S1-LP-01

Biodiversity bugs pests: An ecological perspective

N. K. KRISHNA KUMAR*
Bioversity International, NASC Complex, DPS Marg, Pusa Complex, New Delhi - 110012, India
**Corresponding author E-mail*: k.kumar@cgiar.org

Chemicals pesticides, once a panacea for pest control, of late are at the receiving end for everything that is environmentally unacceptable. Is solution the problem? The paradox cannot be brushed under the carpet. Problems of insect pests assuming an economic status is predominantly, a reflection of a disturbed ecosystem. Monoculture replacing crop diversity, indiscriminate application of fertilizer and weedicides eliminating beneficial microarthropods and microorganisms, pesticides eliminating beneficial arthropods, predators, parasitoids, reptiles and birds up the food web has all contributed to pests and diseases assuming alarming proportion. In a way 'Silent Spring', a book so relevant has been forgotten very much today. Short term benefit/cost ratio, maximizing economic returns and much focus in enhancing productivity at any cost without addressing long term soil, plant, and environmental health is detrimental to sustainable agriculture especially in the developing world. Self-sustaining ecosystems have fewer problems and agriculture should move in that direction. It appears that we are in between devil and deep sea. We can neither afford to reduce production and productivity nor food and nutritional security. But robust soil, water and plant health is a function of diversity at its best and is critical for sustainable agriculture. An ecological understanding of the complex interactions among, soil, water, plant, pollinators, pest, and natural enemies shall address our sustainable development goals without seriously compromising productivity. Future hinges more on a scientific understanding of agrobiodiversity to address today's bugs.

Biosystematics, biodiversity and biocontrol - relationships

V. V. RAMAMURTHY*
ICAR - Indian Agricultural Research Institute, Pusa Campus, New Delhi - 110012, India
**Corresponding author E-mail*: vvr3@vsnl.com

Taxonomy is naming, identifying and classifying organisms. It is the real science behind the handling of living organisms. In the over three centuries, taxonomy does not lag behind, it has become more accumulative and rather inclusive. It contributes credibility and enables easy access. The material and knowledge components of biodiversity are elucidated with taxonomy. Biological control is an area where taxonomy provides the means of exploring diversity and harnessing it for mankind. In exploring more than one trophic interaction as in biological control, the credibility is with taxonomy. Biodiversity encompasses the genetic diversity to the species diversity and this cascading to the ecological diversity. Biological control to be meaningful needs credibility in all these and patterns and processes of nature. Thus, biodiversity is to be addressed in its entirety and at all its hierarchical levels simultaneously. Such addressing will demand integration of fundamentals in taxonomy, ecology and genetics. Harnessing biodiversity and its elements are more demanding now, especially with regard to insects and their associated biological resources, due to species complexes and complex species. The recent concept of push pull technology in agroecosystem is one that must be made relevant to biological control. It will be only if the biological diversity is addressed through a comprehensive approach integrating taxonomy. With recent evidence on the parasitic wasps as new champions of diversity over the beetles, there is tremendous scope for biological control. Its credibility will depend on the unraveling of relationships of taxonomy and biodiversity and channelize these for success.

S1-LP-03

Pest management services through conservation of biological control agents: review, case studies and field experiences

ABRAHAM VERGHESE[1*], PRAKYA SREERAMA KUMAR[2], S. DEVI THANGAM[1], SENTHIL KUMAR RADHAKRISHNAN[1], N. K. KRISHNA KUMAR[3] and G. P. SHETTY[1]

[1]*GPS Institute of Agricultural Management, #1, Techno Industrial Complex, Peenya First Stage, Peenya, Bengaluru - 560058, India*

[2]*ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India*

[3]*Bioversity International, NASC Complex, DPS Marg, Pusa Complex, New Delhi - 110012, India*

[*]*Corresponding author E-mail*: abraham.avergis@gmail.com

Conservation biological control is an approach to enhance the efficacy of natural enemies by ensuring their availability in an agro-ecosystem on a long temporal scale. An increased survival often leads to better fecundity and improved behaviour of the natural enemies, which in turn ensures sustainable pest management. This paper, apart from being a concise review of conservation biological control, deals with selected India-specific case studies and field experiences on habitat manipulation and refugia. Results from a Bengaluru-based study during 2012-2015 on conservation biological control in an organic mango ecosystem are also presented. It also dwells briefly on conservation of insectivorous birds and touches upon conservation biocontrol with respect to entomopathogenic microorganisms and plant disease antagonists.

Research to support New Zealand's plant border biosecurity

BARBARA BARRATT[1*] and DAVID A. J. TEULON[2]
[1]*Invermay Agricultural Centre, Private Bag - 50034, Mosgiel - 9053, New Zealand*
[2]*Plant and Food Research, Lincoln, New Zealand*
[*]*Corresponding author E-mail*: barbara.barratt@agresearch.co.nz

New Zealand has a very strong border biosecurity system to protect its borders from invasive plant pests, pathogens and weeds. As relatively isolated islands, New Zealand has defensible borders and we have been very successful in keeping out some very damaging and high impact pests despite increasing movements of commodities and tourists around the world. A research collaboration known as 'Better Border Biosecurity (B3)' has been developed between research agencies and end user organizations with the objective of reducing the rate of arrival and establishment of damaging and unwanted pests, pathogens and weeds of plants systems of economic and environmental significance. B3 has a number of international collaborators particularly in Australia, the USA, and one of our largest trading partners, China. The growing economy in India means that it also may become a significant trading partner and source of tourists, and hence a source of invasive species in the future. B3 focuses its work in 5 main research areas: risk assessment; pathway risk management; diagnostics; surveillance and eradication. Our research in these areas is planned and carried out in very close partnership with the government departments and increasingly industry sectors with responsibility for the security of our primary industries (agriculture, horticulture, and forestry), our natural environment, and the biosafety of deliberate introductions. This presentation will briefly outline some of our most innovative research approaches in each of the focus areas.

S1-OP-02

Predatory and parasitic insects associated with the dubas bug in date palm orchards in Oman and relationship with insecticide application

ALI ALWAHAIBI[*]
College of Agricultural and Marine Sciences, Sultan Qaboos University, P.O. Box - 34, Alkhoadh P.C - 123, Sultanate of Oman
[*]*Corresponding author E-mail*: awahaibi@squ.edu.om

Dubas bug, *Ommatissus lybicus* Bergevin, is an important pest of date palm in Oman. Great efforts have been made to control this pest mostly through the use of insecticides. We conducted studies to determine the potential natural enemies of this important pest and to assess the effect of insecticide applications in 15 selected sites. Arthropod samples were collected from date palm orchards via surveys conducted during two periods in 2009-2012 and in 2015-2017. Samples were collected by beating date palm leaves and sweeping the understory vegetation. Soil samples were collected from under the trees, and then arthropods were extracted from these samples by Berlese traps. Above-ground and soil arthropods were sorted to different groups and counted. Date palm fronds were collected and egg parasitism was assessed in leaflets and interleaflet areas. Two parasitic wasps fed on dubas bug eggs, while one parasitic wasp attacked the nymphs and adults. Predators confirmed to feed on the dubas bug included ten unidentified predatory species belonging to the Aranae, Mantodea, Neuroptera, Hymenoptera, and Coleoptera. Abundance of natural enemies such as anthocorid bugs, ladybird beetles, ants was lower in sprayed than in unsprayed sites. Species richness of some predatory insect groups (anthocorids, ladybird beetles, and lacewings) was lower in sprayed sites than in unsprayed sites. Higher plant diversity and density could be an important factor influencing the abundance and diversity of natural enemies among different sites.

S1-OP-03

Invasive alien plant species in Nepal

PRAMOD KUMAR JHA*, SEERJANA MAHARJAN, ANJU SHARMA POUDEL and MOHAN SIWAKOTI
Tribhuvan University, Kirtipur - 44600, Kathmandu, Nepal
**Corresponding author E-mail*: pkjhaprof@gmail.com

Invasion by alien plant species has been increasing in Nepal at an alarming rate. A few Invasive Alien Plants (IAPs) have threatened the structure and functions in tropical and temperate ecosystems like richness of native species, cover, soil properties, nutrient cycling, etc. These negative impacts of IAPs have been exacerbated by climate change. In Nepal, *Chromolaena odorata, Lantana camara, Ageratina adenophora, Parthenium hysterophorus, Mikania micarantha, Eichhornia crassipes,* have been reported as most problematic weeds in different ecosystems. The suitable habitats of these IAPs are likely to increase beyond the current distribution in future climate change scenarios as indicated by ecological niche modeling. Regarding management of IAPs, Government of Nepal has developed national strategy that emphasizes on the need of nationwide survey and research of most problematic weeds as well as development of Invasive Plant Atlas by 2020. Different aspects of invasive species including biological control have been studied under the USAID IPM IL funded project in Nepal.

Conservation strategies for management of insect pests of tobacco

SREEDHAR UPPALAPATI*, S. GUNNESWARA RAO and G. RAGHUPATHI RAO
ICAR - Central Tobacco Research Institute, Rajahmundry - 533105, Andhra Pradesh, India
**Corresponding author E-mail*: usreedharctri@yahoo.com

Several species of insect pests pose severe threat to tobacco crop adversely affecting the yield and quality. Conservation biological control is highly effective and suitable for sustainable management of insect pests in tobacco. Studies on evaluation of trap crops against *Helicoverpa armigera* and *Spodoptera litura* and strategies to enhance the effectiveness of trap crops and conservation of natural enemies were conducted to develop an effective management strategy for the pests. Parasitisation of *H. armigera* and *S. litura* in tobacco with trap crops was more, than in tobacco sole crop. Experiments to understand the effect of companion crops revealed that these helped in reduction of insect pest infestation, increased natural enemy activity and improved yield. Use of barrier crops with application of *Verticillium lecanii* reduced *Myzus nicotianae* infestation and increased yield. Integration of barrier crop and foliar sprays of insecticides protected tobacco from whitefly transmitted leaf curl virus disease, increased natural enemy activity and improved yield. Use of selective insecticides that were relatively safe to the native natural enemies helped in suppressing the insect pests. Establishment of Entomophage Park resulted in enhanced activity of natural enemies both in the park as well as in the tobacco and helped in minimizing the pest incidence. Bio-rational pest management modules were highly effective in reducing *S. litura* and *H. armigera* infestation, enhanced natural enemy activity and helped in increasing the production of residue free tobaccos. Thus, conservation strategies helped in increased activity of natural enemies and effective and economical management of insect pests in tobacco.

Enhancing biological suppression through manipulation of ephemeral rice field habitat

CHITRA SHANKER*, C. KANNAN, K. SHABBIR, S. AMUDHAN and GURURAJ KATTI
ICAR - Indian Institute of Rice Research, Rajendranagar - 500030, Hyderabad, India
**Corresponding author E-mail*: chitrashanker@gmail.com

Natural enemies in annual ecosystems like rice are subjected to constantly changing environment. The beneficial ecosystem services in the rice crop habitat can be engineered through appropriate tactics to enhance biological suppression of rice pests. Multi location studies were under taken to assess the biodiversity of natural enemies of key pests of rice and study the impact of habitat manipulation on pest incidence vis-à-vis natural biological suppression. The biodiversity was assessed by visual counts, sweep nets, sticky and pan traps and bait trapping. The stem borer incidence ranged from 0.52 -7.51 % dead hearts and 3.26-9.51% white ears in organic cultivation and from 2.12 -13.18% and 5.46-15.97 % respectively, in chemical input intensive farmers practices. Similarly, there was reduction of hoppers and enhancement of mirid and spider population in fields with organic practices. In seven out of ten locations dead heart incidence was significantly reduced or on par with insecticide treated plots. Egg parasitoids were the critical mortality factor for stem borer and hoppers. Parasitoids effected 14.58-90.00% egg mass parasitisation and 11.69 to 44.14 % egg parasitisation of stem borers and up to 42.04 % of hopper eggs at various locations. Spiders and dragon flies predated on stem borer adults while the parasitoid *Xanthopimpla flavolineata* was predominant at larval stage. Bund crops had significant impact on survival of egg parasitoids and parasitisation of stem borer and hoppers. Planned utilization of ecosystem services of natural enemies is an effective antidote for adverse impact of chemical intensive rice pest management.

S1-OP-06

An Indian perspective of the neglected players for the control of nasty sucking pests

ANKITA GUPTA* and SUNIL JOSHI
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
**Corresponding author E-mail*: ankitagupta.nbaii@gmail.com

The sucking pest complex comprising of mealybugs (Pseudococcidae), soft scales (Coccidae) and armoured scales (Diaspididae), is amongst the deadliest, attacking several agricultural, horticultural and green house crops. They incur severe economic loss due to their activities like sucking plant sap, acting as vectors of viral diseases, and production of honey dew leading to the development of mould. Several species of mealybugs have developed resistance to different pesticides which have been used for their control, the recent being an example of development of resistance in *Phenacoccus solenopsis* to acetamiprid. The ferocious mealybug species in India are *Ferrisia virgata* (Cockerell), *Maconellicoccus hirsutus* (Green), *Nipaecoccus viridis* (Newstead), *Paracoccus marginatus* Williams and Granara de Willink and *Phenacoccus solenopsis* Tinsley, while among soft scales, *Coccus viridis* (Green), *Pulvinaria psidii* Maskell and *P. polygonata* Cockerell have been listed to be important pests of horticultural crops. For tackling these troublesome plant suckers, biological control is the most promising approach as they are sessile and always live in colonies making them more prone to get encountered and parasitized by the parasitoids. Parasitoid diversity, and likewise diversity of host species they parasitize, makes them particularly relevant in the control of pest populations within an explosively diverse ecosystem. Several efforts have been made to control coccids by using exotic and native natural enemies through classical and inundative biological control. In the present study we will list out the potential parasitoid complex of economically important coccids which were encountered in our several years of field surveys and will explore their possible role in management.

S1-OP-07

A systematic account of weed infesting fruit flies (Diptera: Tephritidae) in India

K. J. DAVID[1*], S. K. SINGH[2] and S. RAMANI[3]
[1]*ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India*
[2]*National Museum of Natural History, New Delhi - 110003, India*
[3]*Department of Entomology, University of Agricultural Sciences, GKVK Campus, Bengaluru - 560065, Karnataka, India*
[*]*Corresponding author E-mail*: davidkj.nbaii@gmail.com

Fruit flies (Diptera: Tephritidae) with nearly 5000 described species in 500 genera and six subfamilies, has immense economic importance, both due to the large number of pestiferous species, and, conversely, because of its many actual and potential weed biocontrol agents. Besides 35% of species attacking soft fruits, larvae of 40% species develop in flowers of Asteraceae and most of the remaining species are associated with flowers or their larvae are miners of leaf, stem or root tissues. About twenty species of Tephritidae have been employed as biological control agents of several adventive weeds across the world. Surveys for fruit flies associated with weeds in India revealed the presence of 31 species in 23 genera, 9 tribes and two subfamilies, of which three are yet to be described. Excluding *Coelotrypes* Bezzi (Trypetinae), all taxa were of subfamily Tephritinae. Genera of Tephritinae encountered during the study; *Goniurellia* Hendel, *Ensina* Robineau-Desvoidy, *Terellia* Robineau-Desvoidy, *Scedella* Munro, *Dioxyna* Frey, *Sphaeniscus* Becker, *Sphenella* Robineau-Desvoidy, *Calloptera* Freidberg, *Rhochmopterum* Speiser, *Metasphenisca* Hendel, *Campiglossa* Rondani, *Platensina* Enderlein, *Elaphromyia* Bigot, *Perirhithrum* Bezzi, *Trupanea* Schrank, *Rhabdochaeta* Meijere, *Spathulina* Rondani, *Pristaciura* Hendel, *Tephraciura* Hering, *Procecidochares* Hendel, *Cecidochares* Bezzi and *Pliomelaena* Bezzi. Phylogenetic relationships between 23 genera and nine tribes of weed infesting fruit flies of two subfamilies were analysed using morphological markers by Tree analysis using new Technology (TNT); unambigious, nonhomoplasious synapomorphies were mapped using Winclada. Statistical support for nodes (bremer and bootsrap values) were calculated using TNT.

S1-OP-08

Diversity of entomopathogenic nematodes from Uttar Pradesh and its virulence against major insect pests of vegetables

MANJUNATHA GOWDA THONDIHALU[1*], JAGADEESH PATIL[2], R. VIJAYAKUMAR[1], JAYDEEP HALDER[1], PRATAP A. DIVEKAR[1], A. B. RAI[1] and B. SINGH[1]

[1]*Division of Crop Protection, ICAR - Indian Institute of Vegetable Research, P.B No. 1, P.O Jhakhini, Shahanshapur, Varanasi - 221305, Uttar Pradesh, India*

[2]*ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India*

[*]*Corresponding author E-mail*: goudru9@gmail.com

Entomopathogenic nematodes (EPN) belong to the families Steinernematidae and Heterorhabditidae are effective biological control agents for a variety of economically important insect pests and considered as potential alternatives to chemical insecticides. However, introduction of EPNs as biocontrol agents in one particular region requires prior knowledge of their occurrence and proper identification of native species. Since, India is rich in biodiversity from north to south and from east to west, there is tremendous scope for discovery of new EPN strains/species adapted to local environmental conditions and insect pests. Therefore, in the present study efforts were made to isolate native EPNs. A random survey was conducted at ICAR-IIVR, Varanasi and ICAR-CAFRI, Jhansi, Uttar Pradesh and collected the soil samples. Then soil samples were baited with last instar of wax moth, *Galleria mellonella* larvae and observed regularly for their mortality. From dead insects, EPNs were extracted using a modified white trap method. The identity of EPNs was confirmed through molecular characterization by using the ITS-rDNA region. The sequence of EPNs strains (IIVR EPN03 (MG976754), IIVR JNC01 (MH208855) and IIVR JNC02 (MH208856) showed maximum identity with *Steinernema siamkayai* (99%). Further their efficacy was tested against major insect pests of vegetable crops results showed that, *S. siamkayai* IIVR JNC01 was capable to cause mortality between 30-85%, 60-100% and 62.5-100% in third instar larvae of *Spoladea recurvalis, Spodoptera litura* and *Spilosoma obliqua*, respectively. Hence, *Steinernema siamkayai* native strains can be effectively utilized as biological candidates for the management of insect pests in vegetable crops.

S1-OP-09

Characterization of bacterial diversity associated with brown planthopper, *Nilaparvata lugens* (Stål) and their role in insecticide resistance

GURU PIRASANNA PANDI GOVINDHARAJ*, S. RAGHU, G. BASANA GOWDA, NAVEENKUMAR PATIL, M. ANNAMALAI, G. PRASANTHI, TOTAN ADAK, S. R. PRABHUKARTHIKEYAN, MATHEW BAITE and MAYABINI JENA
ICAR - National Rice Research Institute, Cuttack - 753006, Odisha, India
**Corresponding author E-mail*: guruagri@gmail.com

Current investigation was undertaken to identify the bacterial communities associated with field collected populations of brown planthopper (BPH), *Nilaparvata lugens* from six different locations. Analysis of bacterial communities associated with BPH is the initial step towards understanding the ecological roles of the symbionts. These bacteria were characterized by different morphological, biochemical (starch hydrolysis, gelatin liquefaction, gram reaction, catalase and H2S production) and molecular (16r RNA) parameters. Bacterial isolates produced elevated to flat colonies which are yellow, creamy with production of mucoid exopolysaccharides. They showed varied degree of reaction to biochemical tests. Sequencing of 16 rRNA bacterial genes (V3-V4 region) produced and an amplicon size of 460 bp revealed the diversity of bacterial communities such as *Bacillus* spp, *Enterobacter* spp., *Acenetobacter* spp. *Ochrobactrum pseudogrignonense*, *Micrococcus* spp. *Pseudomonas* spp., *Staphylococcus sciuri*, *Pantoea* spp. *Exiguobacterium enclense* associated with different life stages of BPH. Subsequently, all bacterial isolates were analyzed by restriction fragmented length polymorphism (RFLP) to know the variation within the species using five restriction enzymes (EcoRI, HaeIII, Hind III, BamH I and Taq1). Polymorphism was observed with Taq 1. Commonly used insecticides such as Imidacloprid, Pymetrozine and Dinotefuran were assayed at different concentration to assess the effect of insecticide on inhibition of bacterial growth and micro well dilution assay. Our results revealed that, all the tested insecticides did not inhibit the growth of bacteria even at highest concentration. These bacterial communities might be helpful to development of resistance to the insecticides that need to be confirmed further.

Stethorini (Coleoptera: Coccinellidae) associated with phytophagous mites of south India

C. V. VIDYA[1*] and HASEENA BHASKAR[2]
[1]*AINP on VPM, College of Horticulture, Kerala Agricultural University, Vellanikkara - 680656, Thrissur, Kerala, India*
[2]*Department of Agricultural Entomology, College of Horticulture, Kerala Agricultural University, Vellanikkara - 680656, Thrissur, Kerala, India*
[*]*Corresponding author E-mail*: vidya.cv@kau.in

Surveys were conducted in twenty-seven locations covering three south Indian states *viz*., Kerala, Karnataka and Tamil Nadu during 2015-17 to explore the diversity of Stethorini associated with phytophagous mites. The predatory beetles along with associated mites were collected and male genitalia were studied for species level identification. In addition, mtCOI locus of DNA of the beetle specimens were amplified and sequenced. The study identified 10 species of Stethorini in two genera *viz*., *Parastethorus* and *Stethorus* associated with seven species of mites of the families Tetranychidae and Tenuipalpidae. Genus *Stethorus* is represented by two subgenera, *Stethorus* (*Allostethorus*) and *Stethorus* (*Stethorus*). Of the ten species, six were identified upto species level and four upto generic level. Species identified include *Parastethorus indira* (Kapur), *S.* (*A.*) *forficatus* Poorani, *S.* (*A.*) *pauperculus* (Weise), *S.* (*A.*) *tetranychi* Kapur, *S.* (*S.*) *rani* Kapur and *S. keralicus* Kapur. Sequences of 21 accessions of nine species of Stethorini were submitted to GenBank (NCBI) and accession numbers generated. This is the first submission of COI sequences of these species in the NCBI database. *Stethorus* (*Allostethorus*) *pauperculus* recorded wider prey range which includes *Oligonychus indicus*, *Tetranychus macfarlanei*, and *T. truncatus*. *Stethorus keralicus* was recorded only on *Raoiella indica*. The study identified new prey records for *S. forficatus* (*T. okinawanus* and T. *truncatus*), *S. pauperculus* (*T. macfarlanei*) and *P. indira* (*Eutetranychus orientalis*).

Record of prostigmatid predatory mites from Himachal Pradesh

C. S. JAYARAM*, PAWAN KUMAR SHARMA and AJAY KUMAR SOOD
CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur - 176062, Himachal Pradesh, India
**Corresponding author E-mail*: jay_acari25@yahoo.com

Predatory mites play an important role in agricultural ecosystem and are one of the potential biological control agents of mites and other insect pests of economical plants. Predatory mites are valued by farmers as one of the preferred biological control agents in agriculturally developed countries. Some groups of predatory mites are already explored and have gained importance, but predatory mites of order Prostigmata remain under-utilized. A study conducted during 2016-17 for exploring the predatory mites in Shivalik hill zone of Himachal Pradesh resulted in eight prostigmatid predatory mites belonging to four families *viz*., Erythraeidae, Iolinidae, Stigmaeidae and Tydeidae. The species recorded were *Agistemus* sp. nr. *edulis*, *A. industani* Gonzalez-Rodriguez, *A. javanicum* Gupta, *A. lakoocha* Gupta, *Pronematus sextoni* Baker, *Paraerythraeus delhiensis* Khot, *Tydeus gossabaensis* Gupta and *T. ornamentalicus* Gupta. These all were recorded for the first time from Himachal Pradesh. Mites belonging to *Agistemus* and *Pronematus* were found associated with red spider mites except *A. javanicum* which was recorded on *Polyphagotarsonemus latus* Banks. *P. delhiensis* was found associated with grub of *Brahmina coriacea* (Hope) and plant debris. Whereas *T. gossabaensis* and *T. ornamentalicus* were found on ornamental plants along with two phytoseiid mites namely, *Euseius prasadi* (Chant and McMurtry) and *Typhlodromalus kalimpongensis* Gupta.

Validation of IPM in cotton in whitefly hot spot in North India

ANOOP KUMAR*, R. K. TANWAR, AJANTA BIRAH and S. P. SINGH
ICAR - National Centre for Integrated Pest Management, LBS Centre, Pusa Campus, New Delhi - 110012, India
**Corresponding author E-mail*: anooptiwariento@gmail.com

Cotton crop attracts a large number of insects and many of them become serious pests inflicting significant damage. Sucking pests particularly whitefly, jassid, thrips and mealybug cause significant damage in *Bt* cotton hybrids. During last few years whitefly (*B. tabaci*) has shown an increasing trend in cotton and it acquired the status of epidemic during 2015-16 in North India particularly in Punjab and Haryana in spite of 10-12 sprays of chemical pesticides (tank mixing) leading to reduction in cotton area in the subsequent year. There was an urgent need to develop and validate Integrated Pest Management (IPM) strategy to manage the problem of developing insecticides resistance. In this context ICAR-NCIPM initiated a trial in 7.5 acre in 2016-17 on validation of IPM strategy in cotton in whitefly hot spot at Nihalkhera in Fazilka district of Punjab in farmers' participatory mode. The trial was extended to 42 acres in 2017 comprising two blocks; one near kinnow orchard (14 acres) and the other away from kinnow orchard. IPM interventions included removal of weed hosts around the field, selection of recommended *Bt* hybrid, timely sowing (before 15th May), weekly pest monitoring, installation of yellow sticky traps, sowing of maize/bajra as barrier crop, use of biopesticides, need based application of safer insecticides (Insect growth regulator) and over all crop health management. IPM fields were compared with farmers practice (FP) fields where only insecticides (tank mixing) were applied by the farmers. Observations on population of whitefly, jassid and thrips and predators such as chrysopid, coccinellid and spiders were recorded at weekly interval. Parasitization of whitefly nymphs by parasitoids were also observed at regular interval in IPM and FP fields. During 2016, IPM implementation resulted in > 88 % reduction in chemical pesticides active ingredient (ai) applications compared to FP with only three sprays in IPM (1.2 ka ai/ha) fields against 13 sprays in FP (10.61 kg ai/ha) fields. IPM fields also indicated higher population of beneficial i.e. coccinellid beetle (0.40 adult/plant), lacewing (0.47 eggs or larva/plant), spiders (0.42 adult or spiderlings/plant) recorded in IPM fields as compared to FP (coccinellid beetle 0.06 adults/plant; lacewing 0.11 eggs or larvae/plant; spider 0.15 adult/plant) fields. The population of whitefly (per three leaves) remained below ETL i.e. 8.93 (2.67-27.46) in IPM against 11.40 (1.88-25.21) in FP fields throughout the crop season except (30th SMW) few occasions. IPM helped in reducing input cost with higher yield resulted higher benefit-cost ratio in IPM (2.27) compared to FP (1.32). During 2017 population of whitefly remained below ETL except few occasions. Population of jassid was very high during third week of July. Again IPM implementation resulted significant reduction in chemical pesticides (>90% reduction in active ingredient over FP) application from 3 sprays in IPM (0.537 kg ai/ha) compared to 9 sprays (5.625 kg ai/ha) in FP fields with higher population of natural enemies i.e. coccinellid beetles (0.35 adult/plant), lacewing (0.36 eggs or larva/plant) and spider (0.29 adult or spiderlings/plant) as compared to FP. Parasitization of whitefly nymph by *Encarsia* spp. during July to August was recorded to an extent of 40% in IPM field against trace to nil in FP field along with higher benefit-cost ratio in IPM (2.44) compared to FP (1.73). It is evident from the trial that large scale implementation of IPM in cotton not only helped in reducing the insect pests and application of chemical pesticides but also enhanced the benefit-cost ratio with conservation of natural enemies.

S1-PP-01

New distributional record of *Steinernema hermaphroditum* (Nematoda: Steinernematidae) from Kerala, India

K. M. ANES*, JINU SIVADASAN, MERIN BABU and A. JOSEPH RAJKUMAR
ICAR - Central Plantation Crops Research Institute, Regional Station, Kayamkulam - 690533, Kerala, India
**Corresponding author E-mail*: aneskm@gmail.com

Survey was conducted for distributional geo-mapping and characterization of entomopathogenic nematodes (EPN) in different locations of Kerala, India. Soil samples were collected from various tracts of Alappuzha, Kollam, Pathanamthitta, Idukki and Eranakulam districts of Kerala for the natural occurrence of EPN using soil-baiting techniques with greater wax moth larvae, *Galleria mellonella*. Out of the 141 soil samples baited, 13.5% were found positive for EPN, which included three steinernematids and 16 heterorhabditids identified based on the characteristic colour of the infected cadavers. Soil samples from the experimental plots of ICAR-CPCRI, Regional Station Kayamkulam yielded higher EPN recovery (33.3%). Three heterorhabditids and two steinernematid isolates were further subjected to molecular characterization by sequencing ITS region of the ribosomal DNA using 18s and 26s primers. All the three heterorhabditid species intercepted in the survey, were found to have 99% sequence similarity with *Heterorhabditis indica*. Both the steinernematid isolates were found to be belonging to the glaseri group. One of the steinernematids (CPCRI0905) was 99% homologous with *Steinernema hermaphroditum* and is the first report of this species from South India. The identity of this isolate was confirmed based on the morphological and morphometric characters as well as the presence of first generation hermaphroditic females, which is a unique characteristic feature of *S. hermaphroditum*. The steinernematid isolate CPCRI0804 was found non-homologous with any of the described species and, therefore, presumed to be a new species for identification. The presence of long and highly curved spicule is the striking feature of this unidentified species.

Diversity of spiders in the tomato ecosystem

S. S. ANUSREE[*] and MITHRA MOHAN
College of Agriculture, Vellayani, Sreerangam, Panangodu, Venganoor P.O, Thiruvananthapuram - 695523, Kerala, India
[*]*Corresponding author E-mail*: anusreess777@gmail.com

Spiders are one of the most diverse and cosmopolitan invertebrate predators in the terrestrial ecosystem which play a very important role in natural pest control. The studies conducted at Instructional farm, Vellayani, Thiruvananthapuram disclosed the diversity of spiders in tomato ecosystem which emphasizes the significance of their conservation. The survey was carried out in two cropping seasons viz., April- July and November- February in the year 2016. Fourteen species of spiders under four families and three ecological guilds were recorded from the tomato crop. The important ecological guilds identified were orb-web weavers, stalkers and ambushers, in which orb web weavers were the predominant group. Eight species of spiders were included in the orb-web weavers which consisted of families Araneidae and Tetragnathidae. Family Araneidae exhibited maximum species diversity and were abundant in the tomato ecosystem. Under, Araneidae four species of Neoscona and two species of Argiope were observed whereas under Tetragnathidae two species of spiders were recorded. The ecological guild, stalkers include members of the family Oxyopidae which are active hunters. Family Oxyopidae comprised of three species which were *Oxyopes* sp., *Oxyopes shweta* Tikader and *Peucetia viridans* Hentz. Three species of spiders of the family Thomisidae under ambushers or crab spiders *viz*. *Camaricus formosus* Thorell, *Dieta virens* Thorell and *Thomisus lobosus* Tikader were also recorded from the tomato ecosystem. These generalist predators are one of the important links in food chain and this signifies the importance of conservation of the spider fauna in the tomato ecosystem.

S1-PP-03

Characterization of entomopathogenic nematodes from subtropical regions of India and their efficacy against soil-dwelling life stage of *Helicoverpa armigera*

M. DEVINDRAPPA[1*], JAGADEESH PATIL[2], BANSA SINGH[1] and KRISHAN KUMAR[1]

[1]*ICAR - Indian Institute of Pulses Research, IIRR Crossing Road, Kalyanpur, Kanpur - 208024, Uttar Pradesh, India*

[2]*ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India*

[*]*Corresponding author E-mail*: dnayak4505@gmail.com

Entomopathogenic nematodes (EPNs) in the genera *Heterorhabditis* and *Steinernema* with their symbiotic bacteria *Photorhabdus* and *Xenorhabdus*, respectively, are obligate and lethal parasites of soil-dwelling insect pest, however use of these nematodes as biocontrol agents in particular region requires prior knowledge of their occurrence and proper identification of native species. Hence, there is great scope for finding new EPN strains/species adapted to local environmental conditions and ability to reduce insect pest population. Therefore, in the present study, we collected around 150 soil samples from different pulse growing regions of Uttar Pradesh districts. EPNs were isolated using soil baiting technique. Out of 150 soil samples, 12 samples were found to be positive of *Steinernema* nematodes. Species level identification was confirmed with molecular studies by sequencing of ITS-rDNA region of *Steinernema*. In the BLAST analysis isolates of *Steinernema* IIPR1 showed maximum identity with (99%) *Steinernema siamkayai* whereas, *Steinernema* IIPR5 and *Steinernema* IIPR11 with *S. abbasi* (99%). Further their efficacy was tested against gram pod borer, *Helicoverpa armigera* pupae. Results showed that *S. abbasi* IIPR11was capable of reducing 60 to 90% pupal emergence from the soil. Therefore, these results indicate that, *S. abbasi* IIPR11 native strain can be effectively utilized as one of biological agents in Integrated Pest Management (IPM) programs of *H. armigera* in pulse crops.

Survey and surveillance of natural enemies in mango ecosystem

GUNDAPPA[1*], BALAJI RAJKUMAR[2] and P. K. SHUKLA[1]
[1]*ICAR - Central Institute for Subtropical Horticulture, Rehmankhera P.O, Kakori - 226101, Lucknow, Uttar Pradesh, India*
[2]*ICAR - Indian Institute of Spices Research, Regional Station - Appangala, Heravanad Post, Madikeri - 571201, Karnataka, India*
[*]*Corresponding author E-mail*: gundu6100@gmail.com

Mango, *Mangifera indica* L., is grown throughout the subtropics and tropics and is one of the world's most important fruit crops. India ranks first among world's mango producing countries accounting 45 per cent share of total world's mango production. Although, India is the largest producer of mango but in terms of productivity, it ranks seventh. The low productivity is due to the wide range of geographical diversity and variations in climatic conditions in which it is grown and losses caused by insect pests and diseases. Although mango is affected by large number of insect pests and diseases, some are of great economic importance and are responsible for high loss in the mango production in our country. These insect pests are mango hopper, mealybug, midge, leaf webber, scale insects, stem borer and fruit fly. Insect pest management is very important for the profitable cultivation of mango in India. As it is not possible to control all insect pests completely, it is required that it should be kept below economic threshold level. Natural enemies (predators and parasitoids) play a crucial role in keeping the pest below economic injury level. In order to record the natural enemies associated with mango ecosystem survey was conducted in mango orchards for two years. During the year 2015-16, five species of coccinellids *viz*. *Coccinella septempunctata*, *Cheilomenes sexmaculata*, *Serangium parcesetosum*, *Chilocorus rubidus*, *Scymnus* sp. were observed feeding on mango hoppers and mealybugs. Most abundant predator were *Coccinella septempunctata* and *Cheilomenes sexmaculata*. During the year 2016-17 coccinellids feeding on the mango hopper and mealybugs were observed between 11th to 17th SMW, peak coccinellid population was recorded during mango 13th SMW with 2.5 coccinellid beetles per panicle. Most abundant species of coccinellid was *Coccinella septempunctata*. Parasitoids belonging to the family Ichneumonidae and Braconidae were collected from the mango ecosystem. It was evident that wherever indiscriminate use of insecticides was undertaken natural enemy population was very low. In unprotected orchards abundant natural enemies were recorded. In order to achieve natural control of the pest it is advised to the orchardists that minimal spray may be taken up.

The diversity of coccinellid predators of sucking pests on temperate fruits in Jammu and Kashmir

G. MAHENDIRAN[*]
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
[*]*Corresponding author E-mail*: mahi.weevils@gmail.com

The coccinellid beetles are one of the important predatory species and their potential as biological control agent has already been proven. Hence, the surveys were undertaken to collect and document the coccinellid predator fauna of important sucking pests of temperate fruits in Jammu and Kashmir, India from 2013-2016. A total of 21 species belonging to 14 genera of predatory coccinellids were recorded. Among these, *Adalia tetraspilota*, *Calvia punctata*, and *Harmonia eucharis* were present in three, seven and six different colour morphs, respectively. The species, namely *Halyzia sanscrita*, *Illeis confuse*, *Serangium montazerii* and *Stethorus aptus* were recorded for the first time in Jammu and Kashmir. Twenty-two new prey records were reported, particularly European red mite (*Panonychus ulmi*) was newly reported as prey for 11 coccinellid species in almond and apple orchards. The species, *Priscibrumus uropygialis* was found for the first time feeding on peach stem aphid and mealy plum aphid. Similarly, *Calvia punctata* was recorded for the first time as a predator of apple green aphid, pear psyllid, mealy plum aphid and peach stem aphid. This preliminary study would help in further exploitation of the potential species by studying its biological traits, predatory and survival potential for the management of sucking pests of temperate fruits.

S1-PP-06

Diversity, abundance and predation potential of major aphidophagous predators of *Aphis odinae* (Van der Goot) (Hemiptera: Aphididae) in cashew

R. MARUTHADURAI[*] and A. R. DESAI
ICAR - Central Coastal Agricultural Research Institute, Old Goa - 403402, Goa, India
[*]*Corresponding author E-mail*: duraiento@gmail.com

The aphid, *Aphis odinae* (Van der Goot) (Hemiptera: Aphididae) is a polyphagous, occasional, minor insect pest of cashew (*Anacardium occidentale* L). Field studies were conducted to assess the species composition and abundance of aphidophagous predators in cashew ecosystem during 2015-2016 at Goa. Six species of aphidophagous predators comprising three species of coccinellids, *viz*. *Scymnus castaneus* Sicard, *Cheilomenes sexmaculata* (Fabricius) and *Pseudaspidimerus flaviceps* (Walker) and three species of syrphids, *viz*. *Paragus serratus* (Fabricius), *Dideopsis aegrota* (Fabricius) and *Ischidon scutellaris* (Fabricius) were found predating on *A. odinae*. Among the predators, *S. castaneus* (4.26 grubs/nut) was the most abundant species followed by *P. serratus* (2.39 larvae/nut) and *D. aegrota* (1.2 larvae/leaf) during both the years. The maximum relative density (47.31%) was recorded in *S. castaneus* followed by *P. serratus* (33.60) and *D. aegrota* (7.06%) among the predators. The predator population followed an almost similar trend with that of the prey. Predation of aphids was observed from December onwards and reached its peak during February, coinciding with the maximum population of aphids during both the years. Correlation between the density of aphid and its predators revealed a significant positive correlation. The grub of *S. castaneus* consumed an average of 128.7 aphids during its development. The larva of *P. serratus* consumed an average of 143.2 aphids during its development. The study indicated that the aphidophagous predators comprising of coccinellids and syrphids were quite effective in managing *A. odinae* in cashew plantations.

Predictive habitat distribution modelling framework for root-knot nematode, *Meloidogyne enterolobii* - an emerging pest in India

PRASANNA HOLAJJER*, N. SIVARAJ, BHARAT H. GAWADE, Z. KHAN and B. SARATH BABU
ICAR - National Bureau of Plant Genetic Resources, Regional Station, Hyderabad - 500030, Telangana, India
**Corresponding author E-mail*: prasannaiari@gmail.com

Root-knot nematode, *Meloidogyne enterolobii*, a sedentary endoparasitic nematode species, is considered as one of the most damaging species due to its wide host range, pathogenicity and ability to develop and reproduce on several crops and weeds. It is an important tropical/sub-tropical apomictic species of root knot nematode that has been reported from several countries in North America, South America, Central America and Caribbean, Asia, Africa and EPPO region. Recently, this nematode was reported for the first time from India affecting guava trees in Tamil Nadu. Therefore, in order to assess the potential geographic distribution of *M. enterolobii* in India, species was subjected to ecological niche modelling using Maximum Entropy (MaxEnt) method. Presence points of this nematode species around the globe (geographical coordinates) were obtained from CABI database. The MaxEnt software version 3.3.3k (www.cs.princeton.edu/~schapire/maxent) was used for *M. enterolobii* habitat modelling. DIVA-GIS software version 7.5 was used to generate grid maps. Open source of 19 bioclimatic variables for current and future climatic conditions were used for ecological niche modelling. The climate models generated for the present and future climates indicated that potential region of spread of this nematode are the states in south India *viz*. Tamil Nadu, Kerala, Karnataka and Andhra Pradesh. High probability value of 0.77-1.00 was derived for the predictive habitat distribution model based on the presence points of this nematode around the world. Accordingly, contingent plan/suitable strategy need to be developed for prevention of further spread of this nematode in south Indian states.

Biodiversity of pollinators in four bee-friendly plant species

M. PRATHEEPA*, U. AMALA and T. M. SHIVALINGASWAMY
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
**Corresponding author E-mail*: mpratheepa@gmail.com

Bees are the primary pollinators of many important agricultural crops. Honey bees provide the majority of pollination services on most farms, but native bees serve as an important component of a sustainable pollination strategy. The present study was conducted in the experimental farm of ICAR-National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru, Yelahanka Campus (13.096792N, 77.565976E). The number of bees visiting per flower per minute, time spent by the bees per flower was observed and recorded in four different plants *viz*. *Hamelia patens*, *Ocimum basilicum*, *Asystesia* sp. and *Jacquemontia* sp. The different species of the bees visiting each plant was also recorded. The mean number of bees visited/plant/minute, time spent by the bees in each flower and diversity indices of bees visiting each plant was worked out. The diversity indices of the bees visiting all the four plants was observed to be highest during the morning hours indicated by relatively higher values of Shannon diversity index and Simpson index. The descending order of number of bees visiting the four plants was *viz*. *Jacquemontia* > *Ocimum* > *Asystesia* > *H. patens*. The different bee species visiting the flowers were *Apis florea*, *Apis cerana*, *Amegilla zonata*, *Amegilla confusa*, *Ceratina hieroglyphica* and *Hoplonomia* sp. Time spent by the sonicating bees like *A. zonata* and *A. confusa* was found to be relatively lower compared to other species of bees. The results showed the role of four plants with pollen and nectar rewards attracts the bees could be a candidate species in gardens for *insitu* conservation of bee pollinators.

Arthropod diversity in rose, jasmine and cock's comb ecosystem

R. S. RAMYA[1*], M. GANESH KUMAR[2] and M. RANJITH[2]
[1]*ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India*
[2]*Tamil Nadu Agricultural University, Coimbatore - 641003, India*
[*]*Corresponding author E-mail*: ramya.ento@gmail.com

Conservation of biodiversity is an important concern of humanity and research in this area has been recently rerouted to agroecosystems. The objective of the research was to study the arthropod diversity in cultivated rose, jasmine and cock's comb ecosystems. The collection yielded two classes of arthropods *viz*. Arachnida and Insecta. A total of 12,671 individuals were recorded in 103 families and 14 orders. Majority of individuals from Arachnida fell under the order Araneae. Under Exopterygota, 7 insect orders were represented with majority of individuals falling under Hemiptera. Totally 18 families of Hemipterans were collected with majority of individuals belonging to Pentatomidae. Under Endopterygota, Coleoptera was the most common order with majority of individuals belonging to Coccinellidae. Among the three fields, rose and cock's comb showed the greatest species richness and abundance followed by jasmine. Rose and cock's comb fields had increased arthropod abundance in terms of total numbers, species richness indices (species number, Fisher alpha index, Q statistic, Shannon Weiner index and Brillouin index), dominance indices (Simpson's index, Berger-Parker index and McIntosh index) and evenness indices (Equitability J). This research was aimed at aiding the future studies on factors affecting biodiversity. The information on biodiversity can also throw light on the stability of the ecosystem, particularly in a crop-based ecosystem like the floricultural ecosystem that was explored in our research.

Report of a mermithid nematode infecting *Spodoptera* spp., *Amyna axis* and *Chrysodeixis* spp. in the southern districts of Rajasthan

S. RAMESH BABU[1*], VISHAL SINGH SOMVANSHI[2], P. K. MEENA[1], VICTOR PHANI[2], M. R. KHAN[2], KHUSHBU CHAUHAN[2] and PRAMOD ROKADIA[1]

[1]*Agricultural Research Station, Maharana Pratap University of Agriculture and Technology, Banswara - 327001, Rajasthan, India*

[2]*Division of Nematology, LBS Center, ICAR - Indian Agricultural Research Institute, Pusa Campus - 110012, New Delhi, India*

[*]*Corresponding author E-mail*: babuento@yahoo.co.in

Semilooper complex (*Chrysodeixis* spp. and *Amyna axis*) and *Spodoptera* spp. are the two important polyphagous pests and causes severe economic losses to the soybean crop in India. Mermithids are obligate parasites of arthropods and are principally known to infect several insects from fifteen different orders. As a part of an ongoing study to monitor the diversity of insect pests and insecticide resistance of *Spodoptera* spp. on soybean at Rajasthan, India. The larvae were collected from the field for routine observation for the presence of any bioagents. The study revealed that the nematode parasitism occurred in *Spodoptera litura*, *S. exigua*, *A. axis* and *Chrysodeixis* spp. The percentage of nematode parasitism in *Spodoptera* and *Chrysodeixis* was found to be 7.14 and 9.09, respectively, while less percentage infestation on *A. axis* based on all the collected larvae from different places. After emergence of the nematodes, the larvae died and readily succumbed to bacterial infection and started rotting. All the nematodes emerged from the anterior portion of the larval body. Based on the morphological and molecular observations, the nematode was found to be a species of *Hexamermis*. This is the first report of a mermithid species, *Hexamermis* sp. infecting *Chrysodeixis* spp. and *A. axis* worldwide. The present investigation is the first to carry out the molecular characterization of a *Hexamermis* sp. from India. The mermithid nematodes act as a natural biocontrol agent for many lepidopteran pests but the commercial application of these nematodes in field level are still lacking.

Seasonal incidence and natural enemy complex of aphid, *Aphis punicae* Passerini (Hemiptera: Aphididae) infesting pomegranate in Kashmir

SAJAD MIR[*] and NAVEED ANJUM
Division of Entomology, SKUAST-K, Shalimar - 190001, Jammu and Kashmir, India
[*]*Corresponding author E-mail*: sajad_05@rediffmail.com

Survey on the pest incidence of pomegranate aphid (*Aphis punicae*) and natural enemies associated with it was conducted during 2015 at four locations each in district Srinagar and Baramulla. The studies revealed that the highest mean population of aphids/shoot (33.99) was recorded in Srinagar, whereas, in Baramulla, lower population of aphids/shoot (24.10) was recorded. Data further revealed that among different locations of Srinagar, highest average number of aphids/shoot (40.30) was observed at CITH and minimum (27.54) in Botakadal. Similarly, in district Baramulla highest mean number of aphids/shoot (27.63) was recorded at Sopore whereas, the lowest mean population (21.11/shoot) was observed at Dangerpora. The pest started its activity in the first week of April and reached to its peak in the second week of May in both the districts. Thereafter, the population of aphids declined gradually. The studies on natural enemies revealed existence of six coccinellid predators *viz. Coccinella septempunctata, Harmonia eucharis, Cheilomenes sexmaculata, Adalia tetraspilota, Hippodamia variegata* and *Calvia punctata* and two syrphids *viz. Sphaerophoria scripta* and *Episyrphus balteatus* predating on pomegranate aphids. Among the natural enemies, *C. septempunctata* was found to be the most dominant in both the districts. Overall, the abundance of natural enemies associated with pomegranate aphids in Baramulla was comparatively lesser than Srinagar.

