MEETING REPORT

Applied chemical ecology: Induced and transgenic defences in insect–plant interactions*

Inaugurating the third discussion meeting on applied chemical ecology, M. S. Swaminathan, Chairman, MSSRF, Chennai, emphasized the need for better utilization of modern techniques for a proper appreciation of the role of induced and transgenic defences, and dwelt on the possible impact of transgenic crops on environment and ecology.

Initiating the discussion, T. N. Ananthakrishnan highlighted the need for inter-disciplinary, integrated efforts to develop insect-resistant crop plants. The biochemical and physiological processes resulting in induced resistance are chains of multiple reactions involving several different compounds such as phenolics, terpenes, alkaloids, glycosides and defence-related proteins such as proteinase inhibitors and amylase inhibitors. Proteinase and amylase inhibitor genes provide novel systems and have considerable potential for the improvement of plant defence systems. Jasmonic acid, a fatty acid derivative, is a volatile signalling molecule providing a mechanism for communication between plants, with its equally efficient volatile form, methyl jasmonate. Interestingly, evidence for memory in plants for induced defences is also forthcoming. Other substances like ethylene, abscissic acid, salicylic acid are also induced; the induction process involving phenylalanine ammonia lyase (PAL) which is known to exist in multiple forms, being differently induced by different signals. Breeding programmes for crops could select plants that exhibit high levels of induced resistance against insect pests. Besides, they also provide reliable signals to natural enemies, indicating the presence of host insects. Several signalling pathways coordinate the responses of plants to many stimuli. Fatty-acid signals, such as oxylipins synthesized from linolenic acid regulate expression of defence-related genes. Peptides, phenolics, terpenoids and plant hormones like ethylene also help to coordinate plant responses.

Plant breeders and molecular biologists could plan to switch to induced resistance, since at the molecular level such traits increase variability. Inducing plant defences with elicitors and with transformed plants that include novel genes for induced resistance holds prospects for an effective means of pest control. Further, it may be possible in future to identify and alter the proteinase inhibitors that have activity only against specific target pests, so that genetic engineering for increasingly diverse forms of resistance will provide for the pest control of the future.

Delivering the keynote address R. J. Rabindra, Director, Project Directorate Biological Control, ICAR, Bangalore explained that the development of transgenic plants has paved the way for the management of several pests. Around 30 plant species have been transformed with a variety of *Bt* genes and more than 80 *Bt* insecticide genes have been discovered. Commercialization of transgenic cotton, maize and potato with *Bt* genes has already been done. Transgenic crops are available for the management of lepidopteran pests like *Helicoverpa armigera*, *Leucinodes orbonalis* and *Pthorimaea operculella*, and a few coleopteran pests. In order to solve the possibility of pests developing resistance to the toxins in transgenic plants, the possibility of gene pyramiding with multiple toxin genes is being considered.

Polyphenol oxidase and chlorogenic acid, which are resistant to *Helicoverpa zea* in tomato plants, synergized the activity of *Bt* toxin. *Bt* toxicity was enhanced by the monophenolase activity on the tyrosil residues of the toxin. In addition, polyphenol oxidase produced *o*-quinones from chlorogenic acid and these quinones in turn alkylated the crystal protein. This alkylation was proposed as the mechanism for increasing protein toxicity. Similarly, cinnamic acid and *p*-coumarine enhanced the effect of *Bt* against the sunflower moth *Homoeosoma electellum*. However, in cotton, condensed tannins antagonized the effect of *Bt* in *Heliothis virescens* larvae by post-ingestive interactions in the insect gut. These interactions indicate the scope for enhancing the action of the *Bt* transgene in transgenic plants by selecting the appropriate crop varieties, which are rich in allelochemicals that potentiate the toxin protein.

K. S. Mohan, Monsanto Research Centre, Bangalore, talking on transgenic technology for insect-resistant crops, indicated that there is clear scope for enhancing the natural defence of crop plants by inducing the expression of defence genes by externally applied effectors. The role of methyl jasmonate in the induction of protease inhibitor is a classic example. Manipulation of secondary metabolism is another avenue for insect control. This may involve transforming the plant with several transgenes for manipulation of metabolic pathways, which is quite complex and needs to be refined. The recent successes achieved with the development of 'Golden Rice' with enhanced beta-carotene and iron through introduction of multiple genes, and also the transfer of entire pathway for synthesis of tyrosine-derived cyanogens glucoside from *Sorghum bicolor* to *Arabidopsis thaliana* for resistance to flea beetle are positive indications in this direction.

Mohan also suggested that another area of thrust could be towards identification and characterization of defence compounds (secondary metabolites) produced by plants. The well-characterized ones are alkaloids, terpenes, flavonoids and cyanogens, glucosides among the aproteic and chitinases, β-1,3-glucanases, arcelins, lectins, vicillins, systemins and enzyme inhibitors among the proteics. Future thrust in transgenic technology needs to be in the management of sap-sucking insects. This will also add value to the existing *Bt* crops like corn and cotton, which are designed to provide control of only lepidopteran pests. Transgenic plants developed with lectin genes have shown promise against aphids and plant hoppers, but their value on a commercial scale, either alone or stacked with other resistant genes, is yet to be assessed.

*A report on the third discussion meeting on Applied Chemical Ecology convened by T. N. Ananthakrishnan on 30 November 2002 at COSTED, Chennai.

