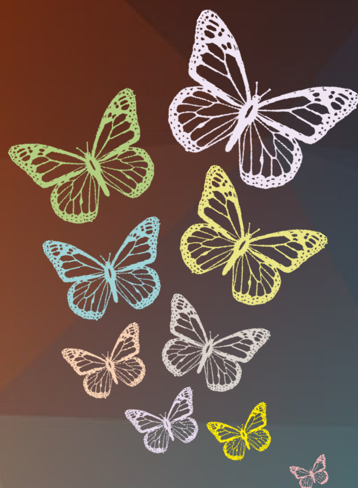

Annual Report
2016-17
वार्षिक प्रतिवेदन

ICAR–NATIONAL BUREAU OF AGRICULTURAL INSECT RESOURCES

Bengaluru, India

राष्ट्रीय कृषि कीट संसाधन ब्यूरो

बेंगलूरु, भारत

The *Sardar Patel Outstanding ICAR Institution Award – 2015* being awarded to NBAIR on 16 July 2016 in New Delhi

Dr Chandish R. Ballal receiving the *Panjabrao Deshmukh Outstanding Woman Scientist Award – 2015* on 16 July 2016 in New Delhi

Dr Abraham Verghese, Director, NBAIR, being greeted on the day of his superannuation on 31 May 2016 at NBAIR, Bengaluru

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Tanaostigma indica – first report of the hymenopteran genus from the Old World (left) (courtesy: Ankita Gupta)

Gastrozona nigrifemur – a new fruit fly species from India (right) (courtesy: K.J. David)

Back

Peucetia viridana, the green lynx spider, devouring a carpenter bee (left) (courtesy: T.M. Shivalingaswamy)

Adults of rugose spiralling whitefly, *Aleurodicus rugioperculatus*, an invasive pest of the coconut palm; inset: *Encarsia guadeloupae*, an effective natural enemy of the pest (right) (courtesy: K. Selvaraj)

PREFACE

Insects have been the scourge of mankind since the dawn of human existence. The greatest threat from insects in early times was as vectors of human diseases. In addition, they also competed for food, destroyed man-made structures and were general irritants. It was however with the ushering in of the Neolithic revolution (ca. 10,000 – 8,000 BCE) and the shift from a nomadic to a settled way of life (with the domestication of plants and animals) that the competition for food from insects became more intense. Since then insects have been consciously viewed as adversaries that have to be eliminated if mankind is to produce adequate quantities of food.

To every agriculturist, whether farmer or research scientist, it is owing to this dis-service to farming that insects are most loathed and feared. Insects have for long been viewed as harbingers of famine. People at large however have remained unaware of — or have underestimated the magnitude of — the numerous services that insects render to keep our larders full as well as to ensure the normal, healthy functioning of terrestrial and freshwater ecosystems.

It is this awareness of the overwhelming importance of the services that insects render to ecosystems in general, and to agroecosystems in particular, as opposed to their dis-services to agriculture that led to the creation of the National Bureau of Agricultural Insect Resources (NBAIR) in 2014. The Project Directorate of Biological Control (PDBC), the institution which metamorphosed into the NBAIR, was singularly focused on one ecosystem service provided by insects, viz. pest regulation. The NBAIR, while carrying forward the legacy of the PDBC has widened its horizon taking into its fold studies on all insect-derived ecosystem services.

Systematics being the cornerstone of all biodiversity studies is an important area of study at NBAIR. Expeditions mounted to the far flung corners of the country have resulted in the discovery of new, intriguing species of insects belonging to the Hymenoptera, Diptera, Hemiptera and Thysanoptera to name a few insect orders in which striking discoveries have been made this year. While work on mite and nematode taxonomy is being continued, studies on the taxonomy of spiders have been initiated. Large collections of insects, spiders and mites have been added to the museum.

The NBAIR, being recognised as a 'National Repository for Insects, Spiders and Mites' by the Ministry of Environment, Forests and Climate Change, Government of India, has been receiving voucher specimens of insects from various parts of the country, adding to the growing collection of insects at the museum. To house this expanding arthropod collection from across the country a new museum is under construction at the Hebbal campus of NBAIR. Facilities are being created for systematists of repute from India and abroad to work on the collections at this museum, thus ensuring that it becomes a centre of excellence in arthropod systematics.

Barcodes have been generated for over 300 species of Indian insects. As this expanding database becomes more comprehensive in the years to come, it will enable the quick and reliable identification of our insects at a meagre cost.

For the first time, the whole genome of *Leucinodes orbonalis*, the brinjal shoot and fruit borer, has been sequenced *de novo*, the study of which should enable the identification of genes involved in insecticide resistance, pheromone reception and olfaction. In turn, this will pave the way for formulating effective management protocols for this intractable pest.

This year witnessed the invasion of our country by a dreaded pest, *Aleurodicus rugioperculatus*, the rugose spiralling whitefly. In collaboration with the Institute of Wood Science and Technology, NBAIR identified the pest and detailed a strategy for its management. Studies are in progress to manage the tomato pinworm, *Tuta absoluta*, an earlier invasive into our country. Indigenous natural enemies have been collected and evaluated in the laboratory; their efficacy in the field is currently being assessed. An efficient pheromone-based monitoring protocol has been developed to facilitate decision making when implementing a pest management programme for the pinworm.

An exciting new vista has been opened with the initiation of studies on the pollination abilities of native solitary and semi-social bees both in the field and under protected conditions. If effective, their nests could be deployed in different agroecosystems, particularly in polyhouses, as an indigenous alternative to imported bumble bee pollinators.

New biocontrol agents like *Geocoris ochropterus*, predatory anthocorid bugs, have been added to the natural enemy arsenal at the Bureau to manage pests including those in storage.

The newly started research programme on the utilisation of insects as nutritious supplements for incorporation in insect feeds is making significant headway. The development of mass production protocols and nutritional experiments on poultry and fish are in progress.

The NBAIR has during the year embarked on charting new territory to harness the services of insects. Other areas which remain to be explored will be taken up in the coming years along with studies currently in progress.

Bengaluru
31 May 2017

Chandish R. Ballal
Director

1. EXECUTIVE SUMMARY

The ICAR–National Bureau of Agricultural Insect Resources is the only institution in the country recognised as a National Repository for agriculturally important insects, spiders and mites. The Bureau is committed to the collection, cataloguing and conservation of insects and other related organisms including mites, spiders, nematodes and microbes associated with arthropods in various agroecosystems of our country. Research work in the Bureau is undertaken in the three Divisions of Insect Systematics, Molecular Entomology and Insect Ecology. Work related to biological control is formulated and coordinated under the All-India Coordinated Research Project (AICRP) on Biological Control of Crop Pests. The results of the research are summarised below.

ICAR–National Bureau of Agricultural Insect Resources

Insect Systematics

Five states were surveyed for Trichogrammatidae in agricultural, natural and disturbed ecosystems. *Chaetostricha magniclavata, Lathromeromyia dimorpha* and *Poropoea baleena* were recorded from areas from where they had not been previously known and a new species of *Trichogrammatoidea* has been described. Seasonal abundance of egg parasitoids was studied in rice, sugarcane and ragi fields in Mandya, Karnataka. Scelionidae was found to be the most abundant family followed by Mymaridae, Trichogrammatidae and Platygastridae in rice and ragi fields while the pattern differed a little in sugarcane with Platygastridae dominating over Trichogrammatidae.

The genus *Megaphragma* and *Trichogrammatoidea bactrae* were collected from Uttarakhand for the first time. *Trichogramma achaeae* and *Trichogrammatoidea bactrae* were collected from eggs of *Tuta absoluta*.

Five new species of Scelionidae, viz. *Oethecoctonus suryaseni*, *Pardoteleia flava*, *Microthoron bloomsdalensis*, *M. shompen* and *Nyleta onge* were described. The male of *M. baeoides* and its bizarre antenna were described. Both male and female *M. baeoides* and female *M. miricornis* were imaged. *Narendraniola* was treated as a junior synonym of *Microthoron*.

Four new species, viz. *Crinibracon chromusae*, *Tanaostigma indica*, *Cotesia trabalae* and *Agiommatus thyrsisae*, were described. Reviewed genus *Cotesia* worldwide for distinct character of first tergite, combining molecular and morphological analyses as well as the parasitoid biology.

Around 1,000 specimens belonging to Sphecidae were added to NBAIR collections. Discovered the hitherto unknown male of *Carinostigmus atterimus* by integrating morphological and molecular methods.

Three species of mealybugs, one soft scale, one aphid and one eriococcid were new additions to the existing collection of aphids and coccids at NBAIR museum. Two mealybugs and an aphid were collected for the first time from India. *Pulvinaria urbicola*, a soft scale, was redescribed.

Two species of Pentatomidae, viz. *Paracritheus trimaculatus* of subfamily Pentatominae and *Amyotea malabarica* of subfamily Asopinae, were redescribed. *Paracritheus trimaculatus* is recorded for the first time from Andaman & Nicobar Islands whereas *Neojurtina typical* and *Brachycoris* were recorded for the first time in India. A new species *Brachycoris tralucidus* is described from India. Twenty-nine pentatomids were barcoded.

Around 1,600 specimens of fruit flies were processed and preserved. Twenty-eight species of fruit flies of 17 genera and four subfamilies were collected from different parts of the country. Three new species of fruit flies were described: *Bactrocera* (*Calodacus*) *chettalli*, *B.* (*C.*) *harrietensis* infesting fruits of *Spondias pinnata* (Anacardiaceae); *Gastrozona nigrifemur* infesting sprouts of *Dendrocalamus strictus* (Poaceae). *Bactrocera* (*Zeugodacus*) *semongokensis* was recorded for the first time in India.

A total of 39 species of non-apis bees belonging to the subfamilies Megachilinae (tribes Megachilini (20) and Lithurgini (5)), Halictinae (9) and Nominae (5) were collected and added to the reference collection.

A new terebrantian thrips species, *Thrips laurencei*, from flowers of *Hydrangea macrophylla* was described. *Crotonothrips polyalthiae* and male of *Frankliniella occidentalis* were recorded for the first time in India. Six genera and 10 species of Thysanoptera were added to the NBAIR reference collection.

A total of 446 weevil specimens were collected/received from 44 locations in 14 states. Twenty four species were identified up to the genus level and the identities of 10 species were confirmed. Among these, *Lepropus chrysochlorus* was reported for the first time in Arunachal Pradesh. New host plants (litchi and beans) were recorded for *Lepropus flavovittatus.*

A checklist for the Indian species of longhorn beetles has been prepared. It consisted of 1,555 longhorn beetles, classified under 72 tribes, 447 genera and seven subfamilies of Cerambycidae as well as Vesperidae and Disteniidae.

Five hundred and fifty spiders belonging to 10 Families were collected from different crops during the surveys undertaken at 15 places in 9 states. *Neoscona shillongensis* (Family Araneidae), *Stegodyphus tibialis* (Family Eresidae) and *Aelurillus ?kronestedti* (Family Salticidae) were new distribution records for Karnataka, Kerala and Tamil Nadu, respectively. Standardised the DNA barcode protocol for spiders for both COI and ITS regions.

Out of the 5,750 mites sampled and processed, 1,380 temporary mounts and 1,239 permanent slides were prepared. The phytoseiids, *Amblyseius largoensis, Euseius alstoniae, E. coccosocius, E. macrospatulatus, Neoseiulus paspalivorus, Paraphytoseius bhadrakaliensis, P. orientalis, Phytoseius namdaphaensis, P. kapuri, P. rachelae* and *Typhlodromips syzygii*, were added to the repository. *Amblyseius largoensis* and two new species of *Lasioseius* (Ascidae) were found to be important natural enemies of *Aceria litchii*. Three stigmaeids (*Agistemus* sp.nr. *terminalis*) and three cunaxids (*Cunaxa* sp.nr. *bambusae*, *Cunaxa* sp.nr. *cynodonae* and *Cunaxa* sp.nr. *womersleyi*) were found to be new predatory mite species.

For the first time, *Heterorhabditis pakistanense* NBAIIH05 and *Steinernema huense* NBAIIS46 were reported from India. Ecological characterization of *H. pakistanense* has been done. Nine *S. simakayi* isolates and four *H. indica* isolates were identified. Field studies showed that *H. indica* NBAIIH38 could be a promising biocontrol agent for *H. consanguinea*, *Leucopholis lepidophora* and *L. burmeisteri*.

Molecular Entomology

Molecular characterisation and DNA barcoding for 188 pest species, 128 predators and parasitoids, 10 species of sphecid wasps, 13 species of spiders and four entomopathogenic nematode species were done using either mitochondrial COI alone or in combination with nuclear ITS2 gene region. New rapid DNA isolation technology from single thrips by non-destructive method was standardised. Unknown male of *Carinostigmus atterimus* (Crabronidae) was discovered after a century by integrating morphological and molecular methods.

A rapid and accurate identification of the new invasive rugose spiralling whitefly, *Aleurodicus rugioperculatus* (Hemiptera: Aleyrodidae) and its indigenous aphelinid parasitoid, *Encarsisa guadeloupae*, was done using CO1 gene. Molecular analysis of 31 populations of whitefly, *Bemisia tabaci* using ITS2 and COI regions revealed the presence of two putative genetic groups Asia1 and AsiaII1. Genomic DNA of 11 field-collected insecticide-resistant populations of cotton pink bollworm, *Pectinophora gossypiella* was processed for molecular mutation analysis.

DNA barcode-based identification and molecular phylogenetic analysis of 42 cerambycid and 20 scarabaeid beetle specimens, 19 termite specimens and 11 collembolan specimens collected from various geographical locations of the country were accomplished. Thirteen spiders (Araneae), 41 *Parapanteles* (Hymenoptera) and 10 semi-aquatic bug species (Heteroptera: Gerromorpha) were characterised using COI gene and barcodes were generated for the same. Barcoding of 13 species of *Parapanteles* was examined utilising a wingless gene region (*wg*) as a marker for molecular systematics. The wingless (wg) protein is a secreted signalling molecule that acts as a morphogen in the development of numerous structures and pattern elements in insects. The present results support DNA barcoding as a decisive tool in the rapid identification of species.

Transcriptome analysis of susceptible and resistant populations of brinjal shoot and fruit borer, *Leucinodes orbonalis*, was performed and 23 million reads data were generated with 49.63% of GC content. SRA submitted at NCBI-GenBank under Bioproject PRJNA352591 and archive accession numbers: SRX2338657 (S), SRX2338658 (R), SRX2338659 (S), SRX2338660 (R). *De-novo* whole genome sequencing of *L. orbonalis* has been done through Illumina paired end and mate pair libraries by HiSeq 2500 IT upgrade system and Pac-Bio 20KB CCS library by RSII system and P6C4 chemistry. SRA submitted at NCBI-GenBank under Bioproject PRJNA377400, archives under SUB2444180.

The transcriptome of susceptible and resistant strains of the diamondback moth, *Plutella xylostella*, was sequenced. *P. xylostella*–ryanodine receptor protein modelling was done by molecular modelling method and prediction of molecular mechanism of diamides resistance in Px-RyR was achieved computationally.

Molecular characterisation revealed the dual specificity of the indigenous *Bacillus thuringiensis* isolate NBAIR-BtAN4, toxic to both lepidopteran and coleopteran insect pests. It carried the coleopteran specific *cry8* gene and lepidopteran specific *cry1* and *cry2* genes. The isolate was toxic against the larvae of *Oryctes rhinoceros*, *Papilio* sp., *Callosobruchus chinensis* and *Sitophilus oryzae* in addition to lepidopteran pests. It showed very high toxicity against the larvae of *C. chinensis* (LC_{50} 6.8 µg/ml), *Helicoverpa armigera* (LC_{50} 414.59 ng/ml) and *Plutella xylostella* (545.15 ng/ml).

Metagenomic studies for unculturable aphid microflora yielded nine clones, among which eight clones showed significant similarity with *Buchnera aphidicola* (Proteobacteria: Enterobacteriaceae), which is the primary endosymbiont of aphids. Culturable microflora from aphids were also studied for qualitative microbial insecticide degradation bioassays and quantitative insecticide degradation using chromatographic methods. Quantitative HPLC analysis for *S. maltophilia* CCF 2-2 and *E. indicum* MPB-2 revealed better imidacloprid degradation by *E. indicum* MPB-2 of 13.6% over 3.8% by *S. maltophilia* CCF 2-2.

For the first time, mitochondrial genomes of *Heterorhabditis indica* and *H. bacteriophora* were sequenced. The entomopathogenic nematodes, *Steinernema abbasi, H. bacteriophora* and *H. indica* and their formulations demonstrated virulence against sweet potato weevil and mustard sawfly. The impact of atmosphere-soil warming on interactions between soil-dwelling herbivore-insects and the efficiency of beneficial entomopathogenic nematodes has been studied for the first time.

Insect Ecology

The invasion and infestation of the rugose spiralling whitefly, *Aleurodicus rugioperculatus* (Hemiptera: Aleyrodidae) on coconut palm in Pollachi taluk of Tamil Nadu was reported for the first time from India. It is the first invasion report from the Oriental region. Subsequently the pest was noticed on banana, custard apple, sapota, mango, guava, water apple, Indian almond, rubber fig and several ornamental plants in the places surveyed in Tamil Nadu, Andhra Pradesh, Karnataka and Kerala. Several of its natural enemies such as *Dichrysa astur*, *Cybocephalus* sp., *Jauravia pallidula, Cheilomenes sexmaculata*, *Neoseiulus* sp. and two parasitoids, *Encarsia guadeloupae*, *Encarsia dispersa*) were also recorded. Across the surveyed locations, the natural parasitism ranged from 15–60%.

Survey of pink bollworm, *Pectinophora gossypiella* on BGII Bt cotton, ash weevil on brinjal and *Tuta absoluta* on tomato and other solanaceous crops was undertaken to access the crop damage in hot spot areas of the country. Appropriate management strategies were advocated to the farmers at regular intervals.

A rearing protocol for *Geocoris ochropterus* has been standardised. Nearly 593 adults can be harvested in 32–35 days from six pairs of adults. Each nymph can consume 586 *Sitotroga cerealella* eggs. Adult female and male can consume 3,372 and 2,307 *S. cerealella* eggs, respectively. In *G. superbus*, five nymphal instars were recorded. The total developmental period was 41.2 days with a nymphal period of 31.2 days. Adult male and female survived for 24.8 and 30.0 days, respectively.

Surveys conducted in different agro-ecosystems indicated that the diversity and richness of natural enemies was the highest in the main crop plus intercrop/border crop and the lowest in sole cropping systems. Native semi-social and solitary bees could be conserved using bamboo trap nests (5–10 mm in diameter) and pithy stem nests of *Caesalpinia pulcherrima*. Native buzz-pollinating, blue-banded bee, *Amegilla zonata* (Apidae: Anthophorinae) significantly increased the fruit set, fruit weight and fruit diameter of tomatoes under open-field conditions.

Growth and development of two detritivorous insects, *Protaetia* sp. and black soldier fly, *Hermetia illuscens*, on different organic wastes were assessed. Up to 600 mg larval weight gain was observed when the insect was fed on protein-rich waste for 10 days, with waste reduction to the tune of 70%.

A new formulation containing δ-octalactone along with other blends of volatiles was developed for attracting the mango fruit fly, *Bactrocera dorsalis*. A new bisexual trap was developed to attract females of the mango fruit fly, *Bactrocera dorsalis.* The flea, *Ctenocephalides felisfelis* was collected from cat and dog. *Ctenocephalides felisorientis* was collected from sheep. A combination of essential oils (lemon grass, eucalyptus and ocimum) was toxic to the housefly, *Musca domestica*. *Metarhizium anisopliae*-infested substrate caused oviposition repellence in *M. domestica*.

Eight isolates of nucleopolyhedroviruses (NPVs) have been obtained from major lepidopteran pests. The occlusion bodies (OBs) were studied through scanning and transmission electron microscopy. The OBs of HearNPV and SpliNPV appeared as irregular and tetrahedral, *Spilosoma obliqua* NPV appeared as tetrahedral, and *Achaea janata* NPV appeared as rods. The LC50 values observed for second instar larvae were 0.17 POB/mm^2 for HearNPV, 4.23 POB/mm^2 for SpliNPV, 1.23POB/mm^2 for AcjaNPV and 2.93 POB/mm^2 for SpobNPV. Both SpliNPV and HearNPV were molecularly characterised by sequencing the polyhedron gene.

Field trials with endophytic isolates of *Beauveria bassiana* against maize and sorghum stem borer (*Chilo partellus*) were conducted during *kharif* and *rabi* seasons at NBAIR's farm. ICAR-NBAIR-Bb-5a isolate was found to be the most effective in reducing the dead hearts, exit holes, galleries, stem tunneling and increasing the yield. The other isolate ICAR-NBAIR-Bb-23 was also found effective against the stem borer in sorghum.

All-India Coordinated Research Project on Biological Control of Crop Pests

Biodiversity of biocontrol agents from various agroecological zones

Two coccinellid predators, viz. *Aiolocaria hexaspilota* and *Serangium* sp. and three pteromalid parasitoids (Hymenoptera), viz. *Cheiropachus* sp., *Macromesus* sp. and *Raphitelus* sp., were reported for the first time from Kashmir.

Nesidiocoris tenuis and *Neochrysocharis formosa* were found associated with the American pinworm, *Tuta absoluta*, in tomato in the mid-hills of Himachal Pradesh. *Baryscapus galactopus* was collected as a hyperpasitoid of *Cotesia glomerata* parasitising *Pieris brassicae* in cauliflower in the same state.

Three different species of earwigs, viz. *Auchenemus hinksi*, *Paralabis dohrini* and *Euborellia shabi* were collected from banana plants infested by pseudostem weevils at Kannara and Vellanikkara in Kerala.

Several natural enemies, including coccinellids (*Coccinella septempunctata*, *Menochilus sexmaculata* and *Scymnus* sp.), *Dipha aphidivora*, *Micromus igorotus*, the syrphid *Eupeodes confrater* and the parasitoid *Encarsia flavoscuttellum*, were recorded on sugarcane woolly aphid in sugarcane. *Coccinella transversalis*, *Menochilus sexmaculata*, *Brumoides suturalis*, *Scymnus coccivora* and *Triommata coccidivora* were associated with mealybug colonies on custard apple. *Acerophagus papayae*, *Mallada boninensis* and *Spalgis epeus* were found feeding on the papaya mealybug. The chrysopid *Chrysoperla zastrowi sillemi* was observed in cotton, maize, beans, sorghum, okra and brinjal, and *Mallada boninensis* on cotton, beans, mango, papaya and hibiscus. Cadavers of *Spodoptera litura* and *Helicoverpa armigera* infected with *Nomuraea rileyi, Metarhizium anisopliae, Sl*NPV, *Ha*NPV were collected from soybean, sorghum, maize, cabbage, pigeonpea and tomato crops in farmers' fields.

Surveillance for alien invasive pests

In coconut, the occurrence of rugose whitefly *Aleurodicus rugioperculatus* was observed from the second week of August 2016 in Anamalai and Pollachi blocks of Coimbatore district in Tamil Nadu.

Surveys for the occurrence and incidence of *Tuta absoluta* in Himachal Pradesh revealed that the pest was present at 42–89% infestation levels in almost all the tomato-growing areas of mid-hills of Himachal Pradesh.

Pest outbreak

A survey conducted covering 10 villages in Jorhat and Majuli districts of Assam indicated the outbreak of *Spodoptera mauritia* and *S. litura* in *sali* rice (cvs Ranjit, Bahadur, Doria, Bora, Komal, Joha, etc.) with the intensity of low to severe attack (50–90%). Larvae of *S. mauritia* were as high as 34–62 per hill in certain locations.

Biological suppression of plant diseases

In rice, among the different bioagents tested, Th-14, PBAT-3 and TCMS-36 were the most promising in reducing diseases and increasing the yield. In chickpea and lentil, among all the isolates PBAT-3, Psf-173 and *Bacillus* were found very promising in reducing pre- and post-emergence seed and plant mortality with increased plant vigour.

Biological suppression of sugarcane pests

Soil application of the entomopathogenic nematode, *Heterorhabditis indica* (or *Steinernema* sp.), the entomopathogenic fungus, *Metarhizium anisopliae* (or *Beauveria bassiana*) in sugarcane after the onset of monsoon rains was found effective in reducing white grub damage, which resulted in higher yield compared with phorate treatment.

Biological suppression of cotton pests

The BIPM practices involving cultivation of *Bt* cotton crop following recommended agronomic practices, growing sorghum as a barrier crop, installation of yellow sticky traps, augmentative releases of chrysopids and application of botanicals/biopesticides rendered significantly lower whitefly population than untreated control. The predator population was significantly more in BIPM (1.36/plant) as compared with chemical control (0.39/plant) and untreated control (0.98/plant).

Biological suppression of pests of cereals and pulses

Field release of *Trichogramma chilonis* at the rate of 75,000 and 1,00,000 parasitoids/ha at 15 days after seedling emergence, three times at weekly intervals was found effective in reducing damage by stem borer damage, which resulted in a higher cob yield in maize.

In pulses, formulations of *Bacillus thuringiensis* PDBC Bt1 (2%) and Delfin were at par with each other and recorded the lowest pod damage against pod borer.

Biological suppression of pests of tropical fruits

Field studies conducted on management of mango hoppers revealed that all the treatments, viz. *B. bassiana* (ITCC 6063) 2 %, malathion 0.1% and azadirachtin 1% were significantly superior to the untreated control.

Field evaluation of *Beauveria bassiana* at the rate of 10 g/litre (IIHR formulation) against tea mosquito bug in guava showed the maximum reduction (81.1%) of fruit damage closely followed by *B. bassiana* at the rate of 5 g/litre (TNAU).

Biological suppression of pests of temperate fruits

For the management of apple root borer, *Dorysthenes hugelii,* although chlorpyriphos (0.06%) was the most effective treatment resulting in 83.2% mortality of the grubs, *Metarhizium anisopliae* was equally effective resulting in 68.3% mortality of the pest. A two-year investigation confirmed the superiority of *Trichogramma cacoeciae* over *T. embryophagum* with increased reduction in fruit damage against codling moth. Integrated management for codling moth involving one spray of chlorpyriphos 20 EC @ 1.5 ml/litre, sequential releases of *T. cacoeciae*, one spray of NSKE, trunk banding, disposal of infested fruits and installation of pheromone traps resulted in 37.7% reduction in damage over control.

Biological suppression of pests of oilseeds

Among all the biopesticides, three sprays of *Metarhizium anisopliae* (2×10^8 spores/g) plus *Lecanicillium lecanii* (2×10^8 spores/g) at the rate of 5 ml/litre at 15-day intervals proved to be the best treatment in reducing aphids in mustard and producing the highest yield (8.23 q/ha) with highest B:C ratio (1.55).

Biological suppression of pests of vegetables

Lower leaf and fruit damage by *Tuta absoluta* was observed in the treatment Azadirachtin 1,500 ppm @ 2 ml/litre (2.67%, 0.58%) followed by the treatment *Beauveria bassiana* @ 4 g/litre (2×10^8cfu g^{-1}) (4.00%, 0.69%) and six releases of *Trichogramma achaeae* @ 50,000/ha (5.33%, 1.12%). Among the bioagents/ biopesticides, *Neoseiulus longispinosus* (10 mites/plant) and azadirachtin (1,500 ppm; 3 ml/litre) were the best treatments for the control of *Tetranychus urticae* in tomato resulting in 60.3% and 51.2% reduction in the mite population over control.

Damage to brinjal shoots (9.0%) and fruits (16.4%) was the minimum in plots that received BIPM package as compared with chemical-control plots (11.5% and 19.7%, respectively). However, the yields were on par (263.78 q/ha and 260.09 q/ha, respectively). *Beauveria bassiana* (ITCC KAU culture) applied at the rate of 20 g/litre was found to be the best in controlling sucking pests in brinjal with minimum pest population. Application of EPN (NBAIR formulation) at the rate of 20 kg/ha along with *Metarhizium anisopliae* (NBAIR formulation) 5 kg/ha mixed with 250 kg FYM/ha resulted in 87.7% reduction in ash weevil numbers with a minimum leaf damage of 8.4%.

Metarhizium anisopliae (2×10^8 cfu) application followed by *Bt* spray (1 kg/ha) proved to be the best treatment in reducing sucking and fruit borer pests in okra, which resulted in the highest yield (8.38 t/ha) next only to the insecticide check (9.31 t/ha).

Beauveria bassiana (Bb-83; IIVR strain) was the most promising against yellow mites in chilli with the highest reduction in mite population (56.6%) followed by *Metarhizium anisopliae* (Ma-35; NBAIR strain) (53.6%). The plots treated with *B. bassiana* (Bb-83) registered significantly highest green chilli yield (6,175 kg/ha) as compared with other entomopathogens.

Cabbage intercropped with mustard and cowpea was found to be the best (1.0 larva/plant) harbouring fewer

Plutella larvae, *Brevicoryne brassicae* (3.4/plant) and higher coccinellids (3.3/plant) and syrphids (3.0/plant). The maximum yield of 175.52 q/ha was also obtained in this treatment.

Biological suppression of polyhouse crop pests

Against the rose aphid, *Macrosiphum rosaeiformis,* azadirachtin (1,500 ppm; 3 ml/litre), *Hippodamyia variegata* (10 beetles/plant) and *Lecanicillium lecanii* (5 g/litre of 10^8 conidia/g) were equally effective, resulting in 50.8 to 69.1% reduction in the aphid population over control. These bioagents were, however, significantly less effective than imidacloprid (0.0075%) which reduced the aphid population to the tune of 96.6% over control.

Large-scale adoption of proven biocontrol technologies

Large-scale validation of IPM practices in rice was carried out in an area of 13 ha at Palla Road Padasekharam in Vadekkenchery Panchayat of Palakkad district of Kerala. IPM plots registered 40% more yield than the non-IPM plots.

BIPM module comprising of erection of pheromone traps (25/ha), releases of *Trichogramma chilonis* (50,000/ha) at weekly intervals and two sprays of *Bt* at the peak flowering stage was demonstrated in 58 acres of brinjal in four villages of Cuttack district in Odisha during *rabi* 2016-17. This practice significantly reduced the shoot and fruit borer infestation with higher B:C ratio as compared with farmers' practice.

In large-scale demonstrations conducted at farmers' fields in collaboration with six sugar mills in Punjab, *Trichogramma chilonis* (released at 50,000/ha at 10-day intervals) reduced the incidence of sugarcane stalk borer (*Chilo auricilius*) by 56.6% in an area of 7,910 acres.

Large-scale demonstrations using *T. chilonis* in farmers' fields were carried out in 355 acres in Hoshiarpur, Nawashahr, Roop Nagar and Pathankot districts of Punjab. A single release of *T. chilonis* (1,00,000/ha) on 15-day-old crop provided effective control of maize stem borer, *Chilo partellus*. The reduction in incidence over control was 52.5% and 69.2% in biocontrol and chemical control, respectively. The net returns over control in biocontrol package were ₹ 5,036.75/- as compared with ₹ 8,239.25/- in chemical control.

2. निष्पादित सारांश

भा. कृ. अनु. प. – राष्ट्रीय कृषि किट संसाधन ब्यूरो, देश का मात्र एक ऐसा संस्थान है जिसको कि कृषि महत्वपूर्ण कीाटों, मकडियों और माइटस की देश भर की राष्ट्रीय धरोहर संजोने के रूप में मान्यता प्राप्त है। यह ब्यूरो, हमारे देश की कृषि पारिस्थितिकी तन्त्र में आर्थ्रोपोड्स के साथ संबंधित कीटों, मकडियों, सूत्रकृमियों और सूक्ष्म जीवों के संग्रहण, सूचीबद्धीकरण और संरक्षण के लिए प्रतिबद्ध है। ब्यूरो के सभी अनुसंधान कार्य तीन प्रभागों – कीट प्रणालियाँ, आण्विक कीट विज्ञान और कीट पारिस्थितिकीय विभतों द्वारा किया जाता है। जैविक नियंत्रण संबंधित क्रियान्वयन और समन्वयन, फसल पीडकों के जैविक नियंत्रण पर अखिल भारतीय समन्वित अनुसंधान परियोजना (ए आई सी आर पी) के अन्तर्गत किए गए। शोध परिणामों को संक्षेप रूप में नीचे उद्धृत किया गया है।

भा.कृ.अनु.प. – राष्ट्रीय कृषि कीट संसाधन ब्यूरो कीट प्रणालियाँ विभाग

ट्राइकोग्रामेटीडे का सर्वेक्षण, पाँच राज्यों के कृषिगत, प्राकृतिक और विक्षेपित पारिस्थितिक तंत्रों में किया गया। *कायटोस्ट्रिका मेग्निक्लेवेटा, लेथरोमीरोमॉयड्आ डायमोरफा* और *पोरोपोईआ बेलीना* को उन क्षेत्रों से अभिलेखित किया गया, जिन क्षेत्रों में उनको पहले नहीं पाया गया था और *ट्रायकोग्रामेटॉयडीआ* की नई प्रजातियों के रूप में वर्णित किया गया। कर्नाटक के माण्ड्या जिले में धान, गन्ने और रागी के खेतों में अण्ड परजीवी कीटों की मौसमीय प्राप्तियों का अध्ययन किया गया। धान और रागी के खेतों में सीलिओनिडे कुल अधिकांशत: पाये गये उसके बाद मायमेरीडे, ट्रायकोग्रामेटिडे और प्लेटीगोस्ट्रीडे पाये गये, जबकि गन्ने के खेत में ये थोड़ा भिन्न पाये गये उसमें प्लेटीगेस्ट्रीडे का, प्रभुत्व ट्रायकोग्रामेटीडे पर पाया गया।

मेगाफ्राग्मा और *ट्रायकोग्रामेटायडिआ बेक्टरे* वंशों को उत्तराखण्ड से पहली बार अभिलेखित किया गया। *ट्रायकोग्रामा एकीये* और *ट्रायकोग्रामेटायडिआ बेक्टरे* को *टयूटा एब्सोल्यूटा* के अण्डों से एकत्र किया गया।

ओथीकोकटोनस सूर्यासेनी स्पे. नि., *पेरडोटेलिआ फ्लेवा* स्पे.नि., *माइक्रोथोरोन ब्लूमस्डेलेन्सिस* स्पे.नि., *मा. शोम्पेन* स्पे.नि. और *नायलेटा ओन्जे* स्पे.नि. नामक सीलीओनिडे की पाँच नई प्रजातियों को वर्णित किया गया। *मा. बेओयड्स* के नर और उसकी श्रंगिकाओं को वर्णित किया गया। *मा. बेओयड्स* के नर और मादाओं तथा *मा. मीरिकोर्निस* की मादा के चित्र लिए गए। *नरेन्द्रानीओला* को *माइक्रोथोरोन* का कनिष्ठ पर्याय माना गया।

क्रायनीब्रेकोन क्रोमुउसे, टेनेओस्टिग्मा इन्डिका, कोटोशिआ ट्रेबाले और *एजीओमेटस थायार्सिसे* नामक चार नई प्रजातियाँ टर्गाईट वर्णित की गई। विश्व भर की *कोटेशिआ* वंश की प्रथम के विशिष्ट चरित्रण, संयोजन आण्विकता और रूपान्तरीय विश्लेषण के साथ–साथ परजीवीय जैविकी की समीक्षा की गई।

स्फेसीडे के अन्तर्गत आनेवाले लगभग 1000 प्रतिदर्शों को रा कृ की सं ब्यूरो के संग्रहण में शामिल किया गया। शारीरीकीय और आण्विक विधियों के एकीकृत विधियों से अभी तक अज्ञात *केरीनोस्टिग्मस एटेरीमस* के नर की खोज की गई।

रा कृ की सं ब्यूरो के संग्रहालय में माहु और कोकसीड के मौजुदा संग्रहण में मीलीबग की तीन प्रजातियाँ, एक मृदुल शल्क कीट, एक माहु और एक एरिओकोकसीड को सम्मिलित किया गया। भारतवर्ष से दो मीलीबग और एक माहु को पहली बार एकत्र किया गया। एक मृदुल शल्क कीट, *पाल्विनेरिआ आर्बिकोला* को पुनः वर्णित किया गया।

पेन्टेटोमिने उपकुल के *पेराक्रीथिअस ट्राइमेकुलेटस* और एसोपीने उपकुल के *ऐमायोटिआ मेलाबेरिका* नामक पेन्टाटोमिडे की दो प्रजातियों को पुन: वर्णित किया गया। *पेराक्रिथिअस ट्राइमेकुलेटस* को अण्डमान और निकोबार द्वीप समूह से पहली बार अभिलेखित किया गया जबकि *निओजुर्टीना टीपिकल* और *ब्रेकीकोरिस* को भारत में पहली बार अभिलेखित किया गया। *ब्रेकीकोरिस ट्रेल्यूसीडस* एक नई प्रजाती को भारत से वर्णित किया गया। उन्नतीस पेन्टाटोमिडस का बारकोड किया गया।

फल मक्खियों की लगभग 1600 प्रतिदर्शों को संसाधित और संरक्षित किया गया। देश के विभिन्न भागों से फल मक्खियों अटढाईस प्रजातियों के 17 वंशों और चार उपकुलों को एकत्र किया गया। *बेक्ट्रोसीरा (केलोडेकस) चेट्टाली, बे. (के.) हेरीएटोन्सिस* को *स्पोन्डिआस पिनेटा* (एनाकाडिएसीए) के ग्रासित फलों से; *गेस्ट्रोजोना नाइग्रीफीमर* को *डेन्ड्रोकेलेमस स्ट्रिक्टस* (पेएसीए) के ग्रसित अंकुरणों से फल मक्खियों की तीन नई प्रजातियों को वर्णित किया गया। *बेक्ट्रोसीरा (जियुगोडेकस) सीमोन्गोकेन्सिस* को भारत मे पहली बार अभिलेखित किया गया।

नॉन एपिस मधमक्खी के मेगाचिलीने संबंधित उपकुलों [मीगाचिलीने जनजाति (20) और लिथुर्गिनी (5)], हेलीक्टिने (9) और नोमीने (5) की कुल 39 प्रजातियों को एकत्र किया गया और संदर्भ संग्रहण में शामिल किया गया ।

हायड्रेन्जिआ मेक्रोफाला के फूलों से *थ्रिप्स लाउरेन्सि* नामक एक नई टेरेब्रेन्टिअन थ्रिप्स की प्रजाति को वर्णित किया गया । *क्रोटोनोथ्रिप्स पोलीएल्थिए* और *फ्रेंकलिनीएल्ला ओक्सीडेन्टेलिस* के नर को भारत में पहली बार अभिलेखित किया गया । थायसेनोप्टेरा के छः वंश और 10 प्रजातियों को रा कृ की सं ब्यूरो के संदर्भ संग्रहण में शामिल किया गया ।

14 राज्यों के 44 स्थानों से विवील के कुल 446 प्रतिदर्श एकत्र / प्राप्त किए गए । चौबीस प्रजातियों की पहचान वंश से *लेप्रोपस क्रायसोक्लोरस* को अरूणाचल प्रदेश में पहली बार पाया गया । *लेप्रोपस फ्लेवोविट्टेटस* के नए परपोषक पौधों (लीची और बीन्स) को अभिलेखित किया गया ।

लम्बे सींगों वाले भारतीय प्रजातियों की बीटीलों के लिए एक चेकलिस्ट तैयार की गई । इस चेकलिस्ट में 1,555 लम्बे सींग वाली बीटल का वर्गीकरण 72 जनजातियों, 447 वंशों और सात उपकुलों जो कि सीरेम्बीसीडे के साथ–साथ वेस्पेरिडे और इस्टेनीडे कुलों के अन्तर्गत आते है ।

