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INDIAN ENTOMOLOGIST

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FEATURING

Tête-à-Tête with Dr. S.N. Puri

Pigeonpea wild relatives for pod borer management

Women in Entomology: Dr. J. Poorani

INDIAN ENTOMOLOGIST

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Editorial Board

***Cover page image: Mr. Nidheesh K B (Madykonam, Kerala-680712 showing a lynx (*Oxyopes* sp.) preying on a stick spider (*Miagrammopes* sp.)**

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EDITORIAL

Entomology Random Thoughts

The Indian Entomologist which is serving as a unique forum for dissemination of Entomology is progressing well and is splendidly moving forward in the right path with the experiences gained in the last two years or so. This forum devoted to Entomology in India could be a platform for introspection of what we all are doing as professional Entomologists. This introspection shall not only perceive how Entomology was performed and disseminated by our earlier generation of Entomologists, but also introspect how we all are taking these forwards with due dedication and determination. Also, it is necessary to deliberate upon how the handling of Entomology ought to improve in the next few years to make it in tandem with the global scenario, especially in some of its critical aspects.

As an Entomologist I have an opportunity to perceive at least some parts of what is going on in Entomology in India. This comes to me as an Editor of few journals which handle Entomology information emanating from Indian Entomologists in the past decade or so. This perception takes into account what are all coming as inputs from Entomologists, many of whom are young and budding entomologists, to Indian Entomologist too. With this background in the back of my mind, I feel it is right time to put forth some of my thoughts on how Entomology has to progress, and take cognisance of changes that are imminent. Thousands of research communications that land up with Indian Journal of Entomology provides update on the current handling of Entomology by professionals in India. The review articles that I had opportunity to peruse provide only a dismal picture of current thinking among us, about what are the prospective and emerging aspects that deserve due deliberation. A good lot of these seem to run of the mill, I must confess with regret. The same is true with the contributions that lad up with Indian Entomologist, though it is only for a short period of last two years. One of the causes for this I feel is there is lack of avenue for all of us to perceive the right and appropriate aspects and generate a thinking process that will pave for the way for the desired directional changes. This will enable the progress of Entomology with change of thought-provoking process that ought to set in with we, all Entomologists.

I just want to quote here two such examples from what I happened to read from the current global science disseminating platforms. These are the platforms that I am sure are the ones any one can peruse to know current thoughts in how the science is progressing, in all its aspects. The first one is an exemplary piece of work by Farisenkov *et al.*, (2022) (doi: https://doi.org/10.1038/s41586-021-04303-7), on the flight performance of tiny beetles; and the second is a correspondence by Costello *et al.*, (2022) (doi: https://doi.org/10.1038/d41586-022-00010-z) on some thoughts of how two million species catalogued by 500 experts. These are random ones, let us all read these, and many more such pieces. Let us introspect how much of our Entomology thoughts, at least perceive the bare minimum we can do and initiate a thought process. I am sure every day we all will have opportunity to at least peruse such thought-provoking disseminations. This must not stop with just perusal, it must percolate down into young minds that practice Entomology now. Also, initiate contributions in the directions of the global thought process, may be even few of us do this, that will be enough and satisfying. In this new year of 2022, let us hope we move towards prospective entomological science.

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

TÊTE-À-TÊTE

A DIALOGUE WITH DR. S.N. PURI

A LEGENDARY ENTOMOLOGIST, A PROVEN LEADER, THE LONGEST SERVING VC OF AGRICULTURAL UNIVERSITIES IN INDIA AND MUCH MORE, YET WITH HIS FEET ON THE GROUND AND A GREAT AFFECTION FOR THE SCIENCE OF FARMING AND FARMERS

Born on 24 January 1945 at Kharsoli, a small village in Nagpur District of Maharashtra, Dr. Subhash N. Puri was a bright student right from the very beginning. He completed his school education at Municipal High School, Mowad, Tehsil Narkhed, Dist. Nagpur. After completing his B.Sc. (Agri.) degree from College of Agriculture, Nagpur in 1968 with second position in order of merit from Nagpur University, he then moved to Indian Agricultural Research Institute (IARI), New Delhi to complete his M.Sc. and Ph.D. degrees in 1970 and 1975, respectively. Dr. Puri started his career in 1973 at Marathwada Agricultural University (MAU), Parbhani (Maharashtra) as an Assistant Entomologist (Cotton) and progressed in his career from Associate Professor, Professor and to become the officiating Head, Department of Entomology at MAU. Dr. Puri then moved to ICAR as a Director of National Centre for Integrated Pest Management (NCIPM), New Delhi during 1995-99. At NCIPM he did pioneering work on promoting IPM programmes in villages which lead to the success story of "Ashta, a model IPM village". Dr. Puri is the only Vice-Chancellor out of all the Agricultural Universties in India who has held the office for the longest period of time of 15.5 years. He started as the VC of Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri (1999-2004) and later as the VC of Central Agricultural University (CAU), Imphal (2004-2014). Both the universitites excelled on par at national level as a result of not only his focused efforts, sense of creativity and responsibility, but also because of the remarkable developments in the infrastructure, research and academics.

During his glorious journey of almost 41 years as a researcher, academician and science manager, Dr. Puri brought many prestigious laurels to himself and to the institutes he served. Some of the individual awards received by Dr. Puri are: Hexamar Foundation Award (1992), Achievement Award for IPM (1998), Sri Dodla Ragava Reddy Memorial Gold Medal Award (2002), Bramharshi Award (2003) by Environmental Protection and Sustainable Development Society (BHU, Varanasi), Honorary Fellowship Award (2002) by Applied Zoologists Research Association, Dr. M.R. Siddiqi Medal Award (2004) and Academic Leadership Award (2010) by Agriculture Today. Dr. Puri held various honorary posts on scientific bodies/ professional societies which includes: President, Society for Plant Protection Sciences (1996-2002); President, Indian

Agricultural Universities Association, New Delhi (2005); President, Indian Universities Association (2012); Member Working Committee of BCCI (2012). Currently he is presiding the President of Entomological Society of India (2004 - till date).

Besides his individual achievements, Dr. Puri is a proven leader in science and academics in India. The grand success story of the model IPM village implemented under the able guidance and dynamic leadership of Dr Puri as a Director, NCIPM brought the institute a good name at national level and the efforts were recognised by ICAR with Outstanding Team Research Award for the Biennium 2003-04. Dr. Puri has made landmark achievements during his tenure as a the VC of MPKV, Rahuri in terms of infrastructure development, increase of revenue income through mobilization of internal resources, strengthening of facilities for academics and research programmes. In recognition of this, MPKV was bestowed with the "Sardar Patel Outstanding Institute Award – 2002" by the ICAR, New Delhi for excellence in the field of Education, Research and Extension Education. Under the leadership of Dr. Puri as VC, the CAU, Imphal occupied second position twice in 2012 and in 2014 at national level as the best University based on its students' performance to secure maximum number of JRF positions.

Dr. Puri speaks to Dr. Babasaheb B. Fand, Associate Editor of Indian Entomologist and talks about his arduous and glorious journey from being a Scientist to the country's longest serving Vice Chancellor of Agril. Universities. The glimpses of the interaction are given below:

Dr. Babasaheb: Sir, on behalf of Indian Entomologists, I thank you for accepting our invitation to speak with the magazine as an Eminent Entomologist of India. Sir, our readers would like to know about your journey from a Scientist to the country's ever longest serving Vice Chancellor.

Dr. Puri: I was basically born and brought up in a rural set up and completed my primary and secondary education from a school at Mowad, my native place which was famous for its quality education at that time. My mother who was a primary teacher was not only the greatest inspiration in my life, but was also the one who identified and nurtured my talents (*Dr. Puri gets emotional for a moment with tears in his eyes in the fond memories of his late mother whom he lost to old age an year ago*). I secured 9th rank in Vidarbha region at Secondary School Certificate (SSC) examination in 1962. After completion of my 10th standard (SSC) examination I took admission in Government Science College in Nagpur. However, I could not pursue the same due to my family's poor economic condition. I then shifted to College of Agriculture, Nagpur and completed my B.Sc. (Agri.) degree with 2nd rank during 1964-68. It was my dream to get admission to IARI, New Delhi for the fellowship the institute provided so it could support my post graduate studies. I completed my M.Sc. (1968-70) and Ph.D. (1970-75) from Division of Entomology, IARI, New Delhi. After completion of my higher studies I joined Marathwada Agricultural University (Now, VNMKV), Parbhani in Maharashtra as an Assistant Cotton Entomologist in the year 1973 and rose to the level of Professor of Entomology in 1979. I was additionally looking after the charge of Head, Department of Entomology for more than 14 years. In the year 1995 I got an opportunity to serve the national agricultural research service by virtue of Director, NCIPM, New Delhi.

Since then the graph of my career went on up and I never looked back. I was selected as a Vice Chancellor of MPKV, Rahuri consecutively for two terms (1999-2004) and CAU, Imphal for two terms (2004-2014). I was also given an additional responsibility of Vice Chancellor of Konkan Krishi Vidyapeeth (KKV), Dapoli (MS) for a short period during 1999-2000.

Dr. Babasaheb: What was the special thing that made you to be an Entomologist? How did you choose Entomology as your profession?

Dr. Puri: I did not choose specifically or purposely Entomology as my profession. It happened as it is and went on. But yes, I do remember two key persons during my Undergraduate studies who inspired me to be an Entomologist, one was Dr. H.S. Thakare and the other was Dr. S.K. Mundewala at College of Agriculture, Nagpur. Both were really hardcore teachers of Entomology, because of which I developed interest in the subject. At that time, under the leadership of Dr. K.R. Thakare, the Entomology Section of the College of Agriculture, Nagpur was famous for its stalwarts. Another interesting thing that I would like to share in this context was that it was my hobby to learn and remember the scientific names of animals and plants. Whenever my teachers of Botany and Zoology asked for identifying the plants and insect specimens, I used to answer with the scientific names rather than only telling common names. Thus, Entomology became a subject of my liking and choice as compared to other students who were generally scared of this subject on account of it. They found it boring and difficult to remember scientific names of the insects. Apart from this, I got fellowship at IARI to pursue my post graduate studies in Entomology. This was turning point in my life to be an Entomologist as the fellowship helped me in supporting my higher studies in the backdrop of poor economic conditions of the family. Once I joined my service, it was my dedication towards the farming community to develop and promote areawide IPM programmes to alleviate the serious pest problems of agricultural crops. The concept of "model IPM village" implemented in the capacity of Director, NCIPM, New Delhi gave me an identity of a "*Man of IPM*". It was the inspiration of Dr. R.S. Paroda, Former DG, ICAR.

Dr. Babasaheb: What are the challenges you faced in achieving your career goals? I think you are perhaps the country's longest serving Vice Chancellor. You have served for two terms as a Vice Chancellor of MPKV, Rahuri and another two terms as a Vice Chancellor of CAU, Imphal. Can you tell us something about the challenges you have to face while serving at these key managerial positions and what was your vision for the Universities you served?

Dr. Puri: As I told you in the beginning, rural and poor family background was one of the biggest hurdles in my early educational life. But my parents, especially my mother, recognized and nurtured my talents and potential in time. Whatever I have achieved in my life is all thanks to my mother. Through my sincere and hard efforts I could ensure fellowship, which was really a boon for me to complete my higher studies at IARI.

I have also struggled through many hardships during my professional career. When I joined MAU, Parbhani in 1973, it was in a budding stage with lack of facilities and a research vision. The biggest challenge before us was to establish well equipped laboratories and to inculcate and nurture an attitude towards research. I was quite lucky to receive full handed support from my seniors and peers in the Department to put in my vision for creating good atmosphere for research and education. Dr. A.K. Raodev, the then Head of Entomology Department and Dr. V.M. Pawar, Professor of Entomology stood strongly behind me and encouraged me in my research and academic endeavours.

Under the able leadership and guidance of Dr. Raodev, a massive campaign was implemented in a Ratoli village to manage the menace of white grubs infesting sorghum crop in Marathwada region. This was the first community-based approach for pest management which involved mechanical destruction of white grub beetles by shaking neem and babul trees during the night time and burning them with a kerosene fire, spraying of insecticides on babul and neem trees and drilling of BHC powder in soil using seed drill. We, the staff of the University, stayed at the village for 10-15 days and made a white grub management campaign a great success story. The noteworthy achievement of this campaign was that it paved the way for establishing the All India Coordinated Research Project (AICRP) on white grubs by ICAR, New Delhi. I was also instrumental in collaboration of the University with Hexamer Foundation. The grants of Rs 6 lakhs per year received under the collaborative programme were used to establish pesticide research laboratory in the Department of Entomology. Under this collaboration, we conducted human health safety trials for the pesticide exposure. Ours was the first Agricultural University in India to conduct such trials and this further paved way for registration of synthetic pyrethroids for use in India during 1976.

The roles of Vice Chancellors at MPKV Rahuri and CAU, Imphal were altogether different with diverse challenges. On one hand, MPKV was a well-established University with a good set up of infrastructure, faculty in place, well-developed land and a jurisdiction of only 10 districts of western part of Maharashtra state. In that way, the job of VC, MPKV was relatively less challenging compared to CAU. When I joined as VC of MPKV in 1999, the financial position of the University was not so good. Therefore, I concentrated my efforts to increase the revenue through the production on University land by mobilization of internal resources and diversification. When I left MPKV in 2004 to join as VC, CAU the annual gross revenue of the University was increased to Rs. 11.0 crores as against the revenue of Rs. 6.0 crores at the time of my joining in 1999.

Besides this, I have strengthened the academic and research infrastructures at different campuses like Dhule, Pune and Kolhapur under the jurisdiction of the University.

Establishment of Hi-Tech Floriculture project at College of Agriculture, Pune was another satisfying experience as MPKV was the first Agricultural University in India to have such a project on commercial lines. The selling of flowers and vegetables grown under polyhouse conditions could earn revenue of Rs. 45 lakhs per annum. Besides, the hands-on training provided under this Hi-Tech project helped in generating skilled manpower. The project was appreciated by the visitors which gave a good recognition to the University at National level. I am most satisfied and happy with my successful tenue as VC, MPKV which helped in bagging a Sardar Patel Outstanding Agricultural University Award from ICAR, New Delhi in 2002. The notable achievements at MPKV, Rahuri both in infrastructure development and revenue generation through mobilization of internal resources can be a guiding path and learning lesson for all future leaders of the University to scale up new heights and widen its horizons.

On the other hand, being the VC of CAU was an uphill task because of its poor infrastructure, inadequate faculty, lack of an established academic council and colleges, and most of all, vast jurisdiction that spread across the seven states of North-Eastern Hill region. I had to start my work right from land acquisition and development of some campuses. Besides this, the biggest challenge was to bring the learned faculty and to retain them at this most unattractive remote place. My focus was to attract the trained manpower by recruiting retired, experienced senior faculties from other parts of the country who could guide the young faculty and students of the University. Thus, CAU in real sense became a Central University. With a good support from ICAR, I could establish two new campuses and strengthen existing academic infrastructures and students hostels of the four campuses in different NE states. Through my own sense of creativity and responsibility, I was able to inspire and motivate the students of CAU who came all the way from very remote areas to appear for the ICAR held All India competitive examinations like JRF and SRF for pursuing higher studies. My vision with hard work and efforts from the academic faculties helped to excel the CAU at national level by securing 2nd rank two times (2012 and 2014) based on maximum number of JRF/SRF positions in ICAR.

The great satisfaction was that I was able to convert a raw material (poorly trained students from remote areas with no exposure to advanced opportunities) into a finished product (qualifying students got national level exposure by getting admissions to other reputed institutes/Universities like IARI). I strongly feel, progress of the University was not merely the development of physical infrastructure, but the creation of trained and knowledgable manpower through HRD activities. This was possible only with cooperation from the Deans and the Faculty members from all the six colleges.

Of course, I have served at Vice Chancellor's post for about 15.5 years (5.5 years at MPKV, Rahuri along with additional responsibility of VC, KKV for short period and 10 years at CAU, Imphal). This can be the longest period in someone's professional life. However, I strongly feel that it is not important for how long I served as a Vice Chancellor, but it is rather important how best I served and what landmark achievements I could deliver in that position (***As it is in his own words***: मैं कितने साल तक वी.सी. रहा ये मायने नही रखता, लेकिन मैने उस पद को कितने सफलतापूर्वक संभाला है, और उस दौरान कौन सी उपलब्धियाँ हासिल कर सका हूँ ये सबसे अधिक महत्त्वपूर्ण है! of course, this was possible only with a strong and an unconditional support from my family. My wife, Dr. Veena Puri played a significant role by supporting me. Dr. Veena had to leave her lucrative medical practice in Parbhani when we shifted to Delhi after my selection as Director, NCIPM. Later, when I joined as VC, MPKV at Rahuri, she resigned from the post of M.D at a Private Hospital in Delhi. Since then, Veena took complete responsibility of growing, nurturing, educating and marrying off of our daughters. It was thanks to her that I could dedicate myself completely to my responsibilities as the VC of MPKV and CAU. I am very lucky to have her as my life partner who stood behind me in all the situations with courage.

Dr. Babasaheb: Sir, you have set an example of 'model IPM village' as a success story of cotton IPM in India when you were the Director of ICAR-NCIPM, New Delhi. Would you please throw a light on your vision as a pioneer in promoting IPM in India?

Dr. Puri: Before telling you about the story of model IPM village, I would like to tell you briefly about how I turned to be an IPM Entomologist. In fact, I did my M.Sc. in biological control with specialization in Insect Parasitology, and Ph.D. in Insect Toxicology. I was working as an Associate Professor of Insect Toxicology at Department of Entomology, MAU Parbhani. In the year 1976, I was deputed to East-West Centre, Hawaii, Honolulu for 2 months to attend an IPM workshop and this was the turning point in my professional career which changed my perception towards IPM. After coming back from the IPM workshop, I started working on IPM strategies and development of IPM modules for management of cotton pests. In my career at MAU, I have guided about 30 M.Sc. and 10 Ph.D. students who were assigned different IPM components to be evaluated for managing pests of cotton and other crops. Among 8 different IPM modules tested, I took the three best modules to farmers' fields in three different villages for their validation. The single best IPM module was selected for a large scale implementation. Thus, a strong research base for 'model IPM village' was laid at MAU itself which came into realization when I took over the responsibility of Director, NCIPM, New Delhi in 1995.

The story behind the concept of model IPM village is really an interesting one. Once, Dr. R.S. Paroda, Hon'ble Ex. DG, ICAR and Secretary DARE at that time called to tell me that one of his colleagues at FAO from Bangladesh was coming to India to visit a village where all the components of IPM were demonstrated. His words stunned me for some time because being a Director, I was not even in a position to name such a single village. I replied to DG politely but confidently that sir there is no such IPM village that you want to show to the visitors. This incidence made me ponder and hence was the real inspiration for me to direct my efforts towards the concept of model IPM village and its implementation. Accordingly, I prepared a project and submitted it to Cotton Corporation of India (CCI) for funding as the ICAR EFC was over and we were needed to wait till the next EFC. However, it was not supported for funding as CCI activities at that time were outside the Maharashtra state. Few days later, I had an interaction with Dr. Kapoor who was a Technical Head, Bayer Crop Sciences Ltd., he agreed to provide a funding of Rs. 6 lakhs for our project. I took Dr. Lavekar, my colleague from Entomology, and others from the Cotton Research Centre, Nanded (under MAU Parbhani) into confidence and discussed with them about the implementation of model IPM village. All of them agreed for the same and accordingly we chose Ashta, a small village in Nanded District of Maharashtra for executing our project.

