Reporting on 'Integration of N science and policies – industry view', R. K. Tewatia (Fertiliser Association of India, New Delhi) informed that South Asia accounts for 11% of global N production and 19% of global N consumption. All the South Asian countries are deficit in fertilizers and raw materials, and depend on import to bridge the demand. There has been remarkable growth in the production and consumption of N fertilizers in India after 1960s and currently, India is globally the second largest producer and user of N-fertilizer. Fertilizer industry recognizes 4R Nutrient Stewardship as an appropriate framework to guide decision for sustainable N-management and desires to improve farmers' awareness on the issue. The Task Force on 'Balanced Use of Fertilizers' recommended the following policy changes: (a) promote fortified and customized fertilizer to correct deficiencies of secondary and micronutrients (2008); (b) promote neem-coated urea (2008); (c) extend subsidy to S and micronutrients (Zn and B) under NBS (2010), (d) introduce new grades of water soluable fertilizers by notifying their general specifications (2015), and (e) promote city compost (2016). It is hoped that such pragmatic policy on behalf of the Government will induce improvement of N-use in Indian agriculture.

Indian experts, while reviewing other sectors, mentioned that growth of NO_x emission during 2001–2011 was 2972 Gg/yr CO_2-e (69%), up from 1487 Gg/yr CO_2-e during 1991–2001. Global models projecting 2050 scenario of NO_x emission in South Asia with 2010 as the base year indicate high emission in the Indian subcontinent. There is also evidence of large-scale transport of pollutants from South Asia to East Asia, and vice versa. It was noted that (1) dry deposition of Nr is more important than wet deposition of NH_3-N; (2) among the various Nr, gaseous ammonia contributes highest N in the atmosphere in India; (3) there is higher content of NH_4-N than NO_3-N in rain water and (4) the Indo-Gangetic region has significantly higher rate of wet deposition of NH_3-N. Such high values of atmospheric Nr are affecting the health of the inhabitants, with recent focus on the quality of Delhi air. Other sectors like fisheries, forestry and grasslands, coastal environment and mangroves, soil health, energy, industry and transport were also discussed.

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MEETING REPORT

Chemoecological approaches for insect borer pest management*

A wide range of agricultural, horticultural and forest trees are vulnerable to insect borer pests causing serious loss to the economy. Cryptic nature of the borers causes the infestations to be overlooked until sizeable damage has occurred. Employing chemical or biological control has not yielded desirable results in suppressing these, as interventions hardly reach the target site/insect. However, the hazard of pesticides remains. Understanding the ecological interaction mediated by cues, especially odours between borers and their host will aid in the development of clean and green technologies.

Semiochemicals are organic compounds that transmit chemical messages. Insects perceive the stimuli from air with olfactory receptors and use them for intra- and inter-species communication. India has islands of expertise in the field of chemical ecology that is scattered across the country. In an attempt to collate the expertise, facilitate interactions and form a cohesive group to solve the problems posed by borer pests, a round table on semiochemicals for borer pest management was organized recently. The meeting was attended by research scientists and students from ICAR institutes; CSIR-Indian Institute of Chemical Technology (IICT), Hyderabad; National Centre for Biological Sciences (NCBS), Bengaluru, and Central Coffee Research Institute, Balehonnur.

Abraham Verghese (ICAR-National Bureau of Agricultural Insect Resources (NBAIR)) traced the genesis of Consortia Research Platform (CRP) on borers. He mentioned that working in isolation would be of little use and hence called for sharing knowledge and facilities to achieve the goals. The round table on semiochemicals for borer pest management would bring together experts and novices to share their ideas. This will help generate ideas in solving the problem caused by borer pest and avoid duplication so as to effectively utilize the resources.

Exchange of ideas cutting across disciplines will generate technologies that would help solve problems associated with pests. One such achievement is the development of a sealer-cum-healer, a technology that could be used with ease by farmers in containing the borer damage in tree crops like mango and cashew.

A. Krishnamoorthy (ICAR-Indian Institute of Horticultural Research (IIHR), Bengaluru) informed that cryptic nature of borers causes greater dependence on semiochemicals for pest management. Teamwork while sharing the expertise and responsibilities among partner institutes will help develop robust semiochemical-based pest management. He mentioned that nanotechnology will aid in the development of dispensers having extended release that will trap insects effectively during the entire crop period irrespective of weather conditions.

In the technical session, N. Bakthavatsalam (ICAR-NBAIR) outlined the principles involved in semiochemical research and its status in horticultural sector in India. He touched upon the role of odour-binding proteins in olfaction, techniques related to monitoring, mass trapping, mating disruption and auto confusion as potential concepts for borer management. P. D. Kamala Jayanthi (ICAR-IIHR) emphasized that a thorough understanding of the bio-ecology of

*A report on a meeting 'Semiochemicals for Borer Pest Management' organized by the ICAR-National Bureau of Agricultural Insect Resources, Bengaluru in association with ICAR-Consortium Research Platform on Borers on 6 August 2015.

target insects would help develop robust pest management methods.

A. R. Prasad (IICT) outlined the chemistry and synthesis of pheromone for groundnut leaf miner, *Aproraema modicella*; citrus leaf miner, *Phyllocnistis citrella*; rice yellow stem borer, *Scirpophaga incertulas* and American boll worm, *Helicoverpa armigera*. They were evaluated in farmer's field and had wide acceptance among farmers. He suggested that this success should be a cue to foster collaboration between IICT and groups in CRP on borers in identifying and synthesizing pheromones.

