrobial compounds, but they can also promote the growth of other beneficial microorganisms.

Conclusion

Millions of years of evolution in a high-risk environment have made ants a potential source of vital antimicrobials. These compounds must still be developed into useful medications and validated in humans. Apart from this, we can learn more about the disease-fighting tactics used by ants, to combat the menace of resistant pathogens and disease. In microbe-rich habitats like soil or decomposing wood, social insects live in big, dense, multigenerational families. As a result, we can argue that disease propagation and/or spread within and among colonies is naturally promoted by nest conditions. Colony social structure, life cycle flexibility and cooperative social defensive activities, on the other hand, minimize the chance of infection and decrease transmission risk among colony members, which we should learn from these magnificent creatures amidst the pandemic situation. Hence, we emphasize on unique cooperative behaviors to follow social distancing, sophisticated hygiene with a sanitary care, self-isolation when gets infected and fundamental organizational mechanisms that make up the building blocks of social immunity which the insect communities have evolved to battle the disease threats.

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Contributions of Dr. S. Pradhan to the field of Entomology

Sangeeta B. Kattimani, Sachin S. Suroshe, Suresh, M. Nebapure and Rajna S

Dr. Shyam Sunder Lal Pradhan, was one of the eminent entomologists in India and was the master of all entomological research areas. He played a remarkable role in bringing the crop protection science in forefront in agriculture science in India. His profound experience in research and teaching in the field of entomology for 33 years, contributed tremendously in fundamental and applied aspects. No surprise he is being known as the 'Father of Modern Applied Entomology' in India.

Dr. S. Pradhan

Early life

Dr. Shyam Sunder Lal Pradhan was born on 13th May, 1913 at Dihwa village, Uttar Pradesh. He completed his schooling from Lucknow with distinction in mathematics in UP board examination. He passed Intermediate examination with a gold medal from Radhaswamy Educational Institute at Agra. He topped Lucknow University in B.Sc. degree in 1932 and completed M.Sc. degree in 1934. The very first support for his entomology research came from Prof. K.N. Bahl under whom he worked in the field of functional morphology and thus awarded D.Sc. degree with best adjudged thesis. His popularity has reached beyond India when he went to Rothamsted Experimental Station, United Kingdom to do a part of PhD research work in Insect toxicology and endowed with Ph.D. degree from the Lucknow University in 1948.

Professional Career

He started his career in 1940 at Indian (Imperial) Council of Agricultural Research, Gorakhpur, UP where he worked on sugarcane pests for a very short period. In the same year, he had joined as an assistant Entomologist at Indian (Imperial) Agricultural Research Institute, Karnal Sub-station, where he worked on Insect Ecology. His experience in insect toxicology from Rothamstead Experimental Station motivated him to establish country's first school of Insect toxicology in 1948 at Division of Entomology, IARI, Pusa, New Delhi. Being a potent academician, Dr. S Pradhan was appointed as the first professor, Division of Entomology in 1958. He became the Head of the Division in 1962 and served for more than 11 years in the position. On 5th February, 1973 he took his heavenly abode before his scheduled retirement from service.

Contributions in research

Dr. Pradhan was dynamic Entomologist and had contributed in different fields of insect science like insect morphology, insect physiology, insect ecology, insect toxicology and storage entomology. He was instrumental in filling research gaps on homology of male genitalia, "Gnathal Glands" in coleopterans, coiling and uncoiling mechanism of proboscis in Lepidoptera. Studies on regeneration of mid-gut epithelium, function of Malpighian tubules in coccinellid beetle and morphology of alimentary canal contributed to the developing areas of insect physiology. His proficiency in mathematics helped to be an accomplished insect ecologist. His contributions on the effect of abiotic and biotic factors on insect life, population dynamics of the pest, assessment and sampling of pest damage and crop losses are highly significant in insect ecology. The classical works like 'Pradhan's equation' and development of 'biometer' are feathers on his cap. With Biometer, he could explain to calculate the date of emergence of insect from one stage to another based on daily bio-thermic value using thermal constant. His well-known 'Biotic theory of periodicity of locust cycles' (1965) describes the temporal and spatial distribution and abundance of locusts. The invention of 'Pusa bin' by Dr. S Pradhan and coworkers in 1969 revolutionized the storage entomology research in India.

In the later part of his research, he worked intensively on insect toxicology. Dr. Pradhan evolved effective chemical control measures against many crop pests through bioassay and field trials. Moreover, his contributions in toxicology included relationship between temperature and insecticide toxicity, relationship between particle size of suspensions and insect mortality, insecticide penetration through insect cuticle *etc*. In one of the most significant contribution, he demonstrated the strong antifeedant activity of neem. The deterrent activity of neem against locust was observed by him and coworkers during locust invasion in 1962 at IARI, Pusa Farms, New Delhi. He was the first to report development of resistance in Singhara beetle against DDT and BHC from Tihari and Dabri villages of New Delhi in 1963. His concept of 'pesticide umbrella', also gained importance in terms of attaining more yield. His leadership made to commence research on insecticide residues at the Division of Entomology, IARI, New Delhi. Dr. S. Pradhan was one of the earliest proponents of the concept of 'integrated pest management'. Studies on host plant resistance were intensified during his tenure as a head of the division. He always emphasized that crop protection research should possess a right place among the agricultural research efforts of the country.