All the technical backup was provided by our scientists from NCIPM, New Delhi. Along with other scientists, I travelled periodically from Delhi to Ashta village in Nanded and guided the farmers through Farmers' Field Schools (FFS). It was the pre-Bt cotton era and the cotton farmers were already in distress due to bollworm damage. We built up a rapport with the villagers and convinced them to follow our instructions right from seed sowing to harvesting. The best IPM module from my PhD students' work was selected for demonstrations over 450 acres area. As seed treatment was necessary to ensure protection of cotton crop at early vegetative stage from the menace of sucking pests, a demonstration was arranged with the help of Bayer Crop Sciences Ltd. to show the farmers how to treat their cotton seeds with Imidacloprid 70 WS. The other components included in an IPM module were: growing of crops like cowpea, maize, etc. for attracting and colonizing natural enemies; local preparation and use of NSKE and HaNPV as an eco-friendly option for pest control; use of pheromone traps; three releases of egg parasitoids *Trichogramma* sp.; installation of bird perches; etc along with FFS to create awareness and provide technical guidance to the farmers. Our intense efforts culminated into a fruitful result with significant increase in the yield of cotton lint from merely 100 kg per acre in farmers' practice to 333 kg per acre in IPM module. Besides, the other benefits were reduced cost of protection, increased benefit: cost ration, increased margin of profit and environmental protection due to reduced pesticide use. "***Thus, Ashta village become a success story as a model IPM village where the farmers were partnering for environmental protection.***" I tried to replicate the Ashta model in cotton villages of Dhule and Ahmednagar Districts when I was a Vice Chancellor at MPKV, Rahuri. Though I am satisfied with the outcome of our project, I strongly feel that the efforts to replicate the concept of model IPM village were not continued to a satisfactory level afterwards.

Dr. Babasaheb: You are serving as a President of Entomological Society of India since 2004. Under your dynamic and esteemed leadership, the Society

is progressing remarkably along with widening the horizons of its activities like scientific publications and organization of symposia and workshops. What are your future plans and vision for further upscaling of the ESI and its reach to the Entomology fraternity?

Dr. Puri: What I strongly feel is that being an oldest and largest society of Entomology professionals of the country, ESI should be a "***think tank"*** for any kind of advice related to plant protection in general and entomology in particular. Secondly, in order to make the society globally competitive and to increase its visibility, we certainly need to widen the sphere of its activities.

"ESI should be a think tank for advice related to plant protection and source of policy making for course curricula of Entomology"

During my tenure as a President of ESI, we have focused more on improving the quality of scientific publication and getting the best rating for our journal. My colleague Dr V.V. Ramamurthy and his team are really working hard for achieving the goals. I think that the quality of scientific publications is a combined responsibility of authors, editors and reviewers. From the year 2020, we constituted different categories of awards to recognise and encourage the young and talented minds. Besides, I feel that there is also a need to constitute "Life time achievement award" to recognise the retired people who contributed immensely to the Entomological science during their professional life. It is my wish that our society should also serve as a "***Source of policy making***" for framing curricula of Entomology courses to be taught in agricultural education across the Country. The overall focus of ESI should be to attract entomology professionals across the regions and encourage them to publish scientific papers of high quality from both national as well as international perspectives. For this, the young people need to come forward and to take the responsibility.

Dr. Babasaheb: How would you like to direct the entomological research in India? What are your expectations from and suggestions for Young Entomologists of our country?

Dr. Puri: Presently, Entomological science has made remarkable progress. However, there are still some important areas that did not receive adequate attention of the researchers. Very few people are working in the area of 'Quarantine'. Emerging pest problems are becoming a real challenge in the context of globalization and looming climate change. Therefore, I think there should be a special wing at each and every Entomology Department of Agricultural Universities and Research Institutes, which is engaged in identification of potential pests that are likely to enter into our country and accordingly should be ready with a specified programme for their management. Taxonomy is another area where we need to strengthen our arms. Under the Network Project on Insect Biosystematics (NPIB), Dr. V.V. Ramamurthy has done a great job in creating fairly good facilities for taxonomy research in different Agricultural Universities who were part of the project as coordinating centres. These endeavours need to be supported on a continued basis. Another area where we need to focus is to reduce the role of chemical insecticides in pest management. Budding Entomologists should also get involved in developing their own new insecticide molecules which are effective yet relatively safer. Research into pheromones and their wider applications should also be planned. One can concentrate on creating maximum number of IPM villages to address the localised pest problems of farmers. In order to increase vast canvas of IPM, the inputs required are major bottleneck. Mass production and self-life enhancement of biopesticides and bioagents and addressing the issues related to their packaging and transport are the major areas of IPM research. As the animal and veterinary sciences are closely related to agriculture, association of the Entomologists who are working on Animal pests/ Veterinary Entomology with Agricultural Entomologists to work for the overall benefit of farming community will be a good idea.

Dr. Babasaheb: Sir, you are a proven science leader both in academics and research. Would you like to pass on a key message to the future science leaders of our country?

Dr. Puri: In our system of research and academics, we seldom give attention to learn about the administration and finance during active span of our career life. However, with rise in position, when we get an opportunity to be a science leader or manager, we must have a sound knowledge of administration and finance in order to handle the related issues and to make the right decisions in time. Furthermore, the decisions you take need to be implemented effectively, else it will be meaningless. Therefore, with my own experience of serving at key managerial positions like Director and Vice Chancellor, I would like to advise the academicians and researchers to enter into administration and finance, know about the rules and regulations for execution of powers. While being at key positions, you should always keep a good rapport with your peers and take them into confidence for getting the work done smoothly. I can confidently tell you that, despite serving for a long time as VC, I tried to maintain a clean record of my service.

Dr. Babasaheb: Any suggestions or specific advice you would like to give for the improvement and wider reach of 'Indian Entomologists' magazine?

Dr. Puri: First of all, I would like to thank Indian Entomologists magazine for interviewing me and bringing at the forefront my achievements to its readers. Indeed, the magazine is doing well. However, as a serving President of ESI, I wish that the magazine should be a mirror to reflect the latest happenings and issues related to plant protection, especially the entomology across the country so as to make aware the entomological fraternity. I wish all the very best for a greater success of the magazine.

Concluding remarks by Dr. Babasaheb:

As an Associate Editor of Indian Entomologist, I got an opportunity to interact with respected Dr. S.N. Puri, a legendary Entomologist, a proven leader, the longest serving VC of Agricultural Universities in India and much more….yet with his feet firmly on the ground and a great affection for farming and the farmers. As I was assigned a task of conducting his interview, I called him and fixed an appointment for the 5th of January, 2022. After travelling almost 96 km from Nagpur, I finally reached Dr. Puri's native place Mowad that lies on Maharashtra's border with Madhya Pradesh. By the time I reached, Dr. Puri was busy in monitoring the harvesting of oranges in his 4 acres of citrus orchards. His energy and fitness even at the age of 77 years was admirable and inspiring to youngsters like me. The most appealing thing to me about Dr Puri was that even after serving on prestigious positions at National level, the man has still stayed humble and even after his retirement he prefers spending most of his time at his farm that is ions away from the glorious world. Besides citrus orchard, he also maintains a desi poultry and goats on his farm. The interview was conducted at his farm house itself by sitting in the laps of nature and breathing a cool breeze of healthy and clean air. We had a lengthy interaction for about more than 2.0 hours and I was most comfortable to talk because of his very simple, kind and humble nature and also due to prior familiarity being his student at MPKV, Rahuri. After the interview was over, we enjoyed a delicious lunch prepared at his farm house. I started my return journey after taking his blessings. Overall, it was really an overwhelming, inspiring and great learning experience for me, thank you Indian Entomologist for this wonderful opportunity.

The interview is conducted by Dr. Babasaheb B. Fand. He is working as Scientist (Agril. Entomology) at ICAR-Central Institute for Cotton Research, Nagpur - 441 108, Maharashtra, India. His area of research is on modelling climate change impacts on cotton insect pests and yield loss aggravation using phenology modelling and GIS based risk mapping approach, development and dissemination to farmers' fields of IPM strategies for cotton insect pests. He is also an Associate Editor of IE.

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FEATURE ARTICLE

Pigeonpea wild relatives: an emerging alternative for the management of pod borer, *Helicoverpa armigera*

Rohini Sreevathsa and Maniraj Rathinam

Abstract : Pigeonpea is one of the important legume crops globally and India occupies second place in production. However, stagnant productivity in pigeonpea due to various biotic and abiotic constraints has been a major problem. Among major yield limiting factors, the lepidopteran pod borer *H. armigera* assumes significance due to its crop damaging potential. Various pest control strategies were developed and are being practiced to manage *H. armigera* damage on pigeonpea. However, controlling *H. armigera* has been difficult due to its broad host range, high migratory behavior and its tendency to develop resistance against various phytotoxins and commercial insecticides. In addition to Bt-based transgenic approaches, efforts towards exploration of alternative strategies to mitigate pod borer damage are being made by scientists. In this aspect, exploitation of genetic variation present in crop wild relatives for crop improvement against insect pests has emerged as a promising strategy. The wild relatives of crop plants are bestowed with an array of resistance traits and hence can form an excellent source of resistance genes. It is therefore crucial to identify, understand and extrapolate the pod borer resistance mechanism to cultivated pigeonpea for the enrichment of genetic diversity and utility in crop improvement programmes.

Key words: Pigeon pea; wild relatives; *Helicoverpa armigera*; resistance response; insect resistance

Pigeonpea is considered as one of the important pulse crops in the world due to high protein content and its ability to grow under semi-arid regions. Though historians and scientists have debated that pigeonpea originated in Africa, the actual origin had been traced to be the peninsular land of India. This fact is strengthened by the presence of pigeonpea progenitor *Cajanus cajanifolius* and high range of crop diversity in India (Purseglove, 1968; Saxena, 1988; Van Der Maesen, 1980; Van Der Maesen, 1990). Furthermore, presence of linguistic and archaeological evidences, daily usage in cuisine and diversity in recipes support the argument of Indian origin (Kajale, 1974; Van Der Maesen, 1990).

Global production of pigeonpea is estimated to be 4.49 MT, out of which India accounts for around 63% of production in a total land area of 3.9 Mha (70%). Among the different pulses cultivated in India, 20% is attributed to pigeonpea making it the second most important pulse crop (FAO, 2019). Pigeonpea growing areas in India are broadly classified into four different agro-ecological zones - north east plain zone, north west plain zone, central zone and south zone. Based on the agro ecological conditions and utilization, pigeonpea is grown as a mono crop, mixed crop and intercrop (Sameer Kumar *et al.,* 2014). Further, based on the crop maturity period, cultivar accessions were classified into super-early duration (<90 days), extra-early duration (<120 days), early duration (120-140 days), mid-early duration (140-160 days), medium duration (160-180) and long duration (>180 days) varieties (Sharma *et al.,* 2019; Saxena *et al.,* 2019).

Pigeonpea is one of the most important sources of dietary proteins for the Indian vegetarian population. In Indian cuisine, pigeonpea dry seeds are mostly used in dehulled split form (dhal). In some regions, green or tender pigeonpea is also eaten as a vegetable (Talari and Shakappa, 2018; Sarkar *et al.,* 2020). In terms of nutritional value, pigeonpea is considered as an alternative and inexpensive protein source for the lower economy class people and vegetarian population in India as well as other under developing countries (Adeola *et al.,* 2017; Talari and Shakappa, 2018). Notably, total protein content in the raw pigonpea seeds' is estimated to be around 20%. Furthermore, it is a good source of healthy carbohydrates, some essential vitamins including folate and important minerals like magnesium, zinc, calcium, phosphorous, potassium and iron. Besides having an array of nutrients, it is also enriched with different bioactive compounds, making it a crucial nutrient resource to fight malnutrition (Talari and Shakappa, 2018; Sarkar *et al.,* 2020). In most parts of the world, pigeonpea is cultivated only as a food crop, whereas in India and some parts of Africa it is utilized as a 'multi-purpose' crop (Daniel and Ong, 1990).

Pigeonpea as a soil ameliorating agent: Growing pigeonpea or other legume crop is one of the conventional and effective agronomy practice to fix atmospheric nitrogen into the soil and is mediated by the bacteria belonging to *Rhizobium* spp. that are present in the root nodules of plants. Apart from symbiosis, the remains of the crop improves soil organic matter and provides additional nitrogen (Daniel and Ong, 1990; Chikowo *et al.,* 2004). Similarly, it has the capability to grow under low phosphorous soil. Particularly, exudates from the root of pigeonpea have extraordinary ability to free the iron bound phosphorus. The root exudates increase the overall phosphorous availability for the crop and also benefits neighboring or subsequent crops cultivated in the soil (Sinclair, 2004).

As cattle feed and fodder: Pigeonpea leaves and pods are rich in protein; green leaves and young pods are often used as cattle feed. However, dried plant portions are also stored and used as cattle fodder in off-season (Daniel and Ong, 1990). Furthermore, pigeonpea seed powder is also used as an alternative to fish meal to balance the protein content (Adeola *et al.,* 2017; Talari and Shakappa, 2018). Besides, significant improvement in cattle growth has been reported from pigeonpea-cattle grazing trail suggesting the role of pigeonpoea as a forage crop (Ayenan *et al.,* 2017).

Other domestic uses: As pigeonpea has strong and woody stems, the dried stems are widely used as fuel in Indian villages and a few African countries (Daniel and Ong, 1990). Additionally, various parts of pigeonpea are being used as a traditional medicine in India, China, and several African countries (Talari and Shakappa, 2018).

Yield gap and major constraints for stagnated productivity in pigeonpea

In India, based on agro climatic zones, different varieties are being cultivated which vary in duration and productivity. The expected yield of commercial pigeonpea varieties could range from 1500-3000 kg/ha, with the actual yield lingering around 700 kg/ha (Sameer Kumar *et al.,* 2014). The huge yield gap in pigeonpea production is due to a range of abiotic and biotic factors (Sharma *et al.,* 2010; Umesha *et al.,* 2017).

Abiotic constraints: Pigeonpea experiences various abiotic stress factors during its life cycle, which includes, moisture stress (waterlogging or drought), temperature stress, and salinity stress. Among them, moisture stress is predominant because pigeonpea is majorly cultivated under rainfed agriculture. In general, excessive or absence of rainfall is common in rainfed agriculture. Comparably, waterlogging is a predominant issue in rainfed agriculture as even a short span of waterlogging (2-3 days) is enough to cause a drastic yield loss or crop loss (Choudhary *et al.,* 2011). In India, waterlogging alone is responsible for an annual yield loss of 25-30% (Sultana, 2010). In a nutshell, pigeonpea cultivation is recommended in areas that receive low rainfall, owing to its inherent ability to tolerate high degree of drought. However, low soil moisture in early seedlings and reproductive stage (terminal drought) adversely affects the productivity (Lopez *et al.,* 1996). Excess salt accumulation on soil surfaces is responsible for the salinity stress. Presence of enormous salt in the soil leads to accumulation of toxic free radicals inside the plant cells, and promotes excessive uptake of sodium (Na^+) and chloride (Cl^-) ions from the soil, which collectively causes cytotoxicity (Deshpande and Nimbalkar, 1982). Salinity stress has been reported to prolong the 50% of flowering of the crop by approximately 2-3 weeks, which substantially reduces the pod weight and count (Promila and Kumar, 1982).

Biotic constraints: During vegetative to reproductive stages, pigeonpea is infected by various phytopathogens and insects. Among the phytopathogens, those belonging to *Fusarium* spp., *Phytopthora* spp. and sterility mosaic virus pose serious threats to crop productivity (Sharma *et al.,* 2010). Fusarium wilt occurs 65 days after sowing (DAS) and the disease severity increases at peak vegetative stage of the crop (180 DAS; Sharma *et al.,* 2010). Additionally, occurrence of drought along with wilt increases the pathogen virulence and leads to substantial yield losses (Sinha *et al.,* 2017). *Phytopthora* blight and sterility mosaic disease infect during the early vegetative stage of the crop (Sharma *et al.,* 2010). Notably, *Phytopthora* blight affects young seedlings (within 60 DAS) and kills within 3 days leading to 100% crop loss. The disease is generally encountered after 3-5 continuous rainy days. Since pigeonpea is a rain fed crop, it is highly prone to get infected by *Phytopthora* blight (Sharma *et al.,* 2010). Similarly, sterility mosaic disease (SMD), which also appears at early vegetative stages is caused by pigeonpea sterility mosaic virus (PSMV), which is transmitted through the mite species *Aceria cajani.* The extent of yield loss caused by SMD varies according to the age of the plant. The infection at an early vegetative stage (before 40 DAS) could result in 95-100% yield loss, whereas, in the later stages yield loss ranges from 27-97 % (Kannaiyan *et al.,* 1984).

Insect pests are critical factors which cause huge loss to pigeonpea seed production. Further, presence of high protein content in seeds and leaves attracts an array of insects. So far, more than 200 insect species have been found to feed on pigeonpea of which 34 are a potential menace not only for pigeonpea but for other crops as well (Lal and Katti, 1998). These insects are oligophagous to polyphagous with different feeding behaviors. Out of these, two polyphagous lepidopteran pests, *H. armigera* and *M. vitrata* are major constraints for stagnated productivity (Wadaskar *et al.,* 2013). *H. armigera* or pod borer is the most devastating among them, which can cause about 80-100% crop losses (Sharma *et al.,* 2010).

H. armigera: a major insect pest of pigeonpea that threatens productivity

Polyphagous insect pests have always been major threats to crop productivity due to their wide range of host specificity. *H. armigera* has a host range of more than 300 plant species across 68 families (Datasheet *H. armigera*: https://www.cabi.org/isc/datasheet/26757). The lifecycle of *H. armigera* is comprised of four stages viz., egg, larva, pupa and moth (adult). For the completion of one lifecycle from egg to moth (Fig. 1) it take 4-6 weeks in summer, and 8-12 weeks in winter. They spend majority of lifespan in the caterpillar stage, during which it feeds voraciously. This feeding behavior of the caterpillar and crop damaging potential makes *H. armigera* the most important pest for pulse crops cultivated worldwide (Pomari-Fernandes *et al.,* 2015). In general, *H. armigera* adults lay eggs on the leaf surface of the host plants. The young caterpillar feeds on leaves and moves to plant reproductive parts i.e. fruits, bolls, pods etc. (Pomari-Fernandes *et al*., 2015). Freshly hatched neonates prefer terminal leaves of pigeonpea, which are more soft and tender. However, later instars feed almost on all reproductive organs including seeds, which leads to substantial yield losses (Sharma *et al*., 2010).

Controlling *H. armigera* through chemical pesticides is a commonly followed practice. However, it is known to possess the tendency to develop resistance towards various host plant toxins and commercial pesticides (Pearce *et al*., 2017). Furthermore, resistance to insecticides in *H. armigera* is attributed to the presence of a large number of gene families involved in detoxification of xenobiotics (Pearce *et al.,* 2017). Enzymes belonging to Cytochrome P450s (CYPs) superfamily are recognized as important factors for insecticide resistance (Tian *et al.,* 2017; Wang *et al.,* 2018). In insects, these enzymes play a vital role in xenobiotics and other photochemical metabolism. Particularly, occurrence of sequence/ expression polymorphism in this gene super family has been correlated with insecticide resistance (Wang *et al.,* 2018). Around 30 % of globally commercialized insecticides are targeted against *H. armigera,* which has put a high selection pressure on the insect to develop resistance against pesticides of different chemical formulae (Ahmad, 2007). As compared to other species of *Helicoverpa*, *H. armigera* population is endemic (DPI&F, 2005) due to which they tend to retain the developed insecticidal resistance trait across generations. However, insect pest species that migrate to different geographical locations would lose the developed insecticidal resistance traits in the further generation (DPI&F, 2005). Insecticide resistance development in *H. armigera* and ecological impact of continuous usage of synthetic chemical insecticides has created a need to look for e alternative approaches to control the pest attack.

Crop improvement in pigeonpea for the management of pod borer

As an alternative to chemical pesticides, improving host plant resistance or tolerance level against target insect pests is a tangible approach. In this direction, efforts were made in ICRISAT, India to identify H. *armigera*-resistant accessions. However, screening of 14,000 pigeonpea accessions identified only low to moderate level of resistance against pod borer. It is therefore necessary to look for alternative sources for pod borer resistance (Reed and Lateef,1990).

