ANNUAL REPORT 2013-14

वार्षिक प्रतिवेदन

NBAII

National Bureau of Agriculturally Important Insects

राष्ट्रीय कृषि प्रमुख कीट ब्यूरो

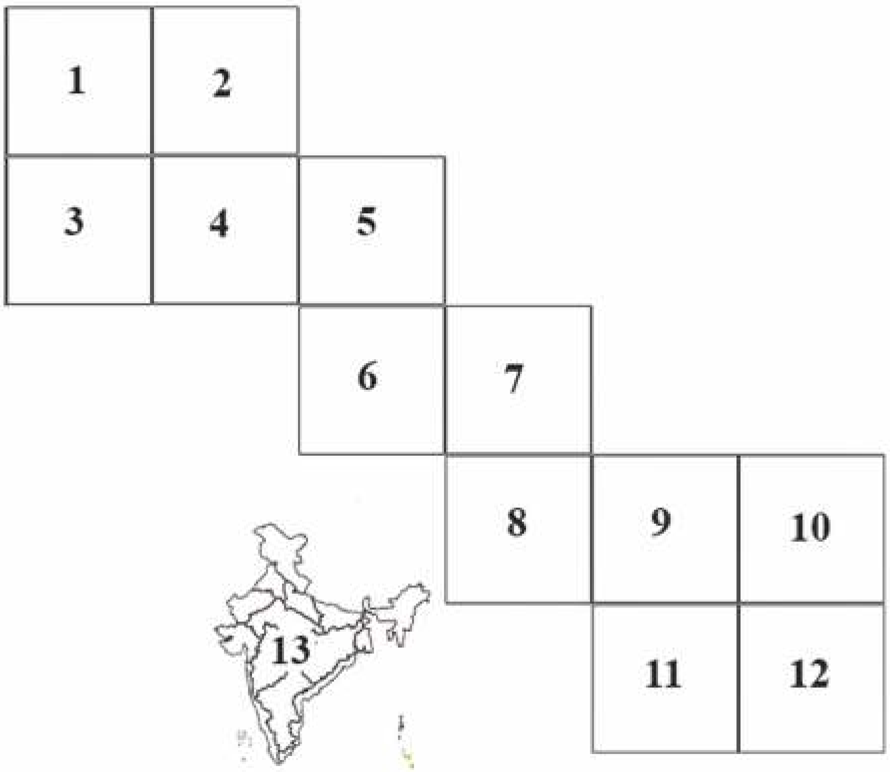

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Photo credits: No. 4 Sunil Joshi; No. 11 Ankita Gupta; all others J. Poorani

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Insectarium opened on the occasion of the National Science Day (28th February 2014) at NBAII

Photo credit: Sunil Joshi

Cover design: Sunil Joshi

Annual Report
2013-14

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National Bureau of Agriculturally Important Insects
(Indian Council of Agricultural Research)
Bengaluru - 560 024, India

राष्ट्रीय कृषि प्रमुख कीट ब्यूरो
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PREFACE

It was in mid 2009 that the NBAII came into being with the objective of documenting the insects and other arthropods in the agroecosystems of our country. Although agricultural entomology was one of the main areas of study since British times the task of documenting them remains largely unfinished. Most studies have concentrated on insect pests that cause significant damage to major crops in the country. Studies on natural enemies having the potential to control some pests have also been made. The vast majority of insects including other arthropods, whether herbivores, detritivores, pollinators, predators or parasitoids remain unstudied and many remain unknown in our agroecosystems. To add to this, no institution in the country can lay claim to housing a reference collection of even those insects and arthropods that we know are present in our agricultural fields. In this context it should be borne in mind that agroecosystems are not self contained, water-tight units; they exchange biotic elements with other ecosystems making the study of all ecosystems a necessity. NBAII has now been entrusted with the task of building up a reference collection backed by competent taxonomy to fill up this lacuna. Besides, NBAII is also mandated to be a source of live insects and insect related resources which now stand at around 400.

Taxonomic expertise at the Bureau being limited, it has been planned to execute studies by selecting insect taxa on the twin bases of importance in agriculture and the paucity of studies on them. During 2013-2014 taxonomic studies including barcoding have progressed remarkably on groups like Coccinellidae, Mymaridae, Trichogrammatidae, Platygastridae, Coccoidea, Aphididae, Pteromalidae, Eucharitidae and Braconidae (Microgastrinae). Work has also been initiated on Cerambycidae, Syrphidae, Pentatomidae, Formicidae, Acarina, etc.

The insect systematics network in collaboration with IARI has been very fruitful. In the last one year 32 new species have been recorded and added to science.

The diversity of entomogenous nematodes and insect pathogens (bacteria, fungi and viruses) is also being studied as they form an integral part of insect resources. In addition to conventional morphological taxonomy, molecular tools are also being deployed to study these organisms. E-resources are being developed for the identification of insect groups being studied at the Bureau by taxonomists, farmers and students from across the country. Bioinformatics is also being developed to facilitate insect molecular study and documentation on a global scale.

A constant vigil is being kept to detect the entry of invasives. A database of probable invasives and their natural enemies is being maintained and updated to ensure that we are in a state of preparedness to initiate measures for their control in the event of their appearance in our agricultural landscapes. Established invasives like the papaya mealybug and eucalyptus gall wasp are being monitored to prevent flare-ups.

Work on chemical characterization of insects focusing on pheromones and other semiochemicals, studies on the impact of climate change on insects of importance in agriculture and on the application of nanotechnology in pest management are also being investigated as components of insect bio-resources for use in IPM across the country.

Veterinary and aquatic entomology (with particular reference to aquaculture), two areas with respect to insects which have suffered a long period of neglect in the country, have been taken up. Barcodes have been generated for a number of insects affecting livestock for the first time in our country. The Center for Insect Bioinformatics, established in October 2013 and equipped with high performing computing systems and many genomics and proteomics commercial software, is hosting the websites Insect Barcode Informatics (*IBIn*), Insect

Pest info (*iInsectinfo*) and Insect Genomics (*iGenBank*). The Centre has also developed an efficient technique for understanding insecticide detoxification, with reference to cytochrome P450 enzymes of *Helicoverpa armigera* and *Trichogramma cacoeciae* using *in-silico* docking technique.

NBAII continues to be the backbone of biocontrol in India with over 100 insects and 300 insect related resources kept alive and shipped to end users, commercial entrepreneurs and SAUs. In the last year nearly a thousand live shipments have been made. Biological control technologies developed at the Bureau are being field-tested with the assistance of many centres spread across the various agro-ecological regions of India.

An insectarium, perhaps a first for the country, was declared open on the National Science Day (28th February 2014); a fitting tribute to Sir C.V.Raman who incidentally was an ardent insect lover and collector. This houses about 28 live insects and readable charts for children and farmers.

Another feather in the cap of the Bureau was the establishment of a Pollinator Conservation Garden on the 25 acre farm in Yelahanka.

The heat and insecticide tolerant strains of *Trichogramma* and *Chrysoperla* were widely field-demonstrated. Besides at least a dozen insect-resource related products were sold fetching a revenue of about Rs.14.50 lakh.

The Bureau was always on top in imparting highly professional and modern insect-related training to more than 200 scientists.

Technologies developed have no meaning unless they reach the stakeholders. Biological control technologies generated at NBAII and AICRP centres have been demonstrated through field demonstrations, training and large plot trials. Extension activities through TV telecasts, radio talks and publication of DVDs and bulletins provide wider access to technologies generated by NBAII.

Institute meetings such as RAC, IRC and IMC were conducted and recommendations were taken for focusing and reorienting our research and administrative programs.

The work carried out by NBAII could not have been more refined but for the timely and critical interventions of the Honourable Secretary, DARE and Director General, ICAR **Dr. S. Ayyappan**. We express our sincere gratitude to him.

The periodical suggestions and reviews by **Dr. Swapan Kumar Datta,** DDG (CS) helped us in reorienting of our research activities.We are highly grateful to him.

Our sincere thanks to **Dr. T. P. Rajendran** retired ADG (PP) and **Dr. P. K. Chakrabarty, ADG (PP)** who helped us improve our performance.

The critical analysis and future road maps for our research programs drawn up by our RAC headed by **Dr. C. A. Viraktamath**, Professor (Emeritus), Department of Entomology, University of Agricultural Sciences, Bangalore are gratefully acknowledged.

The generous help and support extended to NBAII by **Shri Arvind R. Kaushal**, Additional Secretary, DARE and Secretary, ICAR, **Mr. Pradeep Kumar Pujari**, Additional Secretary, DARE and Financial Adviser, ICAR, **Mr. Devendra Kumar**, Director (Finance), ICAR, **Mr. J. Ravi,** Director, Personnel and Administration, ICAR, **Shri Sujit Mitra**, Director (Crop Science), ICAR and **Dr M.P. Singh**, Chief Technical Officer (PP), ICAR are gratefully acknowledged.

The achievements of NBAII could not have been possible but for the support of the scientific, technical, administrative staff, research fellows and contractuals. I take this opportunity to thank them in all sincerity.

June, 2014

Abraham Verghese
Director

Executive Summary

The National Bureau of Agriculturally Important Insects is the only institution in the country that is solely involved in the collection, cataloguing and conservation of insects and related organisms of importance like mites, spiders and microbes/ nematodes associated with arthropods, from the agroecosystems of our country. The Divisions of Insect Systematics, Molecular Entomology and Insect Ecology at the Bureau undertake basic research on agriculturally important insects and their associated organisms (including entomopathogenic nematodes and pathogens) while it formulates and coordinates work on the biological control of crop pests by networking across a number of institutions in the country under the All India Coordinated Research Project (AICRP) on Biological Control of Crop Pests. Summarized below are the results of the research undertaken during 2013 – 2014 in the three Divisions of the Bureau as well as the AICRP on Biological Control of Crop Pests.

Insect Systematics

Surveys

Exploratory surveys for insects and related organisms were undertaken in the states of Kerala, Andhra Pradesh, Tamil Nadu, Assam, Meghalaya, Odisha, Maharashtra, Uttar Pradesh, Tripura, Karnataka and Jammu and Kashmir.

Digitization of type specimens

A total of 106 types were documented including 50 primary types. Digitization of 15 primary types was completed. Webpages have been created for type specimens in NBAII's holdings.

Biosystematics of Trichogrammatidae

Ten genera of Trichogrammatidae were collected in addition to *Trichogramma* and *Trichogrammatoidea*. *Megaphragma*, a genus comprising some of the smallest insects, known earlier from Karnataka and Uttar Pradesh were collected for the first time from Orissa and Meghalaya. *Trichogramma cuttackensis* collected from Bhubaneshwar is the first species of Indian *Trichogramma* for which pseudogenes were detected.

Scanning electron microscopic studies of the genitalia of *Trichogramma rabindrai* and *Trichogrammatoidea armigera* have been completed aiding identification.

Biodiversity of oophagous parasitoids with special reference to Scelionidae

Fifty two genera under five subfamilies have been recorded from India. An additional five genera are now being added raising the total to fifty seven. Twenty seven additional genera of Platygastroidea have been discovered from Odisha.

Mantibaria kerouaci, *Allotropa gundlupetensis*, *A. vanajae*, *A. nigra*, *Amblyaspis fabrei*, *A. panhalensis*, *A. charvakae*, *A. ashmeadi* and *A. tipusultani* are nine new species of Platygastroidea that were discovered and described. *Sceliocerdo viatrix*, a species phoretic on grasshoppers was redescribed.

Biodiversity of economically important Microgastrinae

Five species of parasitic wasps (*Cotesia erionotae*, *Charops plautus*, *Ooencyrtus papilionis*, *Leptobatopsis indica* including a new species, *Dolichogenidea cinnarae*) associated with hesperiids from peninsular India have been documented.

A new species of gregarious endoparasitoid, *Parapanteles echeriae* bred from *Abisara echerius* (Lepidoptera: Riodinidae) is described and illustrated. Two new species of *Glyptapanteles* (*G. clanisae*, *G. trilochae*) and one new species of *Buluka* (*B. horni*) have also been described from South India.

Biodiversity of aphids , coccids and their natural enemies

Metaceronema japonica, Stictacanthus azadirachtae, *Shivaphis celti* and *Odonaspis greenii* were recorded for the first time from Karnataka. *Planococcus bendovi*, *Ctenochiton olivaceum*, *Macrosiphum euphorbiae* and *Milviscutulus mangiferae* were recorded for the first time from South India. *Marsipococcus iceryoides*, *Ceronema fryeri*, *Maacoccus piperis*, *Trijuba oculata*, *Protopulvinaria longivalvata*, *Paralecanium ovatum*, *P. vacuum*, *P. mancum*, *Eriococcus coccineus*, *Duplaspidiotus claviger, Exallomochlus philippinensis* and *Astegopteryx pallida* were recorded for the first time from India.

Twenty nine species of parasitoids were recorded from 43 species of coccids out of which one species of parasitoid was a new record from India, eight were new records from Karnataka and four were new host associations.

Collection and identification of Cerambycidae

Five species of cerambycids *Acanthophorus serraticornis, Batocera rufomaculata, Chelidonium cinctum, Stromatium barbatum* and *Xylotrechus quadripes* have been collected, identified and added to the collection. A key to the subfamilies of adults of Cerambycidae has been developed.

Biosystematics and diversity of entomogenous nematodes in India

Of the 172 soil samples collected from various places in Jammu & Kashmir and Karnataka, only one sample contained EPN which has tentatively been identified as *Steinernema* sp.

Molecular Entomology

Molecular characterization and DNA barcoding of insect pests

More than 500 insects and arachnids were barcoded using primers specific to cytochrome oxidase (CO1). These insects and arachnids belonged to 162 species in eight Orders (Hemiptera, Diptera, Lepidoptera, Coleoptera, Hymenoptera, Mantodea, Isoptera , Araneae and Ixodida) and 63 families. All sequences agreed with Folmer's region, >550 bp with complete species information for 46 species for which Barcodes were generated. The percentage-wise characterization of 162 species was Hemiptera (29.6%), Lepidoptera (22.2%), Diptera (16.7%), Coleoptera (12.3%), Hymenoptera (11.7%), Mantodea (1.9%), Isoptera (1.2%), Araneae (2.5%) and Ixodida (1.9%).

Molecular characterization and DNA barcoding of parasitoids, predators and pollinators

Molecular characterization (using cytochrome oxidase 1(CO1) region) was done for the following parasitoids; *Aprostocetus gala* (KF817576), *Tetrastichus schoenobii* (KJ627790), *Chelonus blackburni* (KF365461), *Bracon hebetor* (KJ 627789), *Quadrastichus mendeli*(KF879806), *Aprostocetus gala* (KF958278), *Sceliocerdo viatrix* (KF938928), *Pseudleptomastix mexicana* (KF365460), *Leptomastix nigrocincta* (KJ489424); pollinators namely *Apis florea* (KF817578), *Apis cerana indica (*KF861941), *Megachile anthracina* (KF861940), *Apis dorsata* (KJ513470); predators namely *Amphiareus constrictus* (KF817577), *Xylocoris flavipes* (KF365462), *Blaptostethus pallescens* (KF365463), *Buchananiella indica* (KF 383326), *Cardiastethus affinis* (KF 383326), *Scymnus nubilus* (KF861939), *Isolia indica* (KJ489423), *Cheilomenes sexmaculata* (KF998579) and a weed killer *Teleonema scrupulosa* (KF817579).