Writer and Mentor

Dr. Pradhan has written about 200 research papers in various Indian and foreign journals and several popular articles in Hindi and English. He wrote two famous books, "Insect Pests of Crops" (1969) and "Agricultural Entomology and Pest Control" (1983). He has guided nearly 65 students including one M. Sc. and 19 Ph. D students. Being the first professor of Entomology, he was instrumental in setting the curricula for M.Sc. and Ph.D. courses of the Division. His chapter on 'Ecology of arid zone insects excluding locusts and grasshoppers in

Human and animal ecology was published by UNESCO.

Awards and honors

Dr. S. Pradhan was the first professor (1958) and was also Head of the Division of Entomology (1962-1973) at IARI, New Delhi. He got Dr. P.B. Sarkar Endowment prize for triennium (1971-1974) from Division of Agricultural Chemicals, IARI, Pusa, New Delhi. He was also awarded with Hari Om Ashram award for his outstanding contribution to science that led to increased production in 1973. He was president of ESI (Entomological Society of India) and also Fellow of Indian National Science Academy. The Silver Jubilee of the society was celebrated in 1964 and a National Seminar was also organized under his able leadership and guidance. In 1969, he organized the International Seminar on Integrated Pest Control as President of the Society. Dr. Pradhan was also Chairman of Entomology Committee of ICAR, New Delhi for many years.

Recognition from abroad

He was one among the six reputed persons invited by UNESCO in 1954 to write a chapter on “Ecology of arid zone insects excluding locusts and grasshoppers” in Human and Animal Ecology published by UNESCO. His theory of “periodicity of locust cycle” was presented at Porton, U.K. in 1970. He was a co-member of FAO panel experts on integrated pest management (IPM). Dr. Pradhan chaired three important sessions in the 14th International Congress of Entomology, held at Canberra, Australia, in August 1972.

Tribute to the legendary scientist

The research of Dr. S. Pradhan is remembered through series of lectures (Dr. S. Pradhan memorial lecture) organized by Division of Entomology every year. Till now, a series of 12 lectures were organized by Division of Entomology, ICAR-IARI. Dr. S. Pradhan would serve as role model to many young entomologists across the world.

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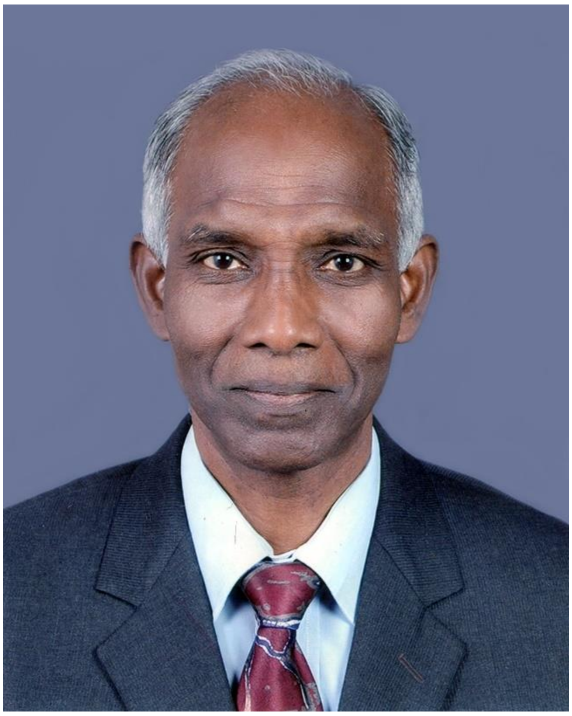
Dr RJR: a teacher-researcher-administrator par excellence

Born on 3rd June 1949, to Mr. Rajaratnam, a public prosecutor and Mrs. Leela, a homemaker, **Rajarethinam Jebamani Rabindra** was blessed to grow up with four sisters. He completed his graduation in B.Sc. (Ag.) from Agricultural College and Research Institute, TNAU, Madurai and his M.Sc. (Ag.) and Ph.D. in Agricultural Entomology from TNAU, Coimbatore. He excelled academically to have the best student awards bestowed on him. His professional career began at TNAU in August 1970 and when he left TNAU in February 2002, he was the Professor and Head, Department of Entomology and Director, Centre of Advanced Studies in Entomology, TNAU, Coimbatore.

R J Rabindra taught at his own alma mater where he had blossomed as a student. Being a student awardee of ICAR and CSIR fellowships and a first-class grad and doctorate in entomology, Dr. Rabindra was a teacher par excellence spanning a period of four decades from 1970. He won the students' hearts as well as the best post-graduate teacher award, the TNAU gold medal in 1998-99. He authored several manuals for students and young workers in pest management and biocontrol, of which Mass production Technology for biocontrol agents written in 1999 is the bible for students even today. During 1992 to 2002, he was the reason for countless students opting for Entomology for higher studies.