Advent of transgenic technology facilitated integration of foreign genes into the targeted organism. In plant species, this technology was first successfully demonstrated in tobacco in 1983 (Fraley *et al.,* 1983). Further, cotton transgenics expressing insecticidal crystal (cry) protein from *Bacillus thuringiensis* (*Bt*) was approved for commercialization in United States in 1996 (Bilal *et al.,* 2012). In India, *Bt* cotton expressing Cry1Ac protein was introduced in the year 2002, which was developed for resistance against cotton boll worm *H. armigera* (Bilal *et al.,* 2012). Notably, adaptation of *Bt* cotton accelerated Indian cotton production, owing to which India became the leading cotton producing country in the world (ISAAA, 2017). Successful outcome of *Bt* cotton gave a positive signal for the utilization of *Bt* insecticidal genes in other agronomically important crops. After accomplishing encouraging results in many crops, *Bt* insecticidal genes have also been utilized for development of podborer resistance in pigeonpea (Table 1). Although efficacy of *Bt* genes was proved in various food crops, the propensity of *H. armigera* to resist *Bt* genes and hurdles in social acceptance of GM food crops, resulted in the need to look for other options.

Utility of pigeonpea wild relatives in crop improvement against *H. armigera*

In the scenario of escalating food demand, scarcity

Table 1. Exploitation of *Bt* ICPs for development of pod borer resistance in pigeonpea

Pigeonpea Cultivar	Name of the Cry gene	References
Pusa 992	*cry2Aa*	Singh *et al.,* 2018
UPAS 120	*cry2Aa, cry1Ac*	Ghosh *et al.,* 2017
PAU 881	*cry1Ac*	Kaur *et al.,* 2016
Asha	*cry1abc*	Das *et al.,* 2016
TTB7	*cry1AcF*	Ramu *et al.*, 2012
JKPL	*cry1Ac*	Krishna *et al.,* 2011
ICPL 87	*cry1ab*	Sharma *et al.,* 2006
ICPL 87	*cry1E-C*	Surekha *et al.,* 2005

of resources, cultivable land and impending climate change impact created the necessity for effectual crop improvement programmes. Understanding the crop genetic diversity between the different species present within a genus would form a solid platform to identify novel alleles (Khan *et al.,* 2020). The genus *Cajanus* totally consists of 34 species among which *C. cajan* is the only cultivar, while the remaining are wild relatives. PWRs are progenitors of *C. cajan*, which are known to be bestowed with various important agronomic traits that were lost during domestication (Kassa *et al*., 2012). Deciphering molecular signatures of wild relatives would not only provide information about the mechanism behind desired traits, but also would allow us to broaden the genetic diversity of the crop (Khan *et al.,* 2020).

Particularly, the geographical hotspots rich in diversity of *Cajanus* species are focused in India followed by North Australia and African countries (Khoury *et al.,* 2015). In past decades, substantial efforts have been made by ICRISAT, India, for the characterization of pigeonpea wild accessions (Sujana *et al*., 2008; Sharma *et al.,* 2009; Parde *et al.,* 2012). Research showed that, PWRs possess enormous potential to provide valuable traits such as tolerance to abiotic stresses including salt tolerance, resistance to pests and diseases, high protein content, rapid seedling growth, photo-insensitivity, cleistogamy, super-early flowering and cytoplasmic male sterility (Mallikarjuna *et al.,* 2006; Sujana *et al.,* 2008; Pazhamala *et al.,* 2015; Muñoz *et al.,* 2017).

Pod borer resistance in PWRs

Pod borer resistance in PWRs are known to be arbitrated by both biochemical and physical barriers. Initial screening performed in Indian PWRs proved that pod borer resistance is linked with biochemical composition and morphological variation present in the pod wall (Sujana *et al.,* 2008; Sharma *et al.,* 2009; Choudhary *et al.,* 2013).

Biochemical basis of pod borer resistance

When plants recognize the herbivore attack by herbivore-associated molecular pattern (HAMP) (Steinbrenner *et al.,* 2020), followed by the activation of phytohormones, especially jasmonic acid, it leads to the activation of jasmonic acid (JA) signaling network. JA signaling is known for the wound and herbivore mediated defense response, which triggers the accumulation of toxic metabolites and /or deterrents and other digestive reducers against insect herbivores (Kessler and Baldwin, 2002). In plants, the biochemical compounds produced in response to herbivory are classified into antibiosis and antixenosis based on their activity. If the plant metabolites possess inhibitory effect on insect growth and development, it is known as antibiosis, and, if they lead to non-preference for oviposition, it is known as antixenosis (Sujana *et al.,* 2008).

Immense efforts were made by Sujana *et al.* (2008), to evaluate the PWRs for their antibiosis and antixenosis properties in 29 accessions belonging to 13 species from different gene pools. Among them, *C. acutifolius* (ICPW 1), *C. albicans* (ICPW 13 and 14), *C. sericeus* (ICPW 159 and 160), *C. platycarpus* (ICPW 68), *C. scarabaeoides* (ICPW 83, 90, 94, 125, 137, 141 and 280), *Paracalyx* scariosa (ICPW 207) and *Rhynchosia aurea* (ICPW210) were found to express high levels of antixenosis, in both choice and no-choice experiments. Further, incorporation of lyophilized pod and leaf powder in diet caused significant effects on larval growth, i.e., reduction in larval weight, prolonged post embryonic development and prolonged pupal and larval growth period. The high level of antibiosis property was reported in *C. acutifolius, C. lineatus*, *C. sericeus*, *C. scarabaeoides*, *C. platycarpus, P. scariosa* and *R. aurea* wild accessions.

Further, information acquired from literature depicted that variation in biochemical composition such as total soluble protein, total soluble sugars, and total condensed tannins are associated with pod borer resistance in PWRs (Choudhary *et al.,* 2013). High amount of soluble sugars, low amount of polyphenols and low amount of condensed tannins in cultivated pigeonpea pods were associated with pod borer susceptibility (Sharma *et al.,* 2009; Choudhary *et al.,* 2013).

Digestive reducers

In response to herbivory, plant produces certain biologically active proteins such as proteinase inhibitors (PIs), amylase inhibitors, and polyphenol oxidases etc. which disrupt food digestion in the insect gut (War *et al.,* 2012). PIs block the insect digestive proteinases and create the depletion of essential amino acids, resulting in reduction of insect growth, prolonged growth cycle, sterility and mortality (Parde *et al.,* 2012). Furthermore, PIs prevent other plant defense proteins from proteolysis by insect gut proteinases. The utility of non-host plant PIs for crop improvement against insect pests have been demonstrated in different crops (Harsulkar *et al.,* 1999; Giri *et al.,* 2003; Jamal *et al.,* 2015). Similarly, proteinase inhibitor activity against *H. armigera* was reported in different PWRs. Among them, accessions belonging to *C. albicans*, *C. cajanifolius*, *C. sericeus*, *F. bracteata*, and *R. bracteata* portrayed superior activity (Parde *et al.,* 2012). Compared to other PWRs, an accession – ICPW 068 belonging to *C. platycarpus* gained more attention since it contained more number of PIs and also had high level of pod borer resistance (Parde *et al.,* 2012; Swathi *et al.,* 2015; Swathi *et al.,* 2016)

Morphological basis of pod borer resistance

Plant structures are the foremost barriers against biotic stresses. The first line of defense against herbivory evolved by the formation of thick wax cuticle, spines, setae and trichomes (War *et al.,* 2012). Plant physical barriers include morphological traits that bestow fitness advantage to the plants by deterring insect egg laying or larval feeding (War *et al.,* 2012). Notably, trichomes (pubescence) present in the plant leaves and reproductive parts were found to be responsible for insect resistance in various plant spp. (Glas *et al.,* 2012; War *et al.,* 2012). Plant trichomes are broadly classified into two types, glandular and non-glandular. The glandular trichomes are multicellular and have the ability to produce, store and secrete large volumes of different groups of secondary metabolites. Moreover, herbivore insects get entrapped in toxic or sticky exudates i.e., terpenes, polyphenols or acyl sugars synthesized by the glandular trichomes (Glas *et al.,* 2012). However, non-glandular trichomes are unicellular, cannot produce or store any secondary metabolites and hinder the movement of herbivore on plant surface or prevent the herbivore to reach the surface (Sharma *et al.,* 2009). Likewise, the association of pubescence traits with *H. armigera* resistance was reported in pigeonpea wild accessions. Accordingly, four types of trichomes A, B (glandular) and C, D (non-glandular) are present in *Cajanus* spp. Variation in number and type of trichomes present on leaves and pod surfaces were found to be linked with difference in pod borer resistance among the pigeonpea wild accessions (Sharma *et al.,* 2009; Choudhary *et al.,* 2013). The wild accessions belonging to *C. scarabaeoides* and *C. sericeus* have high density of non-glandular trichomes (C and D) on pod surface, but lack type A trichomes on pods. High level of pod borer resistance and absence of egg laying reported on *C. scarabaeoides* accessions authenticated the influence of non-glandular trichomes on *H. armigera* resistance in PWRs (Sharma *et al.,* 2009).

Importance of *C. scarabaeoides and C. platycarpus* in pigeonpea crop improvement against *H. armigera*

Out of all PWRs, two pigeonpea wild accessions belonging to *C. scarabaeoides and C. platycarpus* have been reported for the high level of pod borer resistance. Effective pod borer resistance response observed in these *Cajanus* wild accessions are conferred by their antibiosis and antixenosis characters (Sujana *et al.,* 2008; Sharma *et al.,* 2009). Although, strong resistance against pod borer was extensively supported by work done so far, in-depth analysis for understanding the molecular basis of bod borer resistance is required.

Considerable efforts have been made towards transferring pod borer resistance trait to cultivar pigeonpea from *C. scarabaeoides*, at national and global level. In India, a locus conferring *H. armigera* resistance trait in *C. scarabaeoides* accession ICPW-94 was successfully identified in the intraspecific F_2 hybrids developed between *C. cajan* cv. ICP-26 and *C. scarabaeoides* acc. ICPW-94. Further, locus controlling pod borer resistance was found to be linked with non-glandular short trichomes (Mishra *et al.,* 2013). Similarly, another study also demonstrated the non-glandular trichomes present in the *C. scarabaeoides* accessions were transferable to cultivar pigeonpea (Aruna *et al.,* 2005). Studies in the Indian *C. scarabaeoides* accessions revealed that the locus governing pod borer resistance is controlled by the single dominant allele (Aruna *et al.,* 2005; Mishra *et al.,* 2013). Studies conducted on Australian *C. scarabaeoides* acc. IBS 3471 confirmed that pod borer resistance mechanisms are multidimensional and PIs present in the wild accessions are responsible for bod borer resistance (Ngugi-Dawit *et al.,* 2020). However, the specific gene responsible for pod borer resistance in *C. scarabaeoides* accessions has to be identified for proper utilization in crop improvement programmes. Despite exhibiting high level pod borer resistance, incorporating plant pubescence or enhancing digestive reducers in cultivated pigeonpea is expected to make it undesirable for human consumption.

Transferring traits from *C. platycarpus* to *C. cajan* is more complex than *C. scarabaeoides,* but efforts were made through embryo rescue to develop intraspecific hybrids (Mallikarjuna *et al.,* 2006). The embryo rescue method successfully produced fertile hybrids, but needs improvement to produce sufficient seeds, which is necessary for screening against any biotic and abiotic constraints.

Constraints in the utilization of CWRs for crop improvement

Effective crop improvement towards the management of any stress completely depends on the genetic diversity of the crop germplasm. Utilizing genetic diversity across gene pools is a pertinent option to enrich the genetic diversity (Zhang *et al.,* 2017). Genus *Cajanus* consists of 34 species which are placed into different gene pools based on relative ease of crossability with *C. cajan*. Accordingly, primary gene pool consists of all *C. cajan* cultivar accessions and their landraces, while the remaining wild accessions are placed into other gene pools (Fig. 2.1). Crossing is relatively easy between primary and secondary pools and does not require any special treatments to produce fertile hybrids. However, gene transfer from tertiary/quaternary gene pool to primary gene pool is usually difficult. Anyhow, there exits few examples where the possibility of gene transfer from tertiary to primary gene pool was demonstrated, by adopting specific treatment or methods (Mallikarjuna *et al.,* 2006). Successful gene transfer from distant wild relatives (tertiary/quaternary gene pool) is hindered by many factors, i.e., linkage drag, poor viability of hybrids and infertile hybrids production (Brozynska *et al.,* 2016; Zhang *et al.,* 2017).

The elite crop varieties available at present are selected from the successful rounds of domestication from their progenitors or wild relatives (Kassa *et al.,* 2012). The crop progenitors/wild relatives are being exposed to various stress constraints and habituated to grow under extreme weather conditions. CWRs are bestowed with valuable traits to mitigate both biotic and abiotic

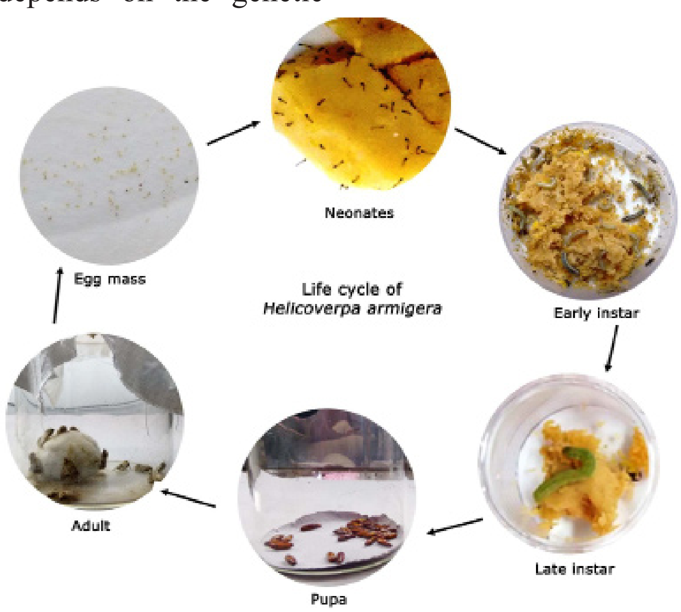

Fig. 1. Life cycle of *Helicoverpa armigera*

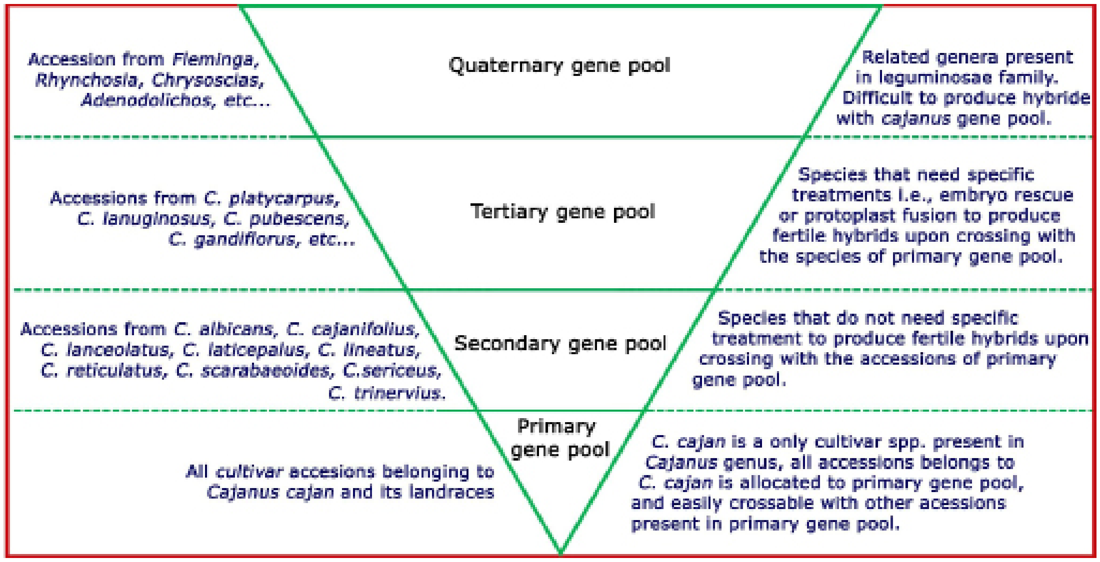

Fig. 2. Gene pool of the genus *Cajanus*

stresses, which is lagging in cultivars (Kassa *et al.,* 2012; Brozynska *et al.,* 2016; Zhang *et al.,* 2017). The domestication process increased the crops yield and palatability, but on the other hand it reduced the genetic diversity of cultivar germplasm. However, constraints occurs in the gene transfer from distant wild relatives to primary germplasm make valuable agronomical traits present in the tertiary/quaternary gene pools go underutilized.

Advanced omics tools as potential options in the utilization of CWRs for crop improvement

Recent advancement in omics tools i.e., whole genome sequencing, global transcriptomic, proteomic and metabolomic profiling aids in better understanding of plant biology. Particularly, genomics of domesticated crops and their related wild species highlighted the importance of CWRs to broaden the genetic diversity of cultivated germplasm (Brozynska *et al.,* 2016; Khan *et al.,* 2020). After knowing the significance of CWRs, genomics programmes have been initiated on important crops wild relatives. It was further elaborated as concepts of pangenome- which provides genetic variation of entire species present in the particular gene pool, and super-pangenome –which provides genetic variation of entire species belonging to a particular genus. Super-pangenome provides comprehensive information about genetic variation catalogue of a specific genus, which facilitates exceptional opportunities for crop improvement (Khan *et al.,* 2020). Further, it enables the identification of several important loci controlling various biotic and abiotic stress resistance/tolerance traits that have been lost during crop domestication. Furthermore, genomics of different crop wild species authenticate pertinent role of CWRs in broadening genetic diversity of cultivar crops, to overcome vulnerabilities against various stress constraints (Brozynska *et al.,* 2016).

In parallel to genomics approach, system biology approach assists in holistic understanding of resistant/ tolerant mechanisms inherent in CWRs. Comparative transcriptomic, proteomic, and metabolomic profiling of cultivar and CWRs allows us to identify novel or differentially expressed gene/protein/ metabolite/ pathway present in wild relatives (Brozynska *et al.,* 2016). Comparative dynamic transcriptome/ metabolome analysis of various crops and their respective CWRs, in response to particular stress conditions endowed significant leads for crop improvement (Wang *et al.,* 2015; Dai *et al.,* 2017) that have been validated through heterologous expression (Khakimov *et al.,* 2015; Zhu *et al.,* 2019). Similarly, recent advancement in metabolomic profiling techniques provides good opportunities to understand the metabolomic change in crops' response to different environmental cues. Especially, untargeted metabolome confers possibility to systemic identification of primary and secondary metabolites present in the plants (Razzaq *et al.,* 2019).

Untargeted metabolomic profiling of susceptible cultivar accession and resistant wild relative spp. provides opportunities for the identification of potential unknown metabolites, which are responsible for host resistance in wild spp. (Alseekh and Fernie, 2021). Integration of metabolomic data with other omics data i.e., genomics, transcriptomics and proteomics leads to discover new pathway (Razzaq *et al.,* 2019).

In classical breeding or marker assisted breeding the trait has to be transferred to cultivar crop for the functional validation. It is not applicable for traits present in the tertiary gene pool or outside the genus. However, advanced omics tools facilitates the identification of resistant/tolerant traits present in the distant plant spp., where crossing is not feasible. Anyhow, identified resistant/tolerant trait has to be integrated into cultivar accessions for crop improvement. This bottleneck can be overcome by adapting advanced biotechnological approaches- CRISPR/Cas9 mediated genome editing (Zsögön *et al.,* 2018) or transgene technology.

Multiple layers of pod borer resistance mechanism in *C. platycarpus*: the story thus far

Exploitation of genetic variation present in crop wild relatives for crop improvement against insect pests has emerged as a promising strategy. Moreover, *H. armigera* resistance has been demonstrated in some of the PWRs. In our lab, we investigated the comparative dynamic transcriptome and proteome under continued herbivory to assess the molecular basis of *H. armigera* resistance in one of the CWRs, *C. platycarpus.* Multi-omics analysis revealed that host plant resistance in *C. platycarpus* shaped by effective management of metabolomics flux for the defense chemical production, and up regulation of defense proteins. The study provided potential leads for carrying out in-depth characterization of the multi-layered resistance response in the wild relative.

Introgression of individual or combination of putative genes by transgenesis can form a potential option for crop improvement in pigeonpea and other legume crops. Furthermore, putative insect resistance genes identified in *C. platycarpus* can serve as markers to assess insect resistance in other cross-compatible wild relatives or other plant species.