Radhika Venkatesan (NCBS) explained the mechanisms involved in herbivore–microbe–plant interactions. Exploiting host plant defence triggered by the plant elicitors, viz. jasmonic and salicylic acids for pest management was discussed.

Techniques involved in sampling of volatiles from the matrices were discussed by Kesavan Subaharan (ICAR-NBAIR). Use of chemical detectors (GC-MS) in tandem with biological detectors (EAD) helps decipher the compounds that cause antennal physiological response. Nanomatrix developed by ICAR in collaboration with Jawaharlal Nehru Centre for Advanced Scientific Research, Bengaluru on loading with pheromone was effective in attracting the pests of coconut like rhinoceros beetle, *Oryctes rhinoceros*; red palm weevil, *Rhynchophorous ferrugineus*, and coffee stem borer, *Xylotrechus quadripus*. The nanomatrix served as a controlled release dispenser with lower load of pheromone and extended life compared to other dispensers.

Principal investigators of crop-based institutes that form a part of CRP on borers presented status papers. A. K. Chakravarthy (ICAR-IIHR) explained the existence of pheromonal polymorphism in *Conogethes* species based on the host plant they feed. P. V. R. Reddy (ICAR-IIHR) explained the importance of mango stem borer, *Batocera rufomaculata*. D. S. Yadav (ICAR-National Research Centre for Grapes, Pune) highlighted the probable presence of contact pheromone in grape stem borer, *Stromatium barbatum*. As this pest had migrated from bamboo to grapes, it was suggested by the participants to look for kairomonal compounds from bamboo.

Haldhar (ICAR-Central Institute for Arid Horticulture, Bikaner) informed that ber fruit borer, *Meridarchis scyrodes* caused 70–80% damage in Gujarat and pheromone will help attract adults. Possibility of using tephritid parapheromones to attract the ber fruit fly, *Carpomyia vesuviana* that causes 60–80% damage in Rajasthan was suggested. The prospects of exploring semiochemicals for ber stone weevil, *Aubeus himalayanus* that causes 50–70% damage in Rajasthan was flagged.

Preliminary electrophysiological and behavioural assay revealed the presence of sex pheromone in the female moth red banded caterpillar, *Deonalis albizonalis*. Dr YSR Horticultural University, Andhra Pradesh will collaborate with ICAR-IIHR to identify the pheromone for this pest.

The Borer platform group felt the need for studies on ecology and behaviour of the pomegranate fruit borer, *Deudorix isocrates*. Placing split banana stem trap in the field attracted banana pseudo stem weevil, *Odoiporus longicollis*, and rhizome weevil, *Cosmopolites sordidus*. Identifying the volatiles from the split stems will help develop kairomonal blends that could be used for attracting the weevils.

V. Sridhar (ICAR-IIHR) informed that a new invasive South American tomato leaf miner, *Tuta absoluta* has spread in the tomato-growing regions of the country. He informed that sex pheromone was effective in trapping the adults. Contextually, it is pertinent to mention that ICAR-NBAIR is working on a sustained-release dispenser for delivery of *T. absoluta* pheromone. Considering the availability of sex pheromones, the participants mentioned that the scope of kairomones may also be explored keeping in view its oligophagy.

During the deliberations it was agreed upon that dose for monitoring and mass trapping of sweet potato weevil, *Cylas formicarius*, needs to be standardized and a semiochemical-based management strategy developed to scale down the loss caused by jasmine borers.

Vinod Kumar (Central Coffee Research Institute) touched upon bionomics, behaviour, nature of damage and distribution of white stem borer (WSB), *Xylotrechus quadripes*; shot hole borer, *Xylosandrus compactus*, and coffee berry borer, *Hypothenemus hampei*. The scope of using aggregation pheromones for management of cashew borers (*Plocaederus ferrugineus*, *P. obesus* and *B. rufomaculata*) was presented by Ravi Prasad (ICAR-Directorate of Cashew Research, Puttur).

Joseph Rajkumar (ICAR-Central Plantation Crops Research Institute, Kayangulam) informed that semiochemical-based approaches are effective in the monitoring and mass trapping of pests of palm. Further, kairomone component could be blended with the pheromone so that the food baits could be dispensed off.

The following points emerged in the concluding session of the round table.

- Identification of semiochemicals for managing the borer pest of perennial trees is to be prioritized, as a trees lost by pest damage is huge economic loss.
- Prior to starting work on semiochemical, it is essential to understand the biology, behaviour and ecology of the pest.
- Protocol for collection and processing of samples related to chemical ecology work is to be standardized by ICAR-NBAIR and IIHR for lepidopterans and coleopteran pest, as this would help isolate the pheromone.
- Work on identifying the semiochemicals of litchi nut weevil and ber fruit weevil is to be initiated. A collaborative effort with the respective crop-based institutes will help fine-tune the semiochemical works related to cashew stem borer, banana pseudostem weevil, coffee stem borer and *C. punctiferalis*.
- A holistic approach to understand the insect–fungus symbiosis in shot hole borer on pomegranate/grapes is to be initiated.
- In case of coconut red palm weevil, focus will be to fine-tune the field delivery and formulating stimulo-deterrent diversionary strategies.
- The expertise available with IICT may be explored by collaboration or as an outsourcing agency for confirmation in pheromone isolation or synthesis.
- Success stories in the form of short films on semiochemical-based attraction in coconut redpalm weevil, banana weevil and sweet potato weevil need to be made for use by extension agencies for popularizing the technologies among farmers.

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