Rosabelle Samuel delivered a lecture on Amplified Fragment Length Polymorphism (AFLP). While explaining the importance of AFLP studies, she talked about taxa and sampling methodology, protocols involved in AFLP and data analyses. Unlike RAPDs, AFLP data are highly reproducible. The AFLP technique produces large sets of polymorphic markers that may be used to analyse closely related taxa. She highlighted the importance of AFLP data in the study of polyploidy evolution. She also demonstrated protocols for cycle sequencing.

D. Yakandawala introduced the methodology of GenBank search. Her lecture was followed by a panel discussion which was jointly conducted by Rosabelle Samuel, Deepthi Yakandawala, Harshendra and Pandey. Sequence alignment using different software was demonstrated to the participants using computers.

On the fourth day, Deepthi Yakandawala delivered a talk on PAUP (Phylogenetic Analysis Using Parsimony). She gave a detailed account of cladistic analysis using both morphological and molecular data. She presented an overview of maximum parsimony, maximum likelihood, Bayesian inference and other methods of analysis and tree-building. This was followed by laboratory exercises on computers.

On the final day of the workshop, Rosabelle Samuel presented two talks, viz. 'Genus *Leonotodon* (Asteraceae) is biphyletic' and 'Molecular phylogeny of Ebanaceae'. The lectures were followed by interactive sessions. Participants were also given training on writing papers on molecular phylogenetics and data analysis. All the participants were provided with handouts related to extraction procedure, amplification, sequencing, sequence alignment and phylogenetic analysis. The workshop was interactive and deliberations were active and lively. The workshop was productive and provided several occasions for interaction between participants and resource persons.

In her valedictory lecture, Prema Jha (Vice-Chancellor, TMBU, Bhagalpur) emphasized the need for molecular systematic studies in developing countries and development of DNA banks of plants in India. She emphasized that the sequence data of Indian plants, when deposited in GenBank, can be retrieved when needed and can solve the problems of patents of Indian plants and products. In the valedictory session, the participants and resource persons shared their experiences.

The major outcome of the workshop was the practical training given to the participants and first-hand information on various aspects of molecular systematics. The workshop also provided an opportunity to the young and senior taxonomists to learn various techniques of extraction, amplification, sequencing, sequence alignment and phylogenetic analysis. Participants were of the view that several such workshops are needed to train young Indian taxonomists in cutting-edge technology.

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MEETING REPORT

Semiochemicals in crop protection*

Inaugurating the Annual meeting, M. S. Swaminathan (MSSRF, Chennai) highlighted the need to improve the economic viability of farming, protection and improvement of land, water, biodiversity and climate resources for sustainable advances in productivity, profitability and stability of major farming systems. Emphasizing the need to strengthen the areas of conservation and green agriculture, he visualized the need to strengthen strategic research with a focus on biotic and abiotic stresses, ensure environmental sustainability, biotechnology, biosecurity and biosafety research, monitoring and strengthening research in the areas of semiochemical technology, nanotechnology, space and information technology, renewable energy technologies, besides strengthening research on technology-delivery systems to accelerate progress in bridging the growing gap between scientific as well as field-level know-how. Strengthening the ecological foundation for sustainable agriculture, extension and anticipatory research is an immediate necessity, with the establishment of a few national centres of excellence in agriculture.

Briefly outlining the theme of the meeting, T. N. Ananthakrishnan (Chennai) highlighted that semiochemicals are increasingly being integrated with a range of methods producing new schemes, with the application of semiochemicals being increasingly utilized for pest monitoring, mass trapping, mating disruption and natural enemy attraction. A bewildering array of secondary plant substances has been identified through diverse biosynthetic pathways, so that increased interest is being evinced on the impact of chemical communication between crop plants and insects. Compared to what has come to be known as the 'supermarket utopia of monoculture', prone to insect outbreaks, the significance of polyculture has come to be appreciated, with newer technologies involving genetic modification and molecular marker associated selection.

Stressing the need for better appreciation of the third component to host plant resistance, apart from vertical and horizontal ones, the need for better understanding of the third trophic level involving parasite/predator attracting semiochemicals, besides diverse blends of volatiles emitted by insect-damaged plants attracting natural enemies, has been highlighted. A better understanding of odour receptors, odour-binding proteins and

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odour-degrading enzymes become relevant, so that integration of semiochemicals with pest management has become a necessary exercise with what has come to be known as the 'stimulo-deterrent diversionary strategy', enabling better appreciation of the need to boost frontier technologies in relation to Integrated Pest Management (IPM).

