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Featuring

Management of Red Palm Weevil

Interview of Padma Shri Prof. Dr. P.K. Rajagopalan

Tête-à-tête with Dr. H.C. Sharma

In conversation with Dr. Ganga Visalakshy

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Editorial Board

***Cover page image: Mr. Raghuram Annadana (Photo taken at Bangalore, Karnataka, 12.02.2022) showing pair of Blue banded bees (*Amegilla* sp.) roosting with their mandibles clamped to a twig.**

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EDITORIAL

INSTIL INSECT SCIENCE IN YOUNG MINDS FOR BETTER LIFE AND CAREER

Insect science is an important area of basic science of biology. This encompasses the biological, agricultural and environmental aspects related to insects. The interactions of insects with humans make entomology an amazing, important and relevant aspect of biology and human life. This is more so because insects and their relatives are the most abundant animals on earth. Insects are ubiquitous and are commonly found in all human habitats, and also in a diversified manner. Due to their diversity, insects play a major role in all the human habitats, especially in maintaining and even sustaining our ecosystems. Thus, insects attract the attention of every one of us at every stage of our life. Their interactions with us start from childhood to even after death with insects inhabiting the dead bodies and carcasses making them forensically important objects. In view of this ubiquitous nature, insects interfere with human life purposefully and significantly. This happens many times benefiting humanity but these considerations take a back burner in general and usually. Many times the harmful and injurious nature of insects get extraordinarily magnified defining these as villains. Negative and harmful nature of insects take lopsided precedence over others, and this needs to be corrected.

Insects, their diversity and the varied functions these perform in the environment provide multifarious economic values. Because of these ramifications insect science offers numerous career opportunities in both basic and applied fields. In view of the importance and relevance of insects explained above, it is essential that core curriculum in schools provide an avenue for students, starting from even primary school education. This is necessary to understand entomology, an important area of biology. Many times as children, the humans start wondering about insects like butterflies, mosquitoes, flies, wasps, bees etc., as and when these are come across. Thus insects always have familiar interactions in our life and this extends for the whole of life. All these imply that we need to provide a balanced education to the children, especially in the basics of insect science, and lay the necessary foundation. This education must focus on insect identification, biology, structure and function, behaviour, ecology, and diversity. It is necessary that insects must be taught in a movement or mission that is integral to biology. As an important component of biodiversity and part of the environment, insects have plentiful interactions with human life. It will be important that as a student, early in our life, we get curious with insects and their interactions, due to their familiarity. We must know this integral aspect of biology in its essential terms to make insect science relevant and purposeful. Making these details known to the children, when they are students, will enable them to select an area of focus which meets their own interest and career objectives.

This way of making children know about insect science, with designs for students interested in careers focusing on the basic biology of insects and other arthropods is immensely valuable. It will go a long way in addressing the relevance and importance of insects in human life. As children, many of us do not get awareness of the multifarious roles the insects play in human life. This option of making the children aware of insect and insect science will facilitate those considering any career involving entomology. It will also make them aware of the plentiful options that are available in insect science- oriented career opportunities. Professional entomologists contribute to the betterment of humankind by detecting the role of insects in the spread of disease and discovering ways of protecting food and fibre crops, and livestock from being damaged. They study the way beneficial insects contribute to the wellbeing of humans, animals, and plants. Career opportunities for entomologists are available with government agencies, state departments of agriculture and forestry, agricultural research stations, university extension service, agrochemical company field representatives- research, and sales; agricultural consulting firms; private agribusiness firms; seed production companies; and international development agencies. Career opportunities also exist as pest control operators; park/ garden/ and golf course pest management specialists; mosquito and weed control; food processing industry; ornamental/ landscaping plant protection; public health service; industrial pest control; and with the armed forces. We must make the children know these early in their career and make insect science relevant and functional to accomplish these towards beneficial facets of human life. It is high time the curriculum is accordingly modulated in the schools so that insect science gets seeded early in our life, befitting the numerous interactive and purposeful values of insects and insect science.

V.V. Ramamurthy
Editor in Chief, Indian Entomologist

FEATURE ARTICLE

Contemporary challenges and future perspectives on the management of red palm weevil

J. R. Faleiro and Mustapha E Bouhssini

Abstract: After gaining foot hold on date palm in the Middle East during the mid-1980s, the Red Palm Weevil (RPW) *Rhynchophorus ferrugineus* Olivier has spread rapidly in several countries emerging as key pest of palms in diverse agro-ecosystems worldwide. The cryptic nature of the pest makes detection of infested palms difficult. However, palms detected in the early stage of attack respond to curative chemical treatment. RPW is currently managed through a pheromone trap based Integrated Pest Management (IPM) strategy comprising of several components, with varying degrees of success and failure. Each component of the current IPM strategy is besieged with drawbacks and challenges, from lack of quarantine protocols coupled with weak enforcement to check the movement of infested planting material, the non-availability of an efficient, easy to use and cost effective infestation detection device, over dependence on chemical treatments, difficulties in the maintenance and servicing of food baited pheromone traps, labour intensive protocol for the removal and disposal of severely infested palms, lack of effective biological control program , poor farmer participation in the control programs, besides inefficient data collection and reporting for proper monitoring and validation of area-wide RPW-IPM programs resulting in the waste of scarce and precious resources. This paper gives an overview of the status and prospects of managing RPW.

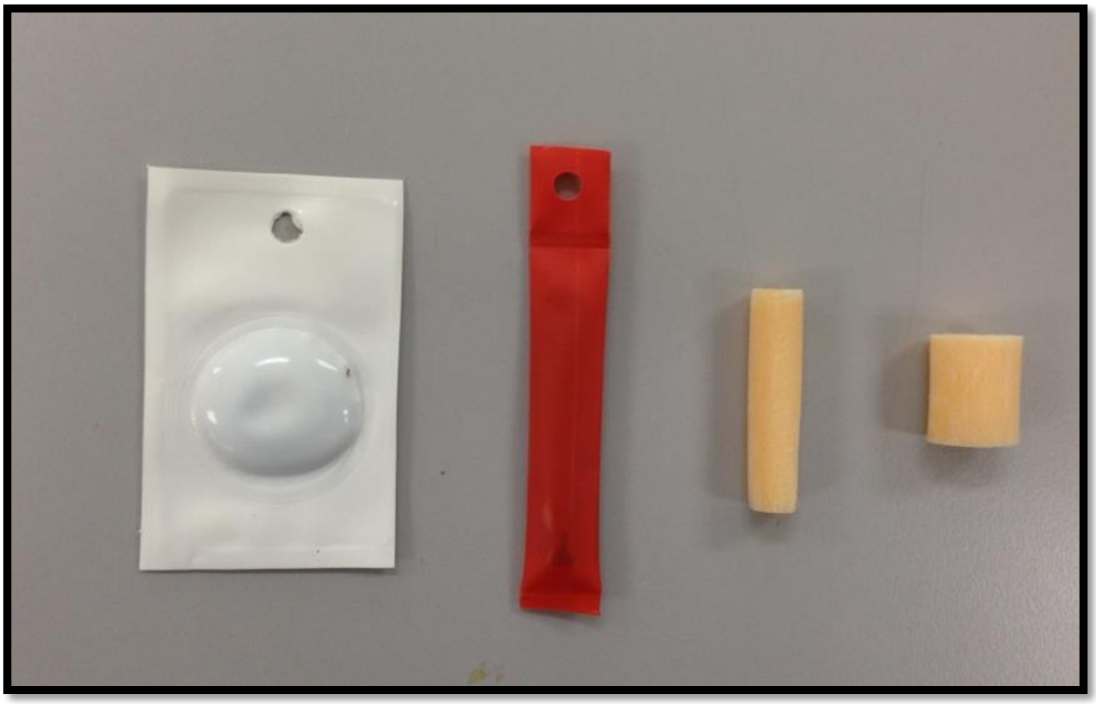
South Asia is the home of the Red Palm Weevil (RPW) *Rhynchophorus ferrugineus* Olivier (Coleoptera: Curculionidae) where it is a key pest of coconut, but has significantly expanded its geographical footprint since the mid-1980s and emerged as the most destructive pest of palms worldwide (Faleiro, 2006; Giblin-Davis et al., 2013; El-Shafie and Faleiro, 2020). During 2019, RPW was detected in Bosnia - Herzegovina in Southeastern Europe and in Bulgaria in the Black Sea Basin. Recent reports of RPW invasion suggest that the pest is establishing in the Caucasian region where it is detected in Abkhazia on the canary island palm in the Republic of Georgia and from East Africa in Djibouti on date palm. Ecological niche modelling predicts that this pest can expand its range further (Fiaboe et al., 2012). Flight mill studies have demonstrated that RPW has the capacity to fly up to 50 km in a day with flight activity being predominantly diurnal.

However, a sizeable population is short distance fliers (<100m) which would explain the aggregated/clumped distribution of infestation (Faleiro et al., 2002; Ávalos et al., 2014; Hoddle et al.,2015). Several overlapping generations of the pest may occur inside a single infested palm (Dembilio and Jacas, 2012), which may be due to the fact that part of the population is characterized by 'non-flyers' (Hoddle et al., 2015).

Colour Morphs of Rhynchophorus ferrugineus

The host range of RPW has also rapidly and significantly increased, from just four palm species in the 1960s to 40 palm species reported in diverse agro-ecosystems (Anonymous, 2013; Giblin-Davis et al., 2013). During March 2017 FAO organized a 'Scientific and High-Level Meeting on the Management of RPW during March, 2017 and through the 'Rome Declaration' called for the urgent need to combat RPW by collaborative efforts and commitments at the country, regional and global levels to stop the spread of this devastating pest.

Several countries are currently working on a wide range of RPW-IPM technologies to address the drawbacks and challenges of the current IPM strategy with ongoing research programs including early detection, phytosanitary measures, new semiochemical techniques involving attract and kill and push-pull strategies, host plant resistance, preventive and curative treatments, biological control, removal and disposal of severely infested palms and data collection using GIS for efficient decision-making that will foster farmer/ homestead owner participation in the management of this deadly pest (Faleiro et al., 2019). Additionally, the socio-economic impacts of RPW need to be assessed



RPW Pheromone Lure Dispensers

(Abdedaiem et al., 2017). Furthermore, lack of farmer participation in the control program in several countries is a limitation for the successful management of this lethal pest (AlDobai and Ferry, 2017; Faleiro et al., 2019), Advanced molecular research on RPW (Soffan et al., 2016; Antony et al., 2019), needs to be exploited for strengthening the existing control strategy.

The current RPW-IPM strategy is besieged with several challenges and area-wide programmes are often constrained due to lack of adequate manpower and resources (Ferry et al., 2018). This paper presents the status, challenges and outlines the future perspectives of the RPW-IPM strategy. Following is an insight on each component of the RPW-IPM strategy.

Semiochemicals: The discovery of the male produced aggregation pheromone (ferrugineol) by Hallett et al., 1993 has led to the wide use of food baited pheromone traps.

to monitor and mass trap the pest (Abraham et al., 1998; Hallett et al., 1999; Vidyasagar et al., 2000; Oehlschlager, 2016; El-Shafie and Faleiro, 2017; Al-Saroj et al., 2017; Soroker et al., 2015; Vacas et al., 2014). Pheromone trap captures help in optimizing/prioritizing inspection of palms to detect infestations. Depending on the availability of human resources, palms around traps with higher visual captures should be inspected on priority.

It is of utmost importance to adopt the best trapping protocols with respect to trap design, density, servicing (periodic renewal of food bait), placement, lure attraction etc., for food baited RPW pheromone traps. Adopting sub-standard trapping protocols would adversely impact the trapping efficiency and consequently limit the success of the control program (Faleiro and Al-Shawaf, 2018). Regular trap servicing (replacement of food bait and water) makes pheromone trapping of RPW cumbersome, labour intensive and costly.

The bait and trap free technique of attract and kill has been used to curtail the emerging adult RPW population (El-Shafie et al., 2011; El-Shafie and Faleiro, 2020). The dry Electrap^{TM} is another service-less RPW dry trap that works without the food bait/water (Al-Saroj et al., 2017). Smart traps capable of recording and transmitting weevil capture data on a 24x7 basis have been developed (Aldhryhim and Al-Ayedh 2015) but have yet to be deployed on a large scale in control programmes. Spotta-UK offer IoT based field validated smart trapping technology against RPW (https://www.spotta.co/agriculture).

Recently high boiling repellents tumerone, vanillin, nepetalactone and cinnamic acid were found to collectively induce a high degree of stimulo-deterrence against RPW with a trap shutdown of 83.8%. RPW repellents need to be tested to protect fresh injury sites on palms and also in devising a broader RPW semiochemical mediated control strategy by deploying the above repellents as non-host volatiles in the field in conjunction with pheromone (ferrugineol) traps in area-wide push-pull RPW control programs (Faleiro et al., 2022).

Detection of infested palms: Although advanced techniques such as detecting chemical signatures, acoustic detection, use of infrared cameras, thermal imaging, satellite imaging/IoT etc., are being researched upon (Pugliese et al., 2018; Mankin, 2017; Soroker et al., 2017), farmers have to rely on visual (manual) inspection to detect an RPW infested palm. Here, regular

45-day interval inspection of date and coconut palms in the susceptible age group of less than 20 years old is vital to break the cycle of the pest by locating an infested palm before adults emerge. In the Canary Island palm, infestation occurs even in older palms and is usually confined to the crown where early detection becomes extremely difficult.

Chemical treatments:

Preventive: Preventive chemical treatments should only be carried out in farms with high weevil activity as gauged from high infestation and removal of infested palms / high trap captures / high seasonal activity. Treat all fresh wounds especially the wounds on palm immediately after frond and offshoot removal (Faleiro,2006; Dembilio et al., 2015; Al-Dosary et al., 2016; Milosavljević et al., 2018). Commonly used insecticides for preventive treatments: imidacloprid, thiamethoxam, avermectin, abamectin, chlorpyrifos, phosmet. Some of the insecticides are being phased out and need to be used with caution. It should be borne in mind that regular, periodic, and preventive insecticide treatments are often unnecessary and excessive, which would have negative impact on the environment as a whole.

Curative: Palms in the early stage of attack recover with insecticide treatment (Ferry and Gomez, 2014; Aldawood, et al., 2013; Gomez and Ferry, 2019). We need to go for the simple diffusion method by cleaning the palm around the infested site on the palm, drilling 4-6 slanting holes 20cm deep at an angle and pouring insecticide solution into each of the holes. Treat the palm again after 15 days. Once the palm recovers and infestation is close to the ground, cover the treated site with soil to facilitate rooting. Commonly used insecticides for curative treatments: imidacloprid, thiamethoxam, avermectin, abamectin. Several pressure injectors are available in the market, which should be used with extreme caution (not > 2bar pressure) to avoid rupture of palm tissue that can lead to death of the treated palm. Only limited number of stem injections may be carried out in ornamental palms, while prohibiting stem injection on a preventive basis in palms grown as food crops (Ferry and Gomez, 2014).

Removal of severely infested palms: Severely infested palms often harbor adult weevils and must be removed (eradicated). Such palms disperse adult weevils in the field that initiate new infestations. In many countries shredding machines are used to destroy severely infested palms. In-situ (on farm site) removal and disposal of severely infested palm tissue by cutting into small pieces (20x10 cm) and soaking with insecticide is recommended (Ferry, 2017). In countries where removal of severely infested palms is outsourced to private agencies, bureaucratic procedures in issuing work orders to contractors often result in delays which in turn leads to the spread of the weevil.

Abandoned and neglected plantations also harbor the pest and have to be closely monitored for incidence of RPW by intensive inspection campaigns. Farmer cooperation to assist in tackling the pest in neglected gardens should also be sought through persistent awareness programs. The technique of attract and kill is suited for such plantations.

Assessing the control program: GIS based models can be developed to validate the strategy at periodic intervals based on trap captures and infestation reports (Massoud et al., 2012; Fajardo et al., 2017). This helps to judiciously use the resources where most required. FAO has proposed real time data base and web portal for the management of RPW at the local, national and NENA Region. Furthermore, a mobile app for android and iOS smart phones to record geo-referenced data at the field location on a standard form needs to be developed. FAO has made initiatives in this regard both at the regional (NENA) and global levels by developing the web based RPW platform to present the RPW maps and analyse data through the '*SusaHamra*' mobile application (Yaseen, 2018; Cressman, 2019).

Phytosanitation/Quarantine: Keep a strict watch on movement of planting material (offshoots/palms) for both farming and landscape gardening so that only treated and pest-free material is allowed to be transported within national boundaries (Faleiro, 2006; FAO, 2019). Although regulations/decrees to regulate the movement of palms for planting exist in several countries, implementing the decree in letter and spirit is often lacking (FAO, 2019; Balijepall and Faleiro 2019). In this context some European Union (EU) guidelines that could be useful are: delimitation of survey and demarcated areas, three monthly official inspections of palm nurseries, annual crop declaration, application of phytosanitary treatments, registration of planting material movement and use of plant passport to monitor trade of palms. Developing certified palm propagation programs (certified seed), through tissue culture would go a long way ensuring the propagation of pest free material.

Palm resistance to RPW: Although some preliminary research has characterized palm cultivars in term of tolerance/susceptibility to RPW (Dembilio et al., 2009; Alayedh, 2008; Faleiro, 2014), host plant resistance has not been fully studied and exploited. Farmers still cultivate their preferred commercial cultivars, which are often the most susceptible to RPW. Efforts should be put in developing handy screening techniques to identify resistant cultivars and parental material for use in breeding programs. Molecular markers associated with resistance to RPW need to be developed and used in breeding programs for the development of resistant cultivars. Advanced molecular techniques such as RNAi could hasten the utilization of host plant resistance against RPW (Al-Dosary et al., 2016).

Protecting fresh wounds: Frond and offshoot removal call for immediate treatment of wounds on the palm to mask the emitting palm volatiles and avoid the gravid female weevil getting attracted to these sites for oviposition.

Impact of irrigation/In-groove humidity: High in-groove humidity is known to attract and harbor adult weevils (Aldryhim and Al-Bukiri, 2003). With flood irrigation water touches the trunk at the ground which encourages adult weevils to oviposit in the collar region of such palms, resulting in new infestations. Build-up of in-groove humidity is accelerated by dense planting coupled with flood irrigation and inadequate drainage.

Biological control: The rapid trans-continental distribution and expansion in host-range of this invasive pest demands urgent attention to explore the most effective and efficient approach to protect date palms in a sustainable manner. Conventional control measures, such as mass pheromone trapping and insecticide application via both injection and spray have not given satisfactory results. Therefore, target-oriented and eco-friendly sustainable approaches should be explored for the management of this pest. The current RPW-IPM program could be significantly strengthened if biological control agents (Mazza et al., 2014) could be delivered to the target site and sustained in the field. Laboratory and semi-field cage studies showed the possibility of infecting RPW adults with *Beauveria bassiana* using pheromone traps (Hajjar, 2015). Reports from Spain suggest that the entomopathogenic nematodes (EPN) (*Steinernema sp)* (Dembilio et al., 2010) and the entomopathogenic fungi (EPF), *Beauveria bassiana* (Gűerri-Agulló et al., 2011) are promising in the field.

The two tachinid parasitoids are: (i) *Billaea menezesi* (Townsend) reported more than 25 years ago in the South of Bahia/Brazil, where parasitism rates of up to 72% on *Rhynchophorus palmarum* (L.) have been registered (Moura et al., 1993); and recently, (ii) *Billaea rhynchophorae* (Blanchard) (Diptera: Tachinidae) reported from oil palm and a native palm species, *Attalea funifera* Mart (Moura et al., 2006). Considering the extremely high parasitization rates registered in Brazil and the observed parasitism of five different genera of palm weevils, the parasitic flies could be a promising complement to the currently employed RPW control methods.

However, before beginning attempts of large-scale introduction, there is a need to do a proof of concept of these tachinid parasitoids to demonstrate their capacity to parasitize RPW successfully.

Extension and capacity building programs: Regular dissemination of the latest information on RPW-IPM among officials, plant protection personnel, extension agents and farmers through capacity building programs and also electronic and print media is essential for the successful control of this pest (FAO, 2019).

Farmer participation in RPW control: Farmer participation and cooperation is vital for any IPM program to succeed (Yu and Leung, 2006). Efforts need to be made to ensure farmer participation in the control programme. The challenge is to enhance the involvement of farmers in the control of RPW in their farms, especially in the GCC countries and keep state support/participation in the program to the bare minimum (FAO, 2019).