9 राज्यों के 15 स्थानों पर विभिन्न फसलों में किए गए सर्वेक्षणों के दौरान 10 कुलों के अन्तर्गत आने वाले पाँच सौ पचास मकडियों को एकत्र किया गया । *निओस्कोना शिलोन्गेन्सिस* (कुल अरेनीडे), *स्टेगोडायफस टीबीएलिस* (कुल इरेसीडे) और *एल्यूरिलस? क्रोनेस्टेडटी* (कुल साल्टीसीडे) को नए वितरण के रूप में क्रमशः कर्नाटक, केरल और तमिलनाडु राज्यों से अभिलेखित किया गया । मकडियों के सी ओ आई और आई टी एस रीजन्स दोनों का डी एन ए बारकोड प्रोटोकाल को मानकीकृत किया गया ।

5750 माइटों के प्रतिदर्शों और संसधित से, 1380 अस्थाई रंजित और 1239 स्थाई रूप से स्लाइडें तैयार की गई । *एम्बलायसिआस, लारजोएन्सिस, यूसिईअस एल्स्टोनिए, यू. कोकोसोकीअस, यू. मेक्रोस्पेटयूलेटस, नीओसेईयुलस पेस्पेलीवोरस, पेराफायटोसीअस भद्राकालीएन्सिस, पे. ओरीएन्टेलिस, फायटोसीअस नेमडाफाएन्सिस, फा. कपुरी, फा. रासेली* और *टायफ्लोड्रोमिप्स सीजगई* नामक फायटोसीडस को रीपोजिटरी में शामिल किया गया । *एम्बलायसिअस लारजोएन्सिस* और *लेसीओसीअस* (एसकीडे) की दो नई प्रजातियों को *एकेरिआ लीची* के प्रमुख प्राकृतिक शत्रु कीटों के रूप में पाया गया । तीन स्टिगमेईड्स (*एजीस्टिमस* स्पे.नि. *टर्मिनोलिस*) और तीन क्यूनेक्सिड्स (*क्यूनेक्सा* स्पे. नि. *बेम्बुसे, क्यूनेक्सा* स्पे.नि. *सायनोडोने* और *क्यूनेक्सा* स्पे.नि. *वामरस्लेई*) को नए परभक्षी माइट प्रजातियों के रूप में पाया गया ।

हेटेरोरहाब्डिटीज पाकीस्टेनेन्स एन बी ए आई आई एच 05 और *स्टेईनेरनेमा ह्यूएन्से* एन बी ए आई आई एस 46 को भारत में पहली बार पाया गया । *हे. पाकीस्टेनेन्स* का पर्यावरणिक चरित्रण किया गया । *स्टे. सीमाकायी* के नौ पृथककरण और *हे. इन्डिका* के चार पृथककरणोंकी पहचान की गई । क्षेत्रीय अध्ययन दर्शाते हैं कि *हे. कोन्सेन्गुईनीआ, लीयूकोफोलिस लेपीडिफोरा* और *ली. ब्रुमेईस्टेरी* के प्रति *हे. इन्डिका* एन बी ए आई आई एच 38 एक प्रभावी जैव नियंत्रण कारक के रूप में उभर सकता है ।

आण्विक कीट विज्ञान विभाग

माइटोकोन्ड्रिअल केवल सी ओ आई या परमाणु आई टी एस 3 जीन के संयोजन के साथ मिलकर 188 कीट प्रजातियों, 128 परभक्षी कीटों और परजीवी कीटों, स्फेसीड वेस्प की 10 प्रजातीयाँ, मकडियों की 13 प्रजातियों और कीट रोगाण्विक सूत्रकृमियों की चार प्रजातियों का आणविक चरित्रण और डी एन ए बारकोडिंग किया गया । गैर–विनाशकारी विधि के द्वारा एकल थ्रिप्स से नई द्रुत डी एन ए पृथककरण प्रौद्योगिकी को मानकीकृत किया गया । शारीरिकीय और आणविक की एकीकृत विधियों के द्वारा एक शताब्दी के बाद केरीनोस्टिग्मस अटेरीमस (कार्बोनिडे) नामक एक अनजान नर की खोज की गई ।

एक नए घुसपैठी रूगोज सर्पिलाकार सफेद मक्खी *एल्यूरोडिकस रूगीओपेरकुलेटस* (हेमीपटेरा : एलीयरोडीडे) की त्वरित रूप से एकदम सटीक पहचान की गई और इसके देशी एफेलीनीड परजीवी कीट, *एनकार्सिआ गुआडेलोऊपे* की पहचान सी ओ 1 जीन के उपयोग से की गई । आई टी एस 2 और सी ओ आई रीजन्स के उपयोग से सफेद मक्खी, *बेमीसीआ टेबेसी* की 31 कीट सँख्याओं के आणविक विश्लेषण से ज्ञात हुआ कि इनमें दो प्यूटेटिव आनुवंशिक समूह एशिया I और एशिया II उपस्थित पाये जाते हैं । कपास के गुलाबी गुलर सूँडी, *पेक्टिनोफोरा गोसीपिएल्ला* की 11 क्षेत्रीय एकत्रित कीटनाशी सहिष्णु कीट सँख्याओं के जीनोमिक डी एन ए आण्विक उत्परिवर्तन विश्लेषण किया गया ।

देश के विभिन्न भौगोलिक स्थानों से एकत्र किए गए 42 सीरेबायसीड और 20 स्क्रेबीड बीटलों के प्रतिदर्शों, 19 दीमक प्रतिदर्शों और 11 कोलेम्बोलन प्रतिदर्शों की डी एन ए बारकोड आधारित पहचान और आणविक फायलोजेनेटिक विश्लेषण किया गया । तेरह मकडियों (अरेनीए), 41 *पेरापेन्टेलेस* (हायमेनोप्टेरा) और अर्द्धजलीय बग की 10 प्रजातियों (हेटेरोप्टेराः गेरोमोरफा) का सी ओ आई जीन के उपयोग से चरित्रण किया

गया और इनका बारकोड तैयार किया गया। आणविक प्रणाली के तौर पर एक विंगलेस जीन रीजन के उपयोग करने के लिए *पेरापेन्टेलस* की 13 प्रजातियों का बारकोडिंग करने की जाँच की गई। विंगलेस प्रोटीन ऐसे अणु स्रावित करता है जो कि कीटों में अनेक संरचनाओं और पैटर्न तत्वों का विकास करके मोर्फोजन की तरह कार्य करता है। वर्तमान परिणामों से प्रजातियों की त्वरित पहचान करने के लिए डी एन ए बारकोडिंग हेतु एक महत्वपूर्ण विधि पाई गई।

बैंगन की कोपल और फल बेधक कीट *लीयुसीनोडस ओरबोनेलिस* की सहिष्णु और प्रतिरोधी सँख्याओं का ट्रान्सक्रिप्टोम विश्लेषण किया गया और 49.63% जी सी अवयवों के साथ 23 मिलियन आँकडे पढने के लिए तैयार किया गया। बायोप्रोजेक्ट पी आर जे एन ए 352591 और आर्चीव एसेशन नम्बर : एस आर एक्स 2338657 (एस), एस आर एक्स 2338658 (आर), एस आर एक्स 2338659 (एस), एस आर एक्स 2338660 (आर) के माध्यम से एन सी बी आई–जीन बैंक में एस आर ए जमा किए गए। *ली. ओरबोनेलिस* की *डी–नोवो* होल जीनोम सीक्वेन्सिन्ग इल्यूमिना पेयर्ड एन्ड और मेट पेयर लायब्रेरिस के माध्यम से एच आई सीक्व 2500 1 टी अपग्रेड सिस्टम और पेक–बायो 20 के बी सी सी एस लायब्रेरी के द्वारा आर एस II सिस्टम और पी 6 सी 4 केमिस्ट्री के द्वारा की गई) बायोप्रोजेक्ट पी आर जे एन ए 377400 और आर्चिव के अन्तर्गत एस यू बी 2444180 के माध्यम से एन सी बी आई–जीन बैंक में एस आर ए जमा किए गए।

डायमण्ड बैक मौथ, *प्लूटेल्ला जाइलोस्टेल्ला* के सहिष्णु और प्रतिरोधी विभेदों का ट्रान्सक्रिप्टोम करके सीक्वेन्स किया गया। आणविक मोडलिन्ग विधि द्वारा *प्लू. जाइलोस्टेल्ला* – रायनोडाईन रीसेप्टर प्रोटीन मोडेलींग तैयार की गई और आणविक तंत्र के पूर्वाग्रह के लिए डाई एमाईड़स सहिष्णुता वाले पी एक्स–आर वाई आर की उपलब्धि प्राप्त की गई।

आणविक चरित्रण से ज्ञात हुआ कि देशी *बेसीलस थ्यूरिनजिएन्सिस* पृथककरण एन बी ए आई आर – बी टी ए एन 4 मे. दोहरी विशिष्टता है, यह लेपीडोप्टेरन और कोलीओप्टेरन दोनो ही कीट पीडकों के लिए विषैले पाये गये। इसके अन्दर कोलीओप्टेरन विशिष्ट *क्राय* 8 जीन और लेपीडोप्टेरन विशिष्ट *क्राय* 1 और *क्राय* 3 जीन्स पाये जाते हैं। यह पृथककरण लेपिडोप्टेरन कीटों के अतिरिक्त *ओरीक्टस रहायनोसेरस, पेपीलिओ* स्पे. *केलोसोब्रुकस चाइनेन्सिस* और *साइटोफाईलस ओराईजे* के प्रति विषाक्त पाया गया। *के. चाइनेन्सिस* (एल सी$_{50}$ 6.8 माइक्रोग्राम/मिली) *हेलीकोवर्पा आर्मिजेरा* (एल सी$_{50}$ 414.59 नेनो ग्राम/मिली.) और *प्लूटेल्ला जाइलोस्टेल्ला* (545.15 नेनो ग्राम/मिली.) के लारवों के प्रति बहुत ज्यादा विषाक्तता प्रदर्शित की गई।

अपरिष्कृत माहु सूक्ष्मजीवाश्म उत्पन्न नौ क्लोन के मेटाजिनोमिक अध्ययन में, आठ क्लोनों ने *बुकनेरा एफिडिकोला* (प्रोटीओबेक्टेरिआ: एन्टेरोबेक्टेरीएसीए) के समान महत्वपूर्ण रूप से दिखाई दिए जो कि माहु के प्राथमिक अन्तः सहजीवी हैं। माहु के परिष्कृत सूक्ष्मजीवारम का सूक्ष्मजीविय गुणात्मक कीटनाशक अपक्षय जैव विश्लेषणात्मक और मात्रात्मक कीटनाशक अपक्षय का फ्रोमेटोग्राफिक विधियों द्वारा अध्ययन किया गया। *एस. माल्टोफिलीआ* सी सी एफ 2–2 और *ई. इन्डिकम* एम पी बी–2 के एच पी एल सी मात्रात्मक विश्लेषण से ज्ञात हुआ कि *ई. इन्डिकम* एम पी बी–2 द्वारा इमीडेक्लोप्रिड का अपक्षय अधिकतम अर्थात 13.6%, जबकि *एस. माल्टोफिलीआ* सी सी एफ 2–2 केवल 3.8% ही पाया गया।

हेटेरोरहाब्डिटिज इन्डिका और *हे. बेक्टेरीओफोरा* के माइटोकोन्ड्रिअल जीनोम्स को पहली बार अनुक्रमित (सीक्वेन्स) किया गया। कीटरोगाण्विक सूत्रकृमि, *स्टेईनर्नेमा अब्बासी, हे. बेक्टेरीओफोरा* और *हे. इन्डिका* और उनके नियमनों को शकरकन्द की विविल और सरसों की साफ्लाई के प्रति विषैला पाया गया। मृदा–अवशेष शाकभक्षी–कीटों और लाभकारी कीटरोगाण्विक की दक्षता के बीच परस्पर क्रियाओं पर वायुमंडल – मृदा तापमान वृद्धि के प्रभाव पर पहली बार अध्ययन किया गया।

कीट पारिस्थितिकी विभाग

भारत में, रूगोज सर्पिलाकार सफेद मक्खी, *एलीयुरोडीकस रूगिओपेरक्युलेटस* (हेमीप्टेरा : एलीयुरोडीडे) को तमिलनाडु प्रदेश के पोलाची तालुक में पहली बार नारियल के वृक्षों पर आक्रमण या ग्रसन करते पाया गया। ओरीएन्टल क्षेत्र में इस कीट के आक्रमण की यह पहली रिपोर्ट है। इसके साथ–साथ तमिलनाडु, आन्ध्रप्रदेश, कर्नाटक और केरल राज्यों के स्थानों पर सर्वेक्षण में पाया गया कि यह कीट केला, शरीफा, चीकू, आम, अमरुद, वाटर एप्पल, भारतीय बादाम, रबर अन्जीर और अनेक अलंकृत पौधों पर इस कीट का ग्रसन पाया गया। इस कीट के प्राकृतिक शत्रु कीट जैसे कि *डाईक्रायसा एस्टर, सायबोसीफेलस* स्पे. *जाउरेविआ पेलीडुला, काईलोकोरस सेक्समेकुलेटा, नीओसेईयूलस* स्पे. और दो परजीवी कीट नामतः *एनकार्सिआ गुआडेलोउपे, एनकार्सिआ डिस्पेर्सा* भी अभिलेखित किए गए। सर्वेक्षण किए गए स्थानों पर परजीवीकरण का विस्तार 15–60% पाया गया।

देश भर के फसल उगानेवाले प्रमुख क्षेत्रों मे बीजी II बीटी कपास पर गुलाबी गूलर सूँडी, *पेक्टिनोफोरा गोसीपिएल्ला,* बैंगन की ऐश वीविल और टमाटर पर *व्यूटा ऐब्सोल्यूटा* तथा अन्य सोलेनेसी कुल की फसलों पर इन कीटों द्वारा होने

वाली क्षति का सर्वेक्षण किया गया । इन कीटों के उपयुक्त प्रबंधन रणनीतियाँ एक नियमित अंतराल पर किसानों को सुझाई गई ।

जीओकोरिस आक्रोप्टेरस के पालने के विधि के प्रोटोकोल को मानकीकृत किया गया । छः जोडी प्रौढ़ों से 32–35 दिनों के अन्दर करीब 593 प्रौढ प्राप्त किए जा सकते है । प्रत्येक निम्फ *साइटोट्रोगा सीरीएलेल्ला* के 586 अण्डों का भक्षण कर सकता है । मादा और नर कीट *सा. सीरीएलेल्ला* के क्रमशः 3372 और 2307 अण्डों का भक्षण कर सकते हैं । *जी. सुपरबग्स* के निम्फ के पाँच निरूप आभिलेखित किए गए । निम्फकाल 31.2 दिनों के साथ पूर्ण वृद्धि काल 41.2 दिनों का पाया गया । नर और मादा प्रौढ़ क्रमशः 24.8 और 30.0 दिन तक जीवित रहते हैं ।

विभिन्न कृषि–पारिस्थितिकी तन्त्रों में सर्वेक्षण किए गए और पाया गया कि प्राकृतिक शत्रु कीटों की सँख्या मुख्य फसल तथा अन्तः फसल / बोर्डर पर फसल बोने के साथ उपयोग करते हैं तब अधिक पाई गई और एकल फसल प्रणाली या तन्त्र में इनकी सँख्या–न्युनतम पाई गई । बाँस प्रपंच घोंसले (5–10 मिमी व्यास वाले आकार के) और *कायसेलपीनिआ पलकेरीमा* के पाईथी तना घोंसले बनाकर स्थानिक अर्द्ध–सामाजिक और एकल मधुमक्खीयों को संरक्षित किया जा सकता है । स्थानिक बज परागणकर्ता, नीले–बेन्ड वाली मधुमक्खी, *एमेजील्ला जोनेटा* (एपीडे : एन्थोफोरीने) को खुले क्षेत्रीय दशाओं में टमाटर की फसल में फल बनने, फल के भार और टमाटर के फल व्यास के बढ़ने में महत्वपूर्ण भूमिका निभाते हैं ।

दो अलगावशील कीटों नामतः *प्रोटेशिआ* स्पे. और ब्लैक सोल्जर फ्लाई, *हरमेसीआ इलुसेन्स* का विभिन्न कार्बनिक अपशिष्टों पर उनकी वृद्धि और विकास का मूल्यांकन किया गया । जब इन कीटों के लारवे प्रोटीन युक्त अपशिष्ट का सेवन करते हैं तो 70% अपशिष्ट की कमी के साथ 10 दिनों में लारवे का वजन 600 मि. ग्रा. तक बढ़ जाता है । *प्रोटोशिआ* स्पे. के भक्षण जाँच परीक्षण में चार पोषकों (मक्का कॉब, कपास के फूल, अरहर के फूल और *इक्जोरा* फूल) दिए गए, उनमें से *प्रोटाशिआ* स्पे.के प्रौढ़ मक्का के कॉब पर अधिक भक्षण करते पाए गए ।

आम की फल मक्खी, *बेक्टरोसीरा डोर्सेलिस* को आकर्षित करने के लिए अन्य ब्लेन्डस वाले वालेटाइल्स 8–ऑक्टालेक्टोन अवयव वाला एक नया नियमन तैयार किया गया । आम की फल मक्खी, *बेक्टरोसीरा डोर्सेलिस* की मादा को आकर्षित करने के लिए एक उभयालिंगी युक्त एक नया प्रपंच तैयार किया गया । बिल्ली और कुत्ते से पिस्सू, *टेनोसीफेलाईडस फेलीजफेलीज* एकत्र की गई, *टेनोसीकोलाइडस फेलीसोरीएन्टिस* भेड से एकत्र की गई । घरेलू मक्खी, *मुस्का डोमेस्टिका* के प्रति एक संयोजन वाला सुगन्धित तेल (नीबूं घास, यूकेलिप्टस और ओकीमम) विषैला पाया गया । *मु. डोमेस्टिका* में अण्डनिक्षेपण रेपेलेन्स अधोस्तर को *मेटारहाईजिअम एनीसोप्लिए* ग्रसित करता पाया गया ।

प्रमुख लेपिडोप्टेरन कीटों से न्यूक्लिओपोलीहेड्रो विषाणुओं (एन पी वी) के आठ पृथककरण प्राप्त किए गए । स्केनिन्ग और ट्रान्समिशन इलेक्ट्रोन सूक्ष्मदर्शी की सहायता से ऑकलुजिअन बॉडीज (ओ बी) का अध्ययन किया गया । हिअर एन पी वी और स्पली एन पी वी की ओ बी अनियमित और टेट्रोहेड्रल के रूप में दिखाई पडती है, *स्पिलोसोमा ऑब्लीकुआ* एन पी वी टेट्राहेड्रल दिखाई पडते हैं और *एकीआ जेनेटा* एन पी वी छड़ के रूप में दिखाई पडते हैं । द्वितीय निरूपीय लारवों के लिए एल सी$_{50}$ मात्रा के निरीक्षण में हिअर एन पी वी के लिए 0.17 पी ओ बी / मि.मी^{2}, स्पली एन पी वी के लिए 4.23 पी ओ बी / मि.मी^{2}, एकजा एन पी वी के लिए 1.23 पी ओ बी . मि.मी^{2} और स्पोबी एनपीवी के लिए 2.93 पी ओ बी / मि.मी^{2} पाई गई । पोलीहेड्रोन जीन सीक्वेन्सिंग के द्वारा स्पली एन पी वी और हिअर एन पी वी दोनों का आणवीकीय चरित्रण किया गया ।

रा.कृ.की.सं. ब्यरो के प्रक्षेत्र पर खरीफ और रबी मौसमों के दौरान, मक्का और ज्वार तना बेधक (*काईलो पारटीलस*) के प्रति *ब्यूवेरीआ बेसीआना* के अन्तः पादपीय पृथककरणों के साथ क्षेत्रीय जाँच परीक्षण लिए गए । आई सी ए आर – एन बी ए आई आर – बी बी – 5 ए पृथककरण को डेड हर्ट, छिद्रों, सुरंगे, तने में सुरंगे को कम करने और उपज बढ़ाने के लिए अत्यन्त प्रभावी पाया गया । एक अन्य पृथककरण आई सी ए आर – एन बी ए आई आर – बी बी – 23 ज्वार के तना बेधक के प्रति प्रभावी पाया गया ।

फसल पीडकों के जैविक नियंत्रण पर अखिल भारतीय समन्वित अनुसंधान परियोजना

विभिन्न कृषि पारिस्थितिकीय क्षेत्रों से जैवनियंत्रण कारकों की जैवविविधता

दो कोक्सीनेलिड परभक्षी कीटों नामतः *ऐलोकेरिआ हेक्सापिलोटा* और *सीरेन्जिअम* स्पे. तथा तीन टेरोमेलिड परजीवी कीट (हायमेनोप्टेरा) नामतः *केरोपेकस* स्पे; *मेक्रोमीसस* स्पे. एवं *रेफीटेलस* स्पे. पहली बार कश्मीर में पाये गये । हिमाचल प्रदेश की बीच पहाडियों में टमाटर की फसल में, अमेरीकन पिनवॉर्म, *टयूटा एबसोल्यूटा* को *नेसीडीओकोरिस टेन्यूईस* और *नीओक्रायसोकेरिस फोरमोसा* के साथ जुडे पाया गया । इसी राज्य में फूलगोभी की फसल पर *कोटेशिआ*

ग्लोमेराटा के हायपर परजीवी कीट के रूप में *बेरीस्केपस गेलेक्टोपस* को एकत्र किया गया जिसको *पिएरिस ब्रेसीके* परजीवित करता है ।

ईअरविग्स की तीन विभिन्न प्रजातियाँ नामतः *आकेनीमस हिन्कसी, पेरालेबिस दोहरीनी* और *यूबोरेलीआ शाबी* को केरल प्रदेश के केन्नारा और वेल्लानिकारा में केले के पौधों पर स्यूडोस्टेम विविलों से एकत्र किए गए ।

गन्ने की फसल में गन्ने के वुली माहु पर अनेक प्राकृतिक शत्रु कीटों जैसे कि कोक्सीनेलिड (*कोक्सीनेल्ला सेप्टमपंकटेटा, मीनोकाईलस सेक्समेकुलेटा* और *स्किमनस* स्पे.), *डाइफा एफिडीवोरा, माइक्रोमस इगोरोटस,* सिरफिड *यूपिओडस कान्फ्रेटर* तथा परजीवी कीट *एनकार्सिआ फ्लेवोस्कुटेलम* अभिलेखित किए गए । शरीफा की फसल में मिलीबगों को कालोनिओं में *कोक्सीनेल्ला ट्रान्सवेरसेलिस, मीनोकाईलस सेक्समेकुलेटा, ब्रूमॉयड्स सुचुरेलिस, स्किमनस कोक्सीवोरा* और *ट्रायोमाटा कोक्सीडीवोरा* पाये गये । पपीते के मीलीबग का भक्षण करते हुए *एसीरोफेगस पपायी, मालाडा बोनीएन्सिस* और *स्पेल्जिस एपिअस* पाये गये । कपास, बीन्स, आम, पपीता और गुडहल पर *मालाडा बोनीएन्सिस* तथा कपास, मक्का, बीन्स, ज्वार, भिण्डी और बैंगन की फसल में *क्रायसोपरला जेस्ट्रोवी सीलेमी* पाए गए । किसान के खेतों में सोयाबीन, ज्वार, मक्का, पातगोभी, अरहर और टमाटर की फसलों से *नोम्यूरीआ रिलेई, मेटारहाईजिअम एनीसोप्लिए, स्पो.* एन पी वी, *हे.* एन पी वी से ग्रसित *स्पोडोप्टेरा लिव्यूरा* और *हेलीकोवर्पा आर्मीजेरा* के कडावर्स एकत्र किए गए ।

विदेशी आक्रामक कीटों के लिए निगरानी

तमिलनाडु के कोयंबटूर जिले में अनामलाई और पोलाची ब्लाकों में अगस्त, 2016 के दूसरे स्पाह में नारियल के वृक्षों पर रूगोज सफेद मक्खी, *एलीयुरोडीकस रूगीओपेरकुलेटस* का ग्रसन देखा गया ।

हिमाचल प्रदेश में *टयूटा एबसोल्यूटा* की प्राप्ति और ग्रसन के सर्वेक्षणों में ज्ञात हुआ कि हिमाचल प्रदेश की पहाडियों के बीच टमाटर उगाने वाले लगभग सभी क्षेत्रों में इस कीट का ग्रसन पर 42% – 89% स्तर तक पाया गया ।

कीट प्रकोप

असम राज्य के जोरहाट और माजुली जिलों के 10 गाँवों में सर्वेक्षण से पता चला कि *साली* धान (रंजीत, बहादुर, डोरीआ, बोरा, कोमल, जोहा, आदि किस्मों) में *स्पोडोप्टेरा माओरीटिआ* और *स्पो. लिट्यूरा* का ग्रसन न्यूनतम से अधिकतम प्रकोप (50–90%) पाया गया । कुछ स्थानों पर *स्पो. माओरीटिआ* के लारवों का ग्रसन अत्यधिक अर्थात 34–62 प्रति पहाडी पाया गया ।

पादप रोगों का जैविक नियंत्रण

धान की फसल में विभिन्न जैवकारकों पर किए गए परीक्षणों में से टी एच–14, पी बी ए टी – 3 और टी सी एस एस – 36 को रोगों को कम करने और उपज बढ़ाने के लिए अत्यन्त प्रभावी पाया गया । चने और मसूर की फसल में सभी पृथककरणों में से पी बी एटी – 3, पी एस एफ – 173 और *बेसीलस* को बीज उगने के पूर्व और बाद में फैधे की मृत्यु करु एवं पौधों की ओजस्व बढ़ाने के लिए बहुत संभाव्य पाया गया ।

गन्ने के हानिकारक कीटों का जैविक नियंत्रण

गन्ने की फसल में, फोरेट उपचार की तुलना में कीटरोगाण्विक सूत्रकृमि, *हेटेरोरहाब्डिटिस इन्डिका* (या *स्टेईनर्नेमा* स्पे.), कीटरोगाण्विक कवक, *मेटारहाईजिअम एनीसोप्लिए* (या *ब्यूवेरिआ बेसीआना*) को मानसून की वर्षा के बाद मृदा में उपयोग करने पर सफेद लट के द्वारा होने वाली क्षति को कम करने और उपज बढाने के लिए प्रभावी पाया गया ।

कपास के हानिकारक कीटों का जैविक नियंत्रण

बीटी कपास की पसल में बी आई पी एम प्रक्रियाओं के परिष्कृत शामिल करने में, निम्नलिखित कृषि शस्य प्रक्रियायें अनुशंसित की गई, ज्वार को बाढ फसल के रूप में लगाना, पीले रंग के चिपकने वाले प्रपंचों को लगाना, क्रायसोपिड्स की संवर्धित रूप से छोड़ना और वानस्पतिक / जैवकीटनाशकों का मिश्रित उपयोग करने पर अनोपचरित क्षेत्रों की अपेक्षा उपरोक्त बी आई पी एम प्रक्रियाओं में सफेद मक्खियों की सँख्या महत्वपूर्ण रूप से कम पाई गई । बी आई पी एम उपचारित दशा में परभक्षी कीटों की सँख्या अधिक (1.36/पौधा) तथा रासायनिक उपचारित दशा में बहुत कम (0.39/पौधा) और अनोपचारित दशा में मध्यम (0.98/पौधा) पाई गई ।

अनाज और दलहनी फसलों में कीटों का जैविक नियंत्रण

मक्का की फसल में, बीजांकुर होने के 15 दिनों के बाद *ट्रायकोग्रामा किलोनिस* को 75,000 और 1,00,000 परजीवी कीट प्रति हेक्टेअर की दर से साप्ताहिक अन्तरालों पर तीन बार छोड़ने पर तना बेधकों द्वारा होने वाली क्षति को कम करने के लिए प्रभावी पाया गया परिणाम स्वरूप मक्का के भुट्टों की उपज अधिकतम प्राप्त हुई ।

दलहनी फसल में *बेसीलस थ्यूरिनाजिसन्सिस* पी डी बी सी बी टी 1 (2%) और डेल्फिन का फली बेधकों के प्रति प्रयोग करने पर फली क्षति न्यूनतम अभिलेखित की गई और दोनों के परिणाम एक दूसरे के समान पाए गये ।

उष्णकटिबंधीय फलों में कीटों का जैविक नियंत्रण

आम के फूदकों का प्रबंधन करने के लिए क्षेत्रीय अध्ययन किए गए जिनसे ज्ञात हुआ कि *ब्यू. बेसीआना* (आई टी सी सी 6063), 2%, मेलाथिऑन 0.1% और अजाडिरेक्टिन 1% थे सभी उपचार अनोपचारित क्षेत्र की अपेक्षा उप्कृष्ट पाए गए।

अमरुद मे टी मॉस्क्यूटो बग के प्राति *ब्यू. बेसीआना* (आई आई एच आर नियमन) का 10 ग्राम / ली. की दर से क्षेत्रीय मूल्यांकन दर्शाते हैं कि फल क्षति अधिकतम कम (81.1%) और उसके बाद *ब्यू. बेसीआना* (टी एन ए यू) का 5 ग्राम / ली. की. दर से प्रयोग के परिणाम प्राप्त हुए।

शीतोष्ण फलों में कीटों का जैविक नियंत्रण

सेब के जड बेधक कीट *डोरीस्थेनेस हयूजेलाई* के प्रबंधन के लिए यद्यपि क्लोरपायरीफॉस (0.06%) का उपचार अत्यन्त प्रभावी पाया गया परिणामतः 83.2% ग्रब मृत पाई गई, *मेटारहाईजिअम एनीसोप्लिए* का उपचार समान रूप से प्रभावी पाया गया परिणामतः 68.3% ग्रब मृत पाई गई। कोडलिंग मौथ् के प्रति *ट्रायकोग्रामा केकोएसीए* को *ट्रा. एम्ब्रीयोफेगम* की अपेक्षा उप्कृष्ट पाया गया परिणाम दो वर्षों की अथक खोज से पुष्टि हुई जिसमें फल क्षति कम करने के लिए उत्कृष्ट पाया गया। कोडलिंग मौथ का एकीकृत प्रबंधन हेतु क्लोरपायरीफॉस 20 ई सी का 1.5 मिली/ली. की दर से एक छिड़काव, अनुक्रमिक रूप से *ट्रा. केकोएसीए* को छोड़ना, एन एस के ई का एक छिड़काव, शाखा पर पट्टी बाँधना, ग्रसित फलों का निष्कासन और फेरोमोन प्रपंचों को लगाना, ये सभी क्रियायें अपनाने पर उपचार की अपेक्षा क्षति में 37.7% की कमी के परिणाम प्राप्त हुए।

तिलहनी फसलों के कीटों का जैविक नियंत्रण

सरसों की फसल में, सभी जैवकीटनाशकों में से *मेटारहाईजिअम एनीसोप्लिए* (2 x 10^8 बीजाणु/ग्राम) तथा *लीकेनिसीलिअम लेकेनाई* (2 x 10^8 बीजाणु/ग्राम) का 5 मि.ली./ली. की दर से 15 दिनों के अंतराल पर तीन बार छिड़काव करने पर माहु की सँख्या को कम करने और अधिकतम उपज (8.23 कुंतल/हे.) के साथ–साथ अधिकतम लाभः लागत अनुपात (1.55) प्राप्त करने के लिए श्रेष्ठ उपचार साबित हुआ।

सब्जियों के हानिकारक कीटों का जैविक नियंत्रण

टयूटा एबसोल्यूटा के द्वारा निचली पत्ती और फलक्षति की रोकथाम के लिए अजाडिरेक्टिन 1,500 पी पी एम का 2 मिली./ली. की दर से प्रयोग करने पर क्रमशः 2.67% और 0.58% पाया इसके बाद *ब्यूवेरिआ बेसीआना* का 4 ग्राम / ली. (2x10^8 सी एफ यू ग्राम$^{-1}$) की दर से प्रयोग करने पर क्रमशः 4.00% और 0.69% तथा *ट्रायकोग्रामा एकीये* को 50,000 प्रति हेक्टेअर की दर से छः बार छोडने पर क्रमशः 5.33% और 1.12% पाया गया। सभी जैवकारकों जैवकीटनाशकों में से *नीओसेईयुलस लेन्गिस्पाईनोसस* (10 माईट/पौधा) और अजाडिरेक्टिन (1,500 पी पी एम ; 3 मिली./ली.) का टमाटर की फसल पर प्रयोग श्रेष्ठ पाया गया परिणामस्वरूप *टेट्रानिकस उर्टिके* माईट की सँख्या की क्रमशः 60.3% और 51.2% कमी, अनोपचारित क्षेत्र की अपेक्षा पाई गई।

बैंगन में, बी आई पी एम पैकेज अपनाऐ गए प्लॉट से कोंपलों और फलों की न्यूनतम क्षति क्रमशः 9.0% और 16.4% जबकि रासायनिक उपचारित प्लॉट में यह क्रमशः 11.5% और 19.7% पाई गई। यद्यपि, उपज एक समान (क्रमशः 236.78 कु./हे. तथा 260.09 कु./हे. पाई गई। बैंगन में, चूसने वाले कीटों की रोकथाम और कीटों की सँख्या न्यूनतम रखने के लिए *ब्यूवेरिआ बेसीआना* (आई टी सी सीं के ए यू संवर्धन) को 20 ग्राम / ली. की दर से प्रयोग करना श्रेष्ठ पाया गया। ई पी एन (एन बी ए आई आर नियमन) को 20 किग्रा./हे. के साथ *मेटारहईजिअम एनीसोप्लिए* (एन बी ए आई आर नियमन) को 5 किग्रां/हे. की दर से 250 किग्रा. गोबर की खाद प्रति हेक्टेअर की दर से मिलाकर प्रयोग करने पर ऐश वीविल की सँख्या में 87.7% कमी के साथ साथ पत्ती की क्षति न्यूनतम (8.4%) पाई गई। भिण्डी की फसल में, चूसनेवाले कीट और फल बेधक की कमी करने के लिए *मेटारहाईजिअम एनीसोप्लिए* (2x10^8 सी एफ यू) का उपयोग इसके बाद बी टी का 1 कि.ग्रा./हे. की दर से प्रयोग करना श्रेष्ठ पाया गया जिसके परिणामस्वरूप अत्यधिक उपज (8.38 टन / हे.) प्राप्त हुई जो कि रासायनिक उपचार की उपज (9.31 टन/हे.) के बाद दूसरे स्थान पर पाई गई।

मिर्च की फसल में, पीली माईट को नियंत्रण करने के लिए *ब्यूवेरीआ बेसीआना* (बी बी–83; आई आई वी आर विभेद) सबसे उत्कृष्ट पाया गया जिसके परिणामस्वरूप माईट की सँख्या में अधिकतम कमी (56.6%) पाइ गई, इसके बाद *मेटारहाईजिअम एनीसोप्लिए* (एम ए – 35; एन बी ए आई आर विभेद) के प्रयोग करने पर माईट की सँख्या में कमी (53.6%) पाई गई। अन्य कीटरोगाणुओं उपचारित प्लॉटों की अपेक्षा *ब्यू. बेसीआना* (बी बी–83) द्वारा उपचारित प्लॉट से हरी मिर्च की महत्वपूर्ण रूप से अधिकतम उपज (6,175 किग्रा./हे.) प्राप्त हुई।

पातगोभी की पसल में सरसों और लोबिया को अन्तः फसल के रूप में उगाने पर यह कम संख्या में *प्लुटेल्ला* लारवों (10/पौधा) *ब्रेवीकोरीने ब्रेसीके* (3.4/पौधा) और

कोक्सीनेलिड (3.3/पौधा) और सिरफिड (3.0/पौधा) की अधिकतम सँख्या में शरण प्रदान करता है । इस उपचार के प्रयोग करने पर अधिकतम उपज (172.52 कुं./हे.) प्राप्त हुई ।

पोलीहाऊस में उगनेवाली फसल कीटों का जैविक नियंत्रण

गुलाब के माहु के प्रति *मेक्रोसीफम रोजेईफोर्मिस,* अजाडीरेक्टिन (1500 पी पी एम; 3 मिली/ली.), *हिप्पोडेमायीआ वेरीएगेटा* (10 बीटल/पौधा) और *लीकेनीसिलिअम लेकेनाई* (5 ग्राम/ली. 10^8 बीजाणु/ग्राम वाला) एकसमान प्रभावी पाये गए, परिणामस्वरूप अनोपचारित दशाओं की अपेक्षा माहु सँख्याओं को 50.8% से 69.1% तक कम कर देते हैं । यद्यपि इमिडिएक्लोप्रिड (0.0075%) के प्रयोग करने पर अनोपचारित की अपेक्षा 96.6% माहु की सँख्या को कम कर देते हैं इस प्रकार इन जैवकारकों को महत्वपूर्ण रूप से कम प्रभावी पाया गया ।

जैव नियंत्रण प्रौद्योगिकियों को बडे पैमाने पर अपनाना सिद्ध हुआ

केरल राज्य के पालाकाड़ जिले के वेडेकेनचेरी पंचायत के अन्तर्गत आने वाले पाला रोड पाडाशेखरम में धान की 13 हेक्टेअर क्षेत्रफल पर आई पी एम प्रक्रियाओं को बडे स्तर पर अपनाकर सत्यापन किया गया । आई पी एम रहित प्लॉटों की अपेक्षा आई पी एम अपनाये गये प्लॉटों में 40% अधिक उपज पाई गई ।

सन 2016–17 में रबी मौसम के दौरान ओडीशा राज्य के कटक जिले के चार गाँवों में बैंगन की 58 एकड क्षेत्रफल की फसल में, अधिक मात्रा में फूलों के आने के समय फेरोमोन प्रपंचों (25/हे.) को लगाना, साप्ताहिक अन्तरालों पर *ट्रायकोग्रामा किलोनिस* (50,000/हे.) को छोडना और *बीटी* के दो छिड़काव करने बी आई पी एम मोडयूल को बडे पैमाने पर प्रदर्शन किया गया । किसान द्वारा अपनाई जाने वाली प्रक्रिया की अपेक्षा इस प्रक्रिया को अपनाने पर कोंपल और फल बेधकों का ग्रसन कम पाया गया साथ ही साथ लाभ: लागत अनुपात अधिकतम प्राप्त हुआ ।

पंजाब राज्य में छ: चीनी मिलों के सहयोग से बडे पैमाने पर लिए गए प्रदर्शन में एकड क्षेत्रफल पर किसानों के खेतों में गन्ने की फसल पर *ट्रायकोग्रामा किलोनिस* (10 दिनों के अंतराल पर 50,000 / हे. की दर से) छोडने पर गन्ने के पोरी बेधक (*काईलो पारटीलस*) के ग्रसन को 56.6% तक कम कर दिया ।

पंजाब राज्य के होशियारपुर, नवाशहर, रूपनगर और पठानकोट जिलों में 355 एकड़ क्षेत्रफल पर किसानों के खेतों में *ट्रा. किलोनिस* परजीवी कीट का वृहद–स्तर पर प्रदर्शन किया गया । *ट्रा. किलोनिस* (1,00,000/हे.) को मक्का की 15 दिनों वाली फसल में एक ही बार में छोडने पर मक्का के तना बेधक कीट, *काईलो पारटीलस* का प्रभावी नियंत्रण पाया गया । नियंत्रण करने के लिए अपनाये गये जैविक नियंत्रण और रासायनिक नियंत्रण वाले खेतों में क्रमश: 52.5% और 69.2% ग्रसन में कमी पायी गयी । नियंत्रण करने के लिए अपनाये गये जैविक नियंत्रण पैकेज अपनाने पर 5,036.75 रूपयों का जबकि रासायनिक नियंत्रण अपनाने पर 8,239.25 रूपयों का कुल लाभ प्राप्त हुआ ।

3. INTRODUCTION

The National Bureau of Agriculturally Important Insects, established in the year 2009, was rechristened the National Bureau of Agricultural Insect Resources on 9 October 2014. This change was effected to create awareness on insects as a natural resource in our agricultural landscapes. This far insects had been paid scant attention in agriculture except as pestiferous species that had to be eliminated.

