

## Key issues of insects in Asia-Pacific region\*

Of late, people are interested in understanding how closely insects, nature and humans are interrelated. The demand for advanced research and expertise in insect biodiversity, insect pest management and insect chemical ecology is increasing rapidly to tackle various problems associated with insects in agriculture and health care.

Insects are closely linked with man and nature. Many insects are serious pests in agriculture, forestry and human life. Concurrently insects are also beneficial friends of humans. Because of various man-made problems such as pollution, global-warming, large-scale monoculture of crop plants, etc., the regional diversity of insects is gravely affected and the insect pest problem is becoming worse than ever before all over the world, in spite of modern pest management methods. However, most countries are facing a problem in understanding insect-related issues due to investigations made in isolation. Hence, there is an urgent need to have close interactions and collaborative research in various fields of entomology involving scientists from all over the world.

With a view to tackle various limitations in insect science, diverse areas in entomology and chemical ecology were discussed in the 5th Asia Pacific Congress of Entomology held at the serene and beautiful Jeju Island in South Korea. About 750 scientists working on insects from all over the world were brought together to discuss a broad range of topics in basic and applied entomology, as well as in chemical ecology. The theme of the congress was 'Insects, nature and humans'.

Under the chairmanship of Kyung Saeng Boo (Seoul National University, Korea), four unique plenary lectures were delivered, viz. (i) Biodiversity, humanity, and sustainability: A case for Korean's DMZ ecosystems by Ke Chung Kim (Pennsylvania State University, USA); (ii) Chemical ecology: Decoding the signal of insects by Wendell L. Roelofs (Cornell University, USA); (iii) Recent

advances in functional genomics of the silkworm by Toru Shimada (University of Tokyo, Japan), and (iv) *Drosophila* models of complex neurological disorders in humans by Young Ho Koh (Hallam University, Korea).

Kim discussed issues pertaining to biodiversity conservation, ecosystem management, the linkage between economic development and environmental degradation related to socio-political milieu. He elucidated the man-made environmental problems and poor understanding of biodiversity. Importance of the Demilitarized Zone (DMZ) between North Korea and South Korea – 246 km in length and 2 km in width – a military demarcation line marking an area of 98,400 hectares with respect to biodiversity, is a corridor devoid of human activity, transformed into a rich natural sanctuary for native plants and animals, particularly those species exterminated or endangered in other parts of Korea.

Roelofs focused on chemical interactions between insects and their environment and exploiting these chemicals (e.g. pheromones, semiochemicals, kairomones, etc.) in insect pest management. He highlighted the importance of interdisciplinary research approach involving scientists of insect bioecology who can develop appropriate bioassays for responses to the chemical signals, and chemists for isolation, characterization and synthesis of chemical compounds using sophisticated instrumentation.

Shimada covered advanced research on insects like whole-genome shotgun (WGS) and expressed sequence tag (EST) analyses of the silkworm *Bombyx mori* genome by Japanese and Chinese scientists. The Chinese group predicted 18,510 protein-coding genes and Japanese scientists had listed ca. 17,000 non-redundant ESTs in *B. mori*. Investigations of both the groups indicated that the gene number of the silkworm is more than that of *Drosophila*. Moreover, the transgenic experiment developed by the Japanese was useful to analyse the sex determining genes, *Sxl*, *tra-2*, *dsx*, *fra*, etc. Japanese scientists had introduced the female-type and male-type *Bmdsx* cDNAs with appropriate promoters into the germline, and obtained their transgenic strains. The

phenotypes indicated that *Bmdsx* regulates sexual differentiation. Shimada was confident that in the near future, not only the ectopic expression in insects but also new genetic tools such as enhancer trap, gene trap and gene search will be the essential tools to express the genetic networks controlling insect-specific biological functions, including metamorphosis, behaviour, reproduction, diapause and so on.