RPW control implemented through private companies:

Area-wide RPW-IPM programs are being outsourced to private companies in some countries. Here the lack of experienced staff to oversee operations in the field is a major constraint. Furthermore, it is essential for the Government authorities to efficiently supervise, monitor and evaluate the control program implemented by the private company, on a regular basis. Inadequate supervision will result in waste of precious resources, besides proliferation of the pest. Efficient control of RPW in the field calls for maintaining continuity of the field operations. Often in countries where RPW control is entrusted to private agencies, there is a delay in providing necessary inputs (pheromones, insecticides, etc.) and also in finalizing the tender/quotation for the subsequent period before the expiry of the on-going tender. Any break in the control operations will dilute the success achieved and result in the spread of the pest.

New FAO initiatives against RPW

Based on the recommendations of the "*Scientific Consultation and High-Level Meeting on Red Palm Weevil Management"* held in Rome during March 2017, FAO has initiated two major projects against RPW during 2018 i) FAO Programme on Red Palm Weevil Eradication for the NENA region and ii) FAO Global RPW management platform.

The regional initiative aims to support efforts/programs of countries in the NENA region to contain the spread and eradication of RPW. The key outputs of the project revolve on governance, monitoring, scientific research, capacity building and coordination of RPW control response coordinated across countries and the region. The program aims to boost ongoing research on the applicable approaches of biological control, innovative detection and studies on socio-economic impacts (Yaseen, 2018).

The global FAO project on RPW monitoring and early warning system aims to address critical shortcomings in the field for effective monitoring and efficient management of RPW; to systematically collect standard geo-referenced data. The data collection system consists of a mobile App and GIS- based online system combined with remote sensing imagery for data analysis and mapping (Cressman, 2019). FAO, 2020 gives a detailed account on the guidelines of RPW management.

Conclusion

Although RPW is a difficult pest to control, there have been success stories in isolated pockets reported from different countries (Hoddle et al., 2013; Al-Dosary et al., 2016). In the recent past, Mauritania and the Canary Island have reported successful containment and eradication of the pest (FAO, 2019). However, the RPW control programs have not been fully successful (FAO, 2019). There is still need to devise efficient, cost effective and farmer friendly early detection tools, besides deploying efficient biological control agents that can be sustained in the field and addressing issues facing application of quarantine measures. There is also an urgent need to further intensify RPW research to develop user friendly technologies with respect to early detection, phytosanitary measures, semiochemical techniques, preventive and curative treatments, biological control, removal of severely infested palms, data collection and decision-making tools that will foster farmer/homestead owner participation in the management of this deadly pest. The effects of the RPW and the measures required to eradicate and control it are having significant impacts on the palm tree populations and landscape in affected areas. In addition to the direct economic losses related to production losses caused by RPW, there are economic losses related to the measures and resources to prevention and control the RPW (chemical and non-chemical). This calls for studies to be carried out on the socio-economic impacts due to RPW. Furthermore, several new RPW-IPM tools (RPW detection sensors, pesticides, injectors, semiochemicals, smart traps, microwave devices etc.) are available in the market, but need proper validation. The current RPW-IPM program offers hope and as witnessed in the Canary Islands of Spain, and Mauritania. Though challenging, with proper planning and coordination supported by adequate resources (human and material), it is possible to successfully control this dreaded pest of palms.

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Dr. Jose Romeno Faleiro: *Dr. Faleiro is internationally renowned for his work on red palm weevil (RPW), with deep insight on both the control and research of this key pest of palms. His work on RPW goes back to nearly three decades when he was deputed during 1993 by the Government of India/ICAR as a member of the Indian Technical Team on RPW to the Ministry of Environment, Water and Agriculture in Saudi Arabia where he worked for a period of five years until 1998 in the Al-Hassa oasis of Saudi Arabia at the Directorate of Agriculture, implementing an area-wide strategy to control RPW. Dr. Faleiro has led Research Projects on RPW in India (Indian Council of Agricultural Research) and Saudi Arabia (Food and Agriculture Organization of the UN and King Faisal University). These projects generated valuable data on RPW involving repellents, GIS, host plant* *resistance, attract & kill, pheromone technology, etc. Several of these findings are widely used to manage RPW in date palm and other palm based agro-ecosystems. Dr. Faleiro has also widely published his research on diverse aspects of RPW in internationally renowned peer reviewed Journals besides writing book chapters and presenting invited talks on RPW in several countries. His publications are widely cited. Since 2008, he has completed numerous consultancy assignments for FAO and other international organizations on RPW in different date producing countries including Egypt, Iraq, Libya, Mauritania, Morocco, Republic of Georgia, Saudi Arabia, Sudan, Tunisia, UAE, and Yemen. Dr. Faleiro delivered a lead talk on the management of RPW during the "Scientific Consultation and High-Level Meetings on Red Palm Weevil Management", organized by FAO and CIHEAM, Italy, 29-31 March, 2017. He has been a resource person on IPM for FAO, ICARDA and Michigan State University, USA. In recognition for his work on RPW in the date palm sector, Dr. Faleiro received the prestigious "Khalifa International Date Palm Award" during 2015 in the "Distinguished Figure" category from the Government of the United Arab Emirates as a lifetime achievement award.*

Dr. Mustapha El Bouhssini: *Dr. El Bouhssini earned his PhD in entomology from Kansas State University (KSU) in 1992. He started his research career as entomologist at the Dryland Research Center (INRA-Morocco) before joining the International Center for Agricultural Research in the Dry Areas (ICARDA) in 1996. Dr. El Bouhssini has been an Adjunct Faculty at KSU, Entomology Department since 2005. He joined Mohamed VI Polytechnic University on in 2021 as Professor of Entomology and Program Lead, Biodiversity and Plant Sciences. His major research focus has been on Integrated Pest Management (IPM) of key pests of cereals, food legumes, date palm and cactus. Dr. El Bouhssini has made exceptional contributions to the development of IPM options that are increasingly used and scaled out particularly in the West Asia, Central Asia, and North Africa regions. Dr. El Bouhssini has been the recipient of several awards that have recognized his achievements in the scientific field of entomology. Major awards include the 2021 Grand Prix Hasan II for Invention & Agronomic Research, category of Advanced Sciences and Technologies, the 2018 Lifetime Achievement Award in plant resistance to insects from the International Association of Plant Resistance to Insects, the 2014 Distinguished Scientist Award from the International Branch of the Entomological Society of America, the 2014 Distinguished Alumnus Award from the Kansas State University Department of Entomology and the 2007 International Plant Protection Award of Distinction from the International Association for the Plant Protection Sciences.*

A Journey Through the History of Medical Entomology in India-An interaction with Padma Shri Prof. Dr. P. K. Rajagopalan

DISTINGUISHED MEDICAL ENTOMOLOGIST SHARED HIS LIFE JOURNEY WITH DR. K.A. SUBRAMANIAN

When I received a phone call from Dr. V. V. Ramamurthy to interview Prof. P. K. Rajagopalan, I was thrilled and scared simultaneously. It was akin to the feeling of seeing Himalaya in close quarters with its full grandeur and towering heights. During my post-graduation days, I had met him briefly when he had visited Vector Control Research Centre, Pondicherry for an official meeting. Because of my interest in natural history, especially in birds and training in medical entomology I was familiar and admired of his classical epidemiological work on Kyasanur Forest Disease, Japanese Encephalitis and Filariasis. Dr. Ramamurthy had shared my contact details with Prof. P. K. Rajagopalan (PKR) and within no time, I got a phone call from him and he spoke to me as if we had known to each other for years with a grandfatherly affection. We immediately fixed an appointment and after two days later on 14th January, 2023 I met him at his residence in Thiruvanmiyur, Chennai. Before meeting him, I made a phone call and he give me a turn-by-turn instruction on how to reach his residence, which was of course far more accurate than Google Maps. Just before reaching his residence, he called and told me that he is waiting for me on the road in front of his apartment so that I don't need to search. I was spellbound. He took me to his study, what stuck me was his ease with computers and social media. He will reply to your emails and WhatsApp messages within minutes. There was no structured interview but he shared his vast experience on vector biology and vector borne disease control spanning over 70 years with clarity and remarkable memory. I felt like interacting with a living library and history of Indian medical entomology unfolded in the next three hours of interaction.

Early Life

Prof. Payyalore Krishna Iyer Rajagopalan, well known among colleagues and friends as PKR was born in October 1930, in Mukteswar Kumaon, in the Himalayas, where his father was working as a veterinarian in the Imperial Bacteriological Laboratory. In 1935 he was shifted to his maternal grandfather's home at

Tattamangalam, a tiny village in the old Cochin State of present Kerala (now in Palakkad district) for school education. After completing school education at young age of little more than 14 years, he moved to Benares Hindu University (BHU) for higher education. He completed his B.Sc., and M.Sc. Degree in Zoology in 1951 with "First Class, and first in Order of merit". The education at BHU in his own words

"*I must confess that I did not learn anything to help me in eking out a future career. The whole system of education was faulty particularly in non-professional colleges at that time. In College of science, BHU, there were many departments apart from Zoology, like Botany, Chemistry, Physics, Geology, etc. All these departments were headed by learned academicians, but no one knowledgeable to teach the latest findings in science*". "*To quote an example, though the exo-erythrocytic cycle of malaria parasite was discovered in 1940 or so, the post graduate students were not taught about this in 1950!*"

Like many other post graduates in the department and in the absence of any other alternative, he joined the department as Ph.D. scholar working on a textbook oriented problems allotted by the professor. However, the library of BHU attracted PKR and he utilized the time to improve his general knowledge in many fields and large part of time was spent there. After two years of "research" at BHU he was called in May 1952 for a personal interview for the post of a Research Assistant in Entomology at the Virus Research Centre, Poona (VRC), a joint venture by the Rockefeller Foundation (RF) and the Indian Council of Medical Research (ICMR).

The interview at VRC in the words of PKR.

"*Dr Austin Kerr, who had worked all his life on Yellow fever, was the Director of VRC. He along with Dr C.G. Pandit, the first Director General of ICMR, and a few others were in the selection committee. They asked about malaria – the only answer I knew (as taught by all the universities at that time) was about Anopheles mosquito as the vector of malaria. When they questioned me further, I was bold enough to ask "Which University teaches anything more about malaria? I was taught about evolution of the horses, elephants, structure of the insect, etc." An Indian member of the selection committee considered my answer impertinent. But Dr Austin Kerr and Dr C.G. Pandit asked me to wait. In the end I was called again and appointed to the position. I was also complimented for telling the truth. Many years of frustration made me to call a spade a spade; I maintain these traits even now and as a result I am disliked by many, also admired, may be , by some, but never ignored, even today!*"

KAS: Sir, can you give us a brief overview of your work at Virus Research Centre, Poona (1953-70)?

PKR: "I started my career as a Medical Entomologist (with the rank of a Research Assistant and a monthly pay of Rs.160/-) at the Virus Research Center, a new institute started by the Rockefeller Foundation and the Indian Council of medical Research in 1952. It was the luckiest break I got for starting my career – primarily because the Centre was managed by well-known American scientists from the Rockefeller Foundation. I was less than 23. My life in VRC was like baptism on fire. Earlier the

Rockefeller Foundation (RF) had done a serological survey in many places in India to detect antibodies to arbo-viruses, and the results were published in a paper by Smithburne, Kerr and Gatne. I think this paper was published around 1949 in the Journal of Immunology. The results had shown the presence of antibodies to several group B viruses. One of the main reasons for this survey itself was to find out why Yellow Fever, had not been reported as a disease entity in India. This then led to establishing a research center to study arboviruses. Dr J Austin Kerr, who was a well-known Yellow Fever expert, was the first Director. Dr Harold Johnson was the chief Virologist and Dr C. Brooke worth, the Medical zoologist. Dr T.Ramachandra Rao came on deputation from Bombay Public Health Department, as Medical Entomologist. Dr Austin Kerr was succeeded by Telford Work as Director, and it is no exaggeration that maximum development and expansion of the VRC took place during his time. Dr C.R.Anderson replaced him as Director. Like his name (WORK) he did work, very diligently. Dr Harold Trapido, who was responsible for controlling malaria in Sardinia, was the Ecologist. But the most knowledgeable and experienced scientist to join the VRC was Dr Jorge Boshell. He was a renowned epidemiologist and naturalist of world stature and had spent many years in the jungles of South America and I was privileged to work with him in the field for six long years, learning all aspects of ecology and epidemiology. I owe a depth of gratitude to Dr T.R.Rao, from whom I learnt Entomology, and to Dr Jorge Boshell., from whom I learnt ecology and epidemiology (particularly of arboviruses), and last and not least to Dr Charles Anderson who taught me about *Integrity in Scientific Research which had stood me in good stead.*

The VRC in the early fifties wanted to find the presence and distribution of different viruses pathogenic to man and all its work was directed towards detecting arboviruses form mosquito, human and animal sources. First, we had to get the experience, and I had to learn all about mosquitoes and other Haematophagous arthropods. Apart from Dr T.R.Rao who taught me the *ABC* of mosquito taxonomy, there was no one else in the Entomology Section. Having led a frustrated life for two years in BHU as a “research Scholar”, I was determined to make it good in life. At the time, I don’t think I had any special aptitude for scientific research in particular. But I persevered. I, along with 6 other insect collectors cycled to different places, doing mosquito collections in the morning; in the afternoon identifying the mosquitoes, and preparing pools of different species for virus isolation. In the evening we did outdoor resting and biting (landing) collections at dusk, and returned by 10 p.m. This was a routine for several years. Can you imagine every day seven cyclists with kit bags cycling all the way to different places to collect mosquitoes? Our team was often ridiculed for our appearance. I learnt the subject the hard way. It was the best ecological study ever carried out by any one “on mosquitoes of Poona district” and the results published in *Indian Journal of Malariology* (authors: Rao and Rajagopalan) and it had about 70 or 80 pages. I was very proud of my first paper and my work was recognized by my bosses.

After Dr Rao left in 1954, I was made the “chief of Entomology section” while still a Research Assistant. Another few years of intensive field work in the rainy, leach infested evergreen forests of Colaba and Ratnagiri districts of forests of Western Maharashtra, virtually enhanced my reputation as a field worker. I was then made head of a newly created Field Entomology Division. I was only 25 then, still a Research Assistant with a few scientists of higher rank working under me! Can you imagine such a set up in present day India? Field work was given the due status it deserved at that time and my hard work was recognized, appreciated and amply rewarded by my American bosses. I also took part in investigation of several fever episodes. I also gained a lot of experience by working on ticks and mites!

KAS: Can you explain us about your studies under taken in the tropical evergreen forests of the Western Ghats of Karnataka?

PKR: I must tell you about the detailed studies of a unique ecosystem undertaken in Devimane Ghat', in North Kanara District, Karnataka State, which was a virgin, tropical, evergreen forest. Very few people of the present generation know about this unique study. An ecological study (read ecosystem study) was undertaken to obtain evidence as to why yellow fever was not present in India. Devimane Ghat, situated on the Sirsi-kumta road in North Kanara District, was a typical virgin tropical evergreen forest, similar to deep jungles of Africa and South America where Yellow Fever was prevalent. A large plot of land on the road side located in the Ghat Road amidst forest surroundings was selected and cleared for establishing a Field Laboratory. Tents were set up with all facilities for lodging, and a laboratory. Kerosene operated Refrigerator and a generator was also set up. The entire operation was financed by the Rockefeller Foundation. I was assisted by another Research Assistant named, Lamba: we also had the services of insect collectors, field workers and technicians, etc. We stayed there throughout the duration of the study which lasted for a little over a year. The program included collection of blood samples from human and animal sources, for serological tests and virus isolation. Arthropod collections from different habitats were also made. All collected material was sent three times a week by special couriers to the main laboratory at Poona, by road and train. Imagine the organizational set up and the logistics involved! I was handling the entire show. One of the main studies was on indoor and outdoor resting and man-biting mosquitoes, and their vertical distribution in the forest. Several tree platforms at different heights were constructed deep inside the jungle and biting collections were made throughout day and night for several months. Previously such a stratification study was done only In Trinidad and in Entebbe (Uganda). The entire planning was done by Dr Austin Kerr.

Unfortunately, these studies at Devimane ghat were abruptly terminated, since the personnel had to be moved to another area. The results of investigations from this study were yet to be analysed and published. Recently questions are being asked about the inter-epidemic cycle of Dengue and Chikungunya viruses and the possibility of the existence of a zoonotic cycle for both Chickungunya and Dengue. The results of studies in Devimane could have provided some lead to study and understand important the inter -epidemic zoonotic cycle of these two viruses. I had actually suggested a detailed study on these lines, and to include large and small mammals like monkeys, rodents (as in KFD) and birds (as in WEE and EEE) in 2013. In depth studies must be undertaken on a long-term basis, similar to one undertaken by the VRC at that time, if one has to understand the ecology and natural history of several of the neglected and emerging tropical diseases, Dengue, Chikungunya, Scrub typhus, KFD, etc., so that a break can applied in the chain of transmission. But now the focus is only project-oriented research and publications (with high impact factors) and not problem oriented research.

KAS: Your Investigation of the epidemic of Japanese Encephalitis (JE) in North Arcot District, Tamil Nadu (1954-57).

PKR: The reporting of Japanese encephalitis (JE) cases in Christian Medical College Hospital (CMCH**)** for the first time in India (1954) gave a shot in the arm to the VRC – AND JUSTIFD ITS EXISTENCE. I am sure both the ICMR and RF (Rockefeller Fo8undation) were wondering what to do in India. For the first time since the VRC was established a vector borne viral disease was discovered in India. It was of enormous importance and the Rockefeller Foundation became involved. Most of the work was done by the entomology team (under my leadership) and Dr. Dandawate who was responsible for the virology. We started our working day at about 8 in the morning, collecting mosquitoes till dusk, later identified the species involved and prepared pools for each species. Many lakhs of specimens were collected, identified and processed for virus isolation. We finished each day's task late at night. We were encouraged very much by our Director, Dr Telford Work, who knew each one of us by name and occupation. An unusual behaviour in a team leader at the time let alone these days. Our efforts were rewarded by the isolation of the JE virus from mosquitoes. The human angle was studied by Dr John Webb and Dr Sheila Pereira of the Pediatrics Dept of Christian Medical College and Hospital (CMCH) who did an excellent study of clinical history of JE (mostly in children). The mosquito vectors implicated belonged to the *Culex vishnui* group. The result of this monumental work was later published in an article, entitled "An analysis of mosquito collections in Japanese encephalitis areas of North Arcot District, 1954-57" and published in *the Indian Journal of Medical Research.*

I and my staff later moved to a field laboratory in Akivedu, West Godavari Dist, Andhra Pradesh, to study migrant birds coming to nest in the Colair Lake. This was a large lake formed by impounding Upputeru River in Eluru Dt. We lived virtually on boats, collecting mosquitoes, blood samples fledglings of migrant birds, mostly Grey Herons, nesting here. We collected Laelaptid mites parasitizing these nests. All material was sent to the headquarters laboratory for processing further. It was very hard life- we were living on duck eggs and canal water. We must have stayed for about 6 months there. Suddenly, my colleague, Lamba left to join the Zoological Survey of India (Dr. B.S. Lamba, who did many studies on breeding behaviour of Indian birds later). He was a great companion and good friend and I missed him as we worked as a team for about five years. The work in Akivedu was again terminated abruptly. All the staff then moved to Sagar, Shimoga District, and Karnataka State to take part in the investigations connected with Kyasanur

Forest Disease. As far as I know the results of the work in Akivedu also has not been published.

A decade or so later, I was summoned to investigate epidemics of JE in Tirunelveli (Tamil Nadu) and in Burdwan and Bankura Districts of West Bengal. In a way JE is environment related disease of seasonal occurrence. The epidemiology also varies somewhat in different places as the studies showed. The major vector, *Culex tritaeniorhynchus* breeds profusely in rain/flood water collections, is primarily zoophilic (feeding on animals) feeding on cattle – you can call this pullulator of mosquito population (as distinct from amplifier for which an animal (pig) or bird (Fledgling Ducks, etc). Drought conditions exist in many parts of India, followed by heavy rainfall, flooding and increased wet cultivation. It has been established that some species of migrant birds (e.g. Grey Herons) nest in these areas, bringing the infection.

Investigations on Kyasanur Forest Disease: Investigations on Kyasanur Forest Disease: (19570)

KAS: Can you elaborate on the discovery of Kyasanur Forest Disease (KFD)?