Insects not only constitute the bulk of living organisms in our world but also render a host of ecosystem services like pollination, natural pest control, recycling of organic matter and so on unbeknownst to most of us. Not confined to any one ecosystem they move between them forming the glue — in Daniel Janzen's apt terminology — that holds all ecosystems together. Consequently it is not only insects in agricultural ecosystems, insects everywhere within the confines our national boundary that are subjects for study. It is only with the knowledge of the insect fauna in agricultural and adjacent ecosystems that we can formulate management strategies to ensure the productivity and sustainability of our agricultural systems.

This shifting perspective on insects in agriculture has been mirrored in the evolution of this bureau. When the possibility of using insects instead of harmful chemicals for the management of insect pests in agriculture was realised the Indian Council of Agricultural Research (ICAR) initiated the All-India Coordinated Research Project (AICRP) on Biological Control of Crop Pests and Weeds in 1977.

Though initially funded by the Department of Science and Technology, Government of India, ICAR began extending full financial support to the programme from 1979. To further strengthen research on biological control the centre was upgraded to the Project Directorate of Biological Control on 19 October 1993. With the growing realisation that effective biological control was predicated on sound taxonomic and ecological knowledge the National Bureau of Agriculturally Important Insects was created on 29 June 2009. NBAIR was subsequently established to document the vast insect resources to enable studies on their multifarious roles in the agroecosystems of our country.

Mandate

ICAR–NATIONAL BUREAU OF AGRICULTURAL INSECT RESOURCES
To act as a nodal agency for collection, characterisation, documentation, conservation, exchange, research and utilisation of agriculturally important insect resources (including mites, spiders and related arthropods) for sustainable agriculture. Capacity building, dissemination of technologies and forging linkages with stakeholders. On-farm validation of biocontrol strategies, forging linkages with commodity-based crop research institutes, AICRP/ AINP and capacity building.

AICRP ON BIOLOGICAL CONTROL OF CROP PESTS
Promotion of biological control as a component of integrated pest and disease management in agricultural and horticultural crops for sustainable crop production Demonstration of usefulness of biocontrol in IPM in farmers' fields.

Organisational set-up

Research is undertaken in the Divisions of Insect Systematics, Molecular Entomology and Insect Ecology. Research on microbial biocontrol is addressed under the AICRP on Biocontrol. The organogram is given on page 15.

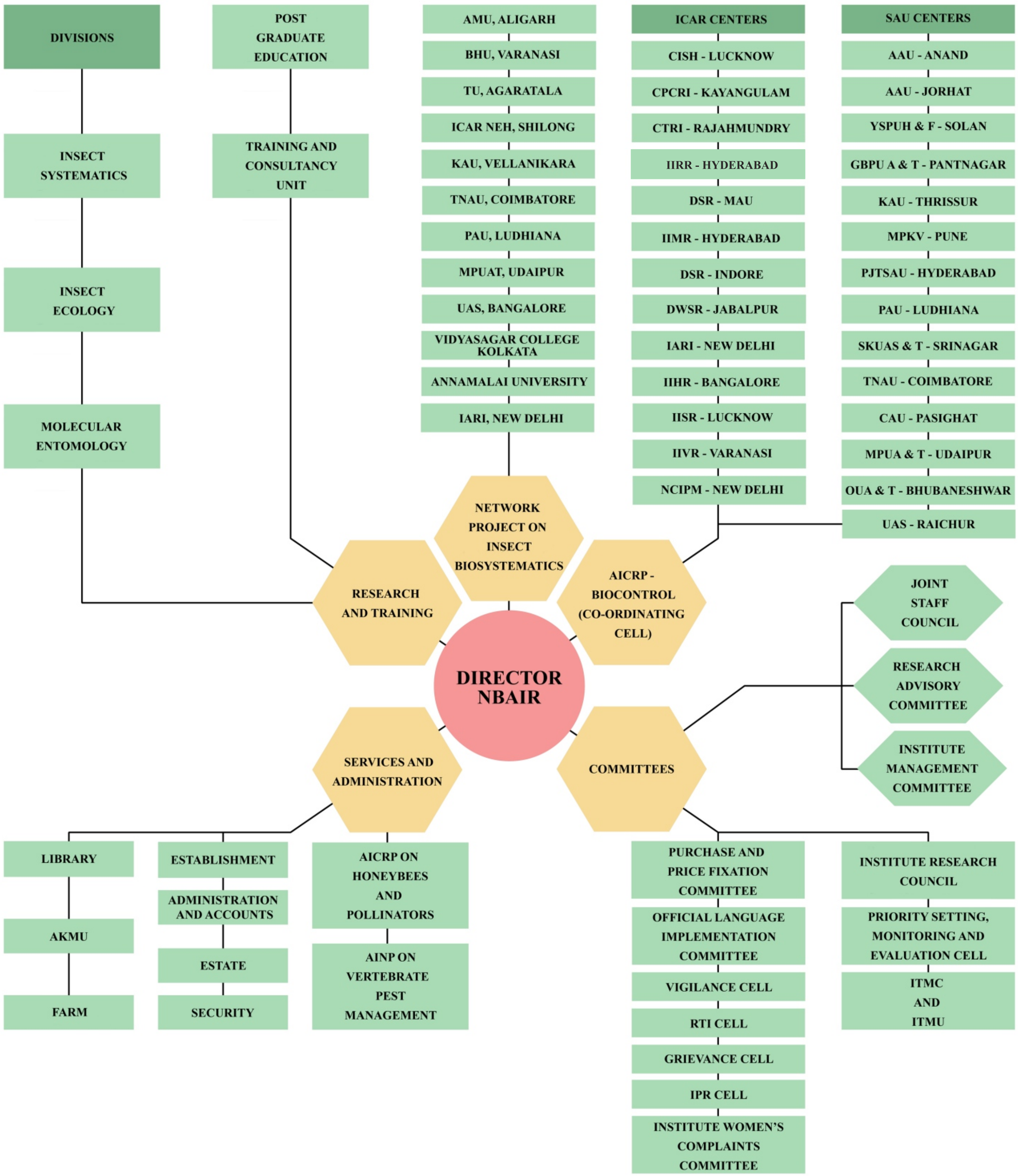
Notable achievements of the past

Basic research

* An ever-expanding image gallery of agriculturally important insects is hosted on NBAIR's website with hundreds of species of insects and over 3,000 images. The USDA and Colorado State University feature this on their site 'ID source' along with another website 'Featured Insects'.

* Factsheets, diagnostics and illustrations on Indian Mymaridae, Chalcididae, Aphelinidae and Pteromalidae have been developed and hosted on the NBAIR website.

Organogram


DIVISIONS
INSECT SYSTEMATICS
INSECT ECOLOGY
MOLECULAR ENTOMOLOGY
POST GRADUATE EDUCATION
TRAINING AND CONSULTANCY UNIT
AMU, ALIGARH
BHU, VARANASI
TU, AGARATALA
ICAR NEH, SHILONG
KAU, VELLANIKARA
TNAU, COIMBATORE
PAU, LUDHIANA
MPUAT, UDAIPUR
UAS, BANGALORE
VIDYASAGAR COLLEGE KOLKATA
ANNAMALAI UNIVERSITY
IARI, NEW DELHI
ICAR CENTERS
CISH - LUCKNOW
CPCRI - KAYANGULAM
CTRI - RAJAHMUNDRY
IIRR - HYDERABAD
DSR - MAU
IIMR - HYDERABAD
DSR - INDORE
DWSR - JABALPUR
IARI - NEW DELHI
IIHR - BANGALORE
IISR - LUCKNOW
IIVR - VARANASI
NCIPM - NEW DELHI
SAU CENTERS
AAU - ANAND
AAU - JORHAT
YSPUH & F - SOLAN
GBPU A & T - PANTNAGAR
KAU - THRISSUR
MPKV - PUNE
PJTSAU - HYDERABAD
PAU - LUDHIANA
SKUAS & T - SRINAGAR
TNAU - COIMBATORE
CAU - PASIGHAT
MPUA & T - UDAIPUR
OUA & T - BHUBANESHWAR
UAS - RAICHUR
NETWORK PROJECT ON INSECT BIOSYSTEMATICS
RESEARCH AND TRAINING
AICRP - BIOCONTROL (CO-ORDINATING CELL)
DIRECTOR NBAIR
SERVICES AND ADMINISTRATION
COMMITTEES
JOINT STAFF COUNCIL
RESEARCH ADVISORY COMMITTEE
INSTITUTE MANAGEMENT COMMITTEE
LIBRARY
AKMU
FARM
ESTABLISHMENT
ADMINISTRATION AND ACCOUNTS
ESTATE
SECURITY
AICRP ON HONEYBEES AND POLLINATORS
AINP ON VERTEBRATE PEST MANAGEMENT
PURCHASE AND PRICE FIXATION COMMITTEE
OFFICIAL LANGUAGE IMPLEMENTATION COMMITTEE
VIGILANCE CELL
RTI CELL
GRIEVANCE CELL
IPR CELL
INSTITUTE WOMEN'S COMPLAINTS COMMITTEE
INSTITUTE RESEARCH COUNCIL
PRIORITY SETTING, MONITORING AND EVALUATION CELL
ITMC AND ITMU

* Insects in agroecosystems is hosted on the NBAIR website (www.nbair.res.in/insectpests/index.php). It includes pests of crops and other common insects from Indian agroecosystems. About a thousand species with 3,500 colour photographs are for viewing and study on the site.
* Webpages on Indian Coccinellidae and Aphids of Karnataka have been constructed and hosted on the NBAIR website.
* A website featuring biocontrol introductions to India (www.nbair.res.in/introductions/insects/index.htm) has also been hosted on the NBAIR website.
* *Anagyrus amnestos,* a potential parasitoid of the invasive Madeira mealybug was described.
* *Paracoccus marginatus* was successfully managed by the exotic parasitoid *Acerophagus papayae*. *Leptocybe invasa* was managed by the parasitoid *Quadrastichus mendeli*.
* Anthocorid predators collected on different host plants were studied for their feeding potential and amenability for culturing indoors in the search for effective agents for use in biocontrol programmes.
* *Cecidochares connexa* released for the management of *Chromolaena odorata* continues to be present in its areas of release.
* A pollinator garden has been developed that has been attracting a large number of bees (belonging to the families Apidae, Megachilidae. Anthophoridae and Halictidae), a host of dipterans and lepidopterans.
* *Liriomyza trifolii* was found to occur at significantly higher levels when carbondioxide and temperatures were higher.
* A cost-effective mass production protocol was developed for *Pseudococcus jackbeardsleyi*.
* Chitosan–aliginate nanoparticles were found to be safe to *Chrysoperla zastrowi sillemi*.
* A collection of insects of importance in veterinary and fisheries sciences has been initiated.
* Totally 205 types belonging to different insect genera in the NBAIR collections have been documented and 35 of them were digitized.
* Twelve new species of Platygasteroidea were described. Sixteen species of aphids and coccids were recorded for the first time from India. Four new species of parasitic hymenoptera were described.
* Barcodes of 103 species of insect natural enemies including parasitoids, predators and pollinators were developed. In addition bar codes were also developed for a total of 165 species belonging to different insect orders.
* Morphology, host records and molecular phylogenetic analyses were integrated to generate boundaries between species/species groups of the genus *Glyptapanteles.*
* The identity of the insect from insect fragments found in a pharmaceutical package was established by employing mitochondrial cytochrome oxidase subunit 1 gene. The insect was found to be Polleniarudis (Fabricius 1794) (Diptera: Calliphoridae).
* Insecticide resistance gene database (IRGD) for key pests has been developed in MySQL as back end and PHP as front-end. It contains 851 sequences for different pests.
* The essential oil of sweet basil, eucalyptus and clove oil were characterized for chemical composition and cidal activity against housefly. Clove oil was more toxic than basil and eucalyptus oil. A gel based matrix was developed for delivery of attractants of the housefly.
* An alcohol free formulation of 'Cuelure' trapped higher number of flies over the 'Cuelure' loaded in plywood pieces. A modified stick trap with methyl eugenol was developed with good catches of *Bactrocera dorsalis.*

Applied research (Biological control)

* The papaya mealybug, eucalyptus gall wasp and the sugarcane woolly aphid were successfully managed by release and management of natural enemies.
* A cost-effective WP/EC based *Trichoderma* (Th-14) formulation and an efficient delivery system were developed. Rice brown spot disease severity was found to be significantly reduced by *Trichoderma* isolates TCMS 5 and TCMS 14a.
* *Metarhizium anisopliae* @ 2 x 10^8 spores/ml was found to cause mycosis in rice bugs. In sugarcane, eight releases of *Trichogramma chilonis* @ 50,000/ha reduced the incidence of early shoot borer and twelve releases of *T. chilonis* @50,000/ha reduced incidence of stalk borer.

* In soyabean SlNPV sprays @ 250 LE/ha (1.5 x 10^{12} POBs) thrice as effective suppressing *Spodoptera litura*. Biosuppression of the safflower aphid, *Uroleucon compositae*, can be achieved with two sprays of *Lecanicillium lecanii* 1% WP in non-spiny safflower.
* In brinjal, shoot and fruit borer incidence can be significantly reduced with two sprays of NSKE and six releases of *T. chilonis; Brumus suturoides* @ 1,500/ha, *Scymnus* @ 1,500/ha and *Cryptolaemus* @ 1,500/ha significantly reduced mealybug populations.
* The BIPM module developed against *Aleurodicus dispersus* on cassava was superior to farmers practice in managing this pest.
* *Neoseiulus longispinosus* @ 1:10 predator:prey ratio in carnation in polyhouses resulted in 91.2% reduction of phytophagous mites and was on par with fenazaquin (0.0025%) which caused 92.1% reduction in the mite population.
* *Blaptostethus pallescens* @ 30 nymphs/m row along with chemical control (Omite 300 ml/acre) was effective in managing *T. urticae* on okra in polyhouses.
* *Xylocoris flavipes* nymphs (30 nymphs/kg of rice) performed better than those of *Blaptostethus pallescens* in minimizing *Corcyra* moth populations in rice in storage.

Financial statements (2016-17)

ICAR–National Bureau of Agricultural Insect Resources

(₹ in lakhs)

Head	Plan	Non-Plan	Total
Pay & allowances	0.00	826.60	826.60
T.A.	7.36	6.00	13.36
Other charges, including equipment	48.18	103.89	152.07
Information technology	0.00	0.00	0.00
Works / petty works	37.37	19.00	56.37
HRD	1.30	0.00	1.30
Pension	0.00	25.87	25.87
Loan	0.00	0.60	0.60
Total	**94.21**	**981.96**	**1,076.17**

All-India Coordinated Research Project on Biological Control of Crop Pests

(₹ in lakhs)

Centre	Pay	T.A.	R.C.	TSP	Total
AAU, Anand	49.51	0.75	1.88	5.00	57.14
AAU, Jorhat	27.28	0.57	0.75	0.00	28.60
ANGRAU(RARS), Anakapalle	18.57	0.18	0.25	7.00	26.00
PJTSAU, Hyderabad	30.48	0.56	0.75	0.00	31.79
DR.YSPUH&F, Solan	32.99	1.01	1.50	2.70	38.20
GBPUAT, Pantnager	20.05	0.56	0.75	0.00	21.36
KAU, Thrissur	33.23	0.75	0.75	0.00	34.73
MPKV, Pune	33.40	0.35	1.90	1.00	36.65
PAU, Ludhiana	66.54	1.50	2.75	0.00	70.79
SKUAT, Srinagar	17.47	0.50	1.00	2.05	21.02
TNAU, Coimbatore	29.25	0.55	1.96	3.25	35.01
MPUAT, Udaipur	0.00	0.00	1.17	0.00	1.17
OUAT, Bhubaneswar	0.00	0.15	1.17	0.00	1.32
CAU, Pasighat	0.00	0.00	1.53	0.00	1.53
UAS, Raichur	0.00	0.25	1.34	0.00	1.59
P.C. Cell, Bengaluru	0.00	4.00	10.00	0.00	14.00
Total	**358.77**	**11.68**	**29.45**	**21.00**	**420.90**

4. RESEARCH ACHIEVEMENTS

ICAR–National Bureau of Agricultural Insect Resources

Division of Insect Systematics

Trichogrammatidae

Surveys for the collection of insects were conducted in the states of Assam, Tamil Nadu, Rajasthan, Kerala and Karnataka. The new species of *Trichogrammatoidea* discovered last year has been described. The types of 17 species of Indian *Trichogrammatoidea* have been accessed and redescribed in keeping with the current descriptors of species in this genus. *Chaetostricha magniclavata* is being recorded from Assam and Tamil Nadu; while *Hayatia indica* is being recorded from Karnataka, Tamil Nadu and Kerala; *Lathromeromyia dimorpha* is recorded from Assam and Karnataka; *Poropoea baleena* is recorded from Karnataka – all these for the first time from these regions in the country. In the survey for the seasonal occurrence of the egg parasitoids (Trichogrammatidae, Mymaridae, Platygastridae and Scelionidae) in sugarcane, rice and ragi ecosystems in Mandya it was found that all these families of parasitoids occurred throughout the year, even during the periods when the fields were fallow. The annual pattern of abundance in rice and ragi were the same: in diminishing order of abundance it was Scelionidae, Mymaridae, Trichogrammatidae and Platygastridae. The pattern of abundance in sugarcane was strikingly different. Scelionidae predominated with their numbers exceeding the combined occurrence of the other three families. Trichogrammatidae was the least abundant of the families (Fig. 1). On a seasonal basis these

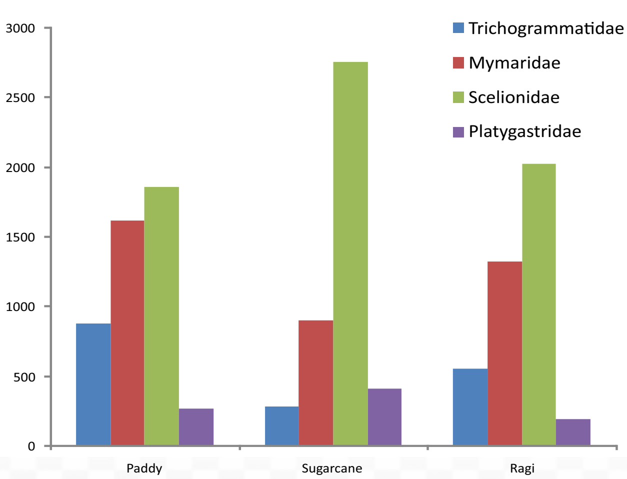


Fig. 1. Abundance (number) of egg parasitoids in three agroecosystems in Mandya (Karnataka)

parasitoids predominated during the period of the Southwest monsoon and a lower peak was also observed towards the end of the Northeast monsoon extending into the winter months. Trichogrammatidae occurred in larger numbers in ragi during the SW monsoon while their populations were greater in the NE monsoon in rice and sugarcane.

Surveys for the collection of trichogrammatids were conducted in Karnataka, Uttar Pradesh, Uttarakhand, Tamil Nadu and Odisha. Ten genera of trichogrammatids were collected. The specimens collected were sorted, processed and mounted on slides for identification. The following genera of trichogrammatids were identified viz., *Aphelinoidea, Lathromeroidea, Megaphragma*, *Oligosita*, *Paracentrobia*, *Trichogramma, Trichogrammatoidea, Tumidiclava, Ufens* and *Xiphogramma*. *Trichogramma achaeae* and *Trichogrammatoidea bactrae* collected from eggs of *Tuta absoluta* in tomato field, while, *Trichogramma danausicida* recorded from eggs of *Danaus* sp. Moreover, indeterminate species of *Trichogramma* was also found to be parasitizing the eggs of *Euthalia garuda* on mango. The genus *Megaphragma* and *Trichogrammatoidea bactrae* were collected form Uttarakhand for the first time. The collected trichogrammatids from different locations were reared for taxonomic studies and added to the live witness being maintained in the insectary. Four species of *Trichogramma* and *Trichogrammatoidea* were given for DNA barcoding.

Platygastroidea

The wasp genus *Oethecoctonus*, which consists of egg parasitoids of tree crickets (Orthoptera: Oecanthidae), was reported for the first time from the Oriental region. A new species *Oethecoctonus suryaseni* (Fig. 2) was described and imaged. *Pardoteleia*, a monotypic genus was reported for the first time from India. A new species *Pardoteleia flava* (Fig. 3) from India was described and imaged.

The hitherto unknown male of this genus was also described and imaged for the first time. *Pardoteleia prater*, the type species was redescribed and imaged with intraspecific variations in the Indian specimens. Two new species of *Microthoron,* viz. *M. bloomsdalensis* (Fig. 4) and *M. shompen* were described. The male of *M. baeoides* and its bizarre antenna were described. Both male and female *M. baeoides* and female *M. miricornis* are imaged. *Narendraniola* was treated as a junior synonym of *Microthoron*. The monotypic genus *Nyleta* was reported for the first time from India. A new species of *Nyleta, N. onge* (Fig. 5) is now described and imaged from the remote island of Little Andaman in the Andaman and Nicobar group of Islands in the Indian Ocean. Variants of the same species were collected from Tamil Nadu. The images of the holotype of *N. striaticeps* are provided for the first time.

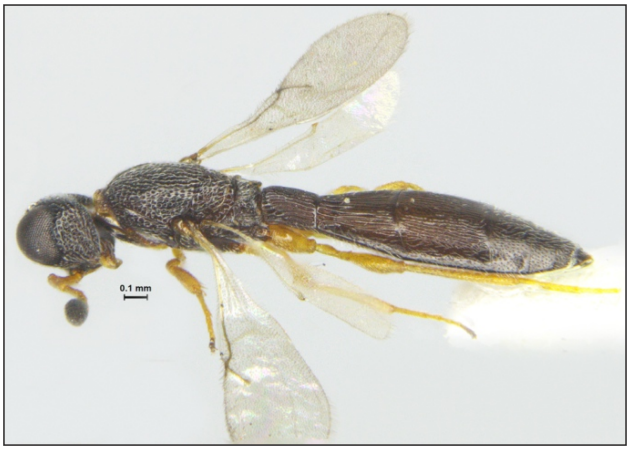


Fig. 2. *Oethecoctonus suryaseni*

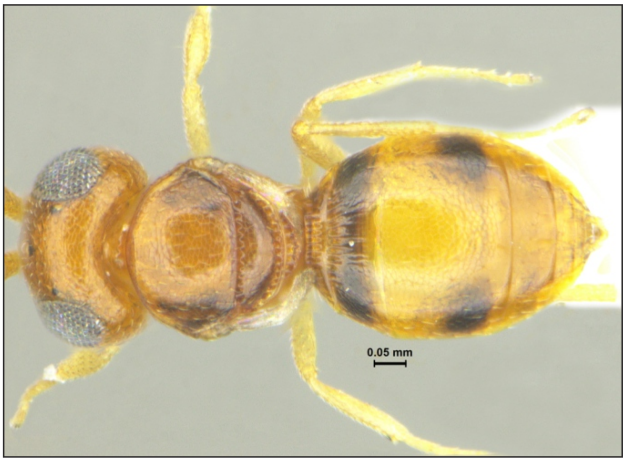


Fig. 3. *Pardoteleia flava*

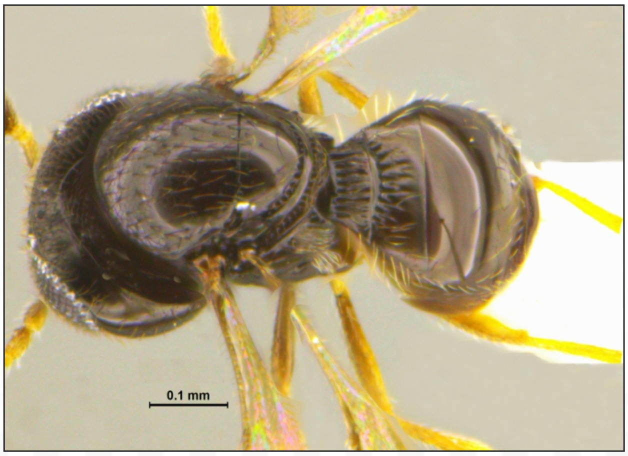


Fig. 4. *Microthoron bloomsdalensis*

Fig. 5. *Nyleta onge*

Parasitic Hymenoptera

The world fauna of *Cotesia* (269 species) was reviewed and a new species, *Cotesia trabalae* described (Fig. 6). The generic placement of species based on molecular/morphological analyses and parasitoid biology is discussed. In neighbour-joining tree the cryptic Indian and African species cluster more closely with other species, and in Bayesian tree they are part of a large unresolved polytomy which provides no support for them being sister species, although it does not preclude that possibility either. Molecular data support the monophyly of *Cotesia*. *Cotesia dictyoplocae* is reported for the first time from *Antheraea assamensis* on *Persea bombycina* in Assam. First time egg parasitism of *Erionota torus,* a recent pest of banana, by *Ooencyrtus pallidipes* reported (80−82% parasitism) in India (Komanal, Karnataka). Identified *Encarsia guadeloupae* and *E. dispersa* for the new invasive *Aleurodicus rugioperculatus* which was found infesting coconut, banana, etc. in Tamil Nadu, Andhra Pradesh, Karnataka and Kerala. *Crinibracon chromusae* (Fig. 7), parasitic on *Hasora chromus* described. Biological information for *Crinibracon* is provided for the first time. *Agiommatus thyrsisae* (Fig. 8) reared from *Gangara thyrsis* eggs described. *Gangara thyrsis* is a new host record for *Agiommatus*. Recorded mean percent parasitism (26.58%), incubation period (6–7 days), females (57.14–73.08%), males (23.08%) and hyperparasitism (3.85–42.86%). *Tanaostigma* is recorded for the first time from the Old World with species, *Tanaostigma indica* (Fig. 9). *Dolichogenidea hasorae* is reassigned from traditionally defined genus *Apanteles*. Reported *Brachymeria lasus* from *Hasora chromus*; *Casinaria ajanta* from *Ampittia dioscorides* and *Parnara* sp.; *Dolichogenidea hasorae* from *Hasora taminatus*; *Glyptapanteles aristolochiae* from *Troides minos*; *Apanteles* sp. from *Telicota bambusae* and *Cotesia* sp. from *Udara akasa*. The majority of these records are first reports except *C. ajanta* from *Parnara* sp. A new web portal on "Indian genera of

Chalcididae" hosted with 23 genera. One hundred and eighty-eight species were digitised and their factsheets with 475 images were hosted on NBAIR's website.

Fig. 6. *Cotesia trabalae*

Fig. 7. *Crinibracon chromusae*

Fig. 8. *Agiommatus thyrsisae*

Fig. 9. *Tanaostigma indica*

Sphecidae

Around 1000 specimens were collected from Karnataka, Tamil Nadu, Assam, Andaman Island and Arunachal Pradesh using yellow pan traps and sweep nets. Collected specimens were sorted, processed, mounted and labeled. Genus level identifications were made for the genera *Carinostigmus*, *Bembecinus, Dianotus, Isorhopalum*, *Stigmus, Liris, Tachytes* and *Tzustigmus*. Species level identifications of Sphecidae wasps belong to the genera *Carinostigmus, Sphex, Bembicinus* and *Stigmus* were done. Discovery of unknown males of *Carinostigmus aterrimus* was made nearly a century after it was first discovered by integrating both morphological and molecular taxonomic methods. DNA barcodes have been generated for 10 species of Sphecidae, viz., *Carinostigmus atterimus*, *Carinostigmus* sp., *Stigmus cuculis*, *Stigmus* sp., *Bembecinus* sp., *Isorhopalum* sp. and *Diadontus* sp., etc.

Hemiptera

A total of seven surveys were conducted for the collection of aphids, coccids and their natural enemies at Udaipur, Yelagiri, Yercaud, Thandikudi and Thadiyankudisai, Shivamogga and Pune and 17, 21, 18, 12, 13 and 16 species of aphids/coccids were collected, respectively from these places. A total of 527 species were identified by making 911 slides by processing 4484 specimens. A total of 75 identification services provided to different SAUs, ICAR institutes and private organisations and through which 105 species were identified. Three species of mealybugs (*Heliococcus singularis*, *Dysmicoccus debregeasiae* and *Planococcus nilgiricus*), one soft scale (*Macoccus watti*), one aphid (*Greenidea maculata*) and one eriococcid (*Gossypariella crematogastri*) were added as new to existing collection of aphids and coccids at NBAIR museum. One aphid, *Schoutedenia emblica* and three species of mealybugs, viz. *Phenacoccus parvus*, *Phenacoccus madeirensis*, *Pseudococcus saccharicola* were recorded for the first time from Udaipur, Rajasthan. Similarly, an armoured scale, *Semelaspidus artocarpi*, an aphid *Imaptientinum impatiens* and a mealybug, *Heliococcus summervillei* were recorded for the first time from South India and two mealybugs and an aphid (*Antonina thaiensis* (Fig. 10), *Exallomochlus hispidus* (Fig. 11), *Uroleucon pseudoambrosiae* (Fig. 12) were collected for the first time from India. A soft scale (*Pulvinaria urbicola*) was redescribed. Thirteen species of mealybugs were deposited for molecular characterisation.

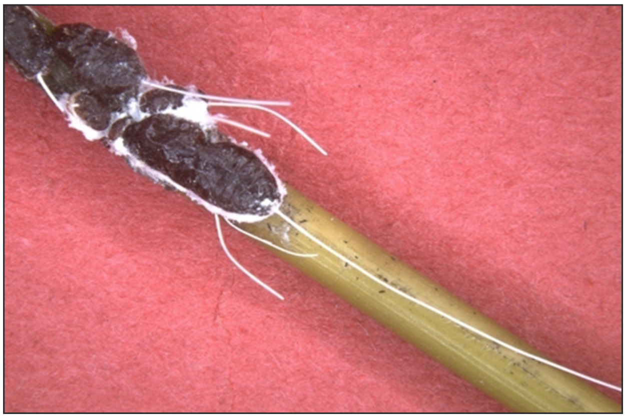


Fig. 10. *Antonina thaiensis*

Fig. 11. *Exallomochlus hispidus*

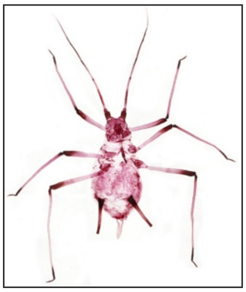


Fig. 12. *Uroleucon pseudoambrosiae*

Pentatomidae

Around 39 collection trips were undertaken for collection of pentatomids. One collection trip was undertaken to Tripura (Churaibari, Agartala, Ambassa, Lembucherra). Nearly 1,076 specimens belonging to 53 species of Pentatomidae from various locations of

Karnataka, Tamil Nadu, Assam, Arunachal Pradesh and Tripura were added to the collection. Fifty-five species of Pentatomidae were identified and digitised. Twenty-nine species of Pentatomidae have been given for DNA barcoding and GenBank accession numbers were generated for 29 species of Pentatomidae. The genus *Acrozangis* is redescribed and a new species is described from southern India. The genus *Brachycoris* is recorded for the first time from India. *Brachycoris* is redescribed and its distribution expanded with the description of *Brachycoris tralucidus* (Fig. 13) based on specimens from southern India. The holotype male and two paratype females are deposited at NBAIR and one paratype female is deposited at the University of Agricultural Sciences, Bengaluru (UASB). Redescribed and illustrated the genus *Neojurtina* and *Neojurtina typica* (Hemiptera: Pentatomidae: Pentatominae: Pentatomini) is recorded for the first time from India (Meghalaya).

Fig. 13. *Brachycoris tralucidus*

Tephritidae

Adults of 73 species of fruit flies belonging to 8 genera, 15 subgenera and 2 tribes from India and III instar larvae of 12 species were characterised using morphological characters. Twenty-eight species of fruit flies were barcoded. Examination of cephalopharyngeal skeleton in III instar larvae of *Bactrocera* and *Dacus* revealed that, in *Bactrocera* group of subgenera, subapical tooth is lacking whereas in *Zeugodacus* group of subgenera and *Dacus* it is prominent. Keys were made for the identification of subfamilies of Tephritidae, tribes of subfamily Dacinae, genera of tribes included, subgenera of *Bactrocera* and *Dacus* apart from the key to 73 species. Examination of male genitalia of tribe Dacini revealed that praeputium (cavity formed inside the glans of Tephritidae by the sclerites guarding gonopore) of genus *Dacus* and species of *Zeugodacus* group of subgenera are patterned whereas in the rest of *Bactrocera* unpatterned. Three new species of subfamily Dacinae were described from India namely, *Bactrocera* (*Calodacus*) *chettalli*, *B.* (*C.*) *harrietensis* infesting fruits of *Spondias pinnata* (Anacardiaceae); *Gastrozona nigrifemur* (Fig. 14) infesting sprouts of *Dendrocalamus strictus* (Poaceae). One species of subfamily Phytalmiinae, *Tritaeniopteron punctalipleura* (Fig. 15) and another of subfamily Dacinae, *Bactrocera* (*Zeugodacus*) *semongokensis* was recorded for the first time from India. Keys to species of subgenus *Calodacus* of genus *Bactrocera* and species of *Gastrozona* were also published.

Fig. 14. *Gastrozona nigrifemur*

Fig. 15. *Tritaeniopteron punctalipleura*

Thysanoptera

Extensive surveys were conducted in Assam (Jorhat), Delhi, Tamil Nadu (Yercaud and Yelagiri) and Karnataka (Shimoga) for the collection of thrips. Collected specimens were sorted, processed and slide mounted. Described a new terebrantian thrips species, *Thrips laurencei* (Fig. 16) collected on flowers of *Hydrangea macrophylla* from Ooty. Newly reported

Crotonothrips polyalthiae (Fig. 17) and male of *Frankliniella occidentalis* (Fig. 18) from India. Newly reported presence of the genus *Franklinothrips* from North East India with species *F. megalops* (Fig. 19). Reported the presence of quarantine thrips, *Frankliniella occidentalis* from Udhagamandalam. Newly added six Thysanoptera genera (*Anascirtothrips*, *Chaetanaphothrips, Crotonothrips, Elaphrothrips*, *Euphysothrips* and *Octothrips*) and 10 species (*Anascirtothrips arorai*, *Caliothrips luckmanni*, *Chaetanaphothrips orchidii*, *Crotonothrips polyalthiae*, *Elaphrothrips greeni*, *Euphysothrips minozzii*, *Euphysothrips subramanii*, *Frankliniella intonsa*, *Frankliniella occidentalis* and *Octothrips bhattii*) to NBAIR reference collection. Ten thrips species, viz. *Frankliniella occidentalis, Franklinella intonsa*, *Franklinothrips vespiformis*, *Karnyothrips melaleucus, Megalurothrips usitatus, Microcephalothrips abdomnalis, Scirtothrips dorsalis, Selenothrips rubrocinctus, Thrips laurencei* and *Thrips palmi* were given for DNA barcoding. GenBank accession numbers were obtained for *Thrips florum, T. orientalis*, *Thrips* sp., *Haplothrips* sp., *Microcephalothrips abdominalis* and *Scirtothrips dorsalis*.

Fig. 16. *Thrips laurencei*

Fig. 17. *Crotonothrips polyalthiae*

Fig. 18. *Frankliniella occidentalis*

Fig. 19. *Franklinothrips megalops*

Cerambycidae and related fauna

The present study reported a total of 1,555 longhorn beetles classified under 72 tribes, 447 genera and seven subfamilies of Cerambycidae as well as Vesperidae and Disteniidae. The report account for 4.2% of species, 7.94% of genera and 28.24% of tribes from India as compared with global records. The sub-familywise distributions of species are: Lamiinae (1,102 species); Cerambycinae (350 species); Prioninae (58 species); Lepturinae (20 species); Disteniinae (Disteniidae) (9 species); Spondylidinae (6 species); Dorcasominae (4 species); Necydalinae (3 species); Philinae (Vesperidae) (3 species). Three species, viz. *Pothyne laosica*, *Neoplocaederus consocius* and *Nepiodes terminalis* were taxonomically examined and reported as new species records for India. Thirty-one species of cerambycids are considered as agriculturally important pests, causing significant damage to the crop plants. These species were freshly collected from their natural habitats and descriptively examined based on morphology, host plants and distribution records. The list included 16 species of Lamiinae, 12 species of Cerambycinae, two species of Prioninae and one species of Lepturinae. An illustrated taxonomic key for these genera was prepared for their easy field identification.

Large sized flea beetles feeding on *Garcinia gummigutta* plants at Indian Cardamom Research Institute, Mayiladumpara and surrounding villages were collected during February 2017 and identified as *Podontia congregata* (Chrysomelidae, Galerucinae, Alticini). Its distribution from the Western Ghats mountains westward to the plains in Kerala was reported earlier by Prathapan and Chaboo (2011). Adult beetles, egg masses and larvae were collected in large numbers and reared under laboratory condition to study the biology. The larval instars developed defensive strategies by completely covering the terga with a continuous thread of slimy faeces. Severe defoliation of twigs was observed on some plants. The different stages of the pest reared under laboratory conditions are presented (Figs 20, 21, 22 & 23).

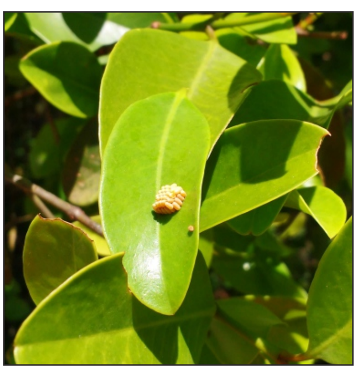


Fig. 20. Egg mass

Fig. 21. Grubs covered with faecal mass

Fig. 22. Pupal cocoon

Fig. 23. Adult beetles

Curculionidae

A total of 446 weevil specimens were collected /received from 44 locations belonging to fourteen states, namely, Andaman and Nicobar Islands, Arunachal Pradesh, Assam, Gujarat, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Maharashtra, Manipur, Meghalaya, Tamil Nadu, Tripura and Uttar Pradesh. Out of 446, 121 specimens belonging to the long snout weevils and 325 come under short snout weevils or broad nose weevils. All the collected specimens were carefully processed, labelled and preserved for further studies. Twenty four species were identified upto the genus level and ten species confirmed their identity at species level. Among these, *Lepropus chrysochlorus* reported for first the time in Arunachal Pradesh. *Lepropus flavovittatus* was recorded on litchi and beans for the first time.

Araneae

A total of 550 numbers of spiders belonging to 10 families have been collected/received from surveys undertaken at 15 places in 9 states covering crops viz., rice, maize, pigeonpea, groundnut, tomato, chilli, mango, mustard, tea and coffee and out of these, 50 spp. have been identified up to species level while 75 have been identified up to generic level. At the species level, *Neoscona shillongensis* (Family Araneidae), *Stegodyphus tibialis* (Family Eresidae) (Fig. 24) and *Aelurillus ?kronestedti* (Family Salticidae) (Fig. 25) are being reported for the new distribution record from Karnataka, Kerala and Tamil Nadu, respectively. The female *Aelurillus kronestedti*, is not described elsewhere the same is under description. The guild structures observed during the surveys are orb-weavers, ground runners, stalkers, burrowers, ambushers, foliage runners, space web builders, sheet web builders and tangle web builders. Orb-weavers, belonging to the families Araneidae, Tetragnathidae constituted the dominant guild composition. Standardised the DNA barcode protocol for spiders for both COI and ITS regions.