During his career at TNAU, he taught both undergraduate and post graduates, guided



Ph. D. students, formulated syllabus for courses, designed practicals, wrote manuals, totally focusing on developing appropriate modules to metamorphose the budding young minds into scientists and teachers. The strong fundamentals he had created for the students helped them to learn and expand their vista of future goals.

Students of Dr. Rabindra reminisce about his unambiguous way of teaching with a great command of language and clarity of thought, even after decades of graduation, with most of them remaining as his ardent devotees. Many learnt entomology from him, while many more learnt leadership qualities. A man of great vision and high intellect, he simplified hypotheses, paid attention to minor details and gave a new meaning to perfection, while teaching.

Every Ph.D student he mentored would vouch for his methodical and meticulous approach. Always prepared for the long-drawn sessions, his clear instructions and constant training to impart knowledge and skill in conceptualization and conduct of experiments with complex protocols bespoke his relentless tutoring. He led by example in being curious, energetic and resourceful and set the bar high for his students, all the while gently nudging them to better themselves and watching with pride as they grew focused. His students never had to scuttle, as usually young researchers do, for manpower or material or methods during the days of research under his guidance. A student could totally devote his time only to research without a worry and their theses were accomplished well before the time. He stayed by his students' side always ready to lend a hand, in theory and practice. Each of his idea was well- thought-out, diligently processed and usually culminated in fine conclusion through refined and repeated testing. Then he let the students to explore further. There were never loose ends, unfinished details or hasty finishing of experimentation.

One of the authors, NG says "During my Ph. D days, he sat me across a small table and taught every single technique personally even when he was at his busiest as the Head of the Department of Entomology. He found time to constantly check on my progress with a word of appreciation or criticism or a challenge. He goaded and coaxed for better contribution. He walked me through the execution of what he taught and then set me free for rest of the experiments. If I am a confident insect pathologist today, the foundation was laid more than 25 years ago, all credit to him."

As a researcher, his major interest was on integrated pest management in pulses, cotton and vegetables. He was one of the leading insect pathologists of the country specializing mainly on insect pathogenic viruses for pest control. He excelled in several advanced research techniques in histology, ultra-microtomy, electron microscopy, molecular analysis for insect viruses, insect cell culture and isoenzyme analysis. Besides leading several Institutional projects, he ran more than 20 externally funded projects.

After three decades at TNAU, he switched to ICAR to don the role of Project Director in February 2002 at Project Directorate of Biological Control (which later was upgraded to National Bureau of Agriculturally Important Insects (NBAII) and now is National Bureau of Agricultural Insect Resources (NBAIR)) and retired in June 2011. He was Director for two terms, a clear indicator of his prowess as a Research Manager. As Director of PDBC / NBAII and Project Coordinator (PC), AICRP on Biological Control, Dr. RJR (as he is fondly called) followed a strictly systematic and meticulous approach to research management, coordination and national and international networking with various organisations. During his tenure as Director, he was more of a teacher and under his constant vigilance the scientists at PDBC were monitored and mentored as students by him, to emerge as meritorious researchers. He critically looked at the research results submitted by the scientists and further challenged to bring out their best. He firmly believed that lab results should be translatable to the farmers' fields.

As PC, AICRP Biocontrol, he was highly successful in the implementation of biological control based IPM projects in 14 agricultural universities and 6 ICAR research institutes covering important crops such as rice, coconut, seed crops, pulses, vegetables, sugarcane, spices, cotton, tobacco and polyhouse crops. Dr. RJR received accolades from the Council for the success stories related to stake holder participatory biological control programme covering 5000 acres in Kerala involving more than 4000 paddy farmers in Thrissur, Kerala. Besides, he developed new research programmes for classical biological control of alien invasive pest species. Successful management of sugarcane woolly aphid in southern India by development and conservation of parasitoids and predators during the year 2005 led to remarkable savings for the Indian farmers which was the landmark achievement of the institute under his leadership. Another feather in his cap was the spectacular control of the papaya mealybug in India through importation of the parasitoid *Acerophogus papayae* from Peurto Rico. He sustained this effort by setting up a national network involving various stake holder entomologists from SAUs, KVKs, CIPM centres, AICRP biocontrol centres, ICAR Institutes and Department of Agriculture and Horticulture for distribution of the parasitoid. This phenomenal achievement would always be remembered as the ICAR’s flagship success story. An eloquent communicator, he could effortlessly persuade national policy makers and international research community, regarding his concepts and missions.

Post retirement, R J Rabindra became the Dean, College of Post Graduate studies, Central Agricultural University, Umiam, Meghalaya, where he served for almost a year. He made stellar contributions in strengthening the college curriculum and facilities, which was a great service to honing the skills of CAU students. He continued to be active, when he returned to Coimbatore after his stint as Dean at CAU. He was on several research advisory committees and from June 2020, he worked as Consultant for TN Government funded FAW program at TNAU. His keen interest in research, even post retirement, was evident during several occasions. He continued to actively participate in all symposia and workshops conducted by NBAIR and AICRP Biocontrol. Seated with the NBAIR researchers in the lab, he was visibly thrilled to confirm the identity of virus infected FAW larvae.