Insecticide resistance / insect endosymbionts

Insecticide resistance bioassays against brinjal shoot and fruit borer, *Leucinodes orbonalis* revealed high levels of resistance to Phosalone and Fenvalerate in Nagpur and Varanasi populations. Enhanced midgut carboxylesterase activity was noticed in resistant populations.

Gut microflora of geographical populations of the parasitoid *Cotesia vestalis*, a parsitoid of the diamond back moth larvae were isolated, identified and characterized. Degradation of insecticides by the bacterial endosymbionts, *Bacillus* sp. and *Enterobacter cancerogenus* was established through minimal media and LC-MS studies. Variations in geographical populations based on heat shock proteins (*Hsps*) were studied. *Hsps* contributing to the sustenance of the parasitoid under stressed conditions were detected.

The endosymbiotic bacterial genera characterized from different leafhopper species were *Enterobacter* spp., *Stenotrophomonas maltophilia*, *Bacillus* spp. *Micrococcus* spp., *Lysinibacillus fusiformis*, *Microbacterium*, *Agrococcus* and *Staphylococcus*. The bacteria *Enterobacter cloacae* and *Bacillus pumilus* showed *in vitro* acephate tolerance. The bacterial endosymbionts associated with aphids identified based on 16S rDNA sequences were *Bacillus aryabhattai, B. cereus, B. firmus, B. horikoshii, B. jeotgali, B. massiliensis, B. subtilis, Exiguobacterium indicum, Moraxella osloensis* and *Paenibacillus lautus.*

Studies on entomopathogenic nematodes (EPN)

Genomics and transcriptomics on genes and pathways related to virulence and pathogenesis of four Indian strains of bacterial symbionts associated with EPN were done. The control of whitegrubs in red gram and fodder grass using EPN was demonstrated. Two technologies on production, down-stream processing and development of WP formulations of EPN and *Pochonia chlamydosporia* were licensed and transferred to Allwin Industries, Indore. EPN strains of NBAII including *Heterorhabditis indica*, *Steinernema carpocapsae, S. abbasi* were screened against *Lepidiota mansueta* in Majouli Island in groundnut and vegetables. EPN formulations against white grubs, cutworms and termites were evaluated through AICRP centre at Jorhat, Assam.

A total of 172 soil samples were collected from mulberry fields of four villages of Jammu and Kashmir, forest vegetation of Monughat (Dhalali, Tripura) and coffee, arecanut, sugarcane, vegetable fields of villages of Karnataka for the isolation of EPN. *Steinernema* sp. was obtained from one sample when soil was baited with larvae of the moth, *Galleria mellonella.*

Bt-cry gene diversity in hot and humid regions

Cry2A CDS (2.2 kb) obtained from eight isolates were cloned in *E. coli* for further studies. The full length gene sequencing of 1.9 kb cry3a (coleopteran specific gene) was done. The 2.37 kb Vip3A (lepidopteran specific gene) and 3.686 kb *cry1Ac* (lepidopteran specific gene) was done using primer walking. The sequences were then sub cloned into *E. coli* expression system. The dipteran toxic *cry2A*, *cry17A*, *cry4A* and *cry44Ba* were identified through PCR analysis. The identification of cry44Ba is a first report from India.

Seven *Bt* isolates expressing the coleopteran specific *cry3A* gene were tested against the coleopteran pest *Sitophilus oryzae*, along with the standard strain (4AA1). The isolate *Bt*AN4 was equally toxic as the standard strain and was the most toxic among the indigenous isolates tested. *Bt*AN4 showed the least LC_{50} value of 89.65 µg/ml and the standard strain showed LC_{50} value of 85.26 µg/ml. It was followed by TrBt10 which showed an LC_{50} value of 96.16 µg/ml.

Insect Ecology

Diversity of anthocorid predators

Anthocorid predators were collected from different host plants. The anthocorids *Buchananiella indica* from crossandra, *Amphiareus constrictus* from sugarcane and *Anthocoris muraleedharani* from *Ficus* were amenable to rearing on alternate laboratory host eggs. *Blaptostethoides pacificus* from sugarcane and *Orius amnesius* from rose were first records for India.

Studies on biology and feeding potential of *Amphiareus constrictus*

The anthocorid predator *Amphiareus constrictus* was collected for the first time from sugarcane in Mandya, Karnataka. It was amenable to production using UV-irradiated *Corcyra cephalonica* eggs. The total developmental period was 16.4 days. Total male feeding potential was 86.7 eggs per day. An adult female could feed on 93.5 eggs.

Studies on anthocorid predator *Buchananiella indica*

Buchananiella indica was amenable to laboratory rearing on alternate laboratory host eggs. It has been reared for more than 10 generations in the laboratory.

Threshold temperatures for *Xylocoris flavipes*

The developmental threshold temperatures for incubation, nymphal and total development of *Xylocoris flavipes* were recorded as 7.85, 12.28 and 11.8 °C, respectively.

Diversity of bioagents and their amenability to rearing

Trichogramma danaidiphaga was able to parasitise *Corcyra* eggs in the laboratory. *Telenomus* sp. was amenable to rearing on *Spodoptera litura* eggs. *Anastatus acherontiae* was amenable to rearing on eri silkworm eggs. *Anastatus bangaloriensis* was amenable to rearing on eri silk worm eggs.

Oviposition behaviour of *Helicoverpa armigera* on pigeonpea plants under elevated CO_2

Females of *H. armigera* laid more eggs on pigeonpea grown at 500 ppm of CO_2 + 2°C compared with plants grown at ambient conditions.

Volatile profile of pigeonpea under elevated CO_2

Plants grown at 500 ppm of CO_2 showed the presence of compounds like α copaene in addition to an array of volatiles, which may be responsible for the attraction of females.

Incidence of *Liriomyza trifolli* on tomato grown under elevated CO_2

The incidence of *Liriomyza trifolii* was significantly higher in the chambers with elevated levels of CO_2 and temperature.

Plant-based and an oil based formulation to attract *Bactrocera dorsalis*

The new formulation was more effective than methyl eugenol in terms of trapping the fruit fly *Bactrocera dorsalis*. Further a gel-like oil based formulation of methyl eugenol showed promising results in attracting *B. dorsalis,* obviating the need to add toxicants.

Plant volatile-based deterrent for *Helicoverpa armigera*

Three formulations of plant-derived volatile compounds were tested for their efficacy as deterrents for *Helicoverpa armigera* on chickpea.

Occurrence of papaya mealybug on papaya and other plants

Acerophagus papayae was found in all the places wherever papaya mealybug was observed. *A. papayae* parasitized up to 72% on *Hibiscus*. About 84–86% parasitization was observed on *Parthenium* and 72–79% on *Sida acuta* and *Acalypha.*

Host range of Jack Beardsley mealybug

Jack Beardsley mealybug, *Pseudococcus jackbeardsleyi*, was found in Tamil Nadu and Karnataka. *Cryptolaemus montrouzieri*, *Spalgis epius* and gnats were keeping it under check.

Mass production of *Pseudococcus jackbeardsleyi* on potato sprouts and pumpkin

Pseudococcus jackbeardsleyi could be cost-effectively produced on potato sprouts and mature green pumpkin.

Eucalyptus gall wasp managment

Leptocybe invasa, the eucalyptus gall wasp, was effectively managed by the release of *Quadrastichus mendeli*. It has been established in Uttar Pradesh, Punjab and Uttaranchal.

Erythrina gall wasp managment

Aprostocetus gala was found to be the major parasitoid of *Quadrastichus erythrinae* with up to 46% parasitization.

Cecidochares connexa for biocontrol of *Chromolaena odorata*

New releases were made in Jharkhand in collaboration with Directorate of Weed Science Research, Jabalpur. Surveys showed that the fly has established in Kerala.

Collection, documentation and identification of non-*Apis* bees on different host plants

Over 200 specimens of bees belonging Apidae, Megachilidae, Anthophoridae, Halictidae have been collected on different host plants, labelled and preserved (both pinned and wet collection) for identification. Nest-building activity of a megachilid was studied in detail and documented.

Establishment of a 'Pollinator Garden'

A "Pollinator Garden" has been developed in about 0.7 acres at the Yelahanka campus. It has over 70 species of plants (trees, shrubs, herbs and climbers) belonging to diverse families which are known to be attractive to many pollinators.

Morphological characterization of gut microflora

A total of 37 culturable gut bacteria and a culturable yeast were characterized and identified from 15 live populations of *Amrasca biguttula biguttula*, *Empoasca* spp., *Nephotettix nigropictus*, *Bothrogonia* and *Nilaparvata lugens*, which were exposed to insecticides.

Characterization and identification of culturable bacteria

The bacteria associated with *Amrasca biguttula biguttula* were *Microbacterium imperial, Bacillus aryabhattai, Staphylococcus epidermidis, Janibacter anopheles, Bacillus cereus, Staphylococcus aureus, Micrococcus luteus, Agrococcus terreus, Bacillus cereus, Staphylococcus warneri, Staphylococcus hominis, Staphylococcus arlettae, Pseudomonas stutzeri, B. pumilus* and *Enterobacter* spp. *Enterobacter cloacae, Stenotrophomonas maltophilia, B. firmis, E. cloacae, Kocuria kristinae, Stenotrophomonas maltophi* and *B. flexus* were associated with *N. nigropictus*. *Empoasca* spp. harboured *B. stratosphericus* and *Micrococcus* spp. *Lysinibacillus fusiformis* was obtained from *Bothrogonia* sp. *Wolbachia* was detected in *Bothrogonia* sp. and *A. biguttula biguttula*.

Growth of *Enterobacter cloacae* in different concentrations of acephate

Maximum growth of *Enterobacter cloacae* was recorded in the minimal broth after 3 days of inoculation in all concentrations of acephate as compard to control. The maximum OD value recorded was 1.0 at 3 days after inoculation under 50 ppm concentration of acephate as compared to control where it was 0.8.

Growth of *Bacillus pumilus* in different concentrations of acephate

Maximum growth of *Bacillus pumilus* was recorded in the minimal broth after 3 days of inoculation in all concentrations of acephate.

Production of digestive enzymes by the microflora associated with *Amrasca biguttula biguttula*

Micrococcus luteus, Agrococcus terreus, Acinetobacter bereziniae, Proteus mirabilis, Pseudomonas stutzeri produced amylase.

Identification of viruliferous leafhoppers from direct field collections

Out of the 15 species of leafhoppers belonging to 5 subfamilies of Cicadellidae tested, only *Batracomorphus angustatus*, *Cicadulina bipunctata*, *Exitianus indicus*, *Hecalus* sp., *Hishimonus phycitis*, *Nirvana pallida* and *Orosius albicinctus* were found to be viruliferous based on symptom production in brinjal, sesame and/or periwinkle.

Feeding processes of putative insect vectors

A comparative analysis of the mouthparts of *Hishimonus phycitis* and *Orosius albicinctus* indicated only minor perceptible differences between the two. In general, on both sesame and brinjal, exploratory probing of *H. phycitis* was more pronounced than that of *O. albicinctus*.

DNA barcoding of three leafhopper species

DNA barcoding was completed for *Nirvana pallida*, *H. phycitis* and *Orosius albicinctus*, and the nucleotide sequences were submitted to GenBank.

Effect of entomofungal pathogens on *Bemisia tabaci* on tomato and capsicum

Lecanicillium lecanii (Vl-8) and *Beauveria bassiana* (Bb-9) significantly controlled whiteflies on tomato (15.29 & 17.21 whiteflies/plant, respectively). *L. lecanii* (Vl-8) and *B. bassiana* (Bb-9) significantly reduced whiteflies on capsicum (6.47 & 6.98 whiteflies/plant, respectively).

Field evaluation of entomofungal pathogens against cabbage aphid

Among the nine fungal pathogen isolates tested, Bb-5a, Ma-6 and Vl-8 isolates showed 60.0-68.25% reduction over control.

Extraction of metabolites from tomato for use in the development of nanosensors

GC-MS spectroscopic analysis of 20-day-old leaves and stems of tomato detected a total of 47 metabolites. Twenty-one metabolites in the stems and 14 metabolites in the leaves were considered as major metabolites and were identified as targets for developing nanosensors.

Chemical profiling of *Bactrocera dorsalis* and *B. caryeae*

Metabolite signatures (NMR) provided a valuable method for identifying the larval stages of two species of *Bactrocera* species.

Non-target effects of chitosan-alginate nanoparticles on *Chrysoperla zastrowi sillemi*

There was no significant effect of continuously feeding the larvae of *Chrysoperla zastrowi sillemi* with *Corcyra cephalonica* eggs mixed with chitosan alginate nanoparticles.

All India Coordinated Research Project on Biological Control of Crop Pests

Biodiversity of biocontrol agents from various agroecological zones

In rice ecosystem of West Bengal, 117 species belonging to 8 orders and 63 families of insects and spiders were collected and identified, of which 45, 44 and 24 were pest species, predators and parasitoids, respectively. Three species of parasitoids collected from eggs of *Scirpophaga incertulus* and *S. fuscifluaviz* were *Tetrastichus schoenobii*, *Trichogramma japonicum* and *Telenomus* sp. The red long winged planthopper, *Diostrombus polites* was abundant in Kalimpong. The skipper *Parnara guttata* was prevalent with 75 per cent parasitisation by *Apanteles* sp. The fungus causing mycosis in rice bugs (*Leptocorisa* sp.) was identified as *Acremonium liolii*.

In vegetable growing areas of Uttar Pradesh, the mealy bug *Phenacoccus solenopsis* was recorded on tomato, brinjal, *Capsicum*, pointed gourd and okra. *Centrococcus insolitus* was noticed on brinjal. Two prominent endoparasitoids *viz*., *Aenasius bombawalei* and *Promuscidea* *unfasciativentris* (Hymenoptera: Encyrtidae) of *P. solenopsis* were noted.

In banana ecosystem of Kerala the earwig, *Auchenomus hincksi* (Dermaptera: Labiidae) was noticed as an egg predator of the pseudostem weevil. *Paralabis dohrni Charhospania nigriceps* and *Euborellia shabi* (Dermaptera: Labiidae) were found feeding on eggs and early instar grubs of the banana rhizome weevil. The coccinellids on the banana aphid were *Pseudaspidimerus trinotatus*, *Scymnus pyrocheilus*, *Jaurovia soror, Scymnus* spp., *Cheilomenes sexmaculata* and *Sticholotis* sp. In pepper, spiders like *Bavia kairali*, *Oxyopes javanus* and *O. swetha* were found predating on pollu beetle. In cotton the parasitoid of flower midge was identified as *Ecrizotomorpha* sp.

Trichogramma, Chrysoperla, Chelonus blackburnii, coccinellids and spiders were the natural enemies collected from south Telangana.

Natural enemies of 16 insect pests of fruit crops were recorded from Kashmir. Among 40 species of natural enemies, 17 were parasitoids and 23 were predators. *Aphidus* sp. was recorded from apple aphid, *Aphis spiraecola* and *Trioxys* sp. from walnut aphid, *Calipteras juglandis*.