Fig. 24. *Stegodyphus tibialis*

Fig. 25. *Aelurillus kronestedti*

Acari

Mite samples originated from around 50 places in 20 districts across 11 states. From the 120 collections, around 5,750 mites were sampled and processed. Totally, 1,380 temporary mounts and 1,239 permanent slides were prepared. Approximately, 70% of all the processed mites belonged to Parasitiformes (Mesostigmata) and the rest belonged to Acariformes [Trombidiformes (28%) and Sarcoptiformes (2%)]. Many phytoseiids were added to the repository, including, *Amblyseius largoensis, Euseius alstoniae, E. coccosocius, E. macrospatulatus, Neoseiulus paspalivorus, Paraphytoseius bhadrakaliensis, P. orientalis, Phytoseius namdaphaensis, P. kapuri, P. rachelae* and *Typhlodromips syzygii.*

Amblyseius largoensis (Fig. 26) and two new species of *Lasioseius* (Ascidae) were found to be important natural enemies of *Aceria litchii*. For the first time, *Euseius alstoniae* and an undescribed *Typhlodromus* sp. were found in association with *Bemisia tabaci* on cotton in Sardulgarh, Mansa district, Punjab. Two possibly new species of *Graminiseius*, both provisionally identified as *Graminiseius* sp. nr. *graminis*, were added to the repository.

Fig. 26. *Amblyseius largoensis*

Raoiella macfarlanei and *Tenuipalpus hastaligni* (Tenuipalpidae) were recorded for the first time in Karnataka.

Three stigmaeids (provisionally identified as *Agistemus* sp. nr. *terminalis*) were found to be new species.

At least three cunaxid mites were found to be new species, yet to be described: *Cunaxa* sp. nr. *bambusae* (palp chaetotaxy differs), *Cunaxa* sp. nr. *cynodonae* (dorsal and palp chaetotaxies differ) (Fig. 27) and *Cunaxa* sp. nr. *womersleyi* (lacks finger-shaped apophysis).

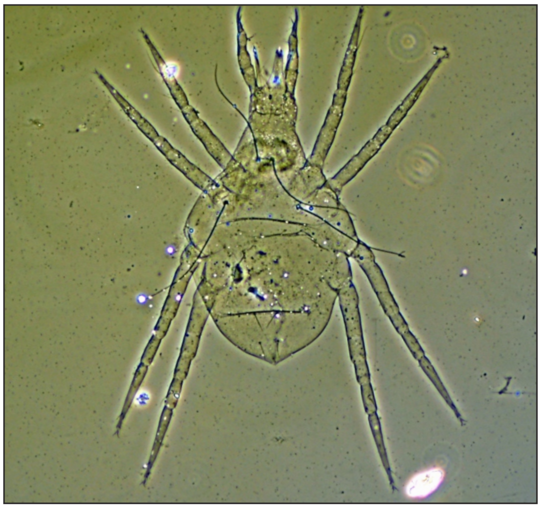


Fig. 27. *Cunaxa* sp.nr. *cynodonae*

Two mitosporic fungi (*Acremonium strictum* and *Trichothecium roseum*) and two entomophthoralean pathogens (*Neozygites* spp.) were found infecting various tetranychid mites, including the tea red spider mite, *Oligonychus coffeae*.

Entomopathogenic nematodes

A soil sample drawn from walnut rhizosphere of Adul Gund of Kargil district and positive sample was anticipated with *Heterorahbditis* nematode, this nematode was identified as *H. pakistanense* through morphological and molecular characterization and named as *Heterorhabditis pakistanense* strain NBAIIH05. Sequence alignment of ITS region of *H. pakistanense* NBAIIH05 showed maximum identity with *H. pakistanense* (99.0%) and formed a highly supported clade. The base sequence (795 bp) of this isolate has been deposited in GenBank, NCBI and accession number was obtained (Fig. 28).

The efficacy of *Steinernema abbasi* and *Heterorhabditis indica*, against *H. consanguinea* was tested under field condition. The percentage reduction in *H. consanguinea* grub population was significantly higher using *H. indica* at a dose of 2.5×10^9 IJ/ha than *S. abbasi* and phorate application. Phorate application was more efficient in reducing the grub population than both nematode species at the lower application rate (1.25×10^9 IJ/ha) (Fig. 29). Overall, these experiments suggest that *H. indica* may be a promising biocontrol agent against *Holotrichia consanguinea*.

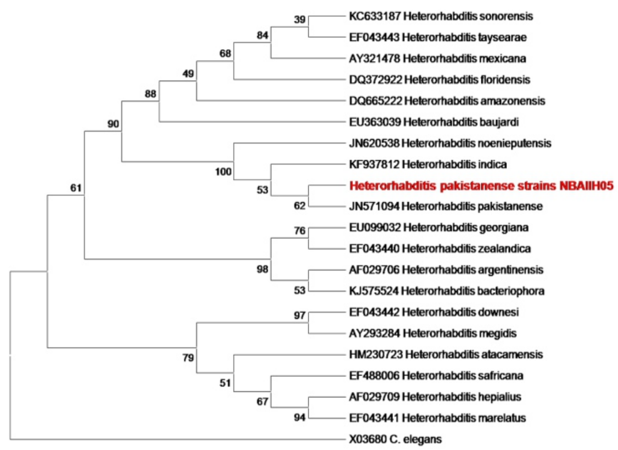


Fig. 28. Phylogenetic relationship of *Heterorhabditis pakistanense* NBAIIH05 based on ITS region by Neighbour-Joining method.

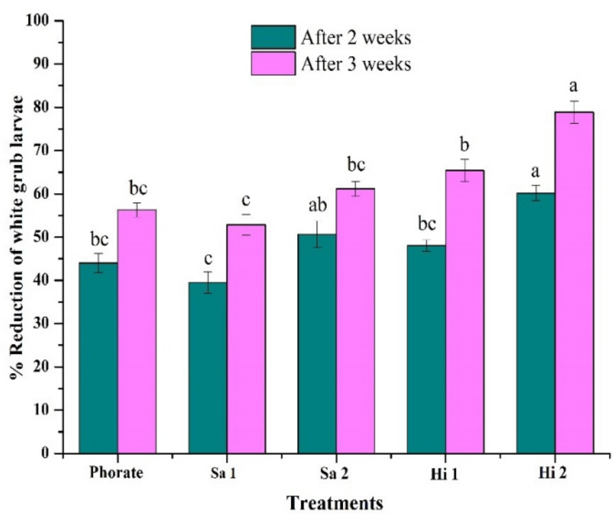


Fig. 29. Percentage reduction of second-instar grubs of *Holotrichia consanguinea*, at 2 and 3 weeks after different treatments in a farmer's field at Belgaum, India. Different letters on the top of bars indicate statistically different values for different nematode concentrations at using Tukey's test (P <0.05). Bars = standard error. Sa, *Steinernema abbasi*; Hi, *Heterorhabditis indica*; 1 = 1.25×10^9 IJ ha^{-1}, 2 = 2.5×10^9 IJ ha^{-1}. Phorate was used at the rate of 2500 ml ha^{-1} as a drench application.

Entomopathogenic nematodes, *H. indica* NBAIIH38 and *Steinernema abbasi* NBAIISa01 along with a commonly used insecticide (chlorpyrifos) were tested against this insect in two field experiments (experiment 1- grubs mainly the second instar stage and experiment 2-mainly in the third instar stage). In both the field experiments, *H. indica* NBAIIH38 at a dose of 3.5×10^5 IJ/palm contributed to significantly higher percentage reduction of the white grub larvae compared with *S. abbasi* NBAIISa01 and chlorpyrifos treatments. Phorate application was also more efficient in reducing the grub population than *S. abbasi* NBAIISa01 at the lower application rate (i.e. 1.7×10^5 IJ/palm) (Fig. 30).

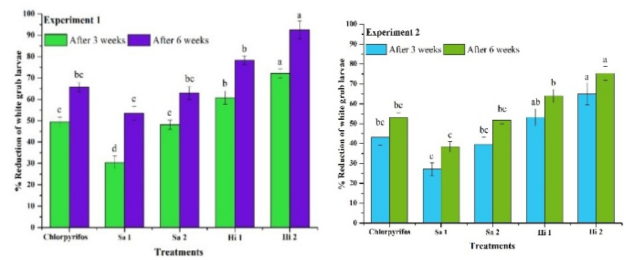


Fig. 30. Percentage reduction of *Leucopholis burmeisteri* in arecanut fields with different treatments 3 and 6 weeks after application in the first experiment (grubs were mainly in the second instar at the time of the experiment) and in the second experiment (grubs were mainly in the third instar at the time of the experiment) in Sirsi, India. Different letters on the top of error bars indicate statistically different values for different nematode concentrations at using Tukey's test (P< 0.05). Bars = standard error. Sa, *Steinernema abbasi*; Hi, *Heterorhabditis indica*; 1 = 1.7×10^5 IJ palm^1, 2 = 3.5×10^5 IJ palm^{-1}. Chlorpyrifos was used at the rate of 5.6 ml palm^{-1} as a drench application.

Division of Molecular Entomology

Molecular characterisation and DNA barcoding of agriculturally important insects

Pest insects

During the period more than 500 insect specimens belonging to different groups were collected from eight states, viz., Karnataka, Tamil Nadu, Kerala, Andhra Pradesh, Punjab, Uttar Pradesh and Assam. A total of 188 morphologically identified insect pest species were molecularly characterised using COI and ITS2 regions. These insects belonged to five orders: Lepidoptera (12 families), Hemiptera (5 families), Coleoptera (4 families), Thysanoptera (2 families), Diptera (7 families) and Orthoptera (1 family). Twenty-five species barcodes were obtained during the period with barcode ID and GPS data.

Leucinodes orbonalis

Molecular characterization of 33 specimens of *Leucinodes orbonalis* collected from 18 different places was completed. DNA sequences were submitted to GenBank and DNA barcodes were developed for all the 33 specimens of *L. orbonalis*. Transition and transversion analyses showed 34 variable sites. Phylogenetic analysis could resolve 17 haplotypes observed in 33 specimens of *L. orbonalis*. Transcriptome analysis of susceptible and resistant populations of *L. orbonalis* was performed and 23 million reads data were generated with 49.63% of GC content. SRA submitted at GenBank under Bioproject PRJNA352591 and archive accession numbers: SRX2338657 (S), SRX2338658 (R), SRX2338659 (S), SRX2338660 (R). *De-novo* whole genome sequencing completed through Illumina paired end and mate pair libraries by HiSeq 2500 1T upgrade system and Pac-Bio 20KB CCS library by RSII system and P6C4 chemistry. SRA submitted to GenBank under Bioproject PRJNA377400, archives under SUB2444180.

Plutella xylostella

The whole transcriptome of susceptible and resistant strains of *Plutella xylostella* were sequenced.The raw data of all the three insects along with the replicates have been submitted to the SRA archives of NCBI and registered as separate bioprojects. *P. xylostella*- ryanodine receptor protein modelling was done by molecular modeling method and prediction of molecular mechanism of diamides resistance in Px-RyR was achieved computationally. Pharmacophore-based virtual screening was carried out to identify *P. xylostella*-ryanodine receptor activators Px-RyR. From the virtual screening of 5 lakh ligand molecules from the database, two molecules were selected for further analysis.

Whiteflies

The new invasive rugose spiraling whitefly, *Aleurodicus rugioperculatus* and its potential aphelinid parasitoid *Encarsia guadeloupae* were identified using COI gene. More than 100 whitefly populations were collected from cotton and other crops in 21 districts spread over six states of India during September 2016 to January 2017. Pupal samples were processed for mounting to confirm the morphological identification of whitefly species. The whiteflies, *B. tabaci*, *Aleurothrixus trachoides, Aleurodicus dispersus, Aleurolobus barodensis, Neomaskelia bergii, Aleurocanthus mangiferae, Aleurocanthus woglumi, Aleurocanthus arecae* and *Aleurodicus rugioperculatus* were identified morphologically. Further, these species were confirmed through DNA barcoding.

Genetic group determination of *B. tabaci* field populations was carried out by the sequence comparisons using the Basic Local Alignment Search Tool (BLAST) algorithm of NCBI. The genetic group identity was further confirmed by the phylogenetic and molecular evolutionary analysis with well-assigned homologous sequences of the *B. tabaci* genetic groups from the consensus sequence database using MEGA version 6. Furthermore, sequence analyses using mitochondrial cyctochrome oxidase I confirmed the presence of two putative genetic groups Asia-1 and Asia-II1 from the surveyed locations.

Thrips

Methodology for rapid DNA extraction protocol from single thrips by non-destructive method has been standardised. DNA barcoding using partial gene amplification of COI gene has been done for nine species of thrips viz., *Thrips* sp., *Thrips florum, Haplothrips* sp., *Scirtothrips dorsalis, Thrips orientalis, Thrips* sp., *Thrips florum, Thrips orientalis, Haplothrips* sp. and *Microcephalothrips abdominalis*. The sequences were submitted to GenBank database and the accession numbers obtained (Table 1).

Table 1. DNA barcoding of thrips

Thrips species	Family	GenBank Acc.
Haplothrips sp. 1	Phlaeothripidae	KY883612
Haplothrips sp. 2	Phlaeothripidae	KY883618
Thrips florum	Thripidae	KY883611
Scirtothrips dorsalis	Thripidae	KY883613
Thrips orientalis	Thripidae	KY883614
Thrips sp.	Thripidae	KY883615
Thrips florum	Thripidae	KY883616
Thrips orientalis	Thripidae	KY883617
Microcephalothrips abdominalis	Thripidae	KY883619

Subterranean insect pests

Samples of scarabaeid beetles, termites and collembolans were collected from various geographical locations in the country. The beetles were identified at the Department of Entomology, GKVK, Bangalore and the Division of Entomology, IARI; termites at the Institute of Wood Science and Technology, Bangalore and collembolans at the Division of Entomology, BHU, Varanasi. DNA was extracted from the specimens following the standard protocols. The DNA was amplified for COI gene for scarabaeids and termites and ITS2 for collembolans using universal primers. The amplified products gene were sequenced and submitted to NCBI to obtain accession numbers (Tables 2 & 3). Barcodes and Barcode Index Numbers (BIN'S) were obtained for species with GenBank accession from the BOLD systems V3. The following soil insect specimens were deposited in the repository of NBAIR with barcode data (Tables 4 & 5)

Table 2. COI gene sequence-based DNA barcoding of scarabaeid beetles and termites

S.No.	Place	Identification	Sub-family	Source	GenBank Acc.
Scarabaeid beetles					
Andhra Pradesh					
1	Anakapalle	*Holotrichia consanguinea*	Melolonthinae	Sugarcane	KU35557
2	Kadapa	*Holotrichia consanguinea*	Melolonthinae	Sugarcane	KU35559
3	Kurnool	*Holotrichia reynaudi*	Melolonthinae	Groundnut	KU35556
Arunachal Pradesh					
4	Pasighat	*Maladera insanabilis*	Melolonthinae	Light trap	KU35554
5	Pasighat	*Maladera insanabilis*	Melolonthinae	Potato	KU35558
Gujarat					
6	Anand	*Adoretus cupreus*	Rutelinae	Light trap	KT252350
7	Anand	*Adoretus duvauceli*	Rutelinae	Light trap	KT254356
Karnataka					
8	Chikkaballapura	*Onthophagus nuchicornis*	Scarabaeinae	Dung	KU355552
9	Chintamani	*Onthophagus nuchicornis*	Scarabaeinae	Dung	KU517667
10	Kolar	*Protaetia cuprea ignicollis*	Cetoninae	Light trap	KU 317768
11	Nandi Hills	*Copris tripartitus*	Scarabaeinae	Cowdung	KU665392
12	Shivamogga	*Leucopholis lepidophora*	Melolonthinae	Arecanut	KU665428
13	Thirthahalli	*Leucopholis lepidophora*	Melolonthinae	Arecanut	KU665428
14	Belagavi	*Leucopholis burmeisteri*	Melolonthinae	Areca nut	KU665432
New Delhi					
15	IARI campus	*Anomala ruficapilla*	Rutelinae	Fallow land	KY640303
16	IARI campus	*Anomala bengalensis*	Rutelinae	Soybean	KY640304
Meghalaya					
17	Shillong	*Protaetia* sp.	Cetoninae	Light trap	KM657490
Tamil Nadu					
18	Theni	*Anomola dimidiata*	Rutelinae	Sugarcane	KU517668
19	Thanjavur	*Hybosorus illigeri*	Scarabaeinae	Cowdung	KU317747
Termites					
Andhra Pradesh					
1	Ambajipeta	*Hypotermes xenotermetis*	Macrotermitinae	Coconut	KY293420
2	Ambajipeta	*Odontotermes obesus*	Macrotermitinae	Sugarcane	KY474376
3	Anakapalle	*Odontotermes omathuri*	Macrotermitinae	Sugarcane	KY676778

Arunachal Pradesh					
4	Pasighat	*Macrognathotermes errator*	Macrotermitinae	Mandarin	KM657789
Jharkhand					
5	Ranchi	*Odontotermes mathuri*	Macrotermitinae	Sugarcane	KY676779
6	Ranchi	*Odontotermes formosanus*	Macrotermitinae	Sugarcane	KY552744
Kerala					
7	Thrissur	*Odontotermes longignathus*	Macrotermitinae	Coconut	KY593993
Karnataka					
8	Kolar	*Odontotermes longignathus*	Macrotermitinae	Tamarind	KX611498
9	Chikkaballapura	*Odontotermes longignathus*	Macrotermitinae	Pan trap	KX583491
10	Thirthahalli	*Odontotermes wallonesis*	Macrotermitinae	Arecanut	KT224388
11	Belagavi	*Odontotermes holmgren*	Macrotermitinae	Arecanut	KT224389
12	Sirsi	*Nasuitermes* sp.	Nasutitermitinae	Arecanut	KT224390
13	Mudigere	*Dicuspiditermes krishna*	Macrotermitinae	Eucalyptus	KT224391
14	Udupi	*Microtermes obesi*	Macrotermitinae	Neem	KM657488
Mizoram					
15	Mizoram	*Hypotermes makhamensis*	Macrotermitinae	Pan trap	KX444138
Meghalaya					
16	Shillong	*Microtermes mycophagus*	Macrotermitinae	Pan trap	KX495579
Tamil Nadu					
17	Theni	*Nasutitermes exitiosus*	Macrotermitinae	Gauva	KM657488
18	Coimbatore	*Odontotermes longignathus*	Macrotermitinae	Teak	KY563711
19	Madurai	*Trinervitermes togoensis*	Macrotermitinae	Pan trap	KY569522

Table 3. ITS2 gene sequence-based DNA barcoding of collembolan insects

S.No.	Place	Identification	Family	Source	GenBank Acc.
Andhra Pradesh					
1	Tirupati	*Isotomurus balteatus*	Isotomidae	Marshy land	KY607523
2	Kadapa	*Lepidocyrtus heterolepsis*	Entomobryidae	Marshy land	KY607525
Karnataka					
3	Bengaluru	*Cyphoderus javanus*	Entomobryidae	Humus	KY609614
4	Malur	*Lepidocyrtus lignorum*	Entomobryidae	Soil litter	KY609615
5	Mandya	*Lepidocyrtus* sp.	Entomobryidae	Soil litter	KY607524
6	Shivamogga	*Smiunthurides appendiculatus*	Sminthurididae	Forest area	KY607521
7	Kolar	*Lepidocyrtus exploratus*	Entomobryidae	Soil litter	KY609515
8	Kanakapura	*Bourletiella hortensis*	Bourletiellidae	Soil litter	KY609514
Tamil Nadu					
9	Coimbatore	*Smiunthurus viridis*	Sminthurididae	Soil litter	KY609549
10	Hosur	*Isotomia thermophilia*	Isotomidae	Soil litter	-
Uttar Pradesh					
11	Varanasi	*Crytptopygus tridentatus*	Isotomidae	Humus	KY609541

Table 4. Scarabaeid beetle specimens deposited at NBAIR repository with barcode data

S.No.	Location	Field ID	Museum ID	Latitude	Longitude	Identification	BINs
1	Anand	Guj Sc-4	SCA-7	22.258°	71.192°	*Adoretus flavus*	ADB2802
2	Anekal	Anekal SC- 4	SCA-1	12.711°	77.691°	*Phyllopertha horticola*	ADA4139
3	Chikkaballapura	Chik SC-1	SCA-6	13.432°	77.728°	*Onthophagus nuchicornis*	AAZ7167
4	Chikkaballapura	Chikka-SC-7	SCA-8	13.432°	77.728°	*Onthophagus nuchicornis*	AAZ7167
5	Chintamani	Chin-Sc-1	SCA-9	13.402°	78.055°	*Onthophagus nuchicornis*	AAZ7167
6	Dasarahalli	DAST SC-14	SCA-4	13.096°	77.835°	*Holotrichia serrata*	ADA3548
7	Dasarahalli	DAST SC-19	SCA-5	13.096°	77.835°	*Anomala ruficapilla*	AAP8590
8	Dasarahalli	DAST SC- 16	SCA-1	13.096°	77.835°	*Protaetia cuprea*	ADA4139
9	Dodda Shivanahalli	Doddashiv SC-1	SCA-16	12.518°	78.213°	*Phyllopertha horticola*	ADA8332
10	Dodda Shivanahalli	Doddashiv SC-2	SCA-17	12.518°	78.213°	*Phyllopertha horticola*	ADA8332
11	Mudhigere	Mudhi-SC-2	SCA-19	13.136°	75.64°	*Onthophagus auritus*	ADA5841
12	Nandi Hills	Nand-SC-1	SCA-20	13.136°	75.64°	*Onthophagus coenobita*	ADA5611
13	Nandi Hills	Nand-SC-2	SCA-21	13.136°	75.64°	*Onthophagus coenobita*	ADA5611
14	Nandi Hills	Nand-SC-3	SCA-22	13.136°	75.64°	*Copris tripartitus*	ADA6490
15	Nandi Hills	Nand-SC-5	SCA-23	13.136°	75.64°	*Onthophagus coenobita*	ADA5611
16	Rajankunte	Rajan-SC-1	SCA-10	12.971°	77.594°	*Onthophagus nuchicornis*	AAZ7167
17	Theni	Then-GB-1 (a)	SCA-11	10.010°	77.467°	*Anomala dimidiata*	ADA6471
18	Valampari	Valam SC- 1	SCA-3	12.792°	79.818°	*Exomala pallidipennis*	ADA4359

Table 5. Termite specimens deposited at NBAIR repository with barcode data

S.No.	Location	Field ID	Museum ID	Latitude	Longitude	Identification	BINs
1	Attur	Attur TE-7	T-2	13.099°	77.568°	*Odontotermes longignathus*	ACY9035
2	Attur	Attur-TE-3	T-19	13.105°	77.563°	*Hypotermes xenotermitis*	ADE0036
3	Marathahalli	MaratTE-1	T-9	12.959°	77.697°	*Hypotermes xenotermitis*	ADB9612
4	Mysore	Mys TE-2	T-1	12.296°	76.639°	*Hypotermes xenotermitis*	ADE0036
5	Mizoram	Mizo-TE-1	T-24	23.164°	92.937°	*Hypotermes makhamensis*	ADE0161
6	Mizoram	Mizo-TE-2	T-25	23.164°	92.937°	*Hypotermes makhamensis*	ADE0161
7	Ooty	Ooty-TE-2	T-12	11.00°	78.00°	*Nasutitermes octopilis*	AAU3458
8	Theni	TN-1	T-26	11.127°	78.656°	*Trinervitermes togoensis*	ADE0334
9	Sivaganga	Sivaganga TE-1	T-4	9.843°	78.481°	*Odontotermes longignathus*	ACY9035
10	Sivaganga	Sivaganga TE-2	T-7	9.843°	78.481°	*Hypotermes xenotermitis*	ACW3617
11	Sivaganga	Sivaganga TE-3	T-8	9.843°	78.481°	*Hypotermes xenotermitis*	ACW3617

Phylogenetic analysis was carried out in MEGA version 7.0.14 software. Distinct species-specific clusters for scarabaeid beetles was observed. All *Onthophagus nuchicornis* collected from parts of Karnataka were placed in the top cluster with the bootstrap value and branch length of 19–100 and 0.00–0.10, respectively. *Anomala ruficapilla* clustered with *Exomala pallidipennis* and diversified as a polyphyletic clade. The geo-species specific cluster 2 (Karnataka) and 4 (Tamil Nadu) was mediated by *Adoretus flavus* from Gujarat, which clustered with *Copris tripartitus* from Karnataka. All samples of *Phyllopertha horticola* from Karnataka formed a distinct cluster-5 (Fig. 31).

The dendrogram for termite's depiced that all the *Odontotermes longignathus* populations occurred in a single cluster with one of the same species from Kolar, as an antecedent that evolved recently. The species of *Hypotermes xenotermitis* from Attur (Karnataka), Uddanpal (Maharashtra) have diverged from the cluster of *Hypotermes makhamensis* from Mizoram. *Trinervitermes togoensis* from Tamil Nadu was observed as an ancestor for the above described clusters, leaving *Hypotermes xenotermitis* (KU687341) Uddanpl as an outgroup (Fig. 32).

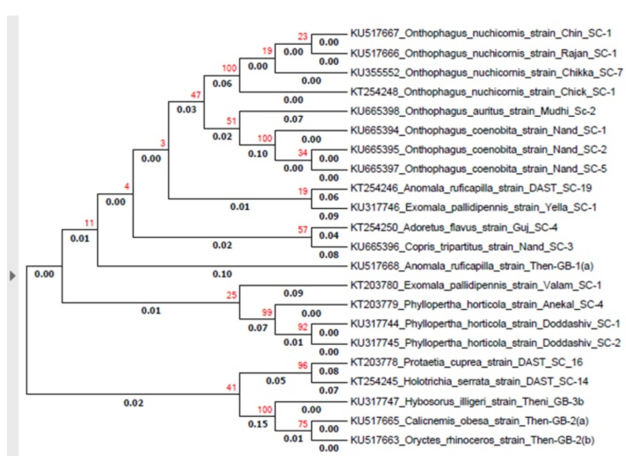


Fig. 31. Phylogeny of scarabaeid beetles from various locations

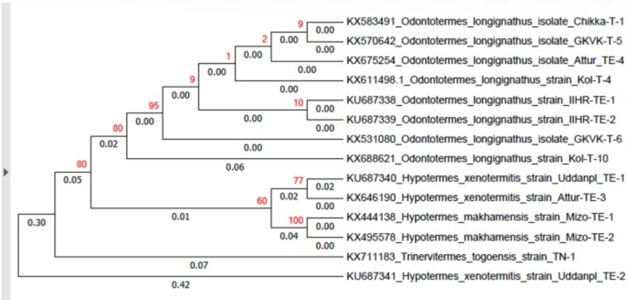


Fig. 32. Phylogeny of termite samples from various locations

Parasitoids and predators

Molecular characterisation and DNA barcodes were generated for 128 agriculturally important parasitoids and predators based on COI gene and ITS2 gene regions. The whole transcriptome of the chrysopid predator, *Chrysoperla zastrowi sillemi* has been sequenced.The raw data has been submitted to the SRA archives of NCBI and registered as separate bioprojects. Six populations of chrysopid collected from different states were identified as *Chrysoperla zastrowi sillemi* using CO1 gene and ITS-2 regions. DNA barcode based on COI gene have been developed for 10 species of sphecid wasps *viz*., *Carinostigmus atterimus*, *Carinostigmus* sp., *Stigmuscuculis*, *Stigmus* sp., *Bembecinus* sp., *Isorhopalum* sp. and *Diadontus* sp.

The following 13 spiders (Araneae) were identified based on the sequence information of CO1 gene: *Argiope trifascita*, *Neoscona theisi*, *Cyrtophora cicatrosa*, *Cyrtophora cicatrosa*, *Tetragnatha javana*, *Pardosa altitudes*, *Neoscona mukerjei*, *Argiope anasuja*, *Oxyopes shweta*, *Argiope anasuja*, *Neoscona theisi*, *Oxyopes shweta*, and *Cyrtophora cicatrosa* (Table 6). Forty-one species of *Parapanteles* (XQ134587–134617) were characterised using CO1 gene. 13 species of *Parapanteles* (KJ078694–078707) were characterised using wingless gene.

The following semi aquatic bugs (Heteroptera: Geromorpha) were characterised based on the sequence information of CO1 gene: *Limnometra fluviorum*, *Laccotrephes griseus*, *Amemboa kumari*, *Chimarrhometra orientalis*, *Ptilomera himalayensis*, *Hydrometra greeni*, *Metrocoris dinenedrai*, *Metrocoris deceptor*, *Ptilomera agroides* and *Metrocoris sikkimensis* (Table 7).

Table 6. Molecular characterisation of spiders using COI gene region

S.No.	Species	Location in Anand district, Gujarat	GenBank Acc.
1	*Argiope trifascita*	Amod	KM054536
2	*Neoscona theisi*	Asodar	KM054537
3	*Cyrtophora cicatrosa*	Davol	KM054538
4	*Cyrtophora cicatrosa*	Khadol	KM054539
5	*Tetragnatha javana*	Gopalpura	KM054540
6	*Pardosa altitudus*	Khadol,	KM054541
7	*Neoscona mukerjei*	Ishwarwada	KM054542
8	*Argiope anasuja*	Petlad	KM054543
9	*Oxyopes shweta*	Pamol	KM054544
10	*Argiope anasuja*	Sunav	KM054545
11	*Neoscona theisi*	Jahangirpura	KM054546
12	*Oxyopes shweta*	Sojitra	KM054547
13	*Cyrtophora cicatrosa*	Gopalpura	KM054548

Table 7. Molecular characterisation of semi-aquatic bugs collected from Sikkim Himalaya using COI gene

S.No.	Species	GenBank Acc.
1	*Limnometra fluviorum*	KX300087
2	*Laccotrephes griseus*	KX365491
3	*Amemboa kumari*	KX775121
4	*Chimarrhometra orientalis*	KY018602
5	*Ptilomera himalayensis*	KY018603
6	*Hydrometra greeni*	KY041641
7	*Metrocoris dinenedrai*	KY212124
8	*Metrocoris deceptor*	KY283957
9	*Ptilomera agroides*	KY556677
10	*Metrocoris sikkimensis*	KY710902

Resistance monitoring of cotton pink bollworm, *Pectinophora gossypiella* on Bt BGII cotton

Survey and collection of pink bollworm, *Pectinophora gossypiella* on different Bt cotton hybrids expressing *cry1Ac* and *cry2Ab* was carried out in three states *viz*., Gujarat, Karnataka and Andhra Pradesh. In Gujarat, the survey covered 10 cotton growing districts namely, Rajkot, Amreli, Dahod, Vadodara, Anand, Bharuch, Bhavnagar, Surendranagar, Ahmedabad and Junagadh. Similarly one district each in Andhra Pradesh and Karnataka, *i.e.*, Nandyal and Raichur respectively were also surveyed for the collection of pink bollworm. Rearing procedure of pink bollworm was standardised in the laboratory. The field collected larvae were reared on an artificial diet with components like cotton seed flour and chickpea flour among other routine diet constituents.

Fig. 33. Severely damaged Bt cotton (BGII) bolls by *P. gossypiella*

Pink bollworm damage assessment on bolls in terms of per cent locule damage, number of larvae/boll and number of exit holes/boll was done. The data were transformed accordingly and the statistical analysis was done using SAS software. All the boll samples recorded severe infestation of pink bollworm larvae (Fig. 33). A maximum of 84.03% locule damage, 2.09 larvae/boll and up to 2.49 exit holes/boll were observed. The boll damage on different BGII cotton hybrids were found on par with that in desi cotton. The number of moth catches per pheromone trap after second picking in some places exceeded 500 adults/day (Fig. 34). The data indicates that pink bollworms are adapting to BG-II *Bt*-cotton. The damage by BG-II resistant pink bollworms in all the cotton growing districts of Gujarat, Nandyal in Andhra Pradesh and Raichur in Karnataka is significant in 2016-17 crop season and is expected to continue in the years to come.

Fig. 34 Trapped male moths of *P. gossypiella* in sex pheromone traps

Abiotic stress tolerant genes/alleles in insects: *In silico* analysis

Cells of all organisms synthesize a small number of heat-shock proteins (HSPs) in response to thermal and certain other stresses. Insects are exposed to multiple environmental stressors across a variety of habitats. There are multiple mechanisms for stress tolerance, thus allowing insects to successfully occupy virtually all ecological niches. Study of diversity and distribution of stress tolerant gene like HSPs on agriculturally important insects is essential to understand the tolerance mechanisms. Around 330 sequences of HSP 70, HSP 90, HSP 60 and HSP 40 genes were collected from NCBI for various insect orders like Lepidoptera, Diptera, Hymenoptera and Hemiptera for their molecular phylogenetic analysis. The bootstrap value above 90% has been considered for interpretation and it has been found that there were no variations on different insect orders but all are having the same origin.

Mapping *cry* gene diversity and entomocidal activity of indigenous *Bacillus thuringiensis* isolates

Cry gene diversity and entomotoxicity were determined for the *Bacillus thuringiensis* isolates recovered from three North Eastern states (Meghalaya, Tripuram and Assam). Among the *cry* genes *cry16* was most abundant accounting for 43% of the samples followed by *cry10A* accounting for 30% of the samples. Whereas, *cry1* and *cry2* were present in 40% of the samples and occurred together. Bt *cry1* is lepidopteran specific whereas *cry2* is dipteran specific (Fig. 35). Other *cry* genes viz., *cry4* (dipteran) and *cry12* (nematicidal) were documented in 23% of the *Bt* isolates. Cry3 the coleopteran toxin occurred in 16% of the samples.

Preliminary characterization indicated that NBAIR-BtAN4 was toxic to coleopteran pests since it carried the *cry8* gene. Further analysis revealed that it also carried lepidopteran specific *cry1* and *cry2* genes. The isolate was active against coleopteran pests *Oryctes rhinoceros*, *Papilio* sp., *Callosobrochus chinensis* and *Sitophilus oryzae*. It showed very high toxicity against the larvae of *C. chinensis* (LC_{50} 6.8 µg/ml), *Helicoverpa armigera (*LC_{50} 414.59 ng/ml) and *Plutella xylostella* (545.15 ng/ml).

NBAIR, Bengaluru and NCIPM, New Delhi undertook a collaborative trial on field efficacy of Bt formulation against lepidopterans on pigeonpea crop at farmer's field in Gulbarga. Significant reduction in *Helicoverpa armigera*, *Maruca vitrata* and leaf webber, *Grapholita critica* infections was noticed.

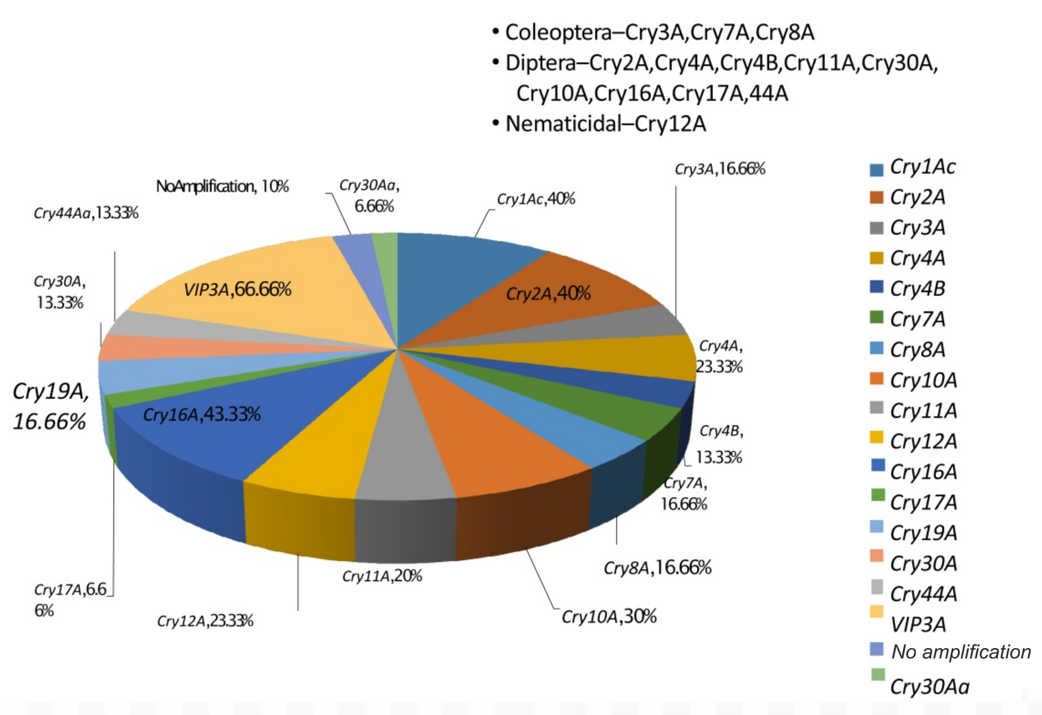


Fig. 35. Distribution of *cry* genes in indigenous isolates of *Bt* collected from northeastern states of India

Microflora associated with insects and their role in host insect fitness

Soil insects

Metagenomics study of the 16S rRNA of the dung beetles, *Onthophagus dama* and *Oniticellus cinctus* was done to understand the species evolutionary relationship and to know the connection with the host through network biology (systems biology). A discrete Gamma distribution was used to model evolutionary rate differences among sites (5 categories (+G, parameter = 0.2900)). The tree is drawn to scale, with branch lengths measured in the number of substitutions per site.

It was obvious from the phylogenetic tree thus constructed that isolates formed a distinct subclade (Figs 36 & 37) in the tree distinguishable from all other reference strains, supported by bootstrap value in neighbour-joining analysis indicating their sequence polymorphism in 16S rDNA region. The data generated was submitted to GenBank as GenBank (*O. dama*), Bioproject ID: PRJNA329583, Biosample id: SAMN05415091 and GenBank (*O. cinctus*), Bioproject id: PRJNA321463, Biosample ID: SAMN05001291. Six different microbial consortia were formulated based on the lignin, cellulose and pectin degrading ability of the gut microbes (Table 8). The microbes were from the gut of soil insects.