Redescription and biology of a common predatory pentatomid, *Eocanthecona furcellata* (Wolff) (Hemiptera: Pentatomidae: Asopinae)

SALINI SANTHAMMA*
ICAR - National Bureau of Agricultural Insect Resources, Yelahanka Campus, Attur Layout, Yelahanka, Bengaluru - 560064, Karnataka, India
**Corresponding author E-mail*: shalinis.nilavu@gmail.com

The genus *Eocanthecona* Bergroth is distributed throughout Australia, Oriental and Palaearctic region. This genus is represented by 20 species across the world. Of these only seven species are reported from India. Among these, *E. canthecona* is an important predator of several crop pests. It is a polyphagous predator and has been reported to feed on a variety of Lepidopterous insects including Noctuidae, Arctiidae, Pyralidae, Hesperiidae, Pieridae, Lasiocampidae, Limacodidae, Saturnidae, Thaumetopoeidae and grubs of Coleoptera including Chrysomelidae. These are dull brown bugs with scattered yellowish or ochraceous patches all over the body. Fore tibiae moderately dilated, with sharp and stout spine on foretibiae, at one third from apex; pronotum with anterolateral margins sinuate and crenulate; humeral angles produced into moderately elongate bispinose process, with anterior one acute and elongate and posterior one is short and blunt; posterior angles of pronotum usually with small, sharp, hook-like process; abdominal sternum of males with pilose glands; basal abdominal sternite with short, stout tubercle, in apposition to metasternal process. The biology of this species was studied under laboratory condition and the total life cycle was 30 days. In this paper, *E. furcellata* is redescribed based on male and female genitalia with note on its biology under laboratory condition. A key to the known species of *Eocanthecona* from India is also provided.

S1-PP-13

Diversity of erebid moths (Lepidoptera: Erebidae) of Aligarh, Uttar Pradesh, India, their pest status and biocontrol to some economically important plants.

SHAHABAB AHMAD FAROOQUI[*] and HINA PARWEZ
Aligarh Muslim University, Aligarh - 202002, Uttar Pradesh, India
[*]*Corresponding author E-mail*: shahababfarooqui@gmail.com

Family Erebidae listed first time from District Aligarh, Uttar Pradesh, India. The information is based on the moth surveys done from January 2018 to April 2018. A total of 32 species under 24 genera of 8 different subfamilies of moth were identified with the help of relevant literature. Subfamily Arctiinae was dominated with 10 species followed by Lymantriinae with 6 species whilst subfamily Ctenuchinae and Scoliopteryginae shared last position having maiden species in each. Moreover, 26 species were found as recognized pests of different agriculturally important plants. Amongst them, 3 moth species have been successfully observed to be naturally controlled by parasitoid wasp species to secure the agriculturally important plant species cultivated in Aligarh region. All the species included are newly recorded from the District Aligarh, U. P.

A comparison on abundance of parasitoids and predators in organic and conventional basmati rice

SUDHENDU SHARMA[*], P. S. SHERA and K. S. SANGHA
Punjab Agricultural University, Ludhiana - 141004, Punjab, India
[*]*Corresponding author E-mail*: sudendhu@pau.edu

A rice field is frequently disturbed by farming practices *i.e.* tillage, irrigation, crop establishment and agrochemical application. Similarly, insect communities depend on both their local environment and features of the surrounding habitats. Keeping this in view, the present studies was conducted on the comparative abundance of natural enemies in organically as well as conventionally (chemical control) grown basmati rice at farmer's field during 2015-16 and 2016-17. The organic field was green manured with the legume *Sesbania aculeata* (Willd.) and the crop pests were managed using neem sprays. The conventional field was supplemented with inorganic fertilizers and pesticides. Different life stages *i.e.* egg, larvae and pupae of rice stem borer and leaf folder were collected and brought to the laboratory to record natural parasitism in both organic and conventional fields. The population of predators was recorded through sweep nets. The spiders' population was recorded using pit fall traps and sweep net. A total of nine parasitoid species including three egg parasitoids (*T. chilonis*, *T. japonicum* and *Telenomus* sp.), three larval parasitoids (*Stenobracon nicevillei*, *Bracon* sp. and *Cotesia* sp.) and three pupal parasitoids (*Tetrastichus* sp., *Brachymeria* sp. and *Xanthopimpla* sp.) were recorded from organic and conventional fields. However, the natural parasitism by these parasitoids was comparatively higher in organic than conventional rice. Similarly, the population of predators like dragonflies, damselflies and spiders were high in organic fields than in conventional fields. The study highlights the significance of conservation of these natural enemies for a sustainable system of rice insect pest management.

Crop diversification enhances conservation of native predatory bug, *Nesidiocoris tenuis* (Reuter) (Heteroptera: Miridae) in tomato

U. AMALA[*], T. M. SHIVALINGASWAMY and M. PRATHEEPA
ICAR - National Bureau of Agricultural Insect Resources, Yelahanka Campus, Attur Layout, Yelahanka, Bengaluru - 560064, Karnataka, India
[*]*Corresponding author E-mail*: amala.uday@gmail.com

Habitat manipulation as a method of conservation biological control which employs cover crops/hedge rows/flower strips crops in the main crop field to conserve the beneficial insect fauna like pollinators and natural enemies. An experiment was conducted in tomato crop where in a sole crop and diversified crop of tomato (field bean - 2 rows as border crop + a patch of sun hemp as hedge row) was observed for the natural build-up of the population of predatory mirid bug, *Nesidiocoris tenuis* at ICAR-National Bureau of Agricultural Insect Resources (NBAIR) Research Farm. Infestation of tomato pinworm, *Tuta absoluta* was found to be the highest in the sole crop (5.60 live mines/plant at 20 DAP) compared to the diversified crop of tomato (1.50 live mines per plant). There was a gradual build up in the population of *N. tenuis* at 20 (2.9 adults per 5 leaves), 40 (3.5 adults per 5 leaves), 60 (4.4 adults per 5 leaves), and 80 (3.6 adults per 5 leaves) days after planting (DAP) in the diversified crop of tomato compared to sole crop (0.8 adults-20 DAP; 1.0 adults- 40 DAP; 0.6 adults-60 DAP and 3.6 adults - 80 DAP). The nymphs and adults of *N. tenuis* were found to predate on red spider mites in the diversified plot during the later stages of the crop. The results of the present study confirmed the role of crop diversification in supporting the population buildup of *N. tenuis* in tomato for biological control of pin worms and spider mites.

Social spider, *Stegodyphus sarasinorum* as a bio-control agent and its conservation strategies

M. SAMPATH KUMAR[1*] and CHITRA SHANKER[2]
[1]*ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India*
[2]*ICAR - Indian Institute of Rice Research, Rajendranagar - 500030, Hyderabad, India*
[*]*Corresponding author E-mail*: ento_sam@yahoo.co.in

Spiders are generalist predators that are numerically more abundant and occupy various niches in agro-ecosystems. Difficulties in laboratory rearing reduces the possibility of its mass multiplication and inundative release. Conservation strategies are mainly adopted to enhance spider abundance and biodiversity for pest management. The possibilities of conserving social spiders in non-crop habitats which can serve as refuge gives a viable and cheap practical option for the farmers. *Stegodyphus* (Araneae: Eresidae) are social spiders, commonly known as the Indian cooperative spider. *Stegodyphus mirandus*, *S. pacificus*, *S. sarasinorum* and *S. tibialis* have been reported from India. Out of these, *S. sarasinorum* is the predominant species with 100 and 1000 spiders living together depending up on the web size and capture prey 10 times as large as their size which is advantageous for biological control. Females of the social species are 7-14 mm in length and exhibits communal nesting, predation, feeding and brood care. The social spiders collected from various places in south India were released for colonization and then deployed in mango orchards and non-crop habits at NBAIR farm. Regular observations taken on the pests trapped in the webs of these spiders showed presence of mango pests though, non-targets like bees, dragonflies, houseflies were also present in web which elucidated its use as a biocontrol agent for pest reduction. Use of selective insecticides and prevention of insecticide drift, right placement of the nest, deterring birds from taking silks and avoiding nest build-up as conservation strategies are also discussed.

Banker plants for augmentation and conservation of *Encarsia sophia* (Hymenoptera: Aphelinidae) for sustainable control of whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae) in polyhouses

GOPALAKRISHNA PILLAI[*] and GANGA VISALAKSHY
ICAR - Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bengaluru - 560089, Karnataka, India
[*]*Corresponding author E-mail*: pillaig@iihr.res.in

The efficiency of native parasitoid, *Encarsia sophia* (Girault and Dodd) (Hymenoptera: Aphelinidae) for the management of greenhouse whitefly, *Bemisia tabaci* (Gennadius) is evaluated in a polyhouse in India. The parasitoid is abundantly available locally and could be easily multiplied on B. tabaci on different host plants. Tomato, eggplant and tobacco were tested as banker plants as they could be used as a non- crop host in crops such as gerbera, tomato or other vegetable crops generally grown in polyhouses. Tomato crop held the maximum parasitoids to eight weeks suggesting that they are preferred for a longer duration. We observed successful parasitoid dispersal and higher levels of parasitism within a meter of release location of the parasitoid and thereafter dispersed up to four meters in the polyhouse. A real estimate of number of parasitoid progeny production was not done in the experiment, but these plants could potentially augment enough parasitoids for effective control of whiteflies. Further studies on dispersal over longer distances however are necessary to determine how many banker plants would be required and how far apart they would need to be. The results of the study suggest the utility of *E. sophia* in conjunction with banker plants is promising for biological control of *B. tabaci* in polyhouses.

Intercropping - a way for *in situ* conservation of natural enemies in pigeonpea, *Cajanus cajan*

T. M. SHIVALINGASWAMY*, A. RAGHAVENDRA, U. AMALA and A. N. SHYLESHA

ICAR - National Bureau of Agricultural Insect Resources, Yelahanka Campus, Attur Layout, Yelahanka, Bengaluru - 560064, Karnataka, India

**Corresponding author E-mail*: swamy.tms@gmail.com

Habitat manipulation is a method of maintaining wildflower strips, hedgerows, intercrops, border rows of flowering crop/non-crop plants in agricultural landscapes to enhance the diversity and abundance of native natural enemies by providing food and shelter. A replicated field trial was conducted in Kharif season of 2011 at Research Farm of ICAR- NBAIR Yelahanka Campus. Intercropping 10 rows of pigeon pea (cv. TTB-7) with 2 rows marigold (cv. Local) and sunflower (cv. KBSH-53) 2 rows along with a sole crop of pigeon pea as a control. Observations on number of pod borer larvae, per cent pod infestation and number of natural enemies per plant were recorded. There was a reduction in the incidence of *Helicoverpa armigera* in pigeon pea + sunflower intercrop (3.6 larvae/10 plants) followed by pigeon pea intercropped with marigold (6.4 larvae/10 plants) with the highest incidence recorded in the sole crop of pigeon pea (12.6 larvae/10 plants). Significant reduction in pod infestation was also recorded in the intercropped plot (14.88%) compared to the plot with the sole crop (20.95%) of pigeon pea. The sole crop of pigeon pea recorded the highest mean population (21.8 bugs/10 plants) in the sole crop compared to the intercropped plots (8.4 bugs/10 plants). The population of major predators like coccinellids and spiders per plant was higher in pigeon pea intercropped with sunflower (15.1 coccinellids and 9.5 spiders/10 plants) and marigold (15.4 coccinellids and 5.7 spiders/10 plants). The results of the study confirmed the role of crop diversification in enhancing the natural biological control of key pests in pigeon pea.

Taking advantage of the Foldscope in biocontrol research and practice

SREERAMA KUMAR PRAKYA*
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
**Corresponding author E-mail*: psreeramakumar@yahoo.co.in

Foldscope, the ultra-affordable paper microscope, has been successfully tried in a suite of activities related to biological control. Minute pests such as aphids, whiteflies, thrips and mites were found to be easy to examine under the Foldscope, which gives a magnification of up to 140×. Certain scale insects and crawlers of mealybugs could also be observed clearly. The 2-micron resolution obtainable was sufficient to differentiate several biocontrol fungi as well as plant pathogens and nematodes. A number of commonly found natural enemies, including parasitoids (e.g., *Trichogramma chilonis*), predatory mites (e.g., *Amblyseius largoensis*, *Neoseiulus longispinosus*, *N. paspalivorus*), plant disease antagonists (e.g., *Trichoderma* spp.) and entomopathogenic fungi (e.g., *Beauveria bassiana*, *Metarhizium anisopliae*), were easily visualized under the Foldscope. Parasitised eggs of insects and fungus-fungus interactions could be clearly examined. The utility of this newly introduced device in biocontrol research and practice is explained.

Utility of nematodes as baits for diversity analysis of nematophagous fungi from selected agro-climatic zones of India

RAMI KASSAM*, DEEBA KAMIL and UMA RAO
Division of Nematology, LBS center, ICAR - Indian Agricultural Research Institute, New Delhi - 110012, India
**Corresponding author E-mail*: ramikassam9@gmail.com

Among the microorganisms that parasitize nematodes or reduce nematode populations by their antagonistic behaviour, some of the fungi have shown great potential as biocontrol agents. The objective of this study was to reinvestigate the local fungal diversity across selected states of India that could be playing a key role in maintaining the natural balance of nematode population *vis-a-vis* to exploit the potential ones for their management. In the present study soil samples were collected from 13 Indian states from the rhizosphere of perennial trees, pulses, cereals, fruits and vegetables and used for isolating nematophagous fungi employing *Meloidogyne incognita* and *Caenorhabditis elegans* as baits in water agar petri plates. Isolation and purification of various fungi revealed the presence of some predominant species belonging to both plant pathogenic and non-pathogenic groups. Based on traditional and molecular technologies the fungi were identified as: *Fusarium verticillioides, F. oxysporum, F. solani, Phoma* sp., *Curvularia lunata, Alternaria* sp., *Trichoderma asperellum, T. harzianum, Paecilomyces fumosoroseus, P. lilacinus, Beauveria bassiana, Arthrobotrys oligospora*. Evaluation of these fungi has shown very interesting and novel leads regarding the natural balance of nematode populations. In view of this, the importance of various fungi in the dynamics of plant parasitic nematodes with particular reference to *M. incognita* under natural field conditions through different mode of actions will be presented.

Plant growth promoting and biocontrol *Actinobacteria* from temperate regions

T. K. RADHA*, T. R. RUPA, G. SELVAKUMAR, A. N. GANESHAMURTHY and K. L. CHINTHANA

ICAR - Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bengaluru - 560089, Karnataka, India

**Corresponding author E-mail*: radhamicro@gmail.com

Actinobacteria are an important group of soil microorganisms involved in decomposition of organic materials andhave the ability to promote plant growth. In addition, they have biocontrol ability against plant pathogens. In our study efforts were made to isolate and screen Actinobacteria from temperate regions for plant growth promoting attributes and for biocontrol potential against *Xanthomonas axonopodis* pv. *punicea.* Soil samples were collected from pomegranate orchards in temperate regions of Jammu and Kashmir, Uttarakhand and Himachal Pradesh. The pH of the soil samples varied from 7.25 to 8.56, EC ranged from 0.22 to 0.96 ds/m, organic carbon 0.15 to 1.97% and available NPK content in the range of low to medium. Actinobacteria were isolated on different media like Actinomycetes isolation agar, ISP-2 medium (International Streptomyces Project), Modified Nutrient agar and Kenknight and Munaier's medium. More than 80 different morphotypes of Actinobacteria were isolated and screened for biocontrol potential against *Xanthomonas axonopodis* pv. *punicea*, out of the 80 isolates tested, 20 isolates showed inhibition zones ranging from 0.80 cm to 2.50 cm under dual culture technique. 30 isolates also exhibited phosphate and zinc solubilizing ability on respective media. Further, these isolates have to be tested under *in vivo* conditions. The identified strains from our study have high potential for suppressing plant pathogens and solubilization of nutrients in pomegranate.

The first report of *Steinernema cholashanense* (Rhabditida: Steinernematidae) from India and its biocontrol potential against potato pests

PRIYANK MHATRE[*], JAGADEESH PATIL, R. VIJAYAKUMAR, E. P. VENKATASALAM and K. L. DIVYA
ICAR - Central Potato Research Station, Udhagamandalam, Nilgiris - 643004, Tamil Nadu, India
[*]*Corresponding author E-mail*: 37riyank.iari@gmail.com

Entomopathogenic nematode (EPNs) belongs to families Steinernematidae and Heterorhabditidae and are the lethal obligate parasites of insect pests which kill a wide range of economically important insect pests. There are several target pests in India that can be controlled with EPNs. There is also a tremendous opportunity for discovery of new nematode strains and species adapted to local environmental conditions and pests. Therefore, in the present study efforts were made to isolate the native strains/species of EPNs. A random sampling was done and soil samples were collected from the farm of ICAR-CPRS, Udhagamandalam, Tamil Nadu, India. The soil samples were baited with black cutworms and observed regularly for their mortality. From dead insects, EPNs were extracted using white trap method. Based on morphological and morphometrical studies, *Steinernema* CPRSUS01 strain showed the resemblance to *Steinernema cholashanense*. Further identity was confirmed with molecular characterization using the ITS-rDNA region. The ITS region of rDNA yielded a single fragment of approximately 735 base pairs and sequence was deposited into the GenBank database (Accession no. MH065747). The sequence of this EPN revealed 99% similarity with *S. cholashanense* isolate from Nepal (GQ377419) and Pakistan (MF039642) and 96% with China population (EF431959). To our knowledge, this is the first report of *S. cholashanense* from India. *S. cholashanense* CPRSUS01 is capable of causing 100% mortality in early instars of *Agrotis ipsilon* and *Phthorimaea operculella* under laboratory condition. Hence the *S. cholashanense* CPRSUS01 can be used for the management of potato insect pests.

Natural enemies in mango ecosystem

SHIVAMURTHY[*] and T. JIJI
Kerala Agricultural University, College of Agriculture, Vellayani - 695522, Kerala, India
[*]*Corresponding author E-mail*: agrico5539@gmail.com

Use of pesticides to manage the insect pests can bring about short term advantage to mango producers. However, this can adversely affect the co-existing natural enemies in the mango ecosystem. In this study, an attempt has been made to understand the role of natural enemies and evaluate the safer molecules in managing the different pests of mango. The observations were recorded by dividing the plant canopy into four quadrants, during January 2015 to December 2016 at two different locations of Thiruvananthapuram district, Kerala. Predatory spiders in the mango ecosystem were identified as *Oxyopes javanus* Thorell, *Argiope pulchella* Thorell, and *Tetragnatha* sp. Predatory reduvid bugs were also recorded feeding on wide variety of insects. Praying mantids, green ants, red ants, mantispids, green lace wings and coccinellid larva were also recorded during the observation. It was observed that the highest number of natural enemies was observed during Feb-March (13.5/quadrant). The least number of natural enemies was during July-August month (4.5/quadrant). During the rest of the observation period, the population of natural enemy remained in a range of 8-10/ quadrants. Along with this, experiment was conducted to evaluate safer molecules to manage the mango hoppers and leaf webber. Among the 10 treatments, *Beauveria bassiana* (ITCC 6063) WP 2% showed the presence of more number of natural enemies (9/quadrant), followed by Azadiractin 1% (7.5/quadrant) after the treatment. Natural enemy numbers in chlorantraniliprole 0.03%, flubendiamide 0.01%, thiamethoxam 0.005%, malathion 0.1%, spinosad 0.015%, emamectin benzoate 0.002%, imidacloprid 0.005%, dimethoate 0.05%, deltamethrin 0.05% and lambda cyhalothrin 0.005% treated plants were in decreasing order. It is clear from study that the natural enemy population closely follows with the pest population. Use of microbial, botanical and green labeled molecules showed relatively high number of natural enemies.

An easy high throughput analysis method for screening of potential biosurfactants population isolated from Shakurbasti railway diesel engine yard

TOUSEEF HUSSAIN[*] and ABRAR AHMAD KHAN
Aligarh Muslim University, Aligarh, India
[*]*Corresponding author E-mail*: hussaintouseef@yahoo.co.in

The wide diversity of biosurfactants makes them an attractive group of compounds for potential use in variety of agricultural and biotechnological applications. Twenty different bacterial strains were isolated, selected and purified from Shakurbasti railway diesel engine shed yard. To confirm the ability of biosurfactant production, among 20 strains, only SKNDLS-08 exhibit good biosurfactant producing activity on GSP agar plate and *Pseudomonas* agar plate and was further screened on the basis of different methods. Our findings suggest that SKNDLS-08 was a *Pseudomonas* spp. which showed the maximum emulsification activity of EI24 (80%), blood hemolysis (> 2cm), CTAB agar plate (> 2cm), qualitative microplate assay, drop collapse on slide. SKNDLS-08 isolate was used to evaluate the antagonistic potential for bio management of potato black scurf disease caused by *Rhizoctonia solani* in dual culture technique, reduced the fungal mycelium (44.91%) and caused the lysis of mycelium of *R. solani* within 48 hr p.i. SKNDLS-08 isolate will further be tested for the production and efficacy of volatile metabolite against *R. solani*. These methods do not need specialized equipment or chemicals and excludes the bias which results from the surfactant properties of medium used for bacterial growth and due to low toxicity these biosurfactants can be efficiently used and in bioremediation purposes.

Session 2: BIOTECHNOLOGICAL APPROACHES IN BIOCONTROL

S2-LP-01

Small insecticidal molecules against crop pests

RAJ KAMAL BHATNAGAR[*] and NISHTHA NAYYAR
International Centre for Genetic Engineering and Biotechnology, Aruna Asaf Ali Marg, New Delhi - 110067, India
[*]*Corresponding author E-mail*: raj@icgeb.res.in

Previous decades have seen excessive use of chemical insecticides to control insect-mediated crop losses. However, toxicological and ecological concerns lead to the quest for more sustainable biological molecules as an alternative. The advent of *Bt* technology witnessed its supersession over chemical control measures and reinvigorated the potential of bio-insecticides as a commercially viable option. But the development of *Bt* resistance in insect populations has raised concerns and entails the invention of alternate measures. In this review, we discuss the recent advancements in the field of *Bt* toxins and evaluate the potential of other insecticidal proteins as well as RNAi pathway as the next generation insecticidal technologies.

S2-LP-02

Role of transgenic *Bt* crops in promoting biological control and integrated pest management

T. M. MANJUNATH*
Director (Retd.), Monsanto Research Centre and Former Vice President, Bio-Control Research Laboratories, PCI, C/o 174, G - Block, Sahakaranagar, Bengaluru - 560092, Karnataka, India
**Corresponding author E-mail*: manjunathtm@gmail.com

Since their commercial introduction in 1996 in the USA, the insect resistant transgenic *Bt* crops, notably *Bt* cotton for control of the notorious cotton bollworms (*Helicoverpa/ Heliothis*, *Earias* and *Pectinophora*) and *Bt* corn against the European corn borer, *Ostrinia nubilalis* (Hubner) have given effective control of target pests and found overwhelming adoption in several countries. As of 2017, these *Bt* crops were cultivated in 14 countries on 101 mha, including 11.4 mha of *Bt* cotton in India, which comprised 53% of 189.8 mha of all GM crops grown in 24 countries. Such extensive cultivation of *Bt* crops, incorporated with genes derived from the bacterium *Bacillus thuringiensis* (*Bt*) that produce host-specific insecticidal proteins, has resulted in higher crop yields by 22% owing to effective control of target pests, increased farmers' profit by 68% and reduced chemical insecticide applications by 37%, thereby providing social, economic, health and environmental benefits. The reduced chemical sprays have contributed to the conservation of parasitoids and predators leading to enhanced biological control, especially of sucking and other non-lepidopteron pests that are not controlled by *Bt*. Further, this technology is user-friendly as it is made available in the seed itself, safe to the environment and non-target organisms including parasitoids and predators, and very powerful that it can match the temporal efficacy of chemical pesticides, thus providing the much-needed strength and stability to IPM. This aspect is highlighted in this paper along with the development, commercialization, regulation, adoption, safety, benefits, and resistance management as well as certain controversies associated with this technology.

S2-OP-01

Yeast volatile organic compounds inhibit ochratoxin-A production by *Aspergillus carbonarius* (Bainier)

QUIRICO MIGHELI[1*], MARIA GRAZIA FARBO[1], PAOLO URGEGHE[1], STEFANO FIORI[1], ZAHOOR UL-HASSAN[2] and SAMIR JAOUA[2]

[1]*Dipartimento di Agraria, Università degli Studi di Sassari, Viale Italia, Sassari, Italy*

[2]*Department of Biological and Environmental Sciences, College of Arts and Sciences, Qatar University, P.O. Box - 2713, Doha, Qatar*

[*]*Corresponding author E-mail*: quirico.migheli@gmail.com

Foods and beverages produced in temperate and tropical regions are susceptible to contamination by ochratoxin-A (OTA), one of the most harmful mycotoxins for human and animal health. *Aspergillus carbonarius* (Bainier) is one of the most frequently isolated OTA producers. Low or non- fermenting yeasts are able to control the growth and sporulation of OTA-producing Aspergilli *in vitro* and on detached grape berries: the biocontrol effect is partly due to the release of volatile organic compounds (VOCs). Beside vegetative growth and sporulation, yeast VOCs significantly reduced the *in vitro* production of OTA by *A. carbonarius*. Exposure to yeast VOCs also affected gene expression, as confirmed by down regulation of polyketide synthase, non-ribosomal peptide synthase and the regulatory genes laeA and veA. The main compound of yeast VOCs was 2-phenylethanol, detected by Headspace-Solid Phase Microextraction-Gas Chromatography-Tandem Mass Spectrometry (HS-SPME-GC-MS) analysis. Yeast VOCs may represent a promising tool for the containment of growth and development of mycotoxigenic fungi, and a valuable aid to prevent food contamination with OTA. Future studies shall evaluate the efficacy of 2-phenylethanol on different commodities/mycotoxigenic fungi.

S2-OP-02

Silencing of a *Meloidogyne incognita* mucin-like gene reduces *Pasteuria penetrans* endospore adhesion on the juvenile cuticle surface

UMA RAO*, VICTOR PHANI and VISHAL SINGH SOMVANSHI
Division of Nematology, ICAR - Indian Agricultural Research Institute, LBS Building, Pusa, New Delhi - 110012, India
**Corresponding author E-mail*: umarao@iari.res.in

Pasteuria penetrans is a gram-positive, endospore-forming soil bacterium of Bacillus–Clostridium clade and is used as a commercial biological control agent against root-knot nematodes of *Meloidogyne* spp. The obligate nature of the bacterium is a major limitation in its wide-scale use. The soil-dwelling bacterial endospores attach to the migrating juveniles' body surface, germinate, proliferate and ultimately kill the nematodes. Mucins are highly glycosylated polypeptides involved in several host-parasite interactions. In order to investigate the factors governing *Meloidogyne-Pasteuria* interaction, we hypothesized that mucin could be an important candidate. We cloned and characterized a full-length mucin-like gene from *M. incognita* (Mi-muc-1, 1125 bp). The protein was found to be rich in serine and threonine with numerous O-glycosylation sites in the sequence. *In situ* hybridization revealed the localization of Mi-muc-1 mRNA in the phasmidial region of the tail. RNAi mediated knockdown of Mi-muc-1 caused a significant five-fold reduction in adhesion of endospores and red blood cells on the nematode body cuticle. RNAi mediated knockdown of Mi-muc-1 led to a 40% reduction in the nematode multiplication factor. Our results suggest that *M. incognita* mucin is directly involved in mediating the adhesion of *Pasteuria* endospores on nematode surface and in the interaction between the nematode and the host plants. In addition to mucin, similar studies focusing on other genes for understanding the molecular interactions between the nematode and *Pasteuria* can to be useful in improving the biological control potential of the latter.

S2-OP-03

Trichoderma virens XYPPX repeat protein (XRP1) is involved in regulation of conidiation and mycoparasitism

RAVINDRA BANSAL[*] and PRASUN K. MUKHERJEE
Bhabha Atomic Research Centre, Govt. of India, 2-4-H Mod Lab, Mumbai - 400085, Maharashtra, India
[*]*Corresponding author E-mail*: ravindra@barc.gov.in

The XYPPX repeat protein (XRP1) is rich in proline, glycine and tyrosine amino acids. *In-silico* studies suggested that the protein is membrane-bound. Role of this protein was studied by generating knockout mutants for this gene in *Trichoderma virens* wild type through double cross-over homologous recombination using split marker technique. Three independent mutants were generated and purified. These mutants were slow growing and had fewer conidiation compared to wild type. The mutants also lost the mycoparasitic ability against the plant pathogen *Sclerotium rolfsii*. Even the conidiation is a light-dependent process, but this gene expression was not affected by light. The XRP1 mutant also showed a significant difference in secondary metabolite viridin biosynthesis. These three characters *i.e.* conidiation, mycoparasitism activity and viridin biosynthesis, are directly and indirectly responsible for making the best *Trichoderma* formulation. The study of this gene would be useful to improve the biocontrol properties of *Trichoderma.*

S2-OP-04

Expression of a novel insecticidal protein from a bryophyte for control of sap sucking pests of cotton

SUBHI SRIVASTAVA[1*], HARPAL SINGH[1], PRAVEEN C. VERMA[1], SANCHITA SINGH[1], ALKA SRIVASTAVA[1], RATNA KATIYAR[2] and P. K. SINGH[1]

[1]*CPMB Division,* CSIR - *National Botanical Research Institute, Rana Pratap Marg, Lucknow - 226001, Uttar Pradesh, India*

[2]*Department of Botany, Lucknow University, Lucknow - 226007, Uttar Pradesh, India*

[*]*Corresponding author E-mail*: subhi.subhsri@gmail.com

Cotton (*Gossypium* sp.), being the major fiber yielding crop, requires biotechnological intervention to minimize yield loss due to insect manifestation. Whiteflies (*Bemisia tabaci*) are considered as the most serious pest in subtropical regions of the world. Whitefly infestation causes approximately 30% loss in the total productivity of cotton. Crude extracts of proteins from Bryophytes were screened for their activity against the sap-sucking pests and were found to cause significant mortality of whiteflies. A novel insecticidal protein was isolated from *Dumortiera hirsuta*. The purification was guided by the insecticidal activity. It was achieved by differential salting out of total soluble proteins with ammonium sulphate, followed by anion exchange and size exclusion chromatography. Final purified fractions were tested for their insecticidal property by insect bioassay. *De novo* sequencing was performed to know the sequence of the concerned protein. Full-length gene was amplified by RACE and was cloned in plant expression vector pBI121. Tobacco transformation was done for validation of protein in the plant system. Transgenic tobacco plants showed significant resistance against the target insect pests. Transgenic cotton plants expressing Dhi-31 were developed targeting these pests. The developed T0 cotton plants were tested in vitro for their activity against whiteflies and aphids. This will complement the existing *Bt* technology in controlling a broader spectrum of insect pests.

S2-OP-05

Prospecting for novel *Bacillus thuringiensis* holotype crystal toxin genes in India

SINGARAVELU BALASUBRAMANIAN*, C. APPUNU, G. S. SURESHA, J. SRIKANTH, C. SANKARANARAYANAN, P. MAHESH, R. NIRMALA, M. RAJESHKUMAR and M. NAVEENARANI

Section of Entomology, ICAR - Sugarcane Breeding Institute, Coimbatore - 641007, Tamil Nadu, India

**Corresponding author E-mail*: bsingaravelu@rediffmail.com

Crystal toxin gene (Cry1) of *Bacillus thuringiensis* (*Bt*) is widely used in the development of transgenic crops for insect control ever since their first commercialization in 1996. Currently, 283 cry1 genes have been cloned and named, and 52 distinct Cry1 gene holotypes are recognized by the International Committee on *Bacillus thuringiensis* Crystal Toxin Nomenclature (http://www.lifesci.sussex.ac.uk/home/Neil_Crickmore/Bt/). A perusal of the database revealed that 20 Crystal toxins comprising 15 of Cry1A and 5 of Cry1I gene families are reported from India, but none of them are distinct holotype genes. In our prospecting studies, we have discovered a *Bt* isolate (SBI-KK 27) carrying multiple cry genes belonging to Cry1A, Cry1C, Cry1D, Cry1E, Cry1I, Cry2A and Vip3B families. Among the different Cry1 family genes identified in this isolate, Cry1D and Cry1E hold promise to be the first Cry1 holotype genes isolated from India. Preliminary bioassay of SBI-KK27 isolate against the sugarcane early shoot borer, *Chilo infuscatellus* Snellen (Lepidoptera: Crambidae), revealed the toxicity of this *Bt* isolate. Two *Bt* isolates harbouring Cry8 holotype genes have also been isolated by us. One of these isolates (*Bt*62) carrying holotype Cry8Sa1 gene (NCBI accession No. JQ740599) was found to be toxic to the polyphagous white grub, *Holotrichia serrata* F. (Coleoptera: Scarabaeidae), while another isolate (SBI-*Bt*41) was toxic to *Oryctes rhinoceros* (L.) (Coleoptera: Scarabaeidae). Functional validation of these Indian origin holotype Cry genes against important lepidopteran and coleopteran pests needs to be carried out for development of insect resistant transgenic crops.

S2-OP-06

Characterization of an insecticidal binary-toxin 'Photox' from Indian isolates of entomopathogenic *Photorhabdus* bacteria

VISHAL SOMVANSHI*, AMIT AHUJA, JYOTI KUSHWAH, UMA RAO, CHETNA MATHUR and TUSHAR DUTTA

Division of Nematology, ICAR - Indian Agricultural Research Institute, LBS Building, Pusa, New Delhi - 110012, India

**Corresponding author E-mail*: vishal.somvanshi@icar.gov.in

Photorhabdus are the bacterial symbionts of entomopathogenic *Heterorhabditis* nematodes and produce several insecticidal protein toxins. Photox is a 46 kDa binary-toxin of mono-ADP-ribosyl-transferases (mARTs) enzyme class and is known to kill insects of 25 different orders. Here, we investigated the genetic and toxicological variation in Photox toxin isolated from various Indian *Photorhabdus* strains. Seven *P. luminescens* strains (H-I, H-II, H-III, H-IV, H-V, H-VI, H-VII) were isolated from *Heterorhabditis* species collected from different geographical regions of India. We sequenced the genomes of five of these *Photorhabdus* species. The nucleotide sequence of Photox from Indian *Photorhabdus* showed considerable difference from the *P. luminescens laumondii* TTO1 Photox gene. The toxin genes from each of these strains were cloned into pGEMT Easy vector in *E. coli* DH5a. In addition, the protein toxin was expressed in pET vector and purified. The rapid virulence annotation assays and purified protein toxicity assays on *Galleria melonella* showed that H-IV Photox was significantly more toxic as compared to other Photox variants when injected at 10-5 dilution and showed LT_{50} = 48 h. In the protein toxicity assays, the H-IV showed LT_{50} = 12 h at 50 ppm dilution. This hypertoxic Photox variant may be introduced into commercially valuable crops through transgenic approaches for sustainable insect-pest management.

S2-OP-07

Management of *Bt* resistant pink bollworm, *Pectinophora gossypiella* (Saunders), in transgenic cotton by Cry1Ac-Vip3AcAa fusion protein: A molecular modeling study

SINDHU THANGARAJ, VENKATESAN THIRUVENGADAM*, GANDHI R. GRACY, MUTHUGOUNDER MOHAN and SUSHIL KUMAR JALALI

ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India

**Corresponding author E-mail*: tvenkat12@gmail.com

Genetically engineered cotton has been introduced to reduce the use of conventional insecticides. *Bt* cotton was initially successful in providing protection against lepidopteran pests; however, over the years, insect pests, especially cotton pink bollworm, *Pectinophora gossypiella*, have developed resistance against *Bacillus thuringiensis* delta-endotoxins (Cry1Ac). These delta-endotoxins are the most well-known insecticidal proteins that are extensively used in sprays and transgenic crops to control *P. gossypiella*. Such resistance issue can be addressed through the development of novel toxins with great toxicity and affinity against a broad range of receptors. Therefore, in the present study, the new insecticidal protein Vip3AcAa has been selected to develop a Cry1Ac-Vip3AcAa fusion protein. The protein Vip3AcAa is synthesized by *B. thuringiensis* during its vegetative growth phase. Molecular modeling method was used to predict the three-dimensional structure of the fusion protein Cry1Ac-Vip3AcAa. Further, molecular dynamics simulation was carried out to obtain the stable structure of the fusion protein. In another side, the three-dimensional structure of the insect-receptor cadherin was developed using computational methods. To achieve the more durable and broader-spectrum insecticidal activity, the developed fusion protein Cry1Ac-Vip3AcAa was inserted into the cadherin receptor through molecular docking study. From the results, it was seen that Cry1Ac-Vip3AcAa showed more hydrogen bond interactions with cadherin than Cry1Ac. These findings revealed that the fusion protein Cry1Ac-Vip3AcAa has a strong affinity against *P. gossypiella* receptor cadherin compared to Cry1Ac toxins. Hence, the fusion protein Cry1Ac-Vip3AcAa has a greater potential for protecting cotton from damage by *P. gossypiella.*

S2-OP-08

Evaluating the bio-insecticidal potential of recombinant spider venom peptide, μ-diguetoxin-Dc1a, against two major lepidopteran insect pests of cotton

BALWANT SINGH[*] and GURVINDER KAUR SAINI
Department of Biosciences and Bioengineering, Indian Institute of Technology, Guwahati - 781039, Assam, India
[*]*Corresponding author E-mail*: s.balwant@iitg.ernet.in

Extensive use of generic chemical insecticides to control insect pest population poses potential risks to human health and the environment because of the appearance of insect resistance. Recombinant anti-insect selective spider peptide toxins modulate voltage-gated ion channels, thus considered as an attractive alternative to chemical insecticides for efficient and environmentally safer means of insect pest control. In the present study, codon optimized gene of spider venom peptide, μ-diguetoxin-Dc1a, was successfully expressed as a soluble fusion protein in the periplasm of *Escherichia coli* NEB Express cells and purified using amylose affinity chromatography. The fusion protein was proteolytically cleaved with Factor Xa protease and size exclusion chromatography was used for further purification of toxin from fusion malE tag. Purified fractions of recombinant μ-diguetoxin-Dc1a (rDc1a) toxin were finally characterized using MALDI-TOF mass spectrometry, Circular dichroism (CD) and Western Blotting. The insecticidal activity of purified rDc1a protein was determined using an intra-hemocoel injection bioassay against two major lepidopteran insect pests *viz. Helicoverpa armigera* and *Spodoptera litura*. Injection bioassays demonstrated that rDc1a was toxic to lepidopteran larvae causing a spastic paralysis with 50% paralytic doses (PD_{50}) ranging from 0.73 to 1.12 nmol/g, indicating that rDc1a has a similar lethality to agricultural pests when compared with the native toxin. As the arsenal of chemical insecticides is diminishing rapidly due to the development of insect resistance, the significant high-level toxicity of rDc1a toxin renders it a potential candidate to be used as bio-insecticide like incorporation in recombinant baculovirus insecticides and construct transgenic plants.

S2-OP-09

Morphological and molecular characterization of *Microplitis maculipennis* Szépligeti (Hymenoptera: Braconidae) from India with notes on its generic placement

VENKATESAN THIRUVENGADAM*, ANKITA GUPTA, RAVI P. MOORE, PREETHI RAGURAMAN and REETA BASKHAR

ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India

**Corresponding author E-mail*: tvenkat12@gmail.com

Microplitis maculipennis Szépligeti is an important parasitoid of castor semilooper *Acanthodelta janata* (L.) a major pest of castor (*Ricinus communis* L.). *Microplitis* Förster shares a remarkable morphological resemblance with moderately diverse genus *Snellenius* Westwood. In this study, molecular characterization of *M. maculipennis* was done using cytochrome oxidase I (COI) to confirm its generic placement in the respective genus. The Bayesian inference (BI) and Maximum Likelihood (ML) phylogenetic analysis performed with a total of 354 published BOLD database sequences (after pre-processing of a total of 2257 COI sequences) of *Microplitis* and *Snellenius* species, representing 129 named species and 226 species determined only to genus raises doubts on the retention of both these genera separately. Our studies reveal that COI gene could not discriminate *Microplitis* and *Snellenius* species clearly.

S2-OP-10

Mining *Pseudomonas koreensis* P2 genome for key antimicrobial genes involved in biological control of plant diseases

ALOK KUMAR SRIVASTAVA[1], RUCHI SRIVASTAVA[1*], HILLOL CHAKDAR[1], PREM LAL KASHYAP[2] and ANIL KUMAR SAXENA[1]

[1]*ICAR - National Bureau of Agriculturally Important Microorganisms, Kushmaur, Maunath Bhanjan - 275103, Uttar Pradesh, India*

[2]*ICAR - Indian Institute of Wheat and Barley Research, Karnal - 132001, Haryana, India*

[*]*Corresponding author E-mail*: ruchisrivastava.biotech@gmail.com

It is well entrenched that most of the bacteria and fungi are hostile colonizers of soil and the roots of plants and thus provide biological control of soil-borne fungal pathogens through the production of antimicrobial compounds (metabolites and enzymes). *Pseudomonas koreensis* P2 is a psycrotolerant bacterium and it produces broad-spectrum antimicrobial metabolites that are responsible for its biocontrol activity. It produces a suite of antimicrobials including Phenazine and Pyoluteorin (an antifungal compound of a bichlorinated pyrrole linked to a resorcinol moiety). It also produces hydrogen cyanide and the siderophore pyoverdine which can suppress target pathogens in the rhizosphere through iron chelation. In this study, we mined the genes responsible for the biosynthesis of antimicrobial (antifungal and antibacterial) compounds from the genome of *P. koreensis* P2. The results revealed the presence of genes (plt/Polyketide synthase modules and related proteins/Acyl-CoA thioesterase II) required for the biosynthesis of pyoluteorin. Phenazine biosynthesis protein PhzF like, uncharacterized isomerase yddE, PhzC-PhzF family, acting in trans to activate the expression phenazine biosynthetic genes were identified. hcnABC gene cluster encoding hydrogen cyanide synthase, PvdS genes involved in the biosynthesis of pyoverdine and ABC transporter for the transportation of the siderophore were found in the genomic sequence of P2. Knowledge of the genes responsible for the production of antimicrobial metabolites will help to clearly understand the biocontrol mechanisms operating in bacteria and to manipulate organisms to produce multiple or novel metabolites not previously described.

Double-stranded RNA-mediated silencing of Chitin Synthase (ChS) gene affects larval development in *Leucinodes orbonalis*

SHIPRA SAXENA[*] and M. V. RAJAM
Department of Genetics, University of Delhi, South Campus, Benito Juarez Road, Dhaula Kuan, New Delhi - 110021, India
[*]*Corresponding author E-mail*: biotech.shiprasaxena@gmail.com

Brinjal (*Solanum melongena*) is the major vegetable crop in India. The crop is extensively affected by *Leucinodes orbonalis* with fruit damage as high as 95% and yield losses of up to 70% in commercial plantings. Use of conventional chemical pesticides damages the environment, including the biotic and abiotic components, and also affects human health. Limited success has been achieved in developing resistant cultivars through traditional plant breeding. *Bt* transgenic approach is successful, but the possibility of resistance by target pest against *Bt* toxin is a major concern. Recently, RNA interference (RNAi) has emerged as a potent method for down-regulating the expression of any gene of interest and proven to be a novel alternative for insect control. Chitin is an essential component of insect cuticle, midgut peritrophic matrix, and several other anatomical structures. It is influenced directly by several enzymes, including Chitin synthase (ChS), Chitinase (CHI) and N-acetyl-glucosaminidase (NAG). Functional analysis using RNAi in various insect species showed that ChSs are essential for survival, ecdysis, oviposition and egg hatching. These findings represent ChS as a vulnerable and insect-selective target for a potential RNAi-mediated pest control strategy. In the present work, partial LoChS cDNA sequence was cloned using degenerate primers. LoChS specific dsRNA expression and formulation was performed in HT115 *Escherichia coli* using L4440 expression vector. Feeding bacterially expressed dsChS in second-instar larvae specifically knocked down their target mRNA and larvae failed to ecdyse, pupate, or emerge as adults as compared to control diet fed larvae. Thus, bacterially expressed dsChS has great potential for effective management of *L. orbonalis*.

de novo genome sequencing and hybrid assembly approaches for complex insect genomes

DUSHYANT SINGH BAGHEL*, K. HARISH, SAILU YELLABOINA and SATHISH PEDDAMMA

Nucleome Informatics Private Limited, 2nd Floor, Genome Block, Plot No. 135, Mythrinagar Phase I, Madinaguda, Hyderabad - 500049, Telangana, India

**Corresponding author E-mail*: dushyant@nucleomeinfo.com

The Insects are the most diverse animal group with approximately 1,000,000 described species. Among the 14 orders of insects studied, the largest genome was found in the mountain grasshopper *Podisma pedestris* (1C-value is 16.93 pg). This genome is about 170-fold larger than the smallest genomes (0.1 pg) of *Psychoda cinerea*, *Coboldia fuscipes*, *Aphidius colemani*, and *Peristenus stygicus* and it indicates that insect genome sizes can vary significantly among species from different orders. The insect gene number is not proportional to the genome size, indicating the complexity of insect genetics. Repeats and elongated introns are another critical issues during assembly of insect genomes. Insects are often physically small, such that very little DNA (nanograms) can be obtained from a single individual, necessitating pooled polymorphic individuals to make libraries which enhances heterozygosity. Hight molecular weight gDNA isolation often has to be optimised for a new insect species. Nucleome has developed High molecular gDNA isolation protocol (50 to 150kb) from pooled insect samples. We use the extensive analysis pipeline for assembly, scaffolding, gap filling, polishing and annotation of insect genomes on datasets generated on fourth generation solutions like 10x genomics, PacBio Sequel and Optical Mapping. The 10x chromium library preparation needs just 1ng starting material to prepare a library and produces up to 100kb linked reads. With diploid aware assemblers like Falcon and Falcon Unzip right quality assembly can be achieved. Supernova assembly of 10x data can be used for hybrid assembly. Optical mapping data support in building consensus maps, super-scaffolding and orientation of the scaffolds.

S2-PP-01

Diversity and molecular phylogeny of *Bt* receptor genes in the genome of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Lepidoptera: Crambidae)

B. KARIYANNA, ADITI AGRAWAL, T. VENKATESAN, R. GANDHI GRACY, S. K. JALALI and M. MOHAN
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
Corresponding author E-mail: kariyannabento@gmail.com

Brinjal or eggplant, *Solanum melongena* L. is one of the top ten vegetables in the world and India ranks second in production after China. The yield and marketable quality of the fruits are severely affected due to the infestation of brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guenee, causing significant loss up to 70 per cent. As a result, brinjal receives multiple applications of the mixture of chemical pesticides. To combat the problem and to reduce the load of pesticides, transgenic brinjal expressing the Cry genes of *Bacillus thuringiensis* is developed and commercialized in Bangladesh. The potential receptors in the midgut region of lepidopteran larvae for Cry toxins are Aminopeptidase N (APN), Cadherins, Alkaline phosphatase (ALN) and ABC binding Cassettes receptor subfamily C2 (ABCC2). The number and diversity of these genes have both evolutionary and environmental significance. Through Illumina and PacBio whole genome and transciptome sequencing, we have identified 52259 annotated unigenes in the genome of *L. orbonalis*. The draft genome mining identified 26 APN, 43 Cadherin, 12 ALN and 108 ABCC2 genes after the genome BLAST against NCBI database. Molecular phylogenies were constrcted by extracting the number genes, *viz.* APN, Cadherin, ALN and ABCC2 from the following lepidopteran *viz. Bombyx mori* (19, 22, 8 and 75), *Plutella xylostella* (24, 23, 4 and 153), *Spodoptera litura* (33, 35, 11 and 174) and *Helicoverpa armigera* (22, 36, 10 and 118). Like other Lepidopteran insects, the genome of *L. orbonalis* possesses an array of *Bt* Cry toxin receptor genes. The information has immense practical significance for the identification and validation of receptors, the molecular basis for receptor recognition and the role of the receptors in case of resistance development.