PKR: In March 1957, all of us working in Akivedu were again transferred to Sagar. Typical of the working style of the then Director, Dr Work, we received a 7 or 8 page telegram which virtually told us – to close Akivedu Field Station, keep all the unmovable laboratory equipment with the local hospital and move to Sagar (Shimoga) and giving details of the road route we should follow, since KFD (Kyasanur Forest Disease) HAD BROKEN OUT THERE! An epidemic of fever occurred among forest frequenting villagers in Shimoga District, Karnataka State, coinciding with monkey deaths in adjoining forests in 1957. The etiological agent was a group B virus, belonging to Russian Spring Summer Encephalitis (RSSE) complex. The virus was isolated from humans, monkeys, questing ticks found on forest floor, from ticks collected as ectoparasites of several species of mammals and birds. The virus was more akin to Omsk Hemorrhagic Fever virus. Since its discovery, more than 25000 human cases and more than 7000 monkey deaths had been reported. The disease in man is fatal unless recognized early and treated symptomatically. Investigations showed the involvement of many large mammals and birds, several species of ticks, several species of small rodents, shrews and an insectivorous bat. A complex natural cycle of the virus had raised many questions. Why did the virus become suddenly active in the area? Was the virus introduced through migrant birds and their ectoparasites? What was the role of the monkey, cattle, birds, small mammals, and shrew and their ectoparasites in the natural cycle of the viral epidemiology? Was there a change in the biocoenotic relationship among the different aspects of the ecosystem? This was, (and even to this day) all very fascinating questions and attempts were made to answer them.

My stay in KFD area (for 13 long years) was the most stimulating, interesting and educative part of my life. It was like the ancient *Gurukula Vasam* (students spending life with their teachers in ancient India learning *Vedas*, music etc). I learnt a lot, took my higher degrees (M.P. H. from University of California School of Public Health, Berkeley and Ph.D. from Poona University). From a Research Assistant, I rose to the rank of Assistant Director. *I even got married during this period!* The isolation of and characterization of KFD virus was memorable in one sense, it was the first time that the etiological agent responsible for a new disease was isolated and identified. There was a dead monkey hanging on the top of a tree in the forest; Dr Work was wondering how to bring the carcass down. I (I was only 27 then) climbed to the top of the tree, brought down the monkey carcass almost in fact; all the organs were harvested and KFD virus was isolated from every organ. Dr Work was so happy that he asked me (in March 1957) to soon get married and that he would be sending me (along with my bride) to the University of California, Berkeley, to study for a M.P.H. in Epidemiology! That was one of the greatest opportunities one could ever wish for. Before doing my M.P.H. at Berkeley, I worked for six months at the Encephalitis Laboratory at Bakersfield, Calif. The Unit was working on the Western Equine Encephalitis, under the direction of William C.Reeves (Professor of Epidemiology), who along with K.F.Meyer and W.Hammond, discovered WEE virus. Dr Reeves arranged that I should also get specially trained in Malaria (in 1958) under Lewis Hackett and in Zoonoses with K.F.Meyer at the Hooper Foundation for Medical Research at San Francisco, and other institutions. Before returning to India, I studied Ticks and Mites at the Institute of Acarology, at College Park, Maryland; and also underwent a four-week course in Ecology at the Bureau of Animal Populations, Oxford, under Charles Elton! On my return to India, I started working again on KFD. I had the proud privilege of working with two of the greatest stalwarts, Dr Salim Ali, the world renowned Ornithologist, who guided me for my Ph.D. work, and Dr Jorge Boshell, a very famous epidemiologist and Naturalist. Dr Boshell had worked for many years on Yellow Fever in South American forests, and discovered the sylvatic cycle incriminating of the Yellow Fever Mosquito, *Haemogogus spegazzini* which was transmitting the zoonoses from monkey to monkey in the forest canopy! I had learnt a lot from him, I consider him my mentor in Public Health, Field Epidemiology and a host of other subjects. Not many had this golden opportunity to learn so many things in their career. There was not a field which we had not touched. They included Mosquitoes, ticks and mites, small and large mammals, both domestic and wild; birds, bats, and their ecto-parasites and most of all, the immensely important field of epidemiology of arthropod borne viruses. At the time, I also learnt a great deal about the how the forest ecosystem influenced the zoonotic cycles**.** IT WAS A CHANCE OF A LIFE TIME. It was an investigation of an epidemic with an unknown etiology and which could be followed as an example in many situations.

When the Rockefeller Foundation withdrew from the VRC, the KFD field station was soon closed down and many important aspects like wild animal and tick reservoirs of the virus, etc, yet to be studied. Scores of scientific papers were published during this period. The assignment at the VRC (1957 March to 1970 June) was my last one, as I was transferred to the WHO-ICMR project on Genetic Control of Mosquitoes at New Delhi.

My stay at the Virus Research Center (now it has been renamed National Institute of Virology) was one of the most enjoyable and educational. I left as a fully qualified and experienced Public Health Entomologist and Vector Ecologist recognized the world over. I owe this to my association with some great scientists of the Rockefeller Foundation and to the doyen of Medical Research in India and founder Director General of Indian Council of Medical Research, Dr C. G. Pandit. No amount of praise would be too much for the way the Rockefeller Foundation ran the affairs of the VRC. They built from scratch an excellent Research Institution, with necessary infrastructure. They developed a cadre of scientists and got them trained at the best of Universities and Research Centres in different parts of the world. They encouraged them, and helped all to achieve higher goals in life, including getting higher academic qualifications. I was one of the luckiest, I may say. I had the opportunity to study the work on Dengue at Bangkok, Japanese encephalitis in Japan, Viruses at Trinidad Regional Virus laboratory, ticks and mites at Institute of Acarology at Maryland, many aspects of Eastern and Western Equine Encephalitis at various centre's in the united States; bird migration on an island (Williams haven//Bremerhaven) north of Germany; studies on yellow fever at East African Virus Laboratory. I also spent a lot of time with the British Museum (Natural History) studying taxonomy of Mosquitoes, Ecology under Charles Elton at the Bureau of Animal Populations, Oxford University, and with Harry Hoogstraal, US Naval Medical Research Unit, Cairo, studying ticks. etc. More than anything else, the training I received from many stalwarts like Drs. T.R. Rao, Harold Johnson; Austin Kerr; Harold Trapido; Telford Work, Charles Anderson; and the most important of all, Dr Jorge Boshell at Shimoga for five long years, were very invaluable**.** Above all they gave me the confidence to think logically and speak authoritatively on many subjects particularly vector ecology and epidemiology which stood me in good stead throughout my professional and retired life.

KAS: Can you explain interesting experiments you carried out on genetic control of mosquitoes under WHO-ICMR Collaborative Research Unit (1970-75)?

PKR: In June 1970, I was transferred along with a few others to the above WHO project. I was appointed as Senior Scientist in charge of Ecology. This Unit was closed in June 1975 after a political controversy. Actually, the Americans wanted to use the accumulated PL-480-rupee funds in India and to spend it for experiments on mosquito ecology and dispersal and the results of which could be used for several purposes, including planning biological warfare. Whether the work was planned for this purpose or not, only future events would have shown. But the Unit was closed down abruptly.

Whereas the avowed object of the Unit was to control the vectors of malaria and Filariasis through genetic control methods, the major work was on the dispersal studies on mosquitoes including the yellow fever mosquito, *Aedes aegypti*. No work was done on *Anopheles* mosquitoes, the vectors of Malaria. While a lot of work was done on the Filariasis vector, *Culex quinquefasciatus*, the Delhi area was not endemic for Filariasis. Quite a lot of work was undertaken, which may not have any relevance to the control of filariasis, much less malaria. The Unit, which had to close down following a political controversy, created a storm in the Indian Parliament, and was quite embarrassing to say the least, to scores of Indian scientists working there., The whole planning was by the United States Public Health Service; they signed an agreement with the WHO, and the latter signed another separate agreement with the Indian Health Department. This was a very unusual arrangement and controversial in the history of Indian Science. To detail the particulars here is beyond the scope of the present write up. This will also hurt several people in India and abroad. There was rivalry between three foreign participating groups, one advocating Chemosterilizaion and irradiant of mosquitoes, and another two groups advocating genetic manipulation Cytoplasmic incompatibility and genetic translocation. One of the groups published a news item in their embassy newsletter that the chemosterilant used for sterilization of mosquitoes thiotepa, is carcinogenic. This stirred a hornet's nest in the nationalist Indian press and one National daily wrote a big article. One of the leading science journalists (KSJ) came to investigate this. The WHO spokesperson (RP) at the GCMU, instead of explaining what is happening, tried to turn him away saying that the WHO policy did not allow giving any press interview! Investigations followed and an adjournment motion was tabled in the Parliament and after a heated debate, which was accepted. This was a unique instance in the parliament's history. Later two Public Accounts Committees (PAC) investigated the matter and finally recommended that the Unit should be closed down. The PAC also gave strict guidelines for research with foreign collaboration. (This regulation, I have seen, is followed more in finding loopholes I into it).

Before going into the scientific achievements of the GCMU, which was quite substantial, I must say what went wrong. The sterile male technique which was used was applied for the first time in mid-western United States, to control Screw Worm flies, which bored cattle skin, causing extensive loss for the leather industry. The females mate only once with the males (as also in the case of mosquitoes). Since there was marked difference in size between male and female puparium, they were able to mass rear the flies, separate all the males at the puparium stage, chemo sterilizes them, and release millions of such sterilized males in the population. The mated females laid sterile eggs and thus in course of time, the screw worm fly density was drastically reduced. This is called the sterile male technique. Some scientists wanted to apply this technique to control mosquitoes. Irrespective of whatever technique was used to sterilize the mosquitoes, done at the pupal stage, a 100 percent separation of sexes was not possible because there was not such distinct difference between the male and female sexes. There was always a contamination of 2 to 5 percent, at the time of separation of males from females. When millions of males are released, 100 to 200 thousand females are also released and which are human biting. This was biggest scientific flaw in the experiment. It was also found that the sterilized males, as well as the genetically manipulated males were not competitive with the wild males, and therefore the results were very disappointing. Added to this was the controversy over whether the chemo sterilant used, thiotepa, was carcinogenic or not.

But the main reason why a controversy erupted was because of the extensive work done on *Aedes aegypti* particularly the studies on dispersal patterns, and the plans to mass release them in an industrial township (Sonepat).

Scientifically speaking, however, five years of very extensive and intense studies were carried out at the GCMU and where several well-known International and national Scientists participated. Outstanding work was carried out on Ecology, Bionomics, Dispersal patterns, and Genetics of *Culex quinquefasciatus and Aedes aegypti*. The Unit also trained and produced a team of highly qualified and experienced scientists. who ultimately formed the bulk of the Research Staff of three ICMR Institutes, (1) The Vector Control Research Centre in Pondicherry (VCRC), (2) The Malaria Research Centre in Delhi (MRC) and later the (3) The Centre for Research in Medical Entomology in Madurai (CRIME)

KAS: I am very much interested to know the history of Vector Control Research Centre, Pondicherry.

PKR: Unlike many Research Institutes**,** Vector control Research Centre (VCRC) was not planned to be established, and of all the places, in Pondicherry. Following a political controversy, the WHO-ICMR Collaborative Research Unit on Genetic Control of Mosquitoes (GCMU) had to close down its operations in Delhi in June 1975. Apart from a few WHO Scientists, the majority of whom were Indians and among whom only three or four had permanent positions at the Virus Research Centre, Poona, and who could go back to their old positions. All the rest would have lost their positions. It is due to the farsightedness of Dr C. Gopalan, the distinguished Director General of ICMR at that time that he wanted to utilize the services of trained scientists, that the VCRC was established. There was no regular budget or program, except that since most of the scientists were entomologists and were working on mosquito control techniques at the GCMU it was decided to shift the staff to a new institute for vector control. Dr Gopalan decided to start a Field Division of the VCRC at Pondicherry. I, being a vector Ecologist, was appointed as its new head. At the same time a Laboratory division was also established at Delhi (in the campus of NICD) with the late Dr K.R.P. Singh, an experimental entomologist who was also from the GCMU, as its head. This was according to the directions given in the 200th report of the Public Accounts Committee of the parliament, as a purely temporary measure pending a final decision by an Expert Committee to be formed by the Government. The total budget per year for the two units was estimated at that time as Rs. One lakh, to be met from the left-over funds of the GCMU Until1st April 1977. Both the field and laboratory units of the VCRC were functioning without a regular budget, or even a staffing pattern and several junior technical staff were recruited on daily wages. During the transition period (July 1975 to March 1977), Dr N. Veeraraghavan, retired Director of Pasteur Institute, Coonoor, was asked to look after the establishments pending a decision. The Governing Body of ICMR then made the VCRC a permanent institute under the Council from 1st April 1977, under my charge. (During the course of the following year, the laboratory division was separated into a distinct unit and named the Malaria

Research Centre (MRC) at Delhi, with Dr K.R.P. Singh, in charge. This is authentic story of how the VCRC came to be established. The entire credit for this development belonged to Dr Gopalan (DG, ICMR), who was a visionary in every respect, and to Dr T. Ramachandra Rao

I would like to mention here, that when the decision to move to Pondicherry was taken, many rickety old vehicles along with old furniture, and other laboratory stuff were moved by road to Pondicherry like a caravan with the only knowledge that they were expected to go to the Jawaharlal Institute of Medical research (JIPMER) a central Government post graduate medical institution. We were told to assemble under a tree to await further instructions!! Actually JIPMER offered only two rooms to establish the newly formed VCRC institute. I remember, the Lt. Governor of Pondicherry, Mr. Cheddy Lal, telling us that in Pondicherry, a small union territory, "we will be a PATCH whereas in any other part of India we will only be a DOT". He was also good enough to arrange a huge old French style mansion, called Eni Bungalow, to establish our Institute. Subsequently one or two more buildings were also hired, so that some scientific work could be started.

Before regularizing the institute, from the April 1977, the governing body of the ICMR, gave the following guidelines and objectives:

"*While the VCRC should have the opportunity and freedom of work to work on any vector borne disease as it became necessary, it needed however to concentrate on malaria and Filariasis as a matter of priority. Specific projects relating to vector control with scientifically based approach was of utmost importance to enhance the management of the two major diseases. The design and execution of various components had to be accurate. Our approach was of immense practical significance, without a proper understanding of the vector ecology, the ecosystem in which the species operated, seasonality, and host preferences-it would have been difficult to predict the seasonal transmission patterns and the levels of disease endemicity*".

For any institution working on vector borne diseases, the above directions were like BIBLE. During my leadership of the VCRC these were our guiding principles. Every effort was made to stick to them as far as money and manpower allowed us to do.

From July 1975 to March 1977 was a period of stabilization and consolidation, and also a period for building to build up an infra structure for the new Institute. I had one senior scientist, the late Dr Reuben and four junior scientists (P.K. Das., P.K.B. Menon, and K.N. Panicker) to assist me, aided by several technical and laboratory personal already on the ground in Pondicherry. I had to recruit additional scientific and technical staff for the Center. I was able to fulfil the mandate of the newly established Research Centre with the encouragement and full support of Dr Gopalan.

Pondicherry at that time was highly endemic for Bancroftian filariasis, with the microfilaria rate of above 20%, and malaria in pockets of Pondicherry villages. But in neighbouring Tamil Nadu, in Salem District, there was *Anopheles stephensi* transmitted urban malaria and *A. culicifacies* transmitted riverine malaria. I opened a field station in Salem (with Dr Reuben in charge) to work on urban and riverine malaria. Since filariasis was endemic in Pondicherry area, an extensive two year study was started on all aspects of Filariasis transmission. These studies were intended to provide entomological and epidemiological data, so that effective control measures could be planned. There was excellent co-operation from the Pondicherry health department and from Tamil Nadu state dept of public health. I must mention here that Dr V. Sambasivam, Director of Public Health,

Pondicherry was a great source of help and support on all matters connected with the VCRC, including giving land on long lease for construction of a new building for the VCRC. Similarly, Dr V. Kapali, the director of Public Health, Tamil Nadu and Mr A.V. Ganesan, the then Chief Entomologist of Tamil Nadu offered unstinted support to the VCRC for its work in Salem and later in Rameswaram, where island malaria was highly prevalent. These studies were taking place simultaneously in these places and the local health departments were helped by the VCRC in controlling malaria. Several papers have been published on malaria control.

It must be mentioned here that in the late seventies, when I was in Pondicherry, there was an outbreak of Japanese Encephalitis (JE) in Burdwan and Bankura districts of West Bengal, and Dr Gopalan wanted the VCRC to investigate. The work was done with the collaboration of the School of Tropical Medicine, Calcutta, where the materials collected were tested for virus isolation/antibodies. A significant finding was that *Culex bitaeniorhynchus* played an important role as vector of JE in certain situations, and that fledgling ducks could also harbour the virus and act as amplifiers in the absence of pigs. Subsequently, the VCRC team led by me also investigated JE epidemics in Tirunelveli District of Tamil Nadu, where the epidemiological situation was similar to North Arcot District, which was also investigated by me as part to the team from Virus Research Centre in 1954-55. In my opinion, a significant and unique work, relatively small in magnitude, was carried out by Dr Panikker in Pudukuppam, a coastal village in Pondicherry, where malaria broke out in epidemic form among the fishermen community. On investigation it was found that a sea water breeding mosquito, *Anopheles subpictus,* where algae was found, was the main vector. In fact, the mosquito breeding depended on the presence of algae. By motivating the community, algae were removed regularly and the local Aurobindo Ashram made handmade paper out of it. It was a profitable venture for those involved and vector control became a commercial venture on a sustainable basis and malaria control was achieved. This was technology in action. This actually became a sort of guideline for future vector control operations and followed very successfully in Shertallai, a technology-based mission project to control Brugian Filariasis.

Coming back to urban Bancroftian filariasis the massive data collected during the two-year study showed that the high microfilaraemia in the population was due to very high biting density of the vector, *Culex quinquefasciatus,* breeding profusely in open drains and that drastic reduction in mF rate could be achieved by controlling mosquito breeding to a significant level. The basic studies carried out were unique, and were patterned after the studies in Rangoon carried out by Hairston, DeMeillon, Jacobski and others. I cannot think of any other study in India or anywhere else similar to this. These findings were utilized for control of filariasis. A five year *Filariasis Control Demonstration Project* was launched in January 1981 in Pondicherry and was inaugurated with great fanfare by the then Union Minister for Health, Shankeranand, and presided over by the Lt. Governor of Pondicherry, and attended by Prof. Ramalingaswamy, DG, and ICMR.

The then Prime Minister of India, Smt. Indira Gandhi, sent a special message. The campaign was planned following Fred Soper's work in Panama Canal Zone**,** *"It was not a campaign that introduced new techniques, but a campaign that illustrated what could be accomplished by application of already known techniques, and applying them more vigorously than ever before, coupled with political sagacity and bulldog tenacity"*.

Padma Shri Prof. Dr. P. K. Rajagopalan working in his residence

Essentially, we had planned the project on the pattern of Fred Soper's *Aedes aegypti* eradication project in the Panama Canal Zone to control yellow fever. Dr P.K. Das was put in charge of this project, with special funding liberally sanctioned by the then DG, Prof Ramalingaswamy. I was given full freedom to operate with full support and with no interference. The project attracted worldwide attention and was visited by experts from abroad. For the first time integrated methods of vector control was used on such a large scale. Many people ridiculed the venture. But Dr Ramachandra Rao, the famous malariologist, gave us support and encouragement which we badly needed, by writing to me—

"The integrated control and environmental are *most important developments. However, they will require a*

lot of dedication and hard work. If successful, as they are bound to be, they will be new watershed in our battle against vectors…They will undoubtedly be expensive in the beginning and will attract adverse comments. Already, some people call it utopian, but all new developments appear to be utopian ".

The project was a great success and the results, already published, showed that it is not necessary to eradicate mosquito breeding (which is impossible in Indian urban situation) to eliminate filarial infection, but if the biting density of the vector could be drastically reduced by integrated control methods we could achieve a drastic reduction in microfilarial rate in the community. At the end of the five-year period, there were only three microfilaria cases in children under five years age! The most important by-product of these studies was the creation of a highly trained cadre of young scientists. In trying to tackle Bancroftian filariasis in most urban situations, it is worthwhile remembering what Sir Ronald Ross said, and I quote

Great is sanitation, the greatest work, except discovery, I think, that a man can do…What is the use of preaching high moralities and policies…to people who dwelling in appalling slums..? You must wipe away those slums, that filth, these diseases…We shall reach the higher civilization, not by any the politicians' shibboleths ...and the rest, all of which have failed-but first by the scientific ordering cities until they are fit for men of the higher civilization to dwell in. We must begin by being cleansers". I was able to show that Ronald Ross was absolutely correct, when we demonstrated success of his methodology in Pondicherry.