Identification	Accession
Enterobacter aerogenes	KX585900
Enterobacter asburiae	KX585902
Enterobacter asburiae	KX585903
Aeromonas caviae	KX585904
Aeromonas sanarellii	KX585905
Ralstonia mannitolilytica	KX585906
Ralstonia solanacearum	KX585907
Aeromonas taiwanensis	KX585908
Enterobacillus tribolii	KX585909
Enterobacter cloacae	KX585910

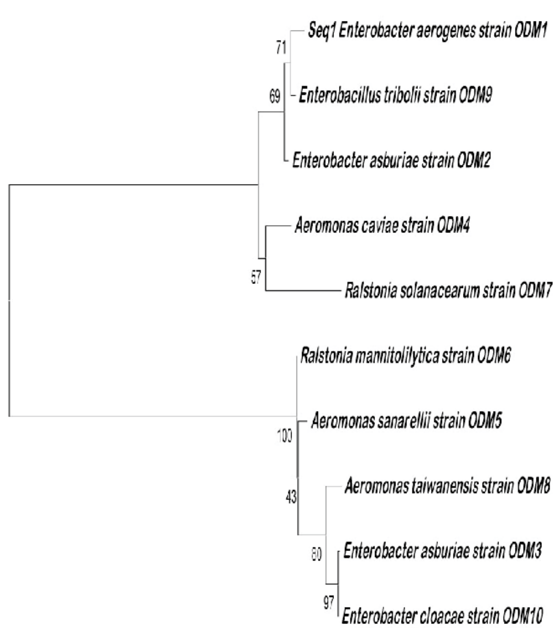


Fig. 36. Molecular cloning and 16S rDNA sequencing based identification of microbial metagenomic DNA from gut of *Onthophagus dama* (GenBank Bioproject ID: PRJNA329583; Biosample ID: SAMN05415091)

Identification	Accession
Uncultured *Dysgonomonas* sp.	KX523835
Uncultured *beta proteobacterium*	KX523836
Uncultured *Enterococcus* sp.	KX523837
Uncultured *Firmicutes bacterium*	KX523838
Enterococcus rotai	KX523839
Gilliamella apicola	KX523840
Peptoniphilaceae bacterium	KX523841
Enterococcus silesiacus	KX523842
Dysgonomonas mossii	KX523843
Enterococcus moraviensis	KX523844
Burkholderiales bacterium	KX523845
Enterococcus caccae	KX523846
Porphyromonas pasteri	KX523847
Gilliamella sp.	KX523849

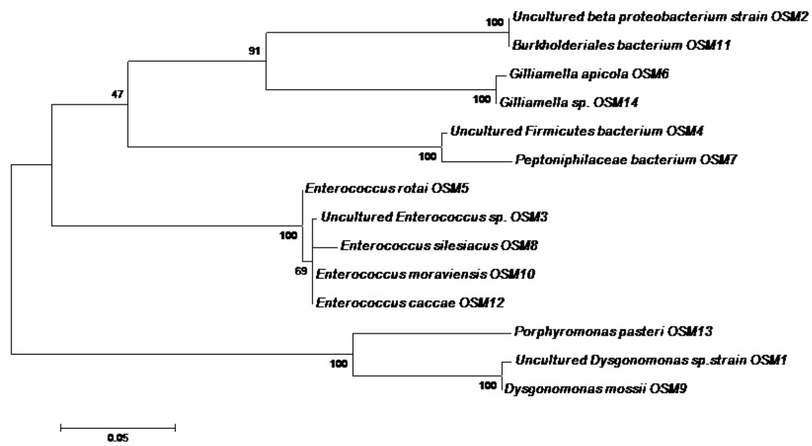


Fig. 37. Molecular cloning and 16S rDNA sequencing based identification of microbial metagenomic DNA from gut of *Oniticellus cinctus*

Table 8. Formulation of microbial consortia

Consortium 1	DHN10.2 - *Bordetella avium*
Source - *Onthophagus dama*	DMN10.3 - *Achromobacter marplatensis* DFY8.16 - *Bacillus tequilensis*
Consortium 2	F30 - *Bacillus subtilis*
Source - *Protaetia aurichalcea*	F21 - *Bacillus stratosphericus* F7 - *P. putida*
Consortium 3	OS5.1 - *Acinetobacter* sp.
Source - *Oniticellus cinctus*	OS10.7 - *Bacillus cereus* OS10.6 - *Kocuria koreensis*
Consortium 4	OPNF5.3 - *Acinetobacter baumannii*
Source - *Onitisphilemon*	OPYH5.15 - *Citrobacter amalonaticus* OPNH10.3 - *Citrobacter freundii*
Consortium 5	HGG25 - *Bacillus pumilus*
Source - *Oryctes rhinoceros*	HGG19 – *Bacillus amyloliquefaciens*
Consortium 6	All of above

Aphids

Metagenomic studies for unculturable aphid microflora were carried out using gDNA isolation, cloning in pGEMT vector, transformation in *E. coli* XL1 blue cells and identification of insert from clones using direct sequencing. A total of 9 clones were identified with >95% similarity in BLAST search. Out of 9 clones 8 showed significant similarity with *Buchnera aphidicola* a (Proteobacteria: Enterobacteriaceae), is the primary endosymbiont of aphids (Table 9). Unculturable microflora representing Enterobacteriaceae were 89% of total population and 11% belonged to Comamonadaceae (Fig. 38). This reveals that the particular bacterium (*Buchnera aphidicola*) is present in higher number (over populated) amongst other microflora of gut.

Qualitative insecticide degradation assays were carried out for twenty four culturable microflora isolated from aphids using minimal media amended with different concentrations of insecticides imidacloprid 17.8% SL and lambda cyhalothrin 5% EC. Growth of microbial cultures streaked on minimal media plates was observed. *Moraxella osloensis* NAE-6, *Stenotrophomonas maltophilia* CCF 2-2, *Exiguobacterium indicum* MPB-2 and *Bacillus subtilis* PDAE1-3 performed better in degradation of both insecticides as revealed by their growth on the plates. Quantitative HPLC analysis of culture supernatant revealed that *E. indicum* strain MPB-2 and *S. maltophilia* strain CCF 2-2 have the ability to degrade the insecticide imidacloprid to the tune of 13.6 and 3.8% (Fig. 39).

Table 9. Unculturable microflora associated with aphids

S.No.	Sequence label	BLAST result	Species	Identity (%)
1	Clone2	NR_025080.1	*Comamonas denitrificans*	99
2	Clone7	KT175926.1	*Buchnera aphidicola* (*Aphis gossypii*)	95
3	Clone8	NR_074512.1	*Buchnera aphidicola* str. Sg	95
4	Clone 9	NR_074512.1	*Buchnera aphidicola* str. Sg	97
5	Clone 11	NR_074512.1	*Buchnera aphidicola* str. Sg	97
6	Clone 12	NR_074512.1	*Buchnera aphidicola* str. Sg	97
7	Clone 13	NR_074512.1	*Buchnera aphidicola* str. Sg	98
8	Clone 15	NR_074512.1	*Buchnera aphidicola* str. Sg	97
9	Clone 19	NR_074512.1	*Buchnera aphidicola* str. Sg	96

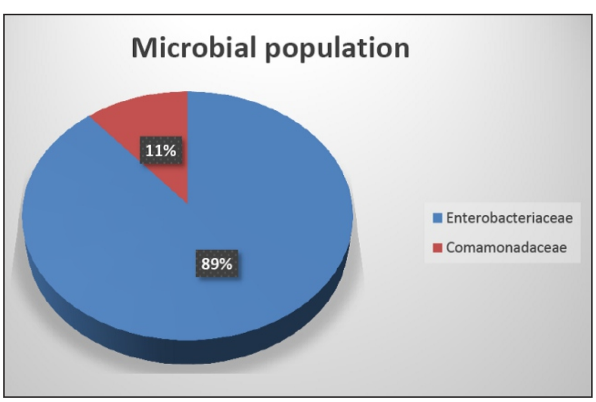


Fig. 38. Generic affiliation of 16S rDNAs sequences obtained from aphids

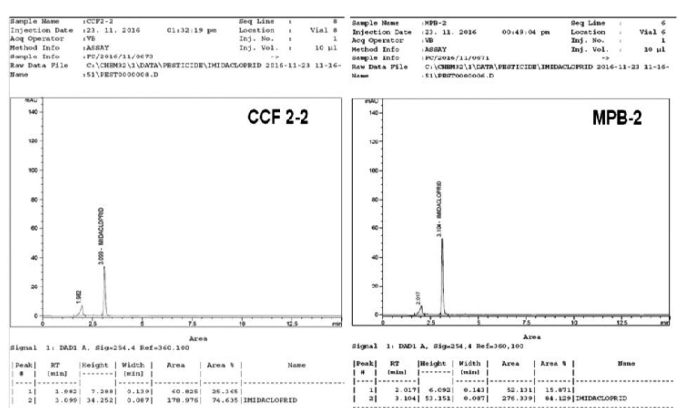


Fig. 39. Quantitative HPLC analysis for microbial imidacloprid degradation (CCF 2-2: *S. maltophilia*-CCF 2-2 and MPB-2: *E. indicum*-MPB-2)

Diversity mapping, DNA barcoding and mitochondrial DNA sequencing of entomopathogenic nematodes (Fig. 40)

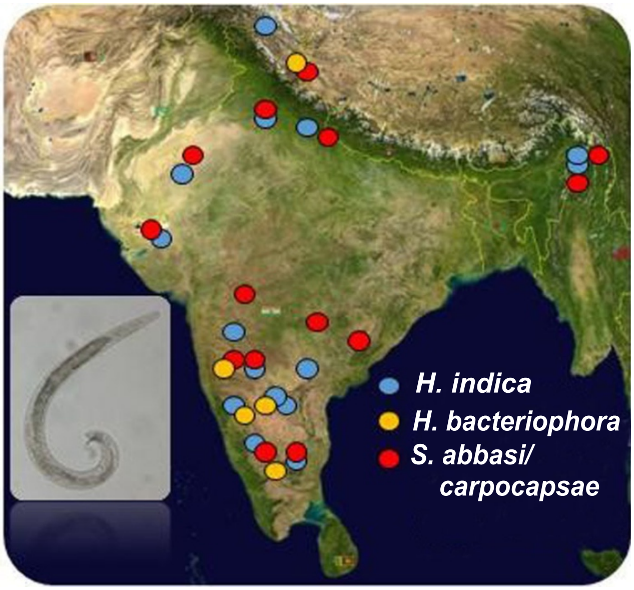


Fig. 40. Distribution of four EPN species recorded in random surveys and sampling

DNA barcoding

COX1 gene based DNA Bar codes were developed for local isolates of *H. indica* (Fig. 41) and *H. bacteriophora* (Fig. 42).

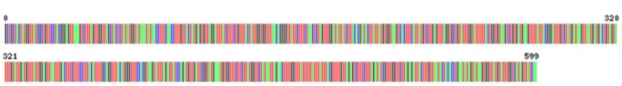


Fig. 41. DNA Bar code developed for local isolate of *H. indica* based on *COX1* gene sequence

Fig. 42. DNA Bar code developed for local isolate of *H. bacteriophora* based on COX1 gene sequence

Mitogenomics of EPN

For the first time, the complete mitochondrial genomes of two entomopathogenic nematodes, *Heterorhabditis indica* and *H. bacteriophora*, were sequenced and the gene distributions were reported (Figs 43 & 44). Mitochondrial genome of *H. indica* comprised 14,556 bp, with AT-rich nucleotide contents (AT ratio of 65.2%), and *H. bacteriophora* of 14,679bp with AT ratio of 64.7%. Thirty-six genes, including 12 protein-coding genes (encoding ATP6, CYTB, COX1, 2 and 3, ND1-6 and ND4L), two rRNA genes and 22 tRNA genes were identified in the genomes.

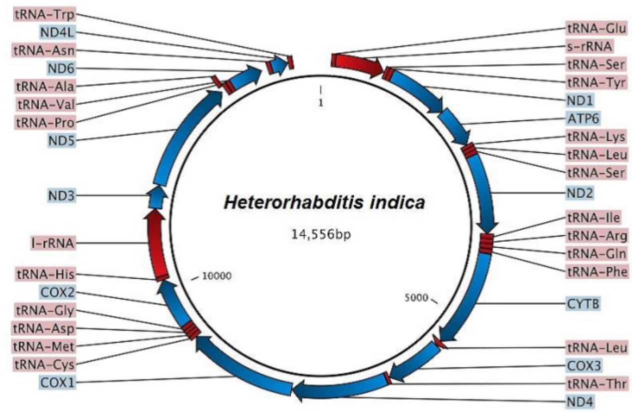


Fig. 43. *Heterorhabditis indica* mitochondrial circular map

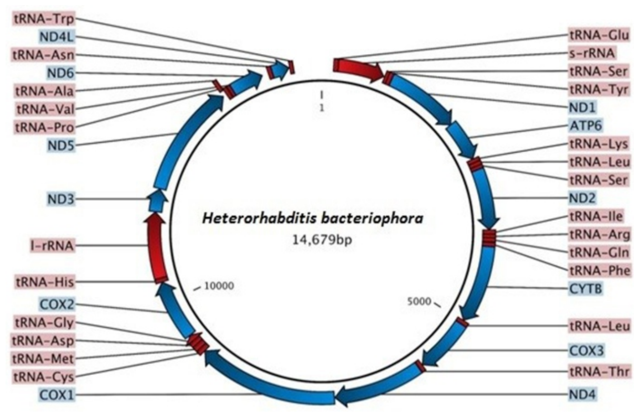


Fig. 44. *Heterorhabditis bacteriophora* mitochondrial circular map

Biology and functional variability of EPN

Biology and functional variability of four populations of *Heterorhabditis* and *Steinernema* completed on mustard saw fly, brinjal ash weevil, wax moth, *Holotrichia serrata* and black soldier fly.

First report on importance of impact of atmosphere-soil warming on interactions between soil-dwelling herbivore-insects and ecological services efficiency of beneficial entomopathogenic nematodes (Fig. 45).

Field efficacy of EPNs for the management of insect pests

Steinernema abbasi, Heterorhabditis bacteriophora and *H. indica* and their formulations demonstrated virulence against SPW (Fig. 46) with larval mortalities of 55–70% in 48–72h. WP formulations of all 3 EPNs recorded significant control of sweet potato weevil (SPW) grubs and recorded higher tuber and stem damage reduction rate. A positive correlation was observed between application dose and per cent mortality of grubs of brinjal ash weevil.

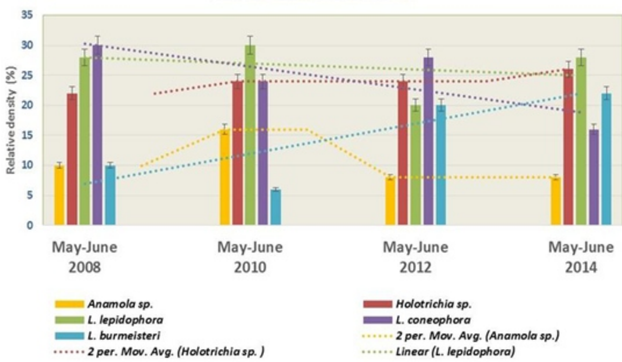


Fig. 45. Dynamics of relative density of whitegrub communities in arecanut and sugarcane with trends at Sulya, Karnataka, during 2008-14

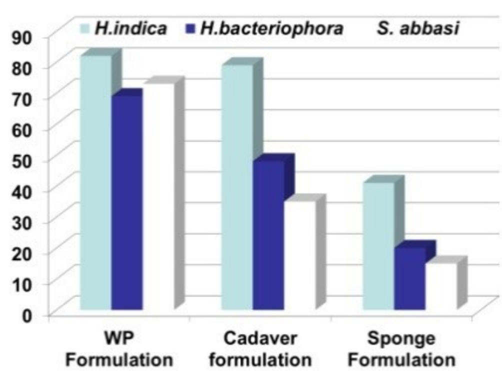


Fig. 46. Percent reduction in SPW larvae in EPN treated plots (Mean of 2 cropping seasons) on sweet potato.

Safety to detritivorous insects and pollinators

Larvae of black soldier fly recorded mortality at 80–100 IJs/larva after 48 h of exposure to *H. indica* and *S. abbasi*. The nematodes completed their lifecycles inside the cadavers but failed to emerge even after seven days.

Division of Insect Ecology

Introduction and studies on natural enemies of some new exotic insect pests and weeds

Papaya mealybug and its natural enemies on papaya and other alternate hosts

The survey conducted in different parts of the state and also the feedback from various AICRP (BC) centers revealed that the papaya mealybug, *Paracoccus marginatus* did not reach pest status and no report of severe incidence of papaya mealybug was observed from mulberry and teak, or any other forest trees during 2016-17. Only 18 requests for *Acerophagus papayae* was received this year.

Erythrina gall wasp management

Quadrastichus erythrinae was found in very low populations in Kolar, Mandya, and Ramnagar districts. *Aprostocetus gala* was found to be the major parasitoid of *Q. erythrinae*. 15–35% parasitisation observed in field.

Establishment of *C. connexa* gall fly

Chromolaena weed biocontrol agent *C. connexa* released at different places has established upto 15 galls per 5 minutes search in 450 m around the released spot. In Puttur area it has spread around 22–25 km from the released spot and in Tataguni estate it has spread to the nearby forest area.

Life cycle of *Anagyrus amnestos* a parasitoid of Madeira mealybug, *P. madeirensis*

Anagyrus amnestos, a koinobiont, gregarious, super parasitoid, completed its larval period in 10–11 days (mean = 8.59 ± 0.50), and its pupal period in 8–10 days (mean = 8.59 ± 0.5). Adult male lived for 3–4 days (mean = 2.86 ± 0.15) with honey and for 1–2 days (mean = 1.3 ± 0.57) without honey.

Invasives observed during 2016-17

Aleurocanthes bangalorensis (Fig. 47) was observed to be severe on jamun trees in and around Bangalore. *Acletoxenus indicusa* dipteran maggot was found feeding on the whitefly. Two encyrtids and one eulophid parasitoid collected have been handed over for identification.

Fig 47. *Aleurocanthes bangalorensis* (top); larva and adult of *Acletoxenus indicus* (bottom)

Heavy incidence of armyworm in Kerala and Assam

Heavy incidence of army worm was recorded in parts of Kerala and Assam. Rice crop was severely affected in these areas. Utilization of Entomopathogenic nematodes and attracting birds by spreading boiled rice was recommended for the management of pests.

Heavy incidence of *Ferrisia virgata* on fruit crops

Heavy incidence of tailed mealybug *F. virgata* was recorded in guava and custard apple in Kanakapura district. About 12 ha of guava was severely affected by the pest. Custard apple in Ramnagar was severely attacked by the pest. Release of *Cryptolaemus* beetles @10 per plant was advocated for its management.

Severe incidence of coconut black-headed caterpillar

Heavy incidence (up to 85%) was recorded in Kadur, Arasikere, Hassan, Maddur, Kollegal, Mysuru, Mandya and Chennarayapattana taluks. Low level of parasitisation by *Goniozus nephantidis* was recorded (less than 10%). *Bracon* was found to the tune of 25–30% in Maddur and Kollegal areas. *Parena* sp., a carabid beetle was recorded in Maddur and one reduviid bug was also recorded feeding on larvae in addition to anthocorid bugs (Fig. 48). Coconut whitefly, *Aleurodicus rugioperculatus* was also found as invasive in various parts of Kerala, Tamil Nadu and Karnataka.

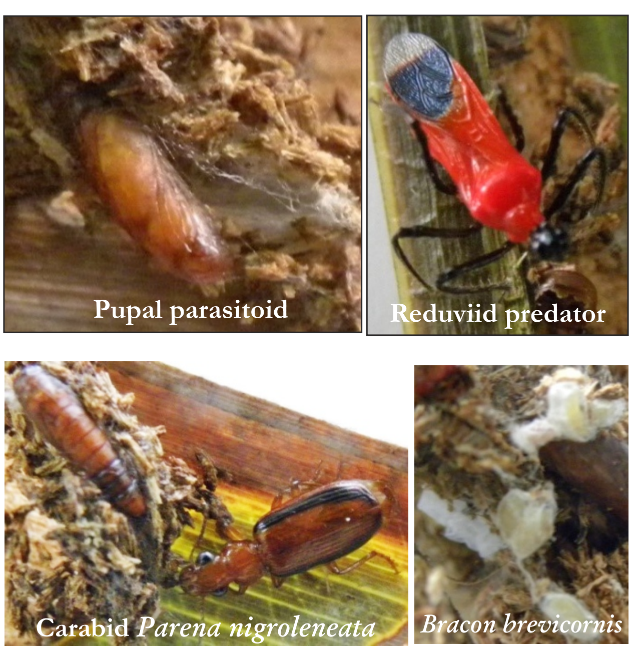


Fig. 48. Natural enemies of coconut black-headed caterpillar, *Opisina arenosella*

Quarantine Screening of imported silk worm from Bulgaria

A bivoltine silkworm, was imported from Bulgaria under an exchange programme between CSRTI, Mysuru, and Bulgaria. The breed KOM-2 with high silk content was imported in the egg stage from Sericulture and Agriculture Experiment station, Vratza, Bulgaria during the first week of November 2016. Quarantine studies were conducted for mother moth examination, egg contamination, egg hatching, purity, etc. The worms were handed over to CSRTI, Mysuru, after basic quarantine screening for further yield analysis.

Survey and monitoring of insect pests/new invasives and their natural enemies

The rugose spiralling whitefly (RSW), *Aleurodicus rugioperculatus* has invaded our country and has been found infesting coconut, banana, custard apple, sapota, mango, guava, water apple, Indian almond, rubber fig and several ornamental plants in Tamil Nadu, Andhra Pradesh, Karnataka and Kerala. Beside these plants, a few life stages of RSW were noticed on jackfruit, cocoa, neem, curry leaf, garden cordon (Figs 49 & 50).

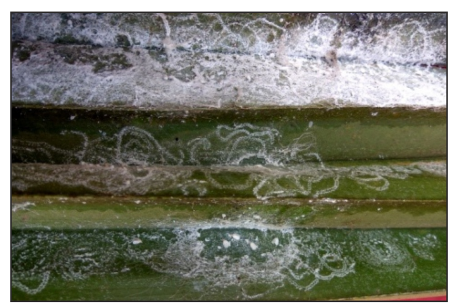


Fig. 49. Damage by RSW

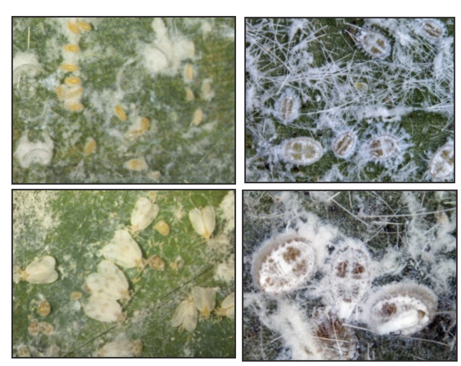


Fig. 50. Lifestages of RSW

However, coconut, banana and Indian almond seem to be the most preferred host plants in India. This is the first report of this pest in India as well as in the Oriental region. It was initially noticed to feed on coconut in Pollachi and Coimbatore (Tamil Nadu) in the month of

August 2016 and later on it was recorded from other parts of peninsular India.

The severity of infestation reached an alarming situation causing extensive damage to coconut, banana, sapota and Indian almond and has assumed major pest status. Occurrence in Pollachi in Coimbatore and Udumalpet in Tiruppur district in Tamil Nadu; almost entire district in Kerala; Rajamundry district in Andhra Pradesh and Udupi and Mangaluru districts in Karnataka have so far, been confirmed.

The most commonly recorded natural enemies of RSW were the predatory green lacewing (*Dichrysa astur*), coccinellids (*Cybocephalus* sp.; *Jauravia pallidula, Cheilomenes sexmaculata*), predatory mites (*Neoseiulus* sp.) and aphelinid parasitoids (*Encarsia guadeloupae*, *Encarsia dispersa*). Across locations, the natural parasitism by this parasitoid ranged from 15.0–60.0%. During the surveys, several natural enemies of *B. tabaci* such as parasitoids *Encarsia* sp., and *Eretomocerus* spp. complex, chrysopid, *Chrysoperla zastrowi sillemi,* predatory mites (*Neoseiulus* sp. and *Lasioseus* sp.), a few coccinellids (*Cheilomenes sexmaculatata* and *Brumoides* sp. were observed (Fig. 51).

Surveys to assess the damage caused by pink bollworm, *Pectinophora gossypiella* on BGII Bt cotton, ash weevil on brinjal and *Tuta absoluta* on tomato and other solanaceous crops (Fig. 52) were undertaken and the details are furnished in Table 10.

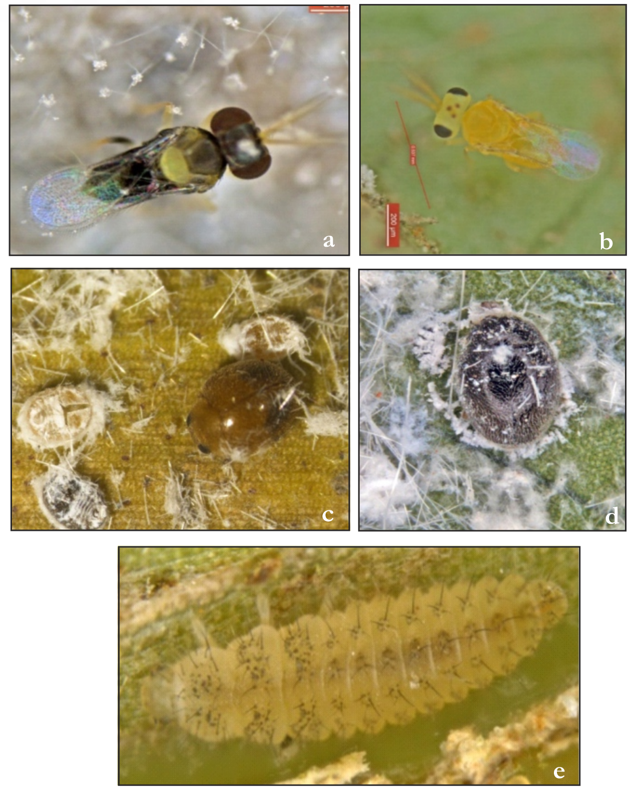


Fig. 51. Natural enemies a. *E. guadeloupae,* b. *E. dispersa* c. *Jauravia* sp., d-e. *Cybocephalus* sp. associated with RSW

Table 10. Survey and monitoring of insect pests/new invasives and their natural enemies

S.No.	Pest surveyed	States surveyed	Host crops	Pest status	Natural enemies observed
1	Tomato leafminer/ pinworm, *Tuta absoluta*	Karnataka, Tamil Nadu, Andhra Pradesh, Telangana, Maharashtra, Gujarat, Odisha, West Bengal	Tomato, potato, brinjal, *Solanum nigrum*, *S. viarum*	Moderate to severe on tomato (1.21 to 32.5% leaf mines and up to 21.3% fruit damage)	*Nesidiochrois tenuis*
2	Ash weevil	Tamil Nadu, Karnataka and Andhra Pradesh	Brinjal	Moderate to severe (9.1 to 17.2% plant wilting due to root damage)	-
3	Rugose spiralling whitefly, *Aleurodicus rugioperculatus*	Karnataka, Tamil Nadu, Andhra Pradesh, Kerala	Coconut, banana, custard apple, sapota, mango, guava, water apple, Indian almond, rubber fig and several ornamental plants	Severity ranged from 40-60% on coconut and 25-40% on banana	*Dichrysa astur*, *Cybocephalus* sp., *Jauravia pallidula*, *Cheilomenes sexmaculata*, *Neoseiulus* sp., *Encarsia guadeloupae*, *E. dispersa*
4	Pink bollworm, *Pectinophora gossypiella*	Gujarat, Karnataka, Andhra Pradesh	Cotton	Severe (18.3 to 90.7% damaged bolls on Bt BGII cotton hybrids)	-

Fig. 52. *T. absoluta* damages on tomato, brinjal and potato

Diversity and predator–prey interactions in predatory mirids and geocorids

A protocol to rear *Geocoris ochropterus* was standardised. *Geocoris ochropterus* was reared on beans and *Sitotroga cerealella* eggs. One oviposition container (500 ml) can accommodate 6 pairs. A female on an average lays 176 eggs with 68% hatchability. So from one container 714 newly emerged nymphs can be harvested. Approximately 83% nymphs develop into adults. So from 6 pairs of adults nearly 593 adults can be harvested in 32–35 days. (Fig. 53)

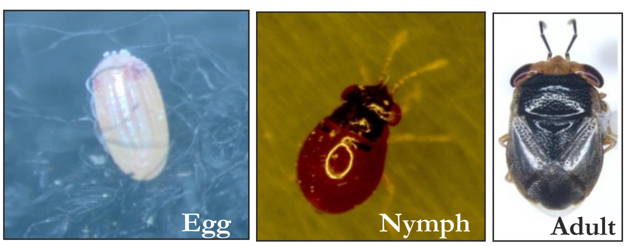


Fig. 53. Different stages of *G. ochropterus*

Feeding potential of *G. ochropterus* on *S. cerealella* eggs was studied. The total number of eggs fed was about 586 during the nymphal period. Total feeding by one female was 3372 eggs and feeding per day was 51.25 eggs. Adult male fed upon 2306.5 eggs and mean feeding per day was 50 eggs (Table 11).

Table 11. Feeding potential of nymph and adult of *Geocoris ochropterus* on *Sitotroga cerealella* eggs

Stage	Average no. of eggs consumed day/ individual	Total no. of eggs by nymph/ adult
1st instar nymph	7.25±1.68	43.5±3.32
2nd instar nymph	14.06±3.10	56.25±3.96
3rd instar nymph	24.06±2.71	96.25±5.45
4th instar nymph	29.65±0.79	148.25±1.33
5th instar nymph	40.29±1.07	241.75±1.30
Total feeding by nymph	-	586±11.03
Adult male	50±2.12	2306.5±11.64
Adult female	51.25±1.25	3372±11.24

Geocoris ochropterus fertility table was studied in the laboratory on *Sitotroga cerealella* eggs. The net reproductive rate was 28.60. The approximate duration of a generation, Net generation time of the predator when reared on *S. cerealella* were 51.9 and 56.77 respectively. The finite rate of increase, hypothetical F_2s and weekly multiplication rate were 1.06, 817.96 and 1.50, respectively when reared on *S. cerealella* (Fig. 54).

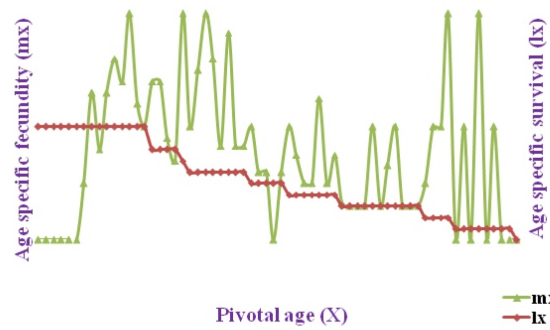


Fig. 54. Age specific survival and fecundity of *Geocoris ochroptreus* on *Sitotroga cerealella* eggs

Biology of the geocorid predator, *G. superbus* was studied under laboratory conditions (Fig. 55) using UV irradiated eggs of the alternate host, *S. cerealella*. The mean incubation period was ten days. A total of five nymphal instars was recorded and the total developmental period was 41.2 days with a nymphal period of 31.2 days. Longevity of adult male and female was 24.8 and 30.0 days, respectively. Mean fecundity per female was 29.4 eggs.

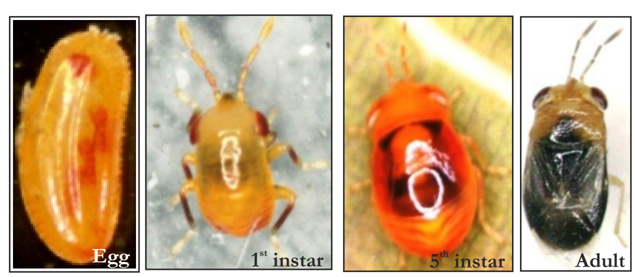


Fig. 55. Different stages of *G. superbus*

Pollinator diversity with special reference to non-*Apis* species

Totally, 190 specimens of non-Apis bees were collected and labelled. Seven species were added to the 39 species in the Institute repository.

An interesting behaviour of nest construction of *Megachile laticeps* in a dry flower of *Markhamia lutea* was observed and detailed nest architecture and biology of the bee were studied (Figs 56 & 57)

Fig. 56. Nest of *M. laticeps* in a dried flower of *Markhamia lutea*

Fig. 57. Nest architecture of *M. laticeps*

Spiders of the families Oxyopidae (*Peucetia viridans* and *P. viridana*) and Thomisidae (*Thomisus* sp.) and mantids were found to be major natural enemies of bees (Fig. 58).

Fig. 58. *Xylocopa* bee caught by *P. viridana*

Habitat manipulation as a tool to conserve beneficial insects

Documentation of beneficial insects in different agro-ecosystems

Diversity and richness of natural enemies was found to be higher in the fields planted with main crop + intercrop/border crop and lower diversity of natural enemies was noticed in the sole crop.

Pithy stems and bamboo trap nests – an efficient way to conserve native bees

Different species of bees and wasps, viz. *Ceratina binghami*, *C. hieroglyphica*, leaf cutter bee *Megachile lerma* and sphecid wasps were found to nest in the pithy stems of *Caesalpinia pulcherrima* with 80 per cent acceptance of nests. The egg to adult stage of small carpenter bee, *C. binghami* was completed in 41.67 days in the pithy trap nests of *C. pulcherrima* (Figs 59 & 60). Bamboo trap nest diameter of 5.0 to 10.00 mm was found to be the optimum diameter size of the trap nests as reflected by the highest per cent acceptance, per cent emergence and more number of cells built by the leaf cutter bee, *M. lanata*.

Fig. 59. Nest architecture of *C. binghami* with different stages

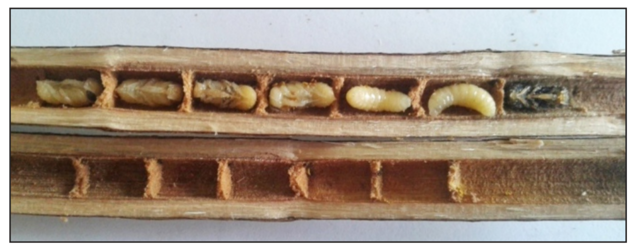


Fig. 60. Full brood nest of *C. binghami*

Role of native buzz pollinating bees in enhancing fruit and seed set in tomatoes

The fruit set, weight, diameter and seed set (Table 12) of tomatoes was significantly higher in the flowers pollinated by the blue banded bee, *Amegilla zonata* followed by the sweat bee *Hoplonomia westwoodi* and the lowest in the flowers that received wind pollination.

Table 12. Influence of three pollination treatments over the fruit parameters of tomatoes

Pollination treatments	Fresh fruit weight (g)	Fruit diameter (mm)	Number of seeds per fruit
Pollination by blue banded bee, *A. zonata*	63.79[a]	57.04[a]	177.12[a]
Pollination by sweat bee, *H. westwoodi*	46.96[b]	43.04[b]	140.50[b]
Wind pollination	25.11[c]	25.50[c]	56.63[c]
Tukey's HSD (0.05%)	59.64	34.59	61.39

Detritivorous insects and associated microorganisms for their scope in farm waste management

Colonies of the detritivorous insects, *Hermetia illucens* (black soldier fly) and *Protaetia* sp. (a scarab beetle) were established in the laboratory. A technique to mass culture *H. illucens* on farm and kitchen wastes has been standardised. It was observed that release of the black soldier fly on farm and kitchen waste resulted in up to 70% reduction in biomass. With regard to biology, a single female fly can lay up to 620 eggs with incubation period of 4–5 days. The larval duration ranging from 14–25 days depends on the organic waste used. Pupal duration lasted about a week (Fig. 61).

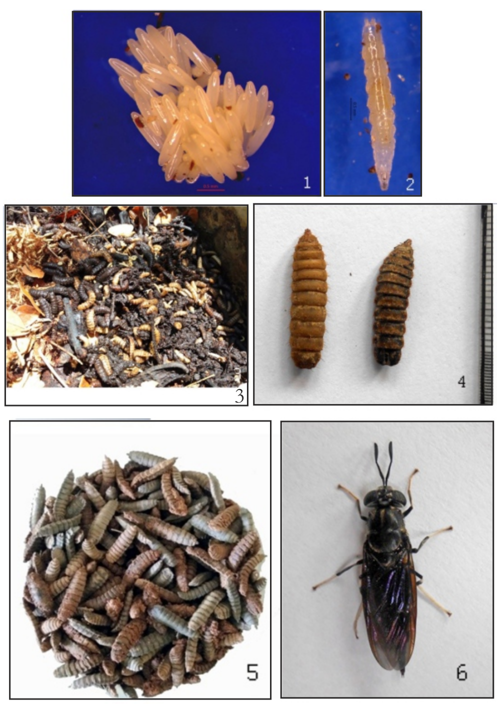


Fig. 61. Different life stages of Black soldier fly, *Hermetia illucens* (L.): 1. creamy white eggs; 2. first instar larva; 3. larvae feeding on farm waste; 4. fully grown larva and pupa; 5. Harvested pupae; 6. adult female.

Preliminary studies on the biology of *Protaetia* sp. revealed that, it requires 5–6 months for completion of one generation. It has four larval instars. Immature stages of this beetle feed on the decaying organic matter of crop residues/wood chips - which mixes the organic and inorganic material and redeposits them in the form of cylindrical pieces of excrement. In this way, grubs turn over the soil and enrich it with organic matter. Larva constructed small earthen cells and pupated inside.

The pupal period lasted 14 to 15 days. Adults were bright brown with a white band, females are bigger than males. The adult longevity was 25 days. Adult laid solitary eggs @16/female at a depth of 2–4 cm in moist soil. Soil moisture is a crucial factor. Eggs were dirty white and oval in shape.

Studies on exploitation of insects as food and feed

Mass culture of the black soldier fly, *Hermetia illucens* Linnaeus (Diptera: Stratiomyidae) for utilization in poultry and fish feed is being undertaken in the institute (Fig. 62). This is a collaborative research project involving ICAR – National Institute of Animal Nutrition and Physiology (NIANP), Bengaluru, the Central Inland Fisheries Research Institute (CIFRI), Regional Station, Bengaluru and NBAIR.

Fig. 62. Black soldier fly, *H. illucens*

Climate change effect on the diversity and bioecology of some important sucking pests

As a part of climate change effects on sucking pests of okra, brinjal, cauliflower and cabbage, field experiments were conducted by growing these plants both in the open fields as well as in the open-top carbon dioxide (OTC) chambers. The OTCs were maintained @ + 2 °C ambient and at 600 ppm of CO_2. The population of aphids and plant hoppers was counted on the plants at 3 days intervals.

The okra crop was sown (cv. Keyonics) on 16-6-2016 and the number of sucking pests on 50 randomly selected leaves was counted in an area of 2 x 2 cm window. The population dynamics of aphids, *Myzus persicae* on okra was initially observed in mid August and continued till first week of October (Fig. 63). The incidence was found to be very low.

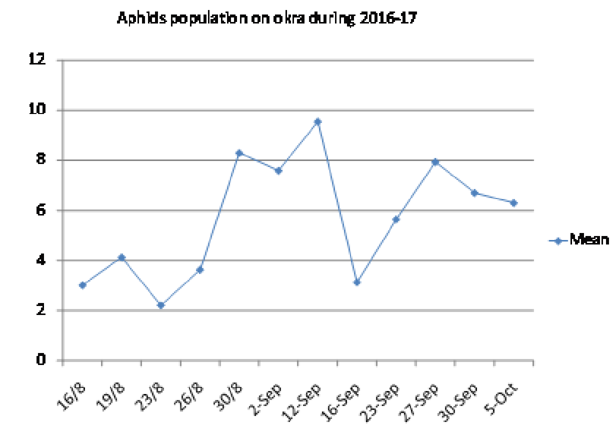


Fig. 63. The population fluctuation of okra aphid in open field conditions. The Y axis indicates the mean number of aphids observed.

In another experiment a cabbage crop (cv. Unnathi) was transplanted on 7-11-2016. The presence of sucking pests on 50 randomly selected leaves was recorded in a window of 4 sq. cm area. The incidence of *Brevicoryne brassicae* was very moderate this year (Fig. 64). The population remained very low till the end of January; after January the population increased rapidly reaching a peak by the end of March.

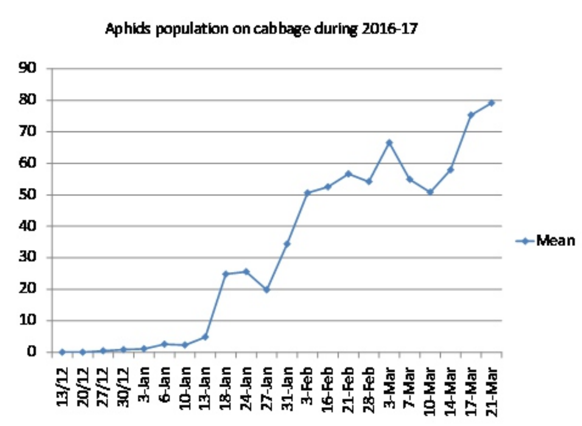


Fig. 64. The population fluctuation of cabbage aphid in open field conditions. The Y axis indicates the mean number of aphids observed

Influence of infochemical diversity on the behavioural ecology of some agriculturally important insects

Phenology related volatile profile on the ovipositional behaviour of *Helicoverpa armigera*

Volatile extracts of different phenological states of chickpea, viz. vegetative, flowering and pod initiation stage, prepared in hexane and tested against were gravid and virgin females as well as mated and unmated males. The studies indicated that hexanol is the compound involved in eliciting ovipositional response in *H. armigera*.

New formulation for attraction of *Bactrocera dorsalis*

A field trial was conducted in mango orchards in Ramagiri with new formulations containing δ-octalactone along with other blends of volatiles identified from susceptible mango cultivars. The formulations were impregnated in wooden blocks and kept in small plastic containers of 750ml capacity with a drop of DDVP. Among the treatments, cocktail 2 recorded highest mean number of flies than other cocktails and control, however the proportion of females was very low (Fig. 65).