S2-PP-02

Development of transgenic cotton (*Gossypium hirsutum* L.) by over expressing a pectin methylesterase gene for broad spectrum resistance against crop insects

ALKA SRIVASTAVA*, GOURAV JAIN and PRAVEEN C. VERMA
CPMB Division, CSIR - National Botanical Research Institute, Rana Pratap Marg, Lucknow - 226001, Uttar Pradesh, India
**Corresponding author E-mail*: alka.shivangi@gmail.com

In the present scenario, 30% of crop production is adversely affected by insect pests and the use of insecticides and pesticides adds to the cost of production. Although the use of insecticides has beneficial effects, they cause severe environmental and health hazards. In the present study, we have shown that manipulating plant's own defense mechanism can impart broad-spectrum insect resistance to plants. Methanol is one of the simplest organic products of plant metabolism and second major volatile organic compound emitted through leaf surface. Naturally occurring methanol is produced by C1 metabolism in plants and also by degradation of pectin in cell walls. Pectin Methylesterase (PME; EC 3.1.1.11) hydrolyzes cell wall pectin and releases methanol via leaf stomata. Over-expression of PME gene derived from *Aspergillus niger* under the control of constitutive promoter in transgenic tobacco plants enhances methanol production and showed upto16 fold higher methanol emission and a maximum of 100% and 85% mortality in *Helicoverpa armigera* and *Spodoptera litura*. Since the continuous over-expression of transgene provides extra genetic load to plant system, therefore, use of an insect inducible promoter to drive AnPME gene for the regulated methanol emission was envisaged. Agrobacterium-mediated genetic transformation of cotton var. (Coker 312) with both (constitutive and inducible) expression system was performed. Preliminary studies of insect bio-assay against *H. armigera* and *S. litura* showed 55% and 65% mortality with upon insect inducible transgenic plants events. The survived insect showed drastic weight reduction and was not further developing to fly to complete their life cycle.

S2-PP-03

Molecular characterization and phylogeny of Indian coccinellids

R. GANDHI GRACY*, T. VENKATESAN, K. SRINIVASAMURTHY and S. K. JALALI

ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India

**Corresponding author E-mail*: gandhi_gracy@yahoo.co.in

Coccinellids play a major role, both in conservative as well as augmentative biological control. In India, several species, especially *Cryptoleamus montrouzieri,* play a major role in the biological control of the green scale *Coccus viridis*. Proper identification and timely releases of biocontrol agents are important in any biological control programme. This study is aimed to develop DNA barcoding for the identification of Indian coccinellids. Around 27 species of coccinellids were collected from different agroclimatic zones across India and identified using the taxonomical key. The genomic DNA has been extracted from each identified specimen using Qiagen Blood and Tissue assay Kit following the manufacturers' instruction. PCR amplification of partial gene sequences of mitochondrial COI gene was done by using the universal COI primers for all the 27 species. Estimation of genetic distance between the species using their COI gene sequences was performed using MEGA.7 software. Molecular phylogeny was constructed using MEGA 7.0 to know the species evolutionary pattern and to define the species delineating factors. The tree was constructed using Neighbour-Joining (NJ) method based on K-2 Parameter distance with the uniform rate of substitution, and the evolutionary pattern was inferred using bootstrap of 1000 replicates with the Jukes-Cantor model. The genetic distance analysis and the phylogeny showed that the intraspecies divergence is 3-5, hence > 3-5% sequence dissimilarity was considered as species delineating factor for the Indian coccinellids.

S2-PP-04

Identification of Cry toxin receptor homologs in a *de novo* transcriptome and their altered expression in resistant pink bollworm, *Pectinophora gossypiella*

ADITI AGRAWAL*, T. VENKATESAN, R. GANDHI GRACY, M. MOHAN, R. S. RAMYA and R. RANGESHWARAN

ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India

**Corresponding author E-mail*: aditigrawal@gmail.com

The pink bollworm, *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) is an important global pest of cotton. In many countries, transgenic cotton producing *Bacillus thuringiensis* (I) crystalline (Cry) proteins kills the pests including the pink bollworm, thereby providing economic and environmental benefits. However, the evolution of pest resistance poses a serious challenge to the continued use of the same genes in such crops. While field populations of the pink bollworm in the USA have remained susceptible to two different Cry toxins, Cry1Ac and Cry2Ab produced simultaneously in stacked *Bt*-cotton, field-evolved practical resistance to *Bt*-cotton has occurred widely in India, thereby threatening its sustainability. Since high levels of resistance to Cry proteins involve alterations in Cry-binding midgut receptors, their identification is needed to develop resistance management strategies. A pink bollworm midgut transcriptome of 26575 transcripts was assembled *de novo* from 20 million illumina Hiseq reads and used as reference for estimation of differential gene expression analysis. A total of 8831 midgut transcripts showed significant constitutive expression differences between *Bt* susceptible and resistant strains. Transcripts coding for previously identified Cry toxin receptors Cadherin, ABC-transportor, alkaline phosphatase, aminopeptidase-N and proteases were also differentially expressed in the midgut of the susceptible and resistant strains. This study significantly expands *P. gossypiella* transcriptomic resources and provides preliminary identification of putative receptor genes with altered expression in *P. gossypiella* resistant to Cry1Ac and Cry2Ab toxin.

S2-PP-05

Extract, Transform, Load (ETL): A data warehouse technique involved in decision support system for assisting in integrated pest management

J. CRUZ ANTONY[1*] and M. PRATHEEPA[2]
[1]Jain University, 102, S. M. Residency, #443, 8th Cross, Lakshmi Layout, Puttenahalli Road, J. P. Nagar 7th Phase, Bengaluru - 560078, Karnataka, India
[2]ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
[*]Corresponding author E-mail: cruzantony.nbaii@gmail.com

Pests can be a big blow to crop production if not properly predicted and controlled. Decision Support System (DSS) is a widely used software tool for pest predictions and thus enable timely and appropriate decisions to be taken for Integrated Pest Management (IPM). DSS tool performs analytical explorations on pest population and its influencing environmental factors for decision making. Such analytical exploration needs efficient data storage and retrieval mechanism wherein the data warehousing technique plays a vital role. Generally, Data Warehouse (DW) is a method used for storing historical and integrated data to support Business Intelligence. In the present study, Extract, Transform, Load (ETL), a DW technique is proposed for data integration as the data is heterogeneous *viz*. pest population on soybean crop from five major districts of Maharashtra and also its respective abiotic features. This DW technique has helped to maintain data integrity, consistency when the voluminous raw data are collected from multiple sources and in time-saving while collating information for the pest management decisions.

S2-PP-06

Identification and isolation of arcelin gene from bruchid resistant pulse variety, *Phaseolus lunatus* by designing gene specific primer

K. HILDA*, S. BHUVARAGAVAN and S. JANARTHANAN
Department of Zoology, University of Madras, Guindy Campus, Chennai - 600025, Tamil Nadu, India
**Corresponding author E-mail*: khilda777@gmail.com

Arcelin (Arc) is a novel anti-metabolic insecticidal seed protein present in several wild accessions of Mexican common bean, *Phaseolus vulgaris*. They belong to multi-gene family encoded by APA locus (arcelin/phytohemagglutinin/a- amylase inhibitors). In recent years, these plant defense proteins are used for crop protection either by conventional breeding or by genetic engineering. We have retrieved all the Arc and Arc-like mRNA variants from genebank, NCBI and legume lectin domains, both alpha and beta lectin signatures, and its N-glycosylation sites were identified by Scan Prosite tool (ExPASy). For designing gene specific primer, all the mRNA was aligned (Clustal Omega) and conserved domain along the N- and C- terminal regions were translated to obtain forward and reverse primers, respectively. Total cDNA obtained from tender leaves and seeds of *P. lunatus* that revealed resistance towards infestation of the bruchid pest, *Callosobruchus maculatus* as against the most susceptible seed variety *Vigna unguiculata* that was used as the template for PCR analysis. Amplification was observed only in seeds of resistant variety (*P. lunatus*), whereas it was completely absent in *Vigna unguiculata*. It was then sequenced and amplicon size was 688 bp. The sequence was further deduced to protein level and its functional domains were identified. Cloning and expression of this functional domain for large scale production of arcelin protein which possesses antibiosis effect against bruchid pest, *C. maculatus* is under investigation.

S2-PP-07

Combining proteomics and transcriptome sequencing to identify putative RNAi targets for the mealybug, *Phenacoccus solenopsis* and their functional validation

SANCHITA SINGH[*], SURJEET KUMAR ARYA, PRAVEEN CHANDRA VERMA and SUBHI SRIVASTAVA

CPMB Division, CSIR - National Botanical Research Institute, Rana Pratap Marg, Lucknow - 226001, Uttar Pradesh, India

[*]*Corresponding author E-mail*: sanchitasingh1993@gmail.com

Cotton mealybug, *Phenacoccus solenopsis*, is a major insect pest of cotton plant, causing extensive crop damage and productivity losses. Different stages of mealybug have their own way of spreading and damaging the crop plants. In this context, we have studied the genome-wide response of mealybug infesting cotton using transcriptomic and proteomic approaches. Comparative analyses have revealed that 40% of the transcriptome and 45% of the proteome were differentially regulated among the different developmental stages. Further transcriptomic and proteomic study showed that developmental and hormone biosynthesis related genes were stimulated, whereas Glycerolipid metabolism, Starch and sucrose metabolism, mTOR signaling pathway were down-regulated. Some differentially expressed genes are associated with functional protein synthesis, anti-microbial protection, development and hormone biosynthesis. Our comprehensive genome-wide analyses have revealed several new and interesting insights into different developmental stages of mealybug. Functional pathway enrichment analysis of differentially expressed genes showed the positive correlation with specific physiological activities of each stage, and these results were confirmed by qRT-PCR experiments. Knowledge gained through this study could be further exploited to develop RNAi strategy against the pest in controlling their spread.

S2-PP-08

Fern rhizome lectin confers broad-spectrum insect resistance in transgenic tobacco

SUSHMITA[*] and PRAVEEN C. VERMA
National Botanical Research Institute, Lucknow - 226001, Uttar Pradesh, India
[*]*Corresponding author E-mail*: sushmitaf17.18@gmail.com

Agricultural crop losses due to insect pest are one of the major limiting factors in agricultural productivity. In the current study, we purified a lectin from the rhizome of a pteridophyte (ML) and characterized it. Native ML was purified from the source plant by affinity-based chromatography using mannose-agarose column up to 95% homogeneity with agglutination activity with concentration 1250 ng/ml. After six days, the LC_{50} of native ML against *Spodoptera litura* is 221.40 µg/ml. The gene of ML is cloned from the source plant using degenerate primers. Complete ORF of ML consists of 447 nucleotides with ~60 % GC content. This potential lectin was then over-expressed in transgenic tobacco plant via *Agrobacterium*-mediated genetic transformation. Putative transgenic lines showed 50% - 75% mortality against chewing pests *Helicoverpa armigera* and *S. litura*. Transgenic plants of ML showed normal growth and their morphological features like stomata, trichome and their density were also similar to the control plants. ML offers a new strategy for obtaining broad-spectrum insect resistance without compromising plant yield and quality.

.

Session 3: PRODUCTION AND UTILIZATION OF MICROBIALS FOR INSECT PEST AND DISEASE MANAGEMENT

S3-LP-01

Biological control in compliance with the Nagoya Protocol: access and benefit sharing

DAVID SMITH*
Director Biological Resources, CABI, Bakeham Lane, Egham, Surrey, TW209TY, United Kingdom
**Corresponding author E-mail*: d.smith@cabi.org

Biological control agents must be collected and utilized in compliance with the Nagoya Protocol on Access and Benefit Sharing (ABS) which is being implemented independently by each country that is signatory to the Protocol. January 2018 saw 50 countries with legislation in place with an additional 50 plus designing their legislative, administrative or policy measures having become party to the protocol. In addition to the problem of dealing with the many different mechanisms countries are putting in place there are a number of issues still to be resolved. These include how to deal with digital sequence information and what activities are considered utilization. It is important that research and development, addressing global societal challenges are not impeded and that science and its output is considered. European guidance considers elements of research and development in biological control trigger the Protocol and benefits should be shared from its use. Even though most people regard classical biocontrol as a public good and success usually results in a release of a natural enemy, a biological control agent, into the environment with no associated revenue. It is essential that countries should agree that for such activities the benefits that are to be shared are the knowledge, know-how, procedures and formulations to produce the biological control solution. Countries that agree could then benefit from facilitated sourcing of organisms from like-minded countries.

S3-LP-02

Trichoderma for plant disease management - a gift of God to mankind

AMAR NATH MUKHOPADHYAY* and CHIRANTAN CHATTOPADHYAY
Former Vice Chancellor, Assam Agricultural University, Jorhat, Assam, India
**Corresponding author E-mail*: amar.mukhopadhyay@gmail.com

Among the microorganisms, *Trichoderma* spp. Are most commonly used as biological control agents and marketed as bio-pesticides, biofertilizers, growth enhancers and stimulants of natural resistance in a variety of fields, greenhouses, nurseries, vegetable, fruit, tree and ornamental crops. Biological control by *Trichoderma* is through direct antagonism of phytopathogenic fungi involving varied mechanisms. Some applications are also effective, such as foliar spray for the management of aerial pathogens with evidence of reduced sensibility to changing environmental conditions apart from active synergistic mixtures containing both the bioactive substances and the living microbial biological control agent. *Trichoderma* are also used as bio-degraders of compost and act as competitors of fungal pathogens in their saprophytic phases, when nutrients are a limiting factor. They are also recognized for their potential in bio and phyto bioremediation. The versatility of *Trichoderma* spp. Includes their adaptability to different ecological surroundings or agricultural situations, as well as to their compatibility with numerous commonly used crop protection products and other biocontrol agents, to synergism with many chemical pesticides and other natural compounds, thus permitting a reduction in the pesticide load normally used in the field. All of these characteristics enlarge the scope of potential applications of *Trichoderma*-based products in the agricultural market not only as a biofungicide against phytopathogens, but also as a general bio-inoculant and improves the agro-ecosystem. Research in *Trichoderma* through a multi-disciplinary approach encompassing ecological and evolutionary understanding could provide environmental, economic and social benefits.

Entomopathogenic fungal × bacterial interactions: potential implications for aphid biocontrol

JUSTIN HATTING*, SCOTT SYDENHAM, NICOLENE COCHRANE and CHUN CHEN
ARC Small Grain, Bethlehem, Free State, South Africa
**Corresponding author E-mail*: hattingj@arc.agric.za

Cereal aphids (Homoptera: Aphididae) are prone to infection by various species of entomopathogenic fungi (EPF), especially from the Entomophthoromycota. In South Africa, one such aphid, *Rhopalosiphum padi*, shows a level of low-susceptibility towards these EPF, compared to more susceptible species like *Diuraphis noxia* and *Metopolophium dirhodum*. Aphid fitness is governed by an obligate, nutrient-provisioning symbiosis with bacteria. However, the effects of the symbiont × aphid interaction on host susceptibility to EPF, is poorly understood. Likewise, bacterial × EPF interactions, whether endophytic or epiphytic, remains largely unexplored. Here, we report on (1) the bacterial complex recorded from the EPF, *Conidiobolus thromboides* (Entomophthorales: Ancylistaceae), following fungal passage through these three aphid hosts and re-isolation on antibiotic versus antibiotic-free culture media; and (2) conidiogenesis/vegetative growth of *C. thromboides* as affected by different bacterial 'loads'. 16S rRNA metagenomics analyses (illumina® software, using Greengenes Database) revealed a surprisingly diverse bacterial complex from *C. thromboides*, averaging 141 ± 10 species across the three aphid backgrounds. The top 7 bacteria comprised a total of 30 species. The most prevalent of these, from the *R. padi*, *D. noxia* and *M. dirhodum* backgrounds, was *Pseudomonas tremae* (77%, 54% and 52%, respectively; antibiotic-free medium). Although only detected at trace levels, a *Serratia-R. padi* association creates an interesting anomaly, as both *S. entomophila* and *S. marcescens* include entomopathogenic strains. Its association with a more 'resistant' aphid species may imply a level of antagonism towards EPF, with subsequent protection against fungal infection. This performance-mediating hypothesis was tested through laboratory bioassays and results are discussed.

S3-OP-02

A baseline study using Plantwise information to assess the contribution of extension services to the uptake of augmentative biological control in selected low to lower middle-income countries

STEVEN EDGINGTON[*]
CABI, Bakeham Lane, Egham, Surrey, TW209TY, United Kingdom
[*]*Corresponding author E-mail*: s.edgington@cabi.org

The uptake of augmentative biological control agents (BCAs) is still limited, particularly in many low to lower middle-income countries. This study focuses on factors that affect the uptake of BCAs for arthropod pests by national extension partners (NEPs) in Plantwise – an agricultural development programme facilitating the establishment of plant clinics where farmers can obtain diagnosis and plant health advice. Using data generated by NEPs, BCA recommendations that appear in extension material and/or are given by extension workers at plant clinics in Ghana, Kenya, Zambia, India, Nepal and Pakistan were analyzed. BCA recommendations were in 13.0% (Zambia) to 61.1% (India) of the extension materials assessed and were in 0.0% (Zambia) to 18.2% (India) of recommendations given by extension workers. Knowledge, availability and price were identified as the main factors affecting the uptake and inclusion of BCA recommendations by NEPs. This baseline study gives novel insight into the potential of NEPs to facilitate the use of BCAs.

S3-OP-03

Bio-protection of cucumber seedlings from *Pythium aphanidermatum* with native antagonistic rhizobacteria

ISSA HASHIL SAID AL-MAHMOOLI*
Sultan Qaboos University, College of Agricultural and Marine Sciences, Department of Crop Sciences, Alkhoud, Muscat, Sultanate of Oman
**Corresponding author E-mail*: issah@squ.edu.om

The potential of native antagonistic bacteria isolated from the rhizosphere of cucumber for the management of damping-off caused by *Pythium aphanidermatum* was evaluated under greenhouse conditions. A total of 34 different bacteria were isolated from the rhizosphere soil samples collected from commercial cucumber fields of Barka, Muscat were screened for their ability to inhibit the growth of *P. aphanidermatum* in dual culture assay. Of the 34 isolates, only 4 isolates (B-11, B-9, AT-3 and 4-A) inhibited the mycelial growth of *P. aphanidermatum* and produced inhibition zones (> 5 mm). The rest of the isolates failed to produce inhibition or produced less than 5 mm. Among the 4 isolates, B-11 produced the highest inhibition zone followed by 9 and AT-3 and recorded inhibition zones of 14 mm, 13 mm and 11 mm respectively. The plant growth promoting activity of four effective antagonistic bacteria was evaluated and these bacteria were identified based on sequence analysis of 16S rDNA gene. The potential of two most effective antagonists, *Pseudomonas resinovorans* (B-11) and *Pseudomonas aeruginosa* (AT-3) were evaluated either individually or in combination with a commercial formulation of *Trichoderma viride* against damping off under greenhouse conditions. Soil application of *P. resinovorans* (B-11) significantly reduced damping-off and increased the percentage of healthy seedlings when compared to *P. aeruginosa* (AT-3) alone or in combination with *T. viride*. This biocontrol treatment exhibited a similar level of control to the soil application with Ridomil or with commercial *T. viride* formulation.

Microbial control of filth flies using fungal, viral, and bacterial agents

CHIRSTOPHER GEDEN*
Center for Medical, Agricultural and Veterinary Entomology, USDA, ARS, 1600 SW 23rd Drive, Gainesville, Florida, USA
**Corresponding author E-mail*: chris.geden@ars.usda.gov

Filth flies such as house flies (*Musca domestica*) and stable flies (*Stomoxys calcitrans*) are two of the most important pests of animal production throughout the world. House fly is especially problematic because it can transmit microbial agents of a myriad of human and animal disease and it is difficult to control with insecticides because of resistance problems. Most of the research on filth fly biological control has focused on parasitic wasps that attack the fly in the pupal stage, but there is an urgent need to develop agents to target other life stages. Salivary gland hypertrophy virus is an interesting pathogen that infects adult house flies and renders them sterile. Efforts to develop this pathogen as a practical BC agent have been stymied by the efficiency of the fly's peritrophic matrix to resist per os infection. Fungal pathogens, especially *Beauveria bassiana*, are promising and some are now available as commercial products. *B. bassiana* can be combined with artificial sweeteners to make bait that does not give the fly a "free" sugar meal. When attempts were made to synergize *B. bassiana* by combining it with bacterial pathogens, combinations with *Pseudomonas protegens* were more effective against adult flies than either pathogen alone, whereas the addition of *Serratia marcescens* and *Photorhabdus temperata* had little effect. *P. protegens* also has potential as a larvicide, especially against stable fly larvae. Some of this activity is due to a toxin produced by *P. protegens* that is effective on its own.

S3-OP-05

Emerging opportunities in field of capacity building and development to promote use of microbial pesticide in Asia

MALVIKA CHAUDHARY*, VINOD PANDIT and RAJENDRAN GANESHAMOORTHY
CABI, CG Block, NASC Complex, DP Shastri Marg, New Delhi - 110012, India
***Corresponding author E-mail*: m.chaudhary@cabi.org

Microbial pesticides have largely been under discussion especially with focus on its extent of use. The constraints flagged are dissemination of information and utilization in spite of considerable amount of efforts put for research for the advancement of technology. Other bottlenecks are lack of need assessment, low understanding across the sector, non-consistent promotion of the technology as alternate to use of pesticide. Across Asia the pattern of advancement and utilization of bio pesticide is not uniform. This paper investigates not only countries like India that has made a big leap in the technology but also less conversant nation like Myanmar. Observations from countries like Nepal, Bangladesh and Sri Lanka form an average status on technology. The policies supporting the technology either presents a miniscule focus pending or nonexistent legislation. The research is focused more on basic aspects, than application or mechanism to promote technology amongst the farmers. There is limited scope of these products in shelves of agro dealers when compared to other inputs. The reason being non-awareness and non-acceptance amongst farmers for microbial as alternates to pesticide. Through research number of technologies addressing major pest and diseases of concern are standardized but the actual use in field is limited in current plant protection practices. Numbers of such cases are observed in the study where these microbes can replace the use of highly hazardous pesticides that are currently practiced.

S3-OP-06

Characterization and evaluation of nucleopolyhedroviruses against lepidopteran pests of crops

G SIVAKUMAR[1*], M. KANNAN[2], M. MOHAN[1], SURABHI KUMARI[1], P. RAVEENDRAN[1], R. RANGESHWARAN[1], VEEGALA RAMESH BABU[3], RICHA VARSHNEY[1] and CHANDISH R. BALLAL[1]

[1]*ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India*

[2]*Department of Nano Science and Technology, Tamil Nadu Agricultural University, Coimbatore - 641003, Tamil Nadu, India*

[3]*Central Research Institute for Jute and Allied Fibres, Barrackpore, Kolkata - 700120, West Bengal, India*

[*]*Corresponding author E-mail*: sivakumarg.nbaii@gmail.com

Chemicalisation is no longer considered sustainable since several agrochemicals when used indiscriminately has led to resistance development besides causing serious environmental problems. Consumer concern about chemical pesticide residues on food is driving the search for an alternative method of pest control. New research suggests that bio-control technology, using insect viruses, could be an effective alternative and environment friendly technique for the management of lepidopteran pests. Five isolates of nucleopolyhedroviruses have been isolated from major insect pests belong to Lepidoptera. Scanning and Transmission electron microscopic studies revealed the polyhedral structures of occlusion bodies of nucleopolyhedrovirus (NPVs). Polyhedral occlusion bodies of *Helicoverpa armigera* NPV (HearNPV) and *Spodoptera litura* NPV (SlNPV) appeared as irregular and tetrahedral, *Spilosoma obliqua* NPV(SoNPV), *Euproctis* NPVappeared as tetrahedral, *Mythimna separata* NPV appeared as hexagonal. Under electron microscopy viruses appeared as crystalline structures of variable shapes of size 0.460-1.030 µm (HearNPV), 0.860- 2.171µm (SlNPV), 1.499 µm to 1.700 µm (MsNPV) and 0.186-1.376 µm (SoNPV) in diameter.The LC50 values observed for second instar larvae were 0.17 POB/mm^2 for HearNPV, 4.23 POB/mm^2 for SlNPV, 1.23 POB/mm^2 for MsNPV and 2.93 POB/mm^2 for SoNPV. Molecular characterization and identity of SlNPV, HearNPV, SoNPV was done using polyhedron (polh) gene. Application of aqueous suspension of SlNPV and SoNPV in grape and Jute fields brought about 90 % and 92% reduction in larval numbers respectively on 10th day of application. It is concluded that the application NPVs could be an effective alternative for the management lepidopteron pests.

S3-OP-07

Potential use of bacterial endophytes and carbendazim tolerant *Trichoderma* for the management of pomegranate wilt caused by *Ceratocystis fimbriata*

SUBBARAMAN SRIRAM*
ICAR - Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bengaluru - 560089, Karnataka, India
**Corresponding author E-mail*: sriram@iihr.res.in

Pomegranate (*Punica granatum*) is a semi-arid zone fruit crop that has excellent medicinal and anti-oxidant properties. The cultivation of this crop has gained importance and area under cultivation has grown over the last two decades. Besides the notorious bacterial blight, the wilt disease caused by *Ceratocystis fimbriata* is a serious production constraint. *C. fimbriata* is a slow pathogen that enters the plant through root system and enters vascular region slowly compared to other vascular wilt pathogens. It produces toxins that cause the yellowing and wilting of the plants. Though use of systemic fungicides is being adopted by the farmers, considering the residual toxicity and export potential it is required to exploit the biological methods to manage the disease. The use of biocontrol agents like *Trichoderma* species can help only in protecting the rhizosphere population. Once the pathogen enters the root system, it cannot be recovered from infection as the bioagents do not enter into the plant system. In such situation the fungicide tolerant *Trichoderma harzianum* that is compatible with systemic fungicides can help. *Trichoderma* can help in reducing the pathogen population in the rhizosphere and systemic chemical can help in recovering the infected plant by its systemic action. *T. harzianum* isolate, GJ16B that was tolerant to carbendazim and propiconazole but was efficient in reducing the growth of *C. fimbriata* and its population and it protected the pomegranate trees when applied along with carbendazim or propiconazole at 0.1%. Combined treatment could protect 9 out of 10 trees even 6 months after pathogen inoculation while in pathogen inoculated plants by 6^{th} month 4 out of 10 trees succumbed to pathogen infection. Simultaneously the endophytes from leaf, stem and roots of pomegranate plants were isolated and screened for their efficacy against *C. fimbriata*. Endophytes from stem and leaves were not effective in inhibiting *C. fimbirata*. Some of them enhanced the perithecia production in *C. fimbriata*. Endophyte isolate PRE4 from root inhibited its growth and sporulation completely which can be exploited for the management of pomegranate wilt as a component of integrated disease management.

S3-OP-08

Entomopathogenic nematodes: isolation from sugarcane fields of subtropical India, bio-efficacy studies against white grub and mass production by monoxenic liquid fermentation technique

SANKARANARAYANAN CHELLAPPA*, B. SINGARAVELU, M. RAJESH KUMAR and S. K. PANDEY

ICAR - Sugarcane Breeding Institute, Coimbatore - 641007, Tamil Nadu, India

**Corresponding author E-mail*: chellappasankar@gmail.com

Survey was conducted in white grub endemic areas of subtropical sugarcane ecosystem in Western UP, Haryana, Punjab and Uttarakhand. From 304 soil samples that were baited with *Galleria mellonella* larvae, 29 soil samples yielded *Heterorhabditis* (16) and *Steinernema* (13). EPN isolates were morphologically identified and confirmed by molecular characterization of the internal transcribed spacer (ITS) region of the nuclear ribosomal genes. Phylogenetic analysis of *Heterorhabditis* and *Steinernema* isolates found during the survey was done based on analysis of the ITS rDNA regions. The major EPNs observed from the subtropical area were *Heterorhabditis indica, H. bacteriophora, S. abbasi, S. carpocapsae, S. siyamkayai, S. surkhetense* and *S. thermophilum*. Pathogenicity studies were conducted with subtropical EPN against larvae of *G. mellonella* and 1st instar white grub *Holotrichia serrata* under laboratory conditions. Mortality of both insects for various EPN dosages was tested and dose dependent mortality was observed. LD_{50} values ranged from 5 to 74 IJs/*G. mellonella* larvae while it was 22.8 to116.6 IJs per white grub. Mass production of EPN, *Steinernema abbasi* strain SBIP4 was attempted by monoxenic liquid culture method. Nine different media composition were tried with or without carbon and lipid sources. Successful multiplication of EPN observed in liquid media and the yield of *S. abbasi* was 8700 IJs/ml of media which was 43-fold compared to initial inoculum. The *in vitro* mass produced IJs were bio assayed against *G. mellonella* and mortality of *G. mellonella* was observed with in vitro produced nematodes.

S3-PP-01

Pseudomonas fluorescens as a biological control agent against *Plutella xylostella* in Cabbage

KANDAN ARAVINDARAM*, U. AMALA, R. RANGESHWARAN and CHANDISH R. BALLAL

ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India

**Corresponding author E-mail*: a.kandan@icar.gov.in

Bio-pesticides offer an alternative option to chemical pesticides because of their low environmental pollution and low toxicity to human health. *Pseudomonas fluorescens* shows insecticidal activity against insect pests. Certain strains of plant root-colonizing *P. fluorescens* bacteria display insect suppression activity, promote plant growth and induce systemic plant defenses. The aim of this study was to evaluate the effectiveness of the entomopathogenic bacteria *P. fluorescens* strain PfDWD against the *Plutella xylostella*. Larvicidal bioassays were performed with different dosages of *P. fluorescens* strains (10^9, 10^8, 10^5, 10^3 and 10^2 cfu/ml) with appropriate control. Two strains (CHA0 and PfDWD) and its combination were pathogenic to larvae of *P. xylostella*. LC50 value 1.88×10^3 cfu/ml of CHA0, 5.59×10^3 cfu/ml of PfDWD and 2.37×10^3cfu/ml of consortia of two strains. Cabbage leaves treated with *P. flourescens* deterred the adults of *P. xylostella* from oviposition recorded with lowest number of eggs laid (15.33) compared to control (57.0). Egg hatchability test showed very less hatchability of *P. xylostella* eggs in *P. fluorescens* strains treated samples compared to control. Under field conditions, PfDWD treated cabbage plots showed highly significant reduction of *P. xylostella* pest (60.33%) followed by CHA0 (36.33%) and consortia (56.67%) on 14^{th} day after treatment. Yield of cabbage increased significantly in *P. fluorescens* treated plants compared to untreated control. These results may suggest that both strains of *P. fluorescens* have potential to be used for management of *P. xylostella*.

Potential of entomopathogenic fungi against tea mosquito bug, *Helopeltis antonii* Signoret infesting cashew

M. S. SMITHA*, K. N. NITHIN and A. SOBHANA
Department of Agricultural Entomology, College of Horticulture, Vellanikkara, Kerala Agricultural University, Thrissur - 680656, Kerala, India
**Corresponding author E-mail*: smitha.ms@kau.in

Bioassay as well as field evaluation were conducted during 2014-2016 to exploit the potential of entomopathogenic fungi on tea mosquito bug, *Helopeltis antonii* Signoret infesting cashew. Bioassay was conducted in a completely randomized design with seven treatments; including three entomopathogenic fungi each at two concentrations *viz.* $1x10^8$ and 1×10^9 spores/ml and water spray as control, replicated thrice maintaining ten insects per replication. Field experiment was laid out in randomized block design consecutively for two years with these entomopathogens @ 10^8 spores/ml. Two sprays were given targeting flowering and nut set stage in the first year, while routine three sprays were followed at flushing, flowering and nut set in the second year. All the three fungi were found pathogenic to adult *H. antonii*. Mortality was observed on third day of inoculation, increased gradually with time, became evident on fifth day with 82.50, 85.00 and 65.00 per cent respectively by *Beauveria bassiana* Balsamo, *Metarhizium anisopliae* Metchnikoff and *Lecanicillium lecanii* Zimmerman @ 10^9 spores/ml. Hundred per cent mortality was observed at sixth day with *B. bassiana* and *M. anisopliae*. In the field evaluation, though the least damage was observed in Kerala Agricultural University Package of Practices (KAU POP) with λ-cyhalothrin-quinalphos-quinalphos rotation, both *B. bassiana* and *L. lecanii* recorded less damage, comparable with KAU POP. In the second year, *B. bassiana* was on par with KAU POP and both *B. bassiana* and *L. lecanii* were superior to control. *B. bassiana* recorded highest nut yield followed by KAU POP and were on par with each other.

S3-PP-03

Role of aphid derived bacteria in degradation of neonicotinoid insecticide, imidacloprid

MAHESH YANDIGERI*, SANJAY YALASHETTI, M. MOHAN and G. SIVAKUMAR

ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India

**Corresponding author E-mail*: micromahesh@gmail.com

Imidacloprid is a pesticide belonging to the neonicotinoids class, being systemic and contact insecticide with high activity. It is often used to kill sucking insects and effective against adult and larval stages. Interminable use of this pesticide has led to increase in pesticide resistance in aphids and its persistence in soil results in environmental pollution which demands remediation. The current investigation was attempted to isolate and characterize imidacloprid degrading bacteria from three aphids belonging to *Aphis craccivora, A. gossypii* and *Myzus persicae* from six geographical locations. A total of 24 bacteria from *A. craccivora*, 8 from *A. gossypii* and 2 from *M. persicae* were isolated and identified using 16S rDNA sequences. The degradation ability of the isolates was evaluated based on their growth on solid minimal salt medium (MSM) amended with different concentrations of imidacloprid 17.8% SL (as C and N source). Fifteen isolates were selected based on their growth on solid media and were tested using MSM broth amended with 100ppm imidacloprid for 7 days by recording growth (A600 nm). Two isolates with better growth in broth medium were subjected for quantitative estimation of the imidacloprid degradation using High Performance Liquid Chromatography (HPLC). The culture supernatant subjected to quantitative HPLC analysis revealed better imidacloprid degradation by *Exiguobacterium indicum* MPB-2 of 13.6% over 3.8% by *Pseudomonas hibiscicola* CCF 2-2. The study inferred that the isolates possessed the ability to degrade imidacloprid by utilizing it as C and N source and by converting imidacloprid in to its byproducts.

S3-PP-04

Bio efficacy of different biopesticides against major foliage feeders on soybean [*Glycine max* (L.) Merrill]

HEMANT SWAMI*
Department of Entomology, MPUAT, Udaipur, Rajasthan, India
**Corresponding author E-mail*: hemantswamy@gmail.com

The results of experiments on bioefficacy of biopesticides against foliage feeders of soybean crop during Kharif, 2016 and 2017 reveal that mean larval population of *Chrysideixis acuta* and *Spodoptera litura* per meter row length ranged from 1.94 to 9.37and 1.68 to 6.98 larvae per meter row length at 3, 7 and 10 days after the application of the treatments, respectively. The application of *Nomuraea rileyi* @ 1×10^8 conidia/litre proved highly effective in reducing the population of *C. acuta* and *S. litura* at 3, 7 and 10 days after the treatment application with mean larval population of 7.88, 4.94 and 1.94; 4.97, 2.76 and 1.68 larvae per meter row length at 3, 7 and 10 days during 2016 and 2017, respectively. The application of *Beauveria bassiana* $l \times 10^8$ cfu/ml minimum @ 5 ml/lit and Spinosad 45 SC @ 0.5 ml/litre followed the treatment application of *N. rileyi* @ 1×10^8 conidia/litre in reducing the larval population at 3, 7 and 10 days after the treatment application. Application of neem seed kernel extract @ 5% was least effective with mean larval population of 8.52, 7.06 and 6.82, 5.73, 4.63 and 4.56 larvae per meter row length at 3, 7 and 10 days after treatments application during 2016 and 2017, respectively. The grain yield was maximum in treatment *N. rileyi* (18.65 q/ha) followed by *B. bassiana* (16.72 q/ha), Spinosad (16.20 q/ha) *Metarhizium anisopliae* (15.78 q/ha), Dipel (15.13q/ha), Neem oil (14.81.72 q/ha) and Neem seed kernel extracts (14.65 q/ha).

S3-PP-05

Microbial biocides - prominent alternatives of tea disease management

SATYA RANJAN SARMAH*, PRANABANAND BHATTACHARYYA, ROFIKA BEGUM, PRSANTA DUTTA and ANOOP KUMAR BAROOAH
Tocklai Tea Research Institute, Tea Research association, Assam, India
**Corresponding author E-mail*: drsrsarmah@tocklai.net

Tea plants offer an ideal host for diverse pest and disease-causing organisms resulting significant crop losses. Increasing pesticide use leads to several adverse effects on environment including flora and fauna. Indiscriminate pesticide uses proves to be inadequate and ineffective in long run due to evolution and adaptation of pests and diseases. To overcome the crisis, there is an urgent need to search for some effective safer alternatives. Among them the beneficial microbes prove its potentiality as an effective biocontrol agent. Considerable success was achieved by using diverse microbial strains of tea ecosystem for controlling diseases in tea plantation of North East India. Multi locational field evaluation of locally isolated microbials were tested for its efficacy on Black rot, Red rust and Fusarium die back caused by *Corticium theae* and *C. invisum*, *Cephaleuros parasiticus* and *C. mycoidea* and *Fusarium solani* respectively. More than 70% reduction of diseases was achieved by microbial treatments in the trials. Among the microbes: *Bacillus, Trichoderma, Streptomyces, Pseudomonas, Azotobacter* species were found to be promising in reducing the disease. The potential microbial strains were identified using 16s rDNA homology. These were deposited in NCBI database. The findings indicate that potent microbial strains are the viable alternative of chemical pesticides in managing diseases of tea. The application technology of microbial biocides is being popularized among tea growers. To meet the demand a mass production unit of microbial biocide was established at Tocklai and continuously supplying quality microbial biocides for use in tea cultivation.

S3-PP-06

Comparative efficacy of liquid and talc-based formulations of *Trichoderma asperellum* with tebuconazole against *Cercospora* leaf spot of bhindi

RESHMY VIJAYARAGHAVAN*, N. DILNA, ANJALY VARGHESE and FRIDIN DAVIS
Kerala Agricultural University, Thrissur, Kerala, India
**Corresponding author E-mail*: reshmy.v@kau.in

Bhindi, one of the most important vegetable crops, is cultivated throughout tropics for its fibrous pods. The plants are susceptible to Cercospora leaf blight (*Cercospora abelmoschi*) where the typical symptoms are characterized by sooty black angular spots and cause severe defoliation. Chemical control based on the use of fungicides is found to be the most effective; however, they leave residue on fruits which are toxic to human beings. Attention is now focused on the use of microbial agents to combat the disease. Hence, an experiment was laid out with 6 treatments in the research plot of CoH, KAU. Treatments were applied on appearance of disease symptoms. Disease severity was recorded using 0-5 scale and PDS was calculated. It was observed that the systemic fungicide, tebuconazole @1.5 ml/l recorded minimum disease severity of 7.92% followed by the liquid and talc formulations of *Trichoderma asperellum* with 12.08 and 14.40% respectively. The results confirm that the fungicide tebuconazole and the formulations of *T. asperellum* were found effective for the management of the disease. However, when the fruits treated with tebuconazole were subjected to residue analysis, it was found that the residue fell below detectable level (BDL) only on 10^{th} day after spray and since the fruit is used without peeling, there is a tremendous risk of action of residues on human health and hence the use of *Trichoderma* is recommended which not only protect plants from infection but also enhances vegetative growth and can reduce the risk caused due to chemicals.

S3-PP-07

Cow manure compost inoculated with *Trichoderma* isolate for the management of sunflower charcoal rot caused by *Macrophomina phaseolina*

J. RAJA*
Department of Plant Pathology, Annamalai University, Chidambaram, Tamil Nadu, India
**Corresponding author E-mail*: rajaj_au@yahoo.co.in

Biological control capability of sixteen *Trichoderma* isolates against *Macrophomina phaseolina* was investigated using screening tests. Dual culture, volatile and non-volatiles tests revealed that *Trichoderma viride* (isolate TvAU-6) best inhibited the growth of *M. phaseolina* in vitro. Sunflower seeds treated with culture filtrate of *Trichoderma* isolates recorded maximum per cent germination and seedling vigour. The results of greenhouse experiments revealed that disease incidence in the soil application with *Trichoderma* isolate fortified cow manure compost was significantly lower than that of the talc-based powder formulation of *Trichoderma*. Cow manure compost alone for soil application showed the lowest effect in reducing charcoal rot disease. The compost application rate when increased consistently decreased the charcoal rot disease incidence. In field experiments, cow manure compost amended with *Trichoderma* isolate for soil application significantly reduced charcoal rot incidence and increasing the seed germination, stem girth, shoot and root lengths, head diameter and seed yield of sunflower crop over untreated control. Population of *M. phaseolina* was reduced when cow manure compost amended with *Trichoderma i*n sunflower plant rhizosphere. The total fungal, bacterial and *Trichoderma* populations were considerably increased. The activity of chitinase and glucanase increased in response to infection with *M. phaseolina* and to a much higher extent as the result of cow manure compost amended with *Trichoderma* as compared with untreated plants. The investigations demonstrate that application of *Trichoderma* colonized cow manure to the soil for the management of charcoal rot disease of sunflower.

S3-PP-08

Biological control of tomato collar rot by endophyte *Bacillus haynesii* 2P2

PRAMOD KUMAR SAHU*, G. P. BRAHMAPRAKASH and ANIL K. SAXENA
ICAR - National Bureau of Agriculturally Important Microorganisms, Kushmaur, Maunath Bhanjan - 275103, Uttar Pradesh, India
**Corresponding author E-mail*: pramod15589@gmail.com

Bacterial endophytes are reported to have protective effects against different plant pathogens. The vast diversity can be screened for isolating potential endophytes giving higher degree of protection. In this study, bacterial endophytes from different cultivars of tomato were isolated and screened for biocontrol. In these, 15 were found having good suppressive ability against three soil borne pathogens of tomato namely, *Sclerotium rolfsii*, *Fusarium oxysporum* f. sp. *Lycopersici* and *Rhizoctonia solani*. Isolates were further screened based on production of siderophore, ammonia, cyclic lipopeptides, HCN and other inhibitory volatile organic compound production. Dual plate assay indicated highest suppression of 78.02% of *Sclerotium rolfsii* by 2PR9b, 74.56% of *Fusarium oxysporum* f. sp. *Lycopersici* by 2P2 and 70.81% of *Rhizoctonia solani* by 3TR2b1. Molecular identification was done by 16s rRNA partial sequencing approach and isolates were screened for genes related to biocontrol activity (iturin, surfactin and bacillomycin). Promising isolates were also screened for seedling vigor enhancement in tomato using paper towel assay. Three bacterial endophytes, *Bacillus haynesii* 2P2; *Bacillus altitudinis* 2PR9b and *Bacillus wiedmannii* 1PR7a had given good antagonism against *Sclerotium rolfsii*and promoted initial growth and development of tomato seedlings. In pot trial, varied response of endophytes against collar rot pathogen *Sclerotium rolfsii* was observed. Induced systemic resistance was tested by phenylalanine ammonia lyase, peroxidase, poly phenol oxidase and ascorbate oxidase activity. Confocal Scanning Laser Microscopy was also used for visualizing impacts of inoculation. There was clear indication of *Bacillus haynesii* 2P2 antagonism on collar rot of tomato.

Comparative infectivity of *Lecanicillium* spp to rice hoppers

S. S. HARI SANKAR* and O. P. REJI RANI
College of Agriculture, Kerala, India
**Corresponding author E-mail*: ssharisankar93@gmail.com

Hoppers being a major constraint in the rice production devitalize the crop transmitting viral diseases like tungro and yellow dwarf. Highly persistent chemical insecticides decimate the natural enemies and pollute water bodies. The genus *Lecanicillium* is known for its pathogenicity to wide variety of sucking pests. A comparison of a potent indigenous isolate of *L. saksenae* (ITCC LsVs 7714) with the NBAIR isolate of *L. lecanii* (Vl8) on their infectivity to paddy hoppers *viz*. *Nilaparvata lugens*, *Nephotettix nigropictus*, *Cofana spectra,* and *Nisia nervosa* were done by bioassay using uniformly aged nymphs and adults. Test insects were sprayed with conidial suspension of the microbes @ 10^7 spores ml^{-1} for ascertaining pathogenicity, and spore suspensions ranging from 10^3 to 10^8 spores ml^{-1} were used for bioassay. Symptoms of mycosis included lethargy and cessation of feeding. *L. saksenae* @ 10^7 spores ml^{-1}, killed all the insects within 72-120 h, while with *L. lecanii* it took 144-168 h. *L. lecanii* was not infective at lower concentrations of 10^6 to 10^4. The LC_{50} values calculated for nymphs of BPH revealed high virulent nature of *L. saksenae* (1.68×10^4 spores ml^{-1}) compared to *L. lecanii* (1.22×10^5 spores ml^{-1}), with a similar trend in all other species and stages tested. This study proves that *L. saksenae* is an ideal candidate for management of rice hoppers. Better performance of EPF can be achieved using more adaptable and virulent geographic isolates.

Sequence analysis and bioassay of *Bacillus thuringiensis* (NBAIR-BTAN4) shows that it is a promising candidate for coleopteran and lepidopteran pests

RANGESHWARAN RAJAGOPAL*, M. MOHAN, A. N. SHYLESHA, MAHESH YANDIGERI, V. APOORVA, G. SIVAKUMAR and JAGADEESH PATIL
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
**Corresponding author E-mail*: rangeshw@gmail.com

A novel *Bacillus thuringiensis* isolate (NBAIR-BTAN4) which expresses bipramidal and spherical crystals was initially identified as toxic to coleopteran pests. Sequence analysis of its genome showed that it expresses Cry2Ab, Cry1Ac, Cry1Ia and Cry2Aa crystal proteins. It also carries 22 other toxin genes including a rare mosquitocidal toxin. Cry1Ia is active against coleopteran pests *Holotrichia* sp. And 50% mortality observed in 76h. The isolate also caused 100% mortality in *Plutella xylostella* within 48h. Against *Sitophilus oryzae* (stored grain pest) a NBAIR-BTAN4 was comparable with the standard strain and was the most toxic among the indigenous isolates tested. BTAN4 showed the least LC_{50} value of 89.65 µg/ml and the standard strain showed LC50 value of 85.26 µg/ml. Also, against *Callosobrochus chinensis* NBAIR-BTAN4 showed very high toxicity (6.85µg/ml).

Management of chilli anthracnose using mycopesticides

NEELAM JOSHI*, K. S. SANGHA, P. S. SHERA and D. S. BUTTAR
Department of Entomology, Punjab Agricultural University, Ludhiana - 141004, Punjab, India
**Corresponding author E-mail*: neelamjoshi_01@pau.edu

Chilli anthracnose is one of the major economic constraints to chilli pepper production worldwide, especially in tropical and subtropical regions. Anthracnose, caused by various species of *Colletotrichum* spp., shows typical symptoms on chilli fruits which include sunken necrotic tissues, with concentric rings of acervuli. Typical anthracnose fungicides are not sustainable, especially due to the high cost and risks to the environment. Hence, present study was carried out to evaluate different mycopesticides for the management of anthracnose on chilli (var. chilli CH1) under Punjab conditions. There were three different mycopesticides *viz*. *Pichia guilliermondii*, *Hanseniaspora uvarum*, *Trichoderma harzianum*, along with recommended fungicide Indofil M 45 and untreated control. There was seedling dip treatment along with three foliar sprays of mycopesticides. The pooled data of two consecutive years revealed that among various fungal antagonists evaluated for the management of chilli anthracnose disease *T. harzianum* was best in terms of lower per cent fruit rot incidence and higher yield. However, chemical control Indofil M 45 (48.36%) recorded highest per cent reduction of fruit rot over control followed by *T. harzianum* (33.04%) and *P. guilliermondii* (32.68%). All treatments were better than untreated control.