Follow up Investigations five years after completion of the clean-up operation produced dramatic results. It showed (1) that Filariasis transmission was reduced to negligible levels and very few new cases of microfilaria carriers were found, and, (2) in spite of the very poor infrastructure in Pondicherry, integrated vector control methods did result in a drastic reduction of mosquito population. This was a no mean achievement, and the outcome was applauded by both the people and government of Pondicherry. It was also concluded that (3) in urban areas with poor sanitation and infrastructure, it was not necessary to completely eliminate the mosquito population; even 60 to 70 percent level of reduction in biting mosquito density can be achieved mostly by environmental sanitation and manipulation, and which could dramatically reduce the disease transmission rate in an overcrowded urban population. A low level microfilaraemia in the population can be adequately treated by that wonder drug, Di Ethyl Carbamazine (DEC), used very successively all over the world, either singly, or in combination with other antihelminth drugs, or medicated with common salt.

In Rameswaram Island, where drug resistant *P. falciparum*, was being transmitted by *Anopheles culicifacies* breeding in innumerable pits where water was being stored for watering coconut plantations. Also, the behaviour of fishermen frequently moving from place to place became accidental carriers of the malaria parasite and spreading the infection to other communities in their travels. A team of brilliant scientists lead by Dr Jambulingam, Dr Sabesan and others unraveled the modus operandi of the disease transmission and their results were published in the British journal, *Journal of Social Sciences*, at the request of its editor, who also wrote a forward to the article. This island was contributing to more than 20% to all malaria cases in the whole state, and the Tamil Nadu Health Department used it as a model for their malaria control programmes.

After attaining its objectives, the field station was closed five years later. This study enabled the Centre to train a large group of young malariologists. Dr Jambulingam was transferred to an assignment to study tribal malaria in Koraput, Orissa, and Dr Sabesan to Shertallai in Kerala, to study *Brugia malayi* transmitted Filariasis. The Shertallai studies proved a great success; it demonstrated how people's participation could play a role in successfully managing the disease.

The Koraput Station, in Orissa, was started in 1985, with Dr Jambulingam in charge. It was a difficult working terrain populated by a tribe of unsophisticated Naxalites. Malaria due to *P.falciparum and P.vivax* has been persistent in this region for many years. A young lady doctor, Dr Govardhini was appointed to attend to all health needs of tribal women including gynecological care. This helped the VCRC to gain the confidence of the tribals. The team did a lot of excellent work, including the finding of several cases positive for *P.malariae* and a few cases for *P.ovale.* This field station was the pride of VCRC because of its contribution to help malaria control in tribal area. Under the dynamic leadership of Dr Jambulingam, excellent long term ecological studies were carried out. A brilliant piece of work was by Dr Gunasekharan, whose studies on *A. fluviatilis* were outstanding. This station also helped to train several more malariologists by the VCRC.

The project on Malayan filariasis control in Shertallai, also started in 1985, was initially a Technology Mission Project under the planning commission of India from which the VCRC withdrew later, a move fully supported by the then DG, Prof. Paintal. This was due to a lack of understanding of the problem by one of the influential but ignorant bureaucrats who evaluated the progress. Malayan filariasis was caused by a nematode, *Brugia malayi*, and is transmitted by Mansonia mosquitoes, which breed in association aquatic vegetation, mainly *Pistia* sp. The terrain is sandy, being near the coast, and only coconut trees are extensively grown in the area. There are innumerable pits which get filled with rain water and which is the main source of water for the plantation. All these pits supported luscious growth of Pistia. The siphons of the larvae of vector mosquitoes are attached to the root and stem of the vegetation for their breathing. If the vegetation is removed, the mosquitoes can't survive. Thus, the main strategy adopted was how to regularly get the vegetation removed, by the people themselves. They use the vegetation as manure. A profitable alternative was provided. During the five years, Dr Sabesan and his colleagues demonstrated total interruption in transmission, by combining vector control through people's participation with chemotherapy. This was achieved with community participation based on a people's movement named FILCO (Filariasis Control Movement) which took over the day to day operations. It was demonstrated that early stages of elephantiasis could be cured. The National Board for Agriculture and Rural

Development (NABARD) was also involved in the program and they helped the villagers to find alternative source of manure for their coconut trees and the giant *Gourami* was extensively grown in the pits where the *Pistia* plants were once grown. Massive rallies were organized (similar to the political rallies held these days) propagating community health through community participation. The incentives given was free treatment including treating chronic cases. The results were perceptible after five years when the transmission chain was broken and no new microfilaria positive cases were recorded in the children below five years of age. The work was published, and universally acknowledged.

The Centre had demonstrated different models for vector control. In Pondicherry, the entire operation was carried out by the VCRC. In Rameswaram, the VCRC controlled malaria with the assistance of the State Government and the success was also repeated with control of urban malaria in Salem and riverine malaria in Sathanur. In coastal malaria control programmes in Pudukuppam and in Brugia malayi transmitted Filariasis in Shertallai, it was done with community participation and the people shared additional economic benefits. Following these success stories, the VCRC prepared MASTER PLANS for vector control in Bangalore City, Visakhapatnam, Neyveli Township and Cochin City. But unfortunately, plans were never implemented in any of these places, under one pretext or another. In my opinion there was no political will to implement the plans, which more dependence of environmental methods. The insecticide lobby was too strong.

In the early eighties, The Center sought and obtained affiliation from both Madras University and Pondicherry University. To fulfill the manpower needs of the country, the VCRC started a two-year M.Sc. Medical Entomology course in the early eighties, with an intake of 12 students per year. The syllabus was carefully drawn up to suit the needs of both research and control of vector borne diseases. Initially sponsored by the WHO, later on it was taken over by the ICMR. The WHO and some other foreign Governments sponsored students from abroad. The Centre was also recognized for the award of Ph.D. degrees in Epidemiology, Medical Entomology, chemistry, Microbiology and biostatistics. The faculty included invited guest lecturers and specialist from India and abroad, in addition to the scientists of VCRC. Till 1990, the VCRC turned out more than hundred M.Sc. and Ph.D.'s. Apart from these, there were many training programs in vector control, Medical Entomology, Microbiology, Chemistry, etc which attracted many people from outside VCRC and rest of India, and from many universities and organizations including WHO. The WHO had recognized the VCRC as its collaborating Center for Integrated methods of Vector Control, in the early eighties.

In conclusion, I would like to state that the duration of my engagement (from 1975 to 1990) was an era of challenges, and entrusted with the responsibility of building up a world class Research Institute. I was helped greatly by the then directors general, Dr. Gopalan, Prof. Ramalingaswamy, and Prof. A.S. Paintal, whom I rate as three of the most distinguished Directors-General of ICMR, and under whom I had the privilege of working as Director of the VCRC. They never said no to any good suggestions and adequate powers and finances were given. The deep devotion and dedication to the cause of VCRC on the part of many of my junior scientific colleagues, and the support given by technical and administrative staff, etc., --all these made it possible for VCRC to become a world class research Institution. Dr Paintal, the last of the Director General under whom I had worked, called the VCRC as the pride of ICMR! I am quoting below what two of the great Scientists, both Directors General of ICMR, wrote to me, and I quote:

"The VCRC is one of the most remarkable institutions that has developed under your inspiration, an ability to link up the science of entomology with environment, with life styles of people with public health engineering.... I wish to pay a tribute to you and to your colleagues for your dedicated work" wrote Prof. Ramalingaswamy on the eve of his retirement on 23 January 1986.

The second one was written by Prof. A.S. Paintal on 29 Oct 1990, on the eve of my retirement on 31 October 1990, and I quote**,**

"The time has now come to say thank you for your services to the council and the cause of science for over three decades. A person of your temperament can not retire from active work-nor will it be so in your case. It was your own choice that you are retiring) instead of continuing in the Council's service for some more time as we wished. During your tenure at NIV, Pune, GCMU Delhi and at VCRC Pondicherry, you have undoubtedly left a mark of excellence in the scientific activities you undertook, more so during the decade you have headed the VCRC, and brought it up from its small stature to the present giant status recognized both in the national and international spheres. You have clearly established and demonstrated what can be achieved with limited resources, given proper initiative, drive and leadership".

Both these letters were unsolicited.

While working as Director at the VCRC, I became a member of the Scientific and Technical Advisory Committee; later a member of WHO Expert committee on Malaria, Filariasis; member of the steering committee on Filariasis, and on Biological Control of Vectors. I was also WHO consultant in Indonesia, Vietnam and Sri Lanka. During this association I acquired a fair idea of how the WHO works. But I came across many Scientists –and the friendship with these scientists I still cherish. Notable among them was Dr Mani Pillai, a well-known Professor of Microbiology at the University of Otago in New Zealand. We shared our love for scientific truth and love for Indian Science.

I retired from service on 31 October 1990, after serving the ICMR (Virus Research Centre, 1953-1970, the WHO-ICMR research unit on Genetic Control of Mosquitoes, 1970-1975, and finally the VCRC, 1975-1990) for 38 years. It was a life time career full of learning, opportunities and challenges and I had enjoyed every year of my work for the ICMR. Since retirement, I had served for nearly a quarter of a century as member of many scientific committees, including my tenure as member of the Scientific Advisory Committee of the VCRC for nearly a quarter of a century, where I had received only goodwill and affection from the Director and Scientists.

I have tried to recall my impressions of my scientific career for 38 long years (in service with ICMR) and twenty years thereafter. Starting my career in 1952, the doyen of Indian Scientists and founder Director General of ICMR, Dr C.G. Pandit, recruited me when I was just a boy of 23,.I had engaged myself in the cause of science for about 60 Years now.. I have the full satisfaction having served under no fewer than three of ICMR's greatest Directors General. The only other DG, who joined ICMR long after I had retired, a very knowledgeable scientist, was Prof N.K. Ganguly. I admired him for his erudition and the way he listened to people. He was attentive to the problems of the institutes, and one could have a scientific discussion with him on any subject. I am proud to say that he had high regards for me.

When I retired, I left behind a research institution, with highly qualified and competent world class scientists to run it, and with all infrastructures fully developed. I feel proud that I accomplished a lot. I was honored with many titles and medals –The Om Prakash Bhasin Award (the sponsors said this was the Indian equivalent to the Nobel Prize), The Charles University, Prague, Gold medal for outstanding Research, and the coveted **PADMA SHRI** award from Government of India, all during my stay in Pondicherry. I have received three **Life Time Achievement Awards,** from (1) Association of Medical Microbiologists of India, (2) National Congress of Parasitology and (3) Anna University Department of Biotechnology. I am still engaged in occasional teaching (at SRM University, Chennai), and do write a lot on science, religion and sociology (thanks to the computer help), all for pleasure and to keep my brain active. At a Global Public Health Conference held in February 2014, by the School of Public Health at SRM University (India's largest private University of excellence) I was one of the five scientists honoured for their contribution to Public Health.

KAS: Your thoughts on modern Vector Control Measures

PKR: The epidemiology of the disease indicates that vector control resorted to now a days after the start of the epidemic is only a public relations measure by health departments, and is totally useless. Whether you sprayed insecticides at this time or not, the epidemic was already declining. What is required is how to predict an epidemic and take vector control measures, at the start of the epidemic and prevent transmission. This requires long term studies on the ecology of the vector population and then study population build up so that an epidemic can be prevented. As it is, very little money (in terms of percentage of GDP) is allotted for research in India, and for Biomedical Research only a pittance. Whenever some serious epidemics (e.g. Japanese encephalitis) occur in India and questions raised in parliament the Government immediately allots money. What about known methods of control which are ignored. What are the practical methods to save lives? Unless you suggest some high-sounding costly research, no suggestions are accepted. But epidemics like JE continue to occur, and no one cares to find out why such epidemics recur in many areas with regular frequency. For JE we still do not have an effective single dose vaccine; and even if you have one, what is the target population and in which area, will you vaccinate? When I wrote a paper detailing the epidemiology, and sent it to the authorities giving examples of practical methods of JE control – the "higher ups" cynically laughed it off saying it is SPICY. But one of the highly respected and well-known fortnightly journal FRONTLINE, with a large circulation, published it with the title "Combating the Killer and which had rave reviews. The authorities seem to be saying *"Our minds are made up; do not confuse us with Facts"!* I have always wondered what the aim of research is. The aim should be to find out new approaches which would be helpful to improve our understanding of the epidemiology and control of the disease.

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Tête-à-tête with Dr. H.C. Sharma

EMINENT INDIAN ENTOMOLOGIST WHO FEATURED IN THE TOP 2% SCIENTISTS IN THE WORLD FOR HIS CONTRIBUTION TO INSECT SCIENCE.

Dr. Hari Chand Sharma, born on 15th June 1954, at Behra, Bilaspur, Himachal Pradesh, India, he has more than 40 years' experience in the field of Entomology. His research was focused on developing insect-resistant varieties, use of transgenic crops for pest management, biosafety of GMOs, climate change effects on agriculture, and sustainable crop production for food security. He did his B.Sc. (Ag.) and M.Sc. (Ag.) from College of Agriculture, Solan, under the jurisdiction of Dr. Y.S. Parmar University of Horticulture and Forestry (Himachal Pradesh), in 1974 and 1976, respectively. He was gold medalist in both bachelors and master's degree. Later, Dr. Sharma obtained his Ph.D. from the Indian Agricultural Research Institute, New Delhi in 1979 with Entomology as specialization.

He served as scientist S1&II (1979-1993), Senior scientist (1994-2001) and Principal Scientist (since 2001) at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Telangana, India. From 2016-2019, he served as Vice Chancellor, Dr YS Parmar University of Horticulture & Forestry, Nauni, Solan, Himachal Pradesh, India. Dr. Sharma also served as a visiting scientist at the University of Wisconsin, Madison, USA (1986/87) and Queensland Department of Primary Industries, Toowoomba, Australia (1996).

Dr. Sharma is an excellent leader, he served as Coordinator of several projects at ICRISAT (Integrated pest management (1999/2000); Biotechnological applications for insect resistance (2003/06); and Genetic enhancement of cereals and legumes in Asia (2006/08). He supervised over 20 projects funded by the national and international funding agencies. He had close collaboration with scientists in USA, Australia, Germany, UK, Belgium, France, and Switzerland. He also undertaken collaborative research on crop production and pest management with over 20 National Agricultural Research Systems in Asia and Africa and Latin America. During his tenure as Vice Chancellor, the university has made tremendous strides in financial management from a net deficit to ample in short time. He was instrumental in many novel activities in university to mention few, setting up Botanical Center for North West Himalayan

Region with support from MoEFCC, and Center of Excellance in Climate Change Research in the Himalayas with support from DST are significant.

Dr. Sharma is a researcher par excellence and very well regarded both in the country and internationally. He published more than 700 scientific publications, in that 289 research papers have been listed in Thomson Science Citation Index/Web of Science with 7505 citations, Hi 42, and iH10 index of 172. His name figured among the top 2 percent scientists in the world, according to a study published by the Stanford University, USA.

To his contribution to insect science, Dr. Sharma has been conferred with several awards like the Consultative Groupon International Agricultural Research (CGIAR) outstanding scientist award 2001, International Plant Protection Award of Distinction 2007, Millennium ICRISAT Science Award 2001, Doreen Mashler Award 2002, Hari-Om Trust Award 2007 of ICAR, Prof. T.N. Ananthakrishnan Award 2002, Life Achievement Award 2019 by International Association of Plant Protection Sciences (IAAPS) and several others. He served as Editor and member of Editorial Boards in many national and international journals. Many professional societies conferred fellowship to Dr. Sharma, he is Fellow, Entomological Society of America (2014) and Fellow, National Academy of Agricultural Sciences (2012) to name a few.

He has served as President of the Council of the International Congresses of Entomology from 2008-16 and instrumental in organizing ICE2012 in Korea and ICE2016 in USA. He was also President for 19th International Plant Protection Congress (IPPC2019) held at Hyderabad in 2019. He served as Member – Governing Board, International Association of Plant Protection Sciences from (2008-15). He was a Co-Chair, Biological Consequences of Global Change, International Union of Biological Sciences (IUBS) during 2009 - 15. He was also a Member of AHTEG Committee of CBD – UNEP.

Dr. Sharma is also an excellent mentor and he has supervised more than 25 PhD scholars and more than 10 post-doctoral fellows/visiting scientists. Many of his students received distinction in thesis research and/or were awarded prizes in research paper/poster presentations and continuing as scientist in different national and international institutes.

Managing Editor of Indian Entomologist Dr. Shashank P.R. had a privilege to interact with Dr. H.C. Sharma and present his magnificent journey in the science and administration. The minutiae of the interview are presented below:

Dr. Shashank P.R. (SPR): Sir, on behalf of Indian Entomologists, I thank you for accepting our invitation. Can you share with us about your childhood and how you selected agriculture as main branch?

Dr. Hari C. Sharma (HCS): A suggestion was made by one of my seniors in the school that if we complete a 4-year degree in agriculture, we get a job of Agriculture Inspector, which sounded quite impressive, although I had no idea what it entailed, despite having been born in a farming family.

SPR: What made you to select entomology as your field of research?

HCS: In third year of BSc Ag, I listened to a presentation by Dr NC Pant, ex-Head, Division of Entomology, IARI, who had joined HP University Shimla as Dean, Faculty of Agriculture in 1973 (He later became Director of Imperial Institute of Entomology, London, where I visited him in 1983). His presentation on Vitamin and amino acid requirements of insects was very interesting, and entomology appeared to be more scientific than some other subjects in agriculture. He also interviewed me for admission in the PhD program at IARI in 1976.

SPR: Can you share your early carrier experiences, what are the challenges and opportunities you have come across?

HCS: My MSc supervisor at College of Agriculture, Solan, Dr RL Adlakha, who was an Alumnus of California University, Berkeley, USA, made me to write my MSc thesis 4 times by hand before the typing the first draft. He made me to change the sequence of the sentences, and re-arrange the paragraphs each time. He ensured that I have the ability to express scientific findings in different styles. As result, I never had any hesitation in writing or presenting scientific findings, and I owe my ability to write scientific papers to Dr RL Adlakha.

Another of mentor was Dr RA Agarwal, former Head, Division of Entomology, IARI. He gave me more respect than my peers, and he was the happier than me when I told him that I stood first in ARS examination in 1978. It was because of his resourcefulness and help, that we established a lab for carrying out biochemical analysis of secondary metabolites that contribute to host plant resistance to insects.

I resigned the ARS job after 6 months, where I was asked to look after administrative business, and l moved to greener pastures at ICRISAT, which appeared to be so, little realizing that it was a huge challenge to sustain oneself under western working environment.

SPR: Your contribution in insect host plant resistant research is significant. In your view, how important is HPR research?

HCS: For a sustainable increase in crop production, the most important component is Variety. And the varieties to be cultivated by the farmers must have resistance or ability to tolerate abiotic and biotic stresses. The levels of resistance could be low, moderate or high., But they should not be more susceptible than the farmers landraces. When varieties with high levels of susceptibility to insects and diseases are released, they lead to disease and pest outbreaks. Under such situations, even the synthetic chemicals fail to control insect pests, and results in crop failures and farmers suicides. Therefore, development of insect-resistant varieties is of utmost importance for sustainable crop production and crop management.

SPR: What are the challenges you have faced in HPR research?

HCS: The major challenge in HPR research is the collaboration between entomology, breeding and biotechnology. It is important to have a clear understanding between different scientists about their role/ contributions, and finally sharing both the resources and the credit. Invariably, the resources are allocated to the breeding units, and they also pioneer the testing and release of varieties for cultivation by the farmers. While this is relatively easier in case of plant diseases, the process of ensuring adequate levels of insect pressure, collection of data, and its interpretation are much more complicated when we are breeding for insect resistance. In this case, there is greater need for financial and human resources, and requires greater input by the entomologists. Progress in breeding for insect resistance can be made much more effectively when the trials are conducted by the entomologists, and the selections are made jointly by the breeders and the entomologists. We followed this process at ICRISAT in letter and spirit, and quite often, the collaborating breeders gave greater credit to the entomology, both in developing high yielding varieties, and in studying nature and inheritance of resistance to insects. In fact, the studies on genetics of insect resistance were largely pioneered by the entomology unit. And this system needs to be followed in All India Coordinated Research Projects on different crops to make HPR a reality in integrated pest and crop management for a sustainable increase in crop production. The major challenges are:

- ❖ Lack of appreciation by the breeders of the importance of, and contribution by the entomologists in developing insect-resistant cultivars.
- ❖ Lack of adequate funding, as most of the funding is given for breeding and biotechnology.
- ❖ Lack of importance/weightage given to pest resistance as compared to yield per se in identifying and releasing varieties for cultivation by the farmers.
- ❖ Unwillingness of the breeders to undertake development of varieties for pest resistance, as this is more challenging, tedious, and takes more time than developing varieties for high yield per se.