“I (CRB, one of the authors) had the privilege of being in the email loop during March to May 2020, when he proactively communicated (through his crisp and articulate mails) with various international organisations, seeking supply of an exotic parasitoid *Apoanagyrus lopezi* to NBAIR to target the invasive Cassava mealy bug. His last telephonic conversation with me was an interesting one, as always, on the indigenous egg parasitoids recorded in India on FAW and which among them could be the potential ones to be utilised for field releases. I will treasure my last personal meeting with RJR Sir on 28th February 2020 at TNAU, Coimbatore during National Science Day celebrations (with the theme “Women in Science”), when I received not only a formal memento, but beautiful words of appreciation and encouragement from him.”

His personal touch in all his dealings and delightful manners endeared him to his students and colleagues. We vividly recall his kind and clear voice, his smile and the warmth with which he spoke. Conversations with Dr RJR, whether personal or telephonic, always began with an enquiry about our family and health or with a word of gratitude to God for keeping all safe in his family. He was always the first one to reach a colleague to console on a personal loss. Without exception, he had the most appropriate, beautiful and wisest words on every occasion: inspiring, soothing and strengthening everyone around. Minimalism was a way of life for him, be it his personal life or his career.

Dr R J Rabindra left for his heavenly abode on 30th June 2021 (exactly 10 years after his superannuation from NBAII) and is survived by his mother Mrs. Leela, wife Mrs. Alice Rabindra, children, Andrew Rabindra, Joshua Rabindra and Johanna Vikram John. Dr RJR was one of the "chosen few" who was a rare intellectual, persistent worker, wonderful orator, great documenter, team leader, planner, educator and an able administrator, with an unobtrusive personality and charm to lace these qualities. Being a staunch believer in the Path of faith, to anyone who crossed his path, Dr RJR gave something to live for. Today he has left his indelible mark in entomology and biological control as well as his disciples' hearts.

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Professor K Chandrashekara (1957-2021): A passionate insect ecologist with a penchant for wasps

Professor Chandrashekara Krishnappa (KC) was one of the versatile entomologists of his generation. His contributions in the behavioral aspects of primitive eusocial wasps and exploring the ant diversity of Western Ghats stand out. He passed away due to long-term lung ailment and covid complications on April 03, 2021, aged 63. His passion for science and nature was reflected in every aspect of his life. We remember him with immense love and gratitude, since he enriched our knowledge of insect science.

I had been his post graduate student; the news of his demise sends by his son in the early morning of 4th April thrown me into agony and down the memory lane of those beautiful days of a decade ago. Prof KC was keen on studying the antimicrobial peptides (AMPs) from insects those days. When I joined as a post-graduate student in his lab, Dr. Jayappa was working on insect AMPs for his doctoral research. The same line of work was decided for me to explore the AMPs in dung beetles. Prof KC was curious to unravel the cellular and innate immunity of dung beetles as they are living in a microbial-laden environment. Dr. Jayappa's thesis has become the foundation for consecutive nine theses that came out of Prof KC's lab on the different aspects of the insect AMPs. Often, I had been among his group of science enthusiasts such as Professors Ganeshiah and ARV Kumar sitting with a cup of coffee around a table laid outside GKVK canteen. I use to astonish the depth of knowledge Professor

KC had on different aspects of evolutionary biology. Now this canteen table must be missing these stalwarts' daily gathering and their creative discussions.

Prof. KC was born on 26th November 1957. He had his early education in Varanasi, received M.Sc (Agri) degree in 1983 from the University of Agricultural Sciences, Bangalore, and a Ph.D. from the Indian Institute of Sciences, Bangalore in 1991 under the guidance of Dr. Raghavendra Gadagkar. Prof KC's doctoral research was unique in examining the social organization and individual behavioral profiles of female wasps of the species *Ropalidia marginata*. By extensive statistical analysis of activity time budgets of *R. marginata* individuals, he discovered three behavioural castes in them with strikingly different division of labour. This revealed that the behavioural patterns in such primitively eusocial insects were likely to be moulded by a complex interaction between selection at the individual and colony levels. Subsequently, he contributed in diverse aspects of insect ecology and diversity research

Professor KC's style of teaching and communication of science in a simplified manner was unique. He strongly emphasized creative thinking and vast reading. He holds the attention of the students for two to three hours without letting them get bored because his classes were more of discussions and debating. He taught entomology in the light of evolutionary biology. His classes on interpretation of experimental results with complicated statistical analysis in a simplified manner made students understand and induced them to think and discover further. He insisted us to explore the library and even he used to teach simple things such as how to search research paper, how to read. He taught us how to hypothesize research problems, how to design experiments and how to interpret results. He always stressed that right framing of hypothesis with clear cut objective is half the thesis done. In addition to the students of GKVK, the Research scholars from IISc and NCBS Bangalore used to attend his thought-provoking lectures. He actively arranged special weekly and monthly lectures by eminent biologists from different parts of the country and abroad.