Biodiversity of diverse agroecosystems

In Maharashtra the natural enemies recorded were coccinellids, *Coccinella septempunctata, Menochilus sexmaculata*, *Scymnus coccivora,*, *Encarsia flavoscutellum, Dipha aphidivora*, *Micromus igorotus*, syrphids on sugarcane woolly aphid in sugarcane, *Coccinella transversalis*, *M. sexmaculata, Brumoides suturalis*, *Scymnus coccivora*,, and *Triommata coccidivora* in mealybug colonies on custard apple, *Acerophagus papayae, Pseudleptomastix mexicana, Mallada boninensis* and *Spalgis epius* on papaya mealy bug and *Eublemma amabilis* on ber. In Solan one species of *Chrysoperla,* 37 species of coccinellid beetles, 20 species of hymenopteran parasitoids of *Liriomyza trifolii* and/or *Chromatomyia horticola,* 3 species of predatory thrips, 2 species of anthocorid bugs, 9 species of syrphids and 9 species of predatory mites were collected.

The egg parasitoid *Trichogramma japonicum* was recovered from sugarcane top borer in Jalandhar. In maize (Punjab) 7.5 to 35.8% natural parasitization with *Trichogramma* was observed. In cotton 35 % *Trichogramma* adults were obtained from field deployed sentinel cards.

Eleven families, 25 genera and 34 species of spiders were recorded in Kashmir and comprised of Araneidae (7 species), Tetragnathidae (5 species) and Salticidae (5 species). Dominant spider species were *Pardosa altitudis, Theridion* sp., *Araneus anantnagensis* and *Tetragnatha mandibulata*. In Gujarat seasonal abundance of predatory spiders in rice ecosystem showed highest species richness for *Neoscona theisi* and *Leucauge* sp. In Rajendranagar of Andhra Pradesh *Tetragnatha* was the most abundant genus followed by *Oxyopes*.

One entomopathogenic nematode *Steinernema* sp. (strain CISH 3) was isolated from mango orchard of Sitapur district, Uttar Pradesh.

Surveillance for alien invasive pests

The papaya mealybug *Paracococcus marginatus* and Jack Beardsley mealybug *Pseudococcus jackbeardsleyi* were recorded in Tamil Nadu and the incidence of sugarcane woolly aphid was 14.8 %/6.25 sq.cm leaf area during July to December 2013 whereas in Karnataka its incidence ranged from 5 to 10 %. In cotton growing areas of Telangana *Phenococcus solenopsis* was predominant over *Maconellicoccus hirsutus.*

Biological suppression of diseases and nematodes

At GBUAT a cost-effective WP/EC based *Trichoderma* (Th-14) formulation and efficient delivery system was developed. High sporulation was observed in *Jhangora* grains amended with 5% jaggery (3.2×10^{10} spores/g). Wheat plants treated with PFa-50 inducer rhizobacteria reduced severity of *Bipolaris sorokiniana* by 51.34 %. Rice brown spot disease severity was significantly reduced by *Trichoderma* isolates TCMS 5 (17.3%) and TCMS 14a (18.3%) as compared to control (48.0%). In Pasighat, bio-efficacy of CHF *Pf*-1 treated brinjal recorded lowest wilt incidence (14.75%) compared to streptomycin (19.83%). The highest yield of 244.55 q/ha was also recorded in CHF *Pf*-1 treatment.

Biological suppression of pests in cereals and pulses

Metarhizium anisopliae @ 2x10^8 spores / ml caused mycosis in rice bugs. In sugarcane eight releases of *Trichogramma chilonis* (tts) @ 50,000 per ha reduced the incidence of early shoot borer by 54.9 % and top borer by 52.2%. Twelve releases of *T. chilonis* @ 50,000 per ha reduced stalk borer by 52.3 %. In sorghum, application of *Metarrhizium anisopliae* (Ma 36 @ 5ml/L) resulted in 18.0% reduction of dead hearts over control and was on par with whorl application of carbofuran granules.

In Tamil Nadu spraying of *Bt* strain NBAII-BTG4 @ 2% thrice was comparable with chlorpyriphos 0.05% in reducing pod damage (11.8%) of *H. armigera* and *Maruca testulalis* and increased the yield (14.8 q/ha) of pigeonpea. However pooled analysis revealed that least pod damage (4.90 %) was observed with chlorpyriphos. In Raichur NBAII BTG 4 *Bt* @ 2ml/L recorded 10.84 % pod damage which was superior to the other bioagents. The treatment recorded significantly higher grain yield of 14.88 q/ha than other treatments.

Biological suppression of pests in oilseeds

In soybean, spraying of *Sl*NPV @ 250 LE/ha (1.5 x 10^{12} POBs / ha) thrice was the most effective in suppressing *Spodoptera litura* with 78.0 per cent larval mortality and 21.95 q/ha yield of soybean. Biosuppression of safflower aphid *Uroleucon compositae* was achieved through two sprays of *Verticillium lecanii* 1.0 % WP in non-spiny safflower.

Biological suppression of pests in vegetables

In tomato the incidence of fruit borer was 6.4 to 8.6 % in BIPM as compared to 14.2 to 15.8 % in farmers' practice at 75 to 105 DAT. The fruit yield (36.80t/ha) was significantly higher in BIPM plot as compared to farmers' practice (32.45t/ha) with a cost: benefit ratio of 1:3.2. In brinjal two sprays of NSKE and six releases of *Trichogramma chilonis* significantly reduced the fruit and shoot damage by sucking pests. *Brumus suturoides* @ 1500/ha, *Scymnus* @ 1500/ha and *Cryptolaemus* @ 1500/ha significantly reduced the population of mealybug. Release of *T. chilonis* @ 50,000 parasitoid/ha followed by spraying of NSKE 5% and *B. thuringiensis* @ 1 L / ha was significantly effective in suppressing the shoot (10.6%) and fruit (15.3%) infestation and increased the marketable yield of brinjal (217.8 q/ha). Maximum reduction (68.2%) of cabbage aphid in polyhouse was achieved by five weekly releases of 2nd instar grubs of *Coccinella septumpunctata* @ 5 / plant. *Bt* formulations, *viz.*, PDBC BT 1 and NBAII BTG 4 @ 1 and 2% were significantly superior in reducing the larval population of diamondback moth by 85.48 to 90.88 % over control.

In potato, entomofungal pathogens *Ma*-4, *Bb*-23 and *Bb*-5a of NBAII reduced the infestation of *D. orientalis* with 19.0, 19.25, and 19.75 % infested tubers. Maximum yield (83.90 q/ha) was obtained in the plots treated with imidacloprid followed by *Ma*-4 NBAII strain (83.12 q/ha) and malathion dust (79.37 q/ha).

Biological suppression of pests in fruit crops

In mango, *Metarhizium anisopliae* @ 1 x 10^9 spores/ml with adjuvant was found effective in suppressing the hopper population (10.6 hoppers/ inflorescence) and increased fruit set (11.8 fruits/ inflorescence). Talc formulation of *M. anisopliae*

(IIHR strain) @ 1kg/100L recorded 77.1 % mortality of mango hoppers. In custard apple release of *Scymnus coccivora* @ 10 grubs per tree twice reduced mealy bugs *M. hirsutus* and *F. virgata* and increased the yield (34.9 kg/tree). In citrus, stem injection of CAU-1 EPN isolate @ 50 ijs/ml of water and as cadaver application against citrus trunk borer, *Anoplophora versteegi* caused 37.22 and 36.43 per cent reduction at Pasighat and Rengging, respectively. In apple combined effect of *Trichograma embryophagum, T. cacoeciae* and pheromone trap revealed maximum reduction of fruit damage (27.66%) by codling moth *(Cydia pomonella)* at Kargil. *M. anisopliae* (10^6 conidia/cm²) was the most effective in controlling apple root borer, *Dorysthenes hugelii* resulting in 82.6 % mortality of larvae and was on par with chlorpyriphos.

Biological suppression of pests in plantation crops

No significant difference was noticed in reducing the tea mosquito bug, *Helopeltis theivora* population with *B. bassiana* IIHR strain (15.75/10 plants), pestoneem (16.25/10 plants) and commercial formulation of *B.bassiana* (17.25 /10 plants). In coconut *Opisina arenosella* infestation caused 74.4% leaf damage in Trivandrum during April 2013 but was brought down to 16.7% over a period of nine months by release of larval parasitoids, *Goniozus nephantidis* and *Bracon brevicornis.* BIPM module evaluated against *Aleurodicus dispersus* on cassava recorded a lower population (76.93 per 5 plants) as compared to farmers' practice (226.11 per 5 plants) and untreated check (320.96 per 5 plants). Maximum yield was recorded from BIPM module (36.79 t/ha) as compared to untreated check (21.60 t/ha). The net profit and benefit:cost ratio (BCR) were also higher in BIPM module (1:3.34) than the farmer's practice (1:2.41). *E. guadeloupae* was found to be the most effective parasitoid in the reduction of *A. dispersus* populations.

Biological suppression of polyhouse crop pests

The initial root-knot nematode population in gerbera field ranged from 520 to 680 IJs/200 cm³ of soil, *Paecilomyces lilacinus* @ 20 kg/ha was found to be most effective (64.3 % reduction) in gall index (52%). Predatory mite, *Neoseiulus longispinosus* at 1:10 predator: prey ratio in carnation resulted in 91.2 % reduction of phytophagous mites and was also on par with fenazaquin (0.0025%) which caused 92.1 % reduction. In rose maximum reduction (69.6 %) of European red mite (*Panonychus ulmi* Koch) was obtained after 4th release of 30 predatory mites/ plant with maximum yield/plot (1173 cut flowers) which was at par with Azadirachtin 3ml/L treated plots. *Blaptostethus pallescens* @ 30 nymphs/ m row along with chemical control (Omite 300 ml/ acre) was found effective in managing *T. urticae* on okra. Oviposition by *Spalgis epius* in relation to host plants showed that the order of preference was *Annona*, guava and hibiscus.

Biological suppression of storage pests in rice

Release of *Xylocoris flavipes* @ 30 nymphs per kg of stored rice (12.75 moths/jar) significantly reduced the emergence of *Corcyra* moths. Maximum number of nymphs was recorded from the treatment of *X. flavipes* @ 30 nymphs/ jar. Release of anthocorid bugs in rice bins could effectively control *Corcyra cephalonica* larvae. *Xylocoris flavipes* nymphs performed better than those of *Blaptostethus pallescens* in minimizing the moth population.

निष्पादित सारांश

राष्ट्रीय कृषि प्रमुख कीट ब्यूरो देश का एक मात्र ऐसा संस्थान है जो कि हमारे देश के कृषि पारिस्थितकी तन्त्र के कीटों और संबंधित प्रमुख जीवों के एकत्रण, सूचीबद्धीकरण और संरक्षण का कार्य कर रहा है। कीट प्रणालियाँ, अण्विक कीट विज्ञान और कीट पारिस्थितिकी विभाग के माध्यम से ब्यूरो में, कृषि प्रमुख कीटों और उनके सहायक जीवों (कीट रोगाण्विक सूत्रकृमि और रोगाणुओं सहित) पर मौलिक अनुसंधान किया जा रहा है और फसल पीडको के जैविक नियंत्रण पर अखिल भारतीय समन्वित अनुसंधान परियोजना (ए आई सी आर पी) के अन्तर्गत यह ब्यूरो अन्य संस्थानों के साथ नेटवर्किंग के माध्यम से पूरे देश में फसल पीडकों के जैविक नियंत्रण का कार्य कर रहा है। वर्ष 2013-2014 के दौरान ब्यूरो के तीनों विभागों के साथ-साथ फसल पीडकों पर ए आई सी आर पी द्वारा किए गए अनुसंधान परिणाम संक्षिप्त रूप मे निम्नलिखित है।

कीट प्रणालियाँ

सर्वेक्षण

देश में विस्तृत रूप से सर्वेक्षण करने के लिए केरल, आन्ध्र प्रदेश, तमिल नाडु, असम, मेघालय, ओडीशा, महाराष्ट्र, उत्तर प्रदेश, त्रिपुरा, कर्नाटक तथा जम्मू और कश्मीर राज्यों से कीट और संबंधित जीवों को एकत्रित किया गया।

प्रारूप प्रतिदर्शों का डिजिटाईजेशन

50 प्राथमिक प्रारूप सहित कुल 106 प्रारूपों का दस्तावेज तैयार किया गया। 15 प्राथमिक प्रारूपों का डिजिटाईजेशन पूरा हो चुका है। रा कृ प्र की ब्यूरो के स्वामित्व में इन प्रतिदर्शों का वेबपेज तैयार किया गया है।

ट्रायकोग्रामेटिडे की जैवप्रणालियाँ

ट्रायकोग्रामा और *ट्रायकोग्रामेटॉयडिआ* सहित ट्रायकोग्रामेटिडे के दस वंशों को एकत्र किया गया। *मेगाफ्रेगमा* वंश के कुछ ऐसे छोटे कीट हैं जो कि पहले कर्नाटक और उत्तर प्रदेश राज्यों में जाने जाते थे, पहली बार इन कीटों को ओडीशा और मेघालय राज्यों से एकत्रित किया गया। भुवनेश्वर से *ट्रायकोग्रामा कटकेन्सिस* एकत्रित की गई जो कि भारतीय *ट्राइकोग्रामा* की पहली प्रजाति है जिसमें स्यूडोजीन्स पाए गए।

ट्राइकोग्रामा रविन्द्राई और *ट्रायकोग्रामेटॉयडिआ आर्मिजेरा* के लिंग का इलैक्ट्रोनिक सूक्ष्मदर्शीय स्कैन कर अध्ययन किया गया।

सीलीओनीडे के विशेष संदर्भ में उफेगस परजीवी कीटों की जैवविविधता

भारत वर्ष से पाँच उपकुलों के अन्तर्गत बावन वंश अभिलेखित किए गए। इनके अतिरिक्त पाँच वंश ओर जुड जाने से इनकी संख्या 57 हो गई है। ओडीशा से प्लेटीगेस्ट्रायडीए के सत्ताईस अतिरिक्त वंश पाए गए हैं। प्लेटीगेस्ट्रायडीए की नौ नई प्रजातियाँ जैसे मेन्टिबेरीआ केराऊकी, *ऐलोट्रोपा गुन्डलूपेटेन्सिस, ऐ. बनाजे, ए. नाइग्रा, एम्बलियास्पिस फेबरी, ऐ. पेनहेलेन्सिस, ऐ. चारवाके, ए. अशमीआडी* और *ऐ. टीपुसुल्तानी* पाई गई और वर्णित की गई। घास के टिड्डे की एक फोरेटिक प्रजाति *सीलीओसेर्डो बायाट्रिक्स* को पुनः वर्णित किया गया।

आर्थिक रूप के मुख्य माइक्रोगेस्ट्रीने (हायमेनोप्टेराः ब्रेकोनिडे) की जैवविविधता

परजीवी वैस्प की पाँच प्रजातियों (*कोटेशिआ एरीओनोटे, कार्पोस प्लेउटस, ऊईन्सर्टस पेपिलीओनिस, लेप्टोबेटोप्सिस इन्डिका* सहित एक नई प्रजाति *डोलीकोजेनिडिआ सिनोर*) जो कि हेस्पेरिड्स से संबंधित हैं, को पेनीनसुलर भारत से एकत्र कर अभिलेखित किया गया।