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FIELD NOTE

Mating trophallaxis in *Diarrhegma modestum* (Fabricius) (Diptera: Tephritidae: Phytalmiinae)

K.J. David, K. Sachin, D. L. Hancock and S. Salini

Mating trophallaxis is one of the courtship display behaviours shown by males of fruit flies to attract or influence a conspecific female. It involves regurgitation or exchange of a fluid or nuptial gift between male and female during copulation (Freidberg, 1981). It can be indirect when it is deposited on the surface and consumed by the female or exchanged directly through labellar contact. Sivinski *et al.* (1999) listed 21 species of fruit flies in subfamilies Phytalmiinae, Tephritinae and Trypetinae that exhibit this behaviour. In Phytalmiinae this behaviour was documented in six species, namely *Afrocneros mundus* (Loew) (Oldroyd, 1964), *Dirioxa pornia* (Walker) (Pritchard, 1967), *Felderimyia gombakensis* Hancock & Drew, *F. fuscipennis* Hendel and *F. flavipennis* Hancock & Drew (Dohm *et al*., 2008). *Diarrhegma modestum* (Fabricius) is a species in subfamily Phytalmiinae, tribe Acanthonevrini and this behaviour is being recorded here for the first time. Genus *Diarrhegma* Bezzi is Oriental in distribution with two described species, namely *D. modestum* (Fabricius) from India and Sri Lanka (Agarwal & Sueyoshi,2005; David & Ramani, 2011; Hancock, 2015) and *D. paritii* (Doleschall) from China, Vietnam and Thailand to Indonesia, Borneo and the southern Philippines (Norrbom *et al*., 1999; Hancock, 2015). *Diarrhegma modestum* is a brilliantly coloured fly with reddish brown scutum, broad yellow prescutellar patch, yellow scutellum and dark patterned wings with hyaline indentations. As is the case with most phytalmiines, *D. modestum* is also saprophytic in its habit; maggots of this species were found feeding on the frass/exudates from the trunk of the drumstick tree (*Moringa oleifera* Lam.: Moringaceae) damaged by a coleopteran borer, by the senior author in Bangalore.

Mating trophallaxis or nuptial gift behaviour of *D. modestum* was observed three times at ICAR-National Bureau of Agricultural Insect Resources, Yelahanka campus, Attur, Yelahanka, Bangalore. On 23.07.2021, a male fly was noticed on the ventral side of a teak leaf (*Tectona grandis* Linn. F.) after producing a frothy secretion near a female; the female moved towards the frothy secretion after nearly 30 seconds and started feeding on it; meanwhile, the male approached the female from behind, but the female retreated; this recurred twice and finally copulation started at the third attempt with the mating observed for 2−3 minutes; during the mating, the female fed on the frothy secretion. Since it was high up in the tree, it was difficult to document via digital photographs. Subsequently, on 30.07.2021, on the ventral surface of a leaf of *Scaveola taccada* (Gaertn.) Roxb. (Goodeniaceae), a male fly was seen producing a white frothy secretion of irregular shape from its mouth and a female fly was seen near the male; after the male stopped producing froth, it receded and waited for the female to accept the nuptial gift; as soon as the female started feeding, the male approached it from behind for copulation; although the female initially retreated, the male successfully copulated and mating lasted tor 3−4 minutes unless interrupted by wind (Fig. 1). On 03.08.2021, two males were observed on the ventral side of a *Scaveola* leaf; one of the males was seen warding off the other male aggressively until finally a single male occupied the leaf. A female was noticed on another old leaf of the same plant feeding on a nuptial gift that might have been produced days before and, although the male attempted to copulate, it was in vain.

Based on these observations, it is evident that a nuptial gift in *D. modestum* is essential for successful copulation. It serves the purpose of attracting a female and overcoming the tendency for it to fly away, thus facilitating mating.

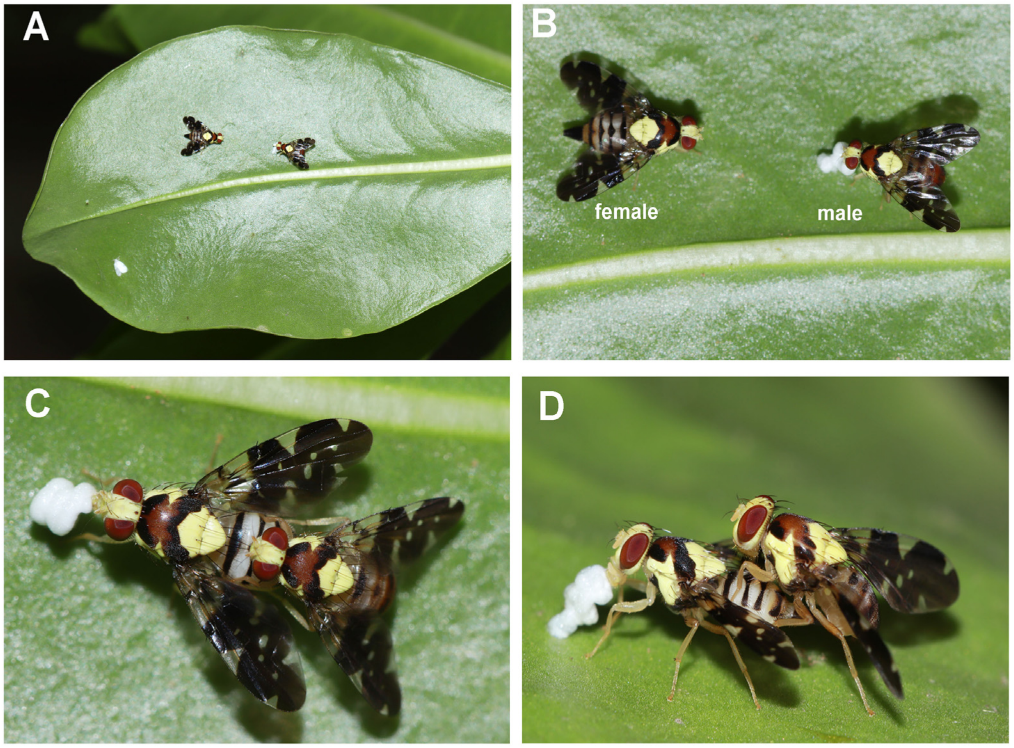

Figure 1. Mating trophallaxis in *Diarrhegma modestum* (Fabricius). A. Male secreting frothy substance on leaf surface and female awaiting; B, close-up view; C, female feeding on frothy secretion while mating (dorsal view); D, female feeding on frothy secretion while mating (lateral view)

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FIELD NOTE

Hornet pests of honey bees in the Indian Himalayas

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Apiculture is an important allied sector of agriculture in India and according to the recent report of National Bee Board, under the agricultural department, India's honey production in 2017-2018 was 1.05 lakh metric tons (MTs) as compared to the 35,000 metric tons (MTs) in 2005-06 (Kumar and Joy, 2018). As per the international demand, the export rate of honey in India has increased by 207% in 2018 and is expected to expand (Bhaskar and Kumar, 2020). Moreover, crop pollination by honey bees increased the crop yield manifold. Agricultural experts say that additional yield obtained due to the pollination by honey bees is 15 to 20 times than the money generated by stockpile products (Aizen *et al.,* 2008). Moreover, Uttarakhand has 4,635 beekeepers and the state produces around 1,193 metric tonnes of honey per year (2017-18) (Anonymous, 2019). Among the major honey producing districts of Uttarakhand, Haridwar, US nagar, Nainital and Dehradun top the list (Uniyal *et al.,* 2018). However, beekeeping in the Indian Himalayas has its own set of problems and the major among them are the insect pest infestations (Shah and Shah, 1991).

More than 12 insect pests are reported to cause damage to honey bees, hives and their products in the Indian Himalayas (Shah and Shah, 1991). Although Greater wax moth (*Galleria mellonella*) and lesser max moth (*Achroia grisella*) are known to cause threat to apiculture. But, recently the hornet pests belonging to family Vespidae have gained the upper hand and are causing direct damages to the foraging bees and are leading to reduction in colony population, making the colonies weak and finally resulting in absconding or deserting of bee colonies (Requier *et al.,* 2020). There are three important hornet species (Figs. 1a to 1c) in the Indian Himalayas that are severe pests in apiary, *viz*., Giant Asian hornet (*Vespa mandarinia*), Yellow legged hornet (*Vespa velutina nigrithorax*) and Greater banded hornet (*Vespa tropica*). These are semi-social hornets that construct horizontal nests on tall trees (Fig. 2), buildings and in abandoned rodent burrows (Dazhi and Yunzhen, 1989). The colony population fluctuates between hundreds to thousands, while the peak population is recorded in the monsoon months of August to September in Uttarakhand. Among the three; *V. mandarinia* is a notorious and most ferocious species that is observed to kill 120-150 forager bees in an hours time (Yoshimoto and Nishida, 2009). The

Fig. 1a. *Vespa mandarinia*

Fig. 1b. *Vespa velutina nigrithorax*

Fig. 1c. *Vespa tropica*

hornets wait at the hive entrance (Fig. 3), catch hold of the foraging bees, decapitate and carry the thoracic part of the bee to their nests to feed the young ones (Nunez-Penichet *et al.,* 2021). The hornet damage is very severe in unmanaged apiaries and in the foot hills, low hills and mid hills of Himalayas, as the climatic conditions are very suitable for the hornet to survive and reproduce (Zhu *et al.,* 2020). The attacks on bee colonies by these hornet species compel the bees to desert the colony and swarm away to a new habitat, thus, causing severe economic losses to the bee keepers. In the present article, we will be briefly elaborating about identification, biology and predatory behavior of *V. mandarinia* an important hornet species of Indian Himalayas.

Fig. 2. Nest of *V. mandarinia* on tall tree branches

Identification, biology and predatory behaviour of Giant Asian hornet (*V. mandarinia*)

V. mandarinia is the largest hornet species in the world and it is known to have originated in temperate and tropical East Asia and South Asia (Smith-Pardo *et al.,* 2020). They prefer to live in low mountains and forests, while almost completely avoid plains and high-altitude climates. They are social hornets that create nests by digging the ground or adapting to pre-existing tunnels of rodents or occupy spaces near rotted pine roots in the mid and low hills of Himalayas (Yamane, 1976).

Identification: *V. mandarinia* is a large hornet with body length of 45 millimeters and wingspan of 70 mm. The sting is around 6 mm long and can inflict very painful sting and inject large amount of potent venom. The hornet's head is yellowish orange in colour with brown antenna. The eyes and ocelli are dark brown to black in colour with large clypeus and gena. The mandibles are dark brownish in colour with black distal portion, very strong and used for digging the ground and decapitating the prey. The thorax and abdomen are dark brown or black in colour with yellowish orange hue. The sixth abdominal segment has a sternal gland, also known as van der Vecht's gland. The scent produced from these glands is used to mark the food source. During the months of September and October, the hornets mark the bee colony to attack in groups for mass slaughtering of the bees (Van der Vecht, 1959; Yamane, 1976; Archer, 1993).

Fig. 3. Hornet waiting at the hive entrance

Fig. 4. Fully developed nest of *V. mandarinia*

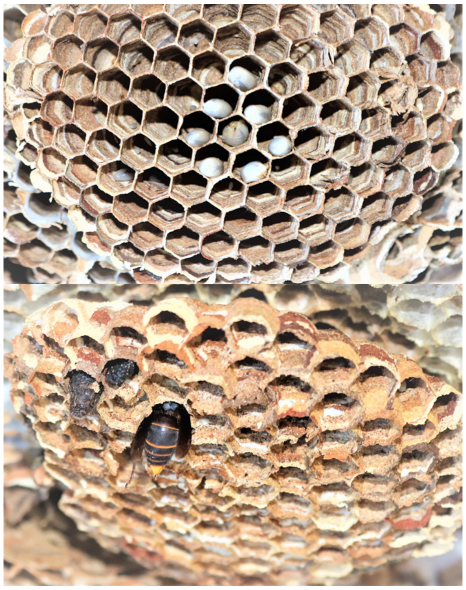

Fig. 5. Queen hornet caring the young ones

Biology and life cycle: The life cycle of *V. mandarinia* consists of six phases (Pre-nesting phase, solitary phase, cooperative phase, polyethic phase, dissolution phase and hibernating phase) and it is consistent with other eusocial hornets. Both the uninseminated and inseminated females end the hibernation period and emerge in mid-April months. The uninseminated females start feeding on sap of oak trees (*Quercus* spp.), while, the inseminated females are initially solitary and along with other females initiate the construction of subterranean or aerial nests. By the end of July, a fully developed nest with 500 cells and 100 workers is formed (Fig. 4) and the queen restricts itself to the colony and worker hornets start foraging. This cooperative phase continues up to late September and once the winter commences (early October), the queen hornet stops laying eggs and shifts its focus to caring the young ones (Fig. 5). The queen dies in late October and the responsibility to produce new queen is taken over by drones and workers. The drones and workers mate mid-air and form inseminated female, while the unmated females are left as uninseminated females. Once again both the females undergo hibernation to start a new colony cycle in the next season (Matsuura and Sakagami, 1973; Stankus, 2020).

Predatory behaviour: The Asian giant hornets primarily feed on larger insects, other eusocial insects, tree sap and honey bees. However, honey bees are the easy targets. The worker hornets wait at the hive entrance, capture the foraging bees, cut apart their head and abdomen and carry the nutritious thoracic region of the bees to their nest for mass provisioning their broods. Usually one hornet can hunt up to 40-60 bees in its hunting phase and 120-150 bees in its slaughtering phase. If the bee colony is weak, the hornets enter into the hive, collect grubs, pupa and honey from the hive and abandon the empty and weak colony.

Designing of the bait trap for managing the hornet menace in the apiaries

Considering the severity of attack and the amount of loss incurred to the apiarists of Indian Himalayas, the Scientists of ICAR- Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora, Uttarakhand, India have designed a new low cost, food bait hornet trap for efficiently reducing the menace of hornets in the region. The trap has shown up to 83% efficiency in trapping the hornets and the Indian patent has been filed for the trap design and its ingredients.

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In conversation with Dr. Janakiraman Poorani

A woman with decades of dedication, passion and hard work, speaks to IE associate editor Dr. S. N. Bhagyasree on her committed journey in the field of insect science.

Dr. Janakiraman Poorani is a self made, self taught, independent woman scientist. She comes from a humble rural background and was born in the temple town of Srirangam in Tamil Nadu. She did her schooling from various towns in Tamil Nadu including Sendamangalam, Erode, Avinashi and Trichy because her father was a bank employee and frequently transferred. She did her B. Sc. (Agriculture) from TNAU, Coimbatore, in 1988 and M.Sc. (Agricultural Entomology) from AC & RI, Madurai (TNAU), in 1990. She completed her Ph.D. with specialization in insect taxonomy at the ICAR-Indian Agricultural Research Institute, New Delhi, in 1994. She joined ARS in 1994 and was initially posted at the Trainers Training Centre, ICAR-IIHR, Bengaluru in 1995. She shifted to the Project Directorate of Biological Control (now National Bureau of Agricultural Insect Resources (NBAIR)), Bengaluru in 1996. She was the only insect taxonomist at PDBC until 2009 when PDBC was renamed as ICAR-NBAII (National Bureau of Agriculturally Important Insects) and later as ICAR-NBAIR (National Bureau of Agricultural Insect Resources). She was involved in the cataloguing of the reference collections at PDBC / NBAIR and contributed substantially to the successful biological control programmes against invasive pests such as the spiralling whitefly and papaya mealybug. She is an expert in the taxonomy of lady beetles (Coleoptera: Coccinellidae) of the Indian Subcontinent /Oriental region with an academic interest in the taxonomy of insect pests, parasitoids and predators. She is keenly interested in developing online diagnostic aids to economically important insects in Indian agriculture for the benefit of entomology students and researchers. As a Principal Investigator of the Network Project on Insect Biosystematics at NBAIR, she was instrumental in augmenting and strengthening the insect collections at NBAIR. She has constructed and hosted as many as eight major databases on agriculturally important insects of India such as Insects in Indian Agroecosystems, Featured Insects, Aphids of Karnataka, Indian Genera of Mymaridae, Aphelinidae and Diapriinae, all of which are hosted on NBAIR's official website and these databases have received more than 14 lakh hits so far. She initiated the digitization of the type collections at NBAIR and hosted the web content on the type material at NBAIR. At present, she is working as a Principal Scientist at ICAR-National Research Centre on Banana, Trichy. She has been revising the Coccinellidae of the Indian region and working on pest mapping, diagnostics and management of banana insect pests. She has visited the Smithsonian National Museum of Natural History, Washington, DC; Australian National Insect Collection, Canberra; and the Natural History Museum, London, for various projects on Coccinellidae and study of type material. She is a strong proponent of more funding and opportunities for insect taxonomists and advocates better networking and collaborations for sharing of specimens and other resources to stem the declining trend in Indian insect taxonomy.

BSN (Bhagyasree S N): Thank you for speaking to Indian Entomologist magazine. How did you pursue career in Entomology and how did you choose working especially on Taxonomy?

J Poorani (JP): My undergraduate classes in entomology were full of fun and the entire class was fond of the entomology teachers who were very good. Many of my classmates including me opted for postgraduation in Entomology because of their influence. When I joined IARI for my Ph.D. programme, I had to choose between Insect Pathology and Insect Taxonomy and I opted for the latter without any hesitation because of the bad smells we used to associate with the insect pathology lab! I was the first Ph. D. student of Dr. V. V. Ramamurthy and worked on entimine weevils, but I was very casual at that time with a lot of other interests particularly in history, literature and sports overriding my academics. I did not do a great job as a Ph.D. student and only after joining ARS as a scientist, I began to do serious taxonomic work.

BSN: Taxonomy of natural enemy of pests was the mandate of NBAIR at that time, still why did you choose to work on Coccinellidae, when parasitoids are considered more important in biological control?

JP: When I joined the Project Directorate of Biological Control (now NBAIR) in 1996, I was asked to choose a group important in biological control and due to my Ph.D. background in Coleoptera, Dr. C. A. Viraktamath suggested Coccinellidae would be the best choice because of its economic importance and the need for revisionary studies on the Indian fauna. There was no dearth of expertise on Indian Hymenoptera then as many Hymenoptera stalwarts like Dr. T.C. Narendran, Dr. M. Hayat, Dr. Farooqui and Dr. Jonathan were actively working and all were prolific publishers of voluminous revisionary works.Besides, though predators and parasitoids are equally important in biological control, there is very little expertise on predatory insects in India. For your information, many groups of Indian Coccinellidae have not been systematically revised even now.

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

JP: My mother was and will always be my first role model – she was an extraordinary person with monumental patience, will power, magnanimity and compassion. I have tried to follow her without much success. My teacher, Dr. K. Gunathilagaraj, former Professor of Entomology, TNAU, made a huge impact on me when I joined M.Sc. (Ag.Entomology) at AC & RI, Madurai. I admire his impish and sardonic sense of humour, outspoken, no-nonsense style and practical approach to life in general and also entomology and I have not seen many people of his ilk. His contribution in kindling the interest of the students in entomology is immense. He is like a father to me and it is a pity his talents and services were largely wasted in TNAU but he is universally loved by his students. Dr. V.V. Ramamurthy, my Ph.D. guide, has been a big influence because he is calm and never gets rattled by anything – I understand now stoicism is a virtue required for Indian taxonomists! I have met and interacted with Dr. C.A. Viraktamath more frequently because I worked in Bangalore and he is a rolemodel, father figure and inspiration to me in every way – I have seen him from closequarters and admire his patience and profound knowledge of insect taxonomy. Among other Indian taxonomists, I have deep respect and admiration for Dr. Mohammad Hayat for his phenomenal scholarship, Dr. K.D. Prathapan for his passion, and Dr. Kumar Ghorpade for his genius. I remain grateful forever to the late Dr. S.P. Singh, Former Director of PDBC,who gave a lot of encouragement and support in my early years as a taxonomist. He was a great administrator who knew the strengths and weaknesses of all the scientists and managed to get the best out of every person – he gave the space and freedom for every scientist irrespective of their age and position.