Navarajan Paul, Indian Agricultural Research Institute (IARI), New Delhi indicated that a number of behavioural chemicals arising from hosts, host secretions, host by-products, associated organisms and food influencing the host habitat location, host selection and acceptance process have been isolated and identified in recent years. Habitat location is influenced by the physical, chemical and biological characteristics of the habitat. Habitats have characteristic odours due to the complex plant and animal assemblages present. Increased parasitism reported due to plant assemblages, food resources and plant extracts supports such a concept. These cues are volatile, thus acting over a distance; they are generally attractants causing the parasitoid to move towards the source.

Another set of cues found in the ecosystem, which are generally of moderate-to-low volatility, stimulate ortho- and klino-taxis or searching. They are important for location of the host by the natural enemy. These are kairomonal compounds released from different stages of host insects or chemicals secreted during feeding or deposition of waste products or during various activities of the host.

Alok Sen, National Chemical Laboratory, Pune presenting the multitrophic perspective of host plant selection in phytophagous insects, opined that studies on host selection behaviour of insects have predominantly been restricted to bitrophic aspects, providing us with an understanding of both mechanical and functional basis of host choice in a species.

M. S. Palaniswamy, Central Tuber Crops Research Institute, Thiruvananthapuram talking on insect–tuber crops interactions with reference to the sweet potato weevil *Cylas formicarius* and *Bemisia tabaci*, the vector of Indian cassava virus, suggested that PR proteins could be used to activate plant defence system at desired levels. He also suggested that with the advancement of genetic transformation technologies, it should be possible to choose and insert genes of PR proteins into crops for increased resistance. As for sweet potato, he indicated that induction of resistance is being attempted through activated defensive enzymes like peroxidase, proteinase inhibitors and cholesterol oxidase.

Speaking on female sex pheromones of shoot and fruit borer of brinjal, K. Srinivasan, TAFE indicated that analysis of sex pheromone gland extracts prepared from insects of Indian and Taiwanese origin confirmed (E)-11-hexadecenyl acetate (E11-16 : Ac) as the major pheromone component, with 0.8 to 2.8% of the related (E)-11-hexadecen-1-ol (E11-16 : OH). Field and wind tunnel release-rate studies confirmed that the release rate of both the compounds was doubled in polyethylene vials compared to white rubber septa.

The role of molecular markers to identify and manage the sweet potato white fly *Bemisia tabaci* was highlighted by N. K. Krishnakumar, IIHR, Bangalore. The utility of molecular markers in differentiating the biotypes or species, geographical distribution, host range, level of insecticide resistance and transmission efficiency of Gemini viruses will be of immense value for the management of white-fly transmitted viruses. The role of molecular markers like cytochromal oxidase gene and ribosomal internal transcribed spacers in the identification and differentiation facilitating the management of biotype-B (*B. argentifolii*) was also discussed.

P. Narayanaswamy, Faculty of Agriculture, Annamalai University highlighted the potential of fungi against insect pests, especially that of the rice ecosystem, enabling the attack of a wide range of pests. The humid-based field situation resulted in the occurrence of innumerable forms of insect mycoses.

Discussing the implication of molecular aspects of insect endocrines in chemical ecology, B. Subramanyam, IARI, New Delhi provided an overall picture of the role of juvenile hormone and ecdysone, and elucidated the molecular mode of action of the two morphogenetic hormones JH and 20 E and their interplay in regulating the developmental programme. Insect endocrinology has seen a quantum jump in its own right as advances in protein, steroid and terpenoid chemistry, micro analytical techniques, radio immunoassays and electron microscopy have all rapidly been integrated. These advances have laid the foundation on which insect biotechnology can be developed for pest management.

The effects of induced resistance in banana to the pseudostem borer *Odoiporus longicollis* were presented by A. M. Ranjith, Kerala Agricultural University, Thrissur. The existence of induced resistance was tested in the banana variety Nendram, exposing the suckers of naturally infested banana to artificial infestation; results showed that in due course resistance to attack was seen.

Speaking on the emerging trends in the chemical ecology of forest pests Prasanth Jacob, Institute of Forest Genetics and Tree Breeding, Coimbatore indicated that due to the changing forestry pattern, minor pests assume the status of major pests and agricultural pests shift their host range to tree crops as in agroforestry. It also resulted in frequent or repeated outbreaks of pests in monoculture plantations. Chemical basis of host-tree specificity and host-plant resistance need to be explored in detail for making considerable progress in forest pest management and tree improvement programmes.

V. V. Sudheendrakumar, Kerala Forest Research Institute, Peechi elaborating on baculovirus as a biocontrol agent against forest pests, notably the dreaded teak defoliator *Hyblea peura*, emphasized that application of HpNPV would certainly be an ecologically acceptable strategy. The production technology, formulation and application of HpNPV and its scope in managing the teak defoliator were discussed, stating that this is probably the first instance of the development of a baculovirus against a forest pest in India. Need to improve the quality of the virus in terms of host range, virulence of using genetic manipulation was also emphasized.

An insight into the utilization aspects of Sporozoa in bicontrol programmes, their interaction with acridid hosts and technological inputs for field application was provided by S. Johny, Gill Research Institute, Chennai. The influence of gregarines on grasshoppers, causing tumours and high mortality of early instars, reduction in fecundity and food consumption was highlighted, besides the impact of *Nosema* sp. which involves the fat bodies and the pericardium of grasshoppers, disturbing the host intermediary metabolism.

Winding-off the meeting, R. J. Rabindra impressed on the need to involve genetic alteration of the target pests or host-plant resistance, behavioural control of the phermones, allelochemicals and growth regulation. Today's concern also relates to the increased role of biologically-based pesticides, with holistic approaches to pest management.

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