MEETING REPORT

Biodiversity, biosignalling and biotechnology in insect–plant interactions*

M. S. Swaminathan (MSSRF, Chennai) inaugurated a discussion meeting on 'Biodiversity, biosignalling and biotechnology in insect–plant interactions', and delivered the Prof. M. S. Mani memorial lecture on 'Biodiversity in agroecosystems'. Emphasizing the need for an evergreen revolution to produce more food from less land and less water without endangering ecological assets, Swaminathan emphasized that ecofriendly technologies should be promoted, with biotechnological tools to develop new crops. Mangroves offered excellent material to develop salt-resistant crops. Similarly, dry-land trees such as *Prosopis julifera* found in drought-prone areas offered valuable genes for drought tolerance, which could be incorporated into different new crop varieties for arid zones. Setting up community-managed gene, seed, water and grain banks in rural areas would go a long way in ensuring food security system in remote areas. S. P. Thyagarajan (University of Madras), speaking on 'Microbiology and biotechnology' outlined the role of insect immunity with special reference to cell free immunity and humoral immunity, with the former noticeable in many Diptera, including mosquitoes and houseflies, while the latter is observed in cockroaches, with these vectors of human disease having developed remarkable resistance through the above mechanisms.

Explaining the theme of the meeting, T. N. Ananthakrishnan indicated that diversity is an important element in all agroecosystems, since genetic diversity is at the heart of sustainable development. Wild relatives of crop species provide the source of genetic diversity with gene reservoirs for crop improvement; this is the take-off point for meaningful biotechnology. Systematics being the 'predictor of biodiversity', agriculture derives significant benefits from systematic information on insects and other arthropods that affect the agroecosystem, he said. Agroecosystems depend on the continued availability of a range of genetic resources and such genetic diversity in agriculture is invariably related to intraspecies diversity. Ecosystem manipulation leading to unfavourable situation to pests and increased opportunities to natural enemies is an essential aspect, so that there is an overall reduction in pest levels.

In today's scenario, engineering terpene emission to make crop plants more attractive to natural enemies is on the cards and in this effort, biotechnology has a great role to play. The majority of volatile compounds released after insect feeding damage are monoterpenes (C_{10}) and sesquiterpenes (C_{15}), which are dominant compounds of many natural volatile blends, which lure natural enemies. Utilization of these mono and sesquiterpenes to increase visits by natural enemies by metabolic engineering is fast gaining recognition, since crops like cotton, maize, bean varieties, to mention a few, are known to differ in the amount and composition of the volatile terpenes they produce. It is here that signalling systems play a vital role.

In his keynote address on 'Rice–gall midge interaction: a new look at genomic level', J. S. Bentur (Rice Research Directorate, Hyderabad) indicated that gall midge populations are known to possess virulence against all the resistance genes identified and deployed so far, with the need to look for new genes or better alleles of the known genes. With the developments in structural, comparative and functional genomics of rice and other cereals, allele mining has a broader scope. Concomitant advances and initiatives in genomics of insect pests like the wheat Hessian fly will broaden our understanding of the insect–plant relations at a higher level of cereal–cecidomyiid interactions. Lastly, other ecological strategies like gene-deployment patterns and use of refugia need to be seriously considered if we are, ever, to achieve this elusive goal of durable resistance. In short, breeding and cultivating resistant rice varieties should be the main approach to manage the rice gall-midges.

K. G. Sivaramakrishnan (Madura College, Madurai), speaking on the multidimensional linkages in biodiversity in agroecosystems emphasized that agroecological practices are oriented towards development of agroecosystems, with a minimal dependence on high agrochemical and energy inputs. By assembling a functional diversity, it should be possible to initiate synergisms which support agroecosystem processes by providing ecological services such as the activation of soil biology, the recycling of nutrients and the enhancement of natural enemies and more effective biological control, where wild vegetation remains at field edges and in association with crops. In other words, pollinators, natural enemies, earthworms and soil microorganisms are all key biodiversity components that play important ecological roles, thus mediating such processes as genetic introgression, natural control, nutrient cycling and decomposition.