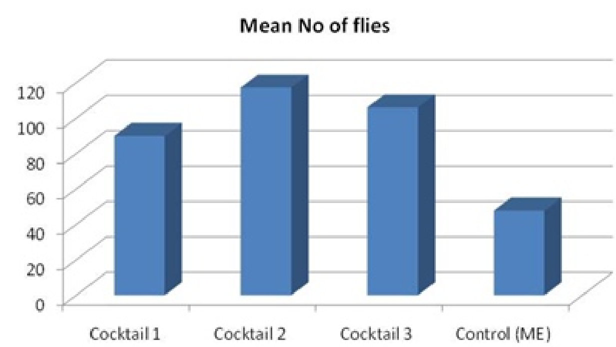


Fig. 65. New cocktail formulations for enhanced catches of mango fruit fly

A bisexual trap for mango fruitfly

A new trap was developed to attract females of mango fruit flies, *Bactrocera dorsalis*. Trials were conducted at Ramagiri in mango orchards. The percentage of females trapped was upto 60%, though the total number of flies were lesser than in methyl eugenol traps. The traps incidentally caught higher number of planthoppers at post-harvest stage.

Chemical characterization and ethology of economically important dipteran pests of veterinary and fisheries

Ctenocephalides felisfelis, a flea, was collected from cat and dog in Karnataka. *Ctenocephalides felisorientis* was collected from sheep in Karnataka and Tamil Nadu.

Ethology of dipterans to botanicals

Combinations of essential oils were evaluated for their toxicity to housefly, *Musca domestica*. Three combinations C1 (lemon grass, eucalyptus and ocimum oils) C2 (eucalyptus, artemesia and ocimum oils) and C3 (geranium, palmorosa and ocimum oils) were tested. C1 was most toxic in adult fumigant toxicity followed by C2 and C3 (Table 13).

Table 13. Toxicity of essential oils to housefly, *Musca domestica*

Compound	Toxicity (µl/dm^3) LC 50	Lower fiducial limits	Upper fiducial limits
C1	53.70	42.56	63.72
C2	72.18	53.59	93.89
C3	93.34	80.00	105.50

Toxicity of essential oil to phorid fly

On toxicity of essential oil to phorid fly, *Megaselia scalaris*, Ajowan oil and its major constituent thymol caused ovicidal effect. The LC 50 for ajowan oil was 0.6 mg/cm^3 and that for thymol was 0.17 mg/cm^3(Fig. 66).

Ajowan oil and thymol caused over 80% larval repellence when used at 7.5 and 5 mg, respectively.

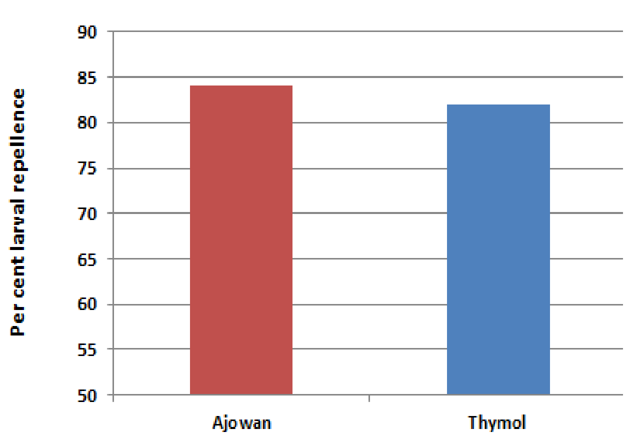


Fig. 66. Repellency of ajowan and thymol to phorid fly, *Megaselia scalaris*

Bioagents for management of housefly

Adult flies of *M. domestica*, when exposed to a diet mixed with entomopathogenic fungi and normal diet, preferred to lay their eggs in the treated diet. Among the concentrations, 10^9 spores/ml caused highest oviposition repellence of 77% followed by 10^8 and 10^{7}spores/ml.

Volatile organic compounds released from *M. anisopliae* for repellence to adult flies. Among the compounds, the following were of interest in causing behavioural changes, viz., Phenyl ethyl alcohol, chloro acetic acid, phenyl ethylene, ethyl benzoic acid, alpha pinene and trimethyl benzoate (Fig. 67).

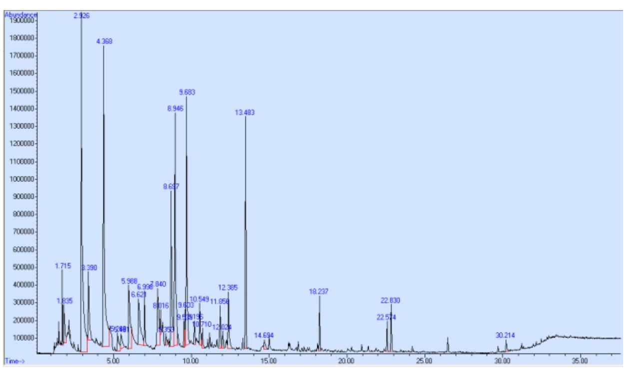


Fig. 67. Chromatogram of volatile organic compounds released from *M. anisopliae*

Characterisation of viruses with special reference to Lepidoptera and Coleoptera

Eight insect virus isolates (NBAIR*Ha*NPV1, NBAIR*Sl*NPV1, NBAIR*Spob*NPV1, NBAIR*Acja*NPV1, NBAIR*Sm*NPV1, NBAIR*Chin*GVI, NBAIR*Chsa*GV1, SKUAST*Euch*NPV1) have been isolated from major insect pests belonging to Lepidoptera (Table 14). The polyhedral occlusion bodies (POBs) were observed under light microscopy and they appeared irregular in shape. Scanning electron microscopic (SEM) and Transmission electron microscopic (TEM) studies revealed that occlusion bodies of nucleopolyhedrovirus (NPV) are with polyhedral structures. Under SEM and TEM the OBs of four viruses appeared as crystalline structures of variable shapes of size 0.460–1.030 µm (HaNPV), 0.860– 2.171µm (SlNPV), 0.682 – 1.120 µm (AcjaNPV) and 0.186–1.376 µm (SpobNPV) in diameter. Polyhedral occlusion bodies of HaNPV and SlNPV appeared as irregular and tetrahedral (Figs 68 & 69), *Spilosoma obliqua* NPV appeared as tetrahedral (Fig. 70).

Table 14. Viruses isolated from major insect pests

Name of the virus	Host	Location	Isolates name
Helicoverpa armigera NPV	Bhendi	Hosur	NBAIRHaNPV1
Spodoptera litura NPV	Cabbage	Bengaluru	NBAIRSlNPV1
Spilosoma obliqua NPV	Mulberry	Yaluvahalli	NBAIRSpobNPV1
Acanthodelta janata NPV	Castor	Tiruchirapalli	NBAIRAcjaNPV1
Spodoptera mauritia NPV	Rice	Alapuzha	NBAIRSmNPV1
Chilo infuscatellus GV	Sugarcane	Coimbatore	NBAIRChinGVI
Chilo sacchariphagus GV	Sugarcane	Coimbatore	NBAIRChsaNPV1
Euproctis chrysorrhoea NPV (Brown tail moth)	Apple	Srinagar	SKUASTEuchNPV1

Table 15. Bioassay studies of NPVs

Insect	LC50 POB/ mm^2 (6^{th} day)	Slope ± SE	Fiducial limits		χ^2	DF
			Lower	Upper		
Helicoverpa armigera	0.17	0.81±0.11	0.09	0.30	0.32	3
Spodoptera litura	4.23	0.96±0.11	2.69	7.00	2.32	3
Acanthodelta janata	1.23	0.92±0.13	0.68	2.20	1.20	3
Spilosoma obliqua	2.93	0.75±0.12	1.50	6.17	1.17	3

Acanthodelta janata NPV appeared as rod-shaped (Fig. 71). The LC50 values observed for second instar larvae were 0.17POB/mm^2 for HaNPV, 4.23POB/mm^2 for SlNPV, 1.23POB/mm^2 for AcjaNPV and 2.93POB/mm^2 for SpobNPV respectively (Table 15). Molecular characterization of *S. litura* NPV and *H. armigera* NPV was done using polyhedron gene. The viral DNA was isolated and the amplification of partial *polh* gene using the degenerate primer prPH-1 (TGTAAAACGACGGCCAGTNRCNGARGAYCCNTT) and prPH-2 (CAGGAAACAGCTATGACCDGGNGCRAAYTCYTT). The PCR product was of 441bp. The nucleotide sequence was submitted to GenBank and accession numbers were obtained. Based on sequence blasting it was identified as *Spodoptera litura* NPV (Acc. No. KY549343) and *Spilosoma obliqua* NPV (KY549344). The efficacy of SpobNPV was evaluated and demonstrated in potato and jute fields against Bihar hairy caterpillar, *Spilosoma obliqua*. Application of SpobNPV @ 2.0x10^{12} POB/ha in potato fields brought about significant control of the Bihar hairy caterpillar within 10 days.

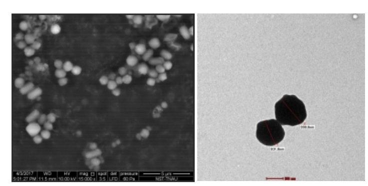


Fig. 68. SEM & TEM of POB of *H. armigera* NPV

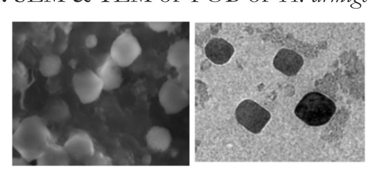


Fig. 69. SEM & TEM of POB of *S. litura* NPV

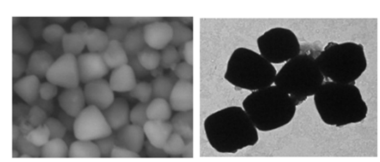


Fig. 70. SEM & TEM of POB of *S. obliqua* NPV

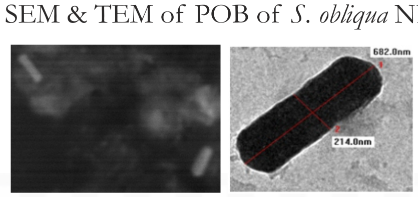


Fig. 71. SEM & TEM of POB of *A. janata* NPV

Exploitation of *Beauveria bassiana* for management of stem borer (*Chilo partellus*) in maize and sorghum through endophytic establishment

A field trial was conducted to evaluate promising isolates of the endophytic *Beauveria bassiana* (NBAIR-Bb-5a, 23 and 45) through foliar applications of oil formulations against stem borer, *Chilo partellus* in maize (cv. Nithyashree) and sorghum (cv. Maldandi M-35) at ICAR-NBAIR, Yelahanka Research Farm. Two foliar sprays of the oil formulation of each isolate of *B. bassiana* (1 x 10^{8}conidia/ml) were applied at 15 and 30 days after germination. Ten second instar larvae of *C. partellus* per plant were released into the inner leaf whorl of the treated and untreated maize/sorghum plants after 5 days of second spray.

NBAIR-Bb-5a isolate showed significantly lower dead hearts (2.7 and 2.53 in *kharif* and *rabi* respectively), exit holes (3.38 and 2.05/plant), galleries (1.98 and 1.40 /plant) and stem tunneling (6.73 and 3.38 cm/plant), as compared to untreated control which showed higher number of dead hearts (5.83 and 7.13), exit holes (6.78 and 6.65/plant), galleries (3.05 and 3.40 no./plant) and stem tunneling (10.83 and 7.03 cm/plant). Significantly higher cob yield was obtained in the plots treated with Bb-5a (11.8 and 13.0 Kg/10plants in *kharif* and *rabi*) compared to control plot (10.0 and 9.0 Kg/10plants) (Table 16 & Fig. 72).

NBAIR-Bb-5a and Bb-23 isolates showed significantly lesser dead hearts (1.8 and 1.83/treatment), exit holes (0.35 and 0.47/plant), stem tunneling (2.85 and 3.27 cm/plant) and galleries (0.22 and 0.20/plant) as compared to the untreated control which recorded higher dead hearts (5.13/treatment), exit holes (1.93 /plant), stem tunneling (9.03cm/plant) and galleries (1.8/plant). The grain yield obtained in Bb-5a treated plot (151g/10plants) was significantly higher compared to untreated control (105 g/10 plants) as shown in (Table 17 & Fig. 73).

Table 16: Effect of endophytic isolates of *B. bassiana* on infestation of maize stem borer in *kharif* and *rabi* seasons (2016)

Isolate	No. of dead hearts / treatment		Dead Hearts (%)		Exit holes/plant		No. of galleries/ plant		Stem tunnelling/ plant (cm)		Cob yield / 10 plants (Kg)	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
Bb-5a	2.70^{a}	2.53^{a}	5.40	4.60	3.38^{a}	2.05^{a}	1.98^{a}	1.40^{a}	6.73^{a}	3.38^{a}	11.8^{a}	13.0^{a}
Bb-23	4.25^{b}	4.85^{bc}	8.50	9.70	5.35^{ab}	4.88^{bc}	2.15^{a}	2.20^{ab}	9.83^{b}	6.10^{bc}	9.9^{a}	9.3^{b}
Bb-45	5.55^{c}	5.45^{c}	11.10	1.90	5.10^{ab}	5.05^{bc}	2.33^{a}	2.50^{bc}	8.53^{ab}	5.80^{bc}	10.2^{a}	10.0^{b}
Control	5.83^{c}	7.13^{d}	11.65	14.26	6.78^{b}	6.65^{c}	3.05^{b}	3.40^{c}	10.83^{b}	7.03^{c}	10.0^{a}	9.0^{b}

Table 17: Effect of endophytic isolates of *B. bassiana* on infestation of sorghum stem borer in *kharif* 2016

Isolate	No. of dead hearts/ treatment	Dead heart (%)	No. of exit holes/ plant	Stem tunnelling/ plant (cm)	No. of galleries /plant	Survival larvae/ plant	Survival pupae/ plant	Grain yield/ 10 plants (g)	Grain yield (q/ha)
Bb-5a	1.80^{a}	3.60	0.35^{a}	2.85^{a}	0.22^{a}	0.00^{a}	0.00^{a}	151^{a}	11.20
Bb-23	1.83^{ab}	3.66	0.47^{a}	3.27^{a}	0.20^{a}	0.04^{a}	0.03^{a}	147^{ab}	10.88
Bb-45	3.10^{b}	6.20	1.47^{b}	7.03^{bc}	1.17^{b}	0.50^{ab}	0.25^{a}	125^{bc}	9.27
Control	5.13^{c}	10.26	1.93^{b}	9.03^{c}	1.80^{b}	1.07^{b}	0.11^{a}	105^{c}	7.77

Note: Means followed by similar letters in the columns are not significantly different at 5% by DMRT

Fig. 72. Extent of stem tunneling caused by *Chilo partellus* in maize stem in Bb5a treated and untreated control plants

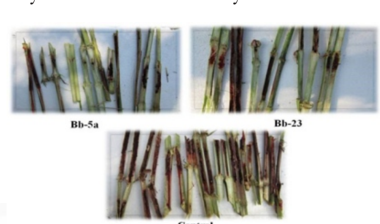


Fig. 73. Extent of stem tunneling caused by *Chilo partellus* in maize stem in Bb5a and Bb23 treated and untreated control plants

All-India Coordinated Research Project on Biological Control of Crop Pests

Biodiversity of biocontrol agents from various agro-ecological zones

Natural parasitisation of *Trichogramma* using sentinel cards showed variation in sugarcane, maize and rice ecosystems. Sugarcane crop recorded maximum parasitisation at RARS, Anakapalle during last week of July 2016 (10.8%); August 2016 (18.6%). *Trichogramma chilonis* parasitisation recorded in paddy during last week of August 2016 (5.23%) and *rabi* maize during first week of February 2017 (1.15%) (ANGRAU).

Trichogramma parasitisation ranged from 0% in chilli to a maximum of 9.3%. Rice crop recorded maximum of 9.3% while in maize it was 5.7% and in cabbage it was as low as 0.8%. The abundance studies pertaining to *Chrysoperla* suggested that *kharif* recorded more predatory presence than in *rabi*. In *kharif*, bitter gourd recorded maximum population (12.0) and minimum was recorded in pigeonpea (2.0). *Chrysoperla* population in *rabi* was maximum (9.0) in brinjal while it was least (5.0) in bitter gourd (PJTSAU).

Two coccinellid predators, viz. *Aiolocaria hexaspilota, Serangium* sp. and three pteromalid parasitoids (Hymenoptera), viz., *Cheiropachus* sp., *Macromesus* sp., and *Raphitelus* sp. were reported first time from Kashmir. Among parasitoids, *Aphelinus mali* and *Encarsia perniciosi* displayed an average of 0.0 – 23.0 and 0.0 – 16.0 per cent parasitism of woolly apple aphids and San Jose scale, respectively. Hyperparasitism by *Marietta* sp. and *Azotus* sp. was noticed during July–August which displayed an upward swing during September 2016. Parasitism by *Cheiropachus* sp., *Macromesus* sp., and *Raphitelus* in xylophagus grubs infesting almonds, was observed from September to December 2016 (SKUAST).

Coccinellid beetles like *Adalia tetraspilota, Coccinella septempunctata, Hippodamia varigieta, Cheilomenes sexmaculata, Propylea lutiopustulata, Chilocorus infernalis, Stethorus* sp., *Priscibrumus uropygialis, Platynaspis saundersii, Harmonia eucharis, Oenopea sauzetii, Oenopia kirbyi, Oenopia sexareata, Illeis* sp., *Coelophora bisselata, Pharoscymnus flexibilis, Scymnus posticalis, Stethorus aptus, Harmonia dimidiata,* and *Adalia tetraspilota* were collected from different cropping systems preying on aphids, whiteflies, scales mites, etc. Green lace wing, *Chrysoperla zastrowi sillemi* was collected from cucumber, okra, brinjal and apple associated with aphids and whiteflies. Syrphid flies namely *Episyrphus balteatus, Eupeodes frequens, Melanostoma univitatum, Betasyrphus serarius, Sphaerophoria indiana, Ischiodon scutellaris, Metasyrphus corollae* and *Scaeva pyrastri* were collected from different crops at different locations of the state. *Dinocalpus coccinellae* was recorded and collected as parasitoid of *Hippodamia variegata* and *Coccinella septempunctata* under mid-hills of Himachal Pradesh. Parasitoids such as *Diadegma semiclausum*, *Cotesia vestalis* and *Diadromus collaris* were collected from larvae and pupae of the diamondback moth, *Plutella xylostella* feeding on cauliflower and cabbage. Anthocorid bugs like *Orius* sp. and *Anthocoris* sp. were found associated with peach leaf curl aphid and thrips in peaches. During survey, *Nesidiocoris tenuis* and *Neochrysocharis formosa* were found associated with the American pin worm, *Tuta absoluta* in tomato under mid hills of the state. *Baryscapus galactopus* was collected as hyperpasitoid of *Cotesia glomerata* parasitizing *Pieris brassicae* in cauliflower. *Campoletis chloridae* was reared from field collected larvae of *Helicoverpa armigera* (YSPUHF).The coccinellid predator, *Coccinella septempunctata*, which feeds on mango hopper and mealybug was recorded during 11th to 17th SMW, and the highest number of beetles (2.5/panicle) recorded at 13th SMW (CISH).

Three different species of earwigs, viz. *Auchenemus hinksi*, *Paralabis dohrini* and *Euborellia shabi* were collected from banana plants infested by pseudostem weevils at Kannara and Vellanikkara (KAU).

The natural enemies inclusive of coccinellids (*Coccinella septempunctata* , *Menochilus sexmaculata*, *Scymnus* sp.), *Dipha aphidivora*, *Micromus igorotus* and syrphid, *Eupeodes confrater* and parasitoid, *Encarsia flavoscutellum* were recorded on SWA in sugarcane, *Coccinella transversalis*, *Menochilus sexmaculata, Brumoides suturalis*, *Scymnus coccivora, Triomata coccidivora* and *B. suturalis* in mealybug colonies on custard apple, *Acerophagus papayae*, *Mallada boninensis* and *Spalgis epius* on papaya mealybugs. The natural parasitism of *Trichogramma* was not noticed in the crops like cotton, maize, soybean, sugarcane, tomato and brinjal in Pune region. The chrysopid, *Chrysoperla zastrowi sillemi* was observed in cotton, maize, bean, jowar, okra and brinjal, and *Mallada boninensis* on cotton, beans, mango, papaya and hibiscus. The *Cryptolaemus* adults were recovered from the custard apple and papaya orchards and on hibiscus. The cadavers of *S. litura a*nd *H. armigera* infected with *Nomuraea rileyi, Metarhizium anisopliae, Sl*NPV, *Ha*NPV were collected from soybean, jawar, maize, cabbage, pigeon pea, tomato crops in farmers' fields. The mealybug, *Paracoccus marginatus* was observed in papaya orchards along with encyrtid parasitoid, *A. papayae* and *S. epius* in Dhule and Pune region (MPKV).

Surveillance for alien invasive pests

In Tamil Nadu, the incidence of papaya mealybug *P. marginatus* was observed in crops like papaya, tapioca, guava, cotton, mulberry, brinjal and the Jack Beardsley mealybug *Pseudococcus jackbeardsleyi* in papaya and tapioca was also observed. In Maharashtra, *Pseudococcus jackbeardsleyi* and *Paracoccus marginatus* were recorded on custard apple and papaya respectively, in Pune region. While, *Tuta absoluta* was recorded on tomato in Pune district during January to May 2016 and again from January to March 2017. It was also reported in the Solapur district in the month of March 2017.

In coconut, the occurrence of rugose whitefly *Aleurodicus rugioperculatus* was observed from second week of August 2016 in Anamalai and Pollachi block of Coimbatore district. The natural enemies observed were *Encarsia* sp., *Mallada* sp., *Cryptolaemus montrouzieri* and *Chrysoperla zastrowi sillemi*.

Survey for occurrence and incidence of the American pinworm, *Tuta absoluta* in solan revealed that the pest was present in almost all the tomato growing of mid-hills of Himachal Pradesh. At these locations 42–89% of the tomato plants were infested with *T. absoluta* with the number of mines/leaf/infested plant varying from 1–11 and fruit damage varying from 0–6% at different locations.

Pest outbreaks

Maximum pink bollworm moth catches were noticed during second week of December (28.75 moths/trap) and it also coincided the highest number of larvae (12.28/25 bolls) (UAS-R).

A massive outbreak of armyworms was noticed in the rice at Kuttanad, Kerala. Within a day or two, more than 2000 ha were completely lost by the attack (KAU).

Coconut whitefly problem was reported from II week of August 2016 onwards. The population of whitefly was severe in Deejay hybrids and medium to low in other varieties. The natural parasitisation of whitefly nymphs was also observed based on the presence of emergence hole of adult parasitoid (TNAU).

A survey conducted covering 10 villages in Jorhat and Majuli districts of Assam revealead *Spodoptera mauritia* and *S. litura* infestation in *Sali* rice (cv. Ranjit, Bahadur, Doria, Bora, Komal and Joha) with the intensity of low to severe attack (50–90%). *S. mauritia,* as high as 34–62 numbers of larvae per hill were observed in certain locations (AAU-J).

Biological suppression of plant diseases

In rice among different bioagents tested, Th-14, PBAT-3 and TCMS-36 were found most promising in reducing diseases, and in increasing yield. In chickpea among all the isolates PBAT-3, Psf-173 and *Bacillus* were found very promising in reducing pre and post emergence seed and plant mortality in field. In lentil among all the isolates PBAT-3, Psf-173, and *Bacillus* were found very promising in reducing pre and post emergence seed and plant mortality in field (GBPUAT).

Biological suppression of sugarcane pests

Study revealed that trash mulching + *T. chilonis* release @ 50,000/ha from 30 DAP six times and two releases after node formation and trash mulching + *T. chilonis* release @ 75,000/ha from 30 DAP six times and two releases after node formation are effective in managing shoot borers in sugarcane with high incremental benefit cost ratio. Soil application of entomopathogenic nematode, *Heterorhabditis indica*/*Steinernema* sp.; entomopathogenic fungi, *Metarrhizium anisopliae*/*Beauveria bassiana* in sugarcane after the onset of monsoon rains were found effective with high per cent reduction in white grub damage resulted in higher yield increase over phorate and untreated control (ANGRAU).

Biological suppression of cotton pests

Significantly lower number of leafhoppers (2.13), whiteflies (2.96), aphids (6.55) and thrips (4.37) were recorded in the application of *L. lecanii* (40 g/10 litres of water) followed by *L. lecanii* (30 g/10 litres of water), *B. bassiana* (40 g/10 litres of water) and *B. bassiana* (30 g/10 litres of water)-AAU. BIPM practices involving cultivation of *Bt* cotton crop following recommended agronomic practices, growing sorghum as a barrier crop, installation of yellow sticky traps, augmentative releases of chrysopids and application of botanicals/ biopesticides rendered significantly lower whitefly population than untreated control. The predator population was significantly more in BIPM (1.36/plant) as compared to chemical control (0.39/plant) and untreated control (0.98/plant). Seed cotton yield in BIPM (22.80 q/ha) was at par with chemical control (23.70 q/ha) and was significantly better than untreated control (21.30 q/ha)-PAU. Minimum larvae of pink bollworm, minimum locule damage were noticed in continuous release of *T. bactrae*. Maximum seed cotton yield of 22.40 q/ha was noticed in continuous release of *T. bactrae* (UAS-R).

Biological suppression of pests of cereals and pulses

Rice

The overall incidence of rice stem borer (4.06% dead hearts, 2.82% white ears) and leaf folder (0.94%) was less in conventionally managed fields as compared to organic fields (4.60% dead hearts, 5.11% white ears, 2.29% leaf folders). The population of planthoppers was less in organic fields (4.36/hill) as compared to conventionally managed fields (4.87/hill). The population of natural enemies was high in organic fields (spiders 6.33/plot, dragonflies 1.67/plot and damselflies 3.26/plot) than in conventional fields (spiders 4.07/plot, dragonflies 0.24/plot and damselflies 0.98/plot). Natural parasitism in the eggs, larvae and pupae of stem borer and leaf folder ranged from 1.97 to 20.18% and 0.31 to 2.44% in organic and conventional rice, respectively (PAU).

Maize

Field release of *Trichogramma chilonis* (at the rate of 75,000 and 100,000 parasitoids per ha) at 15 days after seedling emergence, three times at weekly interval was found effective in reducing maize stem borer damage with higher cob yields. NBAII entomopathogenic strains Bb5a, Bb19 were effective against maize stem borer with less damage caused by *Chilo partellus* resulted in higher cob yields (ANGRAU).

Sorghum

Beauveria bassiana-7 @ 1.5 ml/litre recorded minimum population of larvae and pupae, minimum tunnelling, low number of entry holes, minimum dead hearts and higher yield and it is at par with *Metarhizium anisopliae* - 35 @ 1.5 ml/lit (UAS-R).

Pulses

Formulations of *Bacillus thuringiensis* PDBC Bt1 (1%), Bt 1(2%), NBAII BT G4 (1%), NBAII Bt G4 (2%), Delfin @1 kg/ha, Delfin @ 2.0 kg/ha, *Beauveria bassiana* (Mycojaal) 1.5 kg/ha, *B. bassiana* (Mycojaal) 2.0 kg/ha, chlorpyriphos 20EC @ 3.75 litre/ha and untreated control were evaluated against lepidopteran pests in moong bean. Among all these bioagents, higher dose of PDBC Bt1 (2%) and both doses of Delfin were at par with each other and recorded the lowest pod damage (PAU). *Bacillus thuringiensis* sprayed at 15 days interval recorded the lowest mean infestation of 12.25 per cent, followed by *Beauveria bassiana* sprayed at 15 days interval with 16.59 per cent mean infestation (KAU Thrissur).

Biological suppression of pests of tropical fruits

Mango

Field studies conducted on management of mango hoppers revealed that all the treatments, viz., *Beauveria bassiana* (ITCC 6063) 2 per cent, malathion 0.1 per cent, and azadirachtin 1% were significantly superior to the untreated control. *Beauveria bassiana* (ITCC 6063) 2 per cent and azadirachtin 1 per cent were superior to control in reducing the population of hoppers (KAU Vellayani). Among biopesticides the four sprays of *Lecanicillium lecanii*, *Beauveria bassiana* and *Metarhizium anisopliae* were effective in suppressing mango hoppers. The chemical insecticide treatment imidacloprid was most effective and was followed by *L. lecanii* treatment (DRYSRHU, Ambajipet). Significant reduction in damage by the leaf webbers was observed at 3, 5, 10 and 15 days' intervals, when azadirachtin @ 1 ml/litre and biopesticides, *B.bassiana* ITCC 6063 @ 20 g/litre were applied. Insecticide Malathion 50% EC @ 2 ml/litre was also found effective against the mango webber (KAU-V).

Guava

Field evaluation of *Beauveria bassiana* (IIHR formulation) against tea mosquito bug showed that, *Beauveria bassiana* at 10 g/litre of water had a maximum reduction of fruit damage (81.1%) closely followed by *Beauveria bassiana* at 5 g /litre (TNAU).

Citrus

Among the EPN treatments, CAU-1 stem injection (34.00% reduction) was observed as the best treatment and it was closely followed by CAUH-1 stem injection (27.50% reduction), CAUH-2 stem injection (26.50% reduction) and NBAII-01 stem injection (26.19 % reduction) at Pasighat. However, at Rengging, CAUH-1 stem injection gave the highest reduction in trunk borer infestation among the EPNs with 32.68% reduction and it was closely followed by NBAII-01 stem injection (31.25% reduction) and CAU-1 stem injection (30.20% reduction). The stem injections of the EPNs were found more effective than their respective cadaver treatments (CAU).

Biological suppression of pests of temperate fruits

Apple

For the management of apple root borer, *Dorysthenes hugelii,* although chlorpyriphos (0.06%) was the most effective treatment resulting in 83.2% mortality of the root borer grubs, *Metarhizium anisopliae* was equally effective resulting in 68.3% mortality of the pest (YSPUHF). Two year investigation confirmed the superiority of *Trichogramma cacoeciae* over *T. embryophagum* with increased reduction in fruit damage against codling moth. Integrated management involving one spray of Chlorpyriphos 20 EC @ 1.5 ml/litre + sequential releases of *T. cacoeciae* + one spray of NSKE + trunk banding + disposal of infested fruits + pheromone traps resulted in 37.65% reduction in damage over control (SKUAST). Two releases of anthocorid bugs @ 200/plant resulted in less mite population and higher per cent reduction in mite population (43.23) over check. In laboratory condition, at predator: prey ratio of 1:10, 1:15, 1:20 and 1:25 *B. pallescens* caused total mortality (failure of hatching) of the eggs of spider mites as 93.33, 86.66, 63.33 and 51.00%. Performance of the predator at 1:10 and 1:15 was found best, though statistically on par (SKUAST).

Biological suppression of pests of oilseeds

Mustard

Chemical control (Dimethoate @ 4 ml/litre of water) significantly reduced the aphid population from 53.06 to 0.67 aphids/plant. Among commercial biopesticide formulations (*Beauveria bassiana*, *Lecanicillium lecanii*, *Metarhizium anisopliae*) and neem oil, none was found effective against mustard aphid (PAU). Among all the biopesticides, three sprays of *Metarrhizium anisopliae* (2×10^8 spores/g)+ *Lecanicillium lecanii* (2×10^8 spores/g) @ 5 ml/litre at 15 days interval proved to be the best treatment in reducing the aphids and producing the highest yield (8.23 q/ha) with highest B:C ratio (1.55) (OUAT). Among all entomopathogenic fungi, pooled aphid index count over period over spray was recorded lower in the treatment *B. bassiana* + *L. lecanii* @ 5 g/litre (1.37) which was at par with the treatment *L. lecanii* + *M. anisopliae* @ 5 g/litre (1.40). Higher seed yield was obtained in the treatment *B. bassiana* + *L. lecanii* @ 5 g/litre (9.66 q/ha) followed by *L. lecanii* + *M. anisopliae* @ 5 g/litre (9.28 q/ha) (AAU-A).

Biological suppression of pests of vegetables

Tomato

Lower leaf and fruit damage by *Tuta absoluta* was observed in the treatment Azadirachtin 1,500 ppm @ 2 ml/litre (2.67%, 0.58%) followed by the treatment *Beauveria bassiana* @ 4 g/litre ($2x10^8$cfu/g) (4.00%, 0.69%) and (*Trichogramma achaeae* @ 50,000/ha release - six releases) (5.33%, 1.12%) (AAU-A). Among bio-agents/biopesticides, *Neoseiulus longispinosus* (10 mites/plant) and azadirachtin (1,500 ppm; 3 ml/litre) were the best treatments for the control of *Tetranychus urticae* in tomato resulting in 60.3 and 51.2% reduction in the mite population over control. Both these treatments, however, were significantly less effective than fenazaquin (0.0025%) which caused 91.1% over control (YSPUHF). Per cent fruit damage and the population of sucking pests were less in BIPM compared to chemical treated plot. The yield of BIPM package recorded 242.83 q/ha, which was superior to yield of 234.7 q/ha in chemical control plot (AAU-J)

Brinjal

Damage of shoots (9.03%) and fruits (16.43%) was the lowest in BIPM package as compared to chemical control plots (11.50 and 19.71%, respectively). The yield of BIPM package was 263.78 q/ha as against 260.09 q/ha in chemical control plot and both were found to be on par with each other (AAU-J). Two releases of *T. chilonis* as well as application of neem oil (2 sprays) and *B. thuringiensis* (2 sprays) was found best, recording 7.03% shoot damage and 8.48% fruit damage. The yield was significantly higher in chemical control (328.3 q/ha) followed by BIPM module (262.1 q/ha) (PAU). *Beauveria bassiana* (ITCC KAU culture) 20 g/litre was found superior in controlling the sucking pests with minimum pest population. The yield was also high in the plots treated with *Beauveria bassiana* 20 g/litre compared to the check plot (KAU-V). The application of EPN (NBAIR formulation) 20 kg/ha along with *Metarhizium anisopliae* (NBAIR formulation) 5 kg/ha mixed with 250 kg FYM/ha resulted 87.74% reduction of ash weevil with minimum leaf damage of 8.37% and it was on par with EPN (NBAIR) + *Metarhizium anisopliae* IPM formulation + 250 kg FYM and soil drenching of chlorpyriphos 0.1% (TNAU).

Okra

Metarhizium anisopliae @ 2×10^8 cfu application followed by *Bt* spray @ 1 kg/ha proved to the best treatment in reducing the sucking and fruit borer pests and producing the highest yield (8.38 t/ha) next to insecticidal check (9.31 t/ha) (OUAT). Per cent fruit infestation was less in *Beauveria bassiana* @ 20 g/litre followed by *Metarhizium anisopliae* @ 5 g/litre (KAU-V). Three sprays of chlorpyriphos 0.04% at fortnightly interval were found at par with *B. thuringiensis* @ 1 kg/ha in terms of shoot damage, fruit damage and yield (MPKV).

Chilli

Beauveria bassiana (Bb-83) IIVR strain was found most promising against the yellow mites in chilli with highest reduction (56.57%) over control followed by *Metarhizium anisopliae* (Ma-35) NBAIR strain (53.60%). *Beauveria bassiana* (Bb-83). IIVR strain treated plots registered the highest green chilli yield (6,175 kg/ha) as compared with other entomopathogens (IIVR). *Beauveria bassiana* 20 g/litre and Dimethoate 600 g ai/ha found superior in controlling the sucking pests with minimum pest population. The yield was also high in the plots treated with *Beauveria bassiana* 20 g/litre compared to the check plot (KAU-V).

Capsicum

Chrysoperla zastrowi sillemi (1 larva/plant), *Lecanicillium lecanii* (5 g/litre of 10^8 conidia/g) and azadirachtin (1,500 ppm; 3 ml/litre) were statistically equally effective against green peach aphid, *Myzus persicae* resulting in 54.8 to 61.2% reduction of the aphid population over control, but, were less effective than imidacloprid (0.0075%), which was the most effective treatment resulting in 87.2% reduction of the aphid population over control (YSPUHF).

Cabbage

Cabbage intercropped with mustard and cowpea was found to be the best (1.03 larvae/plant) harbouring lesser *Plutella* population and *Brevicoryne brassicae* population (3.41/plant) with higher coccinellids (3.34/plant) and syrphid (3.01/plant). Maximum yield of 175.52 q/ha was also obtained in this treatment (AAU-J).

Biological suppression of polyhouse crop pests

Beauveria bassiana 1% (10^8 spores/ml and 10^9 spores/ml) and *Lecanicillium lecanii* 1% (10^9 spores/ml) was found to be on par with insecticide Spiromesifen@ 96 g ai ha^{-1} in reducuing aphid population (RARS-Kumarakom). Against rose aphid, *Macrosiphum rosaeiformis,* azadirachtin (1,500 ppm; 3 ml/litre), *Hippodamyia variegata* (10 beetles/plant) and *Lecanicillium lecanii* (5 g/litre of 10^8 conidia/g) were equally effective resulting in 50.8 to 69.1% reduction in the aphid population over control. These bioagents were, however, significantly less effective than imidacloprid (0.0075%) which reduced the aphid population to the tune of 96.6% over control (YSPUHF).

Large-scale adoption of proven biocontrol technologies

Rice

Large-scale validation of IPM practices in rice was carried out in an area of 13 ha at Palla Road Padasekharam in Vadekkenchery Panchayat of Palakkad district. IPM plots registered 40% more yield than the non-IPM plots. The increased yield as well as reduced cost resulted in an increase in profit by ₹ 32,626/ha. The cost-benefit ratio, at 2.15 was higher than the 1.45 obtained in the case of non-IPM fields (KAU).

Pigeonpea

Large-scale demonstration of NBAII BTG 4 *Bt* was carried out in Askihal village of Raichur taluk over an area of 10 ha. The results indicated that NBAII BTG 4 *Bt* recorded 9.04% damage compared with farmer's practice which recorded 8.26% pod damage (UAS-R).

Brinjal

BIPM module comprising of erection of pheromone traps @ 25/ha, release of *Trichogramma chilonis* @ 50,000/ha at weekly intervals and two sprays of *Bt* at peak flowering stage was demonstrated in 58 acres of brinjal crop in four villages of Cuttack district during *rabi* 2016-17. This practice significantly reduced the shoot and fruit borer infestation with higher B:C ratio as compared with farmer's own practice.

Sugarcane

Large-scale demonstrations on the effectiveness of *Trichogramma chilonis* (Biocontrol-based IPM technology) against stalk borer @ 50,000/ha at 10-day intervals over an area of 7,910 acres conducted at farmers' fields in collaboration with six sugar mills in Punjab reduced the incidence of stalk borer, *Chilo auricilius* by 56.6% (PAU).

Maize

Large-scale demonstrations of using *T. chilonis* in farmers' fields was carried out in area of 355 acres in Hoshiarpur, Nawashahr, Roop Nagar and Pathankot districts. Single release of *T. chilonis* @ 1,00,000/ha on 15-day-old crop provided effective control of maize stem borer, *Chilo partellus*. The reduction in incidence over control was 52.51 and 69.24% in biocontrol and chemical control, respectively. The net return over control in biocontrol package was ₹ 5,036.75/- as compared with ₹ 8,239.25/- in chemical control (PAU).

Tribal Sub-Plan programme

One hundred tribal farmers were selected from Dahod district for demonstration and training on use of bioinputs in pigeonpea and chickpea farming (AAU-A). Totally, 143 acres of Araku valley and Chinthapalli area, Visakhapatnam district was covered. Inputs were distributed to 45 paddy farmers; 50 rajma farmers and 67 ginger farmers (ANGRAU).

Six tribal areas of Kargil were selected for benefiting the farmers with IPM technologies of management of codling moth. Basic training related to IPM of codling moth was offered (SKAUST).