Prof KC played key role in the establishment of Butterfly Park at Banneraghatta National Park, Bengaluru. He was the mentor for many outreach activities like Insect exhibition, Coleman lecture series, Moth Day, and *Keeta Vismaya* in GKVK Krishimela. These programmes crowd pullers and created awareness about insects among school kids and the public. Apart from the core subject, he used to teach how to communicate science with the public and how to follow research ethics.

Prof. KC was always affectionate towards insect science. He was a great teacher, mentor and inspired many young minds to follow science, especially into the world of insects. Prof KC will be missed by his students, friends, and colleagues. I wish he would be alive, so that he would guide me the same way whenever I had a personnel or professional problem. Rest in peace my dearest professor, your contributions to the field of insect science will be eternal.

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Dr. Veeresh Kumar (1988-2021): An enthusiastic budding entomologist

First time I met Dr. Veeresh Kumar at my undergraduate campus College of Agriculture Raichur in 2007. He introduced himself, and started asking his doubts and queries about Entomology. I was surprised to see the knowledge he gained in agriculture and entomology in particular during his graduation. It is hard to believe that he is no more. Indian entomology fraternity has lost bright, talented, young entomologist at early age.

Dr. Veeresh Kumar was born on 1st June 1988 at Mukkumpi (Gangavati; Karnataka, India) and completed his primary education in his native place and went to Hosapete (Vijayanagara) for his Pre-University education. Later he joined B.Sc. (Agril.) at University of Agricultural Sciences, Raichur in 2006, completed under graduation with merit fellowship. During this period, he was inspired by his teacher Dr. A. Prabhuraj and inclined towards insect science and chosen Entomology for his post-graduation.

In the year 2010, he cleared ICAR- All India Junior Research Fellowship (JRF) exam with 9th Rank and joined M.Sc. at University of Agriculture Sciences, GKVK, Bangalore. He worked on the thesis titled 'Insect pest dynamics of Jatropha a bio-diesel plant', where he documented the insect pests of Jatropha, their biology and developed management schedules under the guidance of Dr. C.T. Ashok Kumar. His research received a gold medal award for outstanding M.Sc. thesis. Later in the year 2012 he joined Ph.D. at the same university with a UGC fellowship. For his doctoral research, he worked on taxonomic studies of leafcutter bees (Hymenoptera: Megachilidae) of southern India under the guidance of Prof V. V. Belavadi. He described 49 species of leaf cutter bees from South India and also developed artificial nests for leaf cutter bees to conserve pollinator diversity.

Dr. Veeresh Kumar succeeded in Agriculture Research Service (ARS) exam with first rank and joined service in 2015 at ICAR- Central Agroforestry Research Institute, Jhansi. He started research profession with insect pollination studies in Jatropha (*Jatropha curcas*), Sunnhemp (*Crotalaria juncea*, L.), Niger (*Guizotia abyssinica*), *Butea monosperma*, and Donky berry (*Grewia flavescens*). Within a short span of his research career, he published 22 research articles in peer reviewed national and international journals. In addition to this Dr. Veeresh is a good orator and he inspired many students for preparation of competitive exams like ICAR-JRF, SRF and ARS exams by his lectures. For the benefit students he started a YouTube channel “Veeresh Tutorials" where he was teaching basic agriculture and insect science to the aspiring agriculture students and entomologists. His YouTube channel becomes more popular and received lot of appreciation as it was crossed more than one million views within a year. Further, for his insect pollination research, he was awarded DST young scientist award and also selected for Fulbright fellowship for postdoctoral research under USIEF programme, due to his health issues he could not join the programme.

Dr. Veeresh was diagnosed with lung cancer in early 2019 it was shocking for all of us. With timely treatment, he was responded well, due to post covid complications he breathed last on 1st March 2021. I hope his contribution to pollination research in such a short carrier will pave the way for future advancements in the field of insect science. He will remain eternal in the hearts of many young, aspiring students, friends and entomologists.

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Let Me Introduce Myself: Thrips

Tightly holding the host by making grips
Hello, my name is thrips
Hot and dry weather promotes my rate
Body measuring 0.5-15 mm, slender and elongate
From one place to another, wind helps me to spread
Without hand lens, I might resembles a thread
Being a pest, can infest the crop from tip to root
My characteristic feature is fringed wings with bladder foot
Short, 6-10 segmented antennae, found on my head
When attacked, some of my species behave like a dead
Mouthparts are rasping and sucking, right mandible always lack
Colour of my adult varies from white, yellow, brown to black
Pheromone released by opposite sex helps me to seduce
Bisexually, Parthenogenetically in both ways I can reproduce
Small shiny eggs on host I usually lay
Sometimes act as predator by attacking the prey
Nymph, that's people call my immature stages
I am living on this planet since many ages
Exopterygote having pupal stage, that's my prominent character
Transmit the viral diseases by acting as a vector
Weak flier, it can't change my fate
Not good as honey bee, but little bit I do pollinate
Not seen me yet, you can monitor me using a trap
After this brief introduction, I think it's time to wrap.....