Koh had used *Drosophila* as a powerful biological system to address fundamental questions concerning neurological disorders in humans. The clinical symptoms and patho-physiology underlying monogenic neurological disorders, including familial forms of Parkinson's disease, Alzheimer's disease, Huntington's disease, and Ataxia have been proven to be practically replicated in *Drosophila*, when causative mutant proteins are transgenically exposed in *Drosophila* neurons or cells. He identified several mutations that increased the susceptibility of the fly to other genetic or environmental risk factors. Using *Drosophila* as a model for the first time, an attempt was made to understand molecular and cellular aetiologies or complex neurological diseases in humans, which would provide new targets for pharmaco-genetic research aimed at accelerating the development of drugs to alter disease progression during pre-clinical or clinical periods. In addition, it would also help identify at-risk groups both for disease onset and progress during the pre-clinical period by enhanced diagnosis.

In most papers on taxonomy, mitochondrial genome analysis was employed to study the phylogenetic relationships and evolution of closely related insect groups. Systematics of Gelechiidae (in Russia), Sesiidae (in Korea), and Lyonetiidae (Lepidoptera) (in Japan), Braconidae (Hymenoptera) (in Netherlands), etc. was presented. It was reported that rDNA sequences of dipteran species was found to be useful not only to study closely related species, but also intra-generic revisions of Diptera as the sequences showed pronounced differences in closely related species. The importance of database of the insect collections, alien species of Asia Pacific region, change in butterfly community with relation to habitat and land use in Japan and conservation of in-

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sect fauna, especially parasitic hymenoptera in Indonesia were discussed as important aspects of biodiversity and conservation.

In an exclusive session on rice-based ecosystem, it was reported that conservation of spiders in the early season helps reduce outbreak of rice planthoppers in the late season. Augmentative release of mired bug predator *Cyrtorhinus lividipennis* was found highly promising in the suppression of brown planthopper *Nilaparvata lugens* in Japan. The danger and management of invasive alien species Golden Apple Snail, which was introduced to the Philippines from Argentina via Taiwan for enriching protein intake diet and as an aquarium pet and became a serious pest of rice was reported. Under integrated pest management (IPM) of orchard pests, application of pheromone mating disruption as one of the tools for the control of codling moth and other moth species of apple and pear in USA and Japan contributed to drastic reduction of pest density. It was reported that vedalia ladybird beetle predator *Rodolia cardinalis* introduced long ago in Jeju Island is found to check major citrus scale insects (*Icerya purchasi* and *Ceroplastes rubens*) effectively even today. There is a high demand for Jeju oranges in Korea and dwarf variety orange tree orchards are common in Jeju (Figure 1). In another special session on *Bactrocera* fruit fly management, it was reported that a potent attractant of fruit flies, methyl eugenol was known to be present in over 200 plant species belonging to 46 families. Sexually mature male *Bactrocera* was attracted to and compulsively fed on floral methyl eugenol, which acts as a synomone. The fruit fly converts the eugenol into sex pheromone in its body and releases it to attract females for mating, or releases allomone to deter predators. However, lizards fed on synthetic methyl eugenol-consumed flies showed symptoms of liver dysfunction or tumour growth. Different types of lures, including GF-120 fruit fly bait used in Malaysia, Indonesia, Taiwan, Hawaii, etc. were found to be highly effective in the control of fruit flies. Investigations conducted on fruit flies in Taiwan revealed that they have developed resistance to various insecticides.

Chemical ecology sessions were co-hosted by Asia Pacific Association for Chemical Ecology. Most of the papers were on synthesis of semiochemicals and their application in IPM. Studies on sex pheromone isolation and its application

in German cockroach control were conducted in USA. Different species of Asian honey bee sociality was attributed to significant difference in Nasonov gland and in mandibular gland chemicals. Many papers were presented on biosynthesis of sex pheromone in important lepidopteran pests *Helicoverpa*, *Heliothis*, *Spodoptera*, etc. Sex pheromones of hibiscus mealybug *Maconellicoccus hirsutus* in USA and pine defoliator moth *Pseudocoremia suavis* in New Zealand were identified and synthesized to use them for mass trapping, attract-and-kill and mating disruption of the pests. Aggregation pheromone, trans-1-methyl-2-cyclohexen-1-ol in oak borer *Platypus quercivorus* was identified for the control of borers. It was reported that sticky vane pheromone traps effectively trapped males of bagworm *Metisa plana*, an important pest of oil palm in Malaysia. Coupled gas chromatography–electroantennogram detection analysis commonly used in lepidopteran insects was also found useful for identifying lures in fruit fly *Bactrocera dorsalis*. Chemical cues in rice panicles were known to induce feeding behaviour in rice bug *Leptocorisa chinensis*. Similarly, olfactometer and electroantennogram studies on the attraction of wingless tea aphids *Toxoptera aurantii* to tea plants indicated that the main volatiles of tea shoots lure the aphids for sucking of sap.