In his keynote address on 'Molecular crosstalks in insect–plant interaction', Anil Kush (Vittal Mallaya Research Foundation, Bangalore) indicated that plants have evolved defensive strategies to counteract potential invaders. Recent advances in plant defence signalling research have revealed that plants are capable of differentially activating inducible, broad-spectrum defence mechanisms, depending on the type of invader encountered. Plant biologists talk about 'innate immunity' in plants, which is linked to immune responses in mammals and insects. A shared characteristic of innate immunity in animals is the recognition of infectious, 'nonself' agents by a specific receptor and activation kinases cascades, which eventually results in localized and/or systemic response.

Plant hormones like salicylic acid (SA), jasmonic acid (JA) and ethylene (ET) are major players in the network of defence signalling pathways. Crosstalk in SA-, JA- and ET-dependent signalling pathways is thought to be involved in fine-tuning the defence reaction, eventually leading to the activation of an optimal mix of defence responses to resist the intruder. Genetic engineering of the biosynthetic pathways of these signalling compounds and development of protective chemicals mimicking their mode of action, provide useful tools for the development of new strategies for crop protection. The question whether manipulation of defence signalling pathways, either through genetic engineering or through application of defence signal-mimicking plant protectants, will boost the plant's immunity to potential invaders or be a burden in crop protection strategies, needs to be carefully addressed.

Highlighting the role of semiochemicals in rice IPM, J. S. Bentur (Directorate of Rice Research, Hyderabad) indicated that among the semiochemicals, sex pheromones have been the most extensively investigated in case of rice insect pests. Chemical nature and composition of sex pheromones are known for at least eight species of pests attacking the crop in the field apart from three species damaging rice in storage. While lepidopteran pests produce female sex pheromones that attract males, stink bugs are reported to have male sex pheromones that attract females or both sexes, as in the case of coleopteran rice pest Hispa. Being volatile substances, chemically these are less than 20 carbon aldehydes and alcohols and normally composed of 2–3 distinct components expressed in different blends. More research is needed to identify the chemical nature of these substances and effectively use them in IPM. Alternatively, plants can be genetically modified to express efficiently these kairomones for better and natural protection against herbivorous insect pests.

Discussing the chemical and transcriptional analysis of insect-induced volatile signalling in tomato plants, R. S. Annadurai (Vittal Mallaya Research Foundation), indicated that plant volatiles that are copious in nature are responsible for a plethora of interactions varying from defensive to competitive and mutuality. Indirect defence in plants is mediated en route volatile organic compounds, by attracting natural predators and parasites of herbivores. JA, ET and SA are signalling molecules implicated in triggering defence mechanisms after herbivore attack and wounding. The molecular intricacies of these hormones in eliciting a response are yet to be elucidated. The above-ground signalling in crop plants like tomato as volatile functions can guide us for designing better crop varieties and crop protection strategies in many vegetable crops.

Highlighting the importance of semiochemicals for enhancing the efficiency of biocontrol agents, R. J. Rabindra (Project Directorate of Biological Control, Bangalore) indicated that kairomones are used by entomophages for host location, host acceptance and oviposition. Scales of moth insects contain compounds such as tricosane, pentacosane and hexacosane that evoke a behavioural response in several insect predators and parasitoids. A combination of trocosane impregnated in a rubber septa with supplementary diet and spray of acid acid-hyrolvsed L-tryptophan was found to increase the abundance of *Chrysoperla carnea* on cotton. Similarly, tricosane-impregnated septa along with supplementary diet increased the parasitization efficiency of *Trichgramma chilonis* on cotton. Spraying of kairomones on rice plants increased parasitism on *Cnaphalocrocis medinalis* by *Apanteles cypris.* Plants containing genes for expressing increased levels of production of wound hormones are being tested under different levels for their ability to increase attraction of entomophages, which will be a boon for eco-friendly pest management