In collaboration with BAIF and MITTRA, Nashik, the programme was implemented at Dalpatpur and Harsul villages. Training programme on IPM of fruit crops was offered to the tribals. Due to proper and timely application of enriched FYM and spraying of entomopathogenic fungi to control mango hopper and tea mosquito bug, the yields of mango and cashewnut increased (MPKV).

Three trainings to tribal farmers were organised. Sixty tribal farmers were trained on organic cultivation using biofertilizers, growth regulators, antagonists, biopesticides, entomofungal agents and entomophages and establishment of homestead vegetable cultivation. Demonstrations on the use of nimbicidine, *Trichogramma* spp., predators like *Chrysoperla* and *Cryptolaemus* were also conducted (TNAU).

TSP was implemented in four villages in Himachal Pradesh. Two hundred tribal farmers cultivating apple, almond, peas, beans, cauliflower and cabbage in an area of 200 ha were benefitted. Inputs like *Metarhizium anisopliae, Beauveria bassiana,* yellow sticky traps, blue sticky traps, neem product, *Trichoderma viride* and *Pseudomonas* were provided (YSPUHF).

5. GENBANK / BOLD ACCESSIONS

ORGANISM	ACCESSION NUMBER
TERMITES (CO1)	
Odontotermes longignathus	ACY9035
Hypotermes xenotermitis	ADE0036
Hypotermes xenotermitis	ADB9612
Hypotermes xenotermitis	ADE0036
Hypotermes makhamensis	ADE0161
Hypotermes makhamensis	ADE0161
Nasutitermes octopilis	AAU3458
Trinervitermes togoensis	ADE0334
Odontotermes longignathus	ACY9035
Hypotermes xenotermitis	ACW3617
Hypotermes xenotermitis	ACW3617
Hypotermes xenotermetis	KY293420
Odontotermes obesus	KY474376
Odontotermes omathuri	KY676778
Macrognathotermes errator	KM657789
Odontotermes mathuri	KY676779
Odontotermes formosanus	KY552744
Odontotermes longignathus	KY593993
Odontotermes longignathus	KX611498
Odontotermes longignathus	KX583491
Odontotermes wallonesis	KT224388
Odontotermes holmgren	KT224389
Nasuitermes sp.	KT224390
Dicuspiditermes Krishna	KT224391
Microtermes obesi	KM657488
Microtermes mycophagus	KX495579
Nasutitermes exitiosus	KM657488
Odontotermes longignathus	KY563711
Trinervitermes togoensis	KY569522
COLLEMBOLANS (CO1)	
Bourletiella hortensis	KY609515
Smiunthurus viridis	KY609549
SCARABAEID BEETLES (CO1)	
Adoretus flavus	ADB2802
Phyllopertha horticola	ADA4139

Onthophagus nuchicornis	AAZ7167
Onthophagus nuchicornis	AAZ7167
Onthophagus nuchicornis	AAZ7167
Holotrichia serrata	ADA3548
Anomala ruficapilla	AAP8590
Protaetia cuprea	ADA4139
Phyllopertha horticola	ADA8332
Phyllopertha horticola	ADA8332
Onthophagus auritus	ADA5841
Onthophagus coenobita	ADA5611
Onthophagus coenobita	ADA5611
Copris tripartitus	ADA6490
Onthophagus coenobita	ADA5611
THRIPS (CO1)	
Haplothrips sp. 1	KY883612
Haplothrips sp. 2	KY883618
Thrips florum	KY883611
Scirtothrips dorsalis	KY883613
Thrips orientalis	KY883614
Thrips sp.	KY883615
Thrips florum	KY883616
Thrips orientalis	KY883617
Microcephalothrips abdominalis	KY883619
SPIDERS (CO1)	
Argiope trifascita	KM054536
Neoscona theisi	KM054537
Cyrtophora cicatrosa	KM054538
Cyrtophora cicatrosa	KM054539
Tetragnatha guvana	KM054540
Pardosa altitudus	KM054541
Neoscona mukerjei	KM054542
Argiope anasuja	KM054543
Oxyopes swetae	KM054544
Argiope anasuja	KM054545
Neoscona theisi	KM054546
Oxyopes swetae	KM054547
Cyrtophora cicatrosa	KM054548
SEMI-AQUATIC BUGS - GERROMORPHAN SPECIES (CO1)	
Limnometra fluviorum	KX300087
Laccotrephes griseus	KX365491
Amemboa kumari	KX775121
Chimarrhometra orientalis	KY018602

Ptilomera himalayensis	KY018603
Hydrometra greeni	KY041641
Metrocoris dinenedrai	KY212124
Metrocoris deceptor	KY283957
Ptilomera agroides	KY556677
Metrocoris sikkimensis	KY710902
OTHER INSECTS (LEPIDOPTERA) (CO1)	
Clanis phalaris	KX398046
Dendrolimus punctatus	KX101017
Crocidolomia sp.	KX198008
Olepa ricini	KX371816
Hypatima sp.	KU695904
Anarsia sp.	KU695905
Tuta absoluta	KX467347
Orothalassodes falsaria	KU695903
Orgyia australis	KU695908
Chlumetia transversa	KU695899
Chlumetia euthysticha	KU695900
Penicillaria jocosatrix	KU695902
Etanna breviuscula	KU695906
Carea angulata	KX467348
Catopsilia pyranthe	KX463050
Orthaga exvinacea	KU695897
Ceutholopha petalocosma	KU695907
Calguia defiguralis	KU695909
Eteoryctis syngramma	KU695901
Dudua aprobola	KU695898
OTHER INSECTS (HEMIPTERA) (CO1)	
Trialeurodes vaporariorum	KX083584
Aleurolobus musae	KX371824
Bemisia tabaci	KX245419
Aleurodicus dispursus	KX245399
Metopeurum fuscoviride	KX230687
Brachycaudus helichrysi	KX024758
Acyrthosiphon pisum	KX371817
Melanaphis sacchari	KX371818
Aphis punicae	KX371819
Sitobion leelamaniae	KX371820
Aphis craccivora	KX371821
Aphis aurantii	KX371822
Pomponia sp.	KX398044
Pomponia sp.	KX455913

Pomponia tuba	KX463051
Halyomorpha picus	KX398045
Acrosternum gramineum	KX455914
Nezara viridula	KX467339
Nezara viridula	KX467340
Halyomorpha picus	KX467341
Gynenica affinis	KX467342
Plautia crossota	KX467343
Dolycoris indicus	KX467344
Halys serriger	KX467345
Piezodorus hybneri	KX467346
Phenacoccus solani	KU296033
Planococcus citri	KU296034
Maconellicoccus hirsutus	KU296035
Pseudococcus longispinus	KU296036
Phenacoccus solenopsis	KU296037
Paracoccus marginatus	KU296038
Rastrococcus mangiferae	KU296039
Planococcus lilacinus	KU296040
Nipaecoccus viridis	KU296041
Rastrococcus invadens	KU296042

OTHER INSECTS (COLEOPTERA) (CO1)

Lagria sp.	KX463052
Oocassida pudibunda	KX230688
Euwallacea fornicatus TN4	KX371812
Euwallacea fornicatus TN4.1	KX371813
Euwallacea fornicatus TN5	KX371814
Euwallacea fornicatus TN6	KX371815

OTHER INSECTS (HYMENOPTERA) (CO1)

Trigona sp.	KX174315
Scaptotrigona sp.	KX156851
Habrobracon hebetor	KX371823

OTHER INSECTS (THYSANOPTERA) (CO1)

Gynaikothrips uzeli	KU752541
Frankliniella schultzei	KX424958
Thrips sp.	KX424957

OTHER INSECTS (DIPTERA) (CO1)

Chrysomya megacephala	KX230656
Aedes aegypti	KX467336

Anopheles stephensi	KX467337
Fannia sp.	KX230664
Musca domestica	KX230683
Hydrotaea capensis	KX230670
Limnophora sp.	KX230675
Ctenocephalides orientis	KX467332
Ctenocephalides orientis	KX467333
Ctenocephalides felis felis	KX467334
Ctenocephalides felis felis	KX467335
Hermetia illucens	KX230684
Acroceratitis tomentosa	KU985288
Bactrocera affinis	KU985291
Bactrocera bipustulata	KU985303
Bactrocera caryeae	KU985290
Bactrocera caudate	KU985294
Bactrocera digressa	KU985297
Bactrocera diversa	KU985286
Bactrocera gavisa	KU985296
Bactrocera latifrons	KU985284
Bactrocera limbifera	KU985304
Bactrocera minax	KU985287
Bactrocera nigrofemoralis	KU985283
Bactrocera scutellaris	KU985302
Bactrocera tau	KU985285
Bactrocera tau	KU985293
Bactrocera trilineata	KU985295
Bactrocera vishnu	KU985300
Bactrocera waterii	KU985301
Chaetelipsis paradoxa	KU985298
Dacus discophorus	KU985282
Dacus persicus	KU985289
Dacus ramanii	KU985292
Dietheria fasciata	KU985281
Gastrozona spp.	KU985299
Spathulina ochroleuca	KX467338
OTHER INSECTS (CHRYSOPID PREDATORS) (CO1)	
Chrysoperla zastrowi sillemi	KY234204
Chrysoperla zastrowi sillemi	KY486849
Chrysoperla zastrowi sillemi	KY640621
Chrysoperla zastrowi sillemi	KY129799
Chrysoperla zastrowi sillemi	KY511707
Chrysoperla zastrowi sillemi	KY511706

Chrysoperla zastrowi sillemi	KY621482
Chrysoperla zastrowi sillemi	SUB2465513

6. IDENTIFICATION SERVICES

Hymenoptera (Dr Ankita Gupta)

Acharya N.G. Ranga Agricultural University, Tirupati; Navsari Agricultural University, Navsari; Anand Agricultural University, Gujarat; Assam Agricultural University, Jorhat; Bihar Agricultural University, Sabour; Central Sericultural Research & Training Institute, West Bengal; College of Agriculture, IGKV, Chhattisgarh; Dr Yashwant Singh Parmar University of Horticulture and Forestry, Solan; Dr Y.S.R. Horticultural University, Venkataramannagudem; E.I.D. Parry Pvt. Ltd; ICAR–Central Potato Research Station, Shimla; ICAR – Indian Institute of Horticulture Research, Bengaluru; ICAR–Indian Institute of Oilseeds Research, Hyderabad; ICAR–National Bureau of Agricultural Insect Resources, Bengaluru; ICAR – National Institute of Biotic Stress Management, Chhattisgarh; ICAR–National Research Centre for Cashew, Puttur; ICAR–Sugarcane Breeding Institute, Regional Centre, Karnal; Kerala Agricultural University, Thrissur; Koppert Pvt. Ltd; Kuvempu University, Shivamogga; Maharana Pratap University of Agriculture and Technology, Udaipur; Mahatma Phule Krishi Vidyapeeth, Maharashtra; Pulses and Oilseeds Research Station, West Bengal; Punjab Agricultural University, Ludhiana; Tamil Nadu Agricultural University, Coimbatore; University of Agricultural and Horticultural Sciences, Shivamogga; University of Agricultural Sciences, Bengaluru; University of Agricultural Sciences, Dharwad; University of Agricultural Sciences, Mandya.

Trichogrammatidae (Dr O.S. Navik)

Tamil Nadu Agricultural University, Coimbatore.

Platygastroidea (Dr K. Veenakumari)

Assam Agricultural University, Jorhat; ICAR – Indian Institute of Horticulture Research, Bengaluru; University of Agricultural and Horticultural Sciences, Shimoga; University of Agricultural Sciences, Bengaluru.

Hemiptera (Aphids, mealybugs and scale insects) (Dr Sunil Joshi)

Acharya N.G. Ranga Agricultural University, Tirupati; Navsari Agricultural University, Navsari; Anand Agricultural University, Gujarat; Assam Agricultural University, Jorhat; Central Sericultural Research & Training Institute, West Bengal; College of Agriculture, IGKV, Chhattisgarh; Directorate of Plant Protection, Quarantine and Storage; Dr Yashwant Singh Parmar University of Horticulture and Forestry, Solan; Dr Y.S.R. Horticultural University, Venkataramanna gudem; ICAR–Central Potato Research Station, Shimla; ICAR–Indian Institute of Horticulture Research, Bengaluru; ICAR–Indian Institute of Oilseeds Research, Hyderabad; ICAR–National Institute of Biotic Stress Management, Chhattisgarh; ICAR–National Research Centre for Cashew, Puttur; ICAR–Sugarcane Breeding Institute, Regional Centre, Karnal; Kerala Agricultural University, Thrissur; Kuvempu University, Shivamogga; Maharana Pratap University of Agriculture and Technology, Udaipur; Mahatma Phule Krishi Vidyapeeth, Maharashtra; Pulses and Oilseeds Research Station, West Bengal; Punjab Agricultural University, Ludhiana; Tamil Nadu Agricultural University, Coimbatore; University of Agricultural and Horticultural Sciences, Shimoga; University of Agricultural Sciences, Bengaluru; University of Agricultural Sciences, Dharwad; University of Agricultural Sciences, Mandya.

Aleyrodidae (Dr K. Selvaraj)

ICAR–Central Plantation Crops Research Institute, Kayamkulam; Tamil Nadu Agricultural University, Coimbatore.

Pentatomidae (Dr S. Salini)

Dr Yashwant Singh Parmar University of Horticulture and Forestry, Solan; Mahatma Phule Krishi Vidyapeeth, Maharashtra; ICAR–Central Potato Research Station, Shimla.

Miridae (Dr Richa Varshney)

Acharya N.G. Ranga Agricultural University, Tirupati; Kerala Agricultural University, Thrissur.

Thysanoptera (Ms R.R. Rachana)

Agricultural University, Navasari; Anand Agricultural University, Gujarat; BASF Co. Pvt. Ltd; ICAR–Central Potato Research Station, Shimla; ICAR–Indian Institute of Horticulture Research, Bengaluru; ICAR–National Bureau of Agricultural Insect Resources, Bengaluru; ICAR–National Research Centre for Cashew, Puttur; Kerala Agricultural University, Thrissur; Koppert Pvt. Ltd; Mahatma Phule Krishi Vidyapeeth, Maharashtra; Punjab Agricultural University, Ludhiana; Sygenta Pvt. Ltd; University of Agricultural and Horticultural Sciences, Shimoga; University of Agricultural Sciences, Bengaluru; University of Agricultural Sciences, Dharwad; University of Agricultural Sciences, Mandya.

Tephritidae (Dr K.J. David)

Directorate of Plant Protection, Quarantine and Storage; ICAR–Indian Institute of Horticulture Research, Bengaluru; ICAR–Indian Institute of Oilseeds Research, Hyderabad; ICAR–National Bureau of Agricultural Insect Resources, Bengaluru; ICAR–National Institute of Biotic Stress Management, Chhattisgarh; ICAR–National Research Centre for Cashew, Puttur; ICAR–Sugarcane Breeding Institute, Regional Centre, Karnal.

Non-*Apis* bees (Dr U. Amala)

ICAR–National Research Centre for Cashew, Puttur; ICAR–National Research Centre for Orchids, Darjeeling.

Cerambycidae (Dr M. Mohan)

College of Forestry, OUAT, Bhubaneswar; Dr Yashwant Singh Parmar University of Horticulture and Forestry, Solan.

Curculionidae (Dr G. Mahendiran)

College of Forestry, OUAT, Bhubaneswar; Indian Institute of Oilseeds Research, Hyderabad.

Araneae (Dr M. Sampath Kumar)

Assam Agricultural University, Jorhat; University of Agricultural and Horticultural Sciences, Shivamogga; University of Agricultural Sciences, Dharwad.

Acari (Dr P. Sreerama Kumar)

ICAR–Sugarcane Breeding Institute, Regional Centre, Karnal.

7. EXTENSION ACTIVITIES

Live insect cultures

During 2016-17, 113 live insect cultures were maintained. Over the year, 1,251 consignments of insects were supplied to various institutions, students, extension agencies, farmers and private entrepreneurs (Fig. 73) and a revenue of ₹ 4,87,681 was generated.

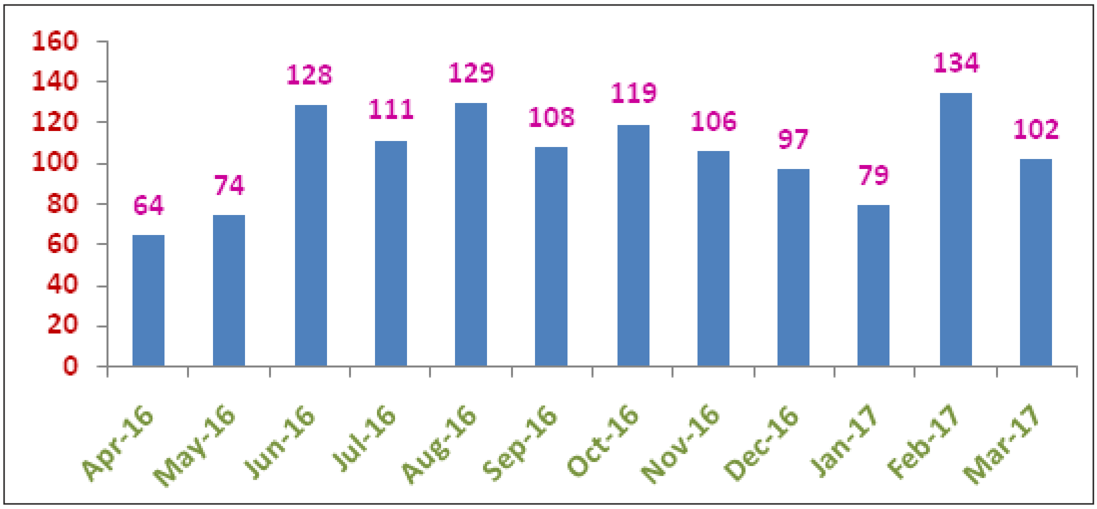


Fig. 73. Live insect cultures maintained and supplied during 2016-17

Microbial cultures

A total of 63 shipments of microbial biocontrol agents, including entomopathogenic fungi and plant disease antagonists, were made during 2016-17 (Fig. 74) generating a revenue of ₹ 2,52,000.

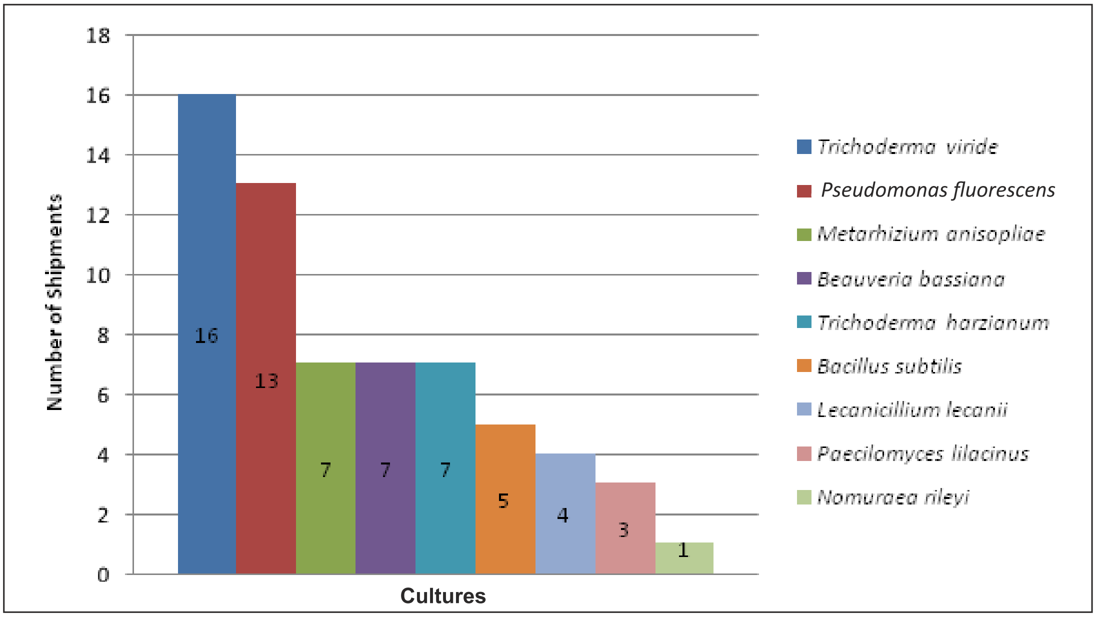


Fig. 74. Microbial cultures supplied during 2016-17

8. AWARDS AND RECOGNITIONS

ICAR–NBAIR

Sardar Patel Outstanding ICAR Institution Award for the year 2015.

Dr Chandish R. Ballal

Panjabrao Deshmukh Outstanding Woman Scientist Award for the year 2015.

SBA – Dr S.P. Singh Lifetime Achievement Award for Biological Control.

DST Travel Grant for attending ICE 2016, USA, 25–30 September 2016.

Dr S. K. Jalali

National Research Development Council (NRDC) – Societal Innovation Award 2017, Department of Scientific and Industrial Research (DSIR) – Cash prize of ₹ 3.0 lakhs (Shared with Venkatesan, T., Rangeshwaran, R., Sivakumar, G. and Sriram, S.).

Dr N. Bakthavatsalam

Best Oral Presentation Award, International Conference on Green Technologies for Health and Environment: Implementation and Policies, Bengaluru, 15–16 December 2016. (Shared with Pushpa, K., Raghavendra, A., Khushboo, S., Soumya, C B., Morrison, N., Vinod Kumar and Narendra Kumar, J. B.)

Dr M. Nagesh

Indian patent granted for the design of small-scale solid state fermentor for production of antagonistic fungi.

Dr A. N. Shylesha

RAC member of CSR&TI, Mysuru.

IMC member of ICAR–NIVEDI, Bengaluru.

Expert member for Ph.D. viva voce of student at Kumaun University, Nainital.

Expert member for conducting viva voce for M.Sc. and Ph.D. qualifying exams at UAS Raichur.

Dr T. Venkatesan

Prof. T.N. Ananthakrishnan Award 2017.

SBA – Dr T.M. Manjunath Award for Biological Control.

Best Oral Presentation Award, Fifth National Conference on Biological Control: Integrating Recent Advances in Pest and Disease Management, Bengaluru, 9–11 February 2017 (Shared with Srimoyee Basu)

Member of PG Board of Studies, Agricultural Entomology, PAJANCOA, Puducherry

Member, Editorial Board, The Journal of Environmental Biology, Lucknow.

Vice-President, Society for Biocontrol Advancement, Bengaluru.

Dr P. Sreerama Kumar

Dr Mahesh K. Upadhyaya Lecture Award, Indian Society of Weed Science, Jabalpur.

Bharat Seva Ratan Gold Medal Award 2016 by Global Economic Progress and Research Association, Tiruvannamalai.

Chief Organising Secretary, Fifth National Conference on Biological Control: Integrating Recent Advances in Pest and Disease Management, Bengaluru, 9–11 February 2017.

Co-author of Lead Paper, Fifth National Conference on Biological Control: Integrating Recent Advances in Pest and Disease Management, Bengaluru, 9–11 February 2017.

Scientific Coordinator, National Symposium on Phytopathogenic Mollicutes: Indian Scenario of Diagnosis, Epidemiology and Disease Management, New Delhi, 16 December 2016.

Lead Speaker, National Symposium on Phytopathogenic Mollicutes: Indian Scenario of Diagnosis, Epidemiology and Disease Management, New Delhi, 17 December 2016.

Co-Chairman, Technical Session 3, National Symposium on Phytopathogenic Mollicutes: Indian Scenario of Diagnosis, Epidemiology and Disease Management, New Delhi, 17 December 2016.

Plenary Speaker, Biennial Conference on Doubling Farmers' Income by 2022: The Role of Weed Science, Maharana Pratap University of Agriculture and Technology, Udaipur, 1–3 March 2017.

Vice-President, Society for Biocontrol Advancement during 2016-17.

Dr K. Subaharan

Resource person for Nanotechnology Workshop, Lebene, Mauritius, 5–7 April 2016.

Best Oral Presentation Award, International Symposium on Coconut Research and Development, ICAR–CPCRI, 10–12 November 2016.

Best Oral Presentation Award, Fifth National Conference on Biological Control: Integrating Recent Advances in Pest and Disease Management, Bengaluru, 9–11 February 2017.

Technical Committee Member to review the Post-Graduate syllabus for Nanotechnology, Tamil Nadu Agricultural University, Coimbatore.

Evaluated the proposal submitted to Department of Ayush on Bioefficacy of medicinal plants on cattle ticks.

External examiner for PG thesis submitted to Anna University.

Interview panel member for selection of Senior Research Fellow of the DBT sponsored project.

Dr R. Rangeshwaran

Best Oral Presentation Award, Fifth National Conference on Biological Control: Integrating recent advances in pest and disease management, Bengaluru, 9–11 February 2017 (Shared with Velavan, V., Manohar, V., Surabhi Kumari, Subima, G., Banerjee, Shylesha, A.N., Mohan, M., Satandra Kumar and Sivakumar, G.)

Dr M. Mohan

Best Poster Award, First International Agro Biodiversity Congress, New Delhi, 6–9 November 2016 (Shared with Varshney R., Ballal C.R. and Mohan M.)

Best Oral Presentation Award, Fifth National Conference on Biological Control: Integrating recent advances in pest and disease management, Bengaluru, 9–11 February 2017 (Shared with Subaharan, K., Bakthavatsalam, N., Rangeshwaran, R. and Ballal, C.R.)

Dr G. Sivakumar

SBA – Dr S. Sithanantham Award for Biological Control.

Award of Excellence for the year 2016 by ICAR-NBAIR, Bengaluru.

Assessor, Agricultural Skill Council of India, Ministry of Agriculture.

Reviewer, research project of Kerala State Council of Science and Technology, Thiruvanthapuram, Kerala.

External examiner for Ph.D. thesis evaluation of Bharathiyar University.

Editor, Journal of Mycology and Plant Pathology, Udaipur.

Secretary, Society for Biocontrol Advancement, Bengaluru

Dr Deepa Bhagat

BRICPL Science Explorer Award 2017.

Gandhian Young Technological Innovation (GYTI) Award (Shared with Parikshitmoitra, Rudra Pratap and Santanu Bhattacharya).

Best Scientist (Research) Award-2015 for Nanoscience, National Conference of Emerging Trends in Agricultural Sciences and its Impact on Sustainable Livelihood, Shobit University, Meerut, 25–26 February 2017.

Dr S. Salini

Fellow of the Society for Biocontrol Advancement, Bengaluru,

Dr K.J. David

Best Oral Presentation Award, PG Science Week 2016, University of Agricultural Sciences, Bengaluru, 25–28 May 2016.

Dr Ankita Gupta

SBA – Dr M. Swamiappan Award for Biosystematics of Biocontrol Agents.

Dr Jagadeesh Patil

International Travel Grant from Science and Engineering Research Board (DST) to attend the 32nd European Society of Nematologists Symposium held during 28 August – 1 September 2016 at University of Minho Braga, Portugal.

Post-Graduate Teacher in Plant Pathology/ Nematology, University of Agricultural and Horticultural Sciences, Shivamogga.

Best Poster Presentation, National Symposium on Climate Smart Agriculture for Nematode Management, ICAR–Central Coastal Agricultural Research Institute, Ela, 11–13 January 2017.

Best Oral Presentation, Fifth National Symposium on Biological Control: Integrating Recent Advances in Pest and Disease Management, Bengaluru, 9–11 February 2017.

Best Oral Presentation, Second National Conference on Frontiers in Eco-biological Sciences and its Applications, Salem, 16–17 March 2017.

Invited Lecturer, Capacity Building Programme on Advances and Innovations in Promotion and

Utilization of Microbials for Biological Control of Crop Pests, Bengaluru, 14–24 December 2016.

Dr M. Sampath Kumar

Fellow of the Society for Biocontrol Advancement, Bengaluru.

Best Oral Presentation Award, Fifth National Conference on Biological Control: Integrating Recent Advances in Pest and Diseases Management, Bengaluru, 9–11 February 2017 (Shared with Chitra Shanker, Jhansirani, B. and Katti, G.)

Rapporteur, Technical Session on Biointensive IPM, Fifth National Conference on Biological Control: Integrating Recent Advances in Pest and Disease Management, Bengaluru, 9–11 February 2017.

Dr K. Selvaraj

Fellow of the Society for Biocontrol Advancement, Bengaluru.

Best Poster Award, Fifth National Conference on Biological Control: Integrating Recent Advances in Pest and Disease Management, Bengaluru, 9–11 February 2017. (Shared with Sundararaj, R., Venkatesan, T., Gupta, A., Ballal, C. R., Jalali, S. K. and Mrudula, H.K.)

Dr U. Amala

Invited Lecturer, Niche Area of Excellence Programme on Taxonomy of Insects and Mites, Bengaluru, 28 December 2016.

Invited Lecturer, Satellite Meeting on Pollinators and Climate Change at XIII Agricultural Science Congress, Bengaluru, 22 February 2017.

Dr Richa Varshney

Best Poster Award, First Agrobiodiversity Congress, New Delhi, 6–9 November 2016 (Shared with Ballal, C.R. and Mohan, M.)

Invited Lecturer, Capacity Building Programme on Advances and Innovations in Promotion and Utilization of Microbials for Biological Control of Crop Pests, Bengaluru, 14–24 December 2016.

Invited Lecturer, Plant Protection and Seed Quality Techniques by National Seeds Corporation, Bangaluru, 24–25 March 2017.

Invited Lecturer, Organic Pest Management in Fruits and Vegetables for Farmers, Seminar-cum-Interface, Bagalkot, 28 August 2016.

Rapporteur, Technical Session, First International Agrobiodiversity Congress, New Delhi, 6–9 November 2016.

Rapporteur, Technical Session, Fifth National Conference on Biological Control: Integrating Recent Advances in Pest and Disease Management, Bengaluru, 9–11 February 2017.

Ms R.R. Rachana

Best Poster Award, First International Agrobiodiversity Congress, New Delhi, 6–9 November 2016 (Shared with Shylesha, A.N.)

Rapporteur, Technical Session, National Meet of Entomologists, Bengaluru, 7–8 October 2016.

Rapporteur, Technical Session, Fifth National Conference on Biological Control: Integrating Recent Advances in Pest and Disease Management, Bengaluru, 9–11 February 2017.

9. AICRP COORDINATION UNIT AND CENTRES

The biocontrol technologies developed at NBAIR are field-tested, validated and demonstrated on a large-scale under the All-India Coordinated Research Project on Biological Control of Crop Pests by select ICAR institutes and State Agricultural Universities.

Coordination unit

ICAR–National Bureau of Agricultural Insect Resources, Bengaluru	Basic research

State Agricultural University-based centres

Acharya N.G. Ranga Agricultural University, Hyderabad	Sugarcane, maize
Anand Agricultural University, Anand	Cotton, pulses, oilseeds, vegetables, weeds
Assam Agricultural University, Jorhat	Sugarcane, pulses, rice, weeds
Central Agricultural University, Pasighat	Rice, vegetables
Dr Y.S. Parmar University of Horticulture and Forestry, Solan	Fruits, vegetables, weeds
Gobind Ballabh Pant University of Agriculture and Technology, Pantnagar	Plant disease antagonists
Kerala Agricultural University, Thrissur	Rice, coconut, weeds, fruits
Maharana Pratap University of Agriculture & Technology, Udaipur	Vegetables, whitegrubs, termites
Mahatma Phule Krishi Vidyapeeth, Pune	Sugarcane, cotton, soybean, guava
Orissa University of Agriculture & Technology, Bhubaneswar	Rice, vegetables
Pandit Jayashankar Telangana State Agricultural University, Hyderabad	Cotton, pulses, oilseeds, sugarcane
Punjab Agricultural University, Ludhiana	Sugarcane, cotton, oilseeds, rice, tomato, weeds
Sher-e-Kashmir University of Agricultural Science & Technology, Srinagar	Temperate fruits, vegetables
Tamil Nadu Agricultural University, Coimbatore	Sugarcane, cotton, pulses, tomato
University of Agricultural Sciences (Raichur), Raichur	Oilseeds, pulses

ICAR Institute-based centres

ICAR–Central Institute of Subtropical Horticulture, Lucknow	Mango
ICAR–Central Plantation Crops Research Institute, Kayangulam	Coconut
ICAR–Central Tobacco Research Institute, Rajamundry	Tobacco, soybean
ICAR–Directorate of Seed Research, Mau	Pigeonpea, sorghum
ICAR–Indian Agricultural Research Institute, New Delhi	Basic research
ICAR–Indian Institute of Horticultural Research, Bengaluru	Fruits and vegetables
ICAR–Indian Institute of Millet Research, Hyderabad	Sorghum
ICAR– Indian Institute of Rice Research, Hyderabad	Rice
ICAR–Indian Institute of Vegetable Research, Varanasi	Vegetables
ICAR–National Centre for Integrated Pest Management, New Delhi	Biocontrol in IPM

Voluntary centres

Dr YSR Horticultural University, Ambajipeta
Indira Gandhi Krishi Viswavidhyalaya, Raipur
KAU–Regional Agricultural Research Station, Kumarakom
Kerala Agricultural University, Vellayani
Uttar Banga Krishi Vishwavidyalaya, Pundibari

10. PUBLICATIONS

Peer-reviewed articles

Aggarwal, N., Sharma, S. & Jalali, S.K. 2016. On-farm impact of biocontrol technology against rice stem borer, *Scirpophagaexcerptalis* (Walker) and rice leaf folder *Cnaphalocrocismedinalis* (Guenee) in aromatic rice. *Entomologia Generalis*, 26 (2): 137–148.

Agrawal, P.K., Raj, B., Radhakrishna, S., Verghese, A., Subaharan, K. & Gupta, A. 2016. Human animal conflict. *Current Science*, 111(10): 1581–1582.

Amala, U. & Shivalingaswamy, T.M. 2017. Role of native buzz pollinator bees in enhancing fruit and seed set in tomatoes under open field conditions. *Journal of Entomology and Zoology Studies,* 5(3): 1742–1744.

Antony, C. J. & Pratheepa, M. 2017. Study of population dynamics of soybean semi-looper *Gesonia gemma* Swinhoe by using rule induction model in Maharashtra, India. *Legume Research,* DOI: 10.18805/lr.v0i0.7297.

Archana, M., D'Souza, P.E. & Patil, J. 2017. Efficacy of entomopathogenic nematodes (Rhabditida: Steinerne matidae and Heterorhabditidae) on developmental stages of house fly, *Musca domestica*. *Journal of Parasitic Diseases*, DOI 10.1007/s12639-017-0889-3.

Archana, M., DSouza, P. E., Ojha, R. & Jalali, S. K. 2016. DNA barcoding of flies commonly prevalent in poultry farms of Bengaluru District. *Journal of Entomology and Zoology Studies*, 4(4): 230–235.

Bakthavatsalam, N. & Subaharan, K. 2016. Innovations in insect pest management: Interventions using insect derived volatiles. *Indian Journal of Plant Genetic Resources*, 29(3): 399–401.

Bakthavatsalam, N., Vinutha, J., Ramakrishna, P., Raghavendra, A., Ravindra, K. V. & Verghese, A. 2016. Autodetection in *Helicoverpa armigera* (Hubner). *Current Science*, 110 (12): 2261–2267.

Ballal, C.R. & Varshney, R. 2016. Insect genetic resources–Innovations in utilisation. *Indian Journal of Plant Genetic Resources,* 29(3): 392–395.

Ballal, C.R., Gupta, A., Mohan, M., Lalitha, Y. & Verghese, A.V. 2016. The new invasive pest *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in India and its natural enemies along with evaluation of Trichogrammatids for its biological control. *Current Science*, 110(11): 2155–2159.

Basu, S., Polhemus, D. A., Subramanian, K. A., Saha, G. K. and Venkatesan, T. 2016. *Metrocoris* Mayr (Insecta: Hempiptera: Gerridae). *Zootaxa*, 4178 (2): 257–277.

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Sreerama Kumar, P., Resmi, M.V., Subramanian, M., Visalakshi, M., Ramanujam, B. and Verghese, A. 2016. Seeing is believing: rice farmers' experiences with biological control in southern India. *Biocontrol News and Information*, 37(3): 22N–23N.

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Subaharan, K. & Amala, U. 2017. Try red ant chutney for lunch. *Indian Express* on 4.1.2017.

Subaharan, K. & Verghese, A. E book on Arthropods of Veterinary and Fisheries. ICAR – National Bureau of Agricultural Insect Resources.

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Varatharajan, R. & Rachana, R.R. 2016. Insect Farming and Pharming. *In: Consortium of third National Meet of Entomologists organized by IIHR, Bangalore.* 56 pp.