Emphasizing the need for an understanding of engineering natural enemy enhancing pathways in crop plants, R. S. Annadurai (Vittal Mallya Scientific Research Foundation, Bangalore) opined that the increasing potential for exploitation of semiochemicals in crop protection strategies has led to interdisciplinary efforts to manipulate plant terpene metabolism, more in view of many terpenes having high economic significance. Pathway engineering has come of age, though breakthroughs are still on the cards, particularly in relation to the possibilities of altering the metabolic pathways to produce new terpenes, especially mono and sesquiterpenes which attract natural enemies. The need therefore to use genetic engineering or conventional breeding to manipulate terpene biosynthesis cannot be overemphasized. Integrated Pest Management strategies combined with plant genetic engineering offers exciting scope for a new wave of plant protection approaches.

Speaking on the dynamics of host plant resistance to insects, S. Uthamasamy (Tamilnadu Agricultural University, Coimbatore) emphasized that host resistance is ecologically sound, economically practical, socially acceptable and is environmentally sustainable technology, classifiable into genetic resistance and induced resistance. A knowledge of genetic resistance to insects contributes to the development of plant varieties with a bound base of insect resistance, which may reduce the develop-

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ment of insect biotypes. The significance of genetic analysis of resistance is evident from the success of the host plant resistance programme in rice for the brown plant hopper (BPH) with resistant varieties, viz. IR 20, IR 36, IR 60 and IR 26 (BPH 1, 2, 3, 4, genes respectively). Induced resistance, which is the qualitative or quantitative enhancement of the defense mechanism of a plant against pests in response to external physical or chemical stimuli, is a non-heritable resistance wherein host plants are induced to impart resistance to tide over pest infestation. Wounding plant tissues may induce changes in protein, lipid and phenol metabolism, as also stimulate the release of a proteinase inhibitor-inducing factor into the vascular transport systems of damaged plants. Transgenic plants which produce insecticidal or antifeedant proteins continuously are safer for consumption, reducing the cost of plant protection. They are eco-friendly and farmer-friendly, with *Bacillus thuringiensis* controlling many lepidopteran, dipteran and coleopteran insects through their Cry proteins used for production of transgenics in different crops. Biotechnology has the potential to move farmers closer to ecologically sustainable practices and could make a considerable impact on agriculture systems in the future.

M. S. Palaniswami (Central Crops Research Institute, Trivandrum), discussing the exploitation of chemical ecology for sustainable pest control, highlighted the fact that pheromones and kairomones hold particular promise for use in sustainable pest control. While sex pheromones and aggregating pheromones are useful in monitoring insect populations, for control by mass trapping, the importance of kairomone lures for controlling fruit flies by the plant kairomone methyl eugenol was highlighted. Being definite in regulating insect systems, some volatile kairomones are important elements in applied entomology enabling sustainable pest management.

G. T. Gujar (Indian Agricultural Research Institute, New Delhi), speaking on 'Insect resistance to xenobiotics: march towards molecular biotechnology', highlighted the case of development of resistance of *Bacillus thuringiensis*, a microbial insecticide, in the diamondback moth, *Plutella xylostella*, both under laboratory selection pressure and field conditions in many countries of the world. Thus never before in the history of plant protection has insecticide resistance acquired an importance as of now and is considered a prerequisite for introduction of plant-incorporated protectants like *B. thuringiensis* transgenic crops. *B. thuringiensis* transgenic crops, which occupy about 14.5 million hectares, are becoming an integral part of contemporary agriculture, generating arguments towards development and environmental issues. The presence of *B. thuringiensis*-tolerant populations coupled with our observations on their ability to evolve resistance significantly when subjected to selection pressure, justifies the need for a strong database on insect susceptibility to xenobiotics. More than two dozen insect pests have shown their ability to evolve resistance to *B. thuringiensis* toxins under selection pressure. This is highly worrisome in view of the diversity of *B. thuringiensis* strains naturally occurring all over the world. The availability of DNA-based genotyping techniques using neonate genomic DNA as template, may provide a precise monitoring of resistance and susceptible allele frequencies, including those of heterozygote individuals in the field populations, unlike bioassay techniques. Further, genomics may be useful for targetted management of specific resistance genes and may also speed up search for families of novel insecticidal targets.