SPR: You have also worked on biosafety of GMOs and also involved in many committees, what is the major difficulty in convincing common people about GMOs?

HCS: We have been involved in development and evaluation of GMOs for pest resistance, and also evaluating them for their biosafety to nontarget organisms, and nutritional quality/ nutritional equivalence. Hundreds of meetings were held to discuss the biosafety of GMOs all over India and in the world, but hardly any funding was available to generate the data on biosafety. Much of the work that we did was funded by IndoSwiss project on biotechnology. Most of the noise on biosafety of GMOs is made by journalists, lawyers and NGOs, who have no knowledge of genes, gene products and their safety to the nontarget organisms including human beings. The scientists never spoke or wrote in general print media, and the misinformation was more widespread than the facts. More painful was the fact when some of the scientists, even the highly placed or respected ones, supported the non-scientific notions. However, the committees that I was involved in DBT, MoEFCC, and the AHTEG committee under Cartaghena protocol, all functioned systematically and scientifically to lay down the rules for testing and commercialization of GMOs. These guidelines/protocols were accepted by the concerned governments.

SPR: *Helicoverpa armigera* is used as a model insect in your lab for many studies, how important is it to select such a major pest for your research?

HCS: While *Helicoverpa* is one of the most important pests of field crops, my first few years in postgraduate research and at ICAR-CICR were focussed on cotton bollworms, and then I worked for nearly 20 years on insect resistance in sorghum /pearl millet to shoot fly, stem borer, midge, and head bugs. In fact, my first project at ICRISAT was on pearl millet insects and *Mythimna*. While discussing the importance/implications of this research, my supervisor, Dr JC Davies, told me, it does not matter on which insect or crop we work, what matters is how we do it, and the outputs that we come up with. It was only in 1999 that I started working on *Helicoverpa*, and this certainly expanded my scope for research, and the outreach to the scientific community and the farmers. Developing robust protocols for rearing this insect continuously in the lab was a major challenge. It took us 2-3 years to develop robust protocols for rearing this and other five insect species in the lab, and this has been the key to the progress that we have made in HPR, transgenics molecular markers and biological control. And any research carried out on *Helicoverpa* as a model insect, certainly makes greater impact, than any other insect species.

SPR: Along with your research you have also been involved in IPM extension activities in India and abroad. Can you please explain your experiences and challenges in the extension work?

HCS: I have had limited involvement and experience in extension of IPM technologies. We largely tested insect-resistant varieties in the farmers' fields (ICSV 197 and ICSV 745 - resistant to sorghum midge; ICPL 88039, ICPL 332WR, and ENT 11 – low to moderate levels of resistance to pod borer in pigeon pea). Only 30 – 40% of the trials were successful. Here, we only provided seeds to the farmers. It did not involve the complex information and technology that we use in IPM. My learnings from this experience have made me to accept the results of 100 percent success in IPM and other trials with a word of caution.

"Any research carried out on Helicoverpa as a model insect, certainly makes greater impact, than any other insect species."

SPR: You have been involved in several projects in your carrier, how difficult is to manage multiple projects at a time?

HCS: It is not difficult to manage multiple projects at a given point of time. What we need is enough staff, and depending on the size and number of projects, the role of a principal investigator changes from a researcher to a manager. The most important component is the environment for freedom to operate.

SPR: Sir, you also served as President, Council of International Congresses of Entomology during 2008-16. What is your experience and suggestions?

HCS: It was a great opportunity and experience. First, a call from an unknown scientist, Dr Frantisek Sehna, Czech Republic, requesting me to be member of the Council of International Congresses of Entomology, and then going against the convention of Secretary General becoming the President of ICE, he persuaded me to take up the responsibility of chairing the council, which till then largely rested with scientists from the northern hemisphere. And with guidance and encouragement from Linn Riddiforld, Washington State, USA (who was president before Frantisek Sehnal) and Dr Sehnal, we steered the ICE with distinction for two congresses in 2012 in South Korea, and 2016 in USA. The last one being a benchmark, where the largest number of entomologists (nearly 7,000) attended the congress in Orlando, USA. My only regret is that I tried to persuade the people in India to put up a proposal for holding the entomology congress in India, but nobody came forward. I wish, concerned entomologists do prepare a proposal to hold the congress in India in 2028 or 2032.

SPR: You have received many awards for your contribution to Entomology from different agencies, which award is close to your heart and why?

HCS: Awards and recognition are accidental. We don't work for them, but getting recognized and appreciated for ones' contributions is certainly heart-warming, and gives you a stimulus to perform better. Being selected for the Excellence in Science – Outstanding Scientist, among the 16 international institutes of Consultative Group on International Agricultural Research (CGIAR) was quite surprising and emotional one, as competing with scientists from centers like IRRI, CIMMYIT, IITA and ICARDA was quite satisfying.

Dr. P.R. Shashank (left) with Dr. H.C. Sharma at Division of Entomology, ICAR-IARI, New Delhi, India

SPR: You have worked in both the CGIAR system and SAU. How do you compare CGIAR with SAU?

HCS: The experience of working in ICRISAT and SAU is diametrically opposite. In ICRISAT, we pursued excellence in science and upright behaviour, and that determined the annual increments and promotions. In the SAUs, people feel that can get the things done through political pressure and patronage, which is unfortunate. For us to progress in the comity of nations, we must reward merit follow ethical behavior, and shun political interference.

SPR: Can you explain your take on work life balance, why it is important?

HCS: It the most important aspect of life. We as scientists, often overlook our responsibilities at home. As a thumb rule, we used to go for a picnic or taking the lunch outside the home – largely home cooked food. And once in three months or whenever the children had school holidays, we used to go to nearby pilgrimage/ historical places. And a cocktail party with the staff and students once in a season was the most important component of what we did, and my appreciation to all the staff and students for their contributions and the role they played in this journey spanning over 4 dacades!!!

SPR: What is your vision for entomological research and extension in India? Suggestions to entomologists who look up to you?

HCS: Our younger generation is much more informed, than probably what we were, five decades back. They have a great challenge to handle in terms of climate change effects on insect biology and population dynamics, insect -host range interactions, expression of resistance to insects and other pest management technologies. We as entomologists must encompass and use modern tools of biotechnology, information technology and nanotechnology. Equally important is to enhance the collaboration with other disciplines/ institutes, and make a concerted effort to interact with entomologists globally. And we must improve our profile of publishing in high impact journals, filing patents, and make ourselves heard in various fora's. I wish a great future for our entomology fraternity in future.

Concluding remarks by Dr. Shashank: I am overwhelmed to meet Dr. H.C. Sharma for an interview. While doing my Ph.D. at UAS, Bangalore my supervisor Dr. A. K. Chakravarthy always tell me about Dr. Sharma and his work in Host Plant Resistance. I was always wanted to meet him and discuss his work, Indian Entomologist has provided this opportunity. When I contacted him over the phone, I introduced myself and explained about our Magazine. In a soft tone, he asked me are you Dr. Pathour from IARI? I was surprised and in a short conversation, I realized that he is well-informed about young entomologists across India. He agrees to an interview and I met him at the Division of Entomology, ICAR-IARI, New Delhi with Dr. M.K. Dhillon who is his doctoral student. I spent nearly three and a half hours with Dr. Sharma, I must say with no hesitation he was the most positive person I have met in recent times. It was a delight to meet him in person and listen to him for such a long period. He shared his journey from childhood to vice chancellor of SAU and beyond. I was really impressed by his jovial way of answering and even after retirement, he is so much enthusiastic about science. His journey will inspire many students who want to continue in science, especially entomology.

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FIELD NOTE

Simultaneous occurrence of white grubs of different ages in *kharif* groundnut from Saurashtra region of Gujarat

Nataraja Maheshala, Harish G, Ananth Kurella, Kiran Kumar Reddy and SD Savaliya

A team of scientists from ICAR-Directorate of Groundnut Research, Junagadh surveyed groundnut fields in Saurashtra region of Gujarat, known as 'groundnut bowl of India'. Survey was aimed at understanding and reporting of crop health including the infestation levels of insect-pest and diseases; soil health and impacts of monsoon rains; socio-economic issues of groundnut farmers and get feedback on improved technologies and varieties. Such surveys were regularly conducted during the crop growing seasons namely, Kharif and rabi-summer. One such survey was conducted during the Kharif season (mid-August, 2022) in Amreli, Gir-Somnath, Junagadh, Porbandar and Rajkot districts of Saurashtra. In these districts, due to excess cumulative rainfall (4199.1 mm) received between June to August, as against the normal cumulative rainfall (2932.7 mm), excessive vegetative growth of crop was observed (Anon., 2022). The major soil-type in the surveyed areas of Saurashtra was fine textured, black clayey soils. Water logging in the field for longer durations resulted in reduced root nodulation and yellowing of foliage. Groundnut crop was around 70 days old and the varieties sown were Girnar-4, GJG 22, GG-9, GG-20, TG-37A, TG-39 and KDG-128.

Survey conducted by Chudasama et al. (2019) identified 23 species of white grubs from light traps collections made from groundnut crop in Junagadh, Gujarat. Soil-inhabiting white grub infestation ranged from 15-100% across the surveyed groundnut fields. The lowest incidence (15%) was observed in Naredi village of Vanthali taluka and Choki Sorath village of Junagadh taluka in Junagadh district; and Thepda village of Kutiyana taluka in Porbandar district. The highest incidence (100%) was noted from Chiroda village of Mendrada taluka in Junagadh district. Nataraja and Jasrotia (2014) reported white grub incidence causing 20-80% damage to groundnut in talukas namely, Porbandar, Ranavav, Jetpur, Kutiyana, Maliya Hatina, Keshod, Visavadar, Mendarada and Dhari of Saurashtra region. An unusual observation that caught scientists' eyes during the survey

Figure 1: White grubs of different age groups infesting same plant. (**Inset:** White grubs infested groundnut crop).

was simultaneous occurrence of different age groups white grubs infesting the same groundnut plant (Figure 1). White grubs were in 2nd to 4th larval instar. This might be due to continuous rains affecting the synchronous adult emergence and oviposition or due to the occurrence of different species of white grubs at the same location. Dashad et al. (2008) reported positive correlation (r=0.69 and 0.76, respectively) between rainfall and the adult emergence patterns of *Holotrichia consanguinea* and *H. serrata*. Earlier reports identified groundnut infesting white grub species, *Phyllognathus dionysius*, *Apogonia rauca*, *H. consanguinea*, *H. serrata*, *H. fissa*, *Adoretus bicolor*, *A. deccanus*, *A. versutus*, *Anomala bengalensis*, *A. dorsalis* and *A. varicolor* (Dashad and Chauhan, 2011; Kapadia et al., 2006).

It was noted that farmers were aware of white grub incidence and nature of damage it causes in groundnut however; they were unaware of life cycle of white grubs as well as management options. Kapadia et al. (2006) reported that *A. rauca* grub and pupal stages lasted for 60-75 and 7-10 days, respectively on groundnut in Saurashtra. While interacting with farmers, scientists have learned about new host plants of adult beetles, papaya (*Carica papaya* L.; Caricaceae), pomegranate (*Punica granatum* L.; Punicaceae), and white gulmohar/sandeshra (*Delonix elata* (L.); Fabaceae), although this warrants further investigation. Earlier reports noted gulmohar (*Delonix regia* Raf.) as host of *H. serrata* (F.) adults (David and Ananthanarayana, 1974) and pomegranate as host of *H. insularis* Brenske adults (Avasthy, 1967).The other major hosts of white grub adults in the region were, mango, guava, tamarind, citrus, jamun, sapota, arjuna, jajube, neem, cluster fig, sacred fig, flame of the forest, golden shower, gum arabic, babool, etc. (Nandagopal, 2004).

Identification of white grub species, abiotic factors influencing adult emergence, and host plants for adult congregation, play significant roles in the effective community level integrated pest management of white grubs. This survey sheds light on the need for such studies.

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The fungus, *Entomophthora muscae* zombifying house fly, *Musca domestica*

Sunny Maanju and Preeti Sharma

Indian common house fly, *Musca domestica* L. (Diptera: Muscidae), is a nuisance household insect pest that lives in association with the humans. However, there is something that is a nuisance to the house fly as well. The fungus, *Entomophthora muscae*, which literally means "fly destroyer", lives off houseflies and other fruit flies. It invades the fly's brain and turns them into a zombie-like state and later kills it in order to reproduce. At dusk of the fourth or fifth day, after it encounters with a fungal spore, an infected house fly stops flying and starts behaving strangely like climbing up and down objects around it. *Entomophthora muscae* forces the infected fly to climb to the top of a high structure in a behaviour referred to as "summiting." In an unorthodox manner, the fly extends its mouthpart down and some liquid drips out and glues the fly to the surface it's standing on. Over the next 10 minutes, the fly's wings point straight up and it dies in a horrific lifelike pose so that the white spongy fungus can shoot out and fire hundreds of tiny reproductive spores from its abdomen. This white mass comprises of hundreds of lollipop-shaped protrusions, each of which launches a microscopic bell-shaped spore at high speed. These spores spread and remain in the surroundings for hours so that they can infect other flies for their survival. The infestation of *E. muscae* can prove, it as an effective biological control agent of house fly, however, the spores seem too fragile to grow under laboratory conditions.

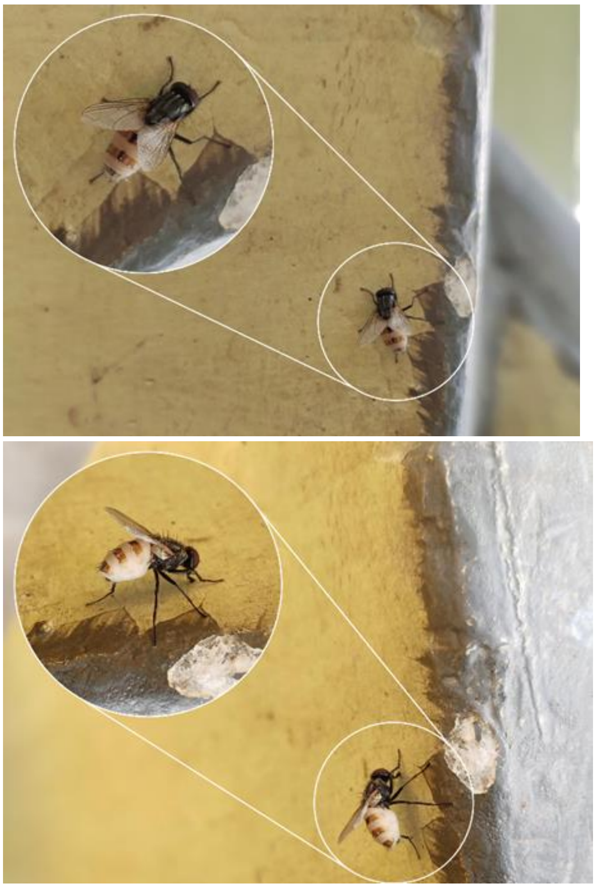

Fig. 1: (a) Lateral-zoomed view and **(b)** Dorsal-zoomed view of Indian common house fly (*Musca domestica*) high-jacked by the fungus, *Entomophthora muscae* with erect hindwings and fungus protruding from the abdomen.

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IN CONVERSATION WITH BIOCONTROL EXPERT DR. GANGA VISALAKSHY

HOLDING THE SELF-CONFIDENCE AS SUPERPOWER DR. GANGA VISALAKSHY SPEAKS TO IE ASSOCIATE EDITOR DR. BHAGYASHREE ABOUT HER JOURNEY FROM A NON-MICROBIOLOGIST TO DEVELOPING THE TWO SUCCESSFUL MICROBIAL FORMULATIONS FOR MANAGEMENT OF PEST IN HORTICULTURAL CROPS

Dr. P N Ganga Visalakshy was born on 7th November 1956, she had her schooling at Palakkad, Kerala in Kanikka Matha English Medium girls high school. She did her graduation from Mercy college, Palakkad with Zoology as main, botany and chemistry as subsidiary subjects. After finishing graduation, she did her post-graduation at Government Victoria College at Palakkad with Zoology as main and Entomology as special subject, where I stepped into world of Insects in 1980. In 1981, married and moved to Bengaluru, Karnataka. I have joined to Commonwealth Institute of Biological Control in 1984, Indian station, Bengaluru, initially joined to pursue Ph. D. course by registering under Mysore University. Later absorbed as entomological assistant in the project "Survey on natural enemies of Diaspine scale insects in south India, parallely continued to do Ph. D, but could not complete due to selection as scientist in Indian Council of Agricultural Research (ICAR) through Agricultural Research Service (ARS) In 1987, joined as a scientist at ICAR-IIHR (Indian Institute of Horticultural Research), Bengaluru at Division of Entomology and Nematology (Biological control of weeds laboratory). Obtained Ph. D in Zoology from Bengaluru University in 2001.

Dr. Ganga Visalakshy has made significant contribution in biological control of weeds and crop pests by using microbials and macrobials. Her technology has made significant contribution in suppression of weeds of national importance. In addition to field application and its impact studies, she worked on their basic aspects such as diapause, dispersal, biotic potential etc. the technique developed by her on determining the age of exotic biocontrol agent of Parthenium, *Zygogramma bicolorata* Pallister adults based on anatomical studies of wing muscles and reproductive organelles and the effect of feeding on sunflower become important findings to resolve the controversy of beetle's host specificity to Parthenium. In 2001, she shifted her field of research to microbial control of horticultural crops and worked till retirement. She worked on sucking pests such as hoppers and thrips on mango, tea mosquito bug in guava and capsicum and rose in polyhouse. Being in the field of microbes, she developed oil-based formulation of *Metarhizium anisopiliae* against hoppers and thrips and *Beauveria bassiana* against tea mosquito bug (TMB) with the shelf life of 14-24 months. The wettable powder formulation reputed to be effective against TMB in tea and on cashew.

She was awarded the honorary fellow by the Indian Society of Weed Science, Fellow of the society of Biological Control and Association for Advancement of Pest Management of Horticultural Ecosystem, she was also awarded Dr. Sitanandan award for her contribution in the field of Biological Control. She has 300 publications in national and international journals and handled many DBT, DST, NABARD, GoI and ICAR project during her tenure. She retired as principal scientist from ICAR-IIHR Bengaluru in 2018.

BSN: Thank you for speaking to Indian entomologists, how did you pursue career in Entomology at ICAR-IIHR?

GV: I didn't have any idea of Entomology, during my masters at Govt. Victoria College, Kerala, we had a special subject "Entomology", there my journey towards entomology begun. After joining as a scientist, I had the opportunity to work in the field of biological control by using macrobials and microbials at IIHR. From 1987 to 2001, worked on biological control of weeds using insects. From 2001 to 2018, worked on biological control of crop pests mainly concentrating on microbials.

BSN: What was your childhood like and what inspired you to be the women you are today?

GV: Am a village girl, i performed average in my studies till my high school later I worked hard to get good marks. The Inspiration from mother is what am today! of course my father never objected in pursuing higher studies, my mother was very particular that her daughters must be educated, employed and independent.

My parents wished to see me as a lawyer or medical doctor since my passion was in teaching, I pursued master's degree. After marriage my husband and in-laws were also supportive in my career and higher studies.

BSN: When faced with obstacles or hardship, where do you find the strength to overcome it?

GV: It's my inner strength. Most of the times I don't mind what had happened, what I got it. I accept things, over time it gets better. When I face obstacles at times, I get disappointed, to get disappointed is a part of job. Alternative way to get out of it is "smile and take it off". I usually don't discuss my problems with others.

BSN: At your time, women from different walks of life faced gender stereotypes that has created a barrier to get education and career, how did you overcome it?

GV: While studying I didn't not face gender inequality or biasness as I did my education at girls college, I had very good time. After joining to work at IIHR, interpersonal relationship was very good without any conflict and gender bias so I never faced any gender related problems.