"Taxonomy in general is demanding and one needs to be patient - to develop minimum scholarship on a group, intensive benchwork over many years is indispensable"

BSN: How do you react when things go out of hand and messed up in your professional life?

JP: As a person, I am very emotional and straight forward - not a good combination. These days I try to be quieter and not react to adverse comments or do anything whatever the provocation.

BSN: What are the biggest challenges you've come across in your profession?

JP: I was the only insect taxonomist in PDBC for nearly 15 years before the PDBC was renamed as NBAII / NBAIR in 2009. I was forced to dabble in so many groups of insects though I was supposed to specialize in Coccinellidae and I had to spend a considerable part of my time in extending identification services to students, researchers, various AICRPs, etc. The most challenging part for an Indian insect taxonomist is that people think a taxonomist should be able to identify all groups of insects.Worldwide, taxonomists work on one superfamily or one or two related families at the most. It is difficult to make people understand that one person cannot identify all groups. I have a lot of ongoing revisionary work on Coccinellidae, which is difficult to finish now because most of my collections are left behind at NBAIR. Taxonomists are like wine, they mature with age – to attain the kind of scholarship of Dr. Viraktamath or Dr. Hayat, you need to work for 25–30 years. Now I am better than I was some 10 years ago, but I do not have the kind of resources I used to have. I wish to complete my illustrated guide to Indian Coccinellidae and bring it out as a free, open source publication and it is taking a long time due to various contraints. In any case, Indian taxonomists have to work against the odds all the time!

BSN: Why have you always kept yourself away from awards? What do you think of awards in general?

JP: Every scientist wants recognition for his/her scientific contributions and I too strongly believe good work should be appreciated and recognized. But the way awards are given away by Professional Societies leaves a lot to be desired because quantity of work, particularly number of publications, gets priority over quality and the most worrisome part is, you can buy an award by paying a nominal fee of Rs. 3000–5000. The dictum "awards beget awards" is absolutely true in India because scientists get multiple awards for the same work submitted repeatedly to various societies and use them to get higher positions and climb up the ladder.

I am completely put off when I see the application procedure prescribed by various societies like submission of voluminous supporting documents, reprints of papers, etc. that require enormous quantities of paper, time and resources. The carbon footprint of preparing an award application must be enormous at this rate! I have decided I will not go through the rigmarole of this tortuous application process for awards. When I see the craze for awards in young scientists, I am deeply amused and disturbed at the same time. I have noticed even single applicants ended up as winners in the absence of competition in many cases and lifetime achievements have been given in taxonomy to people with, say 10 years' experience. It makes no sense at all!

BSN: How would you like to see taxonomic work in future?

JP: The advent of the internet and online resources has made the task of taxonomists a lot easier now. It is inevitable that Indian insect taxonomists will have to do a lot of alpha taxonomy because only about one-third of our insect fauna is known at present. Large scale revisionary taxonomic studies are required for the known taxa because higher phylogenetic classifications of insect orders / families have undergone monumental changes due to combined analysis of molecular and morphological data. It is a sad fact that the most of described insect fauna remains unidentifiable due to lack of revision. We need to discover, describe and document the undescribed ones also in this process. The only way we can make it more acceptable is by integrating the taxonomic revisions and further alpha taxonomy with at least minimum molecular characterization (say a barcode sequence) and include immature stages, biology / ecology, natural enemies, etc.

BSN: Do u think the journey of recognition would be longer for an honest and most patient researcher?

JP: Taxonomy in general is demanding and one needs to be patient - to develop minimum scholarship on a group, intensive benchwork over many years is indispensable. When I began working, it took me six years to complete a checklist of Indian Coccinellidae because I did not have the library resources and had to toil to get the original descriptions. All the old taxonomists had to do a lot of backbreaking work, particularly for making illustrations using a camera lucida, etc. It is a lot easier now - As a taxonomist who began to work in the pre-internet era, I can only marvel at the kind of literature resources, microscopes and imaging facilities, etc. available now to the younger generation of taxonomists. But it is a world full of inequalities and many committed workers in small institutions do not have access to these facilities.

BSN: What is that one thing young taxonomists need to change to bring more authenticity to science?

JP: Many young taxonomists do not even know how to use traditional literature resources like the Zoological Record and have poor knowledge of the ICZN code. Online databases and other resources are very handy and useful but many younger taxonomists will be hard put if the internet is switched off. Training/HRD, funds to travel to foreign repositories, and networking are needed for young taxonomists.

BSN: How does shift from NBAIR to NRC on Banana changed you?

JP: I have not changed in any way except for my location. I shifted to NRCB for only one reason – I left my home in 1984 to pursue B.Sc. (Ag.) at TNAU, Coimbatore and I was away from my parents and family for 31 years for my higher education and employment. My aged mother had severe arthritis and hypertension and she had expressed the wish to be with me for a few years, but she could not come to Bangalore. In 2014, I witnessed the death of Mr. Munuswamy, one of my most valued colleagues at PDBC, who died of old age – I was deeply moved by his demise. On that day, I took an impulsive, immediate decision to get a transfer to NRCB to be with my aged mother because I wanted to take care of her in her old age. Unfortunately, I could spend only three years with my mother who passed away in 2018. In a philosophical vein, I have understood that everything in life is ephemeral and fickle - in ICAR also, people forget your contributions when you move to a new place and it is difficult to rebuild your career in a new place where your work is treated as unimportant.

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

JP: Being a single woman, I have not faced the pressures of having my own family but I have shouldered family responsibilities whenever required because my siblings and their families are all part of my extended larger family. It is difficult for women because they are natural care givers and have more pressures and work to do for the family, raise the kids, etc. when compared to men. I always marvel at the ability of many women who balance family and work successfully because I cannot cook well even today. I am not competent enough to give tips on this aspect.

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

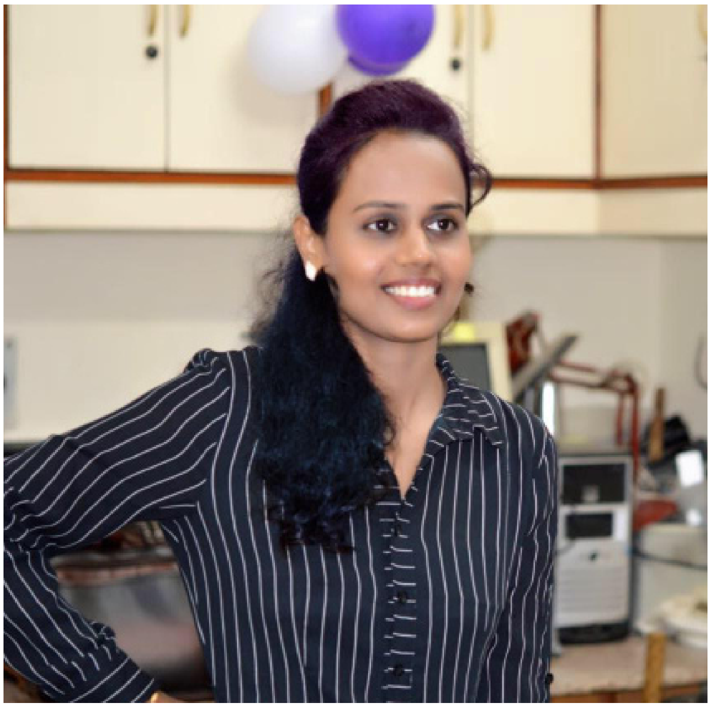
JP: When I see young scientists/entomologists working with the singular aim of building their score card, it is distressing. In my opinion, the ICAR score card has done incalculable damage to the system. All the time young scientists are working out the number of papers to be published, conferences to be attended, technologies/commercialization/institution building and what not for getting the next promotion. I feel the scorecard is also a major reason for young entomologists' reluctance/aversion towards taxonomic research. There should be a more rational, impartial and objective system for evaluating the output of scientists and this is the only way to reduce the undue pressure to perform to fulfil the scorecard requirements. Youngsters should do their job without too much aggression and open self-aggrandisement – if you work hard with sincerity, rewards will come.

Things were much better in my younger days with fewer meetings to attend and fewer reports to submit. I feel young entomologists and other scientists have a lot of distractions now with many unproductive meetings, report submissions, etc. and have less time for productive work. This is a worrying situation and I do not know how this can be changed.

BSN: No doubt you are a brilliant scientist with extreme intellect, why don't you think of good administration?

JP: Administration is not my cup of tea – I am not fit to be an administrator because I am a bit of a nerd, basically an introvert and averse to protocol and VIP culture. Most importantly, I am positively allergic to long meetings, in person or online. I am completely overwhelmed by the number and frequency of various meetings we seem to be having these days! I feel I can contribute more and do good as a scientist than as an administrator.

BSN: Thank you for talking to Indian entomologists and its liberating to here the way you spoke certain facts with elegance.



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REVIEW ARTICLE

RNA interference: An update on its application in insect control

Reshma, R., Sagar, D., and Rajna, S.

Abstract: RNA interference (RNAi) is being used as one of the important technologies for better designing of pest control strategies. It is found to be effective against different insect orders such as Coleoptera, Diptera, Lepidoptera and Hemiptera. The efficiency of RNAi depends on the design of dsRNA and the mode of delivery selected. The delivery of RNAi through transgenic plants is now a reality with some products currently in the market. Topically applied dsRNA/siRNA (Spray induced gene silencing) has attracted attention due to its feasibility & low cost compared to transgenic plants. Sustainable agriculture relies on practices and technologies that combine effectiveness with a minimal environmental footprint. RNAi-based products can revolutionize pest and pathogen management safely and effectively if conception and development are conducted in a precautionary way.

Key words: Gene silencing, Insects, delivery systems, dsRNA

An overview of RNAi in insects

RNAi is a post-transcriptional gene silencing mechanism initiated by introduction of double stranded RNA (dsRNA) leading to generation of loss of function phenotypes by degrading the target gene messenger RNAs (mRNAs). It utilises small RNA (sRNA) as trigger molecules for the manipulation of gene expression. sRNAs are derived from double stranded RNA (dsRNA) and come in a variety of forms each differing in structure, function and biogenesis. E.g, Micro RNA (miRNA, ~22nt long) which is transcribed from plant genomes to regulate expression of endogenous genes (Bosco et al, 2008) and small interfering RNA (siRNA, 20-25nt long) which is derived from exogenous dsRNA sequences or the products of miRNA directed silencing (Broughton *et al.*, 2014). The RNAi pathway involves cleavage of the introduced dsRNA by dicer within cells. The resulting short RNAs or siRNAs get unwound to guide strand and passenger strand, of which the latter degenerates. Guide strand gets incorporated to RNA-induced silencing complex (RISC). The RISC-RNA complex degrades the corresponding mRNA and reduce protein expression (Fig 1).

Sensitivity of insects to RNAi: The efficiency of RNAi varies with insects orders. Coleopterans show high sensitivity to dsRNA, Dipterans show moderate sensitivity while Lepidopterans and Hemipterans show weak sensitivity to dsRNA. This is due to the presence of dsRNA degrading enzymes in their digestive system. RNAi efficiency differs within insects of the same order and also based on the mode of delivery of dsRNA.

Uptake, release and export of dsRNA could affect RNAi efficiency and resistance in insects. Insects can uptake RNA as both dsRNA and siRNA, directly or indirectly. Direct uptake refers to uptake through topical contact or feeding on plant tissues while indirect uptake involves first entering RNA in to plant vascular system and then uptake by insects. The dsRNA reaches insect cells through SID-like transporters or endocytosis or with the help of specific receptors which are found more for long dsRNA when compared to siRNA. After entering the cell, dsRNA should escape from endosomes (internal sorting organelles) to get accessibility to target mRNA which is found to be limiting in some insects. Plants, fungi and nematodes have endogenous RNA dependent RNA polymerase (RdRp) which target on single-stranded RNA molecules and synthesize a second strand, generating dsRNA consequently. This produces a systemic spread of RNAi signaling in them (Zotti *et al.,* 2017). Since RdRp is absent in insects further amplification of dsRNA is not possible. The dsRNA reaches from cell to cell (Systemic RNAi) through special structures like exosomes, nanotubes or other carrier molecules in insects (Karlikow *et al.*, 2016).

CHOICE OF dsRNA TARGETS IN INSECTS

The dsRNA targets selection can be of three types.

1. **Resistance factors:** Targeting genes associated with resistance to existing pesticides or other control measures. E.g, dsRNA targeting sodium channel increased sensitivity to pyrethroids in *Aedes aegypti* (Bona *et al*., 2016), Asian citrus psyllid topically applied with dsRNA against Cyo genes increased sensitivity to imidacloprid (Kilny *et al*., 2014).

2. Developmental and /or arthropod genes: Many insect-specific genes worth considering will reduce the risk of off-target effects in vertebrates. E.g, EcR KD in grain aphids (Yan *et al*., 2016).

3. Intracellular trafficking pathways: These are tightly regulated processes used by a variety of molecules to cross the membranes of living cells. E.g, ESCART protein including *snf7* (Head *et al*., 2017), *vATPases* (Baum *et al*., 2007), COP pathway proteins (Taning *et al.,* 2018), Endocytosis proteins (Pinheiro *et al*., 2018).

Besides these, dsRNA is also being studied for inducing sterility in insects (Whyard *et al*., 2015).

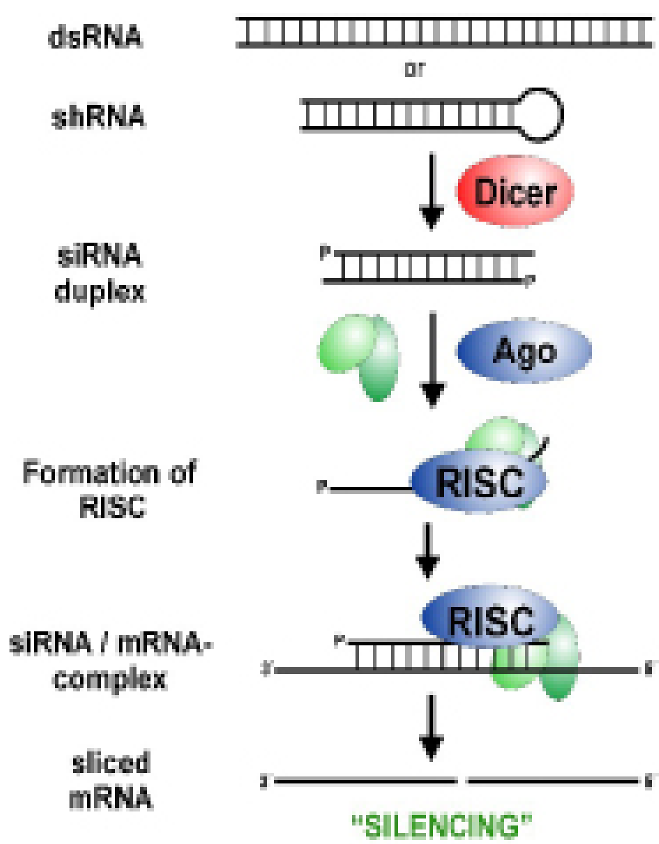

Fig 1: Molecular mechanism of siRNA silencing. Source: http://www.uni-konstanz.de/FuF/chemie/jhartig/

DIFFERENT DELIVERY SYSTEMS OF dsRNA

After choosing the appropriate target genes, the most suitable delivery system has to be selected for the efficient application of RNAi in pest control. In laboratories, methods like artificial feeding and microinjection are utilized. For application of RNAi in fields, methods like Host-induced gene silencing (HIGS), Spray-induced gene silencing (SIGS), Virus-induced gene silencing (VIGS), Stem injection and Root absorption are used. Except for the first method, all others are non-transformative delivery systems.

1. **Host-induced gene silencing (HIGS) (Transgenic inplanta delivery):** Entails the creation of transgenic crops that express the dsRNA specific for the pest.

SmartStax Pro is the first commercial RNAi product targeting on insect pests. It is a transgenic corn crop developed by Monsanto (Bayer crop science) against Western corn rootworm (WCR). It employs a pyramid strategy utilizing two different *Bt* proteins (Cry34Ab1/Cry35Ab1 and Cry3Bb1) as well as dsRNA targeting *snf7* gene expressed in the plant (Head *et al*., 2017). *Bt* protein inserts itself into the gut epithelium and cause gut paralysis and thereby death. Down regulation of *snf7* gene, which plays an essential role in protein trafficking, will also bring mortality of the insect (Bolognesi *et al.*, 2012). This combined strategy lead to the swift death of the pest and less resistance development against the Plant Incorporated Protectant (PIP) (Head *et al.*, 2017). Bt genes also ensure protection from lepidopteran pests like fall armyworm resulting in a healthy crop both above and below ground. This product was approved by the United States Environmental Protection Agency in 2017. In 2016, it was released in Canada and a year later, in 2017, released in the USA.

The advantage of this method is that it provides constant dsRNA exposure thereby achieving long term control with out spray. There are drawbacks associated, like regulation of transgenic crops, high cost of producing transgenic crops, reduced public acceptance, time-consuming production procedure, resistance development due to continuous exposure to dsRNA and absence of established transformation protocols.

2. Spray-induced gene silencing (SIGS) (Topical delivery): This involves the application of dsRNA topically as spray. This is an emerging area under focus due to the restrictions in transgenic approach. It is found to be more effective for insects that are more sensitive to dietary uptake of dsRNA. Given the low persistence of dsRNA in the environment, SIGS most likely need special formulations to increase stability and RNAi efficiency. Different formulations are experimented which includes nanoparticles, synthetic polymer, liposomes, proteinaceous delivery system and chemically modified siRNA.

Nanoparticles: Polyplex based delivery system consisting of either natural or synthetic polymer subunits. The most used nanoparticles are chitosan-based. Zhang *et al*. (2010) demonstrated that *Aedes gambiae* larvae soaked in chitosan-coated dsRNA solution improved RNAi knockdown. The incorporation of dsRNA into such a nanoparticle complex increased the stability and uptake of dsRNA *in vivo* (Zhang *et al*., 2010). This method of oral dsRNA delivery appeared beneficial for the control of African malaria mosquito, *Aedes gambiae* and yellow fever mosquito *A. aegypti* (Zhang *et al*., 2010; Mysore *et al*., 2013).

Synthetic polymer: Guanylated polymers based formulation of dsRNA experimented through oral delivery to *Spodoptera exigua* increased RNAi efficiency (Christiaens *et al*., 2018). Since lepidopterans have a high alkaline gut lumen, rapid nucleolytic degradation of dsRNA takes place in the digestive system resulting in low sensitivity for RNAi. Polymers with high guanidine content provided strong protection against nucleolytic degradation at pH 11. Polymers also enhanced cellular uptake and targeting essential gene *Chitin synthase B*, mortality of the pest also increased.

Liposomes: These are lipid-based transfection agents. Positively charged lipid envelops negatively charged dsRNA forming compact lipid bilayer. RNAi in *Drosophila* sp. using Lipofectamine 2000 and cellfectin improved efficiency (Whyard *et al*., 2009).

Proteinaceous delivery system: Cell-penetrating peptides (CPP) are used here. PTD-DRBD fusion protein (Peptide transduction domain-dsRNA binding domain) is integrated with dsRNA to form RNP (Ribonucleoprotein) improved mortality of cotton boll weevil than naked dsRNA (Gillet *et al*., 2017).

Chemical modifications on siRNA: Modification of one or both strands of dsRNA to improve stability and specificity (Jackson *et al*., 2003). It reduces off-target effects thereby safety concerns and cost-effectiveness are considered.

The advantages of SIGS are that it ensures increased cellular uptake and protection from (nucleolytic) degradation. Since dsRNA is not provided constantly, resistant development is also less. Unlike HIGS, it is easy to regulate. There are drawbacks for this method such as potential implication for biosafety and stability in the environment.