A success story in developing and commercializing a biopesticide "SOLDIER"- a wettable powder formulation of an entomopathogenic nematode, *Heterorhabditis indica* for managing cryptic pests in different agroecosystems in India

S. KUMAR*, S. K. GHOSH, T. NATRAJ and MAHESH G SHETTY
Multiplex Biotech Private Limited, Bengaluru, Karnataka, India
**Corresponding author E-mail*: swapan_1966@hotmail.com

Considering the growing commercial demand Multiplex Biotech private limited (MBT) had obtained EPN technology from NBAII during 2012 and extended it in commercial scale with their in-house RandD and innovative production devices of both host insect (wax moth, *Galleria* sp.) and virulent IJ of *Heterorhabditis indica* strain NBAII Hi1. MBT has successfully scaled up the production capacity more than 20 MT per month within a span of 6 years and delivering in the market as "SOLDIER" with a load of 50-75,000 IJ/gm and shelf-life 8-12 months. Besides mass production, present paper will discuss more on its effective delivery and field performance aspects. MBT could carry out large scale field demonstration against cardamom root grub (*Basilepta* sp.) and recorded 80-90% control after two applications with an effective dosage of 4kg SOLDIER/acre. Similarly, 70-80% control was achieved against arecanut root grubs (*Leucopholis* sp.) by spot application at the plant base and > 50% control of sugarcane root grubs (*Holotricha* sp.) by applying through broadcasting method @ 10kg/acre. An effective control (> 90%) of banana pseudo stem weevil (*Odoiporus longicolis*) was recorded while SOLDIER was applied @ 5gm/plant or 5kg/acre. EPN based products compatibility with insecticides like Imidacloprid which helps to immobilize the insect pest and facilitate rapid penetration of EPN is a scope for discussion along with other water-soluble fertilizers. Sharing of filed experience in extending an EPN based technology in commercial scale, constrain and future possibilities for improvement would be an added scope for the discussion.

Isolation and characterization of *Serratia marcescens* as a bacterial pathogen in fruit piercing moths, *Eudocima* (*Othreis*) *materna* (L.) (Lepidoptera: Noctuidae)

VANDANA VISWANATH*, ARTHIKIRUBHA AYYASAMY and P. D. KAMALA JAYANTHI
T. Stanes Ltd, Bengaluru, Karnataka, India
**Corresponding author E-mail*: phytopharmatestinglab@gmail.com

Members of Genus *Serratia* are well known entomopathogenic bacteria that exhibit pathogenicity across a wide range of insect hosts. In the present study *Serratia marcescens* was isolated and characterized from the field infected larvae of fruit piercing moths (FPM), *Eudocima* (*Othreis*) *materna* (L.) (Lepidoptera: Noctuidae), using molecular identification and bioassays. 16S rDNA sequence analysis and phylogenetic study revealed that the strain belongs to the Genus *Serratia*, showing high sequence similarity (99%) with several strains of *S. marcescens* associated with insects in a clade with strong branch support. The supernatant of S. *marcescens* (LC_{50} - 1.02×10^6 CFU/µl) (SmSt) was swabbed on to the leaves of *E. materna* larval host plant, Amruthaballi (*Tinospora cordifolia* L.) and placed in the sterile petridish containing third and fifth instar larvae of *E. materna* separately for feeding bioassays for a period of 24-48 hrs. Whereas, heat treated S. *marcescens* culture supernatant (HSmSt) and sterile broth supernatant (SbSt) served as controls. After 72 hrs, the larvae fed on SmSt treated leaves showed high mortality associated with characteristic symptoms of reddish bleeding while larvae fed on HSmSt treated leaves showed comparatively less mortality. While the larvae fed on SbSt treated leaves were found healthy and didn't show any characteristic symptoms. Together, the present study showed the possibility of using *S. marcescens* isolate in microbial control of FPM by following the necessary safety concerns. Further, studies to isolate and identify the specific bioactive molecule from this bacterial source against FPM larvae may facilitate its application in the management of larval populations.

S3-PP-14

Isolation of entomopathogenic nematodes (EPNs) and their bio-efficacy against insect-pests of sugarcane in Maharashtra

YOGESH THORAT*, D. N. BORSE, S. K. HOLKAR, A. D. PATHAK and S. N. SINGH
ICAR - Indian Institute of Sugarcane Research, Lucknow - 226002, Uttar Pradesh, India
**Corresponding author E-mail*: yogesh.thorat@icar.gov.in

Sugarcane (*Saccharum officinarum* L.) is an important cash crop of the India. In Maharashtra, the crop productivity has lowered due to deleterious effects of major insect-pests viz., Early shoot borer (*Chilo infuscatellus*), armyworm (*Spodoptera exempta*), and white grub (*Holotrichia* and *Phyllognathus* spp.). Larval stages of these insects are injurious to cane development that causes severe losses in sugarcane every year. Exploitation of efficient EPNs as bio-agents against these pests would be the best strategy to reduce crop loss. In our study, 40 soil samples were collected from sugarcane field at Pravara nagar for isolation of EPN species using *Galleria mellonella* as bait. A brown/maroon colored dead larva was observed in soil samples, isolated and kept on wet blotting paper for incubation at RT for 2 days. The color of dead larva changed from whitish yellow to brown/maroon, no foul smell emanated from cadaver and cuticle became soft. The cadaver was placed white trap apparatus in the inverted position for emergence of infective juveniles (IJs). The isolated EPN species was identified as (*Heterorhabditis* spp.) based on location of excretory pore and presence of mural tooth in IJs. A bio efficacy study was conducted where concentration of 50 IJ3s per ml was sufficient for 40.8% and 62.1% mortality of *G. mellonella* at 3 DAT and 7 DAT, respectively. Hundred IJ3s per ml was effective and caused 43% mortality of early shoot borer larvae and 40% mortality of army worm after 3 DAT.

S3-PP-15

Evaluation of entomopathogenic fungi against *Bemisia tabaci* in tomato and capsicum under protected cultivation

B. RAMANUJAM and B. POORNESHA*
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
**Corresponding author E-mail*: poorniintbiotech@gmail.com

The effect of different isolates of *Beauveria bassiana* (Bb-5a, Bb-36, Bb-68 and Bb-9), *Metarhizium anisopliae* (Ma-42, Ma-41 and Ma-6) and *Lecanicillum lecanii* (Vl-8, Vl-12 and Vl-32) against *Bemisia tabaci* on tomato and capsicum under protected cultivation were conducted for two consecutive years (2012 and 2013). Among the tested isolates, Bb-9, Vl-8 and Bb-5a showed superior suppression of whitefly population in tomato with per cent reduction of 66.56, 65.65 and 59.54% respectively and the same isolates showed 73.15, 71.84 and 63.10% reduction in capsicum respectively. The yields were superior in all treated plots over control.

Survey on polyhouse pests of vegetable cowpea in Kottayam district of Kerala and their management using entomopathogenic fungi

SIBLE GEORGE VARGHESE*, R. PRAVEENA and D. AMBIKA DEVI
RARS, Kerala Agricultural University, Kumarakom, Kerala, India
**Corresponding author E-mail*: sible.gv@kau.in

Survey was done in yard long bean (*Vigna unguiculata* subsp. *Sesquipedalis*) grown in polyhouses of Kottayam district, Kerala, India during 2016 and 2017 for incidence of pests and diseases. Incidence of tetranychid mite *Tetranychus truncatus* Ehara (population ranging from 2-5/cm^2) and white fly *Bemisia tabaci* (0-5/plant) were observed in 50 per cent of polyhouses surveyed during 2016. Infestation of serpentine leaf miner, *Liriomyza trifolii* was recorded in 30 per cent of polyhouses surveyed with 30 to 40 per cent of infested leaves. Incidence of diseases *viz.* powdery mildew, sooty mould, *Cercospora* leaf spot and rust were recorded. During 2017, incidence of serpentine leaf miner and tetranychid mite were observed. Infestation of *Spodoptera litura* was also seen in some polyhouses. Experiment was laid out in polyhouse during 2016 to test the efficacy of entomopathogenic fungi *viz. Beauveria bassiana* and *Lecanicillium lecanii* against various sucking pests of cowpea. Observations recorded 5, 7 and 9 days after second spraying showed *Beauveria bassiana* 1% (10^8 spores/ml and 10^9 spores/ml) and *Lecanicillium lecanii* 1% (10^9 spores/ml) to be to be on par with insecticide Spiromesifen @ 96 g ai ha^{-1} in reducing aphid population. Observations recorded at 3, 5, 7 and 9 days after third spraying also showed the same trend where both the biopesticides at both doses were on par with the insecticide Spiromesifen @ 96 g ai ha^{-1} in reducing aphid incidence. During the experiments in 2017, observations recorded on 3, 5 and 7 days after third spraying also showed that both the entomopathogenic fungi were effective in reducing aphid population.

Role of gut microflora in toxicity of *Bacillus thuringiensis* subspecies *galleriae* to the larvae of *Spodoptera litura* (Lepidoptera: Noctuidae)

SANJAY YALASHETTI*, ONKARAPPA RUDRAPPA, MAHESH S. YANDIGERI and M. MOHAN
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
**Corresponding author E-mail*: sanjuhrg@gmail.com

It is well known that synergistic and additive effects both between *Bt* toxins and other compounds do occur. Mode of action of *B. thuringiensis* (*Bt*) Cry toxins are very specific. Different strains of Bt are specific to different receptors in insect gut wall. Bt toxicity depends on recognizing receptors, damage to the gut by the toxin occurs upon binding to a receptor. Each insect species possesses different types of receptors. Comparatively less attention has been devoted to other important research aspects, such as the complex network of molecular interactions underpinning the host killing mechanism and the role of factors other than the pore-forming toxins that contribute to *B. thuringiensis* pathogenicity and virulence. The presence of symbiotic gut flora in the insect midgut also plays a major role. We examined the interaction between *Bacillus thuringiensis* subsp. *galleriae* and larval gut flora in the lepidopteran pest, *Spodoptera litura*. Dose-mortality bioassays of Bt *galleriae* were conducted on normal and gut flora cured larvae of *S. litura*. The results indicated that the gut microflora play a major role in determining the toxicity of *Bacillus thuringiensis*.

Evaluation of bioagents for the management of nematodes in cardamom

CHINCHU P. BABU[*] and R. NARAYANA
Department of Agricultural Entomology, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, India
[*]*Corresponding author E-mail*: chinchupbabu93@gmail.com

An experiment was conducted during September 2017 in a field located at Thovalappady area of Idukki district, Kerala, to check the efficacy of bioagents for managing nematodes in cardamom. The experiment consists of seven treatments *viz*. T1- *Pseudomonas fluorescens* @ 30 g/plant (Basal application), T2- *Bacillus macerans* @ 30 g/plant (Basal application), T3- *Purpureocillium lilacinum* @ 30 g/plant (Basal application), T4- Neem cake @ 2 kg/plant (Basal application), T5 - mulching with Glyricidia @ 2 kg/plant (Basal application) along with a treated check (carbosulfan 3G @ 25 g/plant as basal application) and an untreated control. Among the bio control agents, *P. fluorescens* @ 30 g/plant (T1) was found to be the best treatment in increasing the yield (11.0 t/ha) which was on par with the chemical check. The lowest nematode population was recorded in the chemical treatment (80.5 J2/200 cc soil and 27.0 nematodes/5g of root) followed by *P. fluorescens* @ 30 g/plant (105.3 J2/200 cc soil and 46.5 nematodes/5g of root). The treatment *P. fluorescens* @ 30 g/plant showed the highest recovery of colony forming units (cfu) from soil (66×10^4) when compared to the other biocontrol agents used. The lowest root knot index was recorded in the chemical treatment (2.1) followed by the treatment P. *fluorescens* @ 30 g/plant (2.4). All other bio agents were equally effective in managing nematodes in cardamom over untreated control.

Isolation, identification and evaluation of native isolate of entomopathogenic nematode, *Heterorhabditis indica* Poinar, Karunakar and David (Tylenchida: Rhabditidae) against banana stem weevil, *Odoiporus longicollis* (Olivier) (Coleoptera: Curculionidae)

GIRIBABU PALANIAPPAN*, C. ANURADHA, B. PADMANABAN, T. ANITHA SREE and S. UMA

ICAR - National Research Centre for Banana, Tiruchirappalli – 639103, Tamil Nadu, India

**Corresponding author E-mail*: giribabunrcb@gmail.com

Weevils are one of the important production constraints of banana cultivation. Entomopathogenic nematodes (*Heterorhabditis indica* and *Steinernema glaseri*) are reported as effective biocontrol agents for management of stem weevil in India. A native isolate of entomopathogenic nematode was isolated from soil samples collected from ICAR-NRC for Banana, Tiruchirappalli, Tamil Nadu using waxmoth larvae baiting and white-trap method. Based on nematode morphological characters, the nematode was identified as *Heterorhabditis* sp. Species identification was done by sequencing the amplified nematode DNA fragment by PCR using primer TW81-AB 28 developed from ITS1-5.8S-ITS2 region of rDNA. Sequence annotation using BLAST analysis showed maximum similarity with *Heterorhabditis indica*. The obtained sequence data was submitted at NCBI Genbank (Accession No. MH299879). *In vitro* bioassay of *H. indica* against banana stem weevil, *Odoiporus longicollis* (Olivier) showed that the nematode was pathogenic, and 100% mortality was occurred within 48 hours at a minimum population level of 250 and 10,000 infective juveniles per larva and adult weevil respectively. Evaluation of *H. indica* against *O. longicollis* on banana stem trap under laboratory conditions showed that more than 80% adult weevils were get killed at 13th day after inoculation of *H. indica* when entomopathogenic nematode suspension was poured inside the stem trap @ 1,00,000 infective juveniles per adult weevil.

Bio-efficacy of different biological control agents for the management of chilli fruit rot/anthracnose disease

B. L. RAGHUNANDAN*, MAYANK V. PATEL, NEHA M. PATEL and D. M. MEHTA
Anand Agricultural University, Anand - 388110, Gujarat, India
**Corresponding author E-mail*: raghumic2@gmail.com

Chilli (*Capsicum* spp.) an important economic crop worldwide is severely infected by fruit rot disease which may cause yield losses of up to 50%. Although different chemical fungicides are being recommended and used for the management of the disease, biocontrol-based strategy attracts considerable attention and offers great potential of novel biocontrol agents. Further, biological control methods for chilli fruit rot/anthracnose disease have not received much attention. With this view of points an investigation was carried out to assess the efficacy of different biological control agents against chilli fruit rot/anthracnose disease. Biocontrol yeast isolates *Pichia guillermondii* (Y-12), *Hansanios porauvarum* (Y-73) and *Trichoderma harzianum* (Th-3), *Pseudomonas fluorescens* (Pf-1) were tested through seed treatment, seedling dip and foliar spray @ concentration of 2×10^8 cfu/ml. The pathogens *viz*. *Colletotrichum capsici*, *Alternaria alternata* and *Periconia byssoides* were found associated with fruit rot during the study. Lowest mean disease intensity (MDI), highest disease control (DC) over untreated control was recorded in the treatment *P. guillermondii* (Y-12) (5.39% MDI, 68.60 % DC) and this was found at par with the treatment *P. fluorescens* (Pf-1) (5.92% MDI, 65.52% DC). However, *T. harzianum* (Th-3) showed satisfactory results. The present study highlights the efficacy of biocontrol yeast species against chilli fruit rot pathogen and these findings serve as base for further exploration and exploitation of yeast species for eco-friendly management of crop diseases.

S3-PP-21

Efficacy of bio-agent formulations towards the management of stem blight of sesame caused by *Macrophomina phaseolina* (Tassi) Goid

SURESH MADUGULA*, S. V. S. GANGADHARA RAO and A. UPENDRA RAO
Department of Plant Pathology, Agricultural college, ANGRAU, Andhra Pradesh, India
**Corresponding author E-mail*: sureshiari@yahoo.co.in

Stem blight or Charcoal rot caused by *Macrophomina phaseolina* (Botryosphaeriaceae) is an important seed (externally as well as internally) and soil borne disease in sesame crop with incidence levels reaching as high as 50-60% under field conditions. A field experiment was carried out at Agricultural Research Station, Yelamanchili during the post rabi season in 2015-16 and under rice fallow situations during 2016-17 at ARS, Ragolu, Andhra Pradesh, India. Four fungicides (Mancozeb, Metalaxyl + macozeb, Carbendazim + mancozeb and Trifloxystrobin + Tebuconazole) and 2 bio-agent formulations (Th4dSC @ 1 and 2 ml/kg and Th4dWP @ 5 and 10 g/kg - obtained from IIOR, Hyderabad) were used as seed treatment agents with sesame variety YLM 66 under RBD conditions. Among the different seed treatments least number of diseases plants were observed in plots sown with YLM 66 seeds treated with Trifloxystrobin + Tebuconazole @ 1.5 g/kg resulting in least PDI of 13.4%. Th4dWP was proved to be best bio-agent formulation resulting in only 14.3% PDI at 1ml/kg dose. Whereas the SC formulation of resulted in 14.3% PDI when applied at 1ml/kg rate compared to control plots (PDI-30.4%) with no seed treatment. The two bio-agent formulations were more effective than the chemicals at both the doses, except for Trifloxystrobin + Tebuconazole, compared to other chemicals proving their bio control efficacy. Thus, the present study reports that seed treatment with Th4dWP and Th4dSC formulations are highly potential in managing the stem blight of sesame which is a low cost and eco-friendly management option compared to chemicals.

S3-PP-22

Evaluation of Spinosyn from *Streptomyces parvulus* for the control of polyphagous pests like *Spodoptera litura* and *Helicoverpa armigera*

PONSUGUMARI MAHALINGAM* and N. UNNAMALAI
Murugappachettiar Research centre, Taramani, Chennai, Tamil Nadu, India
**Corresponding author E-mail*: ponsugumarim@mcrc.murugappa.org

The use of pesticide in India accounts for approximately 3% of total pesticide consumption in the world. Continuous use of chemical pesticides leads to the development of resistance in pests and are harmful to humans, birds and other animals. Growing concerns on human health and safe environment paved a way for alternate safe pesticides. Spinosyn has been reported to be an eco-friendly pesticide. In this study we have isolated *Streptomyces parvulus* from sugarcane field soil, conditions and media were optimized for production of spinosyn. A bioassay experiment to evaluate the toxicity of crude extract of *S. parvulus* having spinosyn A against 2nd instar larvae of *Helicoverpa armigera* and *Spodoptera litura* was conducted at NBAIR, Bengaluru. The LC_{50} value of the spinosyn in the crude extract for *H. armigera* was 0.449 ppm and *S. litura* was 0.560 ppm. Based on LC_{50} values, a field trial was conducted to evaluate the toxicity of the crude extract of *S. parvulus* against pest of tomato and bhendi crops. The spinosyn was effective in the control of *H. armigera* and *S. litura*. Based on our results we report that Spinosyn A from *S. parvulus*is a good candidate for the control of agriculturally important pests. Efforts are being taken to formulate it into an effective product.

Cross infection of *Pieris brassicae* granulosis virus with other siblings of *Pieris* species

RAMAIYER VARATHARAJAN[*], W. SANGEETA, P. H. SUJATA and R. R. RACHANA
Department of Life Sciences, Manipur University, Canchipur, Imphal - 795003, Manipur, India
[*]*Corresponding author E-mail*: rvrajanramya@rediffmail.com

Pieris brassicae (Linn.) is a cosmopolitan oligophagous pest invariably infests vegetable crops of the family Brassicaceae. To control this pest, a specific granulosis virus - PibrGV has been found effective. While evaluating PibrGV against *P. brassicae* under the field condition, it was observed that two other siblings namely *Pieris canidia* and *Pieris dapladice* were also infected by PibrGV in addition to *P. brassicae*. With the aim to confirm this cross infectivity, uninfected normal caterpillars (III instar) of *P. brassicae*, *P. canidia* and *Pontia daplidice* (= *Pieris daplidice*), were simultaneously inoculated with the same concentration @ 5×10^4 polyhedra/ml of PibrGV by leaf disc contamination method. All the inoculated larvae exhibited typical symptoms of viral infection after 5-7 days of post inoculation. Subsequently, the capsules isolated from dead larvae of *P. brassicae* were used for inoculating normal larvae of *P. canidia* and *Pontia daplidice* and later the polyhedra from the above two species were tested against *P. brassicae*. This kind of permutation combination trials unambiguously revealed the cross-infectivity traits of PibrGV. Such cross-infection study reflects the utility of PibrGV for the control of all the three species of pierid caterpillars in the cabbage fields.

Integrating entomopathogenic nematodes and microbes for managing ash weevil (*Myllocerus subfasciatus*) menace in brinjal

R. UMAMAHESWARI*, M. S. RAO and P. N. GANGA VISALAKSHY
ICAR - Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bengaluru - 560089, Karnataka, India
**Corresponding author E-mail*: umanema369@gmail.com

Ash weevils (*Myllocerus subfasciatus*, *M. viridanus*, *M. discolor*) are reported as an economically important weevil in India and emerging as major insect pests in brinjal (*Solanum melongena* L.). Excessive use of chemical insecticides for its control raises concerns about public safety, soil and water pollution, insecticide resistance and effects on non-target organisms. Entomopathogenic nematodes (EPN) have emerged as promising alternatives to chemical pesticides against a variety of economically important pests. Hence studies were conducted to evaluate native strains of EPN *viz*. *Heterorhabditis indica*, *Steinernema carpocapsae* and *S. glaseri* against the grubs and adults of ash weevil under *in vitro*, *in vivo* and field conditions. *H. indica* was found to be highly virulent against the 3rd instar grubs (LC_{50} - 34.52 infective juveniles (IJs/larva) and adult weevils (LC_{50} - 138.42 IJs/ adult). In pot culture trials, maximum mortality of 91.4% of grubs was recorded with *H. indica* at 5 million IJs/ha which was on par with 2.5 million IJs/ha. Under field conditions, EPN were tested individually and in combination with microbial biopesticides *viz*. *Bacillus subtilis* and *Beauveria bassiana*. Among the EPN species, *H. indica* recorded the maximum mortality of 65.13% followed by *S. glaseri* (56.1%) and *S. carpocapsae* (42.3%). In combination with *B. subtilis*, *H. indica* recorded the highest grub mortality of 69.47% and 76% reduction in leaf damage due to ash weevils. Thus, the study proves the antagonistic potential of EPN and its compatibility with other microbial biopesticides widening its scope as an excellent component in IPM of brinjal.

Evaluation of bioagents for their compatibility for the development of consortium to enhance their efficacy

V. AMIRTHA LINGAM*, A. K. TEWARI, MANJU SHARMA, JATINDER KUMAR and ROOPALI SHARMA

G. B. Pant University of Agriculture and Technology, Udham Singh Nagar – 263145, Uttarakhand, India

**Corresponding author E-mail*: amirkumaran@gmail.com

The concept of development of microbial consortia for bio-control relies on the fact that bioagents under natural habitats lives in communities with plants. Diversity in biocontrol mechanisms offered by each bioagents in consortium may help in enhancing disease suppressive in an additive or synergistic manner. An attempt was made to develop guideline for the evaluation of bioagents to test their compatibility before developing bioagent consortium. In the present studies compatibility among biocontrol potential *Trichoderma-Pseudomonas* and *Trichoderma-Trichoderma* isolates were studied by dual culture, mixed formulations and using cell free cultures. In dual culture all the combinations (14 no.) were found compatible with each other as no isolate inhibited the growth of one-another i.e. absence of inhibition zone. All the mixed formulations of potential *Trichoderma-Pseudomonas* isolates (8 no.) were found compatible with each other as they were growing simultaneously on PDA without antagonizing each other. The cell free cultures of each *Trichoderma* and *Pseudomonas* isolates tested with each other using Poison Food Technique showed synergistic effects on their fresh mycelia weight among some combinations while majority showed no significant differences with their checks. Further all the combinations (14 no.) were tested for their effects on seed germination and vigour index of chickpea in glasshouse. All the combinations showed significant seed germination while some combinations *viz*. Th14 + Psf173, TCMS36 + Psf173, Th17 + Th19, Th17+ Psf2, Th17 + TCMS36 and Th14 + Psf2 showed better plant vigour index (43.5 to 44.9%) as compared to their checks (28.8 to 41.5%). These guidelines could be used before developing bioagent consortium and evaluation in field for crop health management.

A novel suspension concentrate formulation of *Bacillus thuringiensis* var. *kurstaki* for effective management of major lepidopteran pests

T. NATARAJ*, S. K. GHOSH and USHA NANDINI
Multiplex Biotech Private Limited, Bengaluru, Karnataka, India
**Corresponding author E-mail*: t.natarajsrn@gmail.com

Bacillus thuringiensis (Btk) cry toxin have employed globally for insect pest management on several crops. Major disadvantages of presently available Bt formulations are its ineffectiveness against older larvae and low persistence on the leaf surface because of lethal impact of UV light, weather, chemical environment of the leaf surface and the presence of proteinases contribute to the degradation of Cry proteins. The development of formulation is one of the most important steps in increasing spore efficacy and of great importance for its commercial viability. Present study was aimed in enhancing product efficacy through reduction of particle size below 1µm by ball milling and increasing spore viability through oil-based formulation. Multiplex Biotech has developed a novel suspension concentrate (SC) formulation of an indigenous isolate (DOR Bt-1) of Btk by producing the bacterial active ingredient through solid substrate fermentation process under laboratory condition. The bio-efficacy of the test formulation has been carried out in compared to wettable powder (WP) formulation at laboratory and field condition against major lepidopteran pests, *Spodoptera litura* on cabbage crops and *Helicoverpa armigera* on tomato crops. The SC formulation has shown significantly better mortality (90-100%) over wettable powder formulation (40-50%) when *H. armigera* larvae were exposed under laboratory condition. Similarly, SC formulation has shown better performance under filed condition in controlling pest population reduction of *H. armigera* (86.66%) and *S. litura* (99.23%). Present paper will brief on the production process of BT by adopting SSF method followed by developing SC formulation and its efficacy studies in details.

S3-PP-27

Pathogenicity testing of indigenous isolates of entomopathogenic fungus, *Lecanicillium lecanii* against tobacco caterpillar, *Spodoptera litura*

D. V. SAI RAM KUMAR*, R. DHANAPAL, C. H. SANDHYA RANI, V. MANOJ KUMAR and R. LAKSHMIPATHY

Agricultural College (ANGRAU), Suryalanka Road, Bapatla - 522101, Andhra Pradesh, India

**Corresponding author E-mail*: sairamkumard@gmail.com

Laboratory bioassays were conducted to assess the pathogenicity testing of native isolates of *Lecanicillium lecanii* against *Spodoptera litura* (Fab.). Five different concentrations *viz.* 1×10^4, 1×10^5, 1×10^6, 1×10^7 and 1×10^8 spores ml^{-1} of each isolate were used and compared with control with larval dip method. Among all six isolates of *L. lecanii*, the least median lethal concentration for 2nd instar of *S. litura* was determined as 1.16×10^5 spores ml^{-1} in L-1 followed by 1.60×10^5 spores ml^{-1} in L-4 and 4.09×10^6 spores ml^{-1} in L-5 isolate. The LT_{50} values of different isolates of entomopathogenic fungus against 2nd instar larvae of *S. litura* were calculated for a uniform highest dose of 1×10^8 spores ml^{-1}. Among all six isolates, L-4 and L-1 showed lowest LT_{50} as 183.61 and 194.96 hours post infection (hpi), respectively.

Evaluation of certain bio pesticides against sucking pests of BhutJalakia

RUDRA NARAYAN BORKAKATI*, DILIP KUMAR SAIKIA and BONAM RAMANUJAM
Department of Entomology, Assam Agricultural University, Barbheta, Jorhat - 785013, Assam, India
**Corresponding author E-mail*: rnbk.agri@gmail.com

BhutJalakia, *Capsicum chinense* Jacq. Is one of the hottest chillies in the world, grown extensively in Assam, Nagaland and Manipur? *Aphis gossypii* Glover; *Scirtothrips dorsalis* Hood; *Polyphagotarsonemus latus* Banks and *Bemisia tabaci* (Genn.) are the major sucking pests of BhutJalakia inflicts damage right from planting to fruiting stages of the crop. An experiment was conducted to evaluate the efficacy of six different strains of entomopathogenic fungus *Metarhizium anisopliae* (Ma) and *Beauveria bassiana* (Bb) for three years from 2014 -2016 at Experimental Farm, Department of Horticulture, AAU, Jorhat viz., AAU strains (Ma-Biometa and Bb-Biosona) and NBAIR strains (Ma-4, Ma-35, Bb-5 and Bb-23) @ 10^9 cfu/ml along with imidacloprid @ 20 g.a.i./ha including untreated control were tested. All the treatments offered a significant reduction of sucking pests after first, second and third spraying over untreated control. Pooled mean of three years data revealed that imidacloprid could significantly reduce the mean population of *A. gossypii* (4.64); *S. dorsalis* (2.03); *P. latus* (4.0) and *B. tabaci* (0.28), followed by Bb-5a (NBAIR Strain) with 7.20, 3.07, 5.2 and 0.64 per 10 leaves and both the treatments were on par in their efficacy after third spray. The rest of the entomopathogenic fungi were statistically at par with each other compared to untreated control plot. Highest yield of 52.64 q/ha recorded in imidacloprid treated plot followed by NBAIR strain of Bb-5a with 45.85 q/ha and both the treatments were significantly different from each other. Minimum yield of 26.78 q/ha was obtained in control plot.

Bioefficacy of fungal biopesticides against *Lipaphis erysimi* Kalt. (Hemiptera: Aphididae) in mustard crop

BHAGABAN PATRO[*] and SHALLINI GODSORA
Department of Entomology, Orissa University of Agriculture and Technology, Surya Nagar, Bhubaneswar - 751003, Odisha, India
[*]*Corresponding author E-mail*: bpatro1959@gmail.com

Field experiments were carried out in randomized block design with three replications in mustard (NRCHB-101) crop grown in the research field of the Department of Entomology, College of Agriculture, Bhubaneswar during two Rabi seasons of 2016-17 and 2017-18 in order to evaluate the bioefficacy of three fungal biopesticides (*Beauveria bassiana, Lecanicillium lecanii, Metarhizium anisopliae*) and their dual combinations against the mustard aphid, *Lipaphis erysimi* Kalt. And compared with check insecticides (imidacloprid), two neem products (neem seed kernel extract, azadirachtin 300 ppm) and untreated control. The results revealed that, the combined application of *L. lecanii* and *M. anisopliae* @ 2.5 ml each per litre of water significantly reduced the aphid population from 15.03 to 4.37 per 5 cm twig after seven days of spraying next to imidacloprid where the population was reduced to 0.72 per 5 cm twig after the same period of exposure. This combined application was also found at par with other two fungal combinations @ 5 ml per litre of water. This combined application of fungal biopesticides also showed highest yield (8.39 q/ha) and incremental cost benefit ratio (1:1.75) next to the chemical check where the yield and incremental cost benefit ratio was found 8.78 q/ha and 1:3.30, respectively. Significantly lowest yield (5.65 q/ha) and highest aphid population (52.28/5 cm twig) were recorded in untreated control.

Biological control of key pest of jute, *Spilosoma obliqua*

B. S. GOTYAL*
ICAR - Central Research Institute for Jute and Allied Fibres, Nilgunj, Barrackpore - 700120, West Bengal, India
**Corresponding author E-mail*: gotyalento@gmail.com

Jute hairy caterpillar, *Spilosoma obliqua* is the key pest and highly polyphagous which infests many economically important crops, often causing severe economic damage including jute crop. In jute it is reported to cause fibre yield loss up to 30%. The jute crop supports large number of *S. obliqua* natural enemies, entomopathogens viz, *Beauveria bassiana*, *Metarhizium anisopliae*, *Bacillus thuringiensis* and NPV. Among the parasitoides identified are *Protapanteles obliquae* (Wilkinson) (Braconidae: Hymenoptera) and *Meteorus spilosomae* Narendran and Rema (Hymenoptera: Braconidae). *P. obliquae* is a gregarious, endoparasitoid specific to *S. obliqua* and parasitize to the extent of 38% up to third instar of larvae. *Meteorus* spp. reported to cause up to 77% of parasitization on *S. obliqua* under field condition indicated the possibility of these parasitoids to be used as potential natural enemies. Among the entomopathogens of *S. obliqua*, *Beauveria bassiana*, *Metarhizium anisopliae*, *Bacillus thuringiensis* and NPV were found be very effective with mortality of 72, 81.25, 64 and 93% respectively. These parasitoids and pathogens can be used as potential bio-control agents against jute hairy caterpillar through conservation, augmentation and mass multiplication.

Infectivity of entomopathogenic fungal bio-agents on yellow mite, *Polyphagotarsonemus latus* Banks of jute

SUBRATA SATPATHY*, B. S. GOTYAL and V. RAMESH BABU
ICAR - Central Research Institute for Jute and Allied Fibres, Nilgunj, Barrackpore - 700120, West Bengal, India
**Corresponding author E-mail*: satp1@rediffmail.com

Broad mite is a serious pest of many field and horticultural crops including jute. As repeated use of acaricides possess problem of resistance, alternatively, the infectivity of talc-based formulation of 3 entomopathogens, *i.e*. *Lecanicillium lecanii* (Ll), *Paecilomyces fumosoroseus* (Pf) and *Beauveria bassiana* (Bb) at $4x10^8$ CFU/l and $6x10^8$ CFU/l concentrations were evaluated against yellow mite under laboratory condition. In both the concentrations, Pf and Bb recorded significantly higher mortality of yellow mite than Ll. At 3-DPT significantly highest mortality was observed in Pf (30.35%) followed by Bb (21.59%) and Ll (4.87%). Later on, at 4 and 5-DPT period the level of mortality in Pf and Bb treated population was at par but significantly higher than Ll. At 5-DPT, Pf recorded maximum cumulative mortality (40.92%) at par with Bb (35.99%) and significantly higher than Ll (12.92%). Significantly higher cumulative mortality at $6X10^8$ CFU/l concentrations during 5 days after treatment was 34.35%. The infectivity of talc-based formulation of Ll at both the concentrations was significantly less than *Pf* and *Bb*. Higher infectivity of *P. fumosoroseus* indicates it to be ideal for yellow mite control in jute.

S3-PP-32

Efficacy of botanicals and fungal formulations for pest management in okra

V. S. UDHAYAKUMAR*, V. KARTHIK, KHAVIYA BALA, K. SURESH and P. K. MUTHUKUMAR

Agricultural College and Research Institute, Department of Entomology, Madurai - 625104, Tamil Nadu, India

**Corresponding author E-mail*: insectthehero@gmail.com

The present investigation was undertaken on efficacy of botanicals and fungal formulations on the incidence of sucking pests and borers of okra. The pests include leaf hopper (*Amrasca biguttula biguttula*), whitefly (*Bemisia tahaci*), aphid (*Aphis gossypii*) and red spider mite (*Tetranychus urticae*), fruit and shoot borer (*Earias vittella*). The maximum leaf hopper population was significantly reduced in standard check (Vijay neem) followed by neem oil 2% and NSKE 5% reduction over the untreated check. The maximum whitefly population was significantly reduced in standard check (Vijay neem) and then neem oil 2% followed by NSKE 5% reduction over the untreated check. The maximum aphid population was significantly reduced in standard check (Vijay neem) followed by NSKE 5% and neem oil 2% reduction over the untreated check. The maximum red spider mite population was significantly reduced in standard check (Vijay neem) followed by neem oil 2% and NSKE 5% reduction over the untreated check. In case of shoot and fruit borer (*Earias vittella*), the maximum population was significantly reduced in standard check (Vijay neem) and then neem oil 2% was significantly reduced followed by pungam oil 2% reduction over the untreated check.

S3-PP-33

Eco-friendly management of lepidopteran insect pests through entomopathogenic nematodes

RASHID PERVEZ[*] and UMA RAO
Division of Nematology, ICAR - Indian Agricultural Research Institute, Pusa, New Delhi - 110012, India
[*]*Corresponding author E-mail*: rashid_pervez@rediffmail.com

In a recent survey, we have isolated six entomopathogenic nematodes from Hapur district (Western Uttar Pradesh) and two isolates have been identified as *Steinernema* spp. And three as *Oscheius* spp. Identification of one isolate is under process. These six newly isolated EPNs have been designated as *Oscheius* sp. (IARI-EPN 01), *Oscheius* sp. (IARI-EPN 02), *Steinernema* sp. (IARI-EPN 03), *Oscheius* sp. (IARI-EPN 04), *Steinernema* sp. (IARI-EPN 05) and IARI-EPN 06 (unidentified). All these were evaluated for infectivity against lepidopteran larvae, *Maruca vitrata* infesting pigeonpea, *Pieris brassicae* infesting mustard and *Spodoptera litura* infesting chickpea. Among the tested EPNs, IARI-EPN 03, IARI-EPN 04, IARI-EPN 06 were found to be promising against *M. vitrata* as they showed 100% mortality within 48 h followed by IARI-EPN 01, IARI-EPN 02 which took 72 h, while IARI-EPN 05 took about 120 h to kill the insects. In case of *P. brassicae*, IARI-EPN 02, IARI-EPN 03, IARI-EPN 06 gave 100% mortality within 48 h, whereas IARI-EPN 01 took more time 120 h to kill the insect. Lastly, IARI-EPN 03 and IARI-EPN 06 was found promising for *S. litura* as both of them caused 100% mortality within 48 h followed by IARI-EPN01, IARI-EPN02 and IARI-EPN 05 that took 72 h, while, IARI-EPN 04 was effective at about 120 h. The present results indicated that, *Steinernema* sp. (IARI-EPN 03) and IARI-EPN 06 (unidentified) were highly virulent against the tested lepidopteran insect pests. Further evaluation of these new EPN isolates under field conditions will indicate their utility in integrated pest management.

Field evaluation of potential bioagents against chickpea wilt complex

MANJU SHARMA[*], A. K. TEWARI, ROOPALI SHARMA and J. KUMAR
Department of Plant Pathology, College of Agriculture, G. B. PantUniversity of Agriculture and Technology, Pantnagar - 263145, Uttarakhand, India
[*]*Corresponding author E-mail*: manju_sharma9917@yahoo.co.in

Chickpea wilt complex is a major problem in all the chickpea growing regions in India. The disease is reported to cause damage at all stages of the plant i.e. from seed emergence to maturity of the plants. The disease is caused by *Sclerotium rolfsii*, *Rhizoctonia solani* and *Fusarium solani* at seed emergence and at seedling stages and *F. oxysporum* at flowering stage. The disease is unmanageable through chemical fungicides. Therefore, in the present studies different potential isolates of *Trichoderma asperellum*, *T. harzianum*, *Pseudomonas fluorescens* and a combination of *Trichoderma* and *Pseudomonas* (PBAT-3) were evaluated in the field to test their efficacy against chickpea wilt complex and yield of chickpea. Bio-agents were applied as seed treatment, and as two foliar sprays cum soil drench. Among various treatments significantly maximum percentage of seed germination was observed in NBAIR-1 and carbendazim (69.8%) and was at par with other treatments as compared to control (65.0%). However significantly minimum plant mortality (30-120 DAS) and minimum mature plant wilt (120 DAS) were observed with BARC (11.1 and 4.7 %), followed by PBAT-3 (15.5.0 and 4.7%) as compared to carbendazim (31.6 and 8.4%) and control (34.2 and 13.9%), respectively.

Validation of bioagent consortium at farmers' fields

A. K. TEWARI*, MANJU SHARMA, ROOPALI SHARMA and J. KUMAR
Department of Plant Pathology, College of Agriculture, G. B. Pant University of Agriculture and Technology, Pantnagar - 263145, Uttarakhand, India
**Corresponding author E-mail*: anandkumartewari@yahoo.co.in

Bioagents with multiple beneficial effects are of great interest in biocontrol of plant pathogens in field. In agriculture the aim of bioagent consortium is mainly for disease-suppressive mechanisms and plant growth promotion. In consortium the impact of field fluctuating biotic and abiotic conditions could be minimized, as some biocontrol mechanism could be effective even if others are non-functional. In addition, such combinations could be effective against multiple phytopathogens. Keeping above in view, large scale field demonstration trials of bioagent consortium (PBAT-3, a combination of *Trichoderma asperellum*-Th14 and*Pseudomonas fluorescens*-Psf173) developed by GBPUAT Pantnagar was conducted in basmati rice (189 ha), and chickpea and lentil (each with 50 ha) at the end Buof certified organic growers at districts Nainital and Udham Singh Nagar (Uttarakhand) for the validation. The consortium was applied as seed bio-priming, and 3-4 foliar sprays/soil drench in rice, chickpea and lentil as also seedling dip treatment in rice. As per farmers' feedback and observations recorded, the consortium was found effective in reducing bacterial leaf blight, sheath blight and blast in rice by 50-70 per cent while plant mortality and mature plant wilt in chickpea and lentil by 60-80 per cent as compared to farmers' practices. Farmers obtained an average additional yield of 4.4 q/ha in rice, 3.0 q/ha in chickpea and 2.5 q/ha in lentil as compared to the farmer's practices. The cost of production of both the practices was almost same in rice (Rs 25,000-27,000/ha), chickpea andlentil (Rs 18000-20,000/ha).

Isolation, evaluation and characterization of indigenous *Streptomyces* isolates for the management of stem and pod rot caused by *Sclerotium rolfsii*

GURURAJ SUNKAD[1*], KHADARBI[1], H. DEEPA[1] and MAHADEVASWAMY[2]
[1]*Department of Plant Pathology, College of Agriculture, University of Agricultural Sciences, Raichur - 584 104, Karnataka, India*
[2]*Department of Agricultural Microbiology, College of Agriculture, University of Agricultural Sciences, Raichur - 584 104, Karnataka, India*
[*]*Corresponding author E-mail*: sunkadgururaj@gmail.com

Groundnut (*Arachis hypogaea* L.) is one of the important oilseed crop of India and stem and pod rot caused by *Sclerotium rolfsii* Sacc. Is an economically important disease of groundnut causing considerable economic loss. In recent years, it has become a devastating disease.In recent years, there has been an increased interest in the search of plant growth-promoting rhizobacteria (PGPR) for sustainable crop production. In the present study, 35 isolates of *Streptomyces* were isolated from the rhizosphere soil of stem and pod rot affected groundnut fields, purified and characterized. All the 35 isolates were Gram positive and out of them nineteen isolates were found promising in inhibiting the mycelia growth of *S. rolfsii*. But significant vegetative growth reduction of *S. rolfsii* was observed inisolates, S-2, S-4 and S-3. The nineteen isolates were further tested for morphological and biochemical characters and they were confirmed to be *Streptomyces* spp. Two isolates were white in colour (S-2 and S-5), S-3 was cream and S-4 was light grey in colour. All the isolates were showed yellow pigmentation when the plates held in reverse condition and the S-3 produced brown coloured pigmentation. All the isolates were positive for the biochemical characterization. Isolates S2 and S4 showed higher production of HCN and siderophores. S-2 showed maximum per cent of inhibition followed by S-4 and S-3 for volatile production. Results suggested that these *Streptomyces* isolates can be developed as potential commercial biocontrol agents for sustainable management of stem and pod rot of groundnut.

Biointensive management of foliar blight and wilt of tomato in Uttarakhand

BHUPESH CHANDRA KABDWAL, ROOPALI SHARMA*, RASHMI TEWARI, A. K. TEWARI and J. KUMAR

Department of Plant Pathology, College of Agriculture, G. B. Pant University of Agriculture and Technology, Pantnagar - 263145, Uttarakhand, India

**Corresponding author E-mail*: roopalibiocontrol@gmail.com

In present investigation certain microbes, *viz*., *Trichoderma harzianum* (Th43), *Pseudomonas fluorescens* (Pf173), Jas mycorriza (AMF) and fungicide (mancozeb) in different combinations were evaluated for growth promotion and against major diseases of tomato. In glasshouse experiment maximum seed germination (91%), maximum shoot and root length (40.83 and 9.79 cm), fresh and dry shoot weight (152.00 and 28.38 g), fresh and dry root weight (9.33 and 3.90 g), maximum plant vigour index (4301.45) was observed in Th + Pf + AMF. In experimental field maximum plant height (43.67 cm), highest number of branches (7.33) per plant, highest weight of fruit (47 g), highest number of fruits (39) per plant, minimum plant mortality (4% at 30DAT and 3.2% in 30-60 DAT), minimum plant disease index (6.85), maximum total yield (256.00 q/ha) and marketable yield (246.67 q/ha) was observed in Th + Pf + JM (SA) + Th + Pf (ST) + Mancozeb (FS). At farmers field minimum plant mortality (7.31%) at 30 DAT (5.73%) in 30- 60 DAT, minimum plant disease index (11.47), maximum yield 249.91 q/ha was observed in Th + Pf + JM (SA) + Th + Pf (ST) + Mancozeb (FS) combination.

Session 4: BIOLOGICAL CONTROL COMPATIBLE APPROACHES

S4-LP-01

Recent collaborative research progress in pheromone-based trapping systems for agri-horticultural pests management in India

SRINIVASAN SITHANANTHAM*
Director, Sun Agro Biotech Research Centre, 3/1978, Mugalivakkam Main Road, Madanandapuram, Chennai - 600125, Tamil Nadu, India
**Corresponding author E-mail*: sithanantham@yahoo.com

The recent progress made by us to improve pheromone trapping impact in India with focus on more efficient trap designs and/or lure dispensers is summarized. One milestone is the waterless trap design (Delta-Plus, patent filed), having additional air vents, developed as more efficient and/or user-friendly alternative to the hitherto used water basin trap or funnel traps for moth borers like eggplant shoot and fruit borer (*Leucinodes orbonalis*), sugarcane early shoot borer (*Chilo infuscatellus*) and rice yellow stem borer (*Scirpophaga incertulas*). Quantum increase in moth catch was achieved for same quantity of lure dispensed by choice of trap design to attract and/or retain more males. Studies on male moth orientation in *L. orbonalis* and *C. infuscatellus* within trap arena around the lure source have indicated possible close-range visual recognition associated with substantial moth escape tendency. The lure dispenser variations and alternative pheromone loadings for enhanced catch size, besides choice of best fit trap type-dispenser combinations contributing to maximizing the moth catches are illustrated. In the parapheromone-based trapping system for the fruit fly species complexes, we could also identify superior trap designs and improved lure dispensers. Our chemical ecology research covering the synergy of blending cuelure with methyl eugenol, besides host plant-based intra-species specialization in melon fruit fly *Bactrocera cucurbitae* populations for olfactory response to host plant volatiles which can also play a role in area-based fruit flies management, are also illustrated. The potential for public-private-partnership for RandD in such semiochemical-based IPM is indicated.

S4-OP-01

Antifungal activity against *Monosporascus cannonballus* and plant growth-promoting potential of bacteria isolated from rhizosphere of melon in Oman

DHUHA AL DAGHARI*
Sultan Qaboos University, Al Khoudh, Muscat -13266394, Oman
**Corresponding author E-mail*: s90142@student.squ.edu.om

Monosporascus root rot/ vine decline (MRR/VD) disease caused by the ascomycete fungus, *Monosporascuscannonballus* is a serious threat in commercial production of melon. The fungus infects roots of melon plant and causes root necrosis, severe stunting and death of plants. In an effort to develop biological control method to reduce the incidence and severity of MRR/VD in melon, six bacterial strains viz., *Pseudomonas menducina* (BG), *Bacillus subtilis* (BD), *Pseudomonas aeruginosa* (A-T3), *Pseudomonas resinovorans* (B-11), *Bacillus oceanisedimini* (H8) and *Bacillus endophyticus* (I-18) showing inhibitory activity against the mycelial growth of *M. cannonballus* in dual culture plate assay were isolated from rhizosphere soil of melon cultivated plots from Barka, Muscat. Compatibility analysis using cross-streak assay on nutrient agar medium revealed that, six bacterial strains were compatible among each other. These rhizobacterial strains were tested for their growth-promoting efficiency on muskmelon seedlings using roll towel method. Among the six strains tested, *Pseudomonas menducina* strain BG recorded the highest seedling vigor, followed by *Pseudomonas resinovorans* (B-11), and *Bacillus endophyticus* (I-18). Scanning electron microscopy studies of fungal mycelium near the inhibition zone revealed severe morphological abnormalities in the mycelium of *M. cannonballus*. In the presence of antagonists, the hyphae of *M. cannonballus* showed shrunken, collapsed, empty hyphae, depressions and loss of turgidness in comparison to the untreated control hyphae. These antagonists show promise for use as biocontrol agents against MRR/VD.