*Chironomus* larvae (Diptera) and other groups of aquatic insects were used to study the water quality. Of the various aquatic organisms, *Epeorus nigrus* (Ephemeroptera) was found highly sensitive to zinc pollution and useful in environment risk assessment.

Most of the papers on insecticide resistance management were on Diamondback moth *Plutella xylostella* in China, Taiwan, Japan, Hawaii, etc. and a few papers were on cotton bollworm *Helicoverpa armigera*, spider mite, mosquito (*Culex pipiens pallens*), etc. In China, *H. armigera* resistance to Bt-cotton is being closely monitored since 1990. It was noticed that the populations of other cotton pests such as aphids, mites, plant bugs, etc. were increasing in Bt-cotton field. Diamondback moth showed resistance to pyrethroid compounds. Mixture of fungicide (IBP) and Malathion dramatically delayed evolution of Malathion resistance in *Cu. pipiens pallens*. In Korea, cinnamaldehyde in *Cinnamomum cassia* bark and 5% cassia oil were found to be potential repellents of *Aedes aegypti* mosquitoes, for protection of humans and domestic animals from vector-borne diseases and biting of the mosquitoes.

Some papers on the application of entomopathogenic nematodes/bacteria in pest management were presented. Biopesticides such as nucleopolyhedrovirus (NPV) and Bt formulations were widely used against *Spodoptera exigua* (in Korea) and *H. armigera* (in Japan) respectively. Entomopathogenic nematodes (EPN), *Steinernema* and *Heterorhabditis* were tried extensively against insect pests of various crops in Korea, Japan, India, Thailand, etc. Of the various NPV isolates of tea pest *Adoxophyes honmai*, AdorNPV-EN and AdorNPV-HO isolates were effective as they kill larvae at second and 3rd to 5th instars respectively, in Japan, whereas other isolates killed larvae at the final instar. Cost-effective production tech-



Figure 1. Dwarf variety orange tree orchard in Jeju Island.

nology was also being tried for mass production of solid and liquid EPN formulations of high quality and shelf-life. Novel cry1-type insecticidal genes from 56 *Bt* strains specific to lepidopteran pests were isolated in Korea for development of the microbial insecticides and transgenic plants. Immunity studies in Diamondback moth larvae infected with bacteria showed increased level of peptidoglycan recognition protein in hemolymph one hour after infection.

Most papers on silkworm were on molecular aspects. Japanese scientists developed the transgenic silkworm *B. mori* using transposon *piggyBac* as a vector and green fluorescent protein as a marker gene. The detection of character was possible due to marker gene expression in the eyes in the G1 generation. Novel genes responsible for diapause at early embryonic stage in *B. mori* were isolated and characterized. In *B. mori* cathepsin D cDNA was found to be involved in both cellular remodelling associated with larval-pupal metamorphosis and gut deterioration during the pupal stage. In another study, injection of double-stranded RNA into *B. mori* obstructed the expression of a major immune protein, hemolin gene and thus silkworm larvae never metamorphosed to pupae. Molecular studies on programmed cell death (PCD) of anterior silk gland in *B. mori* revealed that 20-hydroxyecdysone induces the entire process of PCD through the integration of genomic and non-genomic actions. Similar studies on acetylcholinesterase (AChEs) in German cockroach *Blattella germanica* showed partial cDNAs encoding two AChEs, which were mainly localized in the central nervous system. Fibroin BF-7 in *B. mori* was shown to play a positive role in improvement of memory and cognitive function in impaired brain of rats and humans. Similarly, honey bee venom induced apoptosis in human melanoma A2058 cells via a calcium-dependent signalling pathway. Physiological studies on honey bee *Apis mellifera* showed high level of brain dopamine in virgin queens compared to that of mated ones. High dopamine level in virgin queens could be involved in activation of ovarian follicles arrested in previtellogenic states.