11. ONGOING RESEARCH PROJECTS

A. Institute projects for 2016-17

DIVISION OF INSECT SYSTEMATICS

I. Biosystematics of agriculturally important insects and associated fauna

1. Biosystematics of Trichogrammatidae (Hymenoptera)
(01.04.2013 to 31.05.2017) – Dr Prashanth Mohanraj
2. Biosystematics of oophagous parasitoids with special reference to Platygastroidea (Hymenoptera)
(01.09.2008 to 31.03.2018) – Dr K. Veenakumari
3. Biosystematics of aphids, coccids and diversity of their natural enemies
(01.04.2009 to 31.03.2017) – Dr Sunil Joshi
4. Biosystematics and diversity of agriculturally important Cerambycidae
(01.10.2013 to 31.03.2017) – Dr M. Mohan
5. Biosystematics and diversity of entomogeneous nematodes in India
(01.04.2012 to 31.03.2017) – Dr Jagadeesh Patil
6. Taxonomic studies on fruit flies (Diptera: Tephritidae) of India
(01.04.2012 to 31.03.2020) – Dr K.J. David
7. Taxonomic studies on pentatomidae (Hemiptera: pentatomoidea) of India with special reference to pentatominae
(14.03.2012 to 31.03.2020) – Dr S. Salini
8. Digitization of type specimens in NBAII reference collection
(01.04.2013 to 31.03.2018) – Dr Ankita Gupta
9. Taxonomy, diversity and host-parasitoid association of Ichneumonoidea: Braconidae with special reference to Braconinae, Doryctinae & Microgastrinae
(09.05.2016 to 31.03.2021) – Dr Ankita Gupta
10. Taxonomic studies on Indian Curculionidae (Coleoptera) with emphasis on Entiminae (01.07.2016 to 31.03.2021) – Dr G. Mahendiran
11. Taxonomy and diversity of Indian Thysanoptera with special reference to Terebrantia (01.10.2015 to 31.03.2021) – Ms R.R. Rachana
12. Taxonomy of Indian spiders (Araneae) with reference to agro-ecosystem
(01.07.2016 to 31.03.2021) – Dr M. Sampath Kumar
13. Taxonomy of Indian Trichogrammatidae (Chalcidoidea: Hymenoptera) and evaluation of potential species
(01.09.2016 to 31.03.2022) – Dr Navik Omprakash Samodhi

DIVISION OF MOLECULAR ENTOMOLOGY

II. Molecular characterisation, genomics and bioinformatics of agriculturally important insects, entomopathogenic nematodes and associated microorganisms

14. Molecular characterization and DNA barcoding of some agriculturally important insect pests
(01.04.2013 to 31.09.2018) – Dr S. K. Jalali
15. Studies on molecular and functional diversity of EPN-EPB-insect tritrophism and their utilization against soil pests
(08.07.2016 to 31.03.2019) – Dr M. Nagesh
16. Molecular characterization and DNA barcoding of agriculturally important parasitoids and predators
(01.06.2013 to 31.05.2018) – Dr T. Venkatesan
17. Molecular characterization and DNA barcoding of subterranean insects
(01.04.2014 to 31.03.2019) – Dr K. Srinivasa Murthy
18. Mapping of the Cry gene diversity in hot humid regions of India
(01.04.2011 to 31.03.2017) – Dr R. Rangeshwaran
19. Culturable and unculturable microflora associated with soil insects and other arthropods
(01.04.2013 to 31.03.2017) – Dr R. Rangeshwaran
20. Role of microbial flora of aphids in insecticide resistance
(01.10.2012 to 31.03.2017) – Dr Mahesh Yandigeri
21. Studies of detritivorous insects and associated microorganisms for their scope in farm waste management
(01.10.2016 to 31.03.2018) – Dr Mahesh Yandigeri
22. Distribution of abiotic stress tolerant genes/alleles across insect orders
(01.04.2014 to 31.03.2017) – Dr M. Pratheepa
23. Studies on whiteflies and associated natural enemies for their management
(19.09.2016 to 31.03.2021) – Dr K. Selvaraj
24. Taxonomy and diversity of sphecids
(01.09.2014 to 31.03.2020) – Dr R. Gandhi Gracy
25. Studies on insecticide and Bt resistance in pink bollworm, *pectinophora gossypilla* (Saunders)
(01.09.2016 to 31.03.2020) – Dr Ramya, R. S.
26. Studies on tospovirus–thrips interactions leading to transmission
(01.09.2016 to 30.03.2022) – Ms Daliyamol

DIVISION OF INSECT ECOLOGY

III. Biodiversity conservation, behavioural studies, maintenance and utilisation of arthropod germplasm

27. Documentation, production and utilisation of predatory anthocorids and mites
(24.03.2012 to 31.03.2017) – Dr Chandish R. Ballal
28. Influence of infochemical diversity on the behavioural ecology of some agriculturally important insects
(01.04.2013 to 31.03.2017) – Dr N. Bakthavatsalam

29. Climate change effect on the diversity and bioecology of some important sucking pests (01.04.2014 to 31.03.2019) – Dr N. Bakthavatsalam
30. Exploitation of *Beauveria bassiana* for the management of maize stem borer (*Chilo partellus*) and tomato fruit borer (*Helicoverpa armigera*) through endophytic establishment (01.04.2014 to 31.03.2017) – Dr B. Ramanujam
31. Introduction and studies on natural enemies of some new insect pests and weeds (27.08.2010 to 31.03.2017) – Dr A.N. Shylesha
32. Pollinator diversity in different agro climatic regions with special emphasis in non-*Aphis* species (01.04.2012 to 31.03.2017) – Dr T.M. Shivalingaswamy
33. Documenting agriculturally important mites and establishing an authentic collection (01.04.2014 to 31.03.2019) – Dr P. Sreerama Kumar
34. Chemical characterization and ethology of economically important dipteran pests of veterinary and fisheries (09.10.2014 to09.10.2017) – Dr Kesavan Subaharan
35. Characterization of viruses with special reference to Lepidoptera & Coleoptera (24.11.2015 to 31.03.2021) – Dr G. Sivakumar
36. Synthesis of nanomaterials to act as sensor for semiochemicals in pest management (01.07.2013 to 31.07.2017) – Dr Deepa Bhagat
37. Diversity and predator-prey interactions in predatory mirids and geocorids (01.10.2015 to 31.03.2019) – Dr Richa Varshney
38. Habitat manipulation as a tool to conserve beneficial insects (15.07.2016 to 31.03.2021) – Dr U. Amala
39. Studies on exploitation of insects as food and feed (01.01.2017 to 31.03.2018) – Dr U. Amala

B. Externally funded projects for 2016-17

DIVISION OF INSECT SYSTEMATICS

1. **CRP:** Consortium Research Platform (CRP) on Agrobiodiversity (14.08.2015 to 31.03.2017) – Dr Prashanth Mohanraj
2. **ICAR:** Network project on insect biosystematics (09.04.2012 o 31.03.2017) – Dr Prashanth Mohanraj
3. **ORP:** Open Research Platform on Management of Sucking Pests of Horticultural Crops - Taxonomy of aphids and coccids (04.01.2012 to 31.03.2017) – Dr Sunil Joshi
4. **DST:** Diversity and distribution entomopathogenic nematodes in coconut and arecanut ecosystems (16.05.2014 to 15.05.2017) – Dr Jagadeesh Patil

DIVISION OF MOLECULAR ENTOMOLOGY

5. **CRP:** Consortium Research Project (CRP) on Genomics (01.04.2015 to 31.03.2017) – Dr S. K. Jalali
6. **RASI:** Baseline studies for cotton bollworms with *Bt Cry*1*Fa*1 (22.09.2016 to 21.09.2017) – Dr S. K. Jalali
7. **NICRA:** Development of IPM strategies to combat whitefly and other emerging pests (04.08.2016 to 31.03.2019) – Dr S. K. Jalali
8. **ICAR:** Intellectual property management & transfer/ commercialization of Agricultural Technology Scheme (06.06.2008 to 31.03.2017) – Dr T. Venkatesan
9. **ORP-SP:** ICAR - Outreach Programme on Management of Sucking Pests in Horticultural Crops (02.01.2015 to 31.03.2017) – Dr T. Venkatesan

10. **CRP on Bioinformatics – ICAR:** Centre for Agricultural Bioinformatics (CABin) (01.01.2015 to 31.03.2017) – Dr T. Venkatesan

11. **NFSM:** Establishment/Strengthening of Bio-fertilizer/Bio-control production units in India (03.11.2016 to 31.03.2018) – Dr R. Rangeshwaran

12. **AMAAS:** Culturable and unculturable microbial diversity of aphids and their role in insecticide resistance and other fitness attributes
(01.04.2014 to 31.03.2017) – Dr Mahesh Yandigeri

DIVISION OF INSECT ECOLOGY

13. **DBT:** Studies on extending the shelf life and improving the delivery methods of trichogrammatid egg parasitoids for promoting their commercial mass production in India
(01.07.2013 to 03.01.2017) – Dr Chandish R. Ballal

14. **ICAR-CABI**: The study of biological control of invasive plant species & Indian natural enemies (01.07. 2014 to 31.07.2016) – Dr Chandish R. Ballal

15. **CRP:** Consortium Research Platform (CRP) on Borer in Network Mode
(01.01.2015 to 31.03.2017) – Dr N. Bakthavatsalam

16. **CSRTI**: Investigation on semiochemicals of the silkworm uzifly *Exorista bombycis*
(01.01.2015 to 31.12.2016) – Dr N. Bakthavatsalam

17. **CSRTI:** Identification, characterization, synthesis and field evaluation of sex pheromone of the mulberry leaf roller, *Diaphania pulverulentalis* (Lepidoptera: Pyralidae)
(21.01.2016 to 20.01.2018) – Dr N. Bakthavatsalam

18. **DBT:** Plant-derived botanicals from herbs/shrubs of Indo-Burma biodiversity hotspot for control of stored grain insect pests
(20.03.2015 to 31.03.2018) – Dr N. Bakthavatsalam

19. **ICAR Extramural Project**: Formulation of pheromones for important agricultural pests
(21.01.2016 to 31.03.2017) – Dr N. Bakthavatsalam

20. **ATGC**: Pheromone formulations for mating disruption in some important agricultural insect pests (01.04.2016 to 31.03.2017) – Dr N. Bakthavatsalam

21. **AMAAS:** Development of formulations of *Beauveria bassiana, Metarhizium anisopliae* and *Lecanicillium* spp. for management of certain sucking pests in vegetable crops
(01.04.2014 to 31.03.2017) – Dr B. Ramanujam

22. **DBT**: Controlled release dispensers for delivery of semiochemicals
(25.11.2014 to 24.11.2017) – Dr K. Subaharan

23. **ICAR Extramural project:** Development of stable, low cost, essential oil based mosquito repellent formulations
(01.01.2016 to 31.03.2017) – Dr K. Subaharan

24. **NTRF** : Feasibility of suppression of tea shot hole borer *Euwallacea fornicatus* through its mutualistic *Fusarium* spp.
(01.01.2016 to 31.12.2018) - Dr G. Sivakumar

25. **IISc** : Characterization, functionalisation and assembly of nanosensors and their applications as pheromone sensor for pest management
(03.08.2012 to 30.06.2017) – Dr Deepa Bhagat

26. **CRP :** Consortium Research Platform (CRP) on Nanotechnology
(18.11.2014 to 31.03.2017) – Dr Deepa Bhagat

12. ACTIVITIES OF ITMU

Technologies transferred

1. A herbal-based repellant for termites on woody trees – Repter
2. Novel insecticidal WP formulation of *Heterorhabditis indica* for the biological control of white grubs and other soil insects pests
3. (i) Herbal swabber for the management of white stem borer *Xylotrechus quadripes* in coffee (organic)
   (ii) Booster for boosting plant health in coffee (not for certified organic coffee)

Achievements of ITMU under National Agriculture Innovation Fund project:

1. Total number of technologies available at NBAIR: 21
2. Number of technologies commercialised: 3
3. Number of licensees that purchased technologies from NBAIR: 3
4. Number of technology brochures released: 4
5. Number of IP filed: 1
6. ITMU facilitated the contract research between NBAIR and Rasi Seeds India Private Limited, Salem and between NBAIR and ATGC Private Limited, Hyderabad.

Patent granted

Patent granted for the invention entitled "A simple and novel design for small-scale solid state mass production unit for antagonistic fungi", application number 417/CHE/2006, on 18 August 2016.

Revenue generated during 2016-17

Through technology commercialisation: ₹ 9,25,000
Through contract research: ₹ 10,00,000

Technology information brochures being released by Dr Trilochan Mohapatra, Secretary, DARE & Director-General, ICAR, on 20 May 2016

MoU being exchanged between NBAIR and Planttech

13. CONFERENCE PAPERS

Amala, U. 2017. Impact of raising temperature on solitary bees, p. 12. In: Belavadi, V.V. (ed). *Book of Abstracts, Satellite meeting on Pollinators and Climate change, Thirteenth Indian Science Congress*, University of Agricultural Sciences, Bengaluru, 21–24February 2017.

Amala, U., Shivalingaswamy, T. M. & Pratheepa, M. 2016. Foraging behavior of blue banded bee, *Amegilla zonata* (L.) (Apoidea: Anthophorinae: Hymenoptera) on tomatoes under field conditions, p. 101. In: Bagyaraj, D.J., Balakrishna, A.N., Govindaraju, G., Jagadish, K.S., Kumar, A.R.V., Kumar, N.G., Srinivas, N. & Ravichandra, N.G. (eds). *Book of Abstracts, Eleventh National Symposim on Soil Biology and Ecology,* University of Agricultural Sciences, Bengaluru, 19–21 December 2016.

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Bakthavatslam, N., Raghavendra, A., Sowmya, C. B. & Kushboo, S. 2016. Potential of using semiochemicals to alleviate human – wild animal conflicts. In: *National Conference on Ecology, Sustainable Development and Wildlife Conservation*, St. Joseph's College, Bengaluru, 15–16 December 2016 .

Chavan, A., Shivalingaswamy, T.M. & Amala. U. 2017. Diversity of pollinators in three bee-friendly plant species, p. 191. In: Sreerama Kumar, P., Salini, S., Gupta, A., Gandhi Gracy, R., Subaharan, K. & Ballal, C.R. (eds) *Fifth National Conference on Biological Control: Integrating recent advances in pest and disease management*, Society for Biocontrol Advancement, Bengaluru, 9 –11 February 2017.

Chitra Shanker, Sampathkumar, M., Jhansirani, B. & Gururaj Katti, 2017. Ecological engineering for enhancing biocontrol of hoppers in rice, p. 32. In: Sreerama Kumar, P., Salini, S., Gupta, A., Gandhi Gracy, R., Subaharan, K. & Ballal, C.R. (eds) *Fifth National Conference on Biological Control: Integrating recent advances in pest and disease management*, Society for Biocontrol Advancement, Bengaluru, 9 –11 February 2017.

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David, K.J. 2016. Taxonomic notes on Genus *Tritaeniopteron* De Meijere with a new record for India (Diptera: Tephritidae: Phytalmiinae). p. 159. In: *Book of Abstracts, International conference on Entomology,* Panjabi University, Patiala, 3–5 December 2016.

David, K.J. 2017. Taxonomic Notes on fruit flies of subfamily Tephritinae (Diptera: Tephritidae): Potential Biocontrol agents of weeds. p. 57. In: Sreerama Kumar, P., Salini, S., Gupta, A., Gandhi Gracy, R., Subaharan, K. & Ballal, C.R. (eds). *Book of Abstracts*, *Fifth National Conference on Biological Control: Integrating recent advances in pest and disease management*, Society for Biocontrol Advancement, Bengaluru, 9 –11 February 2017.

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Duraimurugan, P., Sampathkumar, M. & Srinivas, P.S. 2016. Evaluation of synthetic kairomonal attractants against lepidopteran pests of castor, p. 29. In: *Book of Abstracts*, *International Conference on Microbiology, Agriculture and Environmental Sciences*, St. Pious X Degree & PG Colege for Women, Hyderabad, 1–3 September 2016,

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Gupta, A. 2017. A decade of transition in the knowledge of Indian fauna of parasitic Hymenoptera: achievements and challenges. p. 58. In: Sreerama Kumar, P., Salini, S., Gupta, A., Gandhi Gracy, R., Subaharan, K. & Ballal, C.R. (eds). *Book of Abstracts*, *Fifth National Conference on Biological Control: Integrating recent advances in pest and disease management*, Society for Biocontrol Advancement, Bengaluru, 9 –11 February 2017.

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Nagesh, M., Shylesha, A.N., Saleem Javeed, Balachander, M., Nikhita Pai, & Shivalingaswamy, T.M. 2017. *Potential of native entomopathogenic nematodes for the management of a sweet potato weevil, Cylas formicarius Fabricius*, p. 116. In: Sreerama Kumar, P., Salini, S., Gupta, A., Gandhi Gracy, R., Subaharan, K. & Ballal, C.R. (eds) *Book of Abstracts*, *Fifth National Conference on Biological Control: Integrating Recent Advances in Pest and Disease Management*, Society for Biocontrol Advancement, Bengaluru, 9–11 February 2017.

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14. MEETINGS AND DECISIONS

XX Research Advisory Committee Meeting

The 20th meeting of the Research Advisory Committee (RAC) of the National Bureau of Agricultural Insect Resources was held on 6 May 2016, in the conference hall of NBAIR. The following members of the RAC attended the meeting:

1	Dr C.A. Viraktamath	Chairman
2	Dr M. Venkat Rajam	Member
3	Dr Abraham Verghese	Member
4	Dr A.N. Shylesha	Member-Secretary

General recommendations

1. EPNs and other biocontrol agents to be identified for pests in polyhouses/under protected cultivation.
2. New areas of research to be initiated in the following areas: (i) Insects as food and feed (poultry, fishery, etc.) (ii) Detritivorous insects (for the efficient breakdown of agricultural wastes).

Division-wise recommendations

Division of Insect Systematics

1. All the types are to be deposited centrally in the upcoming new state of art insect museum where curators are to be appointed to ensure that the insect collections are taken care of with the attention they require.
2. Alternative methods to be explored for the long term preservation of mites.
3. Care to be taken in the latinisation of names of new taxa to ensure that they are in accord with the provisions in the ICZN.
4. The biocontrol potential of natural enemies being studied by the taxonomists to be explored.
5. Monographs/publications collating information on Indian taxa being studied for reasonably extended periods at the bureau to be prepared and published.

Division of Molecular Entomology

1. Barcoding of museum specimens preserved dry/ in ethanol to be undertaken.
2. Efforts to be made to execute an MoU with ZSI for both molecular and morphological studies.

Division of Insect Ecology

1. Host specific strains of *Blaptostethus pallescens* for biocontrol of mites (especially broad mite) and insects for use in polyhouses to be identified and mass production technology for the predator to be popularised.
2. Efforts to be made to expand the number of existing live insect cultures at the bureau.

XXXII Institute Research Committee Meeting

The 32nd Institute Research Committee meeting of NBAIR was held on 9, 11 and 23 May 2016 under the chairmanship of Dr Abraham Verghese, Director, NBAIR. The scientists presented achievements in their projects during 2015-16.

XXXIII Institute Research Committee Meeting

The 33rd Institute Research Committee meeting of NBAIR was held on 8 July 2016 under the chairmanship of Dr Prashanth Mohanraj, Director (Acting) & Head, Division of Insect Systematics, NBAIR. The newly joined scientists presented the new project proposals. The following general points emerged after detailed discussions,

General comments

1. Include Ms R.R. Rachana as Co-PI in the institute project entitled, "Biosystematics of aphids, coccids and diversity of their natural enemies" of Dr Sunil Joshi was approved.
2. Recommendation for deletion of Dr Poorani in view of her transfer and include Dr G. Mahendiran in the institute project entitled, "Biosystematics and diversity of agriculturally important Cerambycidae" of Dr M. Mohan.
3. The RPP I for the approved projects should be submitted before 10 August 2016.

XXXIV Institute Research Committee Meeting

The 34th Institute Research Committee meeting of NBAIR was held on 19 September 2016 under the chairmanship of Dr Chandish R. Ballal Director, NBAIR. The following general points emerged after detailed discussions:

General comments

1. Include Dr M. Pratheepa as Co-PI in the institute project entitled, "Habitat manipulation as a tool to conserve beneficial insects" as project duration is up to March 2021.
2. The duration of the institute project titled, "Taxonomy of Indian Curculionidae (Coleoptera) with emphasis on Entiminae" of Dr G. Mahendiran is up to March 2021.
3. IRC approved to Dr S. Salini and Dr K.J .David should become Co-PIs in each others institute projects.
4. IRC approved to add a foreign expert as a collaborator in the institute project titled, "Taxonomic studies on Pentatomidae (Hemiptera: Pentatomoidae) of India with special reference to Indian Pentatominae of Dr S. Salini.
5. A proposal for inclusion of Scientist, ICAR-CIFRI Regional station, Bengaluru in the project titled, "Studies on exploitation of insects as food and feed" of Dr U. Amala has been submitted and the same will be permitted after IRC clearance from CIFRI.

15. PARTICIPATION OF SCIENTISTS IN MEETINGS

Abroad

Dr Chandish R.Ballal Dr T. M. Shivalingaswamy	XXV International Congress of Entomology, 25–30 September 2016, Orlando, USA.
Dr Jagadeesh Patil	XXXII European Society of Nematologists Symposium, 28 August–1 September 2016, Universidade do Minho, Braga, Portugal.

India

Dr S.K. Jalali	NTRF Interactive Meeting, 19 April 2016, UPASI, Valparai. XXV AICRP-BC Workshop, 17–18 May 2016, ANGRAU, Visakhapatnam.
Dr N. Bakthavatsalam	National Seminar on Innovative Technologies in Insect Science, 14 October 2016, Gurunanak College, Chennai.
	National Seminar on Fruit Fly, 26 May 2016, IIHR.
	International Conference on Green Technologies for Health and Environment: Implementation and policies, 15–16 December 2016, Bengaluru.
	National Conference on Ecology, Sustainable Development and Wildlife Conservation, 15–16 December 2016, St. Joseph's College, Bengaluru.
Dr M. Nagesh	XIII Agricultural Science Congress, 21–24 February 2017, UAS, GKVK, Bengaluru.
Dr T. Venkatesan	Review Meeting between ICAR, DAC & FW and SAUs regarding Cotton Crop in North India, 12–15 February 2017, ICAR, Krishi Bhavan, New Delhi.
Dr T. M. Shivalingaswamy	Workshop on Beneficial Insects and Bees, A Hidden Treasure in the Agro and Horticulture Sector in India, 24 August 2016, New Delhi.
	Workshop on Agriculture in Mass media, 29 September 2016, UAS, GKVK, Bengaluru.
	Policy Dialogue Meeting of National Biodiversity Authority on Main streaming Biodiversity into the Agricultural Sector, 20 January 2017, NAAS Complex, New Delhi.
Dr P. Sreerama Kumar	International Conference on Global Perspectives in Virus Disease Management, Indian Virological Society, 8–10 December 2016, ICAR–IIHR, Bengaluru.
	Delhi Chapter Meeting & National Symposium on Phytopathogenic Mollicutes: Indian Scenario of Diagnosis, Epidemiology and Disease Management, 17 December 2016, ICAR–IARI, New Delhi.
	Biennial Conference on Doubling Farmers' Income by 2022: The Role of Weed Science, 1–3 March 2017, MPUAT, Udaipur.
Dr K. Subaharan	International Conference on Agricultural Sciences and Food Technology, 25–27 August 2016, UAS, GKVK, Bengaluru
	III International Symposium on Coconut Research and Development, 10–11 November 2016, ICAR–CPCRI, Kasaragod.

	ICMR Sponsored Seminar, 9 September 2016, Nehru Memorial College, Trichy
	UGC Sponsored Agritrans Conference, 3-4 November 2016, Annamalai University, Annamalainagar.
	UGC Sponsored Programme on Frontier Areas of Science and Technology, 30 March 2017, Government Science College, Hassan.
Dr M. Mohan	CRP Meeting on Borers, 6 October 2016, ICAR–IIHR, Bengaluru.
Dr G. Sivakumar	National Level Interactive Meeting on Tea Shot Hole Borer-Management with Special Reference to Fungal Endosymbionts, 19 April 2016, Valparai, Tamil Nadu.
Dr G. Mahendiran	Awareness Workshop on Guidelines for Access to Biological Resources under the Biological Diversity Act, 2002, 28 July 2016, National Biodiversity Authority, Chennai.
Dr U. Amala	XI National Symposium on Soil Biology and Ecology, 19–21 December 2016, UAS, Bengaluru.
Dr Navik Omprakash Samodhi	Behavioural Ecology and Management of Agriculturally Important Animals (BEMAIA), 27–28 December 2016, UAHS, Shivamogga.
Dr R.S. Ramya	X International Conference on Controlled Atmosphere and Fumigation in Stored Products, 6–11November 2016, New Delhi.
	National Symposium on Agrochemicals Research and Education in India: Appraisal and Road Map for Future, 15–17 November 2016, ICAR–IARI, New Delhi.
Dr N. Bakthavatsalam Dr T. Venkatesan	Prof. T.N. Ananthakrishnan Memorial Lecture Series, 2 February 2017. Madras Christian College, Chennai.
Dr M. Nagesh Dr Jagadeesh Patil	National Symposium on Climate Smart Agriculture for Nematode Management, 11–13 January 2017, ICAR–CARS, Goa.
Dr K. Subaharan Dr Ankita Gupta	National Entomologists Meet, 6-7 October 2016, ICAR–IIHR, Bengaluru.
Dr K.J. David Dr S. Salini	International Conference on Entomology, 3–5 December 2016, Punjabi University, Patiala, Punjab.
Dr Chandish R. Ballal Dr S.K. Jalali Dr T. Venkatesan Dr K. Selvaraj	Brainstorming on Invasive Rugose Spiralling Whitefly *Aleurodicus rugioperculatus,* 21 March 2017, Tamil Nadu Agricultural University, Coimbatore.
Dr Chandish R.Ballal Dr N. Bakthavatsalam Dr K. Subaharan Dr M. Mohan Dr Ankita Gupta Dr Richa Varshney Ms R.R. Rachana	First International Agrobiodiversity Congress, 6–9 November 2016, New Delhi.

Dr Chandish R.Ballal Dr N. Bakthavatsalam Dr M. Nagesh Dr T. Venkatesan Dr P. Sreerama Kumar Dr R. Rangeshwaran Dr K. Subaharan Dr M. Mohan Dr G. Sivakumar Dr R. Gandhi Gracy Dr K. J. David Dr S. Salini Dr Ankita Gupta Dr Jagadeesh Patil Dr K. Selvaraj Dr U. Amala Dr RichaVarshney Ms R.R. Rachana Dr Navik Omprakash Samodhi	Fifth National Conference on Biological Control: Integrating Recent Advances in Pest and Disease Management, 9-11 February 2017, ICAR–NBAIR, Bengaluru
All scientists	Brainstorming on Access and Exchange of Insect Germplasm Resources, 23 July 2016, ICAR–NBAIR, Bengaluru.

16. TRAININGS CONDUCTED

S.No.	Trainee(s)	Particulars of training	Date & duration	Coordinator/resource person	Number of participants
1	PG students from BCKV, Kalyani	Summer training to PG students at NBAIR	23–25 May 2016	All scientists of NBAIR	7
2	Dr Jesu Rajan NIPHM, Hyderabad agents	Training on mass production of biocontrol	25–26 May 2016	Dr Chandish R. Ballal Dr Richa Varshney	1
3	Mr Anil Kumar Metahelix Pvt. Ltd.	Training on rearing pink bollworm and spotted bollworm	25 May 2016	Dr Chandish R. Ballal	1
4	Ms Gayathri	Training on mass production of bioagents	25–26 May 2016	Dr Chandish R. Ballal Dr Richa Varshney	1
5	Dr Sameer Narendra Kale, Asst. Prof. (Ento.) Mr. Jeevan Shridhar Arekar, Asst. Prof. (Path.) BSKV Regional Fruit Research Station, Sindhudurg	Training on mass production of biocontrol agents and microbial biopesticides	27–28 June 2016	Dr Chandish R. Ballal Dr B. Ramanujam Dr R. Rangeshwaran	2
6	Ms Leeza Rathore Department of Entomology H.P. Agricultural University Himachal Pradesh	Training on Identification of Mealybugs	18–23 July 2016	Dr Sunil Joshi	1
7	Ms A. Nasreen M.Sc. (Ag.) Department of Entomology TNAU, Coimbatore	Training on mass culturing techniques of anthocorids predators	25–27 July 2016	Dr Chandish R. Ballal Dr Richa Varshney	1
8	Scientists AICRP-BC, PAU, Ludhiana	Training on mass production of biocontrol agents and microbial biopesticides	1–8 August 2016	Dr Chandish R. Ballal Dr B. Ramanujam Dr R.Rangeshwaran	2
9	Dr Shivaji Telang Asst Professor Department of Entomology CRS, Nanded (MS)	Training on mass production of *Corcyra* and *Trichogramma*	9–10 August 2016	Dr Richa Varshney Dr Y. Lalitha	1
10	Dr Rahul R Marathe Ms. Ashwini R Marathe Ms. Vaidehi Dandekar Mitrakida, Pune	Training on use of novel insecticidal WP formulations of *Hetrorhabditis indica* for the biological control of white grubs and other insect pests entomopathogenic nematodes	9–10 August 2016	Dr Jagadeesh Patil	3
11	Dr M.Visalakshi Senior Scientist (Entomology) AICRP, ANGRAU (AP)	Training on mass production of *Trichogramma chilonis* on eri silkworm	29 August 2016	Dr Richa Varshney Dr Y. Lalitha	1

12	Ms. Maneesha MSc (Ag)., Ent. Dept. of Entomology, S V Agricultural College, ANGRAU, Tirupathi	Training on mass production techniques of *Cryptolaemus montrouzieri* and *Paracoccus marginatus*	26–27 Sept. 2016	Dr A.N. Shylesha Dr Richa Varshney	1
13	Ms. Tanuja Naik College of Agriculture Shivamogga	Training on thrips taxonomy	19–24 Sept. 2016	Ms R.R. Rachana	1
14	Mr. B.S. Sudish Deejay Farms, Bengaluru	Training on mass production of bioagents	5–6 Oct. 2016	Dr Richa Varshney Dr Y. Lalitha	1
15	Ms Roselin College of Agriculture, UAS, V.C. Farm, Mandya	Training on thrips mounting	25–26 Oct. 2016	Ms R.R. Rachana	1
16	Mr. Sudhakar Soundarajan Subject Matter Specialist (Plant Protection) ICAR-KVK (BSS) Santhanpara, Idukki, Kerala	Training on mass production of biocontrol agents and microbial pesticides	28–29 Nov. 2016	Dr B. Ramanujam Dr R. Rangeshwaran	1
17	Scientists from ICAR and AICRP centres	Advances and innovation in promotion & utilisation of microbials for biological control of crop pests	14–24 Dec, 2016	Dr M. Nagesh Dr Patil Dr Mahesh Yandigeri	14
18	Ms D.K. Ramya, Student Department of Pharmacognosy, Govt. College of Pharmacy (RGUHS), Bangalore	Bioassay of pesticides and rearing of host insects	19–21 Dec. 2016	Dr M. Mohan Dr Richa Varshney Dr R.S. Ramya Dr Y. Lalitha	1
19.	Administrative and finance staff of NBAIR	Interactive workshop on administrative and finance matters	3–4 January 2017	SAO, FAO, AAO	9

Subject Matter Training for ARS trainees

S.No.	Trainee	Coordinator/ resource person	Date & duration	Number of participants
1	Dr T.N. Madhu Scientist (Agricultural Entomology), CICR, Nagpur	Dr N. Bakthavatsalam	13 May to 12 August 2016 90 days	1

17. DISTINGUISHED VISITORS

1. Dr R.V.S. Korikanthimath, Former Director ICAR–Central Coastal Agricultural Research Institute, Goa, 2 November 2016.
2. Dr B.K. Das, Director, ICAR–Central Inland Fisheries Research Institute, Barrackpore, Kolkata, 3 November 2016.
3. Dr Trilochan Mohapatra, Secretary, DARE & Director-General, ICAR, 20 May 2016 and 14 January 2017.
4. Dr Amita Prasad, IAS, Additional Secretary, Ministry of Environment, Forests and Climate Change, 25 February 2017.

18. MERA GAON MERA GAURAV

Seven teams of scientists/technical officers have adopted a total of 35 villages in Karnataka and Tamil Nadu. The teams visited their respective villages every month and carried out farmer-centric activities, including demonstrations, providing technical guidance and information, and supplying inputs to the needy farmers. Farmers' 'gosthis' were also conducted on a regular basis to sensitise the farmers about the importance of natural enemies and biological control.

The various training programmes conducted during 2016-17 were as follows:

1. Surveys and guidance on management of insect pests and diseases in sugarcane, paddy, tomato, coconut and vegetables and training on use of trichocards and *Goniozus* release at Modur village of Kunigal taluk of Tumakuru district in Karnataka.
2. Training on use and release of trichocards, *Cryptolaemus* and anthocorids were at Chikkasadenahally, T. Bannikuppe, Bheemasandradoddi and Uyyalappanahally in Kanakapura taluk of Ramanagara district in Karnataka. Farmers from Keerampalli, Bagalur, Ramagiri, Mylandahalli, Amerahalli were benefited from the training on pulse production and rice pest management.
3. Training and demonstration on the biological control methods for managing Bihar hairy caterpillar in potato at Aluvahalli, Devishattihalli, Kuppahalli, Chedalapura villages in Chikkaballapura district in Karnataka.

'Gosthis' / Meetings conducted for farmers

Date	No. of participants (district, state)	Purpose
04.11.2016	30 (Bengaluru Rural, Karnataka)	Soil health management
04.10.2016	113 (Krishnagiri, Tamil Nadu)	Safer pest management in brinjal
19.10.2016	25 (Krishnagiri, Tamil Nadu)	Water hyacinth control
14.10.2016	21 (Bengaluru Rural, Karnataka)	Mass rearing of *Corcyra* eggs for production of *Trichogramma* cards
01.11.2016	65 (Krishnagiri, Tamil Nadu)	Farmers meet and distribution of *Rhizobium*
15.12.2016	120 (Krishnagiri, Tamil Nadu)	IPM practices on vegetables

Facilitation for new varieties, seeds and technologies

Activity	No. of farmers	Area covered (ha)
Pheromone traps for trapping tomato pinworm	4	3
Pheromone for management of brinjal shoot and fruit borer	2	7
Rhizobium for pulse production	20	10
New type of traps for trapping melon fly in ridgegourd	1	1
Demonstration of technology on efficacy of nucleoployhedrosis virus against Bihar hairy caterpillar, *Spilosoma obliqua* in potato crop	25	20
Distribution of trichocards	6	0.8
Distribution of water hyacinth weed control agents	3	1.6
Distribution of *Rhizobium* packets	23	4
Distribution of papaya mealybug biocontrol agent	4	3

Apart from these, mobile-based advisories and literature support on pest management in different crops and the role of natural enemies in pest suppression were also provided to farmers on a timely basis. Linkages were also created with other state departments for the betterment of farmers.

Farmers' meeting at Kanakapura

Demonstration on release of *Goniozus nephantidis* on coconut

19. PERSONNEL

S.No.	Name	Designation
Directors		
1.	Dr Abraham Verghese	Director (Superannuated on 31.05.2016)
2.	Dr Prashanth Mohanraj	Director (Acting) (31.05.2016 to 18.07.2016)
3.	Dr Chandish R. Ballal	Director (From 18.07.2016)
Scientists		
Division of Insect Systematics		
4.	Dr Prashanth Mohanraj	Principal Scientist (Agricultural Entomology) & Head, Division of Insect Systematics
5.	Dr K. Veenakumari	Principal Scientist (Agricultural Entomology)
6.	Dr Sunil Joshi	Principal Scientist (Agricultural Entomology)
7.	Dr M. Mohan	Principal Scientist (Agricultural Entomology)
8.	Dr K.J. David	Scientist (Agricultural Entomology)
9.	Dr S. Salini	Scientist (Agricultural Entomology)
10.	Dr G. Mahendiran	Scientist (Agricultural Entomology) (Joined NBAIR on 17.06.2016)
11.	Dr Ankita Gupta	Scientist (Agricultural Entomology)
12.	Dr Jagadeesh Patil	Scientist (Nematology)
13.	Dr M. Sampath Kumar	Scientist (Agricultural Entomology) (Joined NBAIR on 02.06.2016)
14.	Ms R.R. Rachana	Scientist (Agricultural Entomology)
15.	Dr Navik Omprakash Samodhi	Scientist (Agricultural Entomology)
Division of Insect Ecology		
16.	Dr N. Bakthavatsalam	Principal Scientist (Agricultural Entomology) & Head (In-Charge), Division of Insect Ecology
17.	Dr B. Ramanujam	Principal Scientist (Plant Pathology)
18.	Dr A.N. Shylesha	Principal Scientist (Agricultural Entomology)
19.	Dr T.M. Shivalingaswamy	Principal Scientist (Agricultural Entomology)
20.	Dr P. Sreerama Kumar	Principal Scientist (Plant Pathology)
21.	Dr Kesavan Subaharan	Principal Scientist (Agricultural Entomology)
22.	Dr G. Sivakumar	Principal Scientist (Microbiology)
23.	Dr Deepa Bhagat	Senior Scientist (Organic Chemistry)
24.	Dr U. Amala	Scientist (Agricultural Entomology) (Joined NBAIR on 08.06.2016)
25.	Dr Richa Varshney	Scientist (Agricultural Entomology)

Division of Molecular Entomology		
26	Dr S.K. Jalali	Principal Scientist (Agricultural Entomology); Head, Division of Molecular Entomology
27.	Dr M. Nagesh	Principal Scientist (Nematology) (Joined NBAIR on 15.05.2016)
28.	Dr T. Venkatesan	Principal Scientist (Agricultural Entomology)
29.	Dr R. Rangeshwaran	Principal Scientist (Microbiology)
30.	Dr M. Pratheepa	Principal Scientist (Computer Applications)
31.	Dr Mahesh Yandigeri	Senior Scientist (Microbiology)
32.	Dr R. Gandhi Gracy	Scientist (Agricultural Entomology)
33.	Dr S. Selvaraj	Scientist (Agricultural Entomology) (Joined NBAIR on 13.06.2016)
34.	Dr R.S. Ramya	Scientist (Agricultural Entomology)
35.	Ms Daliyamol	Scientist (Plant Pathology) (Left NBAIR on 15.03.2017)
Technical Officers/Assistants		
36.	Ms Shashikala S. Kadam	Chief Technical Officer
37.	Dr Y. Lalitha	Assistant Chief Technical Officer
38.	Mr B.K. Chaubey	Assistant Chief Technical Officer
39.	Mr Satandra Kumar	Assistant Chief Technical Officer
40.	Mr P.K. Sonkusare	Senior Technical Officer (T6)
41.	Ms B.L. Lakshmi	Senior Technical Officer (T6)
42.	Ms L. Laksmi	Senior Technical Officer (T6)
43	Mr H. Jayaram	Senior Technical Officer (T6)
44.	Ms S.K. Rajeshwari	Technical Officer (T5)
45.	Mr P. Raveendran	Technical Officer (T5)
46.	Dr A. Raghavendra	Technical Assistant (Laboratory Technician)
47.	Mr Umesh Kumar Sanjeev	Technical Assistant (Laboratory Technician)
48.	Mr M. Chandrappa	Technical Assistant (Driver)
49.	Mr R. Narayanappa	Technical Assistant (General Operator)
50.	Mr P. Madanathan	Technical Assistant (Driver)
Administrative Staff		
51.	Ms S. Rama	Senior Administrative Officer (Left NBAIR on 22.03.2017)
52.	Mr T.A. Vishwanath	Finance & Accounts Officer
53.	Mr K.N. Visveswara	Private Secretary to Director
54.	Mr Ajit Desai	Assistant Administrative Officer
55.	Ms S. Kaveriamma	Personal Assistant
56.	Mr M. Eswar Reddy	Assistant

57.	Ms Dipanwita Deb	Assistant
58.	Ms M.S. Uma	Junior Stenographer
59.	Ms Nazia Anjum	Upper Division Clerk
60.	Ms P. Anitha	Lower Division Clerk
Supporting Staff		
61.	Mr Ramakrishnaiah	Skilled Supporting Staff
62.	Mr V. Anjenappa	Skilled Supporting Staff
63.	Mr P. Nagaiah	Skilled Supporting Staff

20. EXHIBITIONS

NBAIR participated in the following exhibitions to showcase various research technologies developed at the institute:

1. First International Agrobiodiversity Congress 2016: Science, Technology, Policy and Partnership, organised by Indian Society of Plant Genetic Resources & Bioversity International, 6–9 November, 2016, New Delhi.
2. Regional Agriculture Fair "Krishi Kumbh 2016", organised by ICAR–Indian Institute of Farming Systems Research and Department of Agriculture Cooperation and Farmers' Welfare, Ministry of Agriculture & Farmers' Welfare, 28–30 November 2016, Muzaffarnagar.
3. Regional Horticultural Fair 2017, organised by ICAR–Indian Institute of Horticultural Research, 15–17 January 2017, Bengaluru.
4. XIII Agricultural Science Congress, organised by University of Agricultural Sciences, Bengaluru and National Academy of Agricultural Sciences, 21–24 February 2017, Bengaluru.
5. "Krishi Unnati Mela 2017" organised by ICAR–Indian Agricultural Research Institute and Department of Agriculture Cooperation and Farmers' Welfare, Ministry of Agriculture & Farmers' Welfare, 15–17 March 2017, New Delhi.

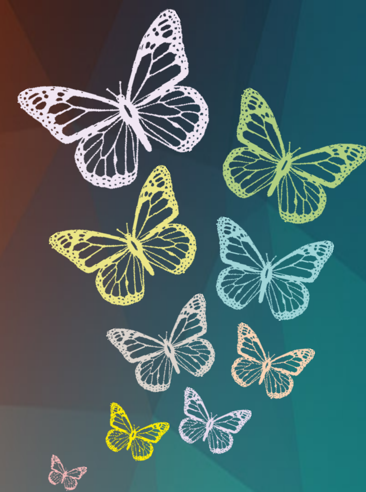
Honourable Union Minister of State for Water Resources, River Development and Ganga Rejuvenation, Dr Sanjeev Kumar Balyan being briefed about NBAIR technologies in Muzaffarnagar

Prof. Gaya Prasad, Vice-Chancellor, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, showing keen interest in NBAIR technologies in Muzaffarnagar

Dr Trilochan Mohapatra, Secretary, DARE & Director-General, ICAR, unveiling the commemorative plaque while laying the foundation stone for the *Indian Agricultural Insect Museum and National Repository* on 20 May 2016 at NBAIR, Bengaluru

Dr Trilochan Mohapatra, Secretary, DARE & Director-General, ICAR, being honoured during the foundation stone laying ceremony on 20 May 2016 at NBAIR, Bengaluru

Participants of the *Fifth National Conference on Biological Control: Integrating Recent Advances in Pest and Disease Management* held on 9–11 February 2017 in Bengaluru



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