S4-OP-02

Effect of *Bacillus* spp. and plant extracts from *Impatiens balsamina* L. on anthracnose disease caused by *Colletotrichum* spp. on mango in Vietnam

UYEN DANG THI KIM[1], NGUYEN VAN HOA[1*]and RANGASWAMY MUNIAPPAN[2]
[1]*The Southern Horticultural Research Institute (SOFRI), Tien Giang Province - 0084, Vietnam*
[2]*The Integrated Pest Management Innovation Lab, Virginia Tech, USA*
[*]*Corresponding author E-mail*: hoauyen28052005@gmail.com

The effect of different isolates of *Bacillus* spp. and plant extract from *Impatiens balsamina* on anthracnose disease of mango, *Colletotrichum* spp. was studied under laboratory conditions at the Plant Protection Division of SOFRI and at field conditions at Caolanh city, Dongthap province. Results indicated that the isolates of *Bacillus* spp. (named BS, BX1, BX2) were effective in suppressing *Colletotrichum truncatum* (61.33% to 62.92%). The *Bacillus* spp. isolates BX2, BX3, BX6 also recorded 61.48%, 62.59%, and 61.11% reduction of *Colletotrichum gloeosporioides* infection. The plant extract from *Impatiens balsamina* at 50%, caused 90% inhibition of *C. truncatum* and *C. gloeosporioides*. Under field conditions, combination of propiconazole and difenoconazole, the plant extract from *Impatiens balsamina* and *Bacillus* spp. caused inhibition of the anthracnose disease on mango leaves in comparison with water spray as control. The combination of propiconazole + difenoconazole, extract of *Impatiens balsamina* + Visil on and *Bacillus* spp. caused reduction of anthracnose disease ratio (37.05%, 48.94%, 55.43%) and disease incidence (9.98%, 13.04%, 13.75%).

S4-OP-03

Fruit fly management in Nepal- a case from plant clinics

DEBRAJ ADHIKARI*, SAMUDRA LAL JOSHI, RESHAM BAHADUR THAPA, VINOD PANDIT and DILLI RAM SHARMA
Ministry of Agriculture, Land Management and Cooperatives, Bharatpur - 14, Chitwan, Nepal
**Corresponding author E-mail*: debhorti@yahoo.com

Fruit fly is one of the important insect pests of horticultural crops both on fruits and vegetables. This pest was reported as a major insect problem after aphids in the plant clinic sessions conducted from September 2013 to July 2016 in Nepal. The groups of horticultural crops most affected by fruit flies were cucurbitaceous vegetables, *i.e*. 79% of all fruit fly queries (bitter gourd, bottle gourd, chayote, cucumber, pumpkin, snake gourd, sponge gourd and squash) followed by fruits 14% (guava, sweet orange, mandarin, mango, peach, and pomegranate) and solanaceous vegetables 6% (brinjal, chillies and tomato). The fruit fly management measures, such as use of para-pheromone lure/traps, sanitation and cultural measures were mostly referred in plant clinics by plant doctors of Nepal. The availability of para-pheromone lures/traps as well as technical know-how of application focusing integrated management measures should be adapted to manage problem of fruit fly in horticultural crops with least disruption to the environment and human health.

Effect of insecticides on adult and preimaginal stages of *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae) and its parasitisation potential

KAMALDEEEP SANGHA*, P. S. SHERA, SUDHENDU SHARMA and JASREET KAUR

Department of Entomology, Punjab Agricultural University, Ludhiana - 141004, Punjab, India

**Corresponding author E-mail*: kssangha@pau.edu

One of the major focuses of IPM is to integrate chemical and biological control tactics for sustainable management of insect pests. Natural enemies have a strong tendency of susceptibility to insecticides as compared to their herbivore hosts/prey. The differential susceptibility of natural enemies to pesticides creates serious compatibility problems for integration of pesticides and natural enemies in IPM programs. The determination of pesticide impact on bio-control agents is therefore important for effective integration of both the strategies. Effect of eleven different insecticides *viz.* chlorantraniliprole, chlorpyriphos, imidacloprid, triazophos, bifenthrin, fipronil, flubendamide, clothianidin, thiamethoxam, methoxyfenozide, was studied against adult and preimaginal stages of *Trichogramma chilonis* used as an augmentative biological control agent against lepidopteran borers in sugarcane agro ecosystems. The effect of these insecticides on parasitisation potential of T chilonis in F_1 generation was also studied. Highest adult mortality was exhibited by triazophos (99.80%) which was at par with chlorpyriphos (99.40%). Lowest mortality was recorded with methoxyfenozide (16.60%) followed by chlorantraniliprole (18.80%), flubendamide (23.20%) and clothianidin (29.20%). No parasitisation was observed with chlorpyriphos, triazophos and bifenthrin. Among the insecticide treatments, significantly higher per cent parasitisation was exhibited with chlorantraniliprole (73.80%) which was at par with clothianidin (71.80%). Chlorpyriphos, bifenthrin and triazophos recorded minimum adult emergence of 21.56, 36.90 and 39.40 per cent, respectively. Triazophos and bifenthrin are more toxic to pupal stage as compared to other stages while chlorpyriphos was found to more toxic to egg stage. Chlorantraniliprole and methoxyfenozide were found to be quite safe to all stages.

S4-OP-05

Bio-intensive pest management in rice - go green initiative!

GURURAJ KATTI and CHITRA SHANKER
ICAR - Indian Institute of Rice Research, Rajendranagar, Hyderabad - 500030, Telangana, India
[*]*Corresponding author E-mail*: gururajkatti@yahoo.com

Going green aims to evolve environmentally friendly and ecologically responsible systems to sustain the environment and its natural resources for current and future generations. Bio-intensive pest management (BIPM) in rice is the development of a practical roadmap to effectively utilize ecosystem functions and services with emphasis on the role of diverse natural enemy populations vis a vis pest for the benefit of human health and environment. BIPM deviates from the conventional IPM by focusing more on measures to restructure the agricultural ecosystem to the disadvantage of a pest and to the advantage of natural enemies. Habitat manipulation through naturally innovative strategies such as use of trap crop and ecological engineering for the management of stem borer and planthoppers, respectively helps to protect rice crop with minimum damage to environment. Bio-intensive IPM also includes key conventional eco-friendly components like pest monitoring, host plant resistance and judicious application of green pesticides. Sex pheromone-based tool for monitoring and managing yellow stem borer with scope for other key pests, a novel scientific approach of e-surveillance using tools of information and communication technology and integration of soil, plant and pest data factors along with weather parameters, provide key inputs for developing pest forewarning systems. Multiple pest resistant varieties developed through amalgamation of conventional and molecular approaches can also revolutionize BIPM in rice. Overall, studies carried out in multi-locations across the country so far have led to development of location specific IPM packages not only addressing the needs of diverse rice ecosystems and but also providing potential income generating means for the farmers.

S4-OP-06

Compatibility and efficacy of entomopathogenic nematode-insecticide combinations against *Holotrichia consanguinea* Blanch. (Coleoptera: Scarabaeidae)

JAGADEESH PATIL*, MANJUNATHA T. GOWDA, PRIYANK HANUMAN MHATRE and VIJAY KUMAR

ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India

**Corresponding author E-mail*: patiljaggi1@gmail.com

Entomopathogenic nematodes (EPNs) are important biological agents used to control a number of insect pests, and can be applied together with various insecticides. Thus, the objective of this work was to evaluate the survival of infective juveniles (IJs) of two species of EPNs, *Heterorhabditis indica* and *Steinernema abbasi*, after exposure to fipronil and imidacloprid and combination of these nematodes and insecticides at different rates for the control of the white grub, *Holotrichia consanguinea*, were evaluated both in the laboratory and in sugarcane fields. In the laboratory assays, the two insecticides fipronil and imidacloprid at different concentrations had no or negligible effect on survival of both the nematode species, with mortality rates below 4.0%. The combinations had a synergistic or additive effect on the third instar grubs of *H. consanguinea* and caused faster mortality than one EPN species or insecticide alone. Mortality and speed of kill were significantly increased in the combination of *Heterorhabditis indica* - fipronil, *H. indica* - imidacloprid and *S. abbasi* - imidacloprid but nematode establishment not affected by these insecticides. Both in the laboratory and in sugarcane fields, the degree of interaction, however, varies with nematode species, being synergistic for *Heterorhabditis indica* - fipronil, *H. indica* - imidacloprid and *S. abbasi* - imidacloprid against grubs. These three nematodes - insecticide combinations produced significantly higher percentage reductions of white grubs than chlorpyrifos treatment. Cost - benefit analysis showed that *H. indica* 8.25×10^8 IJ ha^{-1} combined with imidacloprid is a practical strategy for the management of white grubs in the sugarcane production.

S4-OP-07

Biofumigation-An effective tool in enhancing yield of capsicum (*Capsicum annum*) by suppressing soil-borne pathogens and augmenting biopesticides like *Trichoderma viride* and *Pseudomonas fluorescens* under protected cultivation in India

SWAPAN GHOSH[*], T. NATARAJ, USHA NANDINI and C. ASHA
Multiplex Biotech Private Limited, Peenya Industrial Area, Bengaluru, Karnataka, India
[*]*Corresponding author E-mail*: ghoshswapan66@gmail.com

Biofumigation constitutes an alternative method to methyl bromide to control soil-borne pathogens. The scope of the current research was to develop a formulation of Allyl Isothiocyanate (AITC), commonly called volatile mustard oil and to evaluate its impact on suppression of soil-borne pathogens from lab to field as a compatible approach for enhancing the performances of biopesticides. Multiplex biotech has developed a suspension concentrate formulation of AITC which could support both soil-sterilization and boosting soil fertility. The test formulation has shown > 80% suppression of growth in fungal and bacterial pathogens and reduction of root knot nematodes under controlled condition. A field trial was carried out on capsicum (*Capsicum annum*) grown under polyhouse condition has shown significant reduction of soil-borne fungal pathogens (70-80%) like *Sclerotium rolfsii*, *Fusarium* sp., bacterial pathogens (50-60%) like *Ralstonia* sp., *Xanthomonus* sp. and root knot nematodes (60-70%) when this formulation was applied as pre-planting treatment @ 500 ml/acre through drip irrigation under mulched condition. In addition, it also complemented in enhancing biocontrol activity of *Trichoderma viride* and *Pseudomonas fluorescens*. Improved plant growth (> 18-20%), early flowering and better yield (> 22-33%) was recorded in the treatment where both *Trichoderma viride* and *Pseudomonas fluorescens* were introduced as post fumigation treatment. Highest disease incidences were recorded (43-45% more) in non-fumigated plot. Crop yield (46 tons/acre) was recorded highest in the plot where biopesticide was treated after biofumigation (46 tons/acre) followed by only biofumigated plot (37 tons/acre) as compared to non-fumigated plot (28 tons/acre) which recorded the lowest yield.

S4-OP-08

Eco friendly pest and disease management practices in groundnut

GAYATHRI SUBBIAH[*] and K. VELMURUGAN
ICAR - KVK, Kancheepuram - 603203, Tamil Nadu, India
[*]*Corresponding author E-mail*: gvs30244@gmail.com

Groundnut is the major oil seed crop grower during rabi season covering nearly 2500 ha area in Kancheepuram district of Tamil Nadu. During cropping season the farmers are facing problems of yield loss due to pest and disease attack. The major pest of the area includes tobacco caterpillar, leaf miner, aphids and thrips. Root rot and leaf spot diseases are major issues during growth stages resulting in yield loss of 30% and increased cost of cultivation along with excess use of chemicals to control them. In order to address farmer's problem and promote eco-friendly approaches in pest and disease management, Front Line Demonstration (FLD) was conducted in three villages involving 15 farmers. Demonstration was conducted by supplying critical inputs like *Pseudomonas* for seed treatment (10 g/kg of seed), *Trichoderma viride* for soil application (1 kg/acre), Pheromone traps and spodo lures (10 no's/acre) for tobacco caterpillar control, Sticky traps (10 no's/acre) for sucking pest management and light trap (1 no./acre) for monitoring adult pests. SNPV (250 ml LE/ha) spray was recommended for tobacco caterpillar management. Seed treatment with *Trichoderma* effectively managed root rot incidence compared to farmer's practice where no such treatment was made which resulted in root rot incidence (5%). Yield of 28 q/ha was obtained compared to farmer's practice (26 q/ha). By use of Pheromone traps, the farmers completely avoided application of chemical pesticides to control tobacco caterpillar (*Spodoptera litura*), adult moths of nearly 25 no's per week were trapped which resulted in saving of Rs. 3500/- otherwise spend for pesticide spray. This programme had a positive impact from the farmers' side as they were able to identify pest and diseases and adopt timely recommended practices.

S4-OP-09

Compatibility of insecticides with entomopathogenic fungi, *Metarhizium* spp. and *Beauveria* spp. for bio-intensive management of pink mealybug, *Maconellicoccus hirsutus* (Green) in grapes, *Vitis vinifera* Linnaeus

DEEPENDRA SINGH YADAV[*], YOGITA H. RANADE and SHASHIKANT B. GHULE

ICAR - National Research Centre for Grapes, Manjari Farm P.O, Solapur Road, Pune - 412307, Maharashtra, India

[*]*Corresponding author E-mail*: deependra.yadav@icar.gov.in

Grapes (*Vitis vinifera* Linnaeus) is a high-value crop and also important as a valuable export commodity for India. Pink mealybug, *Maconellicoccus hirsutus* (Green) is one of the most important insect pests infesting grapes. Two entomopathogenic fungi were isolated from field collected *M. hirsutus* infesting grapes and were identified as *Metarhizium* spp. and *Beauveria* spp. The pathogenicity studies showed that both the fungi were capable of infecting *M. hirsutus*. Evaluation of compatibility of these fungi is important to develop strategies for bio-intensive management of mealybugs. The compatibility of seven insecticides (emamectin benzoate, tolfenpyrad, imidacloprid, clothianidin, buprofezin, fipronil, spirotetramat) with these entomopathogens was evaluated under laboratory conditions. The formula proposed by Alves *et al* (1998) that considers the vegetative growth and sporulation of the fungus was used to calculate the toxicity values. The insecticide concentrations were, field recommendation (1 FR), 50% more of an average field recommendation (1.5 FR), 50% less of field recommendation (0.5 FR) and twice the concentration recommendation for field (2 FR). Compatibility studies based on sporulation, germination and vegetative growth of fungi showed that insecticide imidacloprid showed maximum compatibility with both the fungi. At field recommended dose (1 FR), emamectin benzoate, clothianidin and buprofezin were also found to be compatible with both *Metarhizium* spp. and *Beauveria* spp. Tolfenpyrad and spirotetramat were highly incompatible with both the entomopathogens and were found to affect the germination, mycelium growth and sporulation of fungi significantly.

Exploitation of mutualistic fungal symbiont *Fusarium ambrosium* for the suppression of tea shot holeborer, *Euwallacea fornicatus*

P. MAHENDRAN*, G. SIVAKUMAR, V. BALACHANDAR, K. K. SRIKUMAR, B. RADHAKRISHNAN, S. K. JALALI, SURABHI KUMARI and B. SURESH KUMAR
UPASI Tea Research Institute, Division of Entomology, Nirar Dam (BPO), Valparai, Coimbatore - 642127, Tamil Nadu, India
**Corresponding author E-mail*: dr.pmahendran@gmail.com

The shot hole borer (SHB) *Euwallacea fornicatus* (Eichhoff) is considered as one of the major pests of tea in south India. The chemical control options are not advocated due to residue problems on tea leaves. Tea shot hole borer has an obligatory relationship with fungus for their nutrition and survival. The present study explored the feasibility of suppression of *Euwallacea fornicatus* through its mutualistic fungal symbiont *Fusarium ambrosium*. SHB beetles were collected from various tea estates of southern India and molecularly identified using Cytochrome Oxidase I (COI) gene. DNA barcodes were generated to the insects collected at various locations. The fungal symbiont was isolated from insect's head and tea stem gallery and confirmed as *Fusarium ambrosium*. Insects grown in artificial diet containing *F. ambrosium*, formed galleries and completed its life cycle with new generations as compared to diet without fungus. Production of ergosterol from *F.ambrosium* was confirmed through HPLC studies, an important constituent which helps in insect's endurance. Bacteria such as *Bacillus, Pseudomonas, Lysinibacillus, Psychrobacillus* and *Viridibacillus* were isolated from the tea rhizosphere and tea stem galleries of SHB. *Bacillus cereus* and *Bacillus subtilis* highly inhibited the *Fusarium ambrosium* under *in-vitro*. The field experiment proved that the bacterial antagonists *B. cereus* and *B. subtilis* were found effective in suppressing the growth of *F. ambrosium* thereby reduced the SHB population. The soil application of *B. cereus* suppressed the SHB population by 17.5% whereas *B. subtilis* when sprayed over the tea branches reduced population by 15% after 21 days of treatment.

BIPM modules against shoot and fruit borer, *Leucinodes orbonalis* (Guenée) in eggplant, *Solanum melongena* L.

RABINDER KAUR, P. S. SHERA, SUDHENDU SHARMA and K. S. SANGHA
Department of Entomology, Punjab Agricultural University, Ludhiana - 141004, Punjab, India
[*]*Corresponding author E-mail*: rebakaur@pau.edu

The eggplant, *Solanum melongena* L. is the most popular vegetable crop grown by the small-scale farmers throughout the year in India. Among different insect pests, brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* (Guenée) is the most serious pest responsible for reduction in both quantity and quality of fruits. The farmers mostly rely on the use of broad-spectrum pesticides to save their crop from this pest. However, there is a necessity to develop eco-friendly biointensive IPM (BIPM) strategies including botanicals, bioagents and biopesticides to reduce the pesticide load. Hence, present study was carried out during 2015 and 2016 to validate different BIPM modules for the management of this pest on eggplant (var. Punjab Nagina) during main cropping season (March-June). Five different BIPM modules consisting of different combinations of *Trichogramma chilonis* @ 50,000/ha, *Bacillus thuringiensis* based biopesticide @ 1.0 kg/ha and Azadirachtin 1% @ 1.0 litre/ha were evaluated and compared with farmer's practice (chemical control) and untreated control. Based on the results of two years, the chemical control significantly reduced the incidence of BSFB. Among different BIPM modules, lowest shoot and fruit damage due to BSFB and higher yield was recorded in module comprising integration of *T. chilonis* (2 releases - 45 and 66 DAT), application of Azadirachtin 1% (2 sprays at 52 and 73 DAT) and *Bt* formulation (2 sprays at 59 and 80 DAT). The present study gives better prospects of adoption of BIPM strategies for the sustainable management of *L. orbonalis* on eggplant.

Impact of transgenic Bt cotton (Cry1Ac and Cry2Ab) on the parasitoid, *Aenasius arizonensis* (Girault): a host mediated tri-trophic analysis

PARMINDER SHERA*, PRASUN KARMAKAR, SUDHENDU SHARMA and K.S. SANGHA

Department of Entomology, Punjab Agricultural University, Ludhiana - 141004, Punjab, India

**Corresponding author E-mail*: psshera@pau.edu

Genetically modified plants with genes from soil dwelling spore forming bacterium, *Bacillus thuringiensis* Berliner produces δ-endotoxin which is lethal to many phytophagous pests. Transgenic *Bt* cotton providing resistance to lepidopteran insects, is the only crop which is commercialized in India. One of the concerns is the possible effects of genetically modified crops on non-target organisms which play an important role in the ecosystem like biological control, pollination and decomposition. *Aenasius arizonensis* (Girault) is an important solitary endoparasitoid of mealybug, *Phenacoccus solenopsis* Tinsley in *Bt* cotton. We, therefore, conducted a tri-trophic bioassay to study the host mediated effects of transgenic *Bt* cotton (Cry1Ac and Cry2Ab) on the biological parameters and parasitism by the parasitoid. The overall development of *A. arizonensis* in the host, *P. solenopsis* reared on *Bt* cotton plants did not suffer any deleterious effect. There were no significant differences in any of the fitness parameter, i.e. duration from oviposition to mummy formation, mummy formation to adult emergence, total immature period, adult emergence, sex ratio and adult longevity regardless the host, *P. solenopsis* had fed on *Bt* cotton or non-*Bt* cotton plants. The parasitism of mealybug nymphs by *A. arizonensis* was also not different on *Bt* or non-*Bt* cotton plants. ELISA studies confirmed the presence of Cry proteins in *Bt* cotton plants, however, no Cry1Ac or Cry2Ab protein was detected in the host, *P. solenopsis* or its parasitoid, *A. arizonensis.* Our study thus demonstrates that *Bt* cotton expressing dual toxins (Cry1Ac and Cry2Ab) had no apparent effect on the fitness of *A. arizonensis* indicating their safety to this parasitoid.

S4-OP-13

Developing biocontrol and bio-based recommendations for plant doctors in Myanmar using CABI Plantwise online data

KYIN KYIN WIN
Deputy Director, Plant Protection Division, West Gyogone, Insein, Yangon - 11011, Myanmar
Corresponding author E-mail: kyinkyinwin@gmail.com

Since, last twenty-five years, Myanmar farmers are using the agro-chemicals to protect the yield of many crops from pest and diseases. Due to indiscriminate use of many chemicals, the produces were contaminated with pesticide residues. Plant Protection Division (PPD) under the Department of Agriculture in Myanmar has initiated Integrated Pest Management (IPM) program to manage the pest and diseases. IPM section in PPD educates not only the PPD staff but also extension staff to manage the pest and disease by using of Bio control agents and biopesticides. Farmers are being imparted training on the biological control methods by IPM section. Under Plant Protection Division, *Trichogramma* rearing facilities - one in Yangon, two in Mandalay, three in Sagging and four in Yezin Agriculture University were established with EU support seven years back. The facilities produce and supply the parasitic wasps to use on vegetable and rice to control of Lepidoptera pests. Myanmar consumers are now knowledgeable on the pesticide residual effect of field products. Their special request is chemical residue produce from the crops. Good Agriculture Practice (GAP) on fifteen crops was already launched by Department of Agriculture during December 2017.Myanmar GAP is based on IPM packages including biological control method.

Efficacy of entomopathogens for the management of leafhoppers (*Idioscopus* spp.) and thrips (*Scirtothrips dorsalis* Hood) on mango

POLURU VENKATARAMI REDDY* and P. N. GANGA VISALAKSHY
ICAR - Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bengaluru - 560089, Karnataka, India
**Corresponding author E-mail*: pvreddy2011@gmail.com

Sucking pests are one of the most challenging groups of pests to control in several horticultural crops. Entomopathogens have potential to be the safer and viable pest management tools to minimize insecticide usage. Three entomopathogens *viz. Metarhizium anisopliae* (IIHR strain), *Beauvaria bassiana* (IIHR strain) and *Verticilium lecanii* (commercial formulation) were evaluated during 2015 -17 against two major sucking pests *viz*. leafhoppers (*Idioscopus* spp.) and thrips (*Scirtothrips dorsalis* Hood) on mango (Cv. Totapuri) at ICAR - Indian Institute of Horticultural Research, Bengaluru, India. Formulations of entomopathogens were applied as foliar sprays starting from flower initiation at weekly interval. Three sprays were given at flowering stage and one when fruits were at pea size, mainly targeting thrips. An insecticide treatment was included as standard check. The data revealed that all entomopathogens were significantly superior to control in checking the pest populations. Among them, the IIHR developed oil formulation of *M. anisopliae* (0.5 ml/L) was the most effective treatment against both leafhoppers and thrips consecutively for two crop seasons. It resulted in 85.2% reduction in hopper population and was on par with standard check (89.1%). In case of thrips, though the treatment was not superior to chemical check, it was most effective among all fungal formulation treatments. The treatment gave about 74.0% reduction in thrips population and resulted in second very low fruit damage (5.64%) compared to control (16.8%). In the light of the findings of our study, the scope of entomopathogens as an integral component of IPM module of mango is discussed.

S4-OP-15

Effect of herbicides on feeding, survival and development of *Haltica cyanea*, a potential biocontrol agent of the dicot weed, *Ammania baccifera*, in rice ecosystem

AYYAGARI PHANI PADMAKUMARI*, B. SREEDEVI and K. SIVAKRISHNA
ICAR - Indian Institute of Rice Research, Rajendranagar, Hyderabad - 500030, Telangana, India
**Corresponding author E-mail*: padmakumariento@gmail.com

Ammania baccifera L. (Fam: Lathyraceae) is one of the predominant weeds in paddy fields. In nature, the adults and grubs of *Haltica cyanea* (Coleoptera: Chrysomelidae) feed voraciously on the leaves of this weed leading to drying of the plants. In recent times with the gradual change in cultivation practices and increase in labour shortage the use of weedicides in rice ecosystem has increased tremendously. In an endeavor to explore the possibility of the use of these beetles as biocontrol agents, laboratory studies were carried out at ICAR - IIRR to compare the efficacy of *H. cyanea* as a biocontrol agent in comparison with the two recommended herbicides and also study the effect of these herbicides on the biology of the beetle. The two recommended herbicides, 2,4 D - Na salt (for dicot weeds) and Almix® (metsulfuron methyl 10% + chlorimuron ethyl 10% WP recommended for dicots and sedges) were tested at recommended field dose against the larval stages of *H. cyanea*. The effect of these herbicides on survival, feeding, longevity and biology of the bioagent was studied through leaf dip and pot method. It was also observed that 21.67% reduction in shoot weight was observed in beetle released plants as compared to herbicide treatment where 38.5-49.3% reduction in shoot weight was observed within 48h. 2,4 D - Na salt was more toxic to the grubs as compared to Almix.

Area wide farmer participatory bio-management of rhinoceros beetle in coconut plantations

CHANDRIKA MOHAN*, P. ANITHA KUMARI and A. JOSEPH RAJKUMAR
ICAR - Central Plantation Crops Research Institute, Kayamkulam, Kerala, India
**Corresponding author E-mail*: cmcpcri@gmail.com

With the ever-increasing awareness on the harmful effects of chemical pesticides and popularization of organic farming, need for sustainable eco-friendly pest management is gaining momentum. This paper describes about the farmer participatory approaches evolved for sustainable bio management of rhinoceros beetle covering 1500 ha in Kerala, India during the period 2012-2015. The major components of biocontrol of rhinoceros beetle *viz*. application of *Metarhizium anisopliae* in the pest breeding sites, field release of *Oryctes rhinoceros* nudi virus and prophylactic treatment using botanical pesticides were popularized. Using a simple, low cost production technology, *M. anisopliae* was mass multiplied in semi-cooked rice grains which formed a part of the capacity building programme. The farmers were clustered through Farmer Field Schools for imparting knowledge and skill on health management technologies with 14 groups covering 132 farm families. The average knowledge score on pest management among FFS farmers was 51.69 compared to 32.80 in case of non-FFS farmers. Leaf damage by rhinoceros beetle indicated reduction of 76% to 85% and pest incidences on palms were reduced to 54.14% from the initial infestation level of 82.35%. Nut yield showed an increase of 13.1% nuts/palm/year which is an impact of the income improvement due to the interventions. Importance of good agricultural practice like farm level enrichment of organic manure with *Trichoderma harzianum*, moisture conservation by mulching of palm basin and farm hygiene formed the core strategy in the management of pests and diseases. This approach is viable and feasible for replication for pest management in other plantation/perennial crops.

S4-OP-17

Investigation, electrophysiological and behavioural response to the GLV and sex pheromone components of Indian rice pink stem borer, *Sesamia inferens* (Walker) (Lepidoptera: Noctuidae)

M. SAMPATHKUMAR[1*], CHITRA SHANKER[2], CH. PADMAVATHI[2], P. SARO[3]and G. R. KATTI[2]

[1]*ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India*

[2]*ICAR - Indian Institute of Rice Research, Hyderabad -500 030, Telangana, India*

[3]*Punjab Agricultural University, Ludhiana - 141 004, Punjab, India*

[*]*Corresponding author E-mail*: ento_sam@yahoo.co.in

The pink stem borer, *Sesamia inferens* (Walker) (Lepidoptera: Noctuidae) in the recent past is emerging as an important pest of rice, especially grown in upland situation, rice fallow wheat ecosystem, where its damage has been observed as major threat to production. Many options are available for control of this pest. Mostly farmers apply granular insecticides which pose great risk to the non-target organisms and environment. Use of sex pheromone has its unique advantage in that the pheromone traps can be used to decide the time of insecticidal application. Behavioral studies carried out at IIRR, Hyderabad have revealed that sex pheromone secreted by female during scotophase between 22.00 and 23.00 hrs is capable of attracting males. With the expertise available at CPCRI, Kasaragod and IICT, Hyderabad, (Z)-11-16:Ac has been identified as the pheromone molecule. Laboratory (EAG, wind tunnel studies) and field investigations of the identified components have indicated that they resulted in marginally good trap catches. The PSB lure having 5 mg of the pheromone compound resulted a marginal trap catches (8/trap/day) at PAU farm and farmers field at Ludhiana for the second year of retesting (*rabi* 2014-15). On testing with GLV, response was higher for (Z)-3-hexen-1-ol (-1.31 mV) followed by linalool (-0.43 mV) informing these compounds could play an important role in host-plant selection. They may also act as synergists in attracting more insects, either male or female in pheromone traps. The present investigation helps in deployment of sex pheromone technology for effective monitoring and mass trapping of pink stem borer in near future.

S4-PP-01

Effect of bioprotectant on the seasonal incidence of gram pod borer, *Helicoverpa armigera*

ANIL VYAS[*] and GAURANG CHHANGANI
Rajasthan College of Agriculture, Udaipur - 313001, Rajasthan, India
[*]*Corresponding author E-mail*: vyasdr2004@gmail.com

The effect of bioprotectant on the seasonal incidence of gram pod borer *Helicoverpa armigera* was conducted at instructional farm of Department of Entomology, Rajasthan College of Agriculture, Udaipur during *rabi* season of 2018. Gram variety GNG-1581 was sown with different treatments to study the seasonal infestation of gram pod borer and to compare the impact of bordered plants *viz*. mustard, marigold and sunflower along with bio-pesticides which included one spray of NSKE and one spray of Hear NPV. The maximum pod borer population was recorded during 3rd and 4th week of December whereas, minimum pod borer (0.71 larvae per meter row) was recorded during 5th week of November (48th SMW). Biopesticide application resulted in lower mean larval population. Among all the treatments, marigold with bioprotectants had lower pest population (0.89 larvae per meter row) whereas sole gram without bioprotectant application had maximum pest population (2.97 larvae per meter row).

S4-PP-02

Influence of certain newer insecticides on natural enemy population in rice ecosystem

DEVU RAKSHITH ROSHAN[*] and S. V. S. RAJU
Research Scholar, Department of Entomology and Agricultural Zoology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi - 221005, Uttar Pradesh, India
[*]*Corresponding author E-mail*: rakshith.devu@gmail.com

An experiment was conducted during 2016-17 at Agricultural farm, Institute of Agricultural Sciences, BHU, Varanasi to evaluate certain new combination insecticides against the natural enemy population in rice. Ten insecticides *viz*. chlorpyriphos 50 + cypermethrin 5 EC, chlorpyriphos 20EC, cypermethrin 10EC, cypermethrin 10 + indoxacarb 10 SC, indoxacarb 14.5 SC, indoxacarb 15.8 SC, imidacloprid 17.8 SL, fipronil 5SC and deltamethrin 1.8EC were tested. Need based insecticidal sprays were given as per economic threshold limits of major insect pests of rice. Mean number of natural enemies (spiders + coccinellids) per 10 hills per plot was recorded on a day before spray, 3rd, 7th and 14th day after insecticidal spray. The mean number of natural enemies per 10 hills before spray was ranged from 4.63 to 6.04. On 7th day, chloropyriphos 50 + cypermethrin 5 EC treated plots had highest mean natural enemy population (4.91 per 10 hills) followed by plots treated with cypermethrin 10EC (4.47 per 10 hills). The lowest natural enemy population (3.50 per 10 hills) was observed in imidacloprid 17.8 SL treated plots. During 14th day after spray, plots treated with cypermethrin 10 + indoxacarb 10 SC and chlorpyriphos 50 + cypermethrin 5 EC had a mean natural enemy population of 5.19 and 5.12 per 10 hills, respectively which were superior over other insecticidal treatments. A lowest mean natural enemy population of 3.35 per 10 hills was recorded from the plots treated with fipronil 5 SC. These results show that the combination insecticides are safer to the natural enemies.

S4-PP-03

In search of chemical cues for attracting *Triommata coccidivora* (Diptera: Cecidomyiidae), a potential predator of mealybugs

B. R. JAYANTHI MALA[1*], P. D. KAMALA JAYANTHI[1], K. S. SHIVASHANKARA[1] and K. J. DAVID[2]

[1]*Division of Entomology and Nematology, ICAR - Indian Institute of Horticultural Research, Hessaraghatta Lake Post, Bengaluru - 560089, Karnataka, India*

[2]*ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India*

[*]*Corresponding author E-mail*: entjaya@gmail.com

Predatory gall midge, *Triommata coccidivora* (Felt) has been identified as one of the potential predators of mealybugs. These gall midges were found predating on major mealybug species of fruit crops *viz*. *Maconellicoccus hirsutus*, *Ferrisia virgata*, *Rastrococcus iceryoides* and *Planococcus citrii*. Using olfactometer and cage choice/no choice assays, we studied behavioral responses of female gall midge *T. coccidivora* to volatiles emitted from host fruit (custard apple) infested with mealybugs (*M. hirsutus*) subsequently predated by gall midge, *T. coccidivora*. The main objective of this study was to investigate chemical cues that induce behavioural responses in female *T. coccidivora*. Choice bioassays were conducted by using predated mealybug (*M. hirsutus*) with host fruit and unpredated mealybug with host fruit. We found significantly more *T. coccidivora*females attraction to the predated mealybug with host fruit. Similarly, the female gall midges spent significantly more time on predated mealybug along with host fruit. Further, choice tests were conducted mealybug infested host fruits with different levels of predation *viz*. 0%, 25%, 50%, 75%, 100% by gall midges. The female gall midges clearly exhibited their preference for 75% predation irrespective of host fruit presence. Y-tube olfactometer choice assays with predatory gall midges also showed significant preference for 75% predated mealybug with host fruit ($P = 0.009$, $t = 2.41$, $df = 49$). Choice assays for mealybug species specificity by *T. coccidivora* between *M. hirsutus* on host and *F. virgata* on host showed significant preference for *M. hirsutus*. Detailed studies using GCMS/GC-EAD to identify potent chemical cues that induce behavioral responses in female *T. coccidivora* are being envisaged.

S4-PP-04

Effect of horticultural mineral oil on *Tetranychus truncatus* Ehara (Prostigmata: Tetranychidae) and its predator *Neoseiulus longispinosus* (Evans) (Mesostigmata: Phytoseiidae)

KAVYA YADAV[*] and HASEENA BHASKAR
Department of Entomology, Kerala Agricultural University, Vellanikkara, Thrissur - 680654, Kerala, India
[*]*Corresponding author E-mail*: g.a.kavya@gmail.com

Tetranychustruncatus is a serious pest of horticultural crops in Kerala. Laboratory bioassays were conducted to evaluate the efficacy of horticultural mineral oil (HMO) against *T. truncatus* and to test its safety to the predatory mite, *Neoseiuluslongispinosus* at six concentrations of HMO (0.5, 1, 1.5, 2, 2.5 and 3%), six combinations of HMO + neem oil, (0.5, 1, 1.5 and 2% 1:1 v/v; HMO 2.5% + neem oil 2% and HMO 3% + neem oil 2%) and neem oil alone at 2 % with an untreated control. Four days after treatment, 100 per cent mortality of eggs was recorded in the treatments HMO 1.5, 2, 2.5 and 3% and in the treatment combinations of HMO + neem oil at 1, 2, and 3%, while neem oil 2% recorded a mortality of 93.33%. Significantly higher mortality of adult mites was recorded in HMO 3.0% (92%) followed by HMO 2.5% (84%), neem oil 2% (81.33%) and the treatment combination HMO 3% + neem oil 2% (77.33%). No mortality of predator egg was recorded in the treatments 0.5, 1, 1.5 and 2%, while HMO 2.5 and 3% recorded a mortality of 5.56%. Though with increase in the concentration of HMO, a significant increase in the mortality of adult predator was recorded, at the highest concentration of 3%, HMO recorded a mortality of only 27.78 per cent which was on par with neem oil 2% (33.33%). The study revealed that HMO possess very high efficacy against *T. truncatus* and is relatively safer to the predatory mite.

S4-PP-05

Development of bio-rational based management approach against mango hopper in Bangladesh

MD. SHAHADATH HOSSAIN*
Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Mymensingh - 2222, Bangladesh
**Corresponding author E-mail*: mshahadath67@gmail.com

A field experiment was conducted during 2016-17 mango crop season in farmers' fields of Gazipur, Rajshahi and Chapainawabgonj districts of Bangladesh to find out an effective bio-rational based management option for controlling mango hopper, *Idioscopus nagpurensis* (Pruthi) (Hemiptera: Cicadellidae). Randomized complete block design was used incorporating eight treatments with three replications. The treatments were: Pruning of overcrowded and overlapping branches, spraying of Azadirachtin, *Beauveria bassiana*, imidachloprid insecticide, installation of sticky traps (yellow, grey and blue) and untreated control. Lowest leafhopper population was recorded in *Beauveria bassiana* treated plants (3.0 hoppers/sweep/tree) followed by imidachloprid (3.7 hoppers/sweep/tree) treatments. Highest number of fruit retention was recorded in imidachloprid (40.00 fruits/20 inflorescence/tree) followed by *Beauveria bassiana* (32.67 fruits/20 inflorescence/tree) and Azadirachtin (24.00 fruits/20 inflorescence/tree) treated plants. Imidachloprid treatment offered maximum marginal benefit cost ratio (5.60). Increasing trend of hopper population was recorded in untreated control treatment. But considering health and environment issues, spraying of *Beauveria bassiana* @ 5.0 g/L of water at flower initiation stage, flowering stage and pea stage may be recommended for controlling mango hopper.

Biochemical mechanism of resistance to tomato fruit borer, *Helicoverpa armigera* (Hubner) in mid hills of Himachal Pradesh

PRIYANKA THAKUR*, R. S. RANA, K. C. SHARMA and NITESH SHARMA
Dr Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan - 173212, Himachal Pradesh, India
**Corresponding author E-mail*: pqu3010@gmail.com

Mechanism of host plant resistance in different tomato varieties against tomato fruit borer, *Helicoverpa armigera* (Hubner) was evaluated in Solan district. Eight varieties including three self-pollinating indeterminate varieties developed by selection (Solan Lalima, Solan Vajar, Palam Pink) and four hybrids (Naveen 2000+, Heem Sohna, Red Gold, Yash Tomato). To locate the sources for resistance in tomato foliage various macro and micro nutrients were extracted from varieties and chemical composition of tomato fruits like content of total phenols, titrable acidity, reducing sugars and total sugars were estimated to compare varying levels of resistance to *H. armigera*. None of the varieties were found to be completely protected from fruit borer attack but considerable variation in infestation in different varieties was observed. The phenols and sugars content in tomato fruits was found to be negatively correlated with fruit infestation at r = -0.895 and -0.650, respectively, indicating that susceptible varieties were low in phenols and sugars. Nitrogen (r = 0.660), potassium (r = 0.679), magnesium (r = 0.698), iron (r = 0.547) and manganese (r = 0.546) content were found to be optimistically correlated with fruit infestation while, phosphorous (r = -0.857) and zinc (r = -0.801) content did not favor the fruit borer attack. This observed resistance can be exploited for developing cultivars, which could produce the inducible response upon mild infestation, and can act as important component of integrated pest management compatible with other approaches like biological control, cultural control as well as chemical control.

S4-PP-07

Compatibility of the entomopathogenic fungi *Lecanicillium saksenae* with chemical, botanical and microbial pesticides

O. P. REJI RANI*
College of Agriculture, Kerala Agricultural University, Vellayani - 695522, Kerala, India
**Corresponding author E-mail*: rejiniop@gmail.com

Compatibility with insecticides is a prime factor that determines the suitability of an entomopathogen in the IPM package. *Lecanicilium saksenae*, ITCC Accession No: Ls.Vs.1-7714 a potent pathogen of rice bugs, mealy bugs, whiteflies and other sucking pests was found to be infective @ 10^7 spores ml^{-1}. Compatibility with insecticides and botanicals was assessed by poisoned food technique, measuring the colony diameter and spore count and that with *Pseudomonas flourescens* and *Trichoderma viride* by mixing the talc based formulations and assessing the number of colony forming units at weekly intervals. Among the new generation insecticides, spinosad 45 SC was found to be least inhibitory and flubendiamide 39.5 SC showed less inhibition. Indoxacarb 14.5 SC was 100% inhibitory. Both the old and new generation insecticides inhibited sporulation of *L. saksenae*. However, spinosad was least inhibitory followed by chlorantraniliprole. Malathion 50 EC, chlorpyriphos 20 EC and dimethoate 35 EC inhibited sporulation. Hyptis leaf extract and neem seed kernel extract were found inhibitory at the recommended field doses. On co-culturing the isolate at 10^{-6} dilution with *Pseudomonas flourescens* and *Trichoderma viride*, the spore count of *L. saksenae* was lowered. Pathogenicity to a wide range of sucking pests and compatibility to new generation insecticides and botanicals renders *L.saksenae* as an ideal candidate in good agricultural practices as well as in organic farming practices.

S4-PP-08

Integrating biological control and insecticide - an effective management strategy for maize stem borer *Chilo partellus* Swinhoe

SRINIVASA MURTHY KOTILINGAM[*] and B. K. CHOUBEY
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
[*]*Corresponding author E-mail*: ksmurthy.nbaii@gmail.com

Cotesiaflavipes Cameron (Hymenoptera: Braconidae), a gregarious endo-larval parasitoid of the maize stem borer *Chilopartellus* (Swinhoe) was evaluated under field conditions. Releases of the parasitoid either alone or along with the pesticide (fenvalerate), sprayed either prior to or after the releases of the parasitoid gave higher net returns and yield over the untreated control. The parasitism was more effective when releases of the parasitoid were made preceding spray application of insecticides, than when releases were made after insecticidal applications. Four releases of the parasitoid @ 2000/ha @ 500 per release registered maximum number of parasitized cocoons (52.6 per larva), higher yields (4019 kg/ha) and net profits (Rs. 7807/ha), followed by two releases with two sprays of insecticide (40.8, 3809 kg/ha and Rs. 6847/ha, respectively). Though insecticidal treatment resulted in maximum net profits and higher yields than other interventions, the additional costs, ecological hazards and residues associated do not outweigh the benefits of biological control and conservation of natural enemy activities in sustaining yields.

S4-PP-09

Essential oil based nanoemulsion for housefly, *Musca domestica* management

R. SENTHOORRAJA, M. SOWMYA*, KESAVAN SUBAHARAN, T. M. SUBRAMANYA, VINAY and N. BAKTHAVATSALAM
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
**Corresponding author E-mail*: sowmyamithu@gmail.com

The house fly, *Musca domestica* are mechanical carriers of pathogens causing enteric diseases in humans. Synthetic insecticides used in management of *M. domestica* have become less acceptable due to their persistence in the environment, toxicity to non-target organisms and insecticide resistance. Plant derived products like essential oils are safer alternatives, as they possess wide spectrum of biological activities against insects. They are not toxic and qualified as "low-risk pesticides". Volatility, poor water solubility, and oxidation are the limitations in use of phytoncides. Addressing these constraints will aid to popularize its use in pest management. Use of cutting edge technologies to develop a stable formulation will aid to tide over the problem. Nano emulsions of essential oil (Ajowan oil and thymol) prepared were thermodynamically stable and did not have phase separation and turbidity. They were characterized for free thaw test and droplet size and polydispersity index after 60 days of storage. The destabilization (flocculation/Ostwald's ripening) of the droplets was significantly inhibited by the steric repulsion attributing to narrow size distribution of the droplets. Transmission Electron Microscopy reveal that the droplets size range between 20 nm to 50 nm on day one. There was a gradual increase in the droplet size that led to steady destabilization of droplets through flocculation. Emulsions of plant derived products (ajowan and thymol) when used in poultry sheds it had significantly higher level of repellence of flies (12 - 25) as compared to control (178 flies/trap). The efficacy of plant derived emulsions needed reapplication at 15 days interval.

Breaking plant defenses: The case of tannin expulsion in *Hyblaea puera* Cramer

BINDU K. JOSE*, T. V. SAJEEV and E. V. ANOOP
Wood Science Department, Forestry College, Kerala Agricultural University, Vellanikkara, Thrissur - 680654, Kerala, India
**Corresponding author E-mail*: bindukjose@gmail.com

The occurrence of a pest insect on a host plant is determined by the palatability of the plant which in turn is decided on how best the insect can break the plants' defenses. In plants which resort to chemical defenses, this function is carried out through the secondary metabolites evolved for herbivore deterrence. We tested how an insect evades this chemical defense in one of the long-established pest problems in India - the teak defoliator, *Hyblaeapuera* on the teak *Tectonagrandis*. Estimation of tannin content of leaves and faecal pellets using Folin-Denis method gave higher values in leaves during pest outbreak season than during non-outbreak period and that the larvae expelled 99.03% of the tannin intake. This indicates that while the teak tree has primed up its deterrent chemical content during its susceptible period, the teak defoliator is able to counter it by evolving excellent tannin expulsion method. Breaking defenses of plants by lepidopteran insects is done not only by sequestering plant defense chemicals and transforming to the insects' own defense material, but also by having efficient expulsion system at the larval stage as demonstrated in this study. The results indicate that species specific biocontrol agents like the nuclear polyhedrosis virus is the only way towards eco-friendly management of the teak defoliator.

Toxicity of reduced risk insecticides on common green lacewing *Chrysoperla zastrowi sillemi* (Neuroptera: Chrysopidae) larvae *via* ingestion and direct spray techniques under laboratory conditions

M. H. KODANDARAM[*], DEEPAK KUSHWAHA, A. B. RAI
ICAR - Indian Institute of Pulses Research, Regional Research Centre, UAS Campus, Dharwad, Karnataka - 580005, India
[*]*Corresponding author E-mail*: kodandaram75@gmail.com

The common green lacewing, *Chrysoperla zastrowi sillemi* is an important predator in vegetable ecosystem. Reduced-risk insecticides are valuable tools in vegetable pest management and presumably conserving natural enemies. The toxicity of 12 different reduced risk insecticides to third instar larvae of *C. zastrowi sillemi* and their effect on survival of pupa and adult emergence after direct spray and ingestion treatments were evaluated. All the insecticides were used at field recommended rates. Cyantraniliprole, flupyradifurone, flonicamid, sulfoxaflor, spirotetramate, spiromesifen, diafenthiuron, imidacloprid, thiacloprid and neem oil (2.5 ml/l) were found slightly harmful (30-79% mortality) to larvae of *C. zastrowi sillemi* in direct spray bioassays. In ingestion bioassay method, sulfoxaflor, spirotetramate, thiacloprid and thiamethoxam were found to be harmless (< 30% mortality) whereas, cyantraniliprole, flupyradifurone, flonicamid, spiromesifen, diafenthiuron, imidacloprid and neem oil (2.5 ml/l), were slightly harmful (30-79% mortality). Cypermethrin and neem oil (5 ml/l) were found harmful (> 99% mortality) in both the bioassay techniques. Highest pupal survival (66.67%) and adult emergence (53.33%) was recorded in flupyradifurone treatment in direct spray bioassay method. However, when larvae were fed on sulfoxaflor treated food, maximum pupal survival (73.33%) and adult emergence (53.33%) was observed.

S4-PP-12

Efficacy of phytoncides on coconut rhinoceros beetle, *Oryctes rhinoceros* Linn.