BSN: In your career, did you ever face any hardship just because you are women? How did you bounce back from that situation?

GV: As a woman, I never faced any hardships during my career. In 2001, I was shifted to work on microbial control of crop pests, it was an entirely different field for me. Initially little disturbed and confused. But then with determination not to be let down I took research with lot of reading of books in basic, applied and hands on training manuals, started work from isolation to formulation of entomopathogens. Finally with all the hard work, I could bag DBT, DST, Government of India, and ICAR projects on microbials, along with this I could develop oil-based formulation of *Metarhizium anisopiliae* against hoppers and thrips and *Beauveria bassiana* against tea mosquito bug (TMB) with shelf life of 14-24 months which are ready for CIBRC registration.

BSN: Can women, their behaviour or attitude be their own biggest obstacles?

GV: No. I don't think it's because of their behaviour or attitude, there may be some other reason which I don't know. Women are equally capable of doing their job better.

BSN: Although the need for biological control is in great demand, do you think adoption is very slow?

GV: Yes! lack of awareness of the technology by the end users such as farmers and non-availability of biological control agents are some of the important factors in the low adoption of the technology. Farmers expect/presume that biological control agents are easily available over the counter like chemical pesticides and expect results also faster.

At grass root level they do not understand the intricacies and specificity of biological control. So as scientist we must make them understand about the pros and cons of the technology before they adopt. Whereby the confidence of the farmers on the technology is not lost.

BSN: What would you say Zygogramma bicolorata Pallister controversy on sunflower?

GV: The exotic host specific biological control agent *Z. bicolorata* Pallister imported was found to be effective against *Parthenium hysterophorus*, a weed of national importance in India. However, after years of field releases, the beetles were reported feeding on sunflower, a major oil seed crop of our country, raising concern on its host expansion or host specificity in 1992. Further field releases were banned, and a project was floated by ICAR to determine the pest potential of the insect in sunflower.

A study to determine the risk assessment of the insect to sunflower was initiated by me by developing an age index for adults of 0-10 days old based on the status of cuticle, fat body, indirect flight muscles and reproductive organelles.

Most of the field collected adults on sunflower crop were found to have soft cuticle, absence of fat bodies accumulation, undeveloped indirect flight muscles and reproductive organelles indicating they are less than 10 days old and not capable of flight.

Field observations also supported the results whereby large number of the beetles were found crawling to the sunflower field from the parthenium wasteland.

BSN: Why biocontrol practices in India have not been optimally utilized as they could be?

GV: In other countries, I presume it could be due to growing same crops in large area and have more area under polyhouse so adoption of biological control is easy with more impact. In India, farmers have small holdings, diversified crop with multitude of pest, less knowledge on biological control/not exposed to biological control so impact may not be so much. Here in India, if one farmer adopts biological control, they may face distraction from neighbouring farmers by spraying pesticides so biological control is not as effective as expected. We are democratic country, government can support and give subsidy to take up biological control but can’t force!

BSN: What can be done to get easy access to biocontrol agents by farmers?

GV: Government must Increase the biological control agent’s multiplication units by providing funds for it. Government can assist private company to take up mega projects to incorporate biological control agents in few crops, may be perennial crops/polyhouse where the impact can be more, show the success, educate on advantages of biological control, get the confidence of farmers, then farmers starts coming to you and then expand it to other crops wherever possible.

BSN: How would you like to see future of Biological control practices in India?

GV: Adoption of biofertilizers and biopesticides for soil borne pests has been increasing. So I would like to recommend more research work on biological control of aerial pests whereby it becomes an important component in Integrated Pest Management.

BSN: What advice would you give to our young women entomologist and the scientists working on biological control?

GV: Selection of pests and crops where biological control is to be initiated is important as biological control technology is very specific. Understanding the basic bioecological factors influence the pestilence is also important to manage the pest by biological control.

Biological control is a very specific field, in depth knowledge in the basics of methodology is needed. In addition, basic studies will definitely promote / help in publishing scientific article that will help you to come in contact with people working in similar group.

In addition to focusing on the positive aspects of biological control of target pests, research on why and what could be the reason it is not giving satisfactory results are also equally important, which are also to be looked into/researched.

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Pharmacophagy in false tiger moth: An incidental observation at Meghalaya, India

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The false tiger moth, *Dysphania militaris* L. (Geometridae: Lepidoptera) is a species of moth found in tropical regions of South and Southeast Asia countries such as India, China, Myanmar and Indonesia. Carl Linnaeus described it for the first time in the 10th edition of Systema Naturae (https://en.wikipedia.org/wiki/Dysphania_militaris). In India, it has been reported to be distributed in Tripura, Nagaland, Assam, Manipur, Arunachal Pradesh, Meghalaya, Sikkim, West Bengal, and Uttarakhand. *D.militaris* is a day-flying moth that usually feeds on flower nectar and moist patches (Veino and Rakoveine, 2022).

Many terrestrial herbivores are anticipated to crave sodium due to the low sodium content of land plants on which they feed. Mineral reserves accumulated during the larval phase of lepidopteran caterpillars may often be limited and for this reason, there must be a strong selection in the adult Lepidoptera in terms of evolutionary strategies to replenish mineral stocks. Adult Lepidoptera (butterflies and moths) of many species are reported to visit frequently and suck water and nutrients from moist ground, perspiration, tears, feces, or animal carcasses, a behavior known as mud-puddling which is much similar to one such sexually selected behavioral repertoire called pharmacophagy. Pharmacophagy is a mechanism of feeding on various nutritional sources other than regular hosts to acquire beneficial chemicals rather than for nutrition. It is a sexually selected behavior where toxic plant metabolites that serve as pheromone precursors and nuptial gifts by male butterflies are collected (Beck et al. 1999). Males in most lepidopterans provide specialized spermatophores to their mates (Drummond, 1984), which include minerals like sodium (Eisner and Meinwald, 1996) or calcium phosphate (Lai-Fook, 1991), toxic secondary plant metabolites (Schneider, 1993), or nutrition like amino acids (Gilbert, 1979).

The author has photographed the puddling rather pharmacophagy of *D. militaris* adult along a stretch of forest road in Meghalaya (25.2597 N, 92.2001 E). The adult moth was feeding by inserting its proboscis into the wounded or degloved body part of the dead snake for more than 20-25 minutes. The snake died from a vehicle hit on the center of the road. The wound caused by the wheel passing on the snake's body ripped up the skin and where exactly the single *D. militaris* moth spotted to feed by inserting its proboscis. One such comparable observation made by Ray et al. (2021) where, *D. militaris* spotted the various food resources on the road, namely elephant dung, carnivore scats, and road-kills of reptiles, amphibians, crustaceans on the roads near Dehing-Patkai National Park, Assam.

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A gist of unheeded insect calcium channels as a target for insecticides

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A new class of insecticides, diamides provides exceptional control through action on a novel target, the ryanodine receptor (Cordova *et al.*, 2006). Diamides rank third (12%) in the global market after neonicotinoids (24%) and synthetic pyrethroids (15%) (Sparks *et al.*, 2020). There are five insecticides in the market registered against various group of insects belongs to lepidoptera, coleoptera, Hemiptera *etc*. Apart from these insecticides some diamide insecticides are in race includes cyhalodiamide, and tetrachlorantraniliprole and unnamed (Sparks *et al.*, 2020). A third class of diamides, "pyrrole-2 carboxamides" are currently under development (Cordova *et al.*, 2021). However, detailed examination of RyRs from field-collected or lab-selected resistant strains revealed mutations that affected residues located in the C-terminal transmembrane spanning domains is responsible for resistance development against diamides (Guo *et al.*, 2014). Development of insecticides with novel and unique modes of action is necessary to combat widespread insecticide resistance.

Calcium plays a vital role as a second important messenger in controlling physiological functions like neurotransmitter release, muscle contraction, hormone biosynthesis, development and metamorphosis, reproduction, sex pheromone synthesis, cold sensing, olfactory responses, diapauses, carbohydrate and lipid metabolism (Berridge *et al.*, 2000; Toprak *et al.*, 2021). Various kinds of calcium channels regulate these processes, *viz.*, voltage-gated calcium channels (VGCC), Ryanodine and IP_3 sensitive calcium channels, store-operated calcium channels (SOCC), and Transient Receptor Potential (TRP) calcium channels (Luemmen, 2013). The reticence/ modification of these calcium channels leads to disparity in the calcium current, which disturbs the cells' physiological functioning. It ultimately leads to the death of an organism. To exploit calcium channels in pest management, it is vital to comprehend how they operate. Voltage-gated calcium channels and Ryanodine-sensitive calcium channels have been successfully used for pest management (Luemmen, 2013). Ryanodine-sensitive calcium channels are accompanied by ER (Endoplasmic reticulum) / SR (Sarcoplasmic reticulum) of neurons or muscle cells. Recently, two highly promising class of synthetic insecticides, diamides that disrupt calcium homeostasis by interfering with RyRs, have been introduced into the marketplace. VGCC is the macromolecular complexes that localize in the plasma membrane, open in response to membrane depolarization signal and mediate the movement of Ca^{+2} ions. Toxins of insects/ spiders are known to block VGCC reversibly (King *et al.*, 2008). Here is a short rundown of the physiology and pharmacology of various calcium channels that have not yet been targeted explicitly for insecticides.

Unheeded calcium channels for insecticide target

In addition to RyRC and VGCC, other calcium channels, including IP_3-sensitive calcium channels, TRP calcium channels, and store-operated calcium channels (SOCC), also play a crucial role in maintaining calcium homeostasis in insects (Luemmen, 2013). Since no synthetic insecticides are currently available that target these channels, it is imperative to comprehend their structure and pharmacology.

1. IP_3 Sensitive calcium channels

IP_3-sensitive calcium channel is the one which is activated by the secondary messenger inositol 1,4,5-trisphosphate (IP_3) and Ca^{2+} and regulates the intracellular calcium level and is localized on the ER membrane. The IP_3R and RyR are members of a family of tetrameric intracellular Ca^{2+}-release channels encoded by single genes in insects. Insect IP_3Rs are commonly composed of three regions: the ligand binding region (Ca sensor domain), regulatory and transducing region (coupling domain), and channel forming domain. The ligand binding region consists of three subdomains *viz.*, SD (suppressor domain), IBC-β (IP_3 binding core- β) and IBC-α (IP_3 binding core- α) (Fig. 1) (Toprak *et al.*, 2021). There is evidence that ligand binding sites influence the function of the channel-containing domain in both receptors.

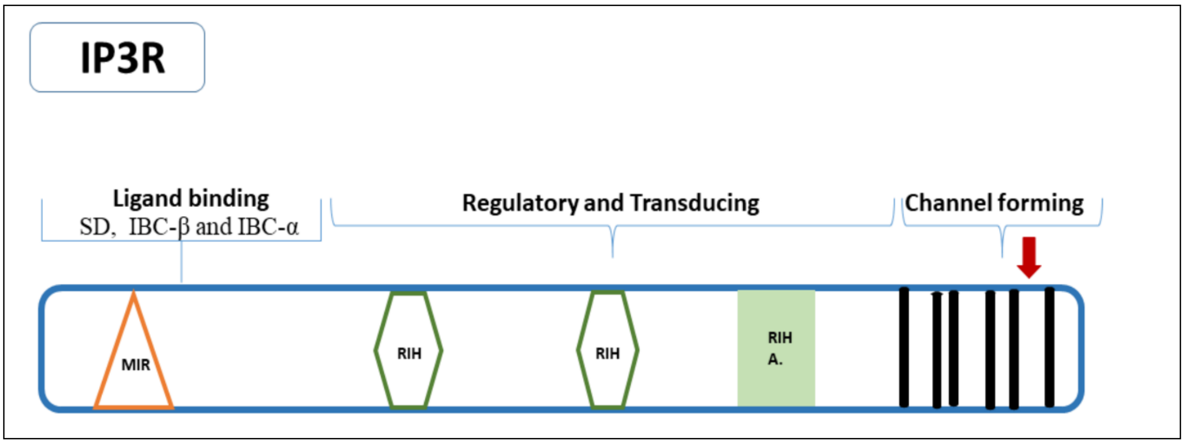

Figure 1: Structure of IP_3Rs (Source: Toprak *et al.*, 2021)

Pathway of IP_3Rs: IP_3Rs are expressed in most cells, particularly in the ER of neurons, fat body adipocytes, and oocytes. Low cytoplasmic Ca^{2+} activates IP_3R, while high concentrations inhibit the channel's activity. G-protein-coupled receptors (GPCRs) in the plasma membrane of the cell stimulate phospholipase C (PLC) that hydrolyzes the phosphorylated plasma membrane glycolipid, phosphatidylinositol 4,5-bisphosphate (PIP_2), into secondary messengers diacylglycerol (DAG) and IP_3

(Fig. 2). IP_3 binds to IP_3-binding sites in the N-terminus of the tetrameric IP_3R to initiate conformational changes that are transmitted down to the transmembrane region leading to the opening of the Ca^{2+}-permeable pore away from the IBC to release the Ca^{2+} from the ER (Toprak *et al.*, 2021).

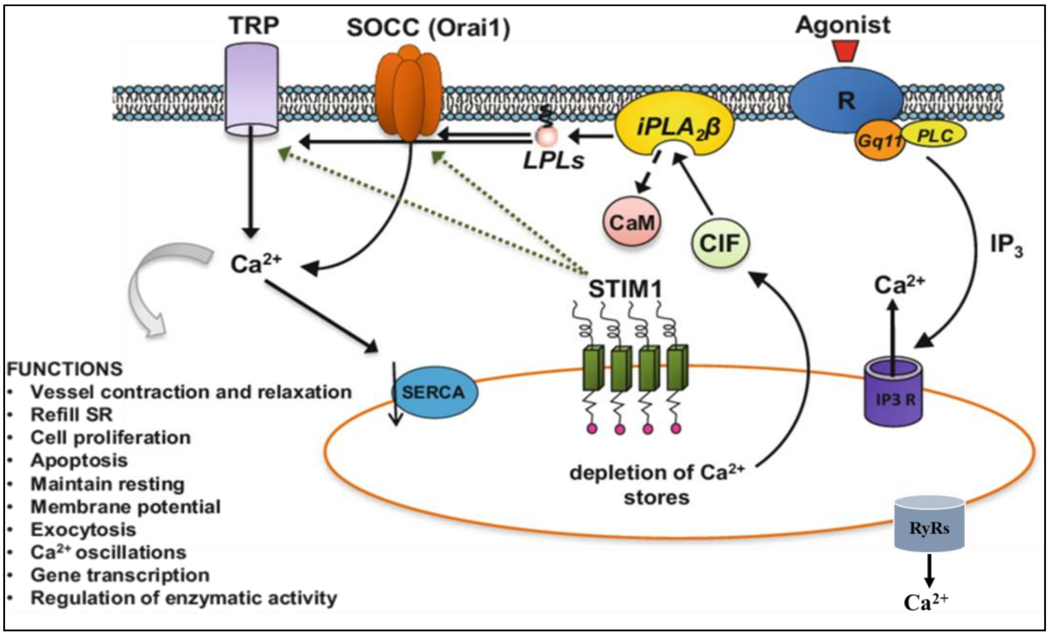

Figure 2: Different Calcium Channels (Modified from the image of Smani et al., 2016)

Markedly, IP_3Rs are essential for viability, but no insecticidal compounds targeting IP_3Rs have been reported in the literature (Luemmen, 2013). The development of pesticides that interfere with the receptors of IP_3 has great potential in pest management.

2. TRP calcium channels

A specific type of calcium entry channel in the plasma membrane was initially identified in a *Drosophila* mutant defective in the visual system. TRP (Transient Receptor Potential) channels translate a variety of visual, mechanical, and chemical stimuli into neuronal signals, thereby serving key functions in sensory processes. TRP channels have evolved to considerable diversity in insects, as indicated by the fact that the *Drosophila* genome contains members of seven TRP subfamilies. Based on amino acid sequence homology, the TRP channel superfamily is classified into seven related subfamilies: TRPC, TRPM, TRPV, TRPA, TRPP, TRPML, and TRPN. TRP channels possess six predicted transmembrane helices and a putative pore loop connecting helices 5 and 6. TRP channels lack the positively charged voltage-sensor residues in helix 4, a characteristic structural feature of voltage-gated Na, K, and Ca^{+2} channels (Fig. 2) (Phillips *et al.*, 1992; Luemmen, 2013).

Some TRP channel subtypes, like the mammalian $TRPV_1$, are activated by capsaicin, vanilloids, and a variety of potentially noxious or irritating compounds (Kissin and Szallasi, 2011). The insecticidal activity of horseradish or yellow mustard extracts was attributed to the presence of allyl- and benzyl-isothiocyanates. The finding that those compounds activated $TRPA_1$ channels in vitro led to the proposal that TRP channels may be possible target sites for new insecticides (Nagata, 2007). Interestingly, some insecticides have been developed to target chordotonal organ TRPV channels (Pyridine azomethine derivatives). However, still there is a wide scope for developing synthetic insecticidal compounds interfering with TRP calcium channels.

3. Store Operated Calcium Channels (SOCC)

Depleting intracellular calcium stores through the activity of calcium release channels triggers calcium entry from the extracellular environment. The process is termed store-operated calcium entry. It is mediated by specialized calcium-conducting channels in the plasma membrane called SOCC/ CRAC (Ca^{2+} release-activated calcium channels). Initially, members of the TRP channel superfamily had been implicated in SOCE. Later, a genome-wide RNAi screen in *Drosophila* for genes affecting SOCE revealed several genes influencing SOCE.

Pathway of SOCC: The stromal interaction molecule (STIM)-Orai1 complex are major player involved in SOCE (Fig. 2). STIM is normally located in the ER transmembrane and senses luminal Ca^{2+} depletion, which leads to its translocation to junctions between the ER and plasma membrane, where it couples with the plasma membrane Ca^{2+} channel protein Orai1. This coupling activates Ca^{2+} release-activated Ca^{2+} (CRAC) channels in the plasma membrane, allowing Ca^{2+} influx from the extracellular pools to the cytosol and then from the cytosol to the ER through SERCA (Sarco/endoplasmic reticulum Ca^{2+} ATPase). Elevation of cytosolic Ca^{2+} to certain levels inactivates CRAC channels, thereby terminating Ca^{2+} influx into the cell, a process known as Ca^{2+}-dependent inactivation (CDI). It is noteworthy that the primary Ca^{2+}-binding protein, calmodulin, is involved in CDI by binding to STIM, disrupting the STIM-Orai1 complex (Luemmen, 2013).

In insects, however, little is known about the pharmacology of SOCC, and potential lead structures for insecticide discovery are not known. As intracellular calcium level is important for cell activity, the development of insecticides that interfere with the store-operated calcium entry process could become a potential insecticide in pest management.

Conclusion

The different calcium-conducting ion channels regulate various physiological processes such as neurotransmission, muscle contraction, and lipid metabolism. Accordingly, calcium channels and pumps have been proposed as novel insecticide target sites. Yet, only two calcium channels, RyRC and VGCC, are exploited for pest control. There is a broad scope for investigating other channels like IP_3 sensitive calcium channels, TRP calcium channels and store operated calcium channels. Further, calcium channels involved in other physiological processes, such as JH synthesis, ecdysone synthesis, lipid metabolism, fluid transport *etc*., are not yet characterized for insecticide targets. It has been expounded that calcium channels comprise promising pesticide targets to meet the requirements of future pest management.

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Plastic eating insects: Current contrivance for plastic pollution

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Global plastic manufacturing has expanded over the past few decades and reached 359 million tonnes in 2018 (Lebreton and Andrady, 2019). Since plastics consumption has grown so quickly, they are now among the materials that are used the most frequently on Earth. As the amount of plastic used increases, plastic pollution is spreading around the globe (Lönnstedt and Eklöv, 2016). Today, everyone agrees that plastic waste contamination is a serious environmental burden. By 2050, it is anticipated that up to 26 billion tonnes of plastic garbage would be generated, with more than half of that waste ending up in landfills before infiltrating ecosystems like wetlands and oceans, seriously polluting the environment (Lönnstedt and Eklöv, 2016). According to a recent study, the total amount of plastic garbage produced to date could reach 6,300 million metric tonnes (Geyer *et al*., 2017). However, less than half of the plastic garbage generated was recycled or dumped in landfills. Our world, which has become known as the "Plastic World," is littered with a sizable amount of remaining plastic garbage (Rochman *et al.*, 2013). Polyethylene, Polystyrene, Polypropylene, and other thermoplastic materials can be heated and moulded into any shape, but thermosetting materials, such as polyurethanes and phenol-formaldehyde cannot be heated or moulded into another shape after they have been set into one (Ghosh *et al*., 2013). Thermoplastics can be recycled in several different ways, however, due to their physicochemical properties, they exhibit varying degrees of resistance to biodegradation. Polyethylene (PE) is one of the major persistent plastics that are not biodegradable at considerable rates in most environments. The inherent resistance of polyethylene to biodegradation stems from its three-dimensional structure, high molecular weight, hydrophobic nature, and lack of functional groups recognizable by microbial enzymatic systems (Harshvardhan and Jha, 2013). Polystyrene (PS) is a synthetic hydrophobic polymer with high molecular weight. Due to its hydrophobic nature and high molecular weight, it is not readily biodegradable (Tsuchii *et al*., 1997). Polypropylene (PP) belongs which upon exposure to ultraviolet radiations and oxidation at high temperatures breaks down into simpler molecules and in microbial degradation, several species of fungi and bacteria can degrade this plastic (Sivan, 2011).

