MEETING REPORT

The black-spotted yellow shoot-and-fruit borer, *Conogethes* spp. (Crambidae: Lepidoptera) – a global perspective*

Insects are one the most diverse groups of organisms that constitute more than two-thirds of identified species of all animals on earth[1]. They are incredibly numerous and play key roles as prey[2], predator[3], pollinator[4], decomposer[5] in both natural and man-made habitats. Some insect groups are increasingly drawing the attention of biologists worldwide due to their ability to rapidly change with time in response to hosts[6], geographical distribution[7], environmental factors[8], ecology and behaviour[9], genetics[10], insecticides[11], etc. with time. One such insect group is the black-spotted yellow shoot-and-fruit borer, the species of the genus *Conogethes* (Crambidae: Lepidoptera). The genus *Conogethes* is taxonomically complex with many closely allied species (Figure 1). One of the most important *Conogethes* spp. is the castor shoot-and-fruit borer or yellow peach moth *Conogethes punctiferalis* Guenee. It is often misidentified and is difficult to manage this species in fruit orchards and plantations. There is an urgent need to collate latest developments, understand the evolutionary and behavioural changes of *Conogethes* spp. for devising effective management strategies. In light of this, a round table discussion on *C. punctiferalis* and allied species was held recently. Over fifty entomologists, entrepreneurs and research biologists working on *Conogethes* species participated in the deliberations. The discussion was devoted to develop a more comprehensive understanding of the enigmatic group of moths scientifically named as *Conogethes* spp.

In his presidential address, A. Krishnamoorthy (Indian Institute of Horticultural Research (IIHR), Bengaluru) highlighted the importance of the round table discussion. He mentioned that by inviting all scientists/researchers working on *Conogethes* to a single platform, one can gather information on latest developments, share expertise, responsibilities and resources as well as avoid duplication of work. A. K. Chakravarthy (IIHR) presented an overview of the *Conogethes* species complex in India and other countries. He mentioned the prevalence of two different *Conogethes* spp. in India, Japan and Australia. The *Conogethes* populations in Japan were earlier identified as *C. punctiferalis*; however, recently, another species *C. pinicolalis* Inoue and Yamanaka has been recognized[12]. Similarly, *C. pluto* (Butler) was reported in addition to *C. punctiferalis* in Australia[13]. In India, the *Conogethes* population infesting castor (*Ricinus communis*) was identified as *C. punctiferalis* and the one infesting cardamom (*Elettaria cardamomum*) was different from *C. punctiferalis*[14]. Chakravarthy elaborated the differences in morphological characters (egg chorion, larva, body setae, genital structures and mouth parts) and behavioural traits (feeding, eclosion, female calling and male song) in *Conogethes* spp.

S. N. Sushil (New Delhi) stressed the importance of *Conogethes* spp. identification for quarantine and biosecurity purposes. He suggested the use of natural enemies, especially parasitoids in particular to egg, larval–pupal and pupal stages for efficient management of *Conogethes* populations in all life stages in the field. He discussed on the issues related to mass rearing of parasitoids and label claims of pesticides for *Conogethes* management. Girija Ganeshan (IIHR) expressed the need for precise species identification using concerted approach of conventional taxonomy with molecular tools. She stated that alternatives to chemical pesticides are the need of the hour for managing these pests and hence researchers have to work on this concept. T. Manjunath Rao (IIHR) released a booklet comprising abstracts on *Conogethes* and emphasized on the short- and long-term objectives for developing management approaches for *Conogethes* spp. The presentations on *Conogethes* spp. were grouped under five themes, viz. identification and status of *Conogethes* spp. on different crops, biology and mass-rearing, host–plant relationships, molecular characterization and semio chemicals, and management of *Conogethes* spp. in cultivated ecosystems.