RAVINDRAN PATTALI[*], KESAVAN SUBAHARAN[2], K. P. CHANDRAN, VIBINA, T. M. SUBRAMANYA[3] and R. SENTHOORRAJA[2]

[1]*ICAR - Central Plantations Crops Research Institute, Kasaragod - 671124, Kerala, India*

[2]*ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India*

[3]*Jawaharlal Nehru Centre for Advanced Scientific Research, Bengaluru - 560064, Karnataka, India*

[*]*Corresponding author E-mail*: ravicpcri@gmail.com

Phytoncides causing desirable bioaction on insects could be exploited as a key element in management of coconut rhinoceros beetle, *Oryctes rhinoceros* Linn. (Coleoptera: Scarabaeidae) a major pest on palms. The growth regulatory or cidal effect of the phytoncides on biostages of rhinoceros beetle was studied to design a strategy for eco-friendly management strategy. The effect of phytoncides (Citridora, basil and ajowan oil) on oviposition, hatchability and fumigant toxicity to the adult and larval stages were evaluated. All the phytoncides tested caused physiological response in the antennae of male and female beetles by electroantennography. The olfactory response of the beetles to phytoncides were confirmed using a Y tube assay. Citridora, basil and ajowan oil @ 1% caused 66.5% oviposition deterrence index (ODI). The major constituent of ajowan oil thymol caused 61.3 % ODI. Phytoncides at 1% caused over 60% reduction in hatchability. On larval and adult toxicity: basil oil > citridora oil > ajowan oil > thymol. Use of polymer matrix for sustained release of the phytoncides in management of rhinoceros beetle in the field will be discussed

S4-PP-13

Management of fruit borer, *Helicoverpa armigera* (Hubner), infesting tomato

M. SAFNA[*] and KUMUD. V. NAIK
Dr Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli - 415712, Maharashtra, India
[*]*Corresponding author E-mail*: safnasanaent@gmail.com

The investigation on the management of fruit borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) infesting tomato was carried out during rabi season of 2015-16 at Central Experimental Station, Wakawali, Ratnagiri district, Maharashtra. Three insecticides were evaluated. Of these, the treatment with chlorantraniliprole 18.5 SC @ 0.005 per cent was the best which recorded the minimum mean fruit infestation (13.82%). The next was spinosad with 17.39 per cent fruit infestation followed by indoxacarb 14.5 SC @ 0.012 per cent, lambda cyhalothrin 5 EC @ 0.0025 per cent, *Bacillus thuringiensis* 1.5 g/1itre, azadirachtin @ 0.003 per cent and quinalphos 25 EC @ 0.025 per cent which recorded 21.64, 23.50, 27.26, 30.51 and 32.70 per cent fruit infestation, respectively. All the above treatments were found to be superior to untreated control which recorded the highest fruit infestation of 38.65%.

Session 5: BIOLOGICAL CONTROL OF INVASIVE PESTS AND WEEDS

S5-LP-01

Classical biological control of invasive weeds - a historical perspective, challenges and future prospects

DJAMI DJEDDOUR* and RICHARD SHAW
CABI, Bakeham Lane, Egham, Surrey, TW209TY, United Kingdom
**Corresponding author E-mail*: d.djeddour@cabi.org

Biological control of weeds using co-evolved natural enemies is a globally recognised approach for the management of some of the world's most intractable invasive exotic plants. Since the first practical attempt at weed biocontrol in India in 1863 against the prickly pear cactus, *Opuntia vulgaris*, the practice has been expanding from use primarily on rangelands and aquatic systems into other "natural" environments. To date, over 550 biocontrol agents have been utilized, targeting 225 weeds in around 130 countries with a number of notable successes both with insect and fungal agents. Fueled by a global environmental awakening and the need to minimize the use of herbicides, weed biocontrol is now a tried and tested discipline, subject to internationally recognized protocols and legislative control, with an exemplary safety record, but it remains an under-utilized tool across much of the world. The most active countries continue to be the USA, Australia, Canada, South Africa and New Zealand; recent releases in the UK and Portugal reflect a raised awareness in the European Union and have helped outline the associated licensing and regulatory pathways. A concerted EU strategy is needed if progress is to be made tackling the most important weeds; resources can then be prioritized and synergized. In this paper, we reflect on some of biocontrol's enduring successes, the potential for new horizons in Europe and beyond, with support from novel technologies as well as examples of the modern regulatory and implementation challenges faced by today's biocontrol practitioners.

S5-OP-01

Functional traits variation of an invasive weed, *Ageratina adenophora* (Asteraceae) along an elevation gradient in Chitwan-Annapurna Landscape, Nepal

ANJU SHARMA POUDEL[1*], BHARAT BABU SHRESTHA[1], PRAMOD KUMAR JHA[1] and RANGASWAMY MUNIAPPAN[2]

[1]*Central Department of Botany, Tribhuvan University, Kathmandu - 44600, Nepal*

[2]*Region XIII - North America Coordinator, IPM CRSP OIRED, Virginia Tech., 526 Prices Fork Road, Blacksburg, VA 24061, USA*

[*]*Corresponding author E-mail*: anjupoudel.ap@gmail.com

Success of invasive plants in their introduced range is often attributed to high fitness of their functional traits to new environment. *Ageratina adenophora* (Sprengel) R. King and H. Robinson, one of the world's aggressive invasive weeds, has invaded from tropical to temperature regions in Nepal. We hypothesized that variation in plant functional traits enables this weed to invade wide elevational climate range. To test this hypothesis, we measured vegetative traits like leaf area LA, specific leaf area SLA and leaf nitrogen content LNC, as well as reproductive traits such as number of floral heads per ramet, total seeds per floral head, number of viable seeds per floral head and number of non-viable seeds per floral head, of *A. adenophora* along elevation gradients of 500, 1000, 1500, 2000 and 2500 m at a site in Chitwan-Annapurna Landscape (CHAL) of Nepal. In each elevation band, three quadrats (10 m × 10 m) were defined and from each quadrat 15 healthy individuals were sampled for vegetative traits and 10 for reproductive traits. Results showed that LA and mature seeds per head exhibited bell shaped response curve along the elevation gradient whereas all other remaining traits declined with the increasing elevation. However, the changes in the traits were gradual (low slope) even towards the uppermost elevation. This may indicate that the performance of *A. adenophora* was not constrained by low temperature at its current highest distribution and the plant may spread further upslope.

S5-OP-02

The spiraling whitefly, *Aleurodicus dispersus* Russell (Hemiptera: Aleyrodidae) in banana plantations in Costa Rica

HELGA BLANCO-METZLER[*] and SERGIO LAPRADE COTO
Crop Protection Research Centre (CIPROC), University of Costa Rica, San Pedro, San Jose - 55555, Costa Rica
[*]*Corresponding author E-mail*: helga.blanco@ucr.ac.cr

A study was conducted to explore the causes for outbreak of the spiraling whitefly, *Aleurodicus disperses* Russell, in commercial banana plantations in Costa Rica. Biotic and abiotic factors affecting the abundance of the spiraling whitefly were registered. Four nymphal parasitoids and six predators were found to affect *A. dispersus* population. 17 families of host plants for *A. dispersus* in the banana area were found, reaching a high reproductive and dispersal rate and pest status in short periods. The use of nematicides during the dry season was found to be the key factor for mortality of natural enemies responsible for maintaining pest populations under economic levels.

S5-OP-03

Effects of different temperatures on development and reproduction of *Aenasius arizonensis* (Girault) (=*Aenasius bambawalei* Hayat) (Hymenoptera:Encyrtidae)

RAZIEH JOODAKI[1], NOOSHIN ZANDI-SOHANI[1*], SARA ZARGHAMI[2] and FATEMEH YARAHMADI[1]

[1]*Department of Plant Protection, Faculty of Agriculture, Khuzestan Agricultural Sciences and Natural Resources University, Mollasani, Iran*

[2]*Department of Plant Protection, Faculty of Agriculture, Shahid Chamran University, Ahvaz, Iran*

[*]*Corresponding author E-mail*: nzandisohani@yahoo.com

Aenasius arizonensis (Girault) (=*Aenasius bambawalei* Hayat) has been recorded as a potential parasitoid wasp in Iran which is able to suppress significantly the population of solepsismealybug, *Phenaccoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae). In this study, the developmental and reproductive biology of *A. arizonensis* was investigated at three constant temperatures (25, 30, and 35°C). Egg to adult developmental time was calculated to be 15.92, 14.03 and 12.05 days for female and 17.44, 13.92, 11.77 days for male. Mean adult longevity ranged from 40.12 at 25°C to 22.93 days at 35°C for females and from 29.41 days at 25°C to 3.71 days at 35°C for males. The mean lifetime fertility of females at 25, 30, and 35°C was 102.42, 119.1, 154.32 offspring, respectively. The intrinsic rate of increase (r_m) was highest (0.214263) at 35°C and lowest at 25°C (0.119225). The mean generation time varied from 30.52 days at 25°C to 20.52 days at 35° C. These data indicate that *A. arizonensis* may be better adapted to high temperatures around 35°C and, therefore, could be a useful biological control agent of *P. solenpsis* during summer when such temperatures are prevalent in Southwestern of Iran. The result can be used to improve mass rearing programs of*A. arizonensis*.

S5-OP-04

Biological control potential of the new invasive fall armyworm, *Spodoptera frugiperda*, in smallholder farming in Africa

TADELE TEFERA*, ESAYAS MENDESIL and BIRHAUN SISAY
International Centre of Insect Physiology and Ecology, ILRI Campus, Gurd Shola, P.O.Box: 5689, Addis Ababa, Ethiopia
**Corresponding author E-mail*: ttefera@icipe.org

The fall armyworm (FAW), *Spodoptera frugiperda,* is a new invasive pest reported from Africa in 2016. A survey was conducted to explore its natural enemies in Ethiopia, Kenya and Tanzania in 2017. Small-holder maize farms were randomly selected and surveyed in the three countries. Five different species of parasitoids were recovered from fall armyworm eggs and larvae that included four Hymenopterans and one Dipteran. These species are new associations with the FAW and is the first report in Africa. In Ethiopia, *Cotesia icipe* was the dominant larval parasitoid with parasitism ranging from 33.8 to 45.3% while in Kenya, the Tachinid fly, *Palexorista zonata*, was the primary parasitoid with 12.5% parasitism. *Charops ater* and *Coccygidium luteum* were the most common parasitoids in Kenya and Tanzania with parasitism ranging from 6 to 12% and 4 to 8.3%, respectively. Eleven pesticidal plants (botanicals) were tested for their efficacy against FAW in laboratory and greenhouse conditions. Among the botanicals tested, *Azadirachta indica*, *Schinnus molle* and *Phytolacca dodecandra* resulted in the highest percentage larval mortality (> 95%) 72 hrs after treatment.

Identification and characterization of larval salivary gland polytene chromosomes of the peach fruit fly, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae)

FARZANA YESMIN[*], M. NAZIM UDDIN, G. M. SAIFUR RAHMAN and M. HASANUZZAMAN

Agrochemicals and Environmental Research Division, IFRB, AERE, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh

[*]*Corresponding author E-mail*: farzanayesmin75@yahoo.com

Peach fruit fly, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) is native to South and South-East Asia. It is a polyphagous species and has a high reproductive potential (ca. 600 eggs in lifetime), high biotic potential, *i.e.* several generations of progeny per year. The species has rapid dispersal ability and can be active throughout the year. Its establishment may have a serious impact on the environment following the initiation of chemical and/or biological control programmes. *B. zonata* is of quarantine significance to EPPO (the European and Mediterranean Plant Protection Organization) countries. The pest is classified on the A1 list of pests recommended for regulation as quarantine pests by Centre for Agriculture and Biosciences International (CABI). The present study initiates an attempt to identify the larval (3rd instar) salivary gland polytene chromosome arms of *B. zonata* using Olympus phase contrast microscope BX 41. A photographic representation of the polytene chromosomes of this species associates with identifying tips as well as most distinguished landmarks of each polytene chromosome arms are described. Each polytene nucleus composed of five long chromosomes. The longer arm is noted as left (L) and the shorter one as right (R) arm followed by the position of centromere. No appearance of polytenized sex chromosomes indicates that five polytene chromosomes correspond to the five autosomes of mitotic chromosomes. Polytene chromosomes are of special interest to construct a genetic sexing strain (GSS) of a pest species. GSS can play important role for the successful application of sterile insect technique (SIT) in field application as part of the biological control programme under Integrated Pest Management (IPM) scheme.

Releases of egg parasitoid *Anastatus fulloi* for control of litchi stink bug *Tessaratoma papillosa*

YI HUI WU*, HSUAN JEN PAN, DEN JEN WU and MEI CHUN LU
Biological Control Branch Miaoli District Agricultural Research and Extension Station Council of Agriculture, Executive Yuan, Dahu, Miaoli 36441, Taiwan
**Corresponding author E-mail*: yhwwhy.tw@yahoo.com.tw

Litchi stink bug (*Tessaratoma papillosa*), an invasive species first reported in Kaohsiung, Taiwan in 2010, has been expanding throughout the western Taiwan. This stink bug not only reduces the yield of litchi (*Litchi chinensis*) and longan (*Dimocarpus longan*), but also damages *Koelreuteria elegans* and *Sapindus mukorosii* that have been used for urban forestation. Among various management approaches, this study is focused on development of a biocontrol framework to suppress the field population of the stink bug. We have identified five species of egg parasitoids of the stink bug which included *Anastatus fulloi*, *A. formosanus*, *Ooencyrtus utetheisae*, *O. phongi* and *Eulophidae* sp. To develop a mass production system, we demonstrated that eggs of the moth *Samia cynthia* can serve as a laboratory host for *A. fulloi* and *A. formosanus*. The stink bug usually lays eggs several times from March to May. A field release test was therefore conducted from the beginning of March with 10,000 *A. fulloi* (sex ratio 1:1) released per hectare every two weeks. In the release sites, parasitism (10~20%) was observed two weeks after the first release and reached up to 70% by the end of the test around May. At the non-release sites, parasitism remained low during the experiment period (*i.e*. 17% by the beginning of May). We also are in the process of developing a novel method involving Unmanned Aircraft System for releasing the egg parasitoids in order to target those longan and litchi orchards located in difficult landscape.

S5-OP-07

Impact of release of classical weed controlling agent *Cecidochares connexa* (Macquart) (Diptera: Tephritidae) on the population of Siam weed *Chromolaena odorata* King and Robinson (Asteraceae) in Karnataka

A. N. SHYLESHA*
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
**Corresponding author E-mail*: anshylesha@gmail.com

Chromolaena odorata King and Robinson (Asteraceae), an important native weed of tropical America, got accidentally introduced into India and became a major weed in the Indian subcontinent. The weed popularly known as Siam weed has spread to several areas. Severe infestation in Buxar, Jalpaiguri and Western Ghats has reduced the area under forest vegetation creating imbalance in the native flora. It is well distributed in North Eastern region, Eastern region of India in Jharkhand and Chhattisgarh areas. Several important biocontrol agents introduced into India during 1971-2001 and released in Kodagu and other weed infested areas of Karnataka did not become established. However, the efforts ere continued. The Siam weed stem gall fly *Cecidochares connexa* (Macquart) (Diptera: Tephritidae) was introduced into India from Bogor, Indonesia during November 2002. The culture was established in the Quarantine laboratory at NBAIR and was released in Tataguni estate, Bengaluru and in Western Ghats. Gall fly successfully colonized. As a classical biological control agent to manage the weed, it was released in infested areas of Puttur and in Tataguni estate in Bengaluru. Establishment of the gall fly was monitored on a 6-monthly basis. The results indicated that the gall fly has spread to a vast area in and around Puttur (48 km length), Udupi (51 km length), Brahmavar and nearby areas. Showing remarkable increase in the number of galls per plant and there was smothering of the weed in the released areas. In Tataguni estate, there was remarkable spread of the gall fly and the entire stretch of Kanakpura (14 km length) road is now with good gall incidence of 80 per cent. The establishment of the gall fly over the last 10 years is satisfactory and the spread of the gall fly is promising with the number of galls per plant has increased to 18 from the pre-count of 1.2 per plant.

S5-OP-08

Aphid population modified the biocontrol activity of ladybirds

DESH DEEPAK CHAUDHARY
Department of Zoology, Indira Gandhi National Tribal University, Amarkantak - 484887, Madhya Pradesh, India
Corresponding author E-mail: ddchaudhary90@gmail.com

Present study considered the aphid resource fluctuation as a stimulus and assessed functional response curves of two generalist ladybird predators, *Menochilus sexmaculatus* (Fabricius) and *Propylea dissecta* (Mulsant). This is the first time that effect of prey densities experienced during early immature development on shaping functional responses of late larval/adult stages is being investigated across all phyla. For this, predators were changed abruptly from their rearing density of scarce/optimal/abundant prey to five testing prey densities (extremely scarce/scarce/sub-optimal/optimal/abundant). Results revealed type-II functional responses for 4^{th} instars and females of *M. sexmaculatus* under three rearing densities; and for 4^{th} instars of *P. dissecta* under optimal prey and their females under scarce/abundant prey rearing densities. However, 4^{th} instars of *P. dissecta* under scarce/abundant prey and females of both ladybirds under optimal prey rearing densities exhibited modified type-II functional response. Further, 4^{th} instars/females of both ladybirds had shortest prey handling time (Th) and their predicted consumption of prey for 24 h (T/Th) was greatest on scarce prey rearing density. Experience of scarce prey rearing probably equips predators to compensate for shortage of food by consuming higher prey biomass than usual on suddenly encountering optimal/abundant prey resource. Also *M. sexmaculatus* better compensates prey resource fluctuation than *P. dissecta*.

Biological suppression of invasive rugose spiraling whitefly *Aleurodicus rugioperculatus* Martin in coconut

K. SELVARAJ[*], T. VENKATESAN, B. V. SUMALATHA and A. N. SHYLESHA
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
[*]*Corresponding author E-mail*: selvaentomo@gmail.com

Population dynamics of rugose spiraling whitefly (RSW), *Aleurodicus rugioperculatus* Martin, and its parasitoid was studied in relation to weather parameters from November 2016- December 2017 on coconut. Results revealed that the infestation of RSW declined from 60.52 % egg spiral per leaflet/leaf in November 2016 to 15.80% egg spiral per leaflet/leaf in December 2017. Further, *Encarsia guadeloupae* Viggiani (Hymenoptera: Aphelinidae) was the only major natural enemy encountered on the RSW causing 16.90% parasitism in December 2016, which had increased to 82.56% by December 2017. The density of the RSW was positively correlated with maximum temperature and negatively correlated with RH. The multiple regression analysis revealed that about 60.15% of the variation in the RSW population density was due to natural parasitism. The parasitoid population was augmented by the re-distribution of *E. guadeloupae* to affected areas through field insectary technique. Further strategies for conservation and encouragement of natural buildup of *E. guadeloupae* through providing reservoir plants/banker plants which protect them from pesticides, shelter and unfavorable weather factors are being worked out. *Canna indica*, commonly known as Indian shot plant, was found to be potent banker plant for conservation of the parasitoid. These may be planted in border as well as in between the coconut garden. The parasitoid population has also increased due to various awareness programmes on its conservation with the help of different stakeholders. Population of the parasitoid also increased phenomenally over a period of time through breeding, favorable weather conditions and also shifting from *A. dispersus* and perennial nature of palms.

S5-OP-10

Influence of weaver ant, *Oecophylla smaragdina* Fabricius (Hymenoptera: Formicidae), on the mealybug parasitism by encyrtid parasitoid (Chalcidoidea: Encyrtidae)

NALINI T. S[*] and S. MANICKAVASAGAM
Department of Entomology, Faculty of Agriculture, Annamalai University, Chidambaram - 608002, Tamil Nadu, India
[*]*Corresponding author E-mail*: nalini_jk@yahoo.com

The influence of *Oecophylla smaragdina* Fabricius (Hymenoptera: Formicidae) on parasitism of *Phenacoccus solenopsis* Tinsley and *Ferrisia virgata* Cockerell (Hemiptera: Pseudococcidae) by *Aenasius arizonensis* (Girault) (= *Aenasius bambawalei* Hayat) and *A. advena* Compere (Chalcidoidea: Encyrtidae) was studied under laboratory conditions. The number of surviving *A. arizonensis* and *A. advena* was 3.40 and 5.20 at 20th minute and 1.0 and 0.8 at 60th minute, respectively. Per cent parasitism was 13.60 and 10.00 in treatment with *O. smaragdina* for *A. arizonensis* and *A. advena*, respectively. Per cent mortality due to *O. smaragdina* attack was 93.33 and 94.67 for *A. arizonensis* and *A. advena*, respectively.

S5-PP-01

Current status of invasive rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae), in Karnataka, India

SANJAY KUMAR PRADHAN[1*] and A. N. SHYLESHA[2]
[1]*University of Agricultural Science, Gandhi Krishi Vignan Kendra, Bengaluru - 560065, Karnataka, India*
[2]*ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India*
[*]*Corresponding author E-mail*: sanjaymkg314@gmail.com

An invasive rugose spiraling whitefly, *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae), was first observed in Florida, United States, in 2009. It was detected for the first time on coconut palm in the Indian states of Tamil Nadu at Pollachi in 2016. Subsequently it was found infesting banana (*Musa* sp.), mango (*Mangifera indica*), sapota (*Manilkara zapota*), Indian almond (*Terminalia catappa*), butterfly palm (*Dypsis lutescens*), guava (*Psidium guajava*), custard apple (*Annona reticulata*) and several ornamental plants in Kerala, Karnataka, Andhra Pradesh and Tamil Nadu. Infestation of the pest was recorded as 20-45% in coconut 18-56% in banana and 21-52% in Indian almond. Survey also revealed natural parasitism by *Encarsia guadeloupae* Viggiani (Hymenoptera: Aphelinidae) to be 15-35% in coconut, 11-18% in banana and 22-38% in sapota. Parasitism by *Encarsia dispersa* Polaszek was also recorded which ranged from 0-7% only in a few host plants where severe infestation was observed. Overall, natural parasitism ranged from 40.0-80.0% in different locations in Karnataka, Tamil Nadu and Kerala. Other commonly observed natural enemies were predatory green lacewing, *Dichochrysa astur* (Banks) (Neuroptera, Chrysopidae), *Cybocephalus* sp. (Coleoptera, Cybocephalidae), coccinellid beetle, *Cheilomenes sexmaculata* (Fabricius) (Coleoptera, Coccinellidae) *etc*. Based on the observations, *E. guadeloupae* can be considered as an effective parasitoid for controlling the rugose spiraling whitefly.

Bio efficacy of entomopathogenic nematodes against serpentine leaf miner, *Liriomyza trifolii* Burgess (Diptera: Agromyzidae) in oilseed crops

GAYATRI BANDARU[*] and P. DURAIMURUGAN
ICAR - Indian Institute of Oilseeds Research, Rajendranagar, Hyderabad - 500030, Telangana, India
[*]*Corresponding author E-mail*: b.gayatri@icar.gov.in

Serpentine leaf miner, *Liriomyza trifolii* Burgess (Diptera: Agromyzidae) is a polyphagus pest native to USA and the Caribbean. It was introduced into India in 1990's along with cut chrysanthemums and it was first reported in the annual castor group meeting held at Hyderabad. It has very wide host range with 78 annual plant species as host. Damage is mainly caused by larva as it mines below the leaf epidermis causing damage to the leaf mesophyll. Adult flies puncture the leaf tissue both for feeding and oviposition causing stripling appearance on leaves. The mines caused by the larva even act entry points for pathogens making the plant susceptible to secondary infection. Several natural enemies like predators, parasitoids and pathogens control leaf miner populations in the field. Most of these natural enemies get killed due to chemicals applied during the season to control other pests. Entomopathogenic nematodes are one of the most virulent pathogens killing different life stages of the insect pests. An entomopathogenic nematode, *Heterorhabditis bacteriphora* (Nematoda, Heterorhabditidae) was tested against late instar larvae and pupa of *L. trifolii*. Infective juveniles (IJs) were inoculated @ 50 IJs per larvae/pupa. About 50% mortality was observed in late instar larvae in 24 hours post infection. Pupae were not affected by this nematode and 100% adult emergence was observed. This bioassay demonstrates that EPNs can be included as a component in biocontrol of *L. trifolii* in oilseed crops.

S5-PP-03

Temperature dependent development of *Oenopia conglobata* (L.) (Coleoptera: Coccinellidae) fed on *Aphis gossypii* (Glover) (Hemiptera: Aphididae)

MOHAMMAD AMIN JALALI[*] and MAHDI ZIAADDINI
Vali-e-Asr University of Rafsanjan, Rafsanjan, Kerman, Iran
[*]*Corresponding author E-mail*: jalali1353@yahoo.com

Lady beetles are known beneficial insects, with a long history in augmentative and classical biological control. The lady beetle *Oenopia conglobata* (L.) is a natural enemy of many herbivores, particularly aphids. The temperature-dependent development of *O. conglobata*, was studied at six constant temperatures (22.5, 25, 27.5, 30, 32.5 and 35ºC) to better understand its development rate and environmental constraints. A linear and a nonlinear (Lactin) models were fitted to the data. In the thermal range from 22.5 to 32.5ºC, rate of development increased for all stages; 35ºC was lethal for all stages and no eggs hatched. The Tb and K values for the biological cycle (egg-adult) were 8.84ºC and 263.15 DD, respectively. The lower temperature, optimum temperature, and upper temperature thresholds were 8.45-8.82, 33.2 and 35.0ºC, respectively, for development from egg to adult. High R2 values and low RSS values revealed a good fit to the experimental data for total development and different developmental stages of *O. conglobata*. The results may contribute to the improvement of effective methods for mass rearing of *O. conglobata*.

Status of new invasive coconut rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin and scope for bio-control in Tamil Nadu

K. RAJAMANICKAM[1*], T. SRINIVASAN[1], K. RAMARAJU[2], M. ALAGAR[1], K. SELVARAJ[3] and T. VENKATESAN[3]

[1]*Coconut Research Station, Tamil Nadu Agricultural University, Aliyar Nagar - 642101, Pollachi, Tamil Nadu, India*

[2]*Tamil Nadu Agricultural University, Coimbatore - 641003, Tamil Nadu, India*

[3]*ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India*

[*]*Corresponding author E-mail*: sprkraja18@rediffmail.com

Rugose spiraling whitefly, *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae) was first reported in India, in Pollachi and surrounding areas of Tamil Nadu during August 2016. Extensive survey was made in all the coconut growing districts in Tamil Nadu. In each coconut garden, approximately 10 trees were randomly selected for observing per cent frond infestation, adult population, natural enemy complex and alternate host plants. A new damage rating scale was also developed. The results revealed that a mean damage grade of 1.39 was observed in Coimbatore district with 34.3 per cent parasitism by *Encarsia guadeloupae* Viggiani (Hymenoptera: Aphelinidae) followed by Kanyakumari (1.1), Tiruppur (1.2) and Tiruppur (5.2) and other districts. The alternate host plants such as banana, nutmeg, hibiscus, custard apple, bhendi, jatropha, citrus, arecanut, neem, parthenium, mango, tapioca, pepper, sapota and certain ornamental plants were noticed. Survey in the farmers' gardens revealed natural parasitism by *E. guadeloupae* ranging from 28.6 to 77.4 per cent in Anaimalai block of Coimbatore District during 2017. Eight predators in the Coccinellidae and Chrysopidae were also identified. It was also observed that *E. guadeloupae* wascapable of bringing about 60 to 70 per cent parasitism of rugose spiraling whitefly aiding in bio-suppression of the pest. A total of 4,264 farmers have been supplied with *E. guadeloupae* for releases in the RSW infested gardens in Tamil Nadu. Several IPM programmes were conducted for sensitizing the farmers to contain the spread of this pest to newer areas.

Population fluctuation of cotton mealy bug, *Phenacoccus solenopsis* Tinsley in relation to weather parameters in *Bt* cotton ecosystem

ARUNKUMAR HOSAMANI[*], S. G. HANCHINAL and G. AKSHATHA
Biocontrol Unit, Main Agricultural Research Station, University of Agricultural Sciences, Raichur - 584104, Karnataka, India
[*]*Corresponding author E-mail:* arent23@gmail.com

Cotton (*Gossypium* spp.) is one of the important fiber crop of the country which occupied an area of 118.81 lakh ha with a productivity of (522 kg lint/ha). The insect pest spectrum of cotton is quite complex with more than 1,326 species throughout the world and nearly 130 species of insect pests and mites are reported to cause damage to cotton crop in India. In recent years, the invasive insect pest, cotton mealy bug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) was appeared in cotton growing areas of Karnataka. A field experiment was conducted to know the incidence of cotton mealy bug during 2016-17 and 2017-18 with an area of 1000 sqm and a popular *Bt* cotton hybrid, KCH-14K59 (Jadoo) BG II was grown and the results indicated that during 2016-17 the peak activity of mealy bug was noticed during first fortnight of January (82.25 mealy bugs/10 cm shoot length) with peak activity parasitoid *Aenasius arizonensis* (20.75 cocoons). During 2017-18 the activity of mealy bug was noticed during last week of January (26.12/10 cm shoot length) which coincided with the peak activity of parasitoid (11.18 cocoons). The weather parameters showed negative and non-significant correlation with relative humidity2 (r = -0.69), rainfall (r = -0.007), maximum (r = -3.14) and minimum temperature (r = -0.40). Relative humidity showed positive and significant correlation ($r = 0.56^{*}$) on incidence of cotton mealy bug.

S5-PP-06

The role of computational analysis in the phylogenetic interpretation of the classical biological control

NAMRATA SINGH*, SUNIL ARCHAK, VINOD PANDIT and MALVIKA CHAUDHARY

CABI, 2nd Floor, CG Block, NASC Complex, DP Shastri Marg, Opposite to Todapur Village, PUSA, New Delhi - 110012, India

**Corresponding author E-mail*: n.singh@cabi.org

The value of its potential impact of classical biological control is often estimated to be extreme being a low cost, chemical free means to control pests and weeds. However, though of a great significance biological control does constitute some inherent risk due to the process of introducing new species into a new area involving the unknown. Evolutionary biology holds much of a fundamental importance behind the theory and practice of biological control as it has the potential to predict the extent to which the adaptation would actually occur further determining not only the success of establishment and control of the target species but also the degree of its impact on the non-target species. Predictions of potential non-target effects in biocontrol research systems make use of the information concerning the phylogenetic relatedness of targets and non-targets of the agent under consideration. Recent progress in genomics and in view of the enormous quantities of genetic databeing sequenced, the emerging computational tools for both population genetics and phylogenetics can help practice biological control more effectively making more accurate assessments of species relationships for agent selection. Advances in DNA sequencing technology and corresponding bioinformatics tools of DNA fragment assembly and annotation has made possible to obtain whole genome sequences of organisms providing opportunities to identify many genes of functional significance furthermore developing molecular markers to resolve evolutionary relationships. These data from the various genome projects in the field of bioinformatics shall lead to a better understanding of the genetics of the host-agent interactions.

Biocontrol of five invasive weeds of Meghalaya- a case study

RAJIB KUMAR BORAH*, JIMI BORAH and SHAHNIN AKHTAR ISLAM

Corresponding author E-mail: rkborah@gmail.com

The state of Meghalaya, in North East India is endowed with a dense cover of natural forest. A vast majority of the forests is owned by communities who traditionally practice shifting cultivation. This has resulted in significant reduction of original forest area leading to drastic change in the floristic composition of the state. This is evident by ubiquitous presence of various invasive weeds such as: *Mikania micrantha*, *Chromolaena odorata*, *Ageratum conyzoides*, *Spilanthes paniculata* and *Spermacoce hispida*. A survey for natural fungal enemies against these weeds was carried out in the state with the objective of identifying potential biocontrol agents. A total of six pathogenic fungi were isolated from infected leaves of these target weeds. Of these, two fungi isolated from leaf spot and leaf necrosis disease of *Mikania micrantha* were identified as *Gliocladium roseum* and *Phomopsis* sp. respectively. The fungus isolated from *S. paniculata, C. odorata, A. conyzoides* was *Fusarium solani* and from *S. hispida* as *F. acuminatum*. Pathogenicity test carried out on target weeds and agricultural crops grown in Meghalaya (maize, chilli, tomato, rice and ginger) showed that all the isolated fungi were found infecting the weeds from which they were isolated and also maize and tomato. They were found non-attacking seedlings of some economically important tree species of Meghalaya *viz. Pinus kesiya*, *Magnolia champaca*, *Alnus nepalensis*, *Chukrasia tabularis*, *Exbucklandia populnea* and *Castanopsis indica*. Hence, these fungi can be tested in field condition on pilot scale, in forest areas but not in agricultural areas where maize or tomato is grown.

Session 6: PRODUCTION AND UTILIZATION OF MACROBIALS FOR INSECT PEST MANAGEMENT

S6-LP-01

Optimizing the genetics of biocontrol agents for classical and augmentative applications

RICHARD STOUTHAMER*
Department of Entomology, University of California, 3401 Watkins Dr., Riverside, CA - 92521, USA
**Corresponding author E-mail*: richards@ucr.edu

Prolonged rearing of biocontrol agents is an unavoidable part of classical and augmentative biological control projects. Yet, little practical attention has been given to the potentially negative impacts of such prolonged rearing for the effectiveness of biocontrol agents once they are released in the field. Several effects of prolonged mass rearing are known of prolonged mass rearing and these include: loss of genetic variation and adaptation to mass rearing conditions (domestication). In classical biological control, the release of natural enemies lacking genetic variation can result in either the establishment of populations that are ineffective, or failure of the establishment and control of the pest. Problems caused by this lack of variation in classical biological control cannot be solved by releasing more individuals of the same mass reared population since they will also lack genetic variation. In augmentative biological control, where the released natural enemies have to do the control without the expectation that they will establish long term populations, quantity can compensate for a lack of quality. However, also for augmentative biological control, release of natural enemies that have not been selected for mass rearing conditions is expected to result in better control. Fortunately, both in classical biological control and in augmentative biocontrol, the problems associated with lack of genetic variation and domestication of the natural enemies can be avoided by simple rearing measures that are not very expensive. These include maintaining separate populations, a large number of isofemale lines etc.

S6-LP-02

Macrobials losing out to microbials: How to tilt the scales?

CHANDISH R. BALLAL*
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
**Corresponding author E-mail*: ballalchandish@gmail.com

Microbial biocontrol agents (entomopathogenic viruses, bacteria and fungi) and macrobials (parasitoids and predators) are considered as green alternatives for pest management as they are eco-friendly and non-target species friendly and hence ideally suited for integration in IPM modules and there is no clear evidence of resistance development in pests. While microbials have an edge over macrobials as conventional techniques can be adopted for their production, storage and field application, the facts that macrobials possess the ability to search and locate their hosts and also that they are exempted from registration requirements are a clear advantage they have over microbials. In India, several commercial units have taken up production of microbial biocontrol agents, while commercial uptake of macrobials is meagre. This paper brings out the constraints faced in commercial uptake of macrobials and the possible solutions for tackling the issue of "macrobials losing out to microbials". Macrobials like trichogrammatids, exotic parasitoid - *Acerophagus papaya* Noyes and Schauff and coccinellid predator - *Cryptolaemus montrouzieri* Mulsant have proved their worth in managing indigenous/invasive pests. For uninterrupted production of macrobials, the challenges faced are in setting up of small-scale or factory-scale automated production facilities and standardizing long-term storage protocols and farmer-friendly release technologies. Facilities and expertise required, and high cost involved in continuous maintenance of host, host plant and macrobial production systems and the difficulty in predicting the success in the field are additional challenges. The emphasis should be on selection of an appropriate species/strain/population of the agent, standardization of simple yet effective production and release technologies and above all, creation of a perfect network of researcher - extension worker - commercial entrepreneur and farmer.

S6-OP-01

Classical biological control of insects and their impact in developed and developing countries: a comparison using the BIOCAT database

STEFAN TOEPFER[1*], M. J. W. COCK[2] and ULRICH KUHLMANN[3]
[1]*CABI, C/o Plant Protection Directorate, Rarosi ut street 110, HU - 6800, Hodmezovasarhely, Hungary*
[2]*CABI, Egham, United Kingdom*
[3]*CABI Europe, Delemont, Switzerland*
[*]*Corresponding author E-mail*: stoepfer@gmx.net

High-income countries may invest more in classical biological control than middle and low-income countries, and correspondingly may benefit more. We analyzed the BIOCAT database of insect classical biological control agents (CBCAs) introduced against invasive insects to examine the patterns behind this. We use the World Bank categories of per capita income to classify countries as low, lower-middle, upper-middle, and high-income. Looking at the countries that have invested moderately (10+ introductions) or extensively (40+), it is clear that high-income countries have been considerably more active. In total, 46 high-income countries out of 154 active countries have made 66% of all agent releases (USA: 31% of all releases). High and middle-income countries made most releases in the 1930's and 1950's to 1970's. Low-income countries started later, peaking in the 1980's. Many classical biological control successes are repeated by using the successful CBCAs against the same pests in other countries. Using successful agents developed by high-income countries is an easy way to tackle some major pests in low and middle-income countries. However, many important pests in these countries are not a target in high-income countries; and these merit funding and investigations. Despite successes (= pest controlled), impact is often poorly assessed if at all, and is seldom documented. Commonly used socio-economic methods can be adapted to assess the biocontrol impacts. Protocols could easily be developed for programmes that reuse agents of known effectiveness, and where basic parameters are understood. Impact assessments should become a part of each classical biological control programme.

S6-OP-02

Efficacy of augmentative release of the parasitoid wasp, *Bracon hebetor* Say against the pearl millet ear-headminer

MAME FATOUMATA GOUDIABY[1*], IBRAHIMA SARR[1], MALICK NIANGO BA[1], MBACKE SEMBENE[1]and RANGASWAMY MUNIAPPAN[2]
[1]*Senegalese Institute of Agricultural Research, BP - 53, Bambey, Diourbel, Senegal*
[2]*IPM Innovation Lab, Virginia Tech, Blacksburg, Virginia, USA*
[*]*Corresponding author E-mail*: bichously.fg@gmail.com

Pearl millet is a staple food cereal crop in the Sahel where it is grown by smallholder farmers for their own consumption. It is a hardy crop with high level of nutrients and can develop on low soil-fertility and in extreme drought conditions. However, the grain yield in farmer fields is far below the potential. The yield losses are mainly due to the millet ear-headminer, *Heliocheilus albipunctella* (de Joannis), which can cause destruction up to 85% in the field. This study was aimed at assessing the efficacy of augmentative releases of the parasitoid wasp, *Bracon hebetor* Say in controlling *H. albipunctella* infesting pearl millet within the groundnut basin of Senegal. The study area was divided into three homogenous blocks (northern, southern and eastern parts) where, in each block,two sets of three villages each were selected, one set for releasing the parasitoid and the other as control (no release). The results showed that the millet ear-headminer was the most common insect pest in all locations representing 80% of the samples compared to the stem borer, *Coniesta ignefusalis* (Hampson). The natural parasitism by *B. hebetor* was around 3% to 15% in the Southern and Central parts of groundnut basin, while it was very high in the Northern part, giving up to 85% larval parasitism. In all villages where the parasitoids were released, an increase in parasitism between 9% and 26% was noted, resulting in significantly lower pest incidence as compared tothat of the control villages.

S6-OP-03

Development of an automated production system for lacewings

JOE AIR JIANG[1*], HUNG-JEN LIN[1], JEN-CHENG WANG[1], YU-CHENG YANG[1], SHENG-HAO CHEN[1], TSUI-SHAN HSU[1], HUNG-JU CHEN[2] and MEI-CHUN LU[2]
[1]*National Taiwan University, Taipei City, Taiwan*
[2]*Miaoli District Agricultural Research and Extension Station, Council of Agriculture, Executive Yuan, Taiwan*
[*]*Corresponding author E-mail*: michael82118@gmail.com

In pest management, biological control is considered as a substitution of pesticides or a method to reduce the use of pesticides. However, the cost of labor for manually breeding natural enemies is too high to bear. Thus, an automated smart system is proposed in this study to produce lacewings. This smart system includes four basic modules: a storage mechanism, a feeding mechanism, an egg-taking mechanism and an egg-placing mechanism. These mechanisms are connected to conveyors or mechanical arms to automatically produce lacewings. Moreover, these mechanisms can transmit real-time data *via* an Internet of Things (IoT) system. Through the remote-control function provided by the IoT system, management personnel could take proper actions if any anomalies are detected. In this study, the performance of the smart lacewing production system and a traditional lacewing breeding method adopted in Taiwan were compared to show the advantages of employing the proposed smart lacewing production system. The research results showed that the automatic process has successfully reduced 96.7% egg-laying time, 90.0% feeding time and 88.5% egg-taking time. These results indicated that adopting the smart lacewing production system could significantly increase the efficiency of production, reduce the cost of labor, and improve the willingness of farmers to use the smart system.

S6-OP-04

Optimizing the mass production system of lacewing

HUNGJU CHEN*, YUCHIN CHAO, MEICHUN LU and JHENGKUAN LIOU
Miaoli District Agricultural Research and Extension Station, Council of Agriculture, Executive Yuan, Taiwan
**Corresponding author E-mail*: hungju@mdais.gov.tw

Biological control has become a worldwide trend for over 50 years and it is also popular in Taiwan. Research on biological control, focusing mainly on lacewings, mantids, ladybugs, spider mites and parasitoids has been carried out for the last 20 years in Taiwan. According to the previously failed business, the key limitation for application of biological control in Taiwan is the labor-intensive mass production techniques. Therefore, we intended to developan automatic production system for the lacewing, *Mallada basalis* (Walker) to reduce the production cost. We improved the space utilization rate, reduced the quantity of feed for larvae, and increased the fecundity of adults in the oviposition unit. Because of cannibalism in larvae of lacewing, the space and food availability could significantly affect their survival rate. We used partition rearing system to prevent cannibalism and precise feeding tools which reduced over 30% of the feeding requirement. On the other hand, for adults, we designed 5 kinds of rearing density which comprised 22/26/33/44/65 cm^3 per lacewing to assesswhether crowding has any effect on the fecundity. There was a declining trend, but no significant difference was observed in fecundity from the density of 44 to 22 cm^3 per lacewing. But, in the density of 65 cm^3 per lacewing, there was a significantly higher fecundity, indicating that crowding should be avoided. This helps in deciding the number of lacewings to be released in oviposition cages for better productivity. Optimization of lacewing rearing methods would facilitate the development of automatic mass production system that is labor-saving and economical.

S6-OP-05

Biological control potential of two species of tephritid fruit fly by parasitoid wasps (Braconidae: Opiinae)

MOR SALOMON*
Israel Cohen Institute for Biological Control, Plants Protection and Marketing Board, Rehovot - 7630510, Israel
**Corresponding author E-mail*: mor.slmn@gmail.com

Fruit flies (Diptera: Tephritidae) are one of the most damaging groups of agricultural pests in the world. An IPM program against *Ceratitis capitata* (Wiedemann) in Israel includesaugmentative releases of several species of parasitoid wasps, showing some success in controlling its population. The fruit fly, *Bactrocera zonata* (Saunders) was recently discovered in a metropolitan area in central Israel. We examined the efficacy of four species of parasitoid wasps in controlling *B. zonata*, and their preferred fruit fly species. The experiments were conducted in a quarantine facility using flies and wasps from laboratory cultures. Each wasp received the optimal aged egg or larvae for parasitism.The results showed that among the three species of egg-pupal parasitoids which belong to the subfamily Opiinae under Braconidae, *Fopius ceratitivorus* Wharton and *F. caudatus* (Szépligeti) did not parasitise eggs of *B. zonata*, while *F. arisanus* (Sonan) did. *Aganaspis daci* (Weld), a larval-pupal parasitoid (Figitidae: Eucoilinae), was found to have parasitized *B. zonata* with higher efficacy than *F. arisanus*. When given a choice, both wasp species showed a higher preference for parasitizing *B. zonata* over *C. capitata*. Interestingly, *F. arisanus* produced more female progeny when it parasitized *C. capitate* as compared to *B. zonata*, whereas in the case of *A. daci*, sex ratio did not vary between the fruit fly species. Overall, our results suggested that both *F. arisanus* and *A. daci* may serve as promising natural enemies against both fruit fly species while being slightly more effective against *B. zonata* when their population overlapped. Future studies will focus on the effect of the wasps' host preference and its impact on the population dynamics of both fruit fly species.

S6-OP-06

A new approach in the tricho card preparation for the inundative release of *Trichogramma* spp.

S. JEYARAJAN NELSON[*] and SUGANTHIGOPINATHAN
Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore - 641003, Tamil Nadu, India
[*]*Corresponding author E-mail*: sjn652003@yahoo.co.in

Egg parasitoids, *Trichogramma* spp. are released for the management of insect pests of various crops using the tricho cards after cutting the card with scissors and fixing the cards on plant parts using stapler/pins/thorns/thread. In order to overcome the problems faced by the farmers due to non-availability of gadgets for cutting and fixing the tricho card, a new method for tricho card preparation and delivery system has been developed. In this method, sticker cards were evaluated for their suitability for egg parasitoids' production and release in the field. A sticker paper size of 16 cm × 11 cm was taken and 12 cm × 9 cm area was marked leaving 5 cm on the top and 1 cm on the other three sides. Sixteen divisions of size 4.5 cm × 1.5 cm were made with sharp knife. One cc (650 mg) eggs of *Corcyra cephalonica* (Stainton) was sprinkled after the liquid gum acacia was smeared on 12 cm × 9 cm area with sixteen divisions. Parasitised *Trichogramma chilonis* Ishii egg card @ 1:6 was used for parasitisation. The rate of parasitisation and parasitoid emergence was 86.2 and 65.1 per cent respectively, and these rates were comparable with that of the conventional trichocards. The parasitised sticker labels were removed from the sticker card and were attached to the leaves of sugarcane, cotton, paddy, brinjal, bhendi, tomato and cabbage. The tricho sticker labels remained on the leaves of the above said plants even after the emergence of parasitoids confirming the effective release of the parasitoids.

Incidence of egg and larval parasitoids of *Chilo partellus* (Swinhoe) in Kharif maize

PRADYUMN KUMAR[1*], JASWINDER KAUR[1], S. B. SUBY, J. C. SEKHAR[3], UPADHYAYA ANJALI[4], BANA JUGAL KISHOR[5] and SITA RAM YADAV[6]

[1]*Division of Entomology, ICAR - Indian Agricultural Research Institute, Pusa Campus, New Delhi - 110012, India*

[2]*ICAR-Indian Institute of Maize Research, PAU Campus, Ludhiana - 141004, Punjab, India*

[3]*WNC, Indian Institute of Maize Research, Rajendranagar, Hyderabad - 500030, Telangana, India*

[4]*9/3, Gainger Avenue, Ashfield, New South Wales - 2131, Australia*

[5]*Agriculture Experimental Station, Navsari Agricultural University, Paria - 396145, Gujarat, India*

[6]*Harnathpura, P. O. Jorpura, Jobner - 303328, Rajasthan, India*

[*]*Corresponding author E-mail*: pradyumn.kumar@gmail.com

The incidence of egg and larval parasitoids of *Chilo partellus* (Swinhoe) was monitored in insecticide-free maize fields at Indian Agricultural Research Institute, New Delhi, for three Kharif seasons from 2013 to 2015. The hymenopteran parasitoid, *Trichogramma* was recorded to be an important egg parasitoid from this area. The egg parasitisation was recorded on the freshly laid eggs of stem borer obtained by releasing the laboratory reared adults of *C. partellus* on maize cultivars, HQPM1 and PMH1 at 12 DAG. No egg parasitisation was observed during Kharif 2013 and 2014, whereas, 12.5 per cent egg parasitisation by *Trichogramma* was recorded during Kharif 2015. The larval parasitoids were monitored by artificially infesting the maize plants with neonates of laboratory reared *C. partellus*. The larvae were allowed to develop on maize plants under field conditions for 20 days and the plants showing stem borer damage were brought to the laboratory. The larvae collected from infested maize plants were reared in laboratory to observe parasitisation by larval parasitoids. The larvae were found to be parasitised by *Cotesia flavipes* Cameron. The parasitoid was found to be active on maize from 40-60 days after germination and the incidence decreased thereafter. The larval parasitisation ranged from 29-100, 41-50 and 20-80 per cent during Kharif 2013, 2014 and 2015, respectively. The larval parasitisation was 58, 40 and 27 per cent at 40, 50 and 60-day old plants, respectively, suggesting that young plants are more attractive to the foraging *Cotesia* females. The current studies also revealed that host densities had no significant effect on percentage parasitism by *Cotesia*.