Ways to degrade the plastic…

Traditional techniques for degrading plastic trash, such as dumping it in a landfill or burning it, chemically treating it, or using heat to break it down, are dangerous to the environment and have negative effects on living things (Yang *et al*., 2011). The primary method of recycling thermoplastic wastes has been mechanical recycling, however after multiple manufacturing cycles, the qualities of most recycled goods have been badly impacted, and the resulting commercial attractiveness is modest. The success of chemical recycling, which is an alternative, depends on the cost of procedures and the potency of catalytic agents (Rahimi and Garca, 2017). Chemical recycling will recycle monomers and other materials from 61 different plastic wastes. Plastic biodegradation by fungal and bacterial strains has been highlighted as a potential solution for removing plastic waste without producing secondary pollution (Lee *et al.*, 2020), but they have some limitations they are slow in the process, and they required optimum conditions for biodegradation.

Can insects combat the issue of plastic pollution?

As the most diverse organisms on the planet, insects are recognised to have a variety of uses that are now being researched by humans. Recent research on plastic decomposition by insects has emerged as an intriguing area in discussions of environmental plastic contamination. Early in the nineteenth century, it was discovered that the insects were eating the plastic container used for insect rearing, albeit digestion had not yet been established. However, chewing on the plastic resulted in the formation of galleries and holes through which the larvae escaped (Singh and Jerram, 1976). Since then, numerous studies have been conducted to determine how amazing insect digests plastic. Seven types of plastics are degraded from the insects till now (Polyethylene (PE), polystyrene (PS), polyvinyl chloride (PVC), polypropylene (PP), polyphenylene sulphide, ethylene-vinyl acetate (EVC), and extruded polystyrene) (Table 1). There are different plastic-eating insects are identified which can digest plastic and convert it into non-hazardous compounds (Bombelli *et al*., 2017). These insects are known to consume plastic since the structural similarity between their food substrate and plastic is almost the same. For instance, bee wax and PE have structural similarities, hence *G. mellonella* biochemical machinery for beeswax metabolism may be used for PE metabolism (Bilal *et al.*, 2021).

Table 1: List of plastic eating insects

Sl. No	Type of plastic	Plastic utilizing insects	References
1	Polyethylene (PE)	*Galleria mellonella; Plodia interpunctella; Tenebrio molitor; Achroea grisella;; Corcyra cephalonica*	Yang *et al*., 2014; Zhang *et al*., 2019; Kundungal *et al*., 2019; Kesti and Thimmappa, 2019; Brandon *et al*., 2018
2	Polystyrene (PS)	*Tenebrio molitor; Uloma spp*; *Zophobas atratus*	Kundungal *et al*., 2019; Yang *et al*., 2020
3	Polyvinyl chloride (PVC)	*T. molitor*	Peng *et al*., 2020
4	Ethylene-vinyl acetate (EVA)	*T. confusum*	Abdulhay, 2020
5	Polyphenylene sulfide	*Z. atratus*	Lee *et al*., 2020

Plastic devouring insects

An array of insects that belongs to the order Coleoptera and Lepidoptera are known to degrade the complex plastic polymer into low molecular weight metabolites. *G. mellonella* larvae have a remarkable capacity to use pre-existing metabolic mechanisms to get energy from PE as a sole source of food (LeMoine *et al*., 2020). In the Coleoptera order, some species which are identified as plastic-feeding insects include Mealworm (*Tenebrio molitor*), Super worm (*Zophobas atratus*), Confused flour beetle (*Tribolium confusum*), *Uloma* spp, and red flour beetle (*Tribolium castaneum*). In the Lepidoptera order, species identified as plastic-feeding insects are the Indian meal moth (*Plodia interpunctella*), the lesser wax moth (*Achroia grisella*), the greater wax moth (*Galleria mellonella*), and the rice mealworm (*Corcyra cephalonica*) (Bilal *et al*., 2021). Insects were found to be capable of eating and quickly degrading up to 50 % of ingested plastic in just 24 hours, according to changes in chemical composition, molecular weight, and isotopic trace following tracks through the intestinal tract (Yang *et al*., 2015a). Hitherto, two kinds of weaponry are identified in insects against plastic degradation *viz*., through gut microbiota and/ or digestive enzymes. It's important to find out how insect enzymes and microbiota contribute to PE degradation (Kong *et al*., 2019).

Armament of insects in plastic degradation

The gut microbiota a degrading arm

Insects are known to harbour a variety of helpful bacteria in their guts known as symbionts, which frequently aid in the conversion of complicated compounds into simpler molecules in the insect body. According to reports, synthetic polymers are broken down by gut microbes. *Enterobacter tabaci* strain and *Bacillus subtilis* subsp. *spizizenii* strain was isolated from the midgut of Indian meal moth larvae, and they have a role in degradation (Mahmoud *et al.,* 2020). *Enterobacter* and *Aspergillus flava* are symbionts of *G. melonella* involved in plastic degradation. One strain of *Exiguobacterium* sp. YT2, isolated from the *T. molitor* gut was found to be capable of degrading 7.5 % of the weight of PS in less than 60 days (Yang *et al.*, 2015b). The PS, PE, and PPS can be degraded by *Pseudomonas aeruginosa* gut bacteria in *Z. atratus. P. aeruginosa* growth rates were not always proportional to biodegradation rates, and the structure and properties of intermediate molecules formed during plastic biodegradation may affect bacterial growth rates (Lee *et al.,* 2020). The gut microbiota of plastic or bran fed *T. castaneum* larvae revealed that *Acinetobacter* sp. was involved in degradation (Wang *et al*., 2020).

Digestive enzyme as a plastic degrading weapon

It can be inferred that an enzyme for the breakdown of LDPE may be created by an insect's digestive system (Kesti and Thimmappa, 2019). According to Przemieniecki *et al.* (2020), mealworms may break down polyethylene using enzymes including esterase and cellulase. By causing pitting and generating carbonyl-containing degradation intermediates in *G. melonella*, salivary glands can break down polyethylene (Peydaei *et al*., 2020). LeMoine *et al.* (2020) found that larvae fed PE had considerably higher activity of putative lipid oxidative enzymes.

Plastic as a sole diet for insects

As was already established, many insects can employ their metabolic processes to consume plastic as their only food supply (LeMoine *et al*., 2020). The best example is that *A. grisella* larvae ingesting and degrading PE as a sole diet survived for almost 1 month, developing into a second generation, though the PE diet did not provide enough nutrients needed for growth and survival. Provision of added nutrition enhanced PE degradation, allowing a high survival rate and enabling the breeding of a second generation with favourable PE biodegradation. It is also reported that mealworm (*Tenebrio molitor*) was capable of degrading and mineralizing Styrofoam (PS foam) when given as a sole diet (Yang *et al.*, 2020). An insect larva, super worm (*Zophobas atratus*), was newly proven to be capable of eating, degrading, and mineralizing PS. Super worms could live with Styrofoam as the sole diet as well as those fed with a normal diet (bran) over 28 days (Yang *et al*., 2020).

Conclusion

It might be beneficial to eliminate plastic pollution by creating innovative clean up techniques. Even though many microbes isolated from various locations have been reported up to this point practically, none of the organisms has been successful. The biodegradation of plastics needs to be thoroughly investigated, particularly the identification of insect microbiota that are symbiotic with plastic breakdown. Insects' complete physiological process depends heavily on the gut bacteria and digestive enzymes found throughout their entire digestive tract. The gut microbiota of insects that consume plastic may contain a variety of unique enzymes for plastic breakdown that might be exploited as a biocatalyst for the recycling and biodegradation of plastic waste. The development of remediation strategies for plastic wastes may benefit from the isolation and characterization of more plastic-degrading microbes from other sources as well as a deeper knowledge of the enzyme system involved in degradation. Additionally, the commercialization of identified enzymes and microbiota for plastic decomposition contributes to environmental sustainability.

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GENERAL ARTICLE

Traditional grain storage structures in Arunachal pradesh

Ajaykumara K. M, Chandrika Umbon, Guru P. N., Denisha Rajkhowa and Jumge Sora

Agriculture is perhaps the most common occupation among people all over the world. In India, more than 70 percent of people rely on agriculture for their livelihood (Jeeva*et al*. 2006). About 10 percent food grains are spoiling under post-harvest conditions due to lack of sufficient storage and processing facilities (Singh and Satapathy, 2003). Storage is the process of keeping grains for a short or long period of time to protect them from changing weather and pests attack. The healthy, clean and uniformly dried

grains are the basic prerequisite of a good storage practice.

A proper grain storage practices plays critical role in preventing losses caused primarily by weevils, beetles, moths and rodents (Kartikeyan *et al*. 2009). It is estimated that 60 to 70 percent of country's food grain production is stored at household level in indigenous storage structures that include various earthen structures to modern storage bins (Mobolade *et al*. 2019). Apart from these, several grain storage containers were made from a variety of locally available materials varying in design, shape, size and functions (Kanwar and Sharma, 2003).

Traditional storage methods are a type of community knowledge that has evolved over the period and has been passed from generation to generation (Natarajan and Santha, 2006). Certain traditional grain storage practices are unique to the society's culture and vary across locals, communities, villages, and countries. These indigenous practices originate from the cultural connection with specific environmental conditions, and they are based on traditional societies' having intimate consciousness of their environment.

The storage practices and methods discussed in this article are comparatively cheap and constructed with readily available local materials, eco-friendly, impart significant high shelf life to stored food grains by effectively reducing or suppressing insect infestation.

Traditional Grain Storage Practices

Paddy straw bin: Paddy straw is used for building straw bin storage structure (Fig 1). It is dried properly, specially prepared, kept straight and the dried straw is woven to form rope that is concentrically arranged over a large area with the bark of *Erythrina indica* Murr. and *E. variegate* Murr. placed alongside the straw. To store grains in this structure, they are mixed with sifted ash before being placed in the straw bin, and then the straw ropes are folded over the grains. Typically, this storage structure is suspended from the roof rafters (Jain *et al*. 2004). This design is used because it is inexpensive and easy to manage through locally available materials which keep the grain cooler. Seed viability of grains stored in the straw bin can last for two years.

In Arunachal Pradesh, the paddy retained at farm level are stored structure such as granary, local made bamboo structures (mar, dully and pachi), ekkam patta (*Phrynium pubinerve*). The structures used by the locals protect the grains to a maximum extent from storage pests. The structures are low cost and constructed with use of locally available material of bamboos, ekkam patta and toko palm are most important.

Fig 1. Paddy straw bin and Supur (Bamboo basket as paddy grain storage structure in Nahu/Komsum)

storage structure commonly used by the resource-poor farmers in the different district of Arunachal Pradesh, India for the storage of food grains such as rice, maize, millet, etc (Fig. 3, 4). The storage capacity of *Nahu* ranges from 5.0–8.0 t and can hold 0.20–0.24 t for seed purpose, with durability for 20 years. These storage structures are built near residential areas in the village and are positioned apart to avoid a fire outbreak. The structure resembles a crib but is divided vertically into three compartments; the lowest compartment for firewood, the middle compartment remains empty, and the grains are stored in Supur (Fig. 1) after thoroughly drying by making airtight compartments at the top, made up of bamboo mats and *Livistona jenkensiana* leaves. To create an airtight compartment for grain storage, finely woven bamboo mats are tightly set on the ground and the walls. After the grains are added to the store, it is tightly covered with a bamboo mat by keeping stones over it, leaving no space left for rodents entry. *L. jenkensiana* used for roofing are replaced every five years (Sarangi *et al*. 2009). The majority of farmers in most rural farming communities stored food grains near the kitchen where the heat and smoke of burning firewood penetrates *Nahu* to keep the food grains free from insect pest infestation (Sarangi *et al*. 2009).When large quantities of grains to be stored, specially raised barns are built; a slow burning fire is lit and hot air is controlled to keep grains dry (Sarangi *et al*. 2009).

Fig 3: Nahu at village Padu, Upper Siang Arunachal Pradesh

Fig 4: Nahu at village Ayeng, East Siang Arunachal Pradesh

Modified Nahu: In recent times during survey in Siang valley of Arunachal Pradesh, we have noticed the traditional storages structures are being constructed using RCC columns in place of wood as they last longer than wooden columns. RCC columns run till plinth level and the main storage housing are constructed using timber frame and walling are done using bamboo sheets. Timber panels are also used widely for walls. Roofing is constructed using timber frames and GI sheets for cover. GI sheets are more preferable as they are easy to install and longer than traditional thatch roof and toko palm as it have to change every two years (Fig. 5, 6). As per the opinion of farmers, the pitch roofs are most preferable structures as they allow quick and easy flow of rainwater and keep the storage space dry.

Fig 5: Modified Nahu at village Padu, Upper Siang, Arunachal Pradesh

Fig 6: Modified Nahu at village Ayeng, East Siang, Arunachal Pradesh

Conclusion

The methods and procedures for storage covered in this article are relatively inexpensive, made from locally accessible materials, environmentally benign, and give stored food grains a significantly long shelf life. These traditional food grains storage and preservation practices can be improved upon or modified as needed to ensure safe grain storage and full realization of agricultural potential in order to meet the increasing food and energy needs, globally.

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GENERAL ARTICLE

Water jetting technology: An eco-friendly approach towards managing sucking pests

Sourabh Maheshwari

Sucking insects are considered to be most notorious group of pests. They possess piercing and sucking type mouth parts with slender needle like stylet to pierce the plant cell in order to suck the juice from leaves and stems. These pests considered being more severe in damaging crop and their complexes are identified until advanced stages of infection. They are also responsible for fungal growth as they secrete honey dew which promotes growth of black sooty mould on plant leaves that also attract Ants. These sap suckers deplete the nutrient value of the leaves and makes the leaves unpalatable and in case of severe incidence growth of plant stunted. Some of them also inject toxic materials into the plants while feeding, which lead to wilting of plants. They also act as vector and transmit plant diseases.

Natural control of Sucking Pests

Sucking pests are naturally controlled during rainy season. When it rains heavily, many small insects get dislodged from plant surfaces by the combined effect of wetness, kinetic energy of the rain drops and strong winds. This observation gave an idea to researcher of Silk Board to develop a water jetting package which attempt to apply the physical force of water against the sucking pest menace in mulberry cultivation.

Water Jetting Technology as a new component of IPM

Spraying strong jet of water is one of the component recently added in IPM. It is recommended to manage the sucking pests like thrips, aphids and mites etc., under both agricultural and horticultural crops. In this technology, the pests are dislodged and washed-out from the plants with strong jet of water and the pest population kept below economic injury level (EIL). This practice is effective and eco-friendly, but it consume bulk quantity of water which is a serious constraint for many agro-ecological regions. Care should be taken during flowering stage of the crop. This approach can be utilized by diverting irrigation water for jetting. This technology also conserves natural enemies in ecosystem.

Water jetting system in Mulberry Garden

Water jetting concept utilizes spray of strong jet of water to manage the sucking pests. This technology is found to be highly successful against major sucking pests of mulberry viz., pink mealybug, Maconellicoccus hirsutus, papaya mealybug, Paracoccus marginatus, mulberry thrips, Pseudodendrothrips mori, spiralling whitefly, Aleurodicus dispersus, mulberry whitefly, Dialeuropora decempuncta, jassid, Empoasca flavescens and mites etc. These sucking pests cause severe damage to mulberry leaf yield and quality. This technology found to be effective for control of these pests in mulberry garden in which a portion of irrigation water from the main pipeline was diverted through a garden hose for jetting.

Study Results of water jetting technology Vs Chemical measures

Sakthivel et al studied comparative efficacy of water jetting technique (by diverting a portion of irrigation water) with chemical measures against some major sucking pests of mulbery. The results shows that the water jetting at 15 and 25 days after pruning (DAP) of mulberry plants was found to be effective in controlling sucking pests. It is also observed that chemical measures drastically reduced the population of insect pest for a short period of time but at long term shows detrimental effect on natural enemies. Highest population of natural enemies were observed in the water jetted plots with slight or no deleterious effect on predatory coccinellids and spiders. Hence it is more viable option for sustainability, especially for region where water availability is not a big constraint.

Benefits of Technology

Farmers' supply water for irrigation as well as sufficient flow quantity can use for generating water pressure to hit the lethal pests and wash them out from plants. Farmers' who do not have pipeline across the garden can establish the system for one acre at a cost lesser than that of the cost of a high volume sprayer. In case of sericulture, chemical measures to control pests in mulberry garden are not possible after initiation of silkworm rearing. But water jetting can be done at any moment if pest incidence is noticed even after initiating silkworm rearing. Another benefit of water jetting is that it removes dust from the leaves which increase photosynthetic activity and silkworm also prefers dust free quality leaves which results in increased silk productivity and income of farmers.

Conclusion

Water jetting technology is highly effective, eco-friendly, user-friendly, economic and could bring solution to the pesticide issues which posses' great threat to environment. Chemical measures are not sustainable for long term as its use lead to development of resistance, especially in case of sucking pests. At the same time, it destroys natural enemy complex because of their high sensitivity towards chemicals. The repeated chemical measures often results in the sudden outbreak of sucking pests i.e., resurgence. Hence this technology can be included in IPM package of practice for managing sucking pests.

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Mating genres in Mecoptera

K Chandrakumara, Vijay R, Basavaraj N Hadimani and Siddanna

All living organisms reproduce to maintain their identity, and each species has its distinctive mating behaviour. Arthropods have developed different mating rituals like the production of serenades (Crickets), performing dances and foreplay (Jumping spider), aphrodisiacs (Moths) *etc*., to attract the opposite sex. Mecopterans are the ones which are branded for their several genres of mating behaviours. Mecopterans resemble those primitive insects such as mayflies. The abdomen typically curves upwards in the male, superficially resembling the tail of a scorpion, hence called the Scorpionfly. In general, grownup mecopterans are habitually scavengers, devouring the soft bodies of dead invertebrates and decaying vegetation. However, some members of Mecoptera such as Panorpids and Bittacids (hanging flies) are predators and feed on the soft bodied insects. *Panorpa*, raids spider webs to feed on trapped insects and even the spiders themselves, whereas, Bittacids capture flies and moths with their specially modified legs. Mecopterans have adopted different kinds of mating strategies which includes salivary secretions as a nuptial gift, dead arthropod as a nuptial gift, hunted prey as a nuptial gift and sexual coercion. However, the attraction of the opposite sex and mating success is depending on the type and quantity of food offered.

MATING APPROACHES

Mating tactics are specific to the different mecopteran families. However, depending on the situation, members of a single family can also demonstrate multiple mating strategies

Salivary secretions as the marital donation

Remarkable sexual dimorphism amid the sexes can be seen in salivary glands. These are short and bifurcated in the female, whereas in males these are well developed and multiple-furcated. Here, the male serves the female with a salivary mass that it discharges. In the course of their secretion, these stiff, pillar-shaped aggregates (salivary mass) cling to a leaf. After secreting the saliva mass, males disseminate sex pheromone by an eversible sac present in the genitalia across a long distance. A female magnetized by the pheromone feeds on the saliva. At the same time, the male holds the female forewing with a notal organ (a specialized clamp-like structure produced from parts of the third and fourth abdominal dorsum in the male) and continues to copulate and which may continue for some hours in some species (Kock *et al*., 2007).