3. **Virus-induced gene silencing (VIGS) (using microorganisms):** Studies revealed that transgene was not required to trigger silencing pathway in plants. Non-transgenic plants infected by viruses induce dsRNA mediated post-transcriptional gene silencing which degrade pest genome. For VIGS, the viral genomes are modified by removing genes which induce virus symptoms and cloning a fragment (usually 300–500-bp) of the target gene with efficient siRNA generation and no off-target genes into the modified viral genome (Xu *et al*., 2006). The recombinant virus is then introduced into plant cells through *Agrobacterium tumefaciens*- mediated transient expression or *in vitro* transcribed RNA inoculation or direct DNA inoculation. After the recombinant virus is introduced into plant cells, the transgene is amplified along with the viral RNA by either an endogenous or a viral RNA-dependent RNA polymerase (RdRp) enzyme generating dsRNA molecules (Dalmay *et al*., 2000), these dsRNA intermediates in gene silencing. Virus-specific for insects & plants can be engineered to produce dsRNA inside the insects themselves or in plants respectively. Here infection with virus induces dsRNA synthesis and gene silencing. Virus-specific

for insects is more acceptable when compared to the latter.

Flock House Virus (FHS) was engineered to express *Drosophila melanogaster* specific dsRNA (Taning *et al.,* 2018). The advantage of using plant infecting virus is that it can move inside plant systematically through phloem, so recombinant virus can target phloem-feeding insects. Since VIGS is transiently transformed it does not cause alteration of the plant genome. Recombinant TMV expressing RNAi effectors infected *Nicotiana benthamina* plants caused death of citrus mealybug feeding on them (Khan *et al*., 2013). This method is beneficial for woody plants since it takes time to produce GM crops. VIGS can be transmitted to plant progeny & actively co-opts the plant to express dsRNA. Virus simulate natural path of cell entry which is an additional benefit of this method. Cross infection of beneficial insects also challenges biosafety. Since viruses are not accepted widely due to these drawbacks, Virus-like particles (VIP) produced by certain microbes is an alternative.

VIGS-like technology is also employed with other microorganisms like bacteria, yeast, entomopathogenic fungi, microalgae etc. The use of microorganisms ensures sustained release of dsRNA. It also prevents rapid degradation of dsRNA in the digestive system. Since common bacteria like *Escherichia coli* are engineered and used, this bacteria may cause infection on beneficial insects too which is found to be one of the drawbacks. Thus, the use of symbiotic bacteria specific for particular insects is more preferred. Besides using bacteria as the delivery system, they are used to produce a large amount of dsRNA which can be sprayed on crops at low costs. The major drawback of VIGS is that it is considered as a GM product and goes through all related regulatory processes.

Comparison of delivery as naked dsRNA, through *E. coli* and symbiotic bacteria *Rhodococcus rhodnii* in kissing bug *Rhodnius prolixus* was successfully done by Whitten *et al.* (2017). They reported that all these methods invoke a systemic response. Though naked dsRNA and *E. coli* produced dsRNA resulted in only transient systemic RNAi (since *E. coli* get eliminated from the cell after dsRNA ingestion), symbiotic bacteria *Rhodococcus rhodnii* colonised the gut and thereby established sustained systemic RNAi. The engineered *R. rhodnii* were also transmitted horizontally through ingestion of faeces which was found to be an additional benefit.

4. Stem injection and root absorption: Both are non-transgenic *in planta* delivery systems. Stem injection was found to be efficient for perennial trees. Hunter *et al.* (2012) reported that citrus trees treated with dsRNA through stem injection and root drench have shown effective control against citrus psyllid and leafhoppers for up to 57 days. Rice plant roots soaked in a solution containing dsRNA targeting *carboxylesterase* and *CYP18A1* genes from brown planthopper significantly knocked down these genes (Li *et al*., 2015). Delivery of dsRNA molecules through irrigation water is an alternative for crops that use irrigation in normal growing systems (Li *et al*., 2015). Though it allows a constant supply of dsRNA, the short persistence of dsRNA is a drawback associated with this method. Therefore, the use of advanced formulations is needed to protect dsRNA from degradation.

OTHER APPLICATIONS OF RNAi BASED PRODUCTS

Besides using against crop pests, RNAi based products are also developed for mosquito control, the human disease vector. A study on the efficiency of genetically engineered yeast expressing interfering RNA corresponding to mosquito neural genes as lure-and-kill mosquito and oviposition attractants were conducted and reported to be successful (Hapairai *et al*., 2017). RNAi based products against pests of beneficial insects were also developed. Deformed Wing Virus infection on both larvae and adults were reduced by feeding European honeybees with dsRNA (Desai *et al*., 2012). RNAi was also efficient against internal microsporidian parasite, *Nosema* (Paldi *et al*., 2010) and obligatory ectoparasite *Varroa destructor* in *Apis mellifera* (Garbian *et al*., 2012). Since dsRNA are target specific, they are found to be harmless against honeybees, so safety is assured.

RNAi BASED PRODUCTS: ACCOMPLISHMENTS

Currently approved RNAi based GM crops are based on ncRNA (non-coding RNA) to control insects (8%) and diseases (27%) or to improve scientific plant traits (65%). With all the drawbacks that GM products raise, more research is focusing on non-transformative delivery of dsRNA for gene silencing.

Monsanto is developing the use of RNAi through a technology called "Biodirect" in which dsRNA formulation is applied exogenously to protect plants against insect and pathogen attacks (https://monsanto.com/innovations/agricultural-biologicals). Syngenta is also developing lines of biocontrol products based on RNAi to protect potato plants from the attack of the colorado potato beetle (https://www.youtube.com/embed/BiVZbAy4NHw?ecver=1).

Since the production of inexpensive RNA is a primary need, a biotechnology start-up working on sprayable RNAi based insecticides *RNAissance Ag* introduced a technology in which industrial fermenting bacterial species are used to produce RNA in safe and cost-effective manner. Their sprayable RNAi based biopesticide against diamondback moth is under early field trial. Considering the hostile environmental condition to which dsRNA molecules are exposed in the field, the biotech company RNAgri (former APSE) developed a system where APSE RNA containers (ARC) are produced by *E. coli* bacteria, allowing the mass production of encapsulated ready to spray dsRNA. Research is being carried out on improving the potential of different RNAi based products and reducing their limitations by scientists from various countries.

During the last decade several researchers have carried work on RNAi based products, still there are some areas left behind. At field level, the time of application and rate of application of dsRNA has to be investigated. Since it is difficult to establish dsRNA uptake under field condition, new methods has to be discovered. The selection of most appropriate target gene, species specificity, cost of dsRNA, delivery of dsRNA formulations and regulation are major challenges while considering about RNAi based biopesticides. In India, since a more scientifically informed approach is followed for regulation of GM crops, topically applied RNAi based products will be a viable alternative. Recent study on topical application of dsRNA against papaya ring spot virus - Tirupati and Delhi isolate was successful providing 94% and 81% resistance respectively (Vadlamudi *et al*., 2020). More studies in SIGS are in need against other economic pests also.

CONCLUSION

RNAi based products have immense potential in managing crop pests, pests which are a threat to beneficial insects, pathogens and insect vectors of human and plant diseases safely and effectively. Although GM products are not widely accepted, non-transformative approaches in RNAi can be exploited as pest control measures. Realization of the complete benefits of the technique can be achieved only through appropriate dsRNA design and delivery mechanisms. The major limitation associated with the products is their less stability and impact on non-target organisms. The use of suitable formulations will reduce the degradation of dsRNA in both environments and inside the host. Bioinformatics based design of dsRNA sequences to minimize homology with endogenous transcripts in both the host plant and NTOs is an important approach to mitigate the risk of biosafety (species-specific products). Synthesis of broad-spectrum biopesticides targeting a wide range of pests can also be explored in this way.

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A guide to prepare Cue-Lure for *Bactrocera cucurbitae* (Coquillett) management in cucurbits

Varun Arya, Srinivasa N., Saniya Tyagi and Raju S.V.S.

Varanasi (Uttar Pradesh, India) considered to be one of the most prominent vegetable belts of the country (Roy *et al*., 2017). Among the vegetables cultivate here, cucurbits (Fig.1) cover the major share in area and production. Among pest and disease complexes infesting cucurbits, majority of damage is caused by fruit fly complex (Bhowmik and Saha, 2017). Melon fruit fly *Bactrocera cucurbitae* (Coquillett) (Tephritidae: Diptera) reported to damage 81 host plants (Shivangi and Swami, 2017) and it considered to be the most serious one. It can cause a yield loss of about 30-100% in cucurbitaceous vegetables depending upon the season and other factors (Dhillon *et al.,* 2005).

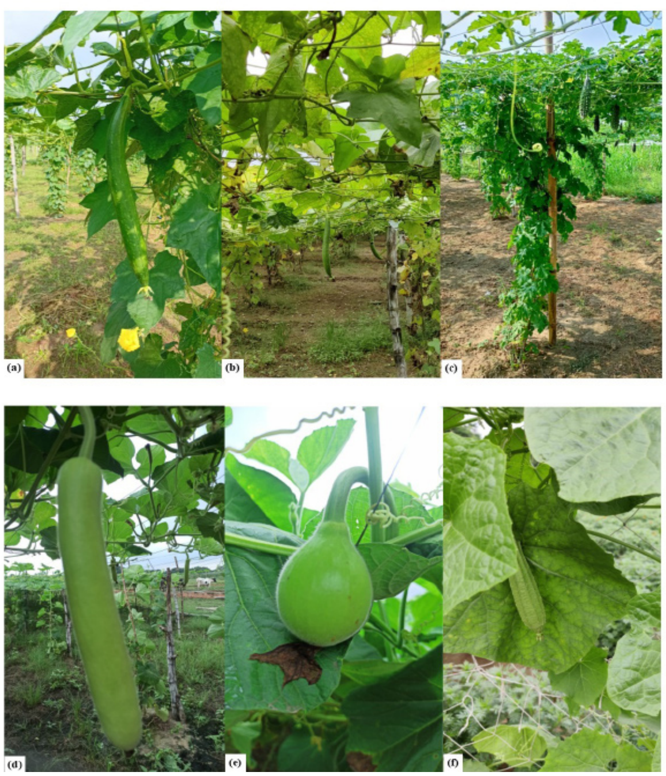

Fig. 1. Cucurbit crops grown in Varanasi, Uttar Pradesh. (a) & (b) Sponge gourd (c) Bitter gourd (d) Bottle gourd (e) Round gourd (f) Ridge gourd

Damage symptoms of *B. cucurbitae*

Adult females lay eggs in soft and tender fruits by puncturing fruit skin with their sharp ovipositor. Infested fruits show brown resinous deposit in the oviposit area, maggots on hatching feed on internal pulp content of the fruit. Damaged fruits also fall off rapidly due to secondary infection by bacteria and fungi. Fruits drop prematurely which are also unfit for consumption. Along with above distorted and malformed fruits are also observed (Fig. 2).

Life cycle of *B. cucurbitae*

Adult female lays eggs in soft and tender fruit tissue. The eggs hatch into maggots in 2-5 days and larval duration ranges from 2-5 days. Matured larvae undergo pupation in soil at a depth of 0.5-15cm. Pupal period ranges from 9-13 days and adult longevity ranges from 13-15 days.

Management of fruit fly, *B. cucurbitae* using pheromone traps

Fruit flies on small and large scale can be managed by pheromone traps. Parapheromones are synthetically

Fig. 2. Fruit fly damaging symptoms in cucurbit crops. (a) Bitter gourd (b) Sponge gourd

Fig. 3. Preparation of cue-lure baited trap with insecticide. (a) Chemicals used for making cue-lure traps (b) Preparation of lure (c) Plywood pieces dipped in cue-lure (d) Dipped plywood pieces covered with aluminum foil.

produced chemical compounds, that have pheromone like action similar to female insect sex pheromones which is released to attract males. The Cue-Lure is a parapheromone which attract males of *B. cucurbitae* (Shelly *et al.,* 2004). The Cue-Lure can be used for monitoring and mass trapping of male flies and baiting with pesticide will helps to kill them immediately.

Preparation of Cue-Lure baited traps

Mix ethyl alcohol, Cue-Lure [4-(p-acetoxyphenyl)-2-butanone] and Malathion 50EC (Insecticide) in the ratio of 6:4:2 in a glass container. Add plywood pieces of size 2″×2″×1″ (l×b×h) into above prepared mixture. Soak the plywood pieces in the Cue-Lure for 24-48 hrs (Fig. 3).

Preparation of low-cost trap bottles

Use transparent water bottle. Turn it upside down and make 2 window holes of 3″×1″ (l×b) from the top 1/3rd of the bottle. Tie the Cue-lure treated wooden blocks in the upper portion of bottle with thread or wire (Fig. 4).

Fig. 4. Installation of cue-lure baited traps in cucurbits field. (a) & (b) Installing low cost trap bottle, 1-2 m above the ground (c) & (d) Installed cue-lure traps in the field.

Usage and recommendation of Cue-Lure

Ten to twelve lure traps per acre are recommended. Traps must be placed from onset of flowering to harvesting (for wide area management) or throughout the year (for monitoring). Change lures in every 30-40 days and examine traps in every 15 days (Fig.

Fig. 5. Male *B. cucurbitae* flies collected in Cue-lure bait traps.

5). Unscrew the bottle cap to collect and discard the collected fruit flies safely.

Caution: Always wear mask and gloves while preparing the Cue-lure and their installation in field to get protection from pesticide. Mix the ethyl alcohol, Cue- Lure and insecticide with a thick stick, wash it properly and discard safely.

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Termites and ants ecosystem: The potentially large source of greenhouse gases

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Methane (CH_4) and carbon dioxide (CO_2) are important greenhouse gases with different sources, whose concentrations in the atmosphere are increasing with time. One major uncertainty in the models of the present and future climate of the earth is the magnitude of emission of these trace gases. Termites and ants are omnipresent social insects in tropical, subtropical, and warm temperate regions of the world and they play an important role in ecosystems. Their thousands and millions of individuals live in a single colony with high coordination. They are also referred to as superorganisms or giant organisms and their combined biomass will be about twice the biomass of all living human beings on the earth (Hölldobler and Wilson 1994; Bar-On *et al.*, 2018). They emit significant quantities of CH_4 and CO_2 into the atmosphere as reported by different studies (Zimmerman *et al.,* 1982; Martius *et al.,* 1993; Dauber and Wolters 2000) but the range in published data is very large which gives ambiguity for their inclusion in global CH_4 and CO_2 budget.

Production of CH_4 and CO_2 in termites occurs as microbial degradation of ingested organic matter. The gut microbiota of lower termite initially breaks up cellulose to glucose monomers which in turn fermented to produce acetate, carbon dioxide, and hydrogen. Thereafter two competing processes occur, acetogenic bacteria reduce the carbon dioxide to another molecule of acetate, whereas methanogenic bacteria reduce the carbon dioxide into methane. The relative proportion of these two processes varies considerably among different species (Brauman *et al.,* 1992).

Studies on greenhouse gases emission by termites and ants

As reported by Zimmerman *et al.* (1982) termites directly emit large quantities of CH_4 (150 Tg y^{-1}) and CO_2 (50000 Tg y^{-1}) into the atmosphere and these laboratory estimation results were corroborated by field measurements of CH_4 emissions from two termite nests in Guatemala. They also estimated largest emission of CH_4 should occur in tropical areas disturbed by human activities. Another study in the Amazon rainforest reported that termites released CH_4 contributes approximately 5% of the annual global flux of CH_4 and estimated global termites mound emission 26 Tg y^{-1} (Martius *et al.,* 1993). The most recent estimates suggest termites contribute around 1 to 3% to the global CH_4 budget (Saunois *et al.,* 2016). Nonetheless, a new study finds that termite mounds oxidize, on average, about half of the termite CH_4 by methanotrophic bacteria living in the mound walls or soil beneath before releasing into the atmosphere (Nauer *et al.*, 2018). Nitrous oxide (N_2O) emissions were also detected in strong termite mounds (Brümmer *et al.,* 2009; Brauman *et al.,* 2015) especially if nitrogen-rich organic matter is available.

The nests of three ant species viz., *Myrmica scabrinodis, Lasius niger*, and *L. flavus* have 1.7 to 2.7 times greater CO_2 emission rate than non-ant influenced soil (Dauber and Wolters 2000). The CH_4 and CO_2 fluxes in forest soils are greatly affected by wood ant nests (Jílková *et al.,* 2015). A recent study finds that leaf-cutter ant, *Atta cephalotes* change the soil CO_2 dynamics by reducing nest soil CO_2 concentration and increasing total emissions. Nest soils accumulate less CO_2 than non-nest soils and these effects remain more than two years in abandoned nests. The ant nest vents emitted up to 100000× more CO_2 than the soil surface, and increased soil CO_2 emissions at the ecosystem level by 0.2 to 0.7% for a Neotropical wet forest (Fernandez-

Bou *et al.,* 2019). Similarly, Mehring *et al.* (2021) find that CO_2 and CH_4 fluxes from nest vents of leaf-cutter ant, *A. cephalotes* were significantly higher than non-nest fluxes, and these nest emissions may have important implications for the carbon budgets of tropical and subtropical American forests. The refuse piles created by leaf-cutting ants provide ideal conditions for extremely high rates of greenhouse gas N_2O production (high microbial biomass, potential denitrification enzyme activity, N content, and anoxia) as reported by Soper *et al.* (2019).

Conclusions

Studies have found that about all species of termites produce CH_4 and they contribute around 1 to 3% to the global CH_4 budget, but the range of CH_4 emissions in published data is strikingly large (0.9 to 150 Tg CH_4 y^{-1}). Most of the direct emission studies are not match with recent science, as they didn't consider the hidden biofilter mechanism present in termite mounds to mitigate CH_4 emission. More studies are required on different termites and ant species to estimate the production of greenhouse gases in different regions of the world by considering all scientific factors in their complex system. Based on presently published data we can't conclusively relate termites and ant's greenhouse gases emission with climate change.

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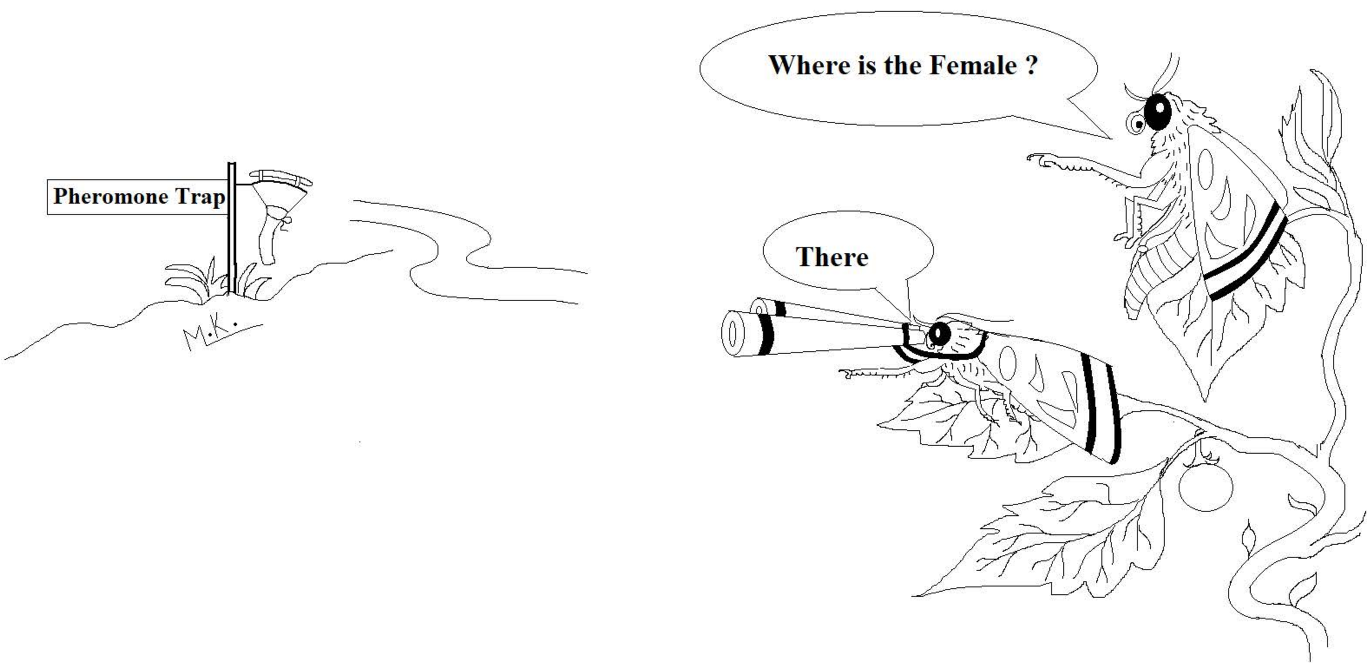

CARTOON BY: Mayank Kumar, Ph.D. Scholar, Department of Entomology, College of Agriculture, G. B. Pant University of Agriculture and Technology, Pantnagar-263145, Uttarakhand, India.