S6-OP-08

Spatial distribution of cabbage aphid, *Brevicoryne brassicae* (L.) and its parasitoid, *Diaeretiella rapae* (McIntosh) under sub-temperate conditions of Himachal Pradesh, India

SUBHASH CHANDER VERMA*, SHIKHA SHARMA and P. L. SHARMA
Department of Entomology, Dr Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan - 173230, Himachal Pradesh, India
**Corresponding author E-mail*: scvermaento@gmail.com

Cabbage aphid, *Brevicoryne brassicae* (L.) (Hemiptera: Aphididae) is one of the most serious pests of cauliflower throughout the world. Knowledge of spatial distribution is important for developing an effective sampling plan and ultimately for IPM strategies for a given pest. In the present study, spatial distribution of *B. brassicae* and its parasitoid, *Diaeretiella rapae* (McIntosh) (Hymenoptera: Braconidae), was studied on cauliflower (*Brassica oleracea* var *botrytis*) under sub-temperate conditions of India during 2017. Both *B. brassicae* and *D. rapae* assumed activity in the fourth week of January and remained active till the end of May with peak activity during fourth week of March 2017. Dispersion indices like variance to mean ratio (s2/X), David-Moore index (IDM = s2/X-1), mean crowding (X*), Lloyd's mean crowding index (X*/X) and 'k' of negative binomial indicated that both the aphid and the parasitoid followed negative binomial distribution throughout the cropping season, Taylor's power equation was $s2 = 1.7013 \times 0.5314$ for *B. brassicae* and $s2 = 2.2057 \times 1.4467$ for *D. rapae*, while Iwao's patchiness regression equation was $X^* = 32.0099+1.7947X$ and $X^* = -2.0678 + 2.2746X$ for *B. brassicae* and *D. rapae*, respectively. Optimum number of samples required varied with the mean density and the desired precision level for both the aphid and the parasitoid.

S6-OP-09

Potential of *Sancassania* sp. as a biocontrol agent of white grub species (Coleoptera: Scarabaeidae)

SREEDEVI KOLLA*
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
**Corresponding author E-mail*: kolla.sreedevi@gmail.com

White grubs belonging to subfamilies Melolonthinae and Rutelinae of Scarabaeidae are serious pests of several crops. Huge losses are estimated in endemic areas that warrant timely management strategies of which use of biocontrol agents is a viable option. The larval population brought to laboratory for rearing has revealed the presence of mites. So, a study has been taken up to identify the mites and assess their role against white grub larvae. The second instar and third instar larvae of *Holotrichia* spp., *Anomala* spp., *Lepidiota mansueta* (Burmeister), *Brahmina* sp. and *Adoretus* sp. were observed on daily basis for the activity of larva and the count of mites on individual larva. The mite-infested larvae were found to be lethargic and have eventually died in course of time. The larval mortality due to mites was higher in melolonthine grubs compared to that of ruteline grubs. Interestingly, unidentified nematode juveniles were also observed in the larval bodies and whether there is any correlation between the population of mites and that of the nematode needs to be assessed. The species of mite was identified as *Sancassania* sp. (Acari: Acaridae). Studies have shown that *Sancassania* not only feeds on insect tissues, but also the infective juveniles of nematodes. The potential of *Sancassania* as a biocontrol agent against white grubs needs to be further explored.

Field efficacy of the larval parasitoid, *Bracon brevicornis* (Wesmael) for the management of mulberry leaf roller, *Diaphania pulverulentalis* Hampson on mulberry in Tamil Nadu and its safety to silkworm, *Bombyx mori* Linnaeus

MAHIBA HELEN[1*], S. RAJAKUMAR[1] and V. SHIVAPRASAD[2]
[1]*Regional Sericulture Research Station, Vaikkalpattarai, Allikuttai Post, Salem - 636003, Tamil Nadu, India*
[2]*Central Sericultural Research and Training Institute, Manandavadi Road, Srirampura, Mysore - 570008, Karnataka, India*
[*]*Corresponding author E-mail*: mahibajill@gmail.com

Leaf roller, *Diaphania pulverulentalis* Hampson, is a serious pest of mulberry in southern India causing severe damage during September to February, especially during the rainy and post rainy seasons, in Tamil Nadu. An attempt was made for biological control of this pest by utilizing its larval parasitoid, *Bracon brevicornis* (Wesmael). Initial field releases of 100 adult parasitoids per acre of mulberry at Regional Sericultural Research Station, Salem, Tamil Nadu, showed reduction of leaf roller larval population up to 85 per cent. Following this, large scale field evaluation was undertaken at major sericultural areas of Tamil Nadu which showed considerable reduction of the leaf roller larval population from 25-30 per cent to below 3-5 per cent. The safety of *B. brevicornis* to silkworm was studied under laboratory conditions. It showed that *B. brevicornis* preferred only *D. pulveruletalis* larvae and, therefore, it can be used for biological control of *D. pulverulentalis* without any harm to silkworm.

Influence of host plant on the biology of *Tetranychus truncatus* Ehara (Prostigmata: Tetranychidae) and its predator, *Neoseiulus longispinosus* (Evans) (Mesostigmata: Phytoseiidae)

HASEENA BHASKAR*
Department of Agricultural Entomology, College of Horticulture, Kerala Agricultural University, Thrissur - 680656, Kerala, India
**Corresponding author E-mail*: haseena.bhaskar@kau.in

An attempt is being made by All India Network Project on Agricultural Acarology, College of Horticulture, Thrissur, Kerala, to standardize the technique for mass rearing of the predatory mite, *Neoseiulus longispinosus* (Evans) on the spider mite, *Tetranychus truncatus* Ehara. To identify a suitable host plant for maintaining the prey and predator, the biology of both the mites were studied in the laboratory separately on okra, cowpea and brinjal following the leaf disc method. The prey recorded shorter developmental duration on okra (6.73 and 7.52 days) when compared to cowpea (7.31 and 9.10 days) and brinjal (7.41 and 8.33 days). Though the total developmental duration of *N. longispinosus* did not vary among host plants, it completed the development in a much shorter duration (3.25 - 3.96 days and 3.42 - 4.10days) than the prey. Both prey and predator recorded longer adult life span on okra (12.00 and 17.80 days; 12.50 and 22.70 days) compared to cowpea (7.10 and 13.70 days; 9.50 and 19.70 days) and brinjal (7.16 and 14.50 days; 9.66 and 20.20 days). Fecundity was also higher for both prey and predator on okra. Mated female of *T. truncatus* on an average laid 108.00, 74.80 and 60.00 eggs, whereas, unmated females laid only 77.00, 45.20 and 45.90 eggs, while the predator recorded a fecundity of 31.00, 26.50 and 25.90 eggs, respectively on okra, cowpea and brinjal. The study identified okra as anideal host plant for rearing *T. truncatus* and *N. longispinosus*.

Reproductive performance of *Trichomalopsis uziae* Sureshan and Kumar, as influenced by density of its female and host with a note on host exposure duration for parasitism

J. B. NARENDRA KUMAR[1*], V. SIVAPRASAD[1] and D. MANJUNATH[2]
[1]*Pest Management Laboratory, Central Sericultural Research and Training Institute, Central Silk Board, Mysuru - 570008, Karnataka, India*
[2]*Department of Studies in Sericulture Science, University of Mysore, Mysuru - 570006, Karnataka, India*
[*]*Corresponding author E-mail*: jbnarendra@gmail.com

Trichomalopsis uziae Sureshan and Kumar (Hymenoptera: Pteromalidae) is a new addition to the already reported parasitoid complex (which is 20 in numbers) of Uzi fly, *Exorista bombycis*(Louis) (Diptera: Tachinidae), which causes 10-20% reduction to the silkworm (*Bombyx mori* L.) cocoon production in the states of Karnataka, Andhra Pradesh, and Tamil Nadu. In the face of non-availability of information on its biological characteristics, an attempt has been made in the current investigation to assess the reproductive performance of *T. uziae* females in relation to its own density (P) as well as its host (H) at the ratios of 1 to 5:5 (P:H) and 1:1 to 50 (P:H). The reproductive performance of the parasitoid was also assessed based on the durations of host exposure for 1 to 10 days at a constant P:H ratio of 1:5. The results revealed that there was no perceptible change in the rate of parasitism at different parasitoid densities. However, the progeny production per female was significantly higher ($P < 0.01$) at a P:H ratio of 1:5 when compared with that of the treatments with 2:5 to 5:5 that remained at par with each other as also the progeny sex ratio. Further, at a variable host density (from 1 to 50), there was a linear decrease in per cent parasitism with increase in host density which was more drastic from a host density of 15 onwards.

Effect of inoculative releases of *Trichogramma chilonis* Ishii against early shoot and internode borers in sugarcane

VISALAKSHI MAHANTHI*and B. BHAVANI
Regional Agricultural Research Station, ANGRAU, Anakapalle, Visakhapatnam - 504201, Andhra Pradesh, India
**Corresponding author E-mail*: visalamahanthi@yahoo.co.in

Studies on the effect of inoculative releases of *Trichogramma chilonis* Ishii in sugarcane fields revealed that the frequency and rate of release of this egg parasitoid had played a significant role in the management of sugarcane borers. In 2015, the incidence of early shoot borer and internode borer was low, 6.54% and 3.92%, respectively, in fields where *T. Chilonis* was released 8 times @ 75,000/ha/release, followed by 7.90% and 3.26% with the same number of releases @ 50,000/ha/release. The incidence was high (10.94% and 5.12%) in untreated control. Similarly, incidence of early shoot borer and internode borer was significantly low (2.27% and 5.85%) in fields where *T. chilonis* was released 8 times @ 75,000/ha/release, as compared to that of untreated control where it was 15.95% and 18.25% during 2016. The sustainability of inoculative releases of *T. chilonis* with highest per cent field recovery was recorded in *T. chilonis* release @ 75,000/ha/release, 8 times during monsoon period (68.63%) and post monsoon period (29.55%) compared to that of pre-monsoon period (12.21%) of 2015. Similarly, highest field recovery of *T. chilonis* was recorded in *T. chilonis* @ 75,000/ha/release, 8 times during monsoon period (20.00%) and post monsoon period (37.59%) compared to that of pre-monsoon period (9.27%) of 2016. Cane yield recorded in main crop of 2015 (47.95 t/ha) and ratoon crop of 2016 (52.42 t/ha) revealed that high rate of *T. chilonis* @ 75,000/ha/release resulted in increased yield (21.77% and 24.64%) over untreated control.

Studies on the predatory potential of *Geocoris ochropterus* (Fieber) (Hemiptera: Lygaeidae)

RICHA VARSHNEY[1*], NEERAJ BUDHLAKOTI[2] and CHANDISH R. BALLAL[1]
[1]ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
[2]ICAR - Indian Agricultural Statistics Research Institute, Library Avenue, Pusa Campus, New Delhi - 110012, India
[*]Corresponding author E-mail: richavarshney84@gmail.com

Geocorids are known to prey on a variety of insects. They comprise more than 25 genera and 275 species across the globe. *Geocoris ochropterus* (Fieber) (Hemiptera: Lygaeidae) could be reared on UV-irradiated eggs of *Sitotroga cerealella* (Olivier) and its biology and life table parameters were studied. Total nymphal period, longevity of adult male and female and fecundity were 25.40, 48.00, 64.40 days and 176.00 eggs, respectively. The net reproductive rate, approximate duration of a generation, net generation time of the predator and finite rate of increase were 28.60, 51.90, 56.77 days and 1.06 respectively. Considering the cost of host eggs alone, the cost of producing 100 adults is INR 161.15 or US $2.49. The intraguild predation study of *G. ochropterus* on *Trichogramma chilonis* Ishii developing on eggs of *Helicoverpa armigera* (Hubner) showed that in choice experiments, both 5th instar nymph and adult of *G. ochropterus* consumed 69.05 and 88.57% of unparasitised eggs of *H. armigera*, respectively, compared to 5.47 and 10.95% of parasitised eggs. Similar trend was observed in no-choice experiments. The predator exhibited a Type II functional response to varying densities of eggs of *H. armigera*. The lower handling time and higher attack rate of adult and 5th instar *G. ochropterus* indicate its potency and efficiency against *H. armigera*. Cage studies showed that different stages of *G. ochropterus* consumed 40-91% of nymphs of *Tetranychus urticae* Koch and 73-93% of nymphs of *Frankliniella schultzei* (Trybom). Thus, *G. ochropterus* can be an important predator to be included in biocontrol programmes.

S6-OP-15

Biointensive pest management strategies for the control of bud borer, *Hendecasis duplifascialis* Hampson, and blossom midge, *Contarinia maculipennis* Felt in jasmine

SUGANTHI GOPINATHAN*, S. JEYRAJAN NELSON and S. SRIDHARAN
Department of Entomology, Tamil Nadu Agricultural University, Coimbatore - 641003, Tamil Nadu, India
**Corresponding author E-mail*: suganthi.a@tnau.ac.in

Tamil Nadu stands first in jasmine production and it is also an exporter. The bud borer and blossom midge are the major pests that attack jasmine buds. This study represents the effort to demonstrate the potential of biocontrol agents and botanicals on bud-damaging insect pests of jasmine. Application of *Beauveria bassiana* (NBAIR formulation) at 5 g/litre of water three times along with 6 releases of *Trichogramma chilonis* Ishii and *Chrysoperla zastrowi sillemi* (Esben-Petersen) at 7 days interval from bud initiation stage gave the best result with only 18.0 per cent bud infestation as compared to 23.1 to 32.3 per cent damage with chemical treatment comprising carbofuran granule @ 20 g/plant and 36.1 per cent damage in untreated control. Application of Azadirachtin @ 1500 ppm @ 2 ml/litre, three times starting from bud initiation stage at 10 days interval proved significantly superior by showing only 9.3 per cent bud damage by blossom midge. The other treatments recorded 10.2 to 37.8 per cent damage, while it was 48.9 per cent in control. Regarding yield, treatment with *B. bassiana* at 5 g/litre of water along with 6 releases of *T. chilonis* and *C. zastrowi sillemi* at 7 days interval was superior and gave 2,000 kg/ha with a CB ratio of 1:2.5. The study revealed that integrated use of biocontrol agents and biopesticides can provide reliable and effective pest control in jasmine while reducing pest management cost and chemical exposure to growers and workers.

S6-PP-01

Integrating biocontrol agents with farmers' practices for the management of diamondback moth, *Plutella xylostella* (Linnaeus), in cabbage

OMPRAKASH NAVIK*, R. S. RAMYA, S. K. JALALI, T. M. SHIVALINGASWAMYand JAGADEESH PATIL
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
**Corresponding author E-mail*: omnavikm@gmail.com

A field trial was conducted in a farmer's cabbage field at Chikkaballapur in Karnataka by integrating biocontrol agents, multiple insecticide tolerant strain (MITS) of*Trichogramma chilonis*Ishii and liquid formulation of *Bacillus thuringiensis* (NBAIR *Bt*G4) with the conventional farmers' practice of using insecticide sprays for the management of diamondback moth. *T. chilonis* and *B. thuringiensis* were used along with need-based insecticide sprays as a bio-intensive treatment while in another treatment, only insecticides were sprayed to represent a farmers' general practice. These experiments were carried out on two weeks old cabbage seedlings. *T. chilonis* Ishii was released at weekly intervals at a rate of 1,00,000 parasitised eggs/ha and altogether 6 releases were made during the trial. Along with this parasitoid, a liquid formulation of *B. thuringiensis* at a dose of 2% was applied after third and fifth release of *T. chilonis*. The number of holes on leaves, larval count and per cent head damage were recorded at 15, 30 and 45 days after treatment (DAT). The results showed that the number of larvae was significantly ($P < 0.05$) less in the field treated with biocontrol-based treatment as compared to that of the field with farmers' practice at 30 and 45 DAT. At 45 DAT, holes on cabbage leaves were 2.2/plant and head damage was 7% in the field treated with biocontrol-based treatment, whereas, it was 8.0 holes/plant and 32.2% head damage in the field treated with only insecticide sprays. These results indicated that biological control can play an important role in the integrated management of diamondback moth.

Evaluation of bio-control agents against shoot and fruit borer, *Earias vittella* (Fabricius), on okra

SHARAD GALANDE[*], R. V. NAKAT, D. S. POKHARKAR, N. D. TAMBOLI, U. B. HOLE and S. B. KHARBADE

AICRP on Biocontrol, Agricultural Entomology Section, College of Agriculture, Pune - 411005, Maharashtra, India

[*]*Corresponding author E-mail*: smgbiol@gmail.com

The shoot and fruit borer, *Earias vittella* (Fabricius), is a major pest of okra in Maharashtra causing losses to the extent of 30 to 40 per cent. Considering the seriousness of the pest, a field experiment was conducted to evaluate different bio-agents for the eco-friendly management of this pest on okra at the research farm of College of Agriculture, Pune, during three consecutive Kharif seasons of 2015-16 to 2017-18. The bio-agents, *viz*. *Metarhizium anisopliae* (NBAIR) @ 1×10^8 spores/g (5 g/litre), *Beauveria bassiana* (NBAIR) @ 1×10^8 spores/g (5 g/litre), 6 releases of *Trichogramma chilonis* Ishii @ 50,000 parasitoids/ha, *Bacillus thuringiensis* var. *galleriae* @ 1 kg/ha and Azadirachtin 1,500 ppm @ 2 ml/litre were compared with standard insecticidal check of chlorpyriphos 20 EC 0.04% and an untreated control. The experiment was laid out in randomized block design with three replications. The results of three years pooled data revealed that the treatment with *B. thuringiensis* var. *galleriae* @ 1 kg/ha was found to be significantly more effective than other treatments in reducing the shoot infestation (6.25%) and fruit damage (11.62%) and increasing the fruit weight (12.94%) except with the standard check of chlorpyriphos. The treatment of *B. thuringiensis* var. *galleriae* @ 1 kg/ha recorded marketable fruit yield of okra (196.88 q/ha with ICBR 1:17.39) which is almost at par with that of chlorpyriphos (201.77 q/ha with ICBR 1:39.51).

Resource-efficient and cost-reduction technology for *Trichogramma chilonis* Ishii production

LAKSHMI MANISHA BACHU*, M. VISALAKSHI, D. V. SAIRAM KUMAR and P. KISHORE VARMA

Regional Agricultural Research Station, Acharya N. G. Ranga Agricultural University, Anakapalle, Visakhapatnam - 531001, Andhra Pradesh, India

**Corresponding author E-mail*: angraumanish@gmail.com

In India, the egg parasitoid *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae) is mass produced on the eggs of rice moth, *Corcyra cephalonica* (Stainton) (Lepidoptera: Pyralidae). The cost of production of *T. chilonis* was studied on eri silkworm and rice moth at AICRP on Biological Control, ANGRAU, Andhra Pradesh. Castor leaves are required for rearing eri silkworm larvae whereas inputs like maize grain, groundnut, streptomycin sulphate and yeast were used for rice moth larval rearing. Rearing of *T. chilonis* on eri silkworm eggs gave higher benefit cost ratio (1.89) and net profit (Rs. 4,620/-) compared to that of *T. chilonis* rearing on rice moth eggs (benefit cost ratio - 1.28 and net profit - Rs. 2,378/-). The results revealed that field release of *T. chilonis* required for one-hectare area was one trichocard having 3,500 *Trichogramma* parasitised eri silkworm eggs as the number of parasitoids emerging from one eri egg was 9 - 10 accounting for about 35,000 - 40,000 egg parasitoids. The number of trichocards required for one-hectare area is 2.5 in case of trichocard reared on rice moth eggs which have about 20,000 eggs as number of *Trichogramma* adults emerging from each rice moth egg is only one. Hence, eri silkworm can be used as an alternate to rice moth for production of *T. chilonis* as a resource-efficient and cost-reducing technology.

S6-PP-04

Development of an abiotic-stress tolerant strain of the egg parasitoid, *Trichogramma chilonis* Ishii, and its utilization for pest management in India

SUSHIL KUMAR JALALI*
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
**Corresponding author E-mail*: jalali1910@yahoo.co.in

A multiple insecticide and temperature-stress tolerant strain of the egg parasitoid, *Trichogramma chilonis* Ishii, was developed by stress selection procedure which took more than 70 generations of selection process. Resistant factor for tolerant strain was 9.55, 2.05, 5.07, 3.69 and 150.02, respectively, for five different groups of insecticides, *viz*. organo-chlorine, organo-phosphate, synthetic pyrethroid, oxa-diazinon and spinosyn.The genes responsible for insecticides tolerance such as *Ache*, *Rdl*, *Kdr* and *VGSC* were amplified and *hsp* gene for high temperature tolerance was also quantified. Generally, under sprayed and at high temperature conditions,the tolerant strain could parasitise 30-60% eggs as compared to 5-15% parasitism by lab-reared strain. Multi-locational field evaluation was initiated for MITS and HTTS in 10 states at 16 different places covering an area of 524 acre of 5 crops, *viz*. sugarcane, rice, tomato, brinjal and cabbage. Field demonstrations of tolerant strain of *T. chilonis* were carried out at different locations on various crops. The results revealed that in Punjab in tomato crop, increase in yield was 8.16 q/acre and reduction in insecticide use was 25% with Rs. 13,872/- overall benefit/acre. Similarly, when tried in rice crop, the results in Gujarat showed an increase in yield of 158.83 kg/acre with Rs. 2,300/- overall benefit/acre; in Arunachal Pradesh, the increase was 772.66 kg/acre with Rs. 10,199/- overall benefit/acre; in Assam, it was 364 kg/acre with Rs. 4,805/- overall benefit/acre, while in Karnataka, the increase in yield was 933 kg/acre with Rs. 14,462/- overall benefit/acre.

S6-PP-05

Influence of photoperiod and temperature on the biological parameters of four trichogrammatids

Y. LALITHA*, S. K. JALALI, T. VENKATESAN AND O. S. NAVIK
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
**Corresponding author E-mail*: ylalitha31121961@gmail.com

Biological parameters of three indigenous species *viz. Trichogrammatoidea bactrae* Nagaraja, *Trichogramma chilonis* Ishii, *Trichogramma japonicum* Ashmead and one exotic species, *Trichogramma pretiosum* Riley were studied under three photoperiod regimes 14:10, 12:12 and 8:16 h L:D and at temperature of 25°C in the environmental chambers. The highest mean parasitism (63.3%), fecundity/female (31.6), female progeny (68.5%), developmental period (11 days) and adult emergence (80.3 to 90.0%) were recorded at 12:12 L:D photoperiod. Statistically, the least parasitism, fecundity and female progeny were recorded at photoperiod of 8L:16D as compared to14L:10D. No significant difference was observed in the developmental period between different photoperiods, which varied from 11 to 13 days. The mean parasitism and fecundity at three photoperiods for *T. chilonis* (71.3%, 35.7) and *Tr. bactrae* (57.7%, 28.8) were at par, whereas, those of *T. japonicum* (50.0%, 25.0) and *T. pretiosum* (22.7%, 11.3) were significantly lower. *Tr. bactrae* produced significantly maximum female progeny (76.9%) compared to that of *T. pretiosum* (54.7%) across the photoperiods, whereas, that of *T. japonicum* (61.5%) and *T. chilonis* (59.4%) were overlapping. The photoperiod regime 12L:12D at temperature of 25°C was observed as ideal for multiplication of trichogrammatids in the laboratory.

S6-PP-06

Developmental biology and predatory potential of *Stethorus punctillum* Weise against two-spotted spider mite, *Tetranychus urticae* Koch, on ladies' finger

RAJENDRA NATH SINGH*, SANDEEP KUMAR SATHUA, SHAFIA ZAINAB, M. RAGHURAMAN and C. P. SRIVASTAVA

Department of Entomology and Agricultural Zoology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi - 221005, Uttar Pradesh, India

**Corresponding author E-mail*: singhrnacarology58@gmail.com

Stethorus punctillum Weise (Coleoptera: Coccinellidae) beetles were sampled from pesticide-free vegetation and reared on ladies' finger crop under poly-house at Institute of Agricultural Sciences, Banaras Hindu University. Later, they were cultured separately at regulated indoor conditions to study the biology and life parameters. Observations on biology and life parameters of *S. punctillum* against the two-spotted spider mite, *Tetranychus urticae* Koch (Arachnida: Tetranychidae), revealed that at temperature of 35°C and 30°C, the average incubation period of the beetle was 2.80 ± 0.38 and 3.13 ± 0.38 days and total larval development period varied from 5.10 ± 1.19 days to 6.70 ± 0.27 days, respectively. The average pupal duration was 3.00 ± 0.65 days with adult longevity of 42 ± 2.24 days (male) and 31.8 ± 1.48 days (female), respectively. The predatory potential or consumption rate of 1st, 2nd, 3rd and 4th instar larvae of *S. punctillum* was 17.10 ± 0.95, 32.67 ± 3.19, 47.67 ± 1.03 and 27.6 ± 2.68 mites per day, respectively. The beetle consumed a total of 141 ± 5.64 number of mites during its entire larval development period. The feeding capacity of adult beetle was recorded as 28.43 ± 4.31 mites per day with a total of 767 ± 116.90 mites throughout its life span at prevailing lab temperature of 30ºC - 35ºC and relative humidity of 68.92 ± 19.88 per cent. The beetle was found to be quite efficient in predating on *T. urticae* population and could be successfully recommended as a bio-control agent against *T. urticae*, both under poly-houses and open field crops.

Feeding potential of the coccinellid, *Cheilomenes sexmaculata* (Fabricius) (Coleoptera: Coccinellidae), on cowpea aphid, *Aphis craccivora* Koch

JAYALAXMI GANGULI*, SONALIKA KOLHEKAR, R. N. GANGULI and SAURABH PADAMSHALI
Department of Entomology, College of Agriculture, Indira Gandhi Krishi Viswavidyalaya, Raipur - 492012, Chhattisgarh, India
**Corresponding author E-mail*: jayaganguli@yahoo.com

Coccinellids are well known predators of soft bodied insects including aphids, mealy bugs and scale insects. Different species of cocinellid beetles are found on various agro-eco-systems, among which *Cheilomenes sexmaculata* (Fabricius) is one of the most commonly observed species on cowpea aphid, *Aphis craccivora* Koch. Feeding potential of *C. sexmaculata* was studied at the Bio-control laboratory, Indira Gandhi Agricultural University, Raipur. Single newly hatched larva (grub) of *C. sexmaculata* was placed in small petriplates and provided daily with cowpea aphid, *A. craccivora*, with four replications. The grubs fed on the soft abdominal part of the body of the aphids leaving the head and thorax. Consumed number of aphids was counted daily on the basis of unfed head and thoracic part. The first instar larvae of *C. sexmaculata* were less voracious (23.5 aphids/24 hrs) than older instars *i.e.* 32.5 aphids/24 hrs and 38.75 aphids/24 hrs in 2nd and 3rd instar, respectively, and maximum consumption was observed in the fourth instar in which an average of 61.37 apterous aphids of *A. craccivora* were consumed in 24 hrs. Adults lived for an average of 20days by consuming on an average of 92.3 aphids/day. Thus, the overall consumption during the entire life span was computed to be 248.4 aphids. Hence, it could be concluded that *C. sexmaculata* plays an important role in managing aphid population in an eco-friendly manner in cowpea eco-system.

S6-PP-08

Tri-trophic interaction of the different diet-fed *Corcyra cephalonica* (Stainton) on feeding efficiency of reduviid predator, *Sycanus collaris* (Fabricius), under laboratory conditions

RATHINDRA NATH GANGULI*
Department of Entomology, College of Agriculture, Indira Gandhi Krishi Viswavidyalaya, Raipur - 492012, Chhattisgarh, India
**Corresponding author E-mail*: rnganguli1@yahoo.co.in

Reduviid bugs, also known as 'Assassin bugs' or 'Kissing bugs', are biological control agents of numerous insect pests. However, very few insects have been used in the pest management programme due to the lack of rearing methods. *Sycanus collaris* (Fabricius) (Hemiptera: Reduviidae) is a voracious and polyphagous reduviid predator of economically important insect pests of agriculture and forests. They kill more prey than they need to satiate themselves. *Corcyra cephalonica* (Stainton) larvae are used as an alternate laboratory host for mass multiplication of reduviid bugs. In the present study, influence of different diet-fed *C. cephalonica* larvae on feeding efficiency of *S. collaris* was studied under laboratory conditions at the Bio-control laboratory, Department of Entomology, College of Agriculture, IGKV, Raipur during February to May 2018. The experimental treatments comprised 12 diets, *viz.* T1, T2, T3, T4, T5, and T6 of solo rice, wheat, maize, jowar, Bajra and mix of rice + maize + bajra (1:1:1), respectively, and T7, T8, T9, T10, T11 and T12 of rice + groundnut, wheat + groundnut, maize + groundnut, jowar + groundnut, bajra + groundnut and mix (rice + maize + bajra) + groundnut, respectively. For this experiment, ten freshly hatched first instar nymphs of *S. collaris* were placed in petri-dish, replicated thrice, and the same number of larvae of *C. cephalonica* reared from different diets were provided throughout their life cycle. Feeding efficiency of different nymphal instars and adults were recorded on daily basis. Morphological parameters for different nymphal instars and adults along with their predatory efficiency and difference in fecundity were also recorded. Results indicated that *S. collaris* showed difference in the preference of the larvae reared from different diets. Feeding efficiency was found to be maximum in T1 (Rice) whereas, it was found to be minimum in T9 (Maize + Groundnut) reared larvae of *C. cephalonica*. The reason may be due to some bio-chemical compounds associated with the diet acting as a factor responsible for preference and non-preference.

Efficacy of the egg parasitoid, *Trichogramma chilonis* Ishii, in the management of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee)

MANOJ KUMAR MAHLA*, GAURANG CHHANGANI and BEERENDER SINGH
Department of Entomology, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur - 313001, Rajasthan, India
**Corresponding author E-mail*: mkmahla@yahoo.co.in

The relative efficacy of three different rates of releases of *Trichogramma chilonis* Ishii was evaluated for management of *Leucinodes orbonalis* (Guenee) in the fields in Rajasthan College of Agriculture, MPUAT, Udaipur during Kharif season of 2016. The three treatments comprised releasing the parasitoid @ 50,000, 1,00,000 and 1,50,000 eggs/ha at 10 days interval starting from 15 DAT. Such releases were made 6 and 8 times. Releases of the parasitoid @ 1,50,000 eggs/ha (T6 and T5) was found to be the most effective one with mean shoot damage of 11.96 and 12.66 per cent, respectively while, the least effective treatments were releases @ 50,000 eggs/ha (T2 and T1) with mean shoot damage of 17.78 and 18.12 per cent. Similarly, against the fruit damage, 6 and 8 times releases of *T. chilonis* @ 1,50,000 eggs/ha (T6 and T5) were most effective with mean fruit damage of 11.67 and 9.80 per cent on number basis and 11.59 and 9.90 per cent fruit damage on weight basis. The least effective treatments were the releases of *T. chilonis* vide T1 and T2 with mean fruit damage of 17.66 and 16.10 per cent on number basis. The results revealed that the maximum parasitisation (47.61 to 47.05 per cent) was recorded in the treatments, T6 and T5, *i.e.* 6 - 8 times releases @ 1,50,000 eggs/ha).

Ecofriendly management of *Pseudodendrothrips mori* Niwa (Thysanoptera: Thripidae) and its impact on abundance of predatory coccinellids in mulberry ecosystem

NALLIAPPAN SAKTHIVEL[1*] and V. SIVAPRASAD[2]
[1]*Regional Sericultural Research Station, Central Silk Board, Govt. of India, Vaikkal Pattarai, Allikkuttai (Post), Salem - 636017, Tamil Nadu, India*
[2]*Central Sericultural Research and Training Institute, Central Silk Board, Govt. of India, Srirampura, Mysore - 570008, Karnataka, India*
[*]*Corresponding author E-mail*: sakthivelcsb@hotmail.com

Efficacy of neem oil, pongamia oil, sprayinga strong jet of water and dichlorovos was studied against the mulberry thrips, *Pseudodendrothrips mori* Niwa (Thysanoptera: Thripidae) and compared to the untreated control. Further, bio-safety of the different treatments to the predatory coccinellids was studied under field conditions. The sprays were given at two intervals *i.e.* 10 days after pruning (DAP) of mulberry garden and at 20 DAP. The populations of thrips and predatory coccinellids were recorded one day prior and 1, 3, 7 and 10 days after each spray up to 30 DAP. The mean values revealed that the highest reduction in thrips population (84.35%) was recorded with two numbers of water jetting and the next best treatments was dichlorovos followed by water jetting (75.17%) and then neem oil followed by water jetting (67.02%). With respect to abundance of predatory coccinellids, highest mean population (6.83) was found in the plots treated two times with water jetting, spray of pongamia oil followed by water jetting (4.82) and neem oil followed by water jetting (4.31), whereas,the least population was recorded with two sprays of dichlorovos (1.04). Among the various treatments, two sprays of strong water jetting at 10 days interval were found superior in reducing the population of thrips and to conserve the predatory coccinellids in mulberry ecosystem.

Survey forparasitoids of shoot, panicle and capsule borer, *Conogethes punctiferalis* (Guenee), (Lepidoptera: Crambidae) of small cardamom in Cardamom Hill Reserve (CHR), Kerala

THIYAGARAJAN PONNUSAMY*, A. S. PRASEEDA and A. B. REMA SHREE
Indian Cardamom Research Institute, Parathode, Munnar-Kumily Highway, Mailadumpara - 685554, Idukki, Kerala, India
**Corresponding author E-mail*: thiyainsect@gmail.com

Small cardamom, *Elettaria cardamomum* (L.) Maton is an economically important spice crop known as 'Queen of spices'and nearly 60 species of insect pests infest cardamom at different stages of its growth. Shoot, panicle and capsule borer, *Conogethes punctiferalis* (Guenee), (Lepidoptera: Crambidae) is one among them. Cardamom Hill Reserve (CHR) is a major source of this spice which is an export-oriented crop and always facing the problem of pesticide residues. To overcome indiscriminate usage of harmful pesticides in cardamom, the effective conservation and augmentation of potential parasitoids will be the future sustainable bio-control strategy to manage *C. punctiferalis* in cardamom eco-system, so survey was conducted in the three different zones *viz*. Vandanmedu (Zone A), Myladumpara (Zone B), and Santhanpara (Zone C) to study the incidence of natural parasitoids of *C. punctiferalis*on cardamom plant parts *viz*. shoot, panicle and capsule in CHR, Idukki from January to June 2018 under pesticide applied cardamom fields (PACF) and pesticide non applied cardamom fields (PNACF). Two natural parasitoids *viz*. larval parasitoid, *Apanteles taragamae* Vierick (Hymenoptera: Braconidae) and larval-pupal parasitoid, *Agrypon* sp. (Hymenoptera: Ichneumonidae) were recorded. Higher level parasitisation of 1.01 to 16.79% was noticed in the case of *A. taragamae* on *C. punctiferalis* which was damaging capsules followed by those feeding on shoots (0.13 to 0.54%) and those on panicles (0.03%). *Agrypon* sp. was noticed on *C. punctiferalis* feeding on shoots only with 5.46 to 9.63% natural parasitisation and this species was not found to be parasitizing *C. punctiferalis* feeding on panicles and capsules. It is suggested that this well-known species of local strain be further evaluated for potential use in mass rearing and augmentative bio-control to manage *C. punctiferalis* in cardamom ecosystem.

Field efficacy of *Pediobius imbrues* (Hymenoptera: Eulophidae) parasitoid on coconut slug caterpillar *Macroplectra nararia* Moore (Lepidoptera: Limacodidae)

N. CHALAPATHI RAO*, G. KRISHNA RAO and G.RAMANANDAM
Horticultural Research Station, Dr. Y. S. R. Horticultural University, Ambajipeta - 534101, Andhra Pradesh, India
**Corresponding author E-mail*: chalapathirao73@gmail.com

Andhra Pradesh is one of the major coconut growing states in India and has an area of 1.42 lakh ha with the coastal districts comprising East and West Godavari commanding fifty per cent of this area. One of the major factors that contribute to the loss of production and productivity in coconut recent years in the state and in these districts in particular was the sporadic outbreak of the coconut slug caterpillar *Macroplectra nararia* Moore (Lepidoptera: Limacodidae). During outbreaks, all the functional leaves are dried leaving only the spindle leaves resulting in shedding of nuts, ultimately resulting in yield loss. The pest was also observed to cause damage to the intercrops like banana and cocoa in coconut-based cropping system during outbreaks. Though many parasitoids were identified against this sporadic pest, none are amenable for laboratory rearing. In March 2015, a new larval parasitoid, *Pediobius imbrues* (Hymenoptera: Eulophidae) which is amenable for lab rearing as a hyper parasitoid on *Bracon hebetor* Say was observed to parasitise *M. nararia* effectively and a natural parasitisation ranging from 2 to 10% was recorded in slug affected coconut gardens. Field release studies of lab-reared *P. imbrues* against slug caterpillar in the affected coconut gardens revealed a maximum of 41.41 and 50.31 per cent parasitisation of slug caterpillar respectively in 2017 and 2018 within 30 days after release and this promising parasitisation provides scope for large scale field releases during slug caterpillar outbreaks.

Session 7: BIOLOGICAL CONTROL: INDUSTRIAL PERSPECTIVE AND POLICY ISSUES

S7-LP-01

Access and benefit sharing and classical biological control: the role of IOBC

BARBARA BARRATT[1]*, PETER G. MASON[2] and MATTHEW J. W. COCK[3]
[1]*AgResearch Invermay, PB 50034, Mosgiel, New Zealand*
[2]*Agriculture and Agri-Food Canada, 960 Carling Ave, Ottawa, Ontario, Canada*
[3]*CABI, Bakeham Lane, Egham, Surrey, TW209TY, UK*
[*]*Corresponding author E-mail*: barbara.barratt@agresearch.co.nz

The Convention on Biological Diversity (CBD) recognizes the sovereign rights of countries over their 'genetic resources' (GRs). An objective of the CBD is the "the fair and equitable sharing of the benefits arising out of the utilization of genetic resources" known as Access and Benefit Sharing (ABS) which aims to prevent exploitation of a country's GRs. The Nagoya Protocol adopted in 2010 provides a legal framework for developing regulations for the implementation of ABS. Invertebrate biological control agents (IBCAs) are GRs and hence subject to ABS provisions. The International Organization for Biological Control (IOBC) established a 'Global Commission on Biological Control and ABS' which strongly recommended that IBCAs be considered as a special case with respect to ABS under the CBD. The IOBC Commission produced a comprehensive document which argued that classical biological control (introduction of natural enemy from the pest's country of origin intended to establish and spread) depends upon multilateral reciprocal relationships between countries and IBCAs are exchanged between countries with little or no money changing hands. Classical IBC was shown to be essentially a public good activity with benefits mainly to the public and society, not the implementer. Augmentative IBCAs developed commercially cannot be patented and profits from their sale are mostly modest. The IOBC Commission has prepared a best practice guide to assist the biological control community to demonstrate due diligence in complying with ABS requirements recommending that best practice should include the development of collaborations, information sharing, training and capability development, and technology transfer.

S7-OP-01

Current status and future perspectives of natural enemies for pest control in Taiwan

LU MEI-CHUN*, CHEN HUNG-JU and WU YI-HUI
Biological Control Branch, Mioali District Agricultural Research and Extension Station, Council of Agriculture, Executive Yuan, Miaoli - 36441, Taiwan
**Corresponding author E-mail*: lumj@mdais.gov.tw

Application of predators for pest control is the best model to retain eco-conservation features of the environment. In Taiwan, the agriculture policy “Reduction the half pesticide consumed in 10 years” has launched since 2017. Pesticide application, which resulted in chemical residues in food, pest resistance, and ecological impacts, leaves doubt for public concern. However, biological control policies that performed through the study of pest behavior, rearing and incorporating into the crop management mode, reproduce a dawn for pest control in modern organic or safety agricultural system. It is more than a century since the first case of natural enemy for pest control in 1990s, Taiwan. So far, a wide range of integrated pest management incorporation with other physical, biological and cropping methods have been established. Predatory and parasitic natural enemies including lacewing, stink bugs, mantis, ladybug, phytoseiids and parasitoid wasps *etc*. were used for controlling the thrips, aphids, spider mites and lepidopteran pests. Recently, research and development of the utilization natural enemies of insects were appealed and concerned because of the organic and food safety issues. Nowadays, we have investigated the mass production and application techniques, storage, handling, and commodity regulations for natural enemy products. Crops with high economic value, bulk and continuous harvest crops are the targets for this program. The final goal is to develop natural enemy products and provide an IPM-based integrated pest management mode to famers, in order to implement natural enemies in agricultural production system, reduce pesticides, and ensure the food security.

Evaluation of different volumes of larvae L3 of *Ceratitis capitata* in parasitic devices to *Diachasmimorpha longicaudata* in massive breeding conditions in the fruit fly national programme, Costa Rica.

ROSSY MORERA-MONTOYA[*] and HELGA BLANCO-METZLER
University of Costa Rica, San José, Sabana Sur, Costa Rica
[*]*Corresponding author E-mail*: rossymorera@gmail.com

Five volumes (60 cc, 70 cc, 80 cc, 90 cc and 100 cc) of larvae L3 of *Ceratitis capitata* in parasitic devices to the parasitoid *Diachasmimorpha longicaudata* were evaluated in massive breeding conditions, with the objective of finding the optimal quantity of host larvae to obtain the best parasite quality parameters. For each evaluated treatment, a multiple-criteria index that took into account all the variables evaluated was obtained, and an analysis of multiple comparisons of means was done according to the Tukey method (LSD, P = 0.05). It was determined that the treatment of 80 cc of larvae presented the best mortality values for females and males resulting in the most promising treatment. Regarding the other variables, there were no significant differences identified, and there was no correlation found between the variable of weight of the host larvae and the sexual proportion variable; however, in fecundity tests, a strong positive correlation (65%) was present between the weight of the host larvae and the parasitism, and there was a strong positive correlation (66%) between the mortality rates of female and male *Ceratitis capitata.*

An assessment on the role of different stakeholders for the promotion of Bio-pesticides in Nepal

SHALIK ADHIKARI[*], V. PANDIT and A. PRASAD DHAKAL
Plant Protection Department, Lalitpur, Harihar Bhawan, Lalitpur- 44600, Nepal
[*]*Corresponding author E-mail*: salikum@gmail.com

Government of Nepal (GoN) has been prioritizing Integrated Pest Management (IPM) strategy as the most important strategy after a sudden outbreak of brown planthopper (BPH) and heavy loss in rice production. GoN has been continuing IPM programs with the successful completion of different phases like technical cooperation, marketing and institutionalization. Awareness creation among multi-sectoral stakeholders is the most and major outcome through IPM program in Nepal. Plantwise, a global program led by CABI, has been working with GoN since 2013 for the improvement of plant health system. This program has also a good impact in the promotion of non-chemical strategies of pest management. Despite of having many national programs, efforts of GoN as well as different Non-governmental Organization, Community Based Organization; a significant progress has not been seen in the use of biological pesticides. This paper has tried to analyze the role of different stakeholders in the promotion of bio-pesticides along with other non-chemical management strategies *viz.* the trend of recommendations by Plant Doctors with the information retrieved from Plantwise Online Management System (POMS), perception of farmers as well as agro-input suppliers to the bio-pesticides, plant clinic interventions for bio-pesticides promotion, and policy review for finding the reason of less use of bio-pesticides in the field. Around 200 farmers who visited plant clinics and 50 agro-inputs suppliers from different regions were randomly selected for the survey with the developed questionnaire. Major problem has been observed in agro-input suppliers among the whole cycle of Bio-pesticide use.

S7-OP-04

Development, registration and commercialization of smart Agbiologicals for sustainable crop production and protection: challenges and opportunities"

VIRENDER DHINGRA[*] and RAJIV DHINGRA
BIO-TOX, 101-102, 1st Floor, Nitika Tower - I, Azadpur Commercial Complex, New Delhi - 110033, India
[*]*Corresponding author E-mail*: biotoxnd@gmail.com

AgBiologicals are gaining increasing acceptance from farmers worldwide as a fundamental part of enhanced crop production and protection: biological crop protection agents offer highly targeted ways of controlling pests and diseases, and provide new resistance management strategies. More and more novel smart biological products are reaching the marketplace with greater investment in proof of efficacy, broader testing across geographies and with advanced technology for fine tuning to meet the growers' pest control needs. Successful commercialization of AgBiologicals hinges on the outcome of the development process and is often limited by a lack of knowledge and experience with biological control agent production and formulation techniques. Critical steps in development, registration and commercialization of successful Smart Microbial Bio-control Agents (Bio-pesticides), recent trends, opportunities, constraints and future strategies would be deliberated at length.

Third International Workshop of the IOBC Global Working Group on Biological Control and Management of Parthenium Weed

S8-OP-01

Biological control of parthenium weed (*Parthenium hysterophorus* L.): Australian experience

KUNJITHAPATHAM DHILEEPAN*, BOYANG SHI, JASON CALLANDER and SEGUN OSUNKOYA

Biosecurity Queensland, Department of Agriculture and Fisheries, Ecosciences Precinct, Boggo Road, Dutton Park, Qld 4102, Australia

**Corresponding author E-mail*: kunjithapatham.dhileepan@daf.qld.gov.au

Parthenium hysterophorus is a weed of national significance in Australia. Biological control of parthenium weed in Australia commenced in 1977 and since then nine insect species and two rust fungi have been introduced there. All agents have established at several localities and seven of them are widespread. However, the time taken for field establishment varied widely between various agents, ranging from one to 15 years. Among them, the stem-galling *Epiblema strenuana* moth, the stem-boring *Listronotus setosipennis* weevil, the seed-feeding *Smicronyx lutulentus* weevil and the root-feeding *Carmenta* sp. nr. *ithacae* moth occur in all parthenium-infested areas at high population levels. The leaf-feeding *Zygogramma bicolorata* beetle occurs only in central and southern Queensland, and not in northern Queensland. The parthenium summer rust occurs seasonally in central and northern Queensland, while the parthenium winter rust is more widespread in southern Queensland than in central Queensland, but not in northern Queensland. The sap-feeding *Stobaera concinna* plant hopper and the leaf-mining *Bucculatrix parthenica* moth have established and are widespread, but their damage levels remain very low. The stem-galling *Conotrachelus albocinereus* weevil and the stem-boring *Platphalonidia mystica* moth are believed to be established, at very low levels. Biological control has resulted in significant reductions in the abundance and impact of parthenium weed in Australia. As a result, the area infested with parthenium weed in central Queensland have declined since the mid-1990s. Due to the absence of many of the effective agents in southern Queensland, agents from central Queensland are being redistributed to southern Queensland. Additionally, based on Australian success, many of these agents have also been introduced into other countries around the world.