Discussing the potential of insect neuropeptides in developing newer insecticides, D. Muraleedharan (University of Kerala, Trivandrum) indicated that neuropeptides offer several opportunities in terms of a variety of targets for newer insecticide development. Two major routes for the development of insect control agents are: (i) deduction of nucleic acid sequences and (ii) structure activity studies which identify critical sites of interaction. Through the first route, molecular genetics can be used to identify precursor and processing enzymes, prepare antagonists and super agonists through gene fusion or even use baculovirus technology to deliver the fusion peptide to the target. Through the second route, active site and binding-site structures may be used to design peptidomimetrics, enzyme inhibitors and receptor blockers. Recombinant DNA technology is being used for information on amino acid sequences of several neuropeptide precursor proteins and also for elucidating structural details of neuropeptides and their receptor proteins. Some of the identified larger candidate neuropeptides could be synthesized in a large scale using recombinant DNA technology, besides expression of the much-needed neuropeptides in insects or cell cultures.

Jim Thomas (Kerala Agricultural University, Trichur) highlighted the emerging strategies in relation to insect pheromones in plant protection. Such newer strategies as *in situ* trapping with live females, pied-piper technology with aggregation of pheromones, auto-dissemination technique with pheromone traps used to disperse microbial or chemosterilants, usage of oviposited pseudostem of banana with marker pheromone or epideictic pheromone, and alarm pheromone in apple orchards, were outlined. Discovering the neurological pathways and enzyme pathways that breakdown the pheromone to cause signal shut-off, were indicated. The need for comprehensive knowledge about threshold of receptors/number of receptor cells, pheromone dosage, persistence of activity, age after emergence, time of call, total time spent on calling, permeation of atmosphere with pheromone from conspecifics, whether females are already mated, and if there is a refractory period after mating, percentage of mated males that get caught and influence of host plant conditioning on production and response to pheromone for better and more efficient use in plant protection, were highlighted.

R. V. Varma (Kerala Forest Research Institute, Trichur) explained aspects pertaining to pheromone trap monitoring system for two major forest insect pests of teak and sal. Teak is the most widely planted species in Indian forests and sal is the second. Outbreaks of teak defoliator are estimated to cause 44% reduction of potential volume increment, while infestations of the sal borer cause complete mortality of the affected trees. Effective management of the teak defoliator, *Hyblaea purea* using baculovirus (HpNPV) is a possibility. However, in large teak plantations, it is extremely difficult to predict the outbreaks. Attempt to use the light trap as a monitoring device has not yielded useful results, increasing the scope for using pheromonal traps in monitoring of the teak defoliator. In case of sal borer, *Holpcerambyx spinicornis*, one of the control strategies practised is the tree-trap method, i.e. use of unsound logs to trap the beetles. The bark is beaten up to allow the sap to ooze out. Beetles are attracted to the fresh exuding sap and are mass-trapped. The exact chemical nature of the sal sap is not known and once this kairomone is isolated, it will be cheaper and less labour-intensive than cutting the trees to obtain the sap. Both these examples indicate the scope for developing a pheromone-based technology which would facilitate timely detection of population build-up and also would help in application of control measures at the site of infestation, preventing large-scale outbreaks.