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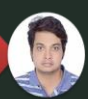
FOURTH INDIAN ENTOMOLOGIST PHOTO CONTEST: THANKS FOR OVERWHELMING RESPONSE

The Indian entomologist photo contest aims to encourage insect photography among photographers, professionals, amateur entomologist and the layman. The theme of the fourth episode of the photo contest was ‘Insects and aspects related to insect life’. With these objective entries were invited during May 25th to June 20th 2021. Each participant was to submit one good photograph which met a few prescribed standards along with the filled in application form in which the participant had to furnish his/her details, caption, description, specifications of the photograph and also a declaration on the ingenuity of the photograph. We received a total from 120 entries which were screened first for the prescribed standards and overall quality of the image. Final evaluation was done by a committee of independent members under the oversight of the three editorial board members and also by an invited expert, based on the following criteria: quality (clarity, lighting, depth of field, composition), relevance of the subject matter (theme, rareness of subjects), creativity and originality. To ensure a blind review the details of the photographer was hidden and the evaluators were only presented with the photograph, caption, description and technical specifications.

- The first place was won by **Mr. Naman Kajli** (202, Raajhans Society, Shreyas Colony, Goregaon East, Mumbai, E-mail: namanpxy31@gmail.com) who captured a Cicada (*Lemuriana apicalis*) ejecting fluid.
- The second place was shared by **Mr. Nyle** (Elamkulam house, Thadakkassery, Palakkad, Kerala, E-mail: nyle.nimbu@gmail.com) for his short of a Golden darlet damselfly (*Ischnura rubilio*) perching on a leaf blade ornamented with dew drops reflecting the surroundings and the morning sun rays and **Mr. Shashank B G** (College of Agriculture, Bheemarayanagudi Shahpur, Karnataka, E-mail: shashankbg006@gmail.com) who captured a shot of dung beetles (*Gymnopleurus* sp.) rolling away a dung ball.
- The third place was shared by **Dr. Prasad S Burange** (Department of Entomology, College of Agriculture, PAU, Ludhiana, E-mail: prasadburange@gmail.com) for his photograph of a spittle bug resting near its froth which had entrapped few tiny flies, Mr. Mohammed Ramees K (Kalathumthodi House, Elamaram PO, Cheruvayoor, Malapuram, Keralal, E-mail: rameeslem@gmail.com) for his shot of cannibalism in robber flies and Mr. Vijay Kamal Meena (Room No-87, Vasant Hostel, IARI, New Delhi, E-mail: vjkamal93@gmail,com) for his photograph of a honey bee (*Apis mellifera*) with pollen load in foraging flight near mustard flowers.

BUG STUDIO ASSOCIATE EDITORS

Mr. S. S. Anooj



Mrs. S. Rajna

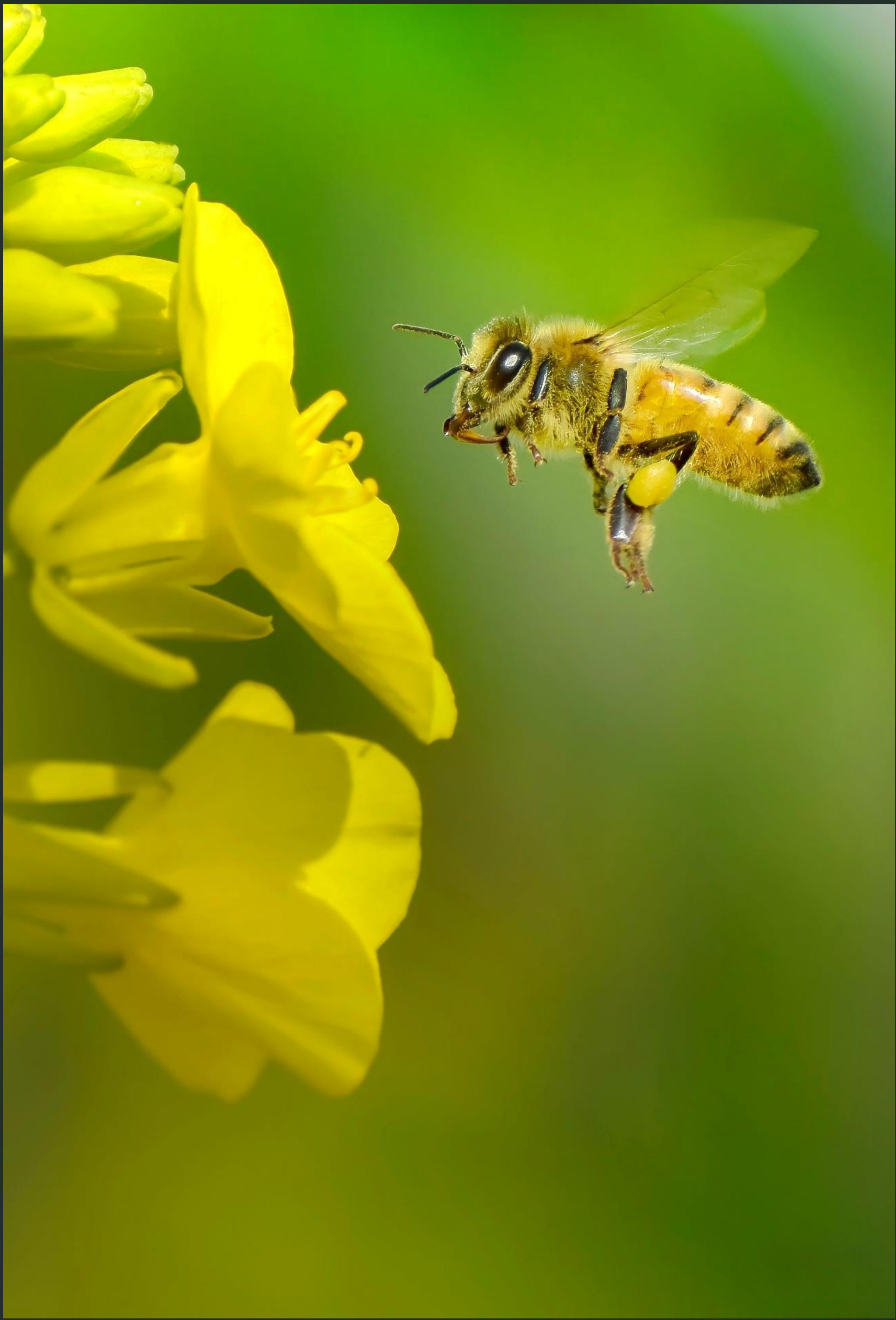
1nd Place: *False rain.* Photo by **Mr. Naman Kajli**, 202, Raajhans Society, Shreyas Colony, Goregaon East, Mumbai. (*Lemuriana apicalis,* CEC BNHS, Film City, Mumbai, 15.06.2021, Nikon D7200 with Nikkor 18-55mm f3.5-5.6G VR lens, ISO 125, f/5.0, 1/80s, FL 38.0 mm with flash, ID credits: Mr. Vivek Sarkar, NCBS, Bengaluru)