Importance of Pesticide dose in Pest management

Mayank Kumar and Ajaykumara K.M.

In our daily life, whenever we get ill and visit medical doctors, they recommend some medicine in some amounts, which we call a dose. If we follow the proper dose with precautionary measures, we recover soon. Likewise, there is also an importance of recommended dose for pest management in plant protection, which has often been overlooked by farmers in their agricultural fields. Most of the time, farmers apply insecticides higher than the recommended dose to get quick results. Though it brings temporarily immediate effects, it results in the resistant pest population, pesticide residue, and environmental pollution in the long run. It can be well understood from the ever known example of heavy use of DDT in the last century. It's immoral and wrong use negatively impacted the environment with many drawbacks. Among these, environmental pollution, residue, and resistance are significant. The famous book Silent Spring, during1960-70s, was given an alert for its negative impact on the environment. In India 2017 there was Yavatmal poisoning in Maharashtra, leading to severe health issues due to food poisoning. After investigation, it has found an active ingredient diafenthiuron. Presently, there are around 20 topmost resistant species of Arthropods all over the globe. Two-spotted spider mites, diamondback moth and green peach aphid, are on top of the list. They have been found resistant against 94, 92 and 76 active ingredients of pesticides, respectively. In India, three insects have found resistance against different active ingredients of insecticides in 2021 (Table 1). Ultimately, it has created a loophole in the food web, which is not acceptable for upcoming generations on this planet.

In the last few decades, careless use of pesticides without adhering to the safety norms and recommended practices posed severe health risks to humans, other living organisms, and the environment. The release of chemicals into the soil, water and air has led to pollution almost in the whole biosphere. Nowadays, consumers are more concerned about their health and safety, for which they are purchasing commodities that are free from pesticides residue. Food agencies are also prioritising those food products with minimum pesticides residues or switching over to organic food.

The Dose

The dose can be well understood by the famous line of Paracelsus known as Father of toxicology that "What is there that is not poison? All things are poison, and nothing is without poison. Solely the dose determines that a thing is not a poison". It shows how a slight change in a particular thing may bring no effect or may bring harmful effects to your body. Only the exact amount (Dose) can keep you in the perfect stage. The same thing can also apply in pest management as recommended dose. Some authentic authority has generally given it for specific pest management under various environmental conditions. In toxicology, a median lethal dose confers the suppression or killing of 50 per cent of the pest population in the field. In calculations, we generally compute up to Lethal concentration 99 (LC99) to check its maximum limit for 100 per cent population. Practically, we aim to suppress the pest population but not eliminate them from the environment. Therefore, most pesticide products use labels and booklets to provide instructions for proper application, including places and environmental conditions in which the product should not be applied. Suppose a farmer follows the same as above. In that case, it results in proper control with no adverse effect on crop and no residue and pollutant in harvested products and environment, respectively. Surprisingly, Rao *et al.* (2009) survey from India and Nepal reported a considerable gap in actual applied and recommended doses. The majority of the farmers initiate plant protection based on the first appearance of the pest, irrespective of their population, crop stage, and damage relationships. Hence, considerations must be given over the above mentioned parameters for effective pest management without altering the ecosystem health.

To standardize the dose, there is an insecticides bioassay. It determines the relationship between the amounts (dose) of insecticides administered and the magnitude of response in a living organism. If toxic effects, i.e. death, result from insecticides, there must be a positive correlation. This relationship is known as the dose-response relationship. There is DDPQS (Directorate of Plant Protection, Quarantine and Storage) for this dose fixation and monitoring in Faridabad, Haryana. It has six divisions in which Central Insecticide Board (CIB) play a crucial role in fixing the recommended dose in any crop against pest in India. They are also used to check the susceptible and resistant pest population by diagnostic and discriminating doses. Diagnostic doses are used to determine the baseline susceptibility of pest against insecticides, while discriminating doses are used to differentiate the susceptible and resistant population of insects against insecticides.

Impact of inaccurate dose

The inaccurate dose is anything above or below the recommended dosages, i.e. overdose and sub-lethal dose, respectively. There are so many harmful effects of inaccurate doses in crop fields, but here we have described the most important effects under the following headings (Figure 1).

1. Resistance in pest population

In the current scenario, resistance to synthetic insecticides is critical problem farmers face in several parts of the world. It is a measurement of an insect's ability to tolerate the toxic effects of a particular insecticide, resulting in the repeated failure of the product to achieve an effective level of control when used according to the label recommendations (Luckmann and Metcalf, 1982). It is the first time Melander (1914) reported in San Jose scale against lime sulphur. Most of the sucking pests have developed biotypes in India against different insecticides.

It is a selection pressure of insecticides on insect pests of agricultural crops to evolve resistance. In selection, pressure dose can influence the mechanism of evolved resistance to the pesticide. Higher doses favour target site resistance, while sub-lethal doses favour other mechanisms, *e.g.* pest resurgence due to hormoligosis. In general, the insect population of crop fields has a cluster of genetic traits that result in susceptibility or competitive advantages in the natural world. When selective pressure is placed on a population against insecticide, individuals predisposed to it effectively mitigate the toxic effects, survive and pass it to their genetic material. The offspring of those resistant individuals then can have the same genes resulting in resistance. Continued exposure of subsequent generations to the same types of insecticides results in a continual increase in the number of individuals with the genetic advantage of resistance to that insecticide. To manage resistant populations, one could use the different chemicals with different modes of action in alternative ways with their accurate dose. Before chemical control, one should check target pest species' economic threshold and status and opt for some IPM based techniques. It makes your food and environment free from pesticides residue and its pollutant.

2. Pesticides residue

When a crop is treated with pesticides, a minimal amount of the pesticides and their metabolites can remain until after they are harvested, called pesticide residue. It will have many harmful effects on all living organisms. At present, among agriculture commodities, fruit and vegetables are recognized as the top categories that contain the highest pesticide residue compared to others due to consuming them in a raw form. Hence, food control is necessary to monitor pesticide residues in food commodities before introducing them into the market and official directions established by authorities to regulate it. In most cases, when pesticides are applied in the crop fields, a tiny portion of the pesticide has reached the target. For example, Pimentel and Berguss (2012) stated that only 50 per cent of applied pesticides are estimated to reach their target pests. However, the remaining pesticide content accumulates in the different environment components and leads to a residue.

3. Environmental pollution

Environmental pollution is the result of using the overdose of pesticides and from multiple activities of humans during pesticides application itself. After pesticide usage, the empty containers are usually buried inside the soil by the practitioner, but chemical remnants ultimately spoil the ground. All modes of application, either as an aerial spray or from foliage to directly soil applied, large amounts of pesticide eventually reach the soil, which degrades both biotic (beneficial microbes) and abiotic properties of soil. The improper timing, direction of spray, wind speed, type of spray *etc.*, during pesticide applications contributes to environmental pollution. Applications during the afternoon time usually promote volatilization. Volatilization evokes toxic content into the atmosphere. Against the wind direction and high wind speed, usually more than 8 km promotes off-target drifts. It affects the micro-biota and population of beneficial insects in the surrounding area. These all activities promote the concentration of toxic contaminants in the environment. These cumulative effects lead to bio-magnification in food chains, for which at now, humans do not have any alternative.

Farmer's role

The most trending popular and sustainable strategy is integrated pest management in the recent past. Farmers have to follow schedule based approaches to control crop pests. From pest monitoring to risk assessment, farmers can employ several tactics like cultural, physical, mechanical and biological methods to control the pest at initial levels. Besides this, biorationals like semiochemicals and insect growth regulators are now in trend for effective pest management. However, their non-availability in the market is limiting for their successful use. Ultimately chemical control can be employed as the last sort of measure in IPM. Farmers can use novel insecticides with very low dose requirements and minimal side effects.

Future prospects

From recent past, most trending popular and sustainable strategy is integrated pest management. Farmers have to follow schedule based strategies to control crop pests. Starting from pest monitoring to risk assessment, farmers can employ several tactics like cultural, physical, mechanical and biological methods to control the pest at initial levels. Besides this biorationals like semio-chemicals and insect growth regulators are now in trend for effective pest management. However, their non availability in market is a limiting factor for their successful use.Ultimately chemical control can be employed as the last sort of measure in IPM. Of which, farmers can use novel insecticides which have very low dose requirement and without much side effects.

Conclusion

In the present era, chemical control is the most adopted strategy among farmers. However, awareness among farmers for protecting themselves and the environment from pesticides hazard is still lacking. Their knowledge of recommended dose is very little. For which, creating awareness on improved formulation, dosage calculations, frequency, and application methods is highly necessary. From the setting of recommended doses by pesticide manufacturers to the implications for the evolution of pesticide resistance and non-target toxicological impact is quite complex. The adverse effects of pesticides are well documented. Nevertheless, to increase the farmers' knowledge about pesticide and their hazards associated with pesticides, one should develop and implement pesticide safety education and certification programs for farmers. They should be trained against pesticides' risks and understand the pesticide regulatory framework.

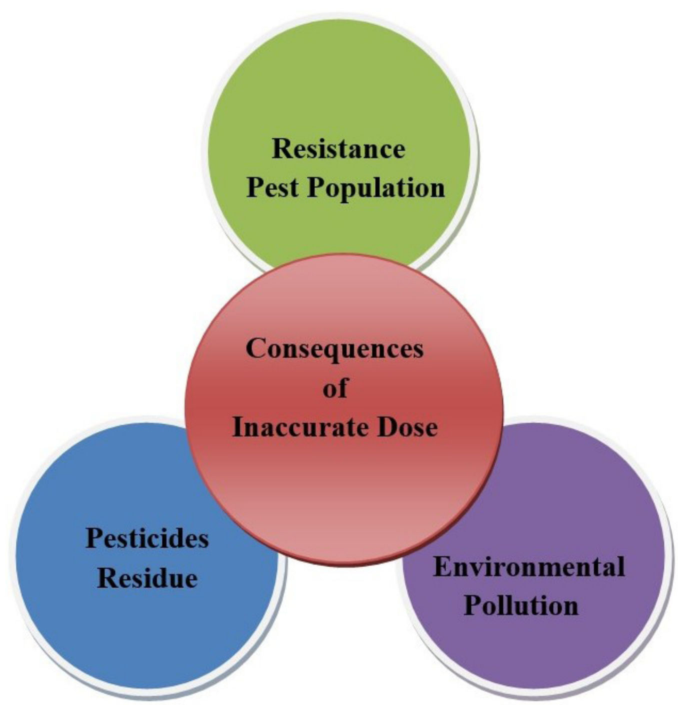

Fig. 1. Harmful effects of inaccurate pesticide dose in crop fields.

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Table 1. Resistant insect in India against different insecticides during 2021 (Source: APRD)

Sl. No.	Insect Name	Family -Order	Cases	Active ingredient	Group
1	*Hyposidra talaca*	Geometridae: Lepidoptera	4	Bifenthrin, Deltamethrin	Agriculture
2	*Plutella xylostella* (Diamond back Moth)	Plutellidae: Lapidoptera	60	Chlorantraniliprole, Cypermthrin, emmamectin benzoate, Fipronil, Flubendimide, Indoxacarb, Novaluron, Spinetoram, Spinosad	Agriculture
3	*Sitopilius oryzae* (Rice weevil)	Lionidae: Coleoptera	1	Deltamethrin	Agriculture

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Contributions of Dr. Swaraj Ghai to the field of Entomology

J. Komal, Kishore Chandra Sahoo, P.R. Shashank and Sachin. S. Suroshe

Many Indian scientists, from time immemorial, have made significant contributions for the society. Dr. Swaraj Ghai, an asset of the ICAR-Indian Agricultural Research Institute (ICAR-IARI), Pusa Campus, New Delhi is one of our country's treasured scientists. As a renowned scientist and insect taxonomist, Dr. Ghai, is known for her indisputable contributions to the field of entomology and has paved the path for many aspiring taxonomists. Her passion to the profession of Entomology runs deep throughout her life.

Early life of Dr. Ghai

Dr. Ghai was born on 15th August in the year 1932. Following India's partition, she and her sister chose to settle in India. They arrived in India as refugees from Pakistan. Despite the insecurities as a young immigrant girl, she believed in hard work and carried herself with confidence. She earned a bachelor's degree in Zoology and later developed an unending passion towards entomology and had post graduated with a specialization in entomology from the reputed Delhi University. She obtained her doctorate in 1965 from ICAR-IARI, New Delhi for Taxonomic studies on mites belonging to Phytoseiidae and Aceosejidae under the guidance of the legendary Dr. M.G. Ramdas Menon.

Her professional career

Dr. Ghai was notably a scientist with unique areas of research interest in different aspects of Entomology. She started to rise in her professional path and had worked initially on the aspects of insect physiology with renowned insect physiologist, Dr. N.C. Pant. Later, her curiosity and interest took a turn towards the aspects of taxonomy of mites, beetles and weevils. She worked along with one the pioneer of mite taxonomist in India, Dr. M.G. Ramdas Menon and gained expertise in it. Apart from her great research contributions, she was engaged in teaching challenging topics like Biosystematics and Acarology and was one of the finest teachers of those times. As a mentor, DR. Ghai had paved the path of many students by giving challenging aspects of research and bringing the best out of her students. She was the chief advisor to 14 students of which 5 had obtained master's degree and 9 have obtained their doctorate under her light of knowledge relating to the taxonomy of mites and Coleoptera. All of the students have attained great positions in their professional career and many of them marked Dr. Ghai as an inspiration and became eminent taxonomists of our nation and one of them is Dr. V.V. Ramamurthy, a taxonomist of international repute, presently Chief Editor of Entomological Society of India. With her excellence in research and mentorship, she was promoted to principal scientist at IARI. She rose to become the longest serving professor of the division of Entomology in 1983 and served as the most hardworking professor for a decade from 7-12-1983 to 31-10-1993. Later, she became the head of the division in 1993 and served for a year. She finally got retired on 14th August 1994.

Overview of research accomplishments

Dr. Ghai grew up to be an expert in taxonomy even though she had worked initially on insect physiology. She had given 39 research contributions of which 18 are related to mite taxonomy, 12 regarding the Coleopteran taxonomy, 4 relating to insect physiology and the rest 5 include research contributions on other group of insects such as Lepidoptera and Hemiptera. A comprehensive analysis of research contributions have been provided (Fig. 1, 2 and 3).

Major research accomplishments

National Pusa Collection (NPC) is one of the Asia's

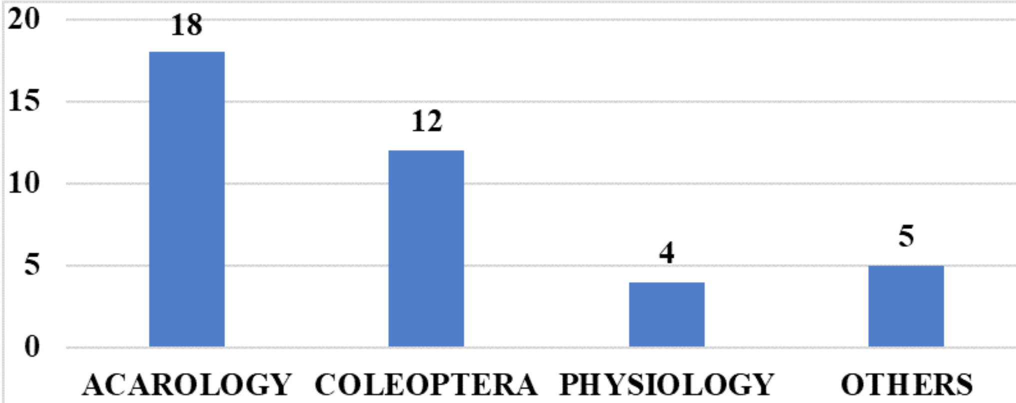

Fig. 1. Research contributions pertaining to different fields of entomology

largest insect repositories held as an integral part of the division of entomology (ICAR-IARI). As a national service for pest diagnostics, every year, on an average over 2000 specimens are identified by the NPC taxonomists. Over the last 50 years, NPC has contributed to the discovery and description of more than 1500 arthropod species which were new to science. Several taxonomic treatises on agriculturally important insects belonging to orders Lepidoptera, Coleoptera, Hemiptera, Orthoptera and Hymenoptera and class Acarina have been published. The incomparable efforts of Dr. Ghai had led to identification of 30 species of mites and 31 species of Coleopteran insects which were new to science and contributed to a substantial proportion of specimens at NPC which serve as an authentic reference for the identification of phytophagous mites, weevils and beetles of economic importance.

Vitamins of B-complex are very essential for the proper growth and reproduction of insects. The requirement of these vitamins like Nicotinic acid, Pantothenic acid and Choline chloride was studied by Dr. Ghai along with Dr. Pant. The quantitative requirement was assessed by rearing the larvae of *Trogoderma granarium* on a diet supplied with increasing concentrations of the vitamins to record the optimum concentration at which the maximum growth of the larvae is seen. Beyond a certain point of concentration, increasing the concentration will bring no change in the growth of the insect and this is said to be the optimum concentration where maximum growth of the larvae is obtained. Likewise, for all the three vitamins the quantitative requirement was analyzed which is still a very important study for diet-based rearing of the insects for any scientific research (Pant and Ghai, 1959).

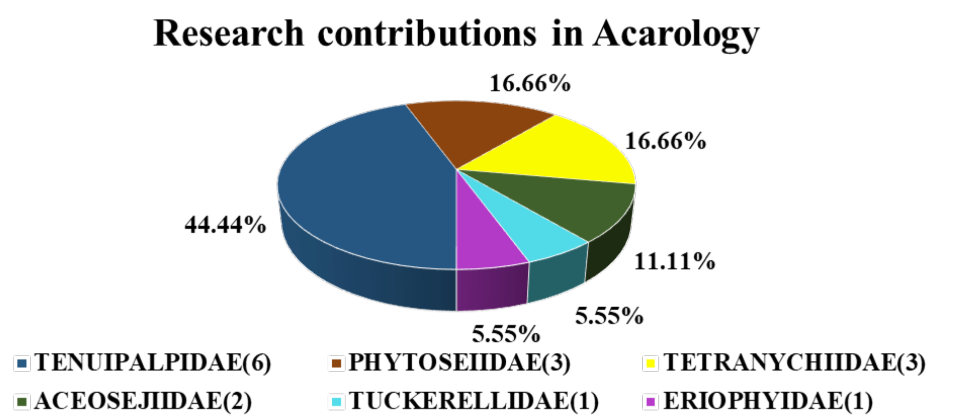

Fig. 2. Taxonomic studies on different families of mites

Dr. Ghai recorded the distribution of brown wheat mite, *Petrobia latens* on wheat in India. It is a vector of barley yellow streak mosaic virus and causing nearly 30% of economic losses even in the current scenario. During her course of collections and thorough surveying, she had recorded these mites on wheat crop in Agronomy and

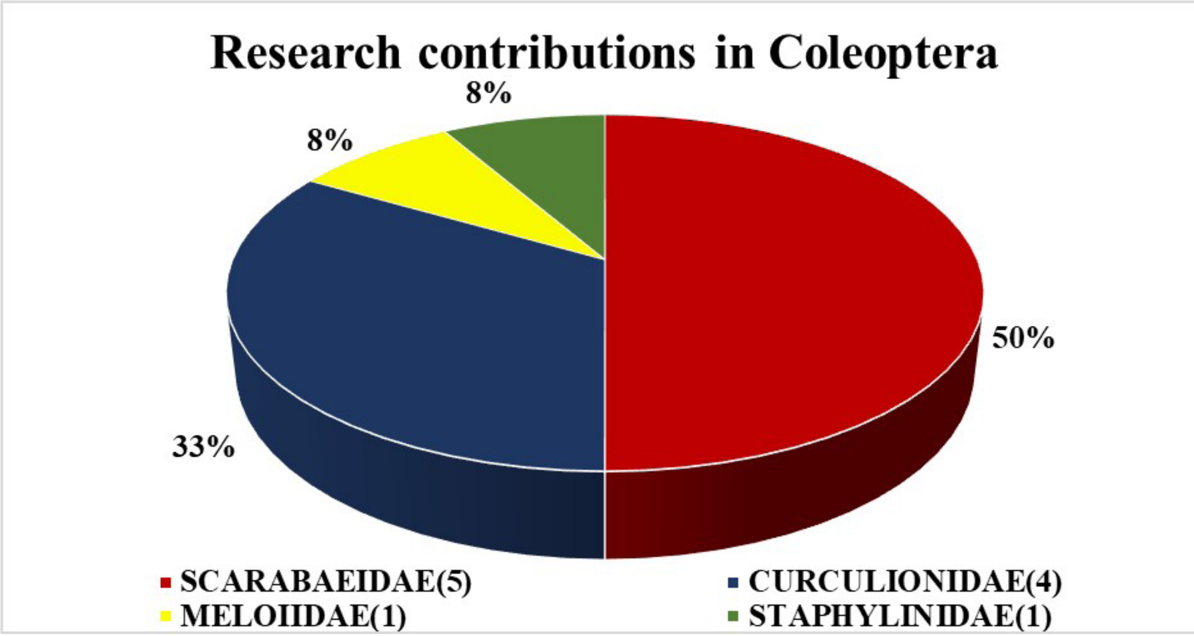

Fig. 3. Taxonomic studies on different families of Coleoptera

Botany fields of IARI. She had even got the specimens of this mite from nearby villages of Delhi, Haryana and Punjab for identification as they were new record from India as a pest of wheat. She has also studied the distribution of this mite in different parts of India thereby stating it as a worldwide pest. Surprisingly, she observed a predatory mite *Lasioseius terrestris* feeding on *Petrobia latens* which was a new record and gave a detailed taxonomic description of it (Ramdas Menon and Ghai, 1968).