एबिसेरा इकेरिअस (लेपिडोप्टेराः रायोडिनिडे) पर पलने वाली, ग्रीगेरीअस अंत परजीवी कीट के रूप में एक नई प्रजाति *पेरापेन्टेलस एकेरीए* वर्णित और उदभासित की गई। दक्षिण भारत से, ग्लायप्टेपेन्टेलस की दो नई प्रजातियाँ (*ग्ला. क्लेनिसे* और *ग्ला. ट्राइलोके*) तथा *बुलुका* की एक नई प्रजाति (*बु. होरनाई*) बर्णित की गई।

माहू, कोक्सीड्स और उनके प्राकृतिक शत्रु कीटों की जैवविविधता

कर्नाटक राज्य से, *मेटासेरोनीमा जेपोनिका* (मास्केल), *स्टिकटेकेन्थस आजादीरेक्टे* (ग्रीन), *शिवाफिस सेल्टी* दास और *ओडोनेस्पिस ग्रीनाई* कोकेरेल पहली बार अभिलेखित की गई। *प्लेनोकोकस बेन्डोवी* विलियम्स, *टेनोकाईटोन ओलीवेसीयम* ग्रीन, *मेक्रोसीफम यूफोरबिए* (थॉमस) और *मीलवीस्कुटूलस मेनिफेर* (ग्रीन) को दक्षिण भारत में पहली बार अभिलेखित किया गया। *मार्सीपोकोकस आईसेरीआॅयड्स* (ग्रीन), *सेरोनीमा फ्रायरी* ग्रीन, *मेकोकोकस पाइपेरिस* (ग्रीन), *ट्राईजुबा ओक्युलेटा* डी लोटो, *प्रोटोपल्विनेरिआ लोन्गिवेलवेटा* ग्रीन, *पेरालेकेनीअम ओवेटम* मोरीसन, *पेरालेकेनीअम बेक्यूम* मोरीसन, *पेरालेकेनीअम नेनकम* (ग्रीन), *एरीओकोकस कोकसीनीअस* कोकेरेल, *डयूपलेस्पाईडिओटस क्लोवीगर* (कोकेरेल), *एक्जाल्लोमोकलस फिलीपिएन्सिस* विलियम्स और *एस्टिगोप्टेरीक्स पालिडा* वेन डेर गूट को भारत वर्ष में पहली बार पाया गया।

कोक्सीड्स की 43 प्रजातियों में से परजीवी कीटों की उन्नतीस प्रजातियाँ अभिलेखित की गई, जिनमें से एक परजीवी कीट की प्रजाति भारत वर्ष में एक नई प्रजाति के रूप में अभिलेखित की गई; कर्नाटक से आठ प्रजातियाँ नई और चार प्रजातियाँ नए परपोषकों सहयोगी अभिलेखित किए गए।

सेरमबाईसीडे (कोलीयोप्टेरा) का एकत्रण और पहचान

एकेन्थोफोरस सेरेटीकोर्निस, बेटोसीरा रूफोमेक्युलेटा, चेलीडोनिअम सीन्कटम, स्ट्रोमेटिअम बारबेटम और *जाईलोट्रेकस क्वाड्रिपस* नामक सीरमबायसिड्स की पाँच प्रजातियाँ एकत्रित की गई, उनकी पहचान की गई और संग्रहण में शामिल किया गया। सेरमबाईसीडे के उपकुलों के प्रौढ़ कीटों की कुँजी विकसित की गई।

भारत वर्ष में कीटरोगाण्विक सूत्रकृमियों की जैवप्रणालियाँ और विविधता

जम्मू और कश्मीर तथा कर्नाटक राज्यों के विभिन्न स्थानों से 172 मृदा नमूने एकत्रित किए गए, जिनमें से एक नमूने में ई पी एन पाया गया जिसकी पहचान *स्टेईनर्नेमा* स्पे. के रूप में की गई।

आण्विक कीटविज्ञान

कीट पीड़कों का आण्विक चरित्रण और डी एन ए बारकोडिंग

प्रतिवेदन के दौरान 500 से अधिक कीटों और अरेक्निड्स का विशिष्ट सायटोक्रोम ऑक्सीडेज (सीओ 1) प्राइमर्स के उपयोग द्वारा बारकोड किया गया। ये कीट और अरेक्निड्स आठ गणों (हेमिप्टेरा, लेपिडोप्टेरा, कोलीयोप्टेरा, हायमेनोप्टेरा, मेन्टोडिआ, अईसोप्टेरा, अरेनीए और ईक्जोडिडा) और 63 कूलों से संबंधित 162 प्रजातियों से संबंध रखते हैं। 46 प्रजातियों के लिए उत्पन्न बारकोड के संपूर्ण प्रजाति सूचना की फोल्मर्स रीजन, >550 बी पी के साथ सभी सीक्वेन्सों की पुष्टि की गई। प्रतिशत के हिसाब से 162 प्रजातियों के चरित्रण में हेमिप्टेरा (29.6%), लेपिडोप्टेरा (22.2%), डिप्टेरा (16.7%), कोलियोप्टेरा (12.3%), हायमेनोप्टेरा (11.7%), मेन्टोडिआ (1.9%), आईसोप्टेरा (1.2%), अरेनीए (2.5%) और ईक्जोडिडा (1.9%) किया गया।

परजीवी कीटों और परभक्षी कीटों का आण्विक चरित्रण और डी एन ए बारकोडिंग

परजीवी कीटों का आण्विक चरित्रण (सायटोक्रोम ऑक्सीडेज (सी ओ 1) रीजन) किया गया, परजीवी कीटों के नाम निम्नलिखित हैं - *एप्रोस्टोसीटस गाला* (के एफ 817576), *टेट्रास्टिकस स्कोनोबी* (के जे 627790), *कीलोनस ब्लैकबर्नी* (के एफ 365461), *ब्रेकोन हेबेटर* (के जे 627789), *क्वाड्रेस्टिकस मेन्डेली* (के एफ 879806), *एप्रोस्टोसीटस गाला* (के एफ 958278), *सीलिओसेरडो बायाट्रिक्स* (के एफ 938928), *स्यूडोलेप्टोमेस्टिक्स मेक्सिकाना* (के एफ 365460), *लेप्टोमेस्टिक्स नाइग्रोसिन्कटा* (के जे 489424), परागणकर्ता कीट जैसे *एपिस फ्लोरिआ* (के एफ 817578), *एपिस सेराना इन्डिका* (के एफ 861941), *मेगाचिले एम्ब्रेसिना* (के एफ 861940), *एपिस डोर्सेटा* (के जे 513470), परभक्षी कीट जैसे *एम्फिएरिअस कॉनस्ट्रिक्टस* (के एफ 817577), *जाइलोकोरिस फ्लेविपस* (के एफ 365462), *ब्लाप्टोस्टेथस पेलेसेन्स* (के एफ 365463), *बुकेनेनिएल्ला इन्डिका* (के एफ 383326), *कार्डिआस्टेथस एफिनिस* (के एफ 383326), *स्किमनस न्यूबिलस* (के एफ 861939), *आईसोलिआ इन्डिका* (के जे 489423), *किलोमिनस सेक्समेकुलेटा* (के एफ 998579) और एक खरपतवारनाशी कीट *टेलीओनीमा स्क्रूपुलोसा* (के एफ 817579) किए गए।

कीटनाशक सहिष्णुता/कीट अन्तःसहजीवितता

नागपुर और वाराणसी की बैंगन कोंपल और फल बेधक *ल्यूसीनोड्स ओरबोनेलिस* पर एमेमेक्टिन बेन्जोएट, फोजेलोन और फेनवेलेरिट रासायनिक कीटनाशकों के प्रति कीटनाशक सहिष्णु जैवविश्लेषण में फोजेलोन और फेनवेलेरिट के प्रति सहिष्णुता स्तर अधिक पाया गया। सहिष्णुता वाले कीटों में मध्य गट कार्बोक्सिलेस्टिएरेज सक्रियता देखी गई।

डायमंड बैक मौथ के लारवों की भौगोलिक कीट सँख्या के परजीवी कीट *कोटेशिआ वेस्टेलिस* के गट सूक्ष्मजीव का पृथककरण करने के बाद पहचान और चरित्रण किया गया। मिनीमल मिडिआ और एल सी एम एस अध्ययन के माध्यम से *बेसीलस* स्पे. ओर *एन्टीरोबेक्टर केन्सेरोजीनस* द्वारा जीवाणुवीय अन्तः सहजीवीतता द्वारा कीटनाशकों का अवनयन की पुष्टि की गई। भौगोलिक कीट सँख्याओं की विविधताओं का हीट शॉक प्रोटीन (एच एस पी एस) के आधार पर अध्ययन किया गया। परजीवी कीटों को स्ट्रैस वाली दशाओं में सहिष्णुता में एच एस जी एस के योगदान की पहचान की गई।

विभिन्न पर्णफुदकों की प्रजातियों से अन्तः सहजीवीय जीवाणुवीय बंशों का चरित्रण किया गया, वे निम्न हैं, *एन्टेरोबेक्टर* स्पे., *स्टेनोट्रोफोमोनाज माल्टोफिलीआ, बेसीलस* स्पे; *माइक्रोकस* स्पे., *लायसीनिबेसीलस फ्यूजिफोर्मिस, माइक्रोबेक्टेरिअम, एग्रोकोकस* और *स्टेफायलोकोकस* पाए गए। *एन्टेरोबेक्टर क्लोएसे* और *बेसीलस प्यूमिलस* जीवाणुओं ने *इनविट्रो* दशा में एसीफेट के प्रति सहिष्णुता दर्शायी। जीवाणुवीय अन्तः सहजीवीता सहयोग माहू के साथ की पहचान 16 एस आर डी एन ए आधार पर सीक्वेन्स *बेसीलस आर्याभिट्टाई, बे. सेरीअस, बे. फर्मस, बे. होरीकोशाई,*

बे. जीओटगाली, बे. माजीलेन्सिस, बे. सबटिलिस, एक्जिगुओ बेक्टेरिअमईन्डिकम, मोराक्सेल्ला ओस्लोएन्सिस और *पेनीबेसीलस लाऊटस* के रूप में की गई।

कीटरोगाण्विक सूत्रकृमियों (ई पी एन) का अध्ययन

ई पी एन सहयोगी जीवाणुवीय सहजीवी चार भारतीय विभेदों के जीनोमिक्स और जीन्स ट्रान्सक्रिप्टोमिक्स तथा विषाक्तता एवं रोगाण्विकता सुनिश्चित की गई। ई पी एन का प्रयोग अरहर और चारागाह फसलों में सफेद लट का नियंत्रण करने के लिए प्रदर्शन किया गया। *पोकोनिआ क्लेमॉयडोस्पोरिआ* और ई पी एन डब्ल्यू पी नियमनों की दो प्रौद्योगिकियों के उत्पादन, उनके प्रसंस्करण और विकास के लाईसेन्स तथा हस्तांतरण आल्विन इन्डस्ट्रिज, इन्दौर को किया गया। माजोली प्रायद्वीप में मूँगफली और सब्जियों वाली फसलों में *लेपिडिओटा मेन्सुएटा* के प्रति *हेटेरोरहब्डिटिस इन्डिका, स्टेईनर्नेमा कार्पोकेप्से, स्टे. अब्बासी* सहित एन बी ए आई आई के ई पी एन विभेदों का परीक्षण किया गया। ए आई सी आर पी केन्द्र, जोरहाट, असम के माध्यम से सफेद लट, कटा सूँडी और दीमक के प्रति ई पी एन नियमनों का निर्धारण किया गया।

ई पी एन के पृथककरण करने के लिए जम्मू और कश्मीर के गाँवों पामपोरे, तराल, बाँदीपोरा और योरखुशीपोरा के शहतुत के खेतों से, मोनुघाट (धलाली, त्रिपुरा) के वनों एवं जंगल से और कर्नाटक राज्य के यू ए एस, धारवाड, मुगाड, नरेन्द्रा, गामनागट्टी एवं गडग के गाँवों से कॉफी, सुपारी, गन्ना और सब्जी वाले खेतों से कुल 172 मृदा नमूने एकत्र किए गए। जब मृदा नमूनों के विश्लेषण मौथ, *गेलेरिआ मेलोनेल्ला* का मृदा प्रपंच तकनीक के रूप में प्रयोग किया गया, तब एक सकारात्मक नमूने में *स्टेईनर्नेमा* स्पे. पाया गया।

शुष्क और आर्द्र क्षेत्रों में *बी टी क्राय* जीन की विविधता

आठ पृथककरणों से प्राप्त *क्राय* 2 ए सी डी एस (2.2 के बी) में *ई. कोली* क्लोन्ड को आगे के अध्ययन के लिए तैयार किया गया। 1.9 के बी *क्राय* 3ए (कोलीओप्टेरन विशिष्ट जीन) सम्पूर्ण जीन सीक्वेन्सिंग का कार्य किया गया। प्राईमर वाकिंग के प्रयोग द्वारा 2.37 के बी वी आई पी 3ए (लेपिडोप्टेरन विशिष्ट जीन) और 3.686 के बी *क्राय* 1ए सी (लेपिडोप्टेरन विशिष्ट जीन) तौयार किए गए। *ई. कोली* एक्सप्रेशन प्रणाली मे सब क्लोन्ड सीक्वेन्स तैयार किए गए। पी सी आर विश्लेषण के माध्यम से डिप्टेरन विषाक्त *क्राय* 2ए, *क्राय* 17ए, *क्राय* 4ए और *क्राय* 44 बी ए की पहचान की गई। *क्राय* 44 बी ए की पहचान भारत वर्ष में सर्वप्रथम अभिलेखित की गई।

कोलीओप्टेरन विशिष्टता दर्शाने वाले *क्राय* 3ए जीन के सात *बीटी* पृथककरणों को मानकीय विभेद (4 एए1) के साथ कोलीओप्टेरन पीडक कीट *साईटोफाईलस ओराइजि* के प्रति परीक्षण किया गया। बी टी ए एन 4 को मानक विभेद के समान विषैला और परीक्षण में प्रयुक्त देशी विभेदों की तुलना में अत्यधिक विषैला विभेद पाया गया। बी टी ए एन 4 ने एल सी$_{50}$ मात्रा 89.65 माइक्रोन ग्राम/मिली. और मानकीय विभेद ने एल सी$_{50}$ मात्रा 85.26 माइक्रोन ग्राम/मिली. दर्शायी, इसके बाद टी आर बी टी 10 ने एल सी$_{50}$ मात्रा 96.16 माइक्रोन ग्राम/मिली दर्शायी।

कीट पारिस्थितीकी विभाग

एन्थोकोरिड परभक्षी कीट विविधता

अनेक पोषक पौधों से एन्थोकोरिड परभक्षी कीट एकत्र किए गए। *बुचानेनिएल्ला इन्डिका* को क्रासेन्ड्रा से, *एम्फिएरियस कॉन्सट्रीक्टस* को गन्ने से और *एन्थोकोरिस मुरलीधरनी* को बरगद से एकत्र कर वैकल्पिक रूप में प्रयोगशाला में उनके परपोषी अन्डों पर पाला गया। भारतवर्ष में, *ब्लाप्टोस्टेथॉयड्स पेसीफाईकस* को गन्ने और *ओरीयस एमेन्सिअस* को गुलाब पर सर्वप्रथम अभिलेखित किया गया।