R. Asokan (IIHR) put forth questions about species complex of *Conogethes* and means to resolve them. C. A. Virakthmath (University of Agricultural Sciences, Bengaluru) explained that an accurate identification of species based on the examination of type specimen is

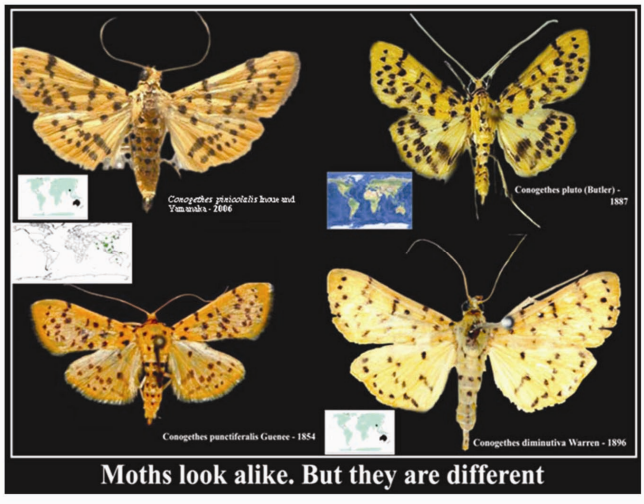

Figure 1. *Conogethes* species complex.

*A report on the round table discussion on 'Biosystematics, Biology and Management strategies of *Conogethes punctiferalis* and allied species (Crambidae: Lepidoptera)', held at the Indian Institute of Horticultural Research, Bengaluru on 22 May 2015.

necessary. As most species in moths are not adequately described by the present-day standards, he emphasized more research on basics such as morphology, behaviour and molecular genetics of this pest and motivating young scientists to undertake these studies with the present technology. He mentioned that species description based on traditional keys and molecular tools is preferred for precise species identification. S. Sithanantham (Sun Agro System, Chennai) mentioned that the GPS-related type specimens should be collected, labelled with tentative codes and characterized based on traditional and molecular taxonomic tools and software programmes to gain insights into the relationships among *Conogethes* spp.

C. M. Senthil Kumar (National Research Centre on Spices, Calicut) described the biology of cardamom shoot and capsule borer, *Conogethes* spp. Incidence of *Conogethes* spp. on ginger (*Zingiber officinale*) and turmeric (*Curcuma longa*) was elaborated. He mentioned the role of hymenopteran insects and mermithid nematodes feeding on *Conogethes* larvae. There are no insecticides recommended so far for management of insect pests on cardamom, except malathion; but this has legal issues. Application of malathion on ginger and turmeric resulted in the problem of residues. He stressed on the importance of biocontrol agents such as *Beauveria* sp., nematodes, bacteria and viruses for managing *Conogethes* spp. Identification and development of resistant variety after a critical study on host plant resistance using different germplasm accessions, and exploration of endosymbionts associated with *Conogethes* spp. could also help in managing this pest. He also stated that collection of volatiles from host plants can be used for behavioural studies. Sandeep Singh (Punjab Agriculture University, Ludhiana) presented the current status of *Conogethes* spp. and its incidence on fruit crops in Punjab. He mentioned that ber (*Ziziphus mauritiana*), loquat (*Eriobotrya japonica*), peach (*Prunus persica*), mango (*Mangifera indica*), pomegranate (*Punica granatum*), plum (*Prunus* sp.), pear (*Pyrus* sp.), guava (*Psidium guajava*), sapota (*Manilkara zapota*) and jackfruit (*Artocarpus heterophyllus*) are extensively damaged by *Conogethes* spp. in Punjab. A. Sujatha (Dr YSR Horticultural University, Andhra Pradesh) mentioned the incidence of *Conogethes* spp. on crops like Dolagondi (*Mucuna pruriens*), guava, jackfruit, pomegranate, sapota, etc. and reported that the incidence of *Conogethes* is increasing year-by-year on these crops in Andhra Pradesh.