2nd Place: *Life thrives in the green.* Photo by **Mr. Nyle**, Elamkulam house, Thadakkassery, Palakkad, Kerala. (*Ischnura rubilio*, Palakkad, Kerala, 30.12.2017, Fujifilm Finepx S20 Pro, ISO 200, F/3, 1/640s, FL 18 mm, ID credits: Mr. Anooj S S, Asst. Professor, College of Agriculture, Padannakkad, Kerala)

2nd Place: *The conservation of Dung beetles*. Photo by **Mr. Shashank B G**, College of Agriculture, Bheemarayanagudi, Shahpur, Karnataka. (*Gymnopleurus* sp., Bheemarayangudi, Karnataka, 16.05.2021, Canon 200D with Canon 55-250 mm F/4-5.6 IS USM lens, ISO 1000, F/6.3, 1/320s, FL 250mm. ID credits: Dr. Nitya Sathiandran, Asst. Professor, SN College, Nattika, Kerala)

3rd Place: *Spittle bug spit*. Photo by **Dr. Prasad S Burange**, Department of Entomology, College of Agriculture, PAU, Ludhiana. [Spittle bug (Cerecopidae: Hemiptera) Nagpur, Maharashtra, 29.09.2017, Canon EOS REBEL T1i with Canon EF 100mm f/2.8L Macro IS USM lens, ISO 200, F/7.1, 1/200s]

3rd Place: *Assassin's creed*. Photo by **Mr. Mohammed Ramees K**, Kalathumthodi House, Elamaram PO, Cheruvayoor, Malapuram, Kerala. (Robber fly (Asilidae: Diptera)), Thrissur, Kerala, 24.04.2020, Nikon D5600 with Nikkor 70-300 mm f/4.5-5.6ED VR lens, ISO 640, f/8, 1/250s, FL 300 mm)



3rd Place: *The pollinator*. Photo by **Mr. Vijay Kamal Meena**, Room No-87, Vasant Hostel, IARI, New Delhi. (*Apis mellifera*, New Delhi, 26.01.2021, Nikon D5600 with Nikkor 70-300 mm f/4.5-5.6ED VR lens, ISO 400, F/8, 1/250s, FL 300 mm, ID credits: Mr. Anooj S S, Asst. Professor, College of Agriculture, Padannakkad, Kerala)

GAMIT SWATI SURESHBHAI

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY, ANAND AGRICULTURAL UNIVERSITY, ANAND, GUJARAT, INDIA

Ms. Swati Sureshbhai Gamit is pursuing her M.Sc. from Department of Agricultural Entomology, B. A. College of Agriculture, Anand Agricultural University. She is working on inventory of plant mites & management of two spotted spider mite (*Tetranychus urticae* Koch) in okra under the guidance of Dr. C. B. Varma, Assistant Research Scientist. Her research work comprises of collection of plant mite specimens from different available fauna of AAU campus followed by its processing and identification. She intends to prepare the list of plant mite species present in the campus which represents the middle Gujarat region. She is also working on the seasonal occurrence of two spotted spider mites, *T. urticae* infesting okra & the occurrence of mites population correlate with different weather parameters. Further, efficacy studies of latest acaricides against the okra mite *T. urticae* under both laboratory & field condition by using standard methodology. In future she is interested to work on the aspects of DNA barcoding which is used for generating reference library for easy identification of the mite species.