एम्फिएरियस कॉन्सट्रीक्टस की जैविकी और भक्षण क्षमता पर अध्ययन

एन्थोकोरिड परभक्षी कीट *एम्फिएरियस कॉन्सट्रीक्टस* को कर्नाटक राज्य के मान्डया जिले के गन्ने से एकत्र किया गया। इन कीटों को अल्ट्रावायलेट-किरणों से उपचारित *कोरसेरा सिफेलोनिका* के अण्डों पर उत्पादन करना श्रेष्ठ पाया गया। कीट का कुल वृद्धिकाल 16.4 दिन पाया गया। इस कीट के नर की भक्षण क्षमता प्रतिदिन 86.7 अण्डे जबकि मादा की दर 93.5 अण्डे भक्षण करते पाए गए।

एन्थोकोरिड परभक्षी कीट *बुचानेनिएल्ला इन्डिका* पर अध्ययन

बुचानेनिएल्ला इन्डिका को वैकल्पिक रूप में प्रयोगशाला में उनके परपोषी अन्डों पर सफलता पूर्वक पाला गया। इस कीट को प्रयोगशाला में 10 पीढ़ीयो से अधिक पाला गया।

जाइलोकोरिस फ्लेविपस पर स्थिरांक तापक्रम का प्रभाव

जाइलोकोरिस फ्लेविपस के इन्कयूबेशन, निम्फीय आर संपूर्ण विकास के लिए सीमांत तापक्रम वृद्धियाँ क्रमशः 7.85, 12.28 और 11.8 अभिलेखित की गई।

जीवित कीट प्रजननद्रव्य की देखरेख और शिपमेन्ट भेजना

कुल 980 खेपों में जीवित कीट प्रजननद्रव्य संवर्धनों को भेजा

गया और तीन लाख छब्बीस हजार तीन सौ तरेपन रूपयों का राजस्व प्राप्त किया।

जैवकारकों की विविधता और उनको पालने के तरीके

ट्रायकोग्रामा डेनाईडिफेगा प्रयोगशाला में *कोरसेरा* के अण्डो को परजीवित करने में सफलता पाई। *टेलीनोमस* स्पे. को *स्पोडोप्टेरा लिट्यूरा* के अण्डो पर पाला जा सका। *एनास्टेटस अचेरोन्टिए* को ऐरी रेशम कीट के अण्डों पर पाला जा सका। *एनास्टेटस बेंगलोरिएन्सिस* को ऐरी रेशम कीट के अण्डों पर पाला जा सका।

एलीवेटर कार्बन डाई ऑक्साईड की दशा में अरहर के पौधों पर *हेलीकोवर्पा आर्मिजेरा* के अण्डनिक्षेपण का व्यवहार

एम्बिएन्ट दशाओं में अरहर उगाये गए पौधों की तुलना में 500 पी पी एम वाली $CO_2 + 2°$ सेग्रे. की दशा में *हे. आर्मिजेरा* की मादाओं ने अधिक अण्डे दिए।

CO_2 की अधिकता की दशाओं में अरहर का वोलेटाईल प्रोफाईल

500 पी पी एम कार्बनडाई आक्साईड पर उगाये गए पौधों में एल्फा कोपेन नामक यौगिक पाया गया जो वोलेटाईल की अतिरिक्त मात्रा पाई गई जो कि मादा कीटों को आकर्षित करने के लिए उत्तरदायी माना जा सकता है।

CO_2 की अधिकता में उगाये गए टमाटर पर *लिरीओमायजा ट्राईफोली* का ग्रसन

कार्वनडाईआक्साईड और तापक्रम की अधिकता में चैम्बर्स में *लीरीओमायजा ट्राईफोली* का ग्रसन महत्वपूर्ण रूप से अधिकतम पाया गया।

बेक्टोसीरा डोर्सेलिस को आकर्षित करने के लिए पादप-आधारित नियमन

फल मक्खी *बेक्ट्रोसीरा डोर्सेलिस* को ट्रैप करने के लिए नये नियमन को मिथाईल यूजीनोल से अत्यन्त प्रभावी पाया गया।

हेलीकोवर्पा आर्मिजरा के लिए पादप वोलेटाईल आधारित डेटेरेन्ट

चने की फसल में, *हेलीकोवर्पा आर्मिजेरा* के लिए पादप-आधारित वोलेटाईल यौगिकों के तीन नियमनों की क्षमता की जाँच की गई।

पपीते के मिलीबग का पपीते और अन्य पौधों पर दिखाई पडना

जहाँ पर भी पपीते के मिलीबग देखे गए, वहाँ पर सभी जगह *एसीरोफेगस पपाये* पाए गए। *हिबिस्कस* पर 72% तक *एसीरोफेगस पपाये* का परजीवीकरण पाया गया। *पार्थेनियम* पर लगभग 84-86% और *साइडा एक्यूडा* तथा *अकेलिफा* पर 72-79% परजीवीकरण पाया गया।

परदेशी कीट जैक बेयर्डस्ली मिलीबग के परपोषी की विस्तार

जैक बेयर्डस्ली मिलीबग, *स्यूडोकोकस जैकबेयर्डस्ली* को तमिलनाडू और कर्नाटक राज्यों में पाया गया। *क्रिप्टोलीमस मोन्ट्रोयूजिएरी, स्पेल्जिस एपिअस* और ग्रेटस को मिलीबग नियंत्रण रखने के लिए सफल पाया गया।

स्यूडोकोकस जैकबेयर्डस्ली का अंकुरित आलू और कद्दू पर बहोत्पादन

स्यूडोकोकस जैकबेयर्डस्ली को अंकुरित आलुओं और परिपक्व हरे कद्दू पर कम लागत से उत्पादित किया गया।

यूकेलिप्टस की गॉल वैस्प का प्रबन्धन

यूकेलिप्टस गॉल वैस्प, *लेप्टोसायबे इनवेसा* को *क्वाड्रास्टिकस मेन्डेली* क्षेत्र में छोड़कर प्रभावपूर्ण रूप से नियंत्रित किया गया। ये कीट उत्तर प्रदेश, पंजाब और उत्तरांचल प्रदेशों में स्थापित हो गए हैं। उत्तर भारत में *क्वा. मेन्डेली* की अपेक्षा *मेगास्टिगमस* अत्यधिक प्रभावी पाए गए।

एरीथ्रिना गॉल वैस्प प्रबन्धन

एप्रोस्टोसीटस गाला कीट परजीवी कीट के *क्वाड्रास्टिकस एरीथ्रिने* को 46% परजीवीकरण के साथ प्रमुख परजीवी कीट के रूप में पाया गया।

सेसीडोकेरस कोनेक्सा का स्थापित होना

खरपतवार विज्ञान अनुसंधान निदेशालय, जबलपुर के सहयोग से झारखंड राज्य में इन कीटों को पहली बार छोडा गया।

नान-एपिस मधुमक्खी का विभिन्न पोषक पौधों पर एकत्रण, प्रलेखन और उनकी पहचान

विभिन्न पोषक पौधों से एपिडे, मेगाचिलिडे, एन्थोफोरिडे, हेलीक्टिडे कुल से संबंध रखने वाले 200 से भी अधिक मधुमक्खी के प्रतिदर्शों को एकत्र करके लेबल और परिरक्षित (पिन और द्रवीय एकत्रण दोनों ही) कर पहचान के लिए रखा गया।

"परागण कर्ता कीट उद्यान" की स्थापना

यलहंका परिसर में लगभग 0.7 एकड क्षेत्रफल पर ''परागणकर्ता कीट उद्यान'' की स्थापना की गई। इस उद्यान 70 से अधिक किस्म के

पौधे हैं जो कि विभिन्न कूलों (वृक्षों, झाडी, शाक और लताओं) से संबंधित है तथा विभिन्न परागणकर्ता कीट को अपनी तरफ आकर्षित करने के लिए जाने जाते हैं।

गट सूक्ष्मजीवों की कार्यिकी चरित्रण

रासायनिक कीटनाशकों से उदभासित *अमरास्का बिगुटुल्ला बिगुटुल्ला*, *एम्पोएस्का स्पे.*, *नेफोटेटिक्स नाइग्रोपिक्टस*, *बोथ्रोगोनिआ* और *नीलपर्वता ल्यूजेन्स* की 15 जीवित सँख्याओं से कुल 37 संवर्धन गट जीवाणु और एक संबर्धन यीस्ट का चरित्रण और पहचान की गई।

संवर्धन जीवाणु का चरित्रण और पहचान

अमरास्का बिगुटुल्ला बिगुटुल्ला के सहयोगी जीवाणुओं में, *माइक्रोबेक्टेरिअम इम्पेरिअल*, *बेसीलस आयभिट्टाई*, *स्टेफायलोकोकस एपिडर्मिडिस*, *जेनीबैक्टर एनोफीलीस*, *बेसीलस सेरेईयस*, *स्टेफायलोकोकस आरीअस*, *माइक्रोकस ल्यूटीएस*, *एग्रोकोकस टेरीअस*, *बेसीलस सेरेईयस*, *स्टेफायलोकोकस वारनेरी*, *स्टेफायलोकोकस होमिनिस*, *स्टेफायलोकोकस आरलीटे*, *स्यूडोमोनाज स्टयूटजेरी*, *बे. प्यूमीलस* और *एन्टेरोबेक्टर स्पे.* पाए गए। *नि. नाइग्रोपिक्टस* के सहयोगी जीवाणु के रूप में, *एन्टेरोबेक्टर क्लोएसे*, *स्टेनोट्रोफोमोनाज माल्टोफिलिआ*, *बे. फर्मिस*, *ए. क्लोएसे*, *कोक्यूरीआ क्रिस्टीनि*, *स्टेनोट्रोफोमोनाज माल्टोफी* और *बे. फ्लेक्सस* पाए गए। *एम्पोएस्का स्पे.* के सहयोगी के रूप में *बे. स्ट्राटोस्फेरीकस* और *माइक्रोकोकस स्पे.* पाए गए। *बोथ्रोगोनिआ स्पे.* से *लायसीनिबेसीलस फ्यूजिफोर्मिस* पाया गया। *बोथ्रोगोनिआ स्पे.* और *अ. बिगुटुल्ला बिगुटुल्ला* से *बोल्बेशिआ* पाया गया।

एसीफेट के विभिन्न सान्द्रणों में *एन्टेरोबेक्टर क्लोएसे* की वृद्धि

एन्टेरोबेक्टर क्लोएसे की वृद्धि अनोपचार की तुलना में, एसीफिट निवेशन के 3 दिन वाले सभी सान्द्रताओं के मिनीमल ब्रॉथ में अत्यधिक वृद्धि अभिलेखित की गई। एसीफेट की 50 पी पी एम सान्द्रता के निवेशन के 3 दिन के बाद ओ डी मात्रा 1.0 के रूप में अधिकतम पाई गई जबकि अनोपचारित में यह मात्रा 0.8 पाई गई।

एसीफेट के विभिन्न सान्द्रणों में *बेसीलस प्यूमिलिस* की वृद्धि

बेसीलस प्यूमिलिस की वृद्धि एसीफेट निवेशन के 3 दिन बाद वाले सभी सन्द्रताओं के मिनीमल ब्रॉथ में अधिकतम वृद्धि अभिलेखित की गई।

सूक्ष्मजीवों द्वारा पाचक एन्जाईम का उत्पादन

माइक्रोकस ल्यूटीअस, *एग्रोकोकस टेरीअस*, *एसीनेटोबेक्टर बेरेजीनिए*, *प्रोटीअस माइरेबिलिस*, *स्यूडोमोनाज स्टयूटजेरी* एमाईलेज उत्पादित करते हैं जो कि पाचन के लिए उपयोगी हैं।

सीधे क्षेत्र से एकत्र विषाक्त पर्णफुदकों की पहचान

सीकाडेलिडे की 5 कूलों के अन्तर्गत आने वाले पर्णफुदकों के परीक्षणों में 15 प्रजातियों की जाँच में केवल *बेट्रेकोमोर्फस एन्गस्टेटस*, *सीकाड्यूलिना बायपंकटेटा*, *एक्जिटिएनस इन्डिकस*, *हीकेलस स्पे.*, *हिस्हिमोनस फायसीटिस*, *निरवाना पालीडा* और *ओरोसीअस एल्बिसिन्कटस* को बैंगन, तिल और/या पेरीविंकल की फसल में लक्षणों के पैदा होने के आधार पर विषाक्त पाए गए।

कीट वेक्टर्स पहुँचाने की भक्षण विधि

हिस्हिमोनस फायसीटिस और *ओरोसिअस एल्बिसिन्कटस* के मुखाँगों की तुलना के विश्लेषण में पाया गया कि इन दोनों के बीच केवल सूक्ष्म अन्तर पाया जाता है। सामान्यतः तिल और बैगंन की फसल में *ओ. एल्बिसिन्कटस* की तुलना में *हि. फायसिटिस* का प्रमुख ग्रसन पाया गया।

तीन पर्ण फुदकों की प्रजातियों का डी एन ए बारकोडिंग

निरवाना पालीडा, *हि. फायसिटिस* और *ओरोसिअस एल्बिसीन्कटस* का डी एन ए बारकोडिंग का कार्य पूर्ण करने के बाद जीन बैंक को इनके न्यूक्लिओटाइड सीक्वेन्स प्रेषित किए गए।

टमाटर और शिमलामिर्च में कीटकवक रोगाणुओं का प्रभाव

टमाटर में, सफेद मक्खी को नियंत्रित करने के लिए *लिकेनिसीलिअम लेकेनी* (वी एल 8) और *बी. बेसीआना* (बी बी 9) के प्रयोग से सफेद मक्खियों को महत्वपूर्ण रूप से क्रमशः 15.29 और 17.21 सफेद मक्खी/पौधा की दर से नियंत्रित किया। शिमला मिर्च में, *लि. लेकेनी* (वी एल 8) और *ब्यूवेरीआ बेसीआना* (बी बी 9) के प्रयोग से सफेद मक्खियों को महत्वपूर्ण रूप से क्रमश 6.47 और 6.98 सफेद मक्खी/ पौधा की दर से नियंत्रित किया गया।

कीटकवकीय रोगाणुओं का पातागोभी माहू के प्रति क्षेत्रीय मूल्यांकन

अनोपचार की अपेक्षा उपचारित दशा में नौ कवकीय रोगाणुओं के परीक्षण में से बी बी 5ए, एम ए6 और वी एल 8 पृथककरणों ने 60.0 से 68.25% कमी प्रदर्शित की है।

नेनौसेन्सर्स के विकास में प्रयोग करने के लिए टमाटर से उपापचयी निष्कर्ष

टमाटर के 20 दिन की *आयु* के पत्ती और तनों से जी सी - एम एस स्पेक्ट्रोस्कोपिक विश्लेषण में कुल 47 उपापचयी तैयार

किए गए। तने से इक्कीस उपापचयी और पत्तियों से 14 उपापचयी को नैनोसेन्सर्स के विकास के लिए सर्वश्रेष्ठ पाया।

बेक्ट्रोसीरा डोर्सेलिस और *बे. केरीएई* का रासायनिक प्रोफाईल

बेक्ट्रोसीरा की दोनों प्रजातियों की लारवा अवस्थाओं की पहचान के लिए, मेटाबोलाइट सीग्नेचर्स (एन एम आर) एक उचित विधि पाई गई।