Mango malformation was a very serious problem for mango growers of India and caused huge economic losses thereby attaining the status of national problem accounting for about 50 to 60% economic losses every year and in severe cases it may go up to 100 %. Mango malformation is a complex phenomenon which is caused by fungi *Fusarium moniliformae var subglutinans,* Eriophyid mite and physiological disorder of the plant. But, the exact biological entity which was causing the malformation in mango trees was not known at that time. Pioneers have recorded this malformation but never attempted to study the Eriophyid mite in detail. Dr. Ghai made the first successful appropriate description of the mite which is still being used for identification. The correct identification and record of the bud mite, *Aceria mangiferae* Sayed from mango orchards of ICAR-IARI is of profound importance. Along with the bud mite, they have identified 3 new predatory species of mites on the mango shoots that were new to science *viz., Typhlodromus roshanlali* Narayanan and Ghai, *Typhlodromus rhenanus* Narayanan and Ghai, *Typhlodromus nesbetti* Narayanan and Ghai. Dr. Ghai was a lady with golden heart who recognized the efforts of the person therefore *Typhlodromus roshanlali* Narayanan and Ghai was named in the honor of Roshanlal who helped them in procuring all the malformed shoots from mango orchards of IARI (Narayanan and Ghai, 1961).

Phytoseiidae is a prominent family of predatory mites and is known to be predacious on many phytophagous mites and form a quite good proportion of biotic community in the ecosystem. Knowledge pertaining to the predatory mites was not adequately established in those times and Dr. Ghai had comprehensively studied taxonomy of Indian Phytoseiidae which was an unexplored area of research in science. During the course of study, she had extensively collected mites from different parts of India like Bangalore, Delhi, Coimbatore and Bombay accounting for 16 species of mites belonging to the genus *Amblyseius* of which 7 species are new to science including *A. bambusae* Ghai and Menon, *A. coccosocius* Ghai and Menon, *A. eucalypti* Ghai and Menon, *A. ipomoeae* Ghai and Menon, *A. lablabi* Ghai and Menon, *A. mangiferae* Ghai and Menon and *A. sacchari* Ghai and Menon. 4 species are new records to India *viz., A. finlandicus* (Oudemans), *A. fraterculus* Berlese, *A. havu* Pritchard & Baker, *A. hibisci* (Chant) and 5 species were already recorded from India. An elaborate key has been provided for all the species (Ghai and Menon, 1967).

The book "Insect Physiology and Anatomy" by Dr. N. C. Pant and Dr. Ghai was published in 1973. This is the most important contribution which stood as a milestone in her career. This book revolves around the physiological and anatomical aspects of insects and gives a very comprehensive and detailed information which is divided into 34 contents of which 6 were contributed by her including the insect integument and moulting, respiratory system, excretory system, circulatory system, male and female reproductive system and the histological techniques (Pant and Ghai, 1973).

As a result of survey of rice ecosystems in India for the lepidopterous pests, Dr. Ghai had described 85 species belonging to 11 different families of Lepidoptera of which the most dominating were the pyralids. Apart from their main host being rice, their alternate hosts were mentioned and provided morphological illustrations for identification (Ghai, 1979).

Holotrichia, the most commonly occurring genus was not adequately quantified with its status. The status of the genus was recorded and stated that it contained 66 species. *Holotrichia serrata* (Fabricius) and *H. consanguinea* Blanchard although being the most destructive and wide spread species of this genus were poorly described till then. Dr. Ghai provided fine descriptions along with illustrations of morphological characters including its elytral vestiture. Taxonomic descriptions of 5 species which were new to science were provided by her *viz*., *H. nagpurensis, H. akolana, H. longilamellata, H. undulata, H. setosifrons* and *H. serricollis* was a species that was new to record from India and it was detailed with all the taxonomic characters (Khan and Ghai, 1982).

Another major research contribution was review of the world fauna of Tenuipalpidae which includes the false spider mites. She has reviewed 562 species of 22 genera in a detailed way providing key to the world genera and throwing light on its distribution across different parts of the world and host preferences (Ghai and Shenhmar, 1984).

Myllocerus (Curculionidae: Coleoptera) is an economically important genus having wide distribution in Tropical regions and form a substantial part of pest complex in crops. Dr. Ghai along with Dr. V.V. Ramamurthy had reviewed the entire genus in the world in an exhaustive manner by acquiring specimens through field surveys and different renowned insect museums like British Museum, Copenhagen Museum, National Pusa Collection, etc. and compiled an annotated checklist of 336 species from world. 73 species were studied of which 15 species were identified new to science and provided with appropriate taxonomic descriptions. A profound key to 89 species was prepared and 58 already known species were supplemented with elytral vestiture characters. Genital structures of 43 male and 37 female insects were detailed (Ramamurthy and Ghai, 1988).

The conclusion we could draw through the contributions of Dr. Swaraj Ghai is that her pioneering research in taxonomy may not be recognised in the form of awards but the dedication she had towards research in the field of taxonomy is what that had made her an eminent taxonomist. Her impactful and worthful contributions will always cherish till the science of Entomology and Acarology exists. She is a lady of inspiration to all the younger generations and a candle light to all her students paving way through her wisdom.

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Dragonfly wings

Sushmita Ghosh

Dragonflies belong to the order Odonata and are known to be one of the most ancient insects living on the planet. The meaning of the term "Odous " is " tooth''. The dragonflies are aerial predators, grab the prey with their basket type feet/ legs. Post catching, they tear off the wings of their prey with the help of their sharp mandibles. It is believed that the first dragonfly had existed somewhere around 300 million years ago. In fact, the largest insect recorded on this planet *Meganeuropsis permiana*, the extinct ancestor of present-day dragonflies had a wingspan of around three feet. This mighty creature was known to have existed prior to the reign of the dinosaurs. Approximately 6337 species of dragonflies exist worldwide. Their habitats range from wetlands to bogs. Dragonflies are often considered as apex predators in the world of insects. They are known to have nearly 98% success rate as a hunter.

The wings of these insects are outgrowths of exoskeleton which helps them in flight. The wings are located at the mesothorax and the metathorax (second and third thoracic segments). The four wings are mostly referred to as the hindwings and the forewings. Dragonflies have their flight muscles attached to their wings. Unlike other insects dragonflies are known to spread out their wings while resting. Dragonflies have two pair of wings and each of them work independently, allowing them to alter the angle of individual wings and increase their agility during flight. Apart from being agile some species are known to reach a speed of almost 18 miles/ hour.

Dragonflies are known to be expert fliers, their wings are known for stability and can bear high load during flapping, hovering and gliding. The wings are primarily composed of veins and membranes. The membranes, a Nano composite material and veins make the wings extremely versatile thus making dragonflies a maneuverable flier. The structure of the wings, specifically the corrugation is known to intensify their aerodynamic skills. They are among the rare species who are known to mate in mid air. Infact their inability to fly becomes a reason for them to starve to death. They are known to hunt preys only during flight. Dragonflies

catch flies or any other insects during their flight and eat them. Studies and observations have confirmed that the thorax of this insect needs to reach 25˚ Cprior to its first flight of the day. Therefore, it is very essential that each of them basks in the sunlight before starting a whole new day

The unique flying pattern has set dragonfly apart from the rest in the insects and flying animals. Majority of the flying creatures are known to engage in a back-and-forth stroke. In contrast to the common pattern, a dragonfly pushes its wings downward and backward followed by upward and forward directions. They do not try to overcome the drag, instead use the same to stay aloft. This asymmetrical flapping of wings results in downward strokes which in turn creates the drag.

The drag plays a crucial role in supporting the weight of the body. The asymmetrical flapping also helps in conserving the body energy. As it beats out of phase the wings located at the back creates an induced flow which again reduces the drags on its fore wings. When a dragonfly flaps its wings, it unintentionally creates a tiny whirlwind below it. The asymmetric rowing motion, i.e. the upward drag is created during the down stroke helps support their body weight.

The architectural properties of the wings make a dragonfly an excellent flyer. The main structure components i.e the veins are connected by the resilin which are known for its high elastic property, at many joints. The wings have numerous longitudinal veins which are often connected. They form closed cells in the membranes. It has been observed that though dragonflies are stiff insects yet they can easily undergo passive deformation during their flight. This action contributes massively to their unique aerodynamic performances. The secret to this extraordinary ability is the presence of resilin which is believed to be the key component that contributes to the movement to their wings. The presence of this rubber-like protein in their wing vein joints and connecting longitudinal to the cross veins. Thus, endowing their wing with the chord wise flexibility. It is believed that resilin is responsible for the flight performance of this insect.

Resilin is also found in the internal cuticle layers of the veins. Along with the structural feature of veins of the wings, the thickness and the number of the cuticle layers, cross sectional shape and material composition, resilin probably contributes to the material properties of the veins and also determines the degree of the elastic deformation. Dragonflies are known to be highly corrugated insects, this unique feature helps in maintaining the stiffness and strength of their wings. The lightweight structure significantly contributes to its aerodynamic performance. Each wing of a dragonfly has muscles that allow the wings to swap the frequency of strokes, angle of attack, phase and amplitude. As already mentioned during the flight the hind wings make frequent upbeat whereas the fore wings beat downwards.

AUTHOR

Susmita Ghosh (Corresponding author) – A amateur macrophotographer and insect enthusiast. She is obsessed with the wonderful world of tiny creatures around us.

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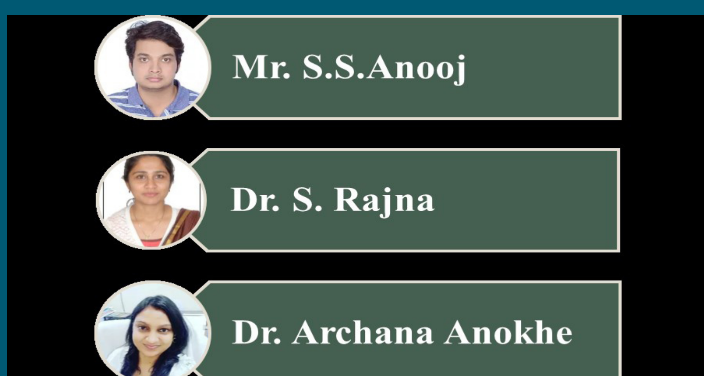
Fifth Indian Entomologist Photo Contest: Thanks for overwhelming response

The Indian entomologist photo contest aims to encourage insect photography among photographers, professionals, amateur entomologist and the layman. The theme of the fifth episode of the photo contest was ‘Insects and aspects related to insect life’. With these objective entries were invited during 20th October to 30th November 2021. Each participant was to submit one good photograph which met a few prescribed standards along with the filled in application form in which the participant had to furnish his/her details, caption, description, specifications of the photograph and also a declaration on the ingenuity of the photograph. We received a total from 72 entries which were screened first for the prescribed standards and overall quality of the image. Final evaluation was done by a committee of independent members under the oversight of the three editorial board members and also by an invited expert, based on the following criteria: quality (clarity, lighting, depth of field, composition), relevance of the subject matter (theme, rareness of subjects), creativity and originality. To ensure a blind review the details of the photographer was hidden and the evaluators were only presented with the photograph, caption, description and technical specifications.

- The first place was won by **Mr. Nidheesh K B** (Kizhakoodan House, Mapranam P O, Madykonam, Kerala-680712, E-mail: nidheeshkbalan@gmail.com) who captured a lynx (*Oxyopes* sp.) preying on a stick spider (*Miagrammopes* sp.). Stick spiders are well known for its camoflauge behaviour and are often confused with stick insects.
- The second place was won by Dr. Rojeet Thangjam (College of Horticulture, Central Agricultural University (Imphal), Thenzawl, Mizoram, India, E-mail: rojeetthangjam@gmail.com) for his photograph of a White Dragon tail butterfly (*Lamproptera curius* Fab.) puddling to seek out nutrients from the bank of Vanva stream, Mizoram.
- The third place was won by Mr. Abhishek Ashok Govekar (HNO 37/17, Near Shiv Sagar Saw MIill, Khorlim Mapusa, Goa-403507, E-mail: abhishekashokgovekar@gmail.com) for his photograph on ants of the subfamily Ponerinae in the act of transporting its pupa and larva.

BUG STUDIO ASSOCIATE EDITORS



1^nd^ Place: 'Your camouflage trick will not work on me'. Lynx, *Oxyopes* sp. preying on a stick spider, *Miagrammopes* sp. (07.11.2021, Thrissur, Kerala). Photo by **Mr. Nidheesh K B** (Kizhakoodan House, Mapranam P O, Madykonam, Kerala-680712), Canon 7D mark ii with Canon EF 100mm f 2.8 L macro lens, ISO 500, f/11, 1/160s). ID credits: Dr. Mathew M Joseph, Head, P G and Research Department of Zoology, Sacred Heart College, Thevara, Kochi, Kerala).

2^nd^ Place: 'The white dragon tail butterfly', *Lamproptera curius* Fab. (21.08.2020, Thenzawl, Mizoram) Photo by **Dr. Rojeet Thangjam** (College of Horticulture, Central Agricultural University, Imphal, Mizoram-796186), Nikon D3300 with Nikkor AF-S 18-55 mm lens, ISO 100, f/16, 1/100s, FL 55 mm).

3rd Place: 'The secret life of ants'. Ants of the subfamily Ponerinae in the act of transporting its pupa and larva, (23.09.2021, Khorlim Mapusa, Goa). Photo by **Mr. Abhishek Ashok Govekar** (HNO 37/17, Near Shiv Sagar Saw MIill, Khorlim Mapusa, Goa-403507), Redmi Note 10 Pro, with Prosumer 55mm Macro lens, using external flash, ISO 354, f/1.79, 1/50s, FL 4.74 mm). ID credits: Mr. Ananad Harshana, Ph.D. Scholar, Division of Entomology, Indian Agricultural Research Institute, New Delhi

KAHKASHAN WALI

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

Kahkashan Wali is currently pursuing her M. Sc. (Ag.) from the Department of Agricultural Entomology at B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat. She is currently working on Biology, seasonal incidence and evaluation of different sex pheromone trap designs (like delta trap, water trap, sleeve trap, bottle with sleeve trap and bottle trap) against shoot and fruit borer, *Leucinodes orbonalis* in Brinjal under the guidance of Dr. C. B. Varma, Assistant Professor. She studied the life cycle of *Leucinodes orbonalis*, under laboratory conditions. She is also working on seasonal incidence of shoot and fruit borer to comprehensively understand the influence of weather parameters on its abundance. Her experiment also aimed to work on mass trapping of brinjal shoot and fruit borer through different sex pheromone trap designs. She believes that her research work will help the farmers by adopting mass trapping technology as prophylactic measures, it will also impart better knowledge regarding the relative benefit of mass trapping technology to the stakeholders, which is immensely lacking in the farming community. In future, she intends to research on the pollination efficiency of honeybees, which might be useful in doubling farmer's income.

SANJAY KUMAR PRADHAN

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY, UNIVERSITY OF AGRICULTURAL SCIENCES, GKVK, BENGALURU, INDIA

Sanjay Kumar Pradhan is currently pursuing his Ph.D. from the Department of Agricultural Entomology, University of Agricultural Sciences, GKVK, Bengaluru, Karnataka. He is currently working on CRISPR/Cas9 mediated editing of target genes in melon fruitfly, *Zeugodacus cucurbitae* (Coquillet) at ICAR-IIHR, Bengaluru under the guidance of Dr. B. Shivanna (Associate Professor, UAS, GKVK, Bengaluru) and Dr. R. Asokan (Principal Scientist, ICAR-IIHR, Bengaluru).

To overcome the disadvantages of SIT techniques used for area wide pest management programme, he is using CRISPR/Cas9 system based site specific mutation of the target genes without affecting the fitness of the insect, which attributes in the management of the pest. So, the goal of management of the fruit flies can be achieved by non-chemical based control method. In future, he is interested to extend his work on CRISPR/Cas9 based genome editing in other agriculturally important insect pests to target important genes, which can be an asset in pest management.

STUDENT CORNER

NIDHI SHARMA

DEPARTMENT OF ENTOMOLOGY, DR YASHWANT SINGH PARMAR UNIVERSITY OF HORTICULTURE AND FORESTRY, NAUNI, SOLAN (H.P.)

Nidhi Sharma is pursuing her Ph.D. from Department of Entomology at Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) under the guidance of Dr. P.L. Sharma (Principal Scientist). She is working on 'Effect of host plants and pesticides on the performance of *Neoseiulus longispinosus* (Evans) against *Tetranychus urticae* Koch.' Under this she has conducted experiments to screen pesticides for safety/toxicity to *N. longispinosus* on five different crops *viz*., bean, tomato, brinjal, okra and cucumber which were sprayed with different pesticides recommended by CIBRC. She had studied the demographic parameters as well as functional response of *N. longispinosus* against *T. urticae* on above mentioned crops. In addition, she is working on standardization of release rate of *N. longispinosus* on different hosts under poly house conditions and host plant for mass production of *N. longispinosus.*

G. R. HITHESH

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

Hithesh G R is currently pursuing his Ph.D. from the Division of Entomology, ICAR-Indian Agricultural Research Institute, Pusa, New Delhi. He is working on conservation of natural enemies in cabbage crop ecosystem under the supervision of Dr. Sachin S. Suroshe, Principal Scientist, ICAR-IARI, Pusa, New Delhi. The indiscriminate use of harmful pesticides for the management of insect pests has already led to development of insecticide resistance, residues, secondary pest outbreaks and pest resurgence issues. The conservation of natural enemies in the cabbage ecosystem plays a vital role in minimizing all these issue. In this context, they are working on the effect of different companion crops *viz*., calendula, sweet alyssum, marigold, cineraria, *etc*., on the insect pests and their natural enemies and also estimating their impact on the biodiversity indices in the cabbage ecosystem. They are also working on tri-trophic interactions influenced by HIPV'S involving natural enemies, cabbage crop and insect pests.

Mr. Kishore Chandra Sahoo, Miss. Akshatha and 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.

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

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

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

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

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

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

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

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

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