Several papers on ecology, behaviour and biocontrol agents were presented. Studies on temperature-dependent development of the tea shot hole borer *Xyle-*

*borus fornicatus* in Sri Lanka, Curciferale vegetable pest *Eurydema dominulus* in Taiwan, pomegranate pest *Spectrobates ceratoniae*, cotton pest *Aphis gossypii*, and cucumber pest *Liriomyza sativae* in Iran were made to optimize the control measures. The parasitoid *Anisopetromalus calandrae* of maize weevil *Sitophilus zeamais* showed behavioural response to the spatial pattern of the weevil. Egg-larval parasitoid *Ascogaster reticulata* exhibited associative learning as it searches its host tea tortrix moth *Adoxophyes honmai* based on the host plant volatiles. The braconid larval parasitoid (*Microplitis croceipes*) of *Helicoverpa* spp. was found to attack conspecific males by ovipositing eggs into their abdomen. The parasite larvae hatched in the abdomen but never fully developed. This is the first report of the larval parasitoid attacking conspecific adult males, which would affect the mass multiplication programme. The braconid parasitoid *Cotesia flavipes* had reduced the population of sugar cane moth borer *Chilo* spp. in Thailand. A large number of natural enemies was found to check citrus mealybug *Nipaecoccus viridis* in Iran and citrus whiteflies in Jahrom region of Fars Province. Different species of native hymenopteran parasitoids were assessed against *Liriomyza* leaf miners in Japan and suitable seasons were identified for the release of different parasitoids for effective parasitization.

Significant contributions were also made in the field of aquatic, agricultural, forest, medical, urban, storage and industrial entomology, and acarology. IPM of various pests such as cotton pests in Nepal, coffee white stem borer in India and Colorado potato beetle in Iran was discussed in detail. It was reported that low quality wood used for dunnage harboured a large number of coleopteran insects in Canada and this could be an important source for transmitting wood-dwelling beetles across borders. Different species of *Anopheles* mosquitoes transmitting malaria in Korea were identified using ITS2 (internally transcribed spacer 2) allele-specific amplification. *Culex pipiens* larval breeding in the septic tanks was reported for the first time in Korea. Genetically modified trehalose rice was found to reduce the infestation of Indian meal moth *Plodia interpunctella*, a storage pest in Korea. Investigations on intercropping of onion or wheat with mango

showed that a large number of syrphid fly and house fly pollinators were attracted to the intercropping field and thus mango yield was significantly increased to that of control plots in Pakistan. Life history trial of giant water strider *Aquarius elongates* was studied in Japan. The water strider adapted obligatory diapause to follow monovoltinism and responded to short-days in fall to emerge and adapted diapause behaviour before winter set in. It was reported that neem oil was effective in controlling two species of mites of rose plants *Tetranychus urticae* and *T. cinnabarinus* in Iran.

Special interest groups discussed insect biomechanics and international long-term ecological research network (ILTER). Stridulation mechanism of crickets for producing sound by rubbing their fore wings together was studied for certain material combinations which render friction and wear-reducing properties, like relative hardness of counterparts, surface energy, structural design regarding fibre orientation, lubrication mode and surface texturing among others. Under ILTER, there was discussion on establishing international research on ecology to initiate field research on the functional roll of arthropod biodiversity. Initial components of the study would be field collection of insects, bioecological studies, and automated computer image analysis identification system, and also genetic barcoding of the fauna.

It could be inferred from the papers presented at the congress that in most parts of the world intensive research is being carried out in the areas of insect biodiversity and conservation, molecular taxonomy, biocontrol, biopesticides, especially on EPN and NPV. More attention has also been given to chemical ecology to promote application of semiochemicals as an ecofriendly tool in pest management. In view of the present scenario of research on insect science in the world, it is high time that India establish a national centre for insect taxonomy and biodiversity and Indian scientists exploit natural resources largely in pest management.

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