S8-OP-02

Nationwide survey of parthenium weed infestations in Bangladesh - risk and threat for food security

ILIAS HOSSAIN*
Regional Wheat Research Centre, Bangladesh Agricultural Research Institute, Rajshahi, Bangladesh
**Corresponding author E-mail*: iliasrwrc@gmail.com

A three-year survey was carried out during 2014-15, 2015-16 and 2016-17 at thirty-five districts in Bangladesh to observe the abundance, habitat and spread of *Parthenium hysterophorus* and to identify how many crops were affected by this weed. The most dense infestations of parthenium weed were found along roadsides, in fallow land, grassland and fields of various crops. We identified only one species of *Parthenium* which affected many crops grown in Bangladesh, including cereal crops such as wheat and maize, pulse crops including mung bean, black gram, field pea, cowpea, and lentil, vegetables crops such as tomato, pointed gourd, brinjal, country bean, and okra, and spice crops including onion, garlic, turmeric, chilli and ginger. Tuber crops such as potato, horticultural crops such as banana, and sugar crops such as sugarcane were also affected by this invasive plant. The highest abundance of parthenium weed occurred at border areas due to the proximity to routes connecting Bangladesh and India. In a preliminary distribution survey conducted in thirty-five districts of Bangladesh, parthenium weed occurred in the greater Jessore, Rajshahi and Mymensingh regions, which border India, where it was present along roadsides and in some crop fields. Now it is the most alarming weed overall in Bangladesh due to its impact on crop production. Parthenium weed grows all year round but it is most abundant in summer. It reduces the pollination of brinjal, tomato, and chilli crops through its allelopathic compounds. The severity of parthenium weed infestations is considered to be causing a heavy toll on food security in Bangladesh. Effective management is needed before the weed further disrupts crop production in Bangladesh.

S8-OP-03

Current spread and integrated management to contain *Parthenium* weed in India

SUSHIL KUMAR*
ICAR - Directorate of Weed Research, Maharajpur, Adhartal, Jabalpur 482004, Madhya Pradesh, India
**Corresponding author E-mail*: sknrcws@gmail.com

Currently *Parthenium hysterophorus* has spread in almost all the states of India but occurs in varying densities. It has severely spread in North and South India, except Kerala where it has occupied limited areas in certain pockets. In extreme arid and cold areas of India, its occurrence is limited. In the North-East region, it is widespread in Assam, but its presence is negligible in Meghalaya, Sikkim, Tripura and Mizoram. Its occurrence is greater in Itanagar and Imphal of Arunachal Pradesh and Manipur state, respectively, but in other areas of these states, its presence is trivial. In Nagaland, it is prevalent in lower areas up to Dimapur but does not occur towards hilly areas after Mezdiphema. In Gujarat and Odisha its spread is limited towards coastal areas. Various management approaches are being used to minimize the losses caused by this weed. The use of the exotic biocontrol agent *Zygogramma bicolorata* has contributed effectively to suppress parthenium weed in India, nevertheless, the weed remains a substantial problem. The biocontrol agent, *Z. bicolorata* has established widely in North, Central and South India and contributes significantly to the control of parthenium weed during the wet season. Efforts are being made to establish this beetle in North-East India but chances seem to be meager for its good establishment. Integrated approaches to manage parthenium weed, including awareness programmes through parthenium weed awareness week undertaken since 2004, have begun to yield good results. People are coming forward to make their premises and village free of parthenium weed. The declaration of two parthenium weed-free villages in Punjab is an indicator of the success of awareness programmes.

Host range evaluation of the leaf-feeding beetle, *Zygogramma bicolorata* and the stem-boring weevil, *Listronotus setosipennis* demonstrates their suitability for biological control of the invasive weed *Parthenium hysterophorus* in Ethiopia

WONDI MERSIE[*]
Virginia State University, Petersburg, VA 23831, USA
[*]*Corresponding author E-mail*: wmersie@vsu.edu

The invasive annual parthenium weed (*Parthenium hysterophorus*), damages agriculture, adversely impacts biodiversity and is hazardous to human and animal health in Ethiopia. This invader has been successfully managed in Australia and India using selected host-specific natural enemies. The host range of two natural enemies, a leaf-feeding beetle, *Zygogramma bicolorata*, and a stem-boring weevil, *Listronotus setosipennis*, was evaluated for biological control of the weed in Ethiopia. The specificity of *Z. bicolorata* and *L. setosipennis* was assessed against 29 non-target plant species. The host range of *Z. bicolorata* and *L. setosipennis* was first assessed using no-choice tests to examine their oviposition and feeding response on non-target plants, relative to parthenium weed. *Zygogramma bicolorata* was further evaluated on selected economically important plant species in choice tests. Both agents were unable to complete development on any test plants offered in no-choice or choice tests. In no-choice tests, no oviposition or feeding by *L. setosipennis* occurred on any non-target species assessed while mean oviposition on parthenium weed was 38.96 ± 3.37 eggs per plant. Based on these results, in combination with host range data from Australia and South Africa, permission for the release of *Z. bicolorata* and *L. setosipennis* in Ethiopia was granted in 2013. Releases were undertaken shortly thereafter and are currently ongoing to assist with the management of this serious invader in Ethiopia. The challenges faced in rearing and releasing both biocontrol agents in Ethiopia will be discussed.

S8-OP-05

Incidence of *Parthenium hysterophorus* and its eco-friendly control by *Zygogramma bicolorata* in Chitrakoot, Madhya Pradesh, India

RAMESH CHANDRA[*] and PREETI TRIPATHI
Department of Biological Sciences, Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Satna - 485334, Madhya Pradesh, India
[*]*Corresponding author E-mail*: rctmgcgv@gmail.com

Parthenium hysterophorus L. is an invasive and environmental pollutant weed. In India, it has spread rapidly, causing multiple problems to the inhabitants. People were affected by allergic reactions including reddening of the skin, swelling of hands, arms and face, itching, and eczema on hands and palms. The plant has become one of the main weeds in almost all types of agricultural land, besides infesting wasteland, community land, road and railway track sides, and forests. *Parthenium hysterophorus* had invaded over 50,000 km² by 1992. The leaf-feeding beetle *Zygogramma bicolorata* appears to have potential in reducing weed density in those parts of India with moderate weather conditions. In the present study, the incidence, density and distribution of *P. hysterophorus* was evaluated, together with aspects of biocontrol by *Zygogramma bicolorata*. Plant and beetle distribution was studied around the local areas of Chitrakoot. In fallow agricultural fields, *Z. bicolorata* caused approximately 99.5% decline in the weed density, without disturbing the soil ecosystem. The studies also indicated that the rate of decline of parthenium weed and the degree of diversity of successional plant species in fallow lands after defoliation by *Zygogramma bicolorata* varied, depending on the duration of weed occupation and the history of land utilization. The beetle was found to be a promising, safe, eco-friendly biocontrol agent. Parthenium is a weed of global concern affecting human and animal health, crop production and biodiversity. The reduction in density of *P. hysterophorus* by *Z. bicolorata* was highly significant so its use is recommended.

Age, mating status and sex influence food consumption and utilization efficiency of *Parthenium* beetle, *Zygogramma bicolorata* Pallister

BHUPENDRA KUMAR*
Department of Zoology, Institute of Science, Banaras Hindu University, Varanasi - 221005, Uttar Pradesh, India
**Corresponding author E-mail*: bhupendrakumar@bhu.ac.in

A study was designed to evaluate the combined effects of age, mating status and sex on the feeding attributes of the chrysomelid beetle, *Zygogramma bicolorata* Pallister when fed on *Parthenium hysterophorus* L., a serious weed of wastelands, pastures and agricultural fields. Newly emerged adult beetles were placed in two groups. Adults of the first group were kept unmated and their daily feeding and growth attributes were assessed for the following 20 days. By comparison, males and females of the second group were allowed to mate on the 11th day (attainment of sexual maturity) and mating pairs were kept individually to assess their daily feeding and growth attributes for the following 10 days. Results revealed higher consumption and growth rates of *Zygogramma bicolorata* females than males. In contrast, males exhibited higher food conversion efficiencies than the females. However, food consumption and growth rates of unmated adults were higher than mated adults. Age-based regression graphs revealed decreased consumption rates, conversion efficiencies and growth rates of *Z. bicolorata* adults with increase in age. However, the mean body biomass of adults increased with increasing age. This further suggested compensatory feeding in *Z. bicolorata* adults as they age. The present findings may be helpful to mass-multiply *Z. bicolorata* in laboratories for the biocontrol of parthenium weed in agricultural farms on the Indian subcontinent.

S8-OP-07

Impact of *Zygogramma bicolorata* on growth of *Parthenium hysterophorus* in Nepal

SEERJANA MAHARJAN[1*], ANJANA DEVKOTA[1], PRAMOD KUMAR JHA[1], MUNIAPPAN RANGASWAMY[2] and BHARAT BABU SHRESTHA[1]
[1]*Central Department of Botany, Tribhuwan University, Kirtipur, Kathmandu 44600, Nepal*
[2]*IPM Innovation Lab, Virginia Tech, VA, USA*
[*]*Corresponding author E-mail*: seerjana9@hotmail.com

Zygogramma bicolorata Pallister, a leaf-feeding beetle released as a biocontrol agent against *Parthenium hysterophorus* L. in India, Australia and elsewhere in Africa, was first reported in Nepal in 2009. The beetle is spreading naturally and has established populations at several locations but the damage incurred by this beetle on *P. hysterophorus* has not been studied. We evaluated the impact of the beetle population on *P. hysterophorus* at different altitudes in Nepal. The experiment was carried out at two altitudes (500m and 1300m asl) in Nepal during May to September 2017 in 1 x $1m^2$ randomized plots. *Zygogramma bicolorata* was released in two densities per plant (single and two beetles), during vegetative and early flowering periods. Individual plants were harvested when signs of senescence were observed, and plant height and total biomass of each plant was measured. Plant height and total biomass varied across the different altitudes in Nepal. Height and biomass of *P. hysterophorus* declined with increasing density of beetles at the lower altitude but the impact was not significant at the higher altitude. The decrease in plant height and total biomass was greater at lower altitude (35% and 55% respectively) as compared to the higher altitude (9% and 39% respectively), inferring that the beetle had greater impact on *P. hysterophorus* at low altitude.

S8-OP-08

Spread of the leaf-feeding beetle *Zygogramma bicolorata* for the biological control of the invasive weed *Parthenium hysterophorus* in Ethiopia

MILLION ABEBE[1]*, LIDYA ALEMAYEHU[1] TESFAYE AMARE[2] and FULEA GELANA[2]
[1]Virginia State University Parthenium Project, Addis Ababa, Ethiopia
[2]Ambo University, Ambo, Ethiopia
[*]Corresponding author E-mail: abebemdz@gmail.com

The invasive parthenium weed (*Parthenium hysterophorus*) reduces the yield of major crops, invades pasture lands and adversely affects human health in Ethiopia. *Zygogramma bicolorata* has been released since 2014 in Ethiopia for biological control of this weed. The spread and abundance of *Z. bicolorata* was evaluated at selected release sites. The distance travelled by the biocontrol agent from the point of release, as well as its abundance, was measured on different occasions. In 2018, *Z. bicolorata* moved 20 m from the release point, within six weeks. At other sites the spread was limited and it took several weeks for the beetle to disperse from the release point. It appears that there is a need to increase the number of release sites and number of individuals released to increase spread of the beetle and eventually its wider occurrence in Ethiopia.

Predicting establishment of the leaf-feeding beetle *Zygogramma bicolorata* (Coleoptera: Chrysomelidae) for the management of *Parthenium hysterophorus* (Asteraceae: Heliantheae) in India: a machine learning approach

YOGITA GHARDE[*] and SUSHIL KUMAR
ICAR - Directorate of Weed Research, Maharajpur, Adhartal, Jabalpur - 482004, Madhya Pradesh, India
[*]*Corresponding author E-mail*: yogitagharde@gmail.com

Parthenium hysterophorus L. is one of the most troublesome weeds of the world, which has invaded non-cropped as well as cropped lands in many tropical and sub-tropical countries including India. Various approaches such as cultural, mechanical, chemical and biological methods have been attempted for its control. Among these, biological control using the Mexican beetle (*Zygogramma bicolorata* Pallister) has been considered the most cost-effective and environmentally safe method in India. Initially it was presumed that *Z. bicolorata* would be a suitable biocontrol agent for a moderate climate and will not establish well in areas experiencing temperatures below 15°C and above 35°C in India. However, during field surveys, the beetle was found to cause widespread defoliation of parthenium weed even under such extremes. Therefore, in order to forecast the establishment of *Z. bicolorata*, a model was developed using climatic indices as independent variables. Machine learning approaches (decision tree) were used for model building. A decision tree using J48 algorithm classified 81.7% instances correctly, and developed rules to predict the establishment of *Z. bicolorata*. Minimum temperature (MMIN) was found to be most important in explaining the degree of establishment of *Z. bicolorata*. It was inferred from the results that although rainfall and relative humidity do not play significant roles if taken individually, their interaction with minimum temperature play significant roles to predict the establishment of *Z. bicolorata*. Several rules were developed using the decision tree model to categorize the establishment of *Z. bicolorata* in three classes *i.e*. negligible, moderate and high. Based on the rules obtained from our study, it was concluded that a site experiencing climate with indices values of average minimum temperature 24.2–26.2°C and rainfall 191.2–257.3 mm during July to October would be highly suitable for establishment of the *Z. bicolorata* population in the region. This model may be useful for the selection of the most suitable sites for release and establishment of *Z. bicolorata* in India, as well as in other parts of the world with similar climatic conditions, for the control of *Parthenium hysterophorus* using a biological approach.

Establishment and early impact of introduced natural enemies to control *Parthenium hysterophorus* in South Africa

LORRAINE STRATHIE[1*], SAKHI SAMBO[1], ALANA DEN BREEYEN[2], FRANK CHIDAWANYIKA[3], MILLY GAREEB[1] and XOLILE MAGOSO[1]

[1]*Agricultural Research Council - Plant Protection Research Institute, Private Bag X6006, Hilton, KwaZulu Natal, South Africa*

[2]*Agricultural Research Council - Plant Protection Research Institute, Private Bag X5017, Stellenbosch, 7599, South Africa*

[3]*University of the Free State, P.O. Box 339, Bloemfontein, 9300, South Africa*

[*]*Corresponding author E-mail*: strathiel@arc.agric.za

Parthenium hysterophorus (Asteraceae: Heliantheae) has spread aggressively and is a serious invader in South Africa and on the African continent, aided by its invasive attributes and local land use habits. In South Africa, biological control is recognized as critical to efforts to curb the spread and impact of the weed. Following host range evaluation, the summer rust fungus (*Puccinia xanthii var. parthenii-hysterophorae* (Pucciniales: Pucciniaceae) and three insect agents (defoliating *Zygogramma bicolorata* (Coleoptera: Chrysomelidae), stem-boring *Listronotus setosipennis* (Coleoptera: Curculionidae) and seed-feeding *Smicronyx lutulentus* (Coleoptera: Curculionidae)) have been released since 2010, 2013 and 2015, respectively. Releases have been undertaken at more than 330 sites in densely invaded KwaZulu-Natal (KZN) and Mpumalanga provinces. All four agents have established, although drought conditions interfered. *Listronotus* has established readily, while *P. xanthii* has spread widely, largely unaided. *Zygogramma* is restricted in distribution. A chemical exclusion field study is underway to assess agent impact on parthenium weed within four treatments in 5m^2 plots in northern KZN province. The dynamics of parthenium weed, other vegetation, and biocontrol agents are assessed. Although still relatively early in the field establishment programme, it is apparent that additional agents are required for broader control. The root-crown borer *Carmenta* sp. nr. *ithacae* (Lepidoptera: Sesiidae) and stem-galler *Epiblema strenuana* (Lepidoptera: Tortricidae) are under evaluation. Despite concerns arising from laboratory host range results for *E. strenuana*, further investigation is desirable due to considerable impact by this agent. Scope exists for broader use of the approved agents, both locally and internationally, to intensify biological control efforts.

S8-OP-11

Current status of biological control of *Parthenium hysterophorus* with mycoherbicide

AJAY KUMAR SINGH[1*] and PRAHARAJU LAXMINARAYANA[2]
AG BioSystems Private Limited, 35E, IDA, Phase V, Cherlapally, Hyderabad - 500051, Telangana, India
[*]*Corresponding author E-mail*: ajayagbio@gmail.com

Weed management through chemical herbicides creates spray drift hazards and adversely affects the environment. Besides, herbicide residues in food commodities, directly or indirectly, affect human health. These effects lead to the search for an alternate method of weed management which is eco-friendly. In this regard, biological approaches are gaining momentum. They include a high degree of specificity to target weed, with no effect on non-target and beneficial plants or man, absence of weed resistance development, and absence of residue build-up in the environment. Currently, fungal weed control is rapidly developing natural phenomena in research areas with implications for plant yield and food production. Fungal weed control may help to maintain the quality of crops and reduce the use of chemical pesticides and other toxic chemicals and offer important natural mortality factors for weed population control under natural environmental conditions. The application of the fungal spores, fermented broth, and their crude metabolite or purified metabolites are a very good source for natural herbicide for the management of parthenium weed. Fungal weed pathogens can produce a wide array of toxins, bioactive metabolites with different biological activities, chemical structures, mechanisms of action, specificity with respect to plants, and environmental impact and stability. This paper will discuss the current research progress on fungi and their secondary metabolite application for the management of parthenium weed.

S8-OP-12

Phytotoxic effect of *Abutilon indicum*, *Tephrosia purpurea*, *Prosopis juliflora* and *Cassia occidentalis* - ethanolic extracts on germination and seedling growth of global invasive weed *Parthenium hysterophorus*

AISHWARYA ANDHARE[*] and SANDEEP DESHMUKH
Dayanand Science College, Latur 413512, Maharashtra, India
[*]*Corresponding author E-mail*: aishaandhare16@gmail.com

A study was conducted to evaluate the bio-herbicidal potential of *Abutilon indicum*, *Tephrosia purpurea*, *Prosopis juliflora*, *Cassia occidentalis* ethanolic extracts on the growth and germination of the invasive weed *Parthenium hysterophorus*. The effect on seed germination and seedling growth was assayed by using Agar germination media. Plant extracts were prepared using ethanol. Ethanolic extracts of each plant and a combination of all plant extracts were tested separately on the germination of parthenium weed seed. All four plant extracts at 25% concentration with distilled water significantly reduced the total germination percent (GP), germination index (GI), germination energy (GE), speed of emergence (SE), seedling vigour index (SVI), and coefficient of the rate of germination (CRG) of *Parthenium hysterophorus*. Inhibition of seed germination was observed to be more sensitive to the extract of the combination mixture of all plants as compared to the single plant extract. Results revealed that the *Abutilon indicum*, *Tephrosia purpurea*, *Prosopis juliflora* and *Cassia occidentalis* plant extracts have phytotoxic properties and thus contain phytotoxic substances. Isolation and characterization of those phytotoxic substances from these plants may act as a tool for new, natural, biodegradable herbicide development to manage the seed of parthenium weed.

S8-OP-13

Techniques to rear three insect agents for the biological control of *Parthenium hysterophorus* in South Africa

MILLY GAREEB, LORRAINE STRATHIE*, SAKHI SAMBO and XOLILE MAGOSO

Agricultural Research Council - Plant Protection Research Institute, Private Bag X6006, Hilton, KwaZulu Natal, South Africa

**Corresponding author E-mail*: strathiel@arc.agric.za

Releases of the stem-borer *Listronotus setosipennis* (Coleoptera: Curculionidae) and defoliator *Zygogramma bicolorata* (Coleoptera: Chrysomelidae) on *Parthenium hysterophorus* began in 2013 in South Africa, followed by the seed-feeder *Smicronyx lutulentus* (Coleoptera: Curculionidae) in 2015, and are ongoing. Rearing techniques were developed. Critical to insect production is the continuous supply of suitable plants. Frequent seedling propagation and transplanting, nutrient application, selective removal of floral material to enhance vegetative production, and timely pest management are necessary. Tunnel facilities maintained at 18 °C to 30 °C, and artificial lighting during winter, enhanced plant growth. Various plant growth forms are required for the differing oviposition and developmental needs of each agent. Breeding cages in temperature-controlled glasshouses (22 °C to 28 °C) contained adult insects which were exposed to potted parthenium weed plants for one to four weeks, agent dependent. Oviposition, larval development, and pupation stages were separated. Insect production was enhanced by increasing the plant replacement frequency in breeding cages and manipulated by moisture application during pupation. Some agents, by their nature, were more readily reared than other agents. Challenges included fertigation systems, planting frequency, pest outbreaks, and timeously supplying suitable plants to meet the needs of insect cultures. Capacity, space, and plant quantity and quality limited agent production. Temperature-controlled facilities enabled year-round production of plants and insect agents, increased timeously for seasonal releases. More than 35,000 *L. setosipennis*, 50,000 *Z. bicolorata* and 35,000 *S. lutulentus* have been released in South Africa. Training and starter cultures were provided to initiate biocontrol programmes in Ethiopia, Tanzania and Uganda.

Distribution and current efforts on biological control of *Parthenium* in Uganda

MOLO RICHARD[1*], AOOL WINNIFRED[1], LORRAINE STRATHIE[2] and WONDIMAGEGNEHU MERSIE[3]

[1]*National Agricultural Research Organization, P. O. Box 7065, Kampala, Uganda*

[2]*Agricultural Research Council-Plant Protection Research Institute, Private Bag X6006, Hilton 3245, South Africa*

[3]*Virginia State University, Petersburg, VA23806, USA*

[*]*Corresponding author E-mail*: richardmolo7@gmail.com

Early detection of *Parthenium hysterophorus* in Uganda did not occur until 2009 when it was first reported there. In 2013, large, dense infestations in agricultural and grazing land caused concern, which stimulated action by government and other stakeholders. This paper provides highlights on assessment of distribution of the weed and an approach to integrate biological control to manage parthenium weed. Countrywide surveys were conducted and reports from affected communities were verified to map the occurrence of the plant. The findings indicated that parthenium weed was widespread in 52 districts that were surveyed of the 121 districts present in Uganda. Hot spots of invasion occurred in the northern part of the country, followed by eastern, central and western Uganda. Two species of biocontrol agents, *Zygogramma bicolorata* (a leaf-feeding beetle) and *Listronotus setosipennis* (a stem-boring weevil) were imported from laboratory-reared cultures in South Africa in January 2018 to control the weed and cultures were established in the screen house for mass-rearing in Uganda. Rearing of the biological control agents in the screen house has been successful with an average 45-67% of adults emerging from soil. A total of 200 individuals of each species has so far been released at a pilot site in central Uganda.

Importation and quarantining of the seed-feeding weevil, *Smicronyx lutulentus*, for prospective control of *Parthenium hysterophorus* in India

PRAKYA SREERAMA KUMAR[1*], M. SAMPATH KUMAR[1], A. N. SHYLESHA[1], CHANDISH R. BALLAL[1], K. DHILEEPAN[2], BOYANG SHI[2] and JASON T. CALLANDER[2]

[1]*ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India*

[2]*Biosecurity Queensland, Department of Agriculture and Fisheries, Ecosciences Precinct, 41 Boggo Road, Dutton Park, Qld 4102, Australia*

[*]*Corresponding author E-mail*: psreeramakumar@yahoo.co.in

The asteraceous plant, *Parthenium hysterophorus*, commonly called parthenium weed, has been causing enormous losses to agriculture and animal husbandry as well as to the environment and human health in India. Although the leaf-feeding beetle *Zygogramma bicolorata*, the only biocontrol agent released against this weed in India, has been fairly successful in keeping the plant under control in certain situations, the enormity of the problem requires additional biocontrol agents to more fully manage the weed. The seed-feeding weevil *Smicronyx lutulentus* was chosen as an additional agent for importation as this agent has been shown to establish and have affect against parthenium weed in Queensland, Australia, and more recently, in South Africa. The 90 *S. lutulentus* adult weevils received from Biosecurity Queensland on 24 April 2018 underwent quarantine processes in the QC-2 facility at the ICAR–National Bureau of Agricultural Insect Resources, Bengaluru. The preliminary biology of *S. lutulentus* in the Indian context and details of the proposed host-specificity studies within quarantine are discussed. Once host-specificity studies confirm the suitability of the weevil for release, a field-release permit will be obtained for limited releases in suitable areas for classical biological control of parthenium weed.

Initiation of a classical biological control programme against *Parthenium hysterophorus* in Pakistan

PHILIP WEYL[1*], ABDUL REHMAN[2], MUHAMMAD ANJUM ALI[3], JULIEN LAMONTAGNE-GODWIN[4], ROGER DAY[5], ARNE WITT[5] and RICHARD SHAW[4]
[1]*Weed Biological Control, CABI, Rue des Grillons 1, Delemont 2800, Jura, Switzerland*
[2]*CABI, Opposite 1 - A, Data Gunj Baksh Road, Rawalpindi, Pakistan*
[3]*Pakistan Agricultural Research Council, 20 Atta Turk Avenue, G - 5/1, Islamabad, Pakistan*
[4]*CABI, Bakeham Lane, Egham, United Kingdom*
[5]*CABI, Canary Bird, 673 Limuru Road, Muthaiga, Nairobi, Kenya*
[*]*Corresponding author E-mail*: p.weyl@cabi.org

Invasive alien plants can pose a serious threat to food security, biodiversity, human and animal health and economic development. Parthenium weed, *Parthenium hysterophorus*, is no exception in Pakistan and steps to reduce its impact and prevent further spread need to be taken. In Pakistan, the plant was first reported from the Gujarat district of Punjab Province in 1980 and since then it has rapidly spread throughout the region. It was identified as a priority for control in Pakistan and an integrated control programme has been launched against this invasive weed. Preliminary surveys in 2009 documented the presence of the biological control agent, *Zygogramma bicolorata*, which naturally dispersed into Pakistan. In Australia and South Africa, more than one biological control agent was required to reach desirable levels of control, so we propose the stem boring weevil *Listronotus setosipennis* for release into Pakistan to complement *Z. bicolorata*. The CABI Action on Invasives Programme is working with Pakistan in developing the biological control programme and host range testing in a Pakistani context, including a test plant list important to Pakistan. The host range testing will be conducted in the quarantine facility on the CABI-Rawalpindi campus in Pakistan. The addition of *L. setosipennis* to the biological control of parthenium weed will be an invaluable asset to the integrated control of this weed in Pakistan. Ultimately, the development of the biological control programme should result in the sustainable control of parthenium weed and a reduction in the amount of manual and chemical control required.

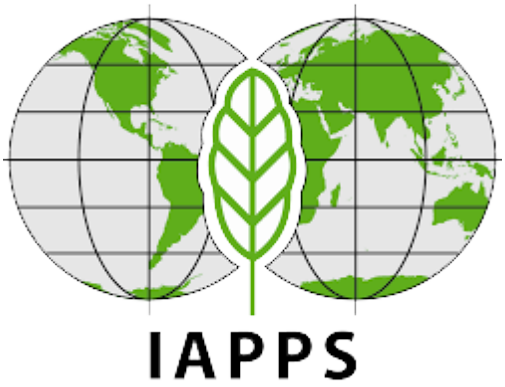
Will parthenium weed become more invasive in the future? - The effect of elevated CO_2 on seeds characteristics

RUNPING MAO[*] and STEVE W. ADKINS
School of Agriculture and Food Science, The University of Queensland, Australia.
[*]*Corresponding author E-mail*: r.mao@uq.net.au

Under a fast changing climate, the invasive potential of *Parthenium hysterophorus* L. is being investigated with increasing concern. The possibility of spread in future environments however, is less explored, especially with respect to the properties of seeds. We compared two biotypes of parthenium weed in Australia, the Clermont biotype, which is generally regarded as more invasive, and the Toogoolawah biotype, which is less invasive, in terms of their seed morphology and germination traits. This study was conducted in growth chambers with environmental settings under ambient (400 ppm) and elevated (700 ppm) CO_2. The results showed the cypselae weight of the Clermont biotype to marginally decrease under elevated CO_2 concentration, but the weight of the Toogoolawah biotype significantly increased under elevated CO_2. While the length of cypselae remained unchanged in both biotypes, the cypselae width of Clermont biotype significantly decreased, while the Toogoolawah biotype significantly increased, resulting in a similar change in total area. With respect to germination, the early harvested cypselae from Clermont biotype produced under ambient CO_2 concentration showed little dormancy, whereas more dormant cypselae were found in the later harvested cypselae as well as under elevated CO_2 concentration. The later harvested cypselae from the Toogoolawah biotype were more dormant under elevated CO_2 concentration. We conclude that elevated CO_2 can change seed properties, and with morphological changes and higher proportion of delayed germination, seeds behaviour in future seed banks and during spread would be more difficult to predict.

Workshop of the IAPPS Working Group on *Tuta absoluta* - Biology, Ecology and Management

International Association for the Plant Protection Sciences



S9-OP-01

Role of IPM Innovation Lab in management of *Tuta absoluta*

RANGASWAMY MUNIAPPAN*
IPM Innovation Lab, Virginia Tech, Blacksburg, Virginia 24060, USA
**Corresponding author E-mail*: rmuni@vt.edu

When the South American tomato leafminer, *Tuta absoluta*, invaded Senegal in 2012, the IPM Innovation Lab organized a regional awareness workshop for the West and Central African countries in Dakar, Senegal in May 2013. In the workshop, presentations on the biology, ecology, spread, monitoring, and control methods of *T. absoluta* were conducted. Pheromone lures and traps were distributed to the participants for monitoring in their respective countries. In November 2013, another regional awareness and management workshop in Addis Ababa, Ethiopia for the East African and South Asian countries was conducted. In this workshop, representatives from India and Nepal participated. Upon returning to India, the representatives produced *T. absoluta* pheromone lures and traps and prepared to distribute them to the farmers when the pest was introduced in November 2014. In 2015, the IPM Innovation Lab conducted awareness workshops in Nepal and Bangladesh and followed up with management workshops when the pest invaded in early 2016. Recognizing the inevitable spread of *T. absoluta* into Cambodia in the near future, the Lab conducted two awareness workshops in early 2017. In addition, several *T. absoluta* symposia in regional and international meetings and conferences in Africa, Asia, Europe, and U.S.A have been conducted. In October 2015, a *T. absoluta* Working Group was formed under the auspices of the International Association for the Plant Protection Sciences.

S9-OP-02

Multi-pathway models to understand the spread and impact of *Tuta absoluta*

ABHIJIN ADIGA*
Biocomplexity Institute of Virginia Tech, Blacksburg, VA 24061, USA
**Corresponding author E-mail*: abhijin@gmail.com

Movement of humans and their goods is widely accepted as the primary driver of invasive species invasions. However, mainstream approaches tend to focus more on the biological and ecological factors than on human-assisted pathways of spread. Modeling the latter remains a challenge owing to its complex nature, unavailability of quality data and lack of systematic modeling methods. Using network science and computational epidemiology, we have developed robust hybrid models to study the role of natural and anthropogenic drivers of invasive species spread, with application to *T. absoluta.* This talk will present our recent efforts in this direction demonstrating the role of this new modeling approach in analyzing spread, the role of tomato trade, effect of climate change and economic impact.

S9-OP-03

Evaluation of different management options against South American tomato leafminer, *Tuta absoluta* in Nepal

LALIT SAH[1*], MUKTI DEVKOTA[1], KIRAN BHUSAL[1], LUKE A COLAVITO[1], GEORGE NORTON[3], EDWIN GEORGE RAJOTTE[2] and R. MUNIAPPAN[3]
[1]*IDE Nepal, PO Box No. 2674, Bakhundole, Lalitpur, Lalitpur, Kathmandu, Nepal*
[2]*Department of Entomology, Pennsylvania State University, 501 ASI Building, USA*
[3]*IPM Innovation Lab, Virginia Tech, Blacksburg, Virginia 24060, USA*
[*]*Corresponding author E-mail*: lpsah@ideglobal.org

The farming of tomatoes has become a profitable business in Nepal. However, production has been limited by several biotic and abiotic factors. At present, the invasive South American tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) has become an important economical pest for both open and polyhouse tomato growers of Nepal. The farmers are adopting various management options based on their knowledge; however, most of the management options are ineffective and require better management technologies. Chemical pesticides have failed to control this pest because of development of insecticide resistance. The IPM Innovation Lab/International Development Enterprises (iDE) Nepal in collaboration with experts from the Government of Nepal, and a team of scientists from the U.S, have been instrumental in identifying, testing and developing new IPM solutions for managing this pest. We present the results of the approaches used to manage this pest. The trial on efficacy of pest exclusion nets was successful in reducing 90% pest population, 89% less leaf damage and 91% less fruit damage with a promising 23.58 more mt/ha yield as compared to open cultivation. Similarly, the results on effectiveness of colored traps with lures showed that the white colored delta traps attracted more moths followed by green, yellow and orange delta traps, respectively. Traps placed at ground level caught more moths followed by traps placed at 1 ft, 2 ft, 3 ft and above 3 ft height. iDE is utilizing a public-private partnership approach to develop smallholder commercial pockets and last mile supply chains to reach farmers with the IPM technologies.

S9-OP-04

Tomato pinworm, *Tuta absoluta* (Meyrick): Biology, host range, population build-up and biocontrol options for its management

M. MOHAN*, K. SUBAHARAN, SHIEK SALMAN, G. NARASA REDDY, OMPRAKASH NAVIK, R. RANGESHWARAN and N. BAKTHAVATSALAM
ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India
**Corresponding author Email*: mohan.nbaii@gmail.com

Tuta absoluta (Meyrick), a lepidopteran leafminer also called a pin borer, belongs to the family Gelichiidae. It is considered one of the most devastating tomato pests in the countries it has invaded so far. Under unmanaged condition, the larvae of *Tut aabsoluta* can cause 100% yield reduction on tomato crops. Its presence was first noticed in India in 2014. Now it is reported from almost all the tomato-growing regions of the country with damage ranging from negligible to cent per cent. Laboratory feeding assays and field survey indicated that the preferred host plant is tomato followed by *Solanum tuberosum*, *S. nigrum* and *S. melongena* among others. Heavy population buildup of *T. absoluta* in Karnataka (Raichur, Kolar and Malur) and Tamil Nadu (Hosur and Krishnagiri) occurred (328.4 to 783.6 adults/pheromone trap per week) during winter months. The damage on tomato fruits during November to February varied between 23.1 to 80.3 per cent. In the neglected and unsprayed tomato fields, there was a significant population of natural enemies of *T. absoluta* such as *Nesidiocoris tenuis*, reduviid bugs and *Trichogramma achaeae*. Screening for effective indigenous *Bacillus thuringiensis* isolates against the second instar larvae indicated that *B. thuringiensis* based formulations will have the potential to check the population of *T. absoluta.*

Functional response of indigenous species *Nesidiocoris tenuis* (Reuter) to invasive leafminer, *Tuta absoluta* (Meyrick)

SARSWATI NEGI*
Department of Entomology, Dr Y. S. Parmar University of Horticulture and Forestry, Solan - 173230, Himachal Pradesh, India
**Corresponding author E-mail*: sarunegi1212@gmail.com

Tuta absoluta (Meyrick), one of the most destructive pests of tomato, invaded India in 2014 and has now emerged as a serious threat to the crop both in open fields and polyhouses. In the present study functional response of a naturally occurring predator, *Nesidiocoris tenuis* (Reuter) to *T. absoluta* has been studied at 25 ± 0.5°C, 70 ± 5% RH and 12L: 12D photoperiod to understand the density responsiveness of the predator to the pest. All the active life stages of the predator exhibited Type-II functional response to eggs and first-instar larvae of the pest. Predator's attack rate increased, and the handling time decreased with the advancement of the development stage. Based on Rogers's random predator equation, predator's attack rate on host eggs and neonate larvae was lowest (0.052 and 0.092, respectively) in the first-instar nymphs and highest (0.193 and 0.180, respectively) in the adults. Handling times of the adult and the fifth-instar for host eggs (0.368 and 0.503 h, respectively) and larvae (0.506 and 0.545 h, respectively) were much shorter than other stages. The maximum number of host eggs and larvae that could be consumed over a period of 24 h by the first, second, third, fourth, fifth-instar and adult of *N. tenuis* was estimated to be 22.35, 40, 36.19, 44.28, 47.71 and 65.22; and 12.28, 20.22, 24.22, 27.62, 44.04 and 47.43 per predator, respectively. Functional response parameters indicate that adults and fifth-instar nymphs were the voracious feeders and could be important for biological control of the pest.

S9-OP-06

Distribution and genetic diversity of tomato leaf miner, *Tuta absoluta* population in India in relation to sterile insect technique application

ASHOK HADAPAD*
Nuclear Agriculture and Biotechnology Division, Bhabha Atomic Research Centre, Mumbai - 400085, Maharashtra, India
**Corresponding author E-mail*: ahadapad@barc.gov.in

Tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is a very invasive and serious pest of tomato. It has become a major pest on tomato crops in open and protected conditions in the world. *Tuta* infestation has been observed recently in different states of India and causes 90 - 100% damage. Due to its invasion capacity, adaptability and high reproduction potential, this pest is being considered as a suitable candidate for Sterile Insect Technique (SIT). To develop SIT for *Tuta*, it is essential to understand the actual distribution, genetic diversity, mass rearing feasibility, optimizing sub-sterility dose and compatibility with other control strategies. Hence, we collected tomato leaf miner samples from different districts of ten states of India and samples were further used for genetic diversity studies. We observed high levels of infestation from Karnataka, Maharashtra, Tamil Nadu and Andhra Pradesh. In particular, Yadgir and Kalburgi districts of Karnataka showed > 90% of tomato fruit damage and complete damage of leaves (blotch). Around 30-60% tomato fruit damage and 40-80% leaf mining was observed in most of the surveyed locations. So far, no infestation and/or adults were trapped from West Bengal and Bihar states during the present survey. Results of mass rearing protocols, radiation dose optimization and genetic diversity studies will be presented. In addition, the importance of the tomato leaf miner in tomato cultivation and integration of the SIT with biocontrol agents for the management of *T. absoluta* will be also be discussed.

S9-OP-07

Efficacy of integrated pest management tools evaluated against *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) on tomato in India

PADAVALA SWATHI, V. SRIDHAR*, R. ASOKAN, S. ONKARA NAIK, H. GADAD and K. S. NITIN

ICAR - Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bengaluru - 560089, Karnataka, India

**Corresponding author E-mail*: vaddi_sridhar@rediffmail.com; vsridhar@iihr.res.in

South American tomato moth, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is an invasive pest on tomato and other solanaceous crops. In general, 20 to 30% yield loss is caused by this pest and may result in 100% damage, if timely management interventions are not followed. IPM has been one of the classical strategies developed and adopted by plant protectionists to combat the insect pests and reduce the losses caused by them. The IPM strategy aims at using all the available options, their integration at ground level to achieve the desired economic and ecological benefits while reducing the losses caused by the pests. Various tools of IPM against *T. absoluta* were evaluated including entomopathogens (*Bacillus thuringiensis, Metarhizium anisopliae, Beauveria bassiana* and *Nomuraea rileyi*), egg parasitoids (*Trichogramma chilonis, T. pretiosum, Trichogrammatoidea bactrae*), light traps, pheromone traps, few insecticides and the results are discussed in this paper. Among the egg parasitoids and synthetic chemicals, *T. pretiosum* and spinetoram 12 SC @ 1.25 ml/l were very effective. Efficacy of various components for the management of *T. absoluta*is discussed in this paper.

Controlled release matrix for delivery of South American tomato moth, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) pheromone

KESAVAN SUBAHARAN[1*], M. ESWARMOORTHY[2], R. SENTHOORRAJA[1], T. M. SUBRAMANYA[2], T. M. VINAY[1], N. BAKTHAVATSALAM[1] and M. MOHAN[1]

[1]*ICAR - National Bureau of Agricultural Insect Resources, H. A. Farm Post, Bellary Road, Hebbal, Bengaluru - 560024, Karnataka, India*

[2]*Chemistry and Physics of Materials Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur P O, Bengaluru - 560064, Karnataka, India*

[*]*Corresponding author E-mail*: subaharan_70@yahoo.com

The South American tomato moth, *Tuta absoluta* (Meyrick) (Gelechiidae: Lepidoptera) is a key pest of tomato, *Solanum lycopersicum* in tomato growing countries across the globe. The female sex pheromone of *T. absoluta* comprises of (3E, 8Z, 11Z)-3, 8, 11-tetradecatrien-l-yl acetate and (3E, 8Z)-3, 8- tetradecadien-l-yl acetate (9:1). Pheromone loaded in rubber septa dispensers are being used @ 30 per ha for trapping the adult males. It has a high release rate of pheromone and warrants frequent replacement. This adds to the cost of the labour and chemistry. Nanoporous materials are a novel carrier/dispenser for the volatile signaling molecules with controlled spatiotemporal release rates. Dispensers made of mesoporous sieves with ordered pore channels were developed for loading the *T. absoluta* pheromone. Characterization by field scanning electron microscopy (FESEM) and X-ray diffraction (XRD) confirmed the ordered structure of the pores on the matrix. Pheromone when loaded in nanomatrix showed delayed dissipation as compared to pheromone alone when assayed by Thermal gravity analysis (TGA). Fourier transform infrared (FT-IR) measurements confirmed the presence of pheromone in the nanomatrix. Entrapped pheromone in the nanomatrix revealed controlled release of pheromone as compared to release from rubber septa. The physiological response in olfactory receptor neurons of the male moths to the pheromone released from nanomatrix was ascertained. Field test of pheromone loaded in nanomatirx captured more moths than unbaited traps. On longevity of pheromone lures, the commercial lure containing 3 mg pheromone was exhausted in 20 - 30 days, whilst pheromone loaded into nanomatrix was effective for 45 - 60 days.

Evaluation of biological control options for the management of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) on tomato

SRIDHAR VADDI*, R. ASOKAN, ONKARA S. NAIK, K. S. NITIN, H. GADAD and P. SWATHI

ICAR - Indian Institute of Horticultural Research, Hesaraghatta Lake Post, Bengaluru - 560089, Karnataka, India

**Corresponding author E-mail:* vsridhar@iihr.res.in

The South American tomato moth, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is an invasive pest on tomato and other solanaceous vegetables; it was first reported in India in 2014 and since then has spread rapidly to different states. In general, 20% to 30% yield loss is caused by this pest and may result in 100% damage, if timely management interventions are not followed. Entomopathogens like *Bacillus thuringiensis*, *Nomuraea rileyi*, *Beauveria bassiana*and *Metarhizium anisopliae* and egg parasitoids (*Trichogramma chilonis, T. pretiosum*, *Trichogrammatoidea bactrae*) are eco-friendly and effective options both under polyhouse and open field conditions. The mirid bug, *Nesidiocoris tenuis* is a good predator on eggs and first instars of *T. absoluta*. These biological control options have been evaluated at ICAR–Indian Institute of Horticultural Research, Bengaluru against *T. absoluta*. Four entomopathogens *viz*. *Bt* (1 ml/l) and *N. rileyi*, *B. bassiana* and *M. anisopliae* @ 1×10^8 cfu/ml were evaluated and three egg parasitoids viz., *T. pretiosum, T. bactrae, T. chilonis* evaluated in separate trials. Egg parasitoids were released at weekly intervals @ 50,000/ha for five weeks. The observations on *T. absoluta* live mines were recorded on 3, 7 and 10 day intervals in each of the treatments. Various entomopathogens have resulted in 70-81% reduction in live larvae of *T. absoluta*on tomato. Among the egg parasitoids evaluated, *T. pretiosum* was found to be promising (25-55% damage reduction). Botanical based Azadirachtin 5% EC at 2 ml/L was effective against *T. absoluta* resulting in 69.87% reduction in live mines of *T. absoluta* and was relatively safe to the natural enemies also. Feeding potential of *Nesidiocoris tenuis* on *T. absoluta* eggs was assessed under laboratory conditions and revealed I, II, III and IV instars of *N. tenuis* can feed up to 27, 33, 47 and 38 (eggs/day), respectively, whereas adults fed up to 27 eggs/day. Being a newly invaded pest attacking major vegetable crops like tomato, these biological control options should be integrated with the other IPM practices for effective management of the pest. Potential of these biological control options as a part of IPM of *T. absoluta* is discussed in this paper.

Thermal requirements of *Tuta absoluta* (Meyrick) and influence of temperature on its population growth on tomato

P. L. SHARMA*, SARSWATI NEGI and S. C. VERMA
Department of Entomology, Dr Y S Parmar University of Horticulture and Forestry, Solan 173230, Himachal Pradesh, India
**Corresponding author E-mail*: sharma.pl@rediffmail.com

Temperature-dependent phenology models are important to examine the influence of temperature on the geographical distribution, population dynamics and management of a particular insect. The present study deals with the impact of temperature on development, survival, reproduction and population growth of a recently invaded and the most destructive pest of tomato, *Tuta absoluta* (Meyrick) with the aim to understand its possible expansion in different agro-climatic zones under predicted climate change. Though *T. absoluta* was able to develop between 15 and 35°C, temperature around 25 - 30°C was more suitable. Survival and fecundity was highest at 25°C and lowest at 35°C. Developmental threshold for different developmental stages of the pest varied from 6.2 to 9.5°C, while the thermal constant required by the insect to complete the development from egg to adult emergence was 500 degree-days. Population growth parameters were also influenced significantly by the rearing temperature. Intrinsic rate of increase, net reproductive rate and finite rate of increase was higher at 25 and 30°C as compared to other temperature regimes. The study concludes that *T. absoluta* can be a serious pest of tomato in mid-hills of north-western Himalayan region and the southern plains of India where temperature fluctuates between 15 - 35°C. Furthermore, the developmental threshold values indicate that the pest can develop and survive at temperatures as low as 6 - 9°C without entering the diapause as long as the food is available.

S9-OP-11

Tuta absoluta, a new pest in IPM tomatoes in Senegal

ELHADJI SERIGNESYLLA[1*] and THIERRY BRÉVAULT[2]
[1]*Rue 63x68 Street, Dakar 18524, Senegal*
[2]*CIRAD - Persyst, Montpellier, France*
[*]*Corresponding author E-mail*: syllaserigne2@gmail.com

Since its first detection in Senegal, the tomato leafminer *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) has become a serious threat to the production of tomatoes in Senegal. The objectives of our study were to get information on *T. absoluta* population dynamics in the main tomato-producing areas, to identify indigenous natural enemies and to analyze the effect of crop management and landscape on the abundance and biological control of the pest. Incidence of *T. absoluta* was very low during the rainy season due to lack of resources. Field monitoringshowedvery low larval parasitism (0.8%) but significant control by generalist predators such as the predatory mirid *Nesidiocoris tenuis* (Hemiptera, Miridae). Field monitoring in 2015 and 2016 showed that hose irrigation and the number of insecticide applicationshad a negative effect on the abundance of *T. absoluta* larvae. At a landscape scale, a positive correlation between the proportion of tomato cropsin the surrounding area and pest abundance was observed. These results should contribute to the development of innovative and more sustainable control methods.

S9-OP-12

Risk assessment and management of tomato leaf miner, *Tuta absoluta*

M. S. HOSSAIN[1], A. K. DAS [1], M. M. HOSSAIN[2], M. Y. MIAN[3] and R. MUNIAPPAN[4]
[1]Horticulture Research Center, BARI, Gazipur, Uttar Pradesh, India
[2]Breeder Seed Production Station, BARI, Debigonj, Panchagarh, Bangladesh
[3]IPM IL, Bangladesh site; [4]IPM IL, Virginia Tech, USA
[*]Corresponding author E-mail:

The survey was conducted at research/growers' tomato fields in several districts viz. Gazipur, Jessore, Comilla Moulvibazar and Panchagarh by installing delta traps containing *Tuta absoluta* lures during summer season May to August 2017 and during winter seasons November 2017 to April 2018 to assess the incidence, intensity and peak period of attack of tomato leafminer, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). Results indicated *Tuta absoluta* damaged up to 27.36% leaves and 25.25% tomato fruits. Among five locations, the highest infestation was observed at Panchagarh and the lowest at Comilla. The peak period of *Tuta* attack was March - April in winter and May - June in summer seasons. The population of this pest was higher during summer season than that of winter season. The *Tuta* pheromone trap catch was positively correlated with the monthly average temperature and relative humidity. Biorational management of *T. absoluta* was carried out in farmers' fields at Chaklarhat village, Tunirhat, Panchagarh district, Bangladesh from January 2018 to June 2018. A total of ten treatments with three replications and RCB design were laid out. Results revealed that foliar spray of Azadirachtin (Bio-Neem plus 1EC @ 1 ml/L of water) + Mass trapping with installation of Delta sex pheromone trap + Application of *Metarrhizium anisolpiae* biopesticide in soil @ 5 g/L of water performed best in reducing *T. absoluta* infestation, increasing marketable yield and marginal benefit cost ratio.