क्राईसोपर्ला जेस्ट्रोवी सिलेमी पर चिटोसन-एल्जिनेट नैनोपार्टिकल्स का अलक्षित प्रभाव

चिटोसन एल्जिनेट नैनोपार्टिकल्स मिश्रित *कोरसेरा सिफेलोनिका* के अण्डों पर *क्राईसोपर्ला जेस्ट्रोवी सिलेमी* के लारवों द्वारा निरंतर भक्षण करने पर कोई महत्वपूर्ण प्रभाव नही पाया गया।

फसल पीड़कों के जैविक नियंत्रण पर अखिल भारतीय समन्वित अनुसंधान परियोजना

विभिन्न कृषि परिस्थितिकीय क्षेत्र में जैव नियंत्रण कारकों की जैवविविधता

पश्चिमी बंगाल के धान परिस्थितीकी तन्त्र से कीट और मकडी की 117 प्रजातियाँ एकत्र किए गए जो कि 8 गणों, 63 कुलों से संबंधित थे ओर उनकी पहचान की गई, ये कीट 45 पीडक प्रजाति, 44 परभक्षी कीट और 24 परजीवी कीट प्रजाति के अन्तर्गत पाई गई। *सिरकोफेगा इन्सर्टुलस* ओर *सि. फस्कीफ्लुएविज* के अण्डों से परजीवी कीट की तीन प्रजातियाँ *टेट्रासटिकस स्कूनोबी, ट्रायकोग्रामा जेपोनीकम* और *टेलीनोमस* स्पे. पाई गई। लम्बे पँखो वाला लाल पादप फुदका *डायोस्ट्रोम्बस पोलाईटस* को कलीमपोन्ग क्षेत्र में बहुतायत से पाया गया। स्किपर, *परनारा गुटाटा* का *एपेन्टेलस* स्पे. द्वारा 75% परजीवीकरण पाया गया। धान की बग (*लेप्टोकोर्सिआ* स्पे.) पर एक कवक पाया गया जिसकी पहचान *एक्रीमोनिअम* लीओलीए के रूप में की गई।

उत्तर प्रदेश के सब्जी उगाने वाले क्षेत्रों में मिलीबग, *फिनेकोकस सोलेनोप्सिस* को टमाटर, बैंगन, शिमला मिर्च, परवल और भिण्डी की फसलों में पाया गया। बैंगान में *सेन्ट्रोकोकस इन्सोलिटस* पाया गया। *फि. सोलेनोप्सिस* के दो प्रमुख अन्तः परजीवी कीट जैसे *एनासीअस बोम्बावाले* और *प्रोम्यूसीडिआ अनफेसकिएटीवेन्ट्रिस* (हायमेनोप्टेराः एनसिर्टिडे) पाए गए।

केरल में, केला पारिस्थितीकी तन्त्र से ईयरविग, *आउचेनोमेस हिन्कसी* (डर्मेप्टेराः लेबीडे) पाया गया जो कि स्यूडो स्टेम बिबिल *पेरालेबिस डोहर्नी, चारहोस्पानिआ नाइग्रीसेप्स* और *यबोरेलिआ साबी* (डर्मेप्टेरा; लेबीडे) के अण्डों और केले के रहाईजोम विबिल के तरूण निरूपीय ग्रब का भक्षण करते पाए गए। केले के माहू पर कोक्सीनेलिड के रूप में, *स्यूडेस्पिडिमेरस ट्राईनोटेटस, स्किमनस पायरोकिलस, जाउरोबिआ सोरोर, स्किमनस* स्पे. *किलोमीनस सेक्समेकुलेटा* और *स्टिकोलीटिस* स्पे. पाए गए। काली मिर्च में, पोलू बीटल का भक्षण करते हुए मकडियाँ जैसे *बाबिआ केराली, आक्सीओपस जेवेनस* और *आ. श्वेता* पाए गए। कपास में, फूल की मिज के परजीवीकीट के रूप में *एक्रिजोटोमोर्फा* स्पे. की पहचान हुई।

कश्मीर में, फल वाली फसलों के 16 कीट पीड़कों के शत्रु कीटो को अभिलेखित किया गया। प्राकृतिक शत्रु कीटों की 40 प्रजातियों में से 17 परजीवी कीट और 23 परभक्षी कीट के रूप में पाए गए। सेब के माहू *एफिस स्पाईकोला* से *एफीडस* स्पे. और अखरोट के माहू *केलीपटेरस जुगलान्डिस* से *ट्राईओक्सिस* स्पे. पाए गए।

विभिन्न कृषि पारिस्थितिक तन्त्र की जैवविविधता

दक्षिण तेलंगाना क्षेत्र से *ट्राइकोग्रामा, क्राईसोपरला, किलोनस ब्लेकबर्नी,* कोक्सीनेलिडस और मकडी के रूप में प्राकृतिक शत्रु कीट के रूप में पाए गए। महाराष्ट्र में, गन्ने की फसल से प्राकृतिक शत्रु कीटों के रूप में, कोक्सिनेलिडस, *कोक्सीनेल्ला सेपटमपंकटेटा, मीनोकिलस सेक्समेकुलेटा, स्किमनस कोक्सीवोरा, एनकार्सिआ फ्लेवोस्कूटेलम, डाइफा एफिडिवोरा, माइक्रोमस इगोरोटस,* गन्ने के वुली एफिड पर सिरफिड पाए गए। शरीफा की फसल में, मिलीबग की कालोनी में, *कोक्सीनेल्ला ट्रान्सवर्सेलिस, मि. सेक्समुकेलेटा, ब्रुमॉयडस सुचुरेलिस, स्किमनस कोक्सीवोरा* और *ट्रायोमाटा कोकसीडोवोरा* पाए गए। पपीते के मिलीबग पर *एसीरोफेगस पपाए, स्यूडोलेप्टोमेस्टिक्स मेक्सिकाना, मलाडा बोनिनेन्सिस* और *स्पेजिस एपिअस* और बेर पर लाख कीट का परभक्षी कीट *यूब्लेमा एमाबिलिस* पाया गया। सोलन में, *क्रायसोपर्ला* की एक प्रजाति, कोकसीनेलिड की 37 प्रजातियाँ, *लिरीओमायजा ट्रायफोली* और/या *क्रोमेटोमायईआ हार्टिकोला* की हायमेनोप्टेरन परजीवी कीटों की 20 प्रजातियाँ, थ्रिप्स की 3 परभक्षी कीट प्रजातियां, 2 प्रजातियाँ एन्थोकोरिड बग की 2 प्रजातियाँ, सिरफिड परभक्षी कीट की 9 प्रजातियाँ और परभक्षी माइट की 9 प्रजातियाँ एकत्र की गई।

जालन्धर में गन्ने के अगोला बेधक कीट से अण्ड परजीवी कीट *ट्राइकोग्रामा जेपोनिकम* की पुनः प्राप्ति की गई। मक्का में (पंजाब) *ट्राइकोग्रामा* द्वारा प्राकृतिक परजीवीकरण 7.5 से 35.8% पाया गया। कपास में, प्राकृतिक परजीवित सेन्टीनेल कार्ड से, 35% *ट्राइकोग्रामा* प्रौढ़ कीट प्राप्त किए गए।

कश्मीर में, मकडी की ग्यारह कूल, 25 वंश और 34 प्रजातियाँ पाई गई और अरेनीडे (7 प्रजाति), टेट्राग्नाथिडे (5 प्रजाति) और साल्टिसिडे (5 प्रजाति) के रूप में संकलित की गई। जिन मकडियों का प्रभुत्व पाया गया उनके नाम है, *पारडोसा एल्टिट्यूडिस, थेरीडिऑनस्पे., अरेनिअस अनन्तनेजिएन्सिस* और *टेट्राग्नाथा मेन्डिबुलाटा*। गुजरात में, मौसमीय बहुतायत में धान पारिस्थितिकी तन्त्र में परभक्षी मकडियों के रूप में अधिकाशतः *नीओस्कोना थेईसी* और *लीयूकेजस्पे.* प्रजातियाँ अधिकतम पाई गई। आन्ध्र प्रदेश के राजेन्द्रनगर में *टेट्राग्नाथा* की मात्रा अधिकतम इसके बाद *आक्सीओपेस* पाए गए।

उ. प्र. के सीतापुर जिले के आम के बाग से एक कीट रोगाण्विक सूत्रकृमि पृथक किया गया जिसकी पहचान *स्टेईनर्नेमा स्पे.* (सी आई एस एच 3 विभेद) के रूप में हुई।

विदेशी हानिकारक कीटों का अनुवीक्षण

तमिल नाडू में पपीते के मिलीबग *पेराकोकस मार्जिनेटस* और जैक बेयर्डस्ले मिलीबग, *स्यूडोकोकस जेकबेयर्डस्लेई* अभिलेखित किए गए और जुलाई से दिसम्बर 2013 के दौरान गन्ने के वुली माहू का ग्रसन 14.8% प्रति 6.25 वर्ग सेमी पत्ती क्षेत्रफल की दर से पाई गई, जबकि कर्नाटक में इसका विस्तार 5 से 10% पाया गया। तेलंगाना के कपास उगाने वाले क्षेत्रों में *मेकोनेलीकोकस हिर्सुटस* से भी अधिक प्रभुत्व *फिनोकोकस सोलेनोप्सिस* का पाया गया।

रोगो और सूत्रकृमियों का जैविक दमन

गो ब पं कृ एवं प्रौ वि, में कम लागत से डब्ल्यू पी/ई सी आधारित *ट्राइकोडर्मा* (टी एच 14) नियमन और सक्षम डिलीवरी सिस्टम तैयार किया गया। झंगोरा दानों में 5% गुड (3.2×10^{10} बीजाणु/ग्रा.) के साथ सुधार की गई विधि में बीजाणु अत्यधिक पाए गए। गेहूं के पौधों को पी एफ ए 50 इन्डयूसर रहाइजोबेक्टेरिआ से उपचारित करने पर *बाइपोलेरिस सोरेकिनिआना* की ग्रसनता को 51.34% कम किया गया। धान में ब्राऊन धब्बे रोग के प्रति *ट्राईकोडर्मा* पृथककरण टी सी एम एस 5 और टी सी एम एस 14 ए के प्रयोग से क्रमशः 17.3% और 18.3% तक की रोग में कमी पाई गई जबकि अनोपचारित खेत में 48.0% देखा गया। पासीघाट में, सी एच एफ पी एफ 1 से उपचारित बैंगन में मुरझान ग्रसन 14.75% जबकि स्ट्रेप्टोमायसीन उपचारित क्षेत्र में 19.83% पाया गया। सी एच एफ पी एफ 1 उपचारित क्षेत्र से उपज भी अधिकतम (244.55 कु./हे.) प्राप्त हुई।

अन्न और दलहनी फसलों के हानिकारक कीटों का जैविक दमन

धान की बग में *मेटारहाईजिअम एनिसोप्लिए* का 2×10^{8} बीजाणु/मिली. प्रयोग घातक सिद्ध हुआ। गन्ने में *ट्रा. किलोनिस* (टीटीएस) को 50,000/हे. की दर से आठ बार क्षेत्र में छोड़ने पर अगेती तना बेधक का ग्रसन 54.9% कम और अगोला बेधक ग्रसन 52.2% कम पाया गया। *ट्रा. किलोनिस* को 50,000/हे. की दर से बारह बार छोड़ने पर पोरी बेधक ग्रसन को 52.3% कम किया जा सका। ज्वार में, *मे. एनीसोप्लिए* (एम ए 36 का 5 मिली/ली. की दर से) का प्रयोग करने पर अनोपचारित की अपेक्षा 18.0% डेड हर्ट में कमी पाई गई और इसका प्रयोग कार्बोफ्यूरान ग्रेन्यूल्स के समान प्रभावी पाया गया।

तमिल नाडू में, *बी टी* विभेद एन बी ए आई आई-बीटी जी 4 को 2% की दर से तीन छिड़काव करना क्लोरोपायरीफॉस का 0.05% की दर से प्रयोग करने के परिणाम स्वरुप *हे. आर्मिजेरा* और *मारूका डेस्टुलेलिस* द्वारा फली क्षति (11.8%) कम करने के लिए एक समान और अरहर की उपज बढाने (14.8 कु./हे) के लिए अच्छा पाया गया। यद्यपि, क्लोरोपायरीफॉस प्रयोग करने पर फली क्षति न्यूनतम (4.90%) पाई गई ऐसा पूल्ड विश्लेषण में पाया गया। रायचूर में, एन बी ए आई आई बीटी जी 4 *बीटी* का 2 मिली/ली की दर से प्रयोग करने पर फली क्षति 10.84% अभिलेखित की गई जो कि अन्य जैवकारकों के प्रयोग से उत्कृष्ट पाई गई। उपचारित क्षेत्र से दानों की उपज महत्वपूर्ण रूप से अधिकतम 14.88 कु./हे. प्राप्त हुई जो कि अन्य उपचारों से अधिक पाई गई।

तिलहनी फसलों के हानिकारक कीटों का जैविक दमन

सोयाबीन में, *स्पो लि* एन पी वी को 250 एल ई/हे. की दर से तीन बार प्रयोग करने पर *स्पोडोप्टेरा लिट्यूरा* का 78.0 प्रतिशत लारवों के लिए घातकता के साथ नियंत्रण के लिए अत्यन्त प्रभावी पाया गया और सोयाबीन की उपज 21.95 कु./हे. प्राप्त हुई। काँटे रहित कुसुम में, *वर्टिसिलियम लेकेनी* को 1.0% डब्ल्यू पी की दर से दो बार छिड़काव करने पर कुसुम के माहू, *यूरोलियूकोन कम्पोजिटे* के जैव नियंत्रण करने की उपलब्धि पाई गई।

सब्जियों वाली फसलों के हानिकारक कीटों का जैविक नियंत्रण

टमाटर की फसल में रोपण के 75 से 105 दिनों के बाद जैव प्रबलित कीट प्रबन्धन (बी आई पी एम) विधि में फल बेधक कीट का ग्रसन 6.4 से 8.6% जबकि किसान द्वारा अपनाई गई प्रक्रिया वाले क्षेत्रों में ग्रसन 14.2 से 15.8% पाया गया। बी आई पी एम अपनाए गए प्लॉट से उपज अधिकतम (32.45 टन/हे.) जबकि किसान द्वारा अपनाई गई प्रक्रिया वाले प्लॉट से उपज (32.45 टन/हे) लागतः लाभ अनुपात 1:3.2 को साथ प्राप्त हुई। बैंगन में नीम बीज अर्क के दो छिड़काव और *ट्राइकोग्रामा किलोनिस* को छः बार छोड़ने पर चूषक पीडकों द्वारा फल और कोंपल शाक क्षति को महत्वपूर्ण रूप से कम किया जा सका।