Another similar strategy to attract a promising mate nearby is that male vibrates his wings and swings his abdomen up and down rhythmically and releases sex pheromones from a pouch-like gland located in the genital bulb. After luring a female, the male stops delivering olfactory signals and secretes a drop of liquid salivary secretion that sticks to his mouthparts. When the female tries to feed on the salivary discharge, the male advances to her lateral side and seizes her IXth abdominal segment with his gonostyli. As a result, the male and female take an O-shaped mating stance, with only their mouthparts and genitalia making contact (Fig. 1). During copulation, the female is continuously supplied with the liquid salivary secretion by the male in a mouth-to-mouth mode. When feeding on salivary secretion, the female frequently cooperates with the male to maintain a firm mating posture and when it stops feeding, the female ends copulation by lashing her abdomen to break off the vaginal connection and departs the male (Zhong *et al*., 2015). This is the most common sort of mating ritual among Panorpids.

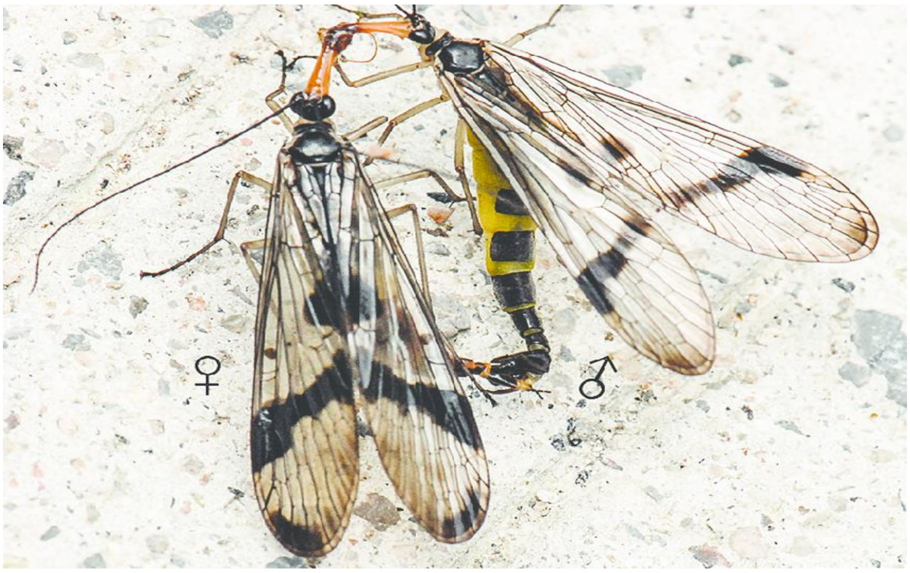

Figure 1: Copulation of *Furcatopanorpa longihypovalva* takes O-shaped stance (Zhong *et al.,* 2015)

Dead arthropod as a nuptial gift

The diet of Panorpidae comprises around 89-97% of deceased insects of which, Dipterans share 47-69% (Thornhill, 1975). Male feeds on dead arthropods and diffuse sex attractant while standing adjacent to the dead arthropod, also parade wing movements and abdominal vibrations to attract females. Males guard nuptial offerings against other males that attempt to seize them through aggression. During hostile interactions, males seldom hook a rival's wing or leg through a pair of sharp claspers formed from the distal end of the genital bulb.

According to laboratory and arena experiments, dead arthropod presentation is preferred over saliva presentation by *Panorpa* males (Fig. 2). Forced copulation is employed by males only after they have exhausted all other options due to resource scarcity, which might be caused by a lack of absolute resource availability, intensified male-male rivalry, or both. Furthermore, the body weight of males decides their success in the competition for resources. The larger the male the more he engages in discretions ensuing in more relative mating triumph (Thornhill and Gwynne, 1986; Thornhill, 1981).

Figure 2: *Panorpa communis* with prey(Richard Bartz, Munich aka Makro Freak image; https://en.wikipedia.org/wiki/Panorpa_communis#/media/File:Panorpa_communis_with_prey_Diogma_glabrata_glabrata.jpg)

Prey arthropod being a bridal reward

This kind of mating strategy is most frequent in hanging flies (Bittacids) (Fig. 3). Soft-bodied insects like aphids, tipulids and houseflies are the major prey of Bittacids. They hang on vegetation to quest the target which arrives in their vicinity. After grabbing the prey, the male releases the pheromone, and a female comes near the male and drops her wings. By this moment the female is dangling directly in the obverse of the male. Males use wing-lowering as the cue for the presentation of prey to the female. During prey offering and feeding by the female, the male holds the prey employing both hind legs and one or both middle legs. The male tries to pair his genitalia as the female start feeding on the nuptial reward. Ultimately, the female engages the male's genitalia once she has assessed the excellence of his nuptial offering

(Iwasaki, 1996). These Bittacids can also exhibit transvestism and piracy practices to steal the prey so that, the time to capture prey is reduced and exposure to predators is also less (Thornhill, 1979).

Figure 3: Hanging scorpionflies *(Bittacus* sp.) with moth prey

(Naskrecki's image from Life in the season of death, 2013; https://thesmallermajority.com/2013/07/23/hanging-in-there/)

Rape / Sexual duress

Rape encompasses a male with no nuptial offering *i.e.*, salivary mass or dead insect, hastening on a passing female along with fixing out his moveable abdomen at her. It is the most common ritual in Panorpids. The abdominal tip is a large and muscular genital bulb accompanied by a terminal duo of genital claspers. The male slowly endeavours to change the position of the female after successfully snatching a leg or wing of the female through his genital claspers. Afterwards, he locks the forward edge of the female's right forewing inside the notal organ. Females fight briskly to escape as soon as grasped by such a male's genital claspers. The male tries to clinch the genitalia of the female with his genital claspers once the female wings are secured. But the female struggles to retain her abdominal tip away after the male's probing claspers. The male keeps holding the female's wing with the notal organ during copulation and which could remain for a few hours in some species. However, the contribution of rape behaviour to the reproductive success or genetic propagation of the rapist is unclear from studies to date. Although efficacious rape (*i.e*., including insemination) might be uncommon this one is usurping behaviour meant for a male to adopt when he is aggressively eliminated from his salivary secreting capacity and the tenure of a dead insect. The fitness achievement of the *Panorpa* rapist is comprehended when the behaviour of these insects is paired with their ecological scenario (Thornhill, 1980) (Fig. 4).

Figure 4: Sexual coercion in *Boreus brumalis*

(Naskrecki's image from Life in the season of death, 2013; https://thesmallermajority.com/2013/01/23/life-in-the-season-of-death/)

Conclusion

The goal of every single organism resting on this earth is self-perpetuation, which is also true of mecopterans. Mecopterans are habituated to moist environments and also to hotter climates, where they act as scavengers of dead arthropods and predators of moribund organisms. Although mecopterans are of little apparent economic significance, they represent a systematically and biologically important, ancient insect lineage. A wide array of mating-related morphological specializations presumably reflects more varied historical mating strategies and behaviours in the Panorpoidea group. Mecopterans may have developed a broad array of mating strategies due to a lack of absolute resource availability, increased male-male rivalry, or both. Intense male-male competition in the resource-defense polygynous mating system creates different options for males of different competitive abilities. It is evident that the resource for which males compete is scarce and essential to female reproduction. The preferred mating genres for both sexes are those that lead to greater fitness, *i.e.*, more copulatory success and survival for males, and greater fertility and survival for females. Mating specialization in mecopterans provides the first insights into the long-term evolution of sexual competition over mating among insects.

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Firefly, ecology and environment: A webinar in India

Parveza, A.K. Chakravarthy, Amlan Das

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

Fireflies are indicators of climax vegetation, found in tropical as well as temperate regions. Fireflies produce cold light with no infrared or other harmful frequencies. At times, adults serve as pollinators and predators and are essential for stable ecosystem functioning. Adults emit flashes of light synchronously that attract tourists in large numbers. So, fireflies are a source of growing eco-tourism (Lewis 2016 and Fuzi *et al* 2021).

Adults are generally identified by pronotum dorsally extending forward covering head, head, without median ocellus and base of antennae separated on head. Adults are with leathery dorsal elytra and luminous organs in ventral side of abdomen, generally more pronounced in males than females. Larvae are generally flat, cylindrical, or worm-like with distinct segmentation and lateral expanded pleurae.

Larvae in aquatic species are often with reduced sclerites and might have gills. Adults are found in moist grassy patches, verges, hedge banks and larvae under soil, stones, etc. Life stages may be in terrestrial or aquatic habitats, arboreal or subterranean. Larvae are carnivorous. feeding on snails, slugs, earthworms, ants, termites, gastropods and decaying organic matter (Riley *et al* 2021).

Fig 1. Firefly Egg, larvae, adult and Congregation population of fireflies at night (http://indiasendangered.com/say-no-to-firefly-festival-period/)

The Webinar

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

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

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

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

The Western Ghats

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

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

Threats

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

Mitigation

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

The following recommendation was made at the end of the webinar

- Development of a portal on fireflies in India.
- A checklist and the Field Guide for Indian subcontinent.
- Flyers on fireflies for the pubic highlighting the ecological significance of fireflies.
- Establishment of an *Asia-Pacific Fireflyers Network* (adjunct to Fireflyers International Network).
- Establishment of a firefly park in Karnataka, India, first of its kind in Asia.
- Declaration of a part of the Charmadi Ghats as a protected area.
- Standardization of protocols for rearing and mass multiplication of select firefly species.
- Development of logo and organizing Firefly-Walk in Charmadi ghats, and other part of Western Ghats, India.

The webinar concludes with the vote of thanks.

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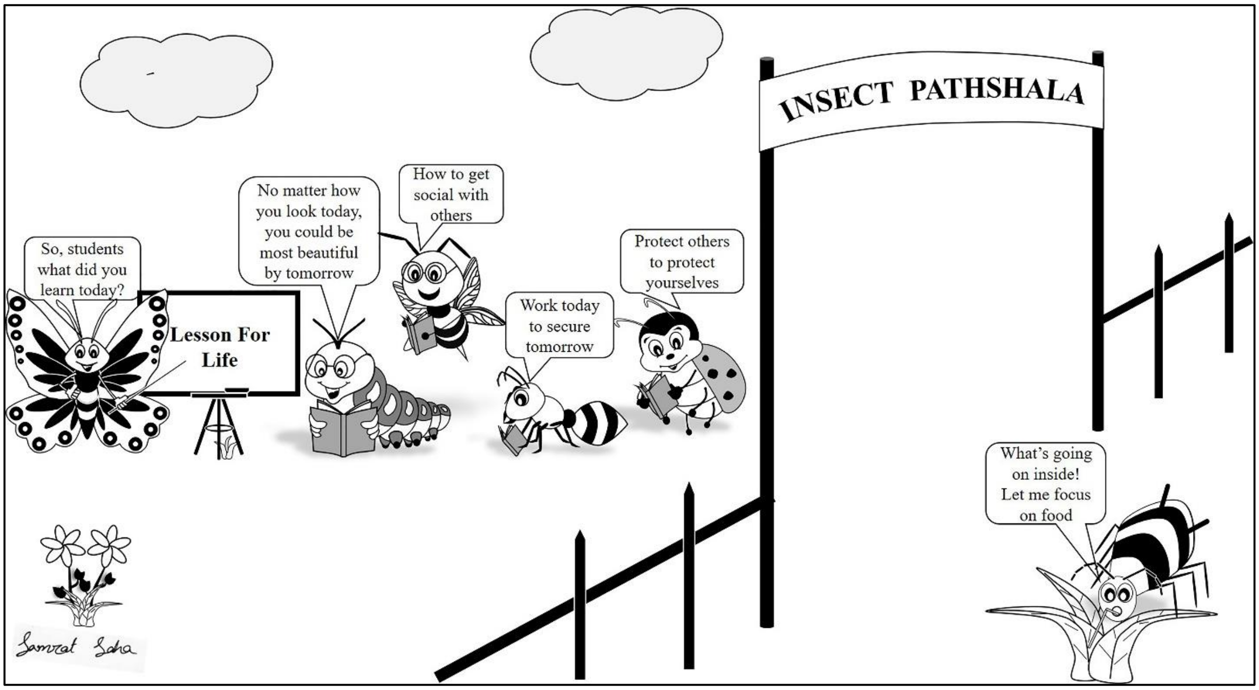
The webinar was live-streamed on EMPRI website (https://empri.karnataka.gov.in/news/Fireflies,%20Ecology%20&%20Environment%20webinar%20recordings/en)

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

CARTOON

INSECT PATHSHALA



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Seventh Indian Entomologist Photo Contest

The Indian entomologist photo contest aims to encourage insect photography among photographers, professionals, amateur entomologist, and the layman. The theme of the seventh episode of the photo contest was ‘Insects and aspects related to insect life’. With these objectives, entries were invited during 8th November to 15th December 2022. Each participant should 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.

In the Seventh photo contest, we received 130 entries. These 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 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 best photo award was given to Mr. Raghuram Annadana, Address: 20133, Tower 20, Prestige Ferns Residency, Harlur Road, Off Sarjapur Road, Bangalore – 560102, Karnataka e-mail: araghu@gmail.com, who captured the emergence of pair of Blue banded bees (*Amegilla* sp.) roosting with their mandibles clamped to a twig.

BUG STUDIO ASSOCIATE EDITORS

Dr. Rajna S.

Mr. Anooj S. S.

Dr. Archana Anokhe

Best Photo: Seeing Double: P*air of Blue banded bees (Amegilla sp.)* roosting with their mandibles clamped to a twig. Photo by Mr. Raghuram Annadana, Address: 20133, Tower 20, Prestige Ferns Residency, Harlur Road, Off Sarjapur Road, Bangalore – 560102, Karnataka, India. Photo taken on 12.02.2022, Nikon D850 DSLR Venus Laowa, 100mm 2x Macro Lens, 1/200, ISO200, F11, 11.2 MP.

Second place: A deadly Arachnidism -*Spider preying on foraging bee.* Photo by Mr Riju Nath, Address: Uttar Banga Krishi Viswavidyalaya, Pundibari - 736165, Cooch Behar, West Bengal, India. Photo taken on 30.06.2020, ASUS Zenfone Pro Max M1, SO-100, Focal length-3mm, Image resolution-2690 X 1903, 72dpi

Third place: Feeding -Grizzled pintail (*Acisoma panorpoides* feeding on *Ischunura rubilio)* Photo by Dr S S Suresh, Address: PO Box 396, Ibri 516, Sultanate of Oman. Photo taken on 29.05.2022 at Trichur, Kerala. Canon 70 D, Canon 100 mm macro 2.8, 1/100 sec, f/16.0, ISO 125, 100 mm

ASHIRWAD TRIPATHY

DEPARTMENT OF FOREST ENTOMOLOGY, FOREST RESEARCH INSTITUTE, DEHRADUN, UTTARAKHAND

Mr. Ashirwad Tripathy is pursuing his PhD degree from Department of Forest Entomology, Forest Protection Division, Forest Research Institute, Dehradun, Uttarakhand. He is currently working on the species diversity of ants (Formicidae: Hymenoptera) and their biotic interactions in two different forest types of Garhwal, Uttarakhand under the guidance of Dr. Arun Pratap Singh (Scientist G, Officer in Charge), F.R.I., Dehradun and co-guidance of Dr. Himender Bharti (Professor), Punjabi University, Patiala. His focus interest is to compare the ant diversity and taxonomy in Himalayan Moist Temperate Deciduous and Tropical Moist Shiwalik Sal forests of Garhwal, Uttarakhand. In addition, he is studying the potential distribution of important ant species in the high altitude and Shiwalik forests using ecological niche modelling. He is also looking into the biotic interactions of ants in the forest both at inter and intra specific level, and the variations in the antennal sensilla of ant species in different forest types. He states *"**forests are not just a piece of land with vegetation but an ecosystem with multiple micro ecosystems inside it. As we go for sight-seeing landscapes, waterfalls, etc., similarly invertebrates encounter these every day in their micro level world**"*. In future he intends to carry out studies on the gut microflora of ants in Indian context

ARUN SAI KUMAR

DEPT. OF AGRICULTURAL ENTOMOLOGY, UNIVERSITY OF AGRICULTURAL SCIENCES, RAICHUR, KARNATAKA, INDIA

Mr. Arun Sai Kumar is a Ph.D. student working on Fidelity of genetic interferences to improve the resistance against pod borer, *Helicoverpa armigera* in pigeonpea crop under the guidance of Dr. Rachappa. V. and Dr. Jaba Jagadish (ICRISAT, Hyderabad). Goal of the investigation is to explore non-utilized, potential candidate wild relatives to identify new genetic resources resistant to pod borers in pigeonpea and to determine the biochemical and molecular basis of insect resistance mechanisms in contrasting pigeonpea lines through non-targeted metabolomic profiling. Further he is planning to continue his research on ***assessing genetic diversity of wild relatives of pigeonpea exhibiting resistance to pod borers*** by using morphological, biochemical, and molecular markers.

HEMANT KUMAR

DIVISION OF ENTOMOLOGY,
ICAR-INDIAN AGRICULTURAL RESEARCH INSTITUTE, NEW DELHI

Mr. Hemant Kumar is a PhD Scholar at the Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi, in the major field of Insect Physiology. He is currently working on impact of heat stress on reproductive physiology of *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae) under the guidance of Dr. Sagar D. (Scientist), ICAR-IARI. He is studying the expression of differentially expressed transcripts, variations in reproductive parameters, antioxidant enzymes and protein profile in male accessory glands of *Spodoptera litura* in response to heat stress at sublethal temperatures. The common cutworm, *S. litura*, is highly polyphagous affecting many major crops and a notorious pest of agriculture in Indian condition. Such studies can provide preliminary information to predict its future status, distribution, fitness and extent of damage under the changing climatic conditions. As a student of Agricultural Sciences, Hemant says, ***"Mother Nature possesses its own regulatory mechanisms to maintain the balance of life on earth, which we refer as biotic and abiotic factors. And I see a great scope of exploration of this nature driven factors which can open innovative ideas for pest management"***. He intends to continue his future research on impact of climate change on insect pests.

AKSHATHA G

DEPT. OF AGRICULTURAL ENTOMOLOGY,
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Akshatha is pursuing her Ph.D. at the Dept. of Agricultural Entomology, UAS, Raichur under the guidance of Dr. M. Bheemanna. She is working on radiation induced inherited sterility technique for the management of pink bollworm. She is studying the substerlized (doses which carry the inherited sterility to further generations) gamma radiation (100, 150 Gy) induced inherited sterility in *Pectinophora gossypiella* on subsequent generations and the pheromone response of normal and irradiated males. In addition, she wants to know the efficiency of irradiated male *P. gossypiella* at different ratios under caged condition. She is also planning to study the ***interaction of gamma radiation (100 Gy and 150 Gy) induced inherited sterility with diapause and proteomic changes on the haemolymph protein of pink bollworm***. She believes that this technique has a great potential and can be an important tool for the eco-friendly management of certain serious agricultural pests, and in future she intends to carry forward her research on SIT in other major insect pests.

SOWMYA M

DEPARTMENT OF BIOCHEMISTRY,
JAIN (DEEMED-TO- BE UNIVERSITY),
BANGALORE, KARNATAKA, INDIA

Sowmya M is pursuing Ph.D. in Biochemistry from Jain (Deemed-to- be University), Bangalore, Karnataka. She is currently working on effect of phytoncides on physiology and biochemistry of *Corcyra cephalonica* (rice moth) under the guidance of Dr. Kesavan Subaharan (Principal scientist, Division of Germplasm Conservation and Utilization ICAR-NBAIR, Bangalore). *C. cephalonica* is serious pest on stored cereals, pulses coffee and nuts. Management of stored product pest is difficult using chemical insecticides due to their ill effects on consumers. To counteract the detrimental effects of the insecticides being used to control this pest, she is working on effect of plant derived essential oils and constituents to control this pest. She exploiting plant derived essential oils and constituents for insecticidal activity against egg, larvae, and adult stages of *C. cephalonica* and also evaluating the effect plant chemicals on insect detoxification enzymes. She is also studying the effect of sub lethal doses of EOs and constituents on growth, development, and macromolecules of *C. cephalonica*. She is also elucidating the physiological and behavioural responses of *C. cephalonica* female moths to plant compounds. ***Due to their volatility, essential oils are particularly susceptible to biodegradation. To over this she is also working on advanced delivery systems to deliver active ingredients to the target species***. She is eager to carry on with her research into the effectiveness of phytochemicals against other significant pests that attack stored grains.

Mr. Kishore Chandra Sahoo, Ms. Akshatha, Mr. Sanath R. M., Student Associate Editors of IE compiled the information for this section.

Indian Entomologist is a biannual on-line magazine and blog site 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.

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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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