Chandish R. Ballal (National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru) described mass rearing of *Conogethes* spp. on semi-synthetic diet. She mentioned the utility of Nuclear Polyhedrosis Virus (NPV), nematodes, spiders, and hymenopteran parasitoids like *Chelonus blackburni* for managing *Conogethes* populations in cultivated ecosystems. She also suggested that *Trichogramma* and *Chelonus blackburni* are potential parasitoids against *Conogethes* spp. L. Hanumantharaya (College of Horticulture, Mudigere) gave a brief presentation on the seasonal incidence of *Conogethes* spp. on cardamom. He mentioned that *Conogethes* infestation was high on cardamom during June–July and September–November. Experiments on new molecules conducted on ruling cardamom clones like M1, M2 and Kalayani Gold suggested that insecticides such as fluebendamide and spinosad were effective against *Conogethes* spp. P. N. Ganga Visalakshy (IIHR) provided information on the biocontrol agents against *Conogethes* spp. on cardamom. She suggested the usage of biopesticides to reduce pesticide residues on cardamom.

N. Bakthavatsalam (NBAIR, Bengaluru) gave a brief presentation on the utility of pheromones on *C. punctiferalis*. He mentioned that the minor and major compounds identified were (E)-10-hexadecenal, (Z)-10 hexadecenal and 16-hexadecenal. The blend of (Z)-10-hexadecenal and 16-hexadecenal did not catch any males; however a blend containing 16-hexadecenal, (E)-10-hexadecenal and (Z)-10-hexadecenal (16 : 100 : 8) and a binary blend of (E)-10-hexadecenal and (Z)-10-hexadecenal (100 : 8) caught significantly greater number of males. A pheromone formulation (D400-1:4) containing 400 µg of blend (Z)-10:16-Ald and (E)-10:16-Ald at the ratio 1 : 4 was effective in field trials. An abstract sent by Xiao and Honda[15] to the round table discussion reported that female sex pheromone systems of *C. punctiferalis* and *C. pinicolalis* are quite similar, which allows cross-attraction by males. The sex pheromone consisted of (E)-10-hexadecenal (E10-16:Ald) and (Z)-10-hexadecenal (Z10-16:Ald) in the ratio 95.4 : 4.5. The final conspecific sexual recognition in each species was accomplished with a male pheromone. Recently, two hydrocarbons were observed as pheromone synergists in female pheromone system of *C. punctiferalis*, which functioned in a short-distance calling female. A similar system was prospected in *C. pinicolalis*; however, these new hydrocarbon synergists did not contribute to reproductive isolation between *C. punctiferalis* and *C. pinicolalis*. A mixture of Z9-27:CH and Z3Z6Z9-23:CH was reported to show higher synergistic activity. A full set of the sex pheromone system of yellow peach moth consisted of E10-16:Ald, Z10-16:Ald for a long-range attraction and Z9-27:CH, Z3Z6Z9-23:CH for the final recognition of females by males in near-pheromone source. An abstract sent by Regupathy mentioned an injection of *Bacillus thuringiensis* (*Bt*) preparation into the bore hole of Stem and Capsule Borer (SCB) effectively checked the pest resurgence. The native isolates of entomopathogenic fungi (EPF) *Metarhizium* sp. and *Beauveria bassiana* and entomopathogenic nematode (EPN) *Heterorhabditis indica* successfully infected the larvae of *C. punctiferalis* in the laboratory. Though biocontrol agents like *Bt* and EPF are promising, certain factors like high specific activity limit their use on crops. The unilateral application of *Bt* and EPF is not economical as the cost : benefit ratio is low.

Kubendran (Bayer Crop Science, Bengaluru) discussed the chemical properties and characterization of combi-product, flubendamide + thiocloprid on *Conogethes* spp. infesting cardamom in his presentation. He mentioned that Bell expert, flubendamide + thiocloprid was more effective on cardamom panicle borer at 30 days after anthesis. Mayank Yadav (Dow AgroSciences, Mumbai) presented the chemical properties of Spinotoram, the new member of the spinosyn class of insect management tool. He stated that synthetic modifications of major (*Spinosyn*J) and minor (*Spinosyn*L) ingredients confer improved insecticidal activity and residuality in spinotoram. It has broad-spectrum insect control with excellent residual activity and unique mode of action with no known cross-resistance. Spinotoram is effective against many insect pests including *Conogethes* on tree fruits, nuts, grapes, soybeans, cotton, maize and vegetables.