क्रुमस सुचुरॉयड्स को 1500/हे., *स्किमनस* को 1500/हे. और *क्रिप्टोलेमिस* को 1500/हे. के दर से छोड़ने पर मिलीबग की सँख्याओं को महत्वपूर्ण रूप से कम किया गया। बैंगन की फसल में *ट्रा. किलोनिस* को 50000 परजीवी कीट/हे. की दर से छोड़ने के साथ नीम बीज अर्क का 5% छिड़काव और *बे. थ्यूरिनजिएन्सिस* को 1 ली/हे. की दर से छिड़काव करने पर कोंपल शाक ग्रसन (10.6%) और फल बेधक ग्रसन (15.3%) कम किया गया और बैंगन की बाजार योन्य उपज बढ़ी (217.8 कु./हे.) पाई। पोलीहाऊस में पातगोभी के माहू का ग्रसन अत्यधिक कम (15.3%) करने के लिए *कोक्सिनेल्ला सेप्टमपंकटेटा* के दूसरे निरूपीय ग्रबों को 5/पौधा की दर से छोड़ने पर उपलब्धि प्राप्त की। अनोपचारित प्लॉट की अपेक्षा *बी टी* नियमनों जैसे पी डी बी सी बी टी 1 और एन बी ए आई आई बी टी जी 4 को 1 और 2% की दर से प्रयोग करने पर डायमण्ड बैक मौथ के लारवों की सँख्या को महत्वपूर्ण रूप से 85.48 से 90.88% तक कम करने के लिए उत्कृष्ट पाया गया।

आलू की फसल में, एम ए 4, बी बी 23 और बी बी 5 ए नामक एन बी ए आई आई कीट कवकीय रोगाणुओं का प्रयोग करने पर *डोरीलस ओरिएन्टेलिस* के कन्द ग्रसन को क्रमशः 19.0, 19.25 और 19.75% तक कम किया जा सका। ईमिडेक्लोप्रिड प्रयोग किए गए प्लॉट से उपज अधिकतम (83.90 कु./हे.) इसके बाद एन बी ए आई आई विभेद एम ए-4 उपचारित प्लॉट (83.12 कु./हे.) और मेलाथियॉन डस्ट उपचारित प्लॉट (79.37 कु./हे) से उपज प्राप्त हुई।

फल वाली फसलों के हानिकारक कीटों का जैविक दमन

आम में फूदकों का नियंत्रण करने के लिए *मेटारहाईजिअम एनीसोप्लिए* को 1 X 10^9 बीजाणु/मिली की दर से उपचारित करने पर फूदकों की सँख्या का सफलतापूर्वक नियंत्रण (10.6 फुदके/पुष्पक्रम) और फल सेट होने की दर भी बढ़ी (11.8 फल/पुष्पक्रम) पाई गई। मे. एनीसोप्लिए (आई आई एच आर विभेद) को 1 किग्रा/100 ली. की दर से प्रयोग करने पर आम के फुदकों के लिए 77.1% तक घातक पाया गया। शरीफा में, *स्किमनस कोक्सीबोरा* को 10 ग्रब प्रति वृक्ष दो बार छोड़ने पर *मेकोनेलीकोकस हिर्सुटस* और *फे. विरगेटा* नामक मिलीबगों की सँख्या कम की जा सकी और उपज बढ़ी (34.9 किग्रा/वृक्ष) पाई गई। नींबु वर्ग के वृक्षों में नींबू की शाखा बेधक, *एनोप्लोफोरा वर्सटीगी* के नियंत्रण के लिए पासीघाट और रेन्जिंग क्षेत्रों में नींबू के वृक्षों के तने में सी ए यू 1 ई पी एन पृथककरण को 50 आई जे एस/मिली पानी और कडावर की तरह प्रयोग करने पर दोनो स्थानों पर क्रमशः 37.22 और 36.43 प्रतिशत बेधकों की कमी पाई गई। कारगिल में, सेब की फसल में कोडलिंग मौथ (*सायडिआ पोमोनेल्ला*) को नियंत्रित करने के लिए *ट्राइकोग्रामा एम्ब्रियोफेगम, ट्रा. केकोएसिए* और फेरोमोन प्रपंच का मिश्रित प्रयोग करने के प्रभाव उत्कृष्ट पाया और परिणामस्वरूप कोडलिंग मौथ द्वारा फल क्षति में अत्यधिक कमी (27.66%) पाई गई। सेब के जड़ बेधक, *डोरीस्टेथेनेस ह्यूजेली* को नियंत्रित करने के लिए *मे. एनीसोप्लिए* (10^6 कोनिडिआ/सेमी^{2}) का प्रयोग अतिप्रभावी पाया गया, जिसके उपचार करने पर जड़ बेधक के लारवों में 82.6% घातकता पाई गई और इसको क्लोरपायरीफॉस के समान प्रभावी पाया गया।

रोपण फसलों के हानिकारक कीटों का जैविक नियंत्रण

चाय मच्छर बग, *हेलोपेल्टिस थेईवोरा* की सँख्या को कम करने के लिए *ब्यूवेरिआ बेसीआना* आई आई एच आर विभेद (15.75/10 पौधे), पेस्टोनीम (16.25/10 पौधे) और *ब्यू. बेसीआना* के व्यवसायिक नियमन (17.25/10 पौधे) के प्रयोग में, कोई महत्वपूर्ण अन्तर दिखाई नहीं पड़ा। अप्रैल 2013 के दौरान त्रिवेन्द्रम में, नारियल की पत्तियों को *ओपिसिना एरेनोसेल्ला* द्वारा 74.4% क्षति पाई गई किन्तु लारवा परजीवी कीट, *गोनिओजस निफेन्टिडिस* और *ब्रेकान ब्रेविकोर्निस* को क्षेत्र में छोड़ने पर ग्रसन को नौमाह के अन्दर 16.7% तक कम किया गया। कसावा की फसल में, *एलीयूरोडिकस डिस्पर्सस* के प्रति बी आई पी एम मोड्यूल के मूल्यांकन में कीट सँख्या न्यूनतम (76.93 प्रति 5 पौधे) जबकि किसान द्वारा अपनाई गई प्रक्रिया में कीट सँख्या अधिक (226 प्रति 5 पौधे) तथा अनोपचारित क्षेत्रों में कीट सँख्या अधिकतम (320.96 प्रति 5 पौधे) पाई गई। बी आई पी एम अपनाए प्लॉट से उपज अत्यधिक (36.79 टन/हे.) जबकि अनोपचारित प्लॉट से उपज कम (21.60 टन/हे.) पाई गई। किसान द्वारा अपनाई गई प्रक्रिया की अपेक्षा बी आई पी एम मोड्यूल अपनाने पर कुल लाभ तथा लाभः लागत अनुपात (बी सी आर) अधिकतम अर्थात 1:3.34 जबकि किसान प्रक्रिया में यह अनुपात केवल 1:2.41 पाया गया। *ए. डिस्पर्सस* की सँख्या को कम करने के लिए *एनकार्सिआ गुओडेलोऊपे* परजीवी कीट को अत्यन्त प्रभावी पाया गया।

पोलीहाऊस फसलों के हानिकारक कीटों का जैविक नियंत्रण

जरबेरा उगाए गए क्षेत्र में प्रारम्भ दशा में भूमि में जड़ ग्रंथि सूत्रकृमियों की सँख्या का विस्तार 520-680 आई जे एस/200 सेमी^{3} पाया गया। *पेसीलोमायसस लिलेसीनस* को 20 किग्रा./हे. की दर से प्रयोग करना अति प्रभावी (64.3% कमी) पाया गया और गॉल इन्डेक्स (52%) में कमी पायी गयी। फायटोफेगस माईट के प्रति परभक्षी माईट, *नीओसेईयूलस लोन्गिस्पाईनोसस* को 1:10 की दर से परभक्षी माईटः भक्षित माईट अनुपात में छोड़ने के परिणामस्वरूप फायटोफेगस माईट में 91.2% कमी और इसको फेनाजेक्वीन (0.0025%) के समान प्रभावी

पाया गया जिसके प्रयोग से माईट में 92.1% कमी पाई गई। गुलाब में 30 परभक्षी माईट/पौधा की दर से चार बार छोडने के बाद यूरोपियन लाल माईट (*पेनोनायचुसूल्माई कॉच*) की सँख्या में अधिकतम कमी (69.6%) तथा उपज/प्लॉट अधिकतम (1173 कट फ्लावर्स) पाई जो कि आजदिरेक्टिन 3 मिली/ली उपचारित प्लॉट के समान ही पाई गई। भिण्डी में, *टेट्रास्टिकस उर्टिके* का प्रबन्धन करने के लिए *ब्लाष्टोस्टेथस पेलेसेन्स* को 30 निम्फ/मी लाईन के साथ रासायनिक नियंत्रण (ओमाईट 300 मिली/एकड) का प्रयोग प्रभावी पाया गया। *स्येल्जिस एपिअस* का पोषक पौधो पर अण्डनिक्षेपण के संबंध में *एनोना*, अमरूद और गुडहल के क्रम में पोषक पौधों को प्राथमिकता देते पाए गए।

धान के संग्रहण पीडको का जैविक दमन

जाईलोकोरिस फ्लेविपस को 30 निम्फ/प्रति किग्रा की दर से संग्रहित धान (12.75 मौथ/जार) में छोड़ने पर *कोरसेरा* मौथ निकलने की सँख्या को महत्वपूर्ण रूप से कम कर देता है। *जा. फ्लेविपस* के 30 निम्फ प्रति जार छोड़ने का उपचार करने पर निम्फों की सँख्या अधिकतम अभिलेखित की गई। एन्थोकोरिड बग को धान के बडे डिब्बों में छोड़ने पर *कोरसेरा सीफेलोनिका* लारवों को नियंत्रित करने के लिए प्रभावी पाया गया। मौथ कीट सँख्या को न्यूनतम बनाए रखने के लिए *ब्लाष्टोस्टेथस पेलेसेन्स* की अपेक्षा *जा. फ्लेविपस* के निम्फों में, उत्कृष्ट कार्य करने की क्षमता पाई गई।

INTRODUCTION

Brief History

Insects form a bulk (70 per cent) of living organisms and are widely distributed. A small percentage of them are harmful to agriculture while the large majority are directly or indirectly useful to agriculture and the environment. The National Bureau of Agriculturally Important Insects (NBAII) came into existence on 29th June, 2009 in recognition of the fact that insects and associated organisms of agricultural importance in our country had not been adequately documented in spite of their having been the focus of studies since British times. Further, registration of live germplasm of insect resources utilized in biocontrol, sericulture, apiculture, etc. was a necessity to avoid it being lost. It was also felt that barcoding the insect resources of the country was of paramount importance as insects are extremely important to the Indian economy and ecology. A series of changes in perception in the area of insect pest management resulted in the transformation of this institution from one initially involved in research on evolving biological control technologies to combat insect pests to one focused on studies in the areas of taxonomy and diversity of insects in agroecosystems in addition to biocontrol.

It was as early as in 1977 that the Indian Council of Agricultural Research (ICAR), New Delhi initiated the All India Coordinated Research Project (AICRP) on Biological Control of Crop Pests and Weeds with funds from the Department of Science and Technology, Government of India. By subsequently extending full financial support the ICAR brought the project under its research umbrella in 1979. With growing realization that biological control is the technology of the future the centre was upgraded to the Project Directorate of Biological Control on 19th October, 1993. The understanding that biological control had its underpinnings in competent taxonomy and an understanding of ecology in agroecosystems led to the reorientation of research in the institution and its rechristening as the NBAII.

Mandate

National Bureau of Agriculturally Important Insects
To act as a nodal agency for collection, characterization, documentation, conservation, exchange and utilization of agriculturally important insect resources (including mites and spiders) for sustainable agriculture
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

Notable achievements of the past

Basic Research and Strategic Support to Biological Control

- The image gallery of agriculturally important insects hosted on NBAII's website include 500 species of insects with over 3000 photographs. This along with another website 'Featured Insects' on insect bioagents was included in 'ID Source' hosted by the United States Department of Agriculture and Colorado State University.
- An interactive LucID Phoenix key to the genera of Indian Mymaridae was prepared with fact sheets, diagnostics and illustrations.
- 'Insects in Indian Agroecosystems' has been hosted on the NBAII website. URL: http://www.nbaii.res.in/insectpests/index.php (for pests of crops and other common insects in

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Indian agroecosystems, 850 species featured so far with over 3000 colour photographs).

- A website on Indian Coccinellidae with image galleries of common species and their natural enemies has been constructed and hosted.
- Aphids of Karnataka - Web photo album on Picasaweb (the largest of its kind with ~1300 digital photographs of aphids of Karnataka) has been hosted. URL: http://picasaweb. google. com/home
- Biocontrol introductions. http://www.nbaii.res.in/ Introductions/Insects/ index.htm (for ~185 species of introduced bioagents in India) has been hosted on the NBAII website.
- Thirty three genera of Telenominae, Teleasinae, Scelioninae, Sceliotrachelinae and Platygastrinae were collected and identified from the Andaman Islands.
- *Dvivarnus* a new platygastroid genus was erected in the subfamily Teleasinae and a new species *D. punctatus* was described.Three new species of Sceliotrachelinae, *Plutomerus veereshi*, *Fidiobia virakthamati* and *F.nagarajae* were described. This was the first record of *Fidiobia* from India.Twelve species of Microgastrinae (Braconidae) were described from India. Among these *Glyptapanteles hypermnestrae* and *Dolichogenidea kunhi* have agricultural importance.Two new species *Poropoea bella* (Trichogrammatidae) and *Zaplatycerus notialis* (Encyrtidae) were described. Four new species of fruit flies, *Euphranta dysoxli, E. diffusa, E. thandikudi and E. hyalipennis* were described from India.
- A catalogue of the fauna of Microgastrinae of Reunion Island was published with a key to 34 species belonging to 13 genera including many species of Indian origin.
- Molecular tools were used to resolve the identities of cryptic species of *Apanteles*, *viz*., *A. mohandasi* and *A. taragamae*.
- The aphids *Pleotrichophorus chrysanthemi* and *Reticulaphis foveolatae* and the invasive mealybug *Pseudococcus jackbeardsleyi* were recorded for the first time from India. Four species of fruit flies, *Coelotrypes latilimbatus, Dimerinogophrys parilis, D. pallidipennis, Hardyadrama excoecariae* and an undescribed species of *Coelopacidia* were recorded as new from India. *Lohiella longicornis* was recorded for the first time from India parasitizing *Drepanococcus chiton* which is a new host association.
- *Coccipolipus synonychae* (Acari:Podapolidae) was described as a parasite of the giant bamboo ladybird, *Synonycha grandis*.
- *Paracoccus marginatus*, the papaya mealybug was successfully kept under check wherever it resurfaced with releases of the parasitoid *Acerophagus papayae*. Several parasitoids (*Allotropa* sp., *Anagyrus* sp., *A. qadrii* and *A. loecki*) were found parasitizing the Madeira mealybug *Phenacoccus madeirensis* which occurred on cotton near Bandipur (Karnataka).
- A total of 82 culturable bacteria were isolated from *Aphis gossypi*, *A. crassivora* and *Myzus persicae* collected from Bangalore, Malur and Dharwad districts of Karnataka.Based on 16S rDNA sequence homology *Bacillus aryabhattai, B. cereus. B. jeotgali,B. massiliensis, B. sbtilis, Exiguobacterium indicum, Moraxella osloensis, Paenibacillus lautus,Pseudomonas hibiscicola, Stenotrophomonas maltophilia Zimmermanella faecalis* were found associated with aphids.
- A diet containing nutritional and phagostimulatory compounds was developed.

It enhanced biological parameters like developmental period and adult longevity in *Leucinodes orbonalis*.

- A database on entomopathogenic nematodes (Steinernematidae and Heterorhabditidae) was developed providing information on systematics, diagnostic characters, diversity maps, bioecology, mass production techniques, formulation and storage, application and source of availabilityof commercial products. It is user friendly and available in DVD format.
- Eleven anthocorid (Anthocoridae) predators of thrips were collected from different plants (including crops) during different seasons.An undescribed species of *Montandoniola* was recorded on *Butea monosperma*. *Orius maxidentex* was recorded for the first time from the Andaman islands.
- Eggs of *C. cephalonica* could be stored for five days at 14 degrees Celsius resulting in over 70 % hatching and 90 % adult emergence.
- The per cent parasitism and adult emergence of *Trichogramma embryophagum* reared on the eggs of the eri silk moth was enhanced resulting in 92.2 % parasitism and 70.7 % adult emergence.
- Fifteen species of non-*Apis* pollinators belonging to Megachilidae, Apidae, Xylocopidae and Anthophoridae were documented in pigeonpea plants in addition to butterflies and flies. *Apis dorsata, A.cerana* and *A.florea* constituted 40 % of the total bees observed during flowering. At 38 % Megachilidae constituted the second largest group.
- Though pigeonpea is a self pollinated crop, outcrossing was observed to the extent of 3 – 40 %. Ninety two per cent seed set was observed in bee visited pods.
- Pigeonpea intercropped with marigold was found to be effective in enhancing yield as compared to pigeonpea intercropped with sunflower. Intercrops were found to be better than pigeonpea as a sole crop.
- The incidence of *Maruca vitrata, Aphis gossypii* and *Orgyia leucostigma* did not significantly differ at various levels of carbon dioxide and temperature in open top carbon dioxide chambers with simulated levels of carbon dioxide and temperature.The incidence of *Coccidohystrix insolita* was however significantly greater on plants grown at elevated levels of carbon dioxide (500 ppm) and temperature (+2 deg Celsius).
- Two effective plant based compounds were formulated for attracting fruit flies and *Leptocybe invasa.*
- Novel nanogels with increased field life to disrupt the life cycles of crop pests were synthesized in collaboration with the Department of Organic Chemistry, IISc, Bangalore.
- A toxicant free oil-based parapheromone trap was developed in collaboration with IIHR, Bangalore.

Applied Research (Biological Control)

- The successful management of the papaya mealybug through releases of the exotic parasitoid *Acerophagus papayae* resulted in savings of Rs.714.55 crore during 2012 - 2013.The papaya mealybug continues to be suppressed effectively by the released parasitoids and the expected savings is in the same order.
- Combined application of *Heterorhabditis indica* and *Metarhizium anisopliae* reduced 75 and 67 % population of adults and grubs of *Myllocerus subfasciatus*.Around 82 and 80 % recovery of *H. indica* (NBAII hi01)and *S. abbasi* (Sa01) strains was made in red lateritic soils after five months of application.
- Field trials conducted at Varnanagar and Nagaon villages of W. Maharashtra showed

that application of aqueous and cadaver formulations of *H. indica* and *S. abbasi* improved the tiller density and cane height of sugarcane. These species performed better than *S.carpocapsae* and *S. glaseri*.

- *Blaptostethus pallescens* reduced populations of the nymphs and adults of *F. schultzei* by 74.0 and 89.3 % respectively, as compared to a reduction of 41.3 % in the control.
- *Encarsia flavoscutellum, Dipha aphidivora* and *Micromus igorotus* were found to continue suppressing the sugarcane woolly aphid in areas of its re-occurrence in Maharashtra and Tamil Nadu.
- *Verticillium lecanii* was better than *Metarhizium anisopliae* in lowering populations of the safflower aphid, *Uroleucon compositae* in Andhra Pradesh. However it was on par with neem oil and together they were on par with the insecticidal check. The yield was 469 – 509 kg/ha. in treated fields as compared to 245 kg/ha. in the control. The corresponding figures for the aphid populations were 65 – 123 aphids/10 plants and 413 – 435 aphids / 10 plants, respectively.
- Three sprays of *Sl*NPV @ 250 LE / ha. (1.5 x 10^{12} POBs / ha.) was significantly superior to botanicals in suppressing larval populations of *Spodoptera litura* (3 larvae /m row) recording 78.5 per cent mortality due to virus infection and a yield of 21.6 q / ha. soybean in Maharshtra.
- Systematic monitoring and release of the larval parasitoids *Goniozus nephantidis* and *Bracon brevicornis* against the coconut leaf caterpillar (*Opisina arenosella*) reduced leaf damage (42 per cent) and pest population (93 %) in a period of seven months in Kerala. It was also effective in Karnataka.
- Spraying *Metarhizium anisopliae* @ 1 x 10^9 spores / ml during the off season in December followed by four sprays of the pathogen mixed with adjuvant (sunflower oil 1 ml / L) at weekly intervals during flowering was superior to other treatments in suppressing the hopper population and in increasing fruit set in Andhra Pradesh and Maharashtra.
- Two releases of *Scymnus coccivora* @10 grubs / infested tree at monthly intervals from July–August effectively suppressed *Maconellicoccus hirsutus* (9.8 mealybugs / fruit) and *Ferrisia virgata* (3.3 mealybugs / fruit) in custard apple and increased yield of marketable fruits (34.1 kg / tree). *Cryptolaemus montrouzieri* @ 5 grubs / tree was found to be equally effective.
- *Blaptostethus pallescens* @10 nymphs /plant minimized populations of the mite *Tetranychus urticae* on brinjal and okra in Punjab. While *B. pallesecens* was found to be as effective as Omite in Okra it was less effective than Omite when used against the mite on brinjal.
- *Stethorus pauperculus* (Coccinellidae) and *Amblyseius* sp.@ 10 beetles and 5 mites / plant were effective in reducing populations of the two spotted spider mite *T. urticae* in carnations under protected conditions. The biocontrol agents were however not as effective as the acaricide Abamectin in suppressing the mite.
- Three releases of the predatory mite *Neoseiulus longispinosus* at 1:10 predator : prey ratio were found to be as effective as Profenophos in suppressing populations of *T. urticae*.

Organizational set-up

The NBAII is organized into three divisions, *viz.*, Division of Insect Systematics, Division of Molecular Entomology and Division of Insect Ecology. Research on microbial biocontrol is being addressed under the coordination cell of the AICRP on Biological Control (Fig.1).

Financial Statement 2013-14
National Bureau of Agriculturally Important Insects, Bangalore

(₹ in lakhs)

Head	Plan	Non-Plan	Total
Pay & Allowances	0.00	583.08	**583.08**
T.A.	10.50	3.37	**13.87**
Other Charges including equi. Lab.	127.08	134.33	**261.41**
Information Technology	0.00	0.00	0.00
Works/ petty works	0.00	19.90	**19.90**
HRD	2.42	0.00	**2.42**
Pension	0.00	56.00	**56.00**
Loan	0.00	0.99	**0.99**
TOTAL	**140.00**	**797.67**	**937.67**

AICRP Centres (ICAR share only)
Expenditure (2013-14)

Name of the centre	Expenditure (₹ in lakhs)
AAU, Anand	44.63
AAU, Jorhat	25.82
ANGRAU, Hyderabad	30.66
Dr. YSPUH&F, Nauni, Solan	36.18
GBPUA&T, Pantnagar	9.04
KAU, Thrissur	26.32
MPKV, Pune	29.57
PAU, Ludhiana	53.24
SKUAS&T, Srinagar	21.80
TNAU, Coimbatore	30.56
PC Cell, Bangalore	7.00
MPUAT, Udaipur	1.30
OUAT, Bhubaneshwar	1.87
CAU, Manipur	2.01
Total	**320.00**

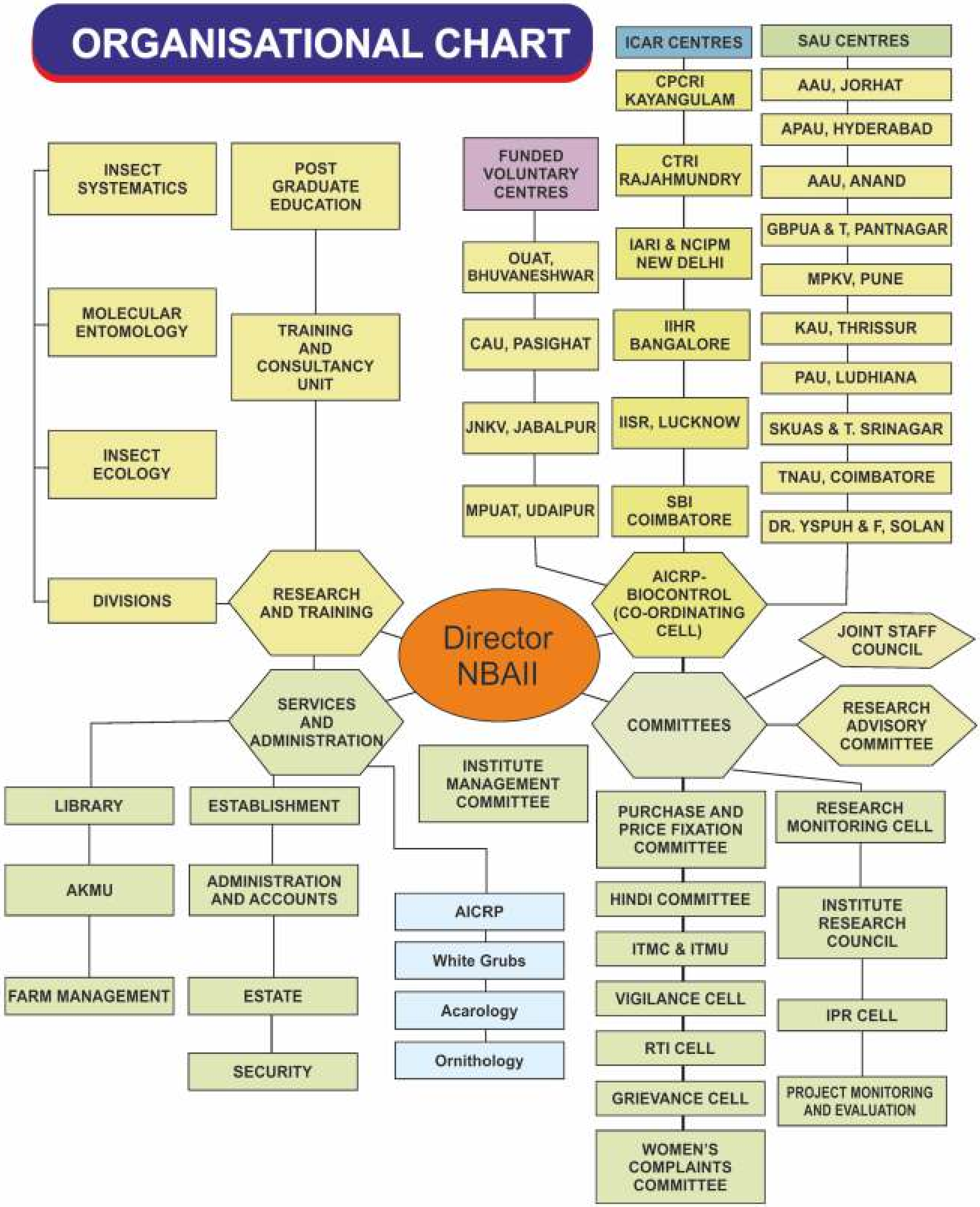


Fig 1. Organisational Chart of NBAII

RESEARCH ACHIEVEMENTS

National Bureau of Agriculturally Important Insects

Division of Insect Systematics

Surveys

Exploratory surveys for insects were undertaken in the states of Assam, Meghalaya (Umiam and Umran), Tripura, Odisha (Bhubhaneshwar, Jaraka and Cuttack), Maharashtra (Powai, Satara), Uttar Pradesh and Karnataka. In Karnataka collections were extensively made from a number of districts, *viz.*, Ramanagara (Magadi), Mandya, Bengaluru (Kengeri, Hebbal, Hessaraghatta, Attur, Devanahalli), Shimoga,Chikkamagalur, and Chikkaballapur (Nandi Hills, Chintamani). Field, vegetable and fruit crops in addition to forests and other natural vegetations were surveyed.

Digitization of type specimens in NBAII reference collection

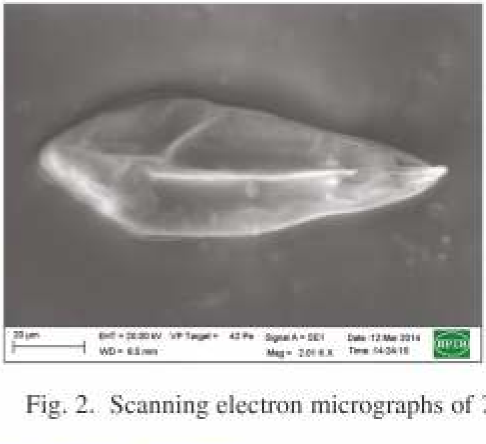
List of type specimens in NBAII holdings was compiled with complete details. Totally 106 types belonging to Hymenoptera, Coleoptera, Thysanoptera, and Diptera were documented, including 50 primary types. Digitization was done for 15 primary types of Coleoptera (Coccinellidae), Braconidae (Microgastrinae) and Platygastridae. Webpages were created for type specimens in NBAII's holdings with details of original combination, current valid name, sex / stage, type status, verbatim label data, original publication and high resolution images of the type specimen featuring the diagnostic characters.

Biosystematics of Trichogrammatidae (Hymenoptera)

Ten genera of Trichogrammatidae were collected in addition to *Trichogramma* and *Trichogrammatoidea*. Of these, *Lathromeroidea* is a new record for south India while *Paratrichogramma* is a new record for Karnataka. *Trichogrammatoidea nana* collected from Meghalaya is the first record of the genus from Northeast India. *Trichogramma cuttackensis* was collected from Bhubaneshwar which though contiguous is the only place from where it is known from outside its type locality. This species does not multiply on the eggs of *Corcyra cephalonica* but can be reared on the eggs of Sphingidae. This is also the first species of Indian *Trichogramma* for which we detected pseudogenes.

Megaphragma, a genus comprising some of the smallest insects, known earlier from Karnataka and Uttar Pradesh were collected for the first time from Orissa and Meghalaya.

A species closely resembling *Trichogramma*



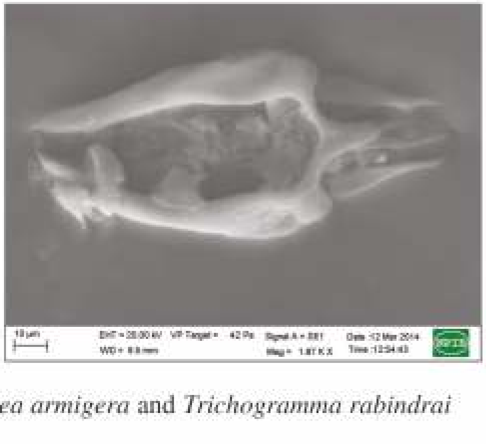


Fig. 2. Scanning electron micrographs of *Trichogrammatoidea armigera* and *Trichogramma rabindrai*

Table 1. List of genera of Platygastroidea with new/old distribution records

Genera		New/old distribution record
TELENOMINAE		
1	*Phanuromyia*	New record for India
TELEASINAE		
2	*Trimorus (Neotrimorus)*	New record for Andamans
SCELIOTRACHELINAE		
3	*Amitus*	Hitherto recorded only from