Speaking on the structure-dependent activities of semiochemicals and their impact in IPM, S. Mohankumar (Tamil Nadu Agriculture University, Coimbatore) mentioned that insect receptor systems could detect messenger compounds at extremely low concentrations, thus indicating the sensitivity and specificity to semiochemicals. Pheromones, the intraspecific chemical messengers, influence a range of behaviours and biological processes in the receiving individual. Sex pheromones (that attract a mate) and aggregation pheromones (that call others to a suitable food or nesting site) are the important components in pest management programmes. Allelochemicals, the inter-specific chemical messengers (kairomones and allomones) given-off by food sources (plants/animals) play a vital role in pest management, especially in the utilization of biocontrol agents. Mohan Kumar highlighted the role of pheromone biosynthesis activating neuropeptide and pheromone-binding proteins in lepidopteran pheromone biosynthesis, besides the role of limonoids and alkaloids having feeding deterrent, insect-repellents and antihormone properties against insect pests. The role of allelochemicals and P450 enzymes was highlighted as well as that of molecular forces deriving insect–plant interactions.

Over the past ten years, there has been tremendous success in the area of computational protein design. *De novo* design of novel structures is particularly important because the protein backbone must be designed in addition to the amino acid side chains. To address this issue, researchers have developed a variety of methods for generating protein-like scaffolds and for optimizing the protein backbone in conjunction with the amino acid sequence.

Exploring semiochemicals for implementation in rice IPM, G. Ravi (Tamil Nadu Rice Research Institute, Aduthurai) indicated that plant volatiles induced modulation of orientation behaviour in key rice pests such as hopper, leaf folder, stem borer and ear head bug. Plant volatiles are also known to serve as kairo-

mone cues for natural enemies to move either towards the host, the potential host community or its micro-habitat. Infochemicals, mainly kairomones and synomones from the infested rice plant help in the selection and discrimination of host insects by parasitoids. Concentration of chemical cues changes with variety, growth stage and host density. Salivary enzymes in BPH, especially *Beta* glucosidase, play an important role in host-induced volatile production in rice plant. The larval parasitoid *Cotesia chilonis* uses a combination of volatiles from plant, larva and/or frass for locating larvae. Another closely related parasitoid, *Cotesia ruficrus* which prefers both striped borer and leaf folder, uses volatiles of the larvae and their frass for discriminating damaged rice plants.

Trehalose and amino acids such as leucine, phenylalanine, aspartic acid, serine, cystine, alanine, valine and threonine are the components identified in the frass material of the host larvae. Rice volatiles also play an important role in the foraging behaviour of the predatory *Cyrotorhinus lividipennis* in the rice ecosystem. *C. lividipennis* uses honeydew from rice hoppers as host-searching kairomone. Further, jasmonate signalling pathway plays an important role in induced plant defence against pests and pathogens.

Speaking on the role of insect neuropeptides and application in pest management, A. Joseph Rajkumar (Kerala Agriculture University, Cardamom Research Station, Pampadampara) indicated that genes of several neuropeptides were cloned adopting biotechnological approaches, so as to disrupt vital endocrine functions directly on the target insect pest or by developing transgenic food plants. By understanding the amino acid sequence it is also possible to design and devise agonist, antagonists and even mimics of the neuropeptides leading to endocrine-based biopesticides. A new peptide hormone-based bioinsecticide technology, Trypsin Modulating Oostatic Factor developed from mosquitoes down-regulates the expression of trypsin-like proteases, which are primarily insect digestive proteases. Neuropeptides are a diverse widespread class of signalling substances in the nervous system. Insect neuropeptides function as neurotransmitters, neuromodulators, and neurohormones and are therefore called 'master regulators' of development, behaviour, metabolism and reproduction. Remarkable advances in the field of neuropeptide research and the comparative approach paved way for the discovery of many novel peptide structures.

Discussing some aspects of advances in resistance dynamics, A. M. Ranjit (Kerala Agriculture University, Trichur) indicated that specific plant-quality characters, such as alkaloid content, trichome density, etc. influence the overall quality of a plant as a host for insects, and cause of variation in herbivore population dynamics. Changes in abiotic environment and consequent stress, can change plant quality and lead to outbreaks of herbivores. Herbivore and pathogen damage can also cause induced resistance or susceptibility in the plant and herbivore-induced changes in plant resistance might drive fluctuations in insect populations. 'If genetic differences among plants give rise to different dynamics in the populations of insects that feed on them, then evolutionary changes in plant characters affecting herbivores (such as resistance characters) might lead to changes in long-term herbivore dynamics.' Induced and constitutive plant resistance can have short and long-term effects on insect herbivore population dynamics. Studies have shown that models representing the hypothesis that the three resistance types – no resistance, constitutive resistance and induced resistance – differed in their effects on the population dynamics of Mexican bean beetles on soybean varieties, have been validated.