In the afternoon technical session, Virakthmath provided some suggestions for identifying and understanding the fundamentals of *Conogethes* spp. He mentioned that except for the *Conogethes* population on cardamom, not much work has been conducted on fruit crops. Hence taxonomy of *Conogethes* spp. on fruit crops should be initiated. The first and foremost is to examine types of known species and revise the species of the genus from the Indian region so that these species could be accurately identified. He mentioned that a systematic procedure should be followed for the collection of *Conogethes* (immature and adults) on different hosts and that a minimum of five male and five female samples is required for identification. *Conogethes* spp. infesting castor and cardamom should be collected separately for identification. GPS coordinates, host plant and passport data should be recorded. Kamala Jayanthi (IIHR) suggested adding the behavioural aspects in passport data. Krishnamoorthy suggested inclusion of photo documentation and month-wise and year-wise bio-ecological data.

Virakthmath mentioned integrated taxonomic tools to be employed for identifying cryptic *Conogethes* spp. Mass rearing technique for *Conogethes* spp. should be established to conduct biological and behavioural studies in the laboratory. Economically important crops and pest occurrence have to be recorded. Population structure of *Conogethes* in different seasons and different stages and its interaction with host plants should be established. Monitoring the movement of *Conogethes* population from one crop to another across different regions is necessary to gain insights into its bioecology and distribution. Resistant host plant varieties should be identified or developed. A thorough study on chemical ecology of *C. punctiferalis* and allied species should be initiated. Volatiles collection from resistance and susceptible crop varieties for preference and behaviour studies should be made. Role of effective biocontrol agents such as *Trichogramma* and *C. blackburni* should be investigated against *Conogethes* spp. Biological agents such as EPF, EPN, bacteria, viruses, etc. could also be employed for managing *Conogethes*.

Krishnamoorthy mentioned that evaluation of egg parasitoids such as *T. chilonis* and *T. pretiosum*, should be explored. Adult trapping systems based on host plant as trap, light trap and kairomones should be carried out. The feasibility of using climate change software, CLIMAX could be worked out for the *Conogethes* species distribution in climate change scenario. Virakthmath suggested taking the help of scientists who are working on pyralid taxonomy for proper identification of *Conogethes*. Chakravarthy mentioned that larvae of *Conogethes* spp. are cryptic and internal tissue-feeders. Thus low levels of infestation are not detected and through infested fruits, the pest is spread from one country to another. For instance, between 2007 and 2011 *Conogethes* larvae were intercepted in the imported fruits in the United Kingdom about 12 times. He suggested that pest risk analysis be carried out on mango, grapes (*Vitis* sp.) and cocoa (*Theobroma cacao*) in India. Guava, castor (*Ricinus communis*) and sapota exported from India, Pakistan, Sri Lanka, Thailand and other Asian countries need to be strictly examined for the presence of larvae of *Conogethes* sp. He also pointed out that apple (*Malus pumila*), chestnut (*Castanea* sp.), pea (*Pisum sativum*), peach, apricot (*Prunus armeniaca*) imported to Japan, Korea and China need strict quarantine measures as these fruits may carry eggs and larvae of *Conogethes* sp. Similarly, durian exported from Malaysia to other countries like Europe, Australia and Hawaii warrants strict quarantine measures. He suggested that nanoparticles and biorational pesticide molecules, nanogels for pheromones and semiochemicals should be developed. Virakthmath suggested having a network on *Conogethes* spp. established by Chakravarthy will provide information about research activities on *Conogethes* and other allied species informally through newsletter and website.

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