Speaking on baculoviral insecticides as potential tools in insect pest management, R. J. Rabindra (Project Directorate of Biological Control, Bangalore) highlighted the factors which would lead to the successful use of baculoviruses in pest management, in particular the selection of a highly virulent strain of the virus from any available insects harbouring the virus. The need for artificial virulence to UV light and plant surface environment, low cost *in vivo* mass production system, formulation with good shelf life (> 18 months), and field persistence (7–10 days), timely sprays of the pest would lead to more efficient control. Their high virulence and host specificity have made them attractive, ecofriendly pest-control agents, with considerable utility in controlling *Helicoverpa armigera*, *Adisura atkinsoni* and *Amsacta albistriga*. The granular viruses have been used for the management of *Chilo infuscatellus* in sugarcane and *P. xylostella*, the diamond-backed moth. The incorporation of baculoviruses into a pragmatic integrative pest management programme to harvest the full benefits of biological control was emphasized.

The application of biotechnology in microbial control with special reference to *B. thuringiensis* was discussed by J. S. Kennedy (Tamilnadu Agricultural Research Institute, Coimbatore). He indicated that fusion of genes from baculovirus with *Bt* genes is being used to expand the host range of *B. thuringiensis*. Citing a number of instances of attempts to improve the efficiency of *Bt*, he indicated that Ecogen pioneered a strategy in which strains of *Bt* were engineered to produce a complex mixture of toxins using recombinant plasmids.

B. Vasantharaj David (Sun Agro Biotech Research Center, Chennai), speaking on emerging insecticides and resistance to insecticides, emphasized that though a number of new molecules have already been introduced into the country, such molecules have already shown resistance in some other parts of the world. Continued efforts to introduce new ecofriendly and safer molecules and the likelihood of development of resistance in major pest species should not be overlooked. He emphasized the need for an appropriate insecticide resistance management approach in crop protection. Generating baseline data on resistance and monitoring and characterization of resistance to the insecticides in the pest species are essential for successful management of resistance. Many types of insects have developed resistance to all known classes of pesticides. Ion channels are the primary targets for several classes of natural and synthetic insecticides. The rapid development of electrophysiology and molecular biology techniques in insect resistance research during recent years has greatly facilitated the study of ion channels at cellular and molecular levels. Electrophysiological and isotopic flux methods and mircofluorometric determination provide an alternate approach for the estimation of insecticides in the ion channels.

Emphasizing the need to recognize biodiversity in relation to whitefly vectors of plant-viral diseases, Alexander Jesudasan (Madras Christian College, Tambaram) indicated that molecular systematics of *Bemisia tabaci* has revealed the existence of 16 biotypes, and biotypes A and B have gained importance recently owing to the intensity of damage inflicted to crops and can be distinguished by certain morphological features of the pupal case. The existence of biotypes or host races of *B. tabaci* was proposed in the 1950s after the discovery that morphologically indistinguishable populations of *B. tabaci* exhibited measurably different biological traits with respect to host range, host plant adaptability, and plant virus transmission capabilities. Recently, recognized differences among populations of *B. tabaci* have led to the suggestion that *B. tabaci*, the sweet potato whitefly, and *B. argentifolii*, the silverleaf whitefly, represent either different biotypes of *B. tabaci* or are members of a species complex. Specific whitefly phenotypes and the interactions with their host plants therefore directly influence both pest status and the dynamics of virus–vector–host interactions. The outcome of these interactions would throw light as to whether successful colonization will occur or whether infestations are likely to reach or surpass economic threshold levels, and whether vector populations will disperse and mediate the transmission of plant viruses.

Presiding over the plenary session, S. Chelliah (formerly of the MSSRF, Chennai) stressed that technical generation should be within a time frame, with due focus on cost-effectiveness and feasibility of adoption by end-users. The farming practices by Indian farmers and existence of mixed cropping in limited farm holdings are to be considered while studying the effect of plant volatiles on pests and beneficials. Incorporating the biological and behavioural aspects of pest management components developed over the years, IPM models are to be developed in major crops like rice, cotton, sugarcane and vegetables for large-scale adoption by practising farmers.

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