Indicating recent trends in pheromone technology for crop protection, S. Narasimhan (Asthagiri Herbal Research Foundation, Chennai) said that crop protection through pheromone technology is gaining importance in the present-day demand for safe, pesticide-free products. The technology in India is yet to take-off for sustained growth and application. The major impediments are: cost and lack of availability of pheromones; a well-defined protocol for the development of a suitable product and application methods; and involvement of many parameters in the field to capture the insects. In order to gain a quantum jump in the technology it is necessary to consider non-conventional approaches, which involve an in-depth study of the behaviour of the insects to semiochemicals.

The impact of kairomones of the tea shot hole borer, *Euwallacea formicatus* was discussed by A. Babu (UPASI Tea Research Foundation, Valparai). He indicated that in an attempt to confirm whether the volatile compounds emitted from partially dried cut-stems *Montanoa bipinnatifida* were entirely different from those from green stems of the same plant, studies were carried out by analysing the different volatile compounds. The main objective was to find the possible kairomones (if any) responsible for attraction of *E. fornicatus* towards this jungle plant.

Discussion relating to exploiting chemical ecology for sustainable pest control against forest pest was made by S. Murugesan (Institute of Forest Genetics and Tree Breeding, Coimbatore). He indicated that major forest pests like *Hyblaea puera* and *Eutectona machaeralis* on teak cause severe damage, and several approaches exist for better management of insect pests in forestry. Among the many possible mechanisms that could be responsible for protecting trees from herbivores, is induced plant chemical defence. Insect feeding induces changes in plant function in terms of biochemical, physiological and morphological aspects, which tend to alter plant growth. Damage to plant tissue due to insect feeding leads to translocation of the signal from the damaged site to other parts of a plant resulting in induced resistance, the expression of which tends to vary with the age, season and growth habit. Induced defences tend to be more effective against unpredictable herbivores than intrinsic defences (expression in the plant). Utilization of induced defence management has the potential to increase total forest productivity, provided the factors that influence the induced responses in forest trees are understood. If induced defences are more effective against insect herbivores, then the tree will have more energy to allocate for biomass production. Genotypes representing a range of induced resistance types could be incorporated into forest plantations. A forest plantation, genetically diverse because of variations in induced resistance response, is likely be more stable when faced with an uncertain array of insect pests. Induced resistance is a relatively new and exciting aspect of complex interaction between forest trees and their herbivores.

N. Bhaktavatsalam (Project Directorate of Biological Control, Bangalore), speaking on kairomones for increasing the efficiency of Chrysopids and Trichogrammatids, indicated that Chrysopids have long been considered as efficient natural

enemies mainly against aphids, neonate larvae of lepidopterans. Adults of Chrysopids were attracted to the honey dew secretions of homopterans. On chemical analysis, it was proved that L-tryptophan was an important compound responsible for this. Acid-hydrolysed L-tryptophan was found to act as an ovipositional attractant for the Chrysopids. Other methods of hydrolysis using weak acids or oxidation using amino acid oxidizers were not as effective as acid hydrolysis of L-tryptophan. Indole acetaldehyde, the likely end-product of L-tryptophan on acid hydrolysis, showed some attraction to Chrysopids. Larvae of Chrysopids use the scales of moths as kairomones. Unsaturated hydrocarbons like tricosane, pentacosane and hexacosane, the constituents of moth scales, were found to increase the searching behaviour of Chrysopid larvae. In field studies, combination of tricosane-impregnated septa along with supplementary food and spray of acid-hydrolysed L-tryptophan increased the abundance of Chrysopids on cotton.

Presiding over the concluding session of the meeting, T. M. Manjunath (Bangalore) posed a question as to whether pheromones are a monitoring devise or a pest management practice. While semiochemicals are the domain of organic chemists, their application forms the domain of entomologists, thus making the collaboration of organic chemists and entomologists essential in order to achieve successful marketing of products. While mass trapping may not have such a major impact, mating disruption does, besides pest monitoring. Alexander Jesudasan (Madras Christian College, Chennai) re-emphasized the role of semiochemicals in plant protection and called for increased inputs in this area.

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