B. L. MANISHA

DEPARTMENT OF ENTOMOLOGY, S.V. AGRICULTURE COLLEGE, TIRUPATI, ACHARYA N.G. RANGA AGRICULTURAL UNIVERSITY, ANDHRA PRADESH, INDIA

B. L. Manisha is pursuing her doctoral degree from department of entomology at S.V. Agricultural College, Tirupati, Andhra Pradesh on distribution pattern, host suitability, molecular variability and management of *Spodoptera frugiperda* on maize under the chairmanship of Dr. N.C. Venkateswarlu and guidance of Dr. M.S.V. Chalam. Her research work encompasses of collection of fall armyworm (FAW) specimens confined to rayalaseema region of Andhra Pradesh to contemplate molecular variation within the population on host crops *viz*., ragi, maize, black gram and cabbage as well as to study host suitability under greenhouse conditions, studying the larval and adult taxonomic characters to give a complete species description. She intends to examine the impact of intercropping systems using push pull strategy for management of fall armyworm entailing wide host range *viz*., maize, black gram, ragi, korra, radish, field bean, cauliflower, cowpea and onion. She is also working on evaluation of IPM modules in management of fall armyworm apart from assessment of distribution pattern by correlating with different weather parameters.

SOURAV SEN

DEPARTMENT OF ENTOMOLOGY, ASSAM AGRICULTURAL UNIVERSITY, JORHAT, ASSAM, INDIA

Sourav Sen is pursuing his M.Sc. (Ag.) under the supervision of Dr. Shimantini Borkataki. He is working on stingless bee (*Tetragonula iridipennis* Smith) under the AICRP on Honey bees and Pollinators. He is studying foraging activity and pollination efficiency of stingless bee in cucumber under the poly-house ecosystem as well as to find out the changing patterns of brood, pollen and honey areas of stingless bee in three different kinds of wooden hives and correlate them with several meteorological parameters. His experiments also aimed to observe different pollen and nectar sources of stingless bee throughout the year in the Jorhat campus of AAU. He believes that his experiment will help the future pollination projects by stingless bees especially under the protected condition. In future, he wants to continue his research on wild bees, their taxonomy, behaviour, interaction with different wild flora and fauna.

KRITI SINGH

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY, BIDHAN CHANDRA KRISHI VISWAVIDYALAYA, MOHANPUR, NADIA, WEST BENGAL, INDIA

Kriti Singh is a PhD scholar and currently working on the identification and distribution of aphids from the lower gangetic plains of West Bengal, India under the guidance of Dr. Kusal Roy (Associate Professor). Her work is aimed at the identification of different species of aphids using morph-taxonomic methods. It also includes the preparation of a checklist of the different aphid species prevalent in the lower gangetic plains of West Bengal. This research would help to discover new species of aphids and report new host plants being occupied by the existing and new species. She believes that her research outcomes will enrich the knowledge of Indian aphid diversity and will give direction to manage pestiferous aphid species in agricultural and forest ecosystems. In future she would like to continue this research, expanding it all over West Bengal as well as to a wider variety of host plants. She would also like to incorporate molecular methods for more precise identification of different species.

Ms. Arya P. S., Mr. Priyankar Mondal, Mr. Mogili Ramaiah, Student Associate Editors of IE compiled the information for this section.

ABOUT THE MAGAZINE

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

Notes for Contributors

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

About articles

IE is intended to publish following categories of articles

Commentary – We encourage opinions or critical analysis of current entomological happenings. Submissions should be no more than 5,000 words in length.

Reviews – two types of reviews will be published a. invited review (editorial team will contact eminent entomologists to contribute) and b. peer reviewed review (any author/s can submit a comprehensive reviews on modern entomological developments).

Feature articles – these must be of broad interest to biologists, amateur and professional entomologists. These articles should be no longer than approximately 5,000 words. Articles should contain high quality photographs.

Natural histories & short research articles- with focus on insect life cycle, occurrence etc. and have the same requirements as feature articles. Submissions should be up to 5,000 words in length.

Field notes - on unusual observations entomologists encounter during fieldwork (Invasive insects, outbreaks, behaviour etc.). Submissions should be no more than 2,000 words in length.

Bug studio- "Indian Entomologist Photo Contest" will be conducted for every volume of the magazine and best three winners will be announced in the magazine. Images should be submitted as high quality (300 dpi TIFF, jpeg files) files with a detailed photo caption. The announcement for photo contest will be made on our website www.indianentomologist.org

Student corner- students working on interesting topics of entomology to share their views and opinions about their research work. Can submit with personal photograph; it should not be more than 1,000 words in length.

We encourage entomologists to contact us if you have any interesting story to share about insects.

Contributions to be sent to the Managing Editor, in digital format (MS Word) as an e-mail attachment to indianentomologist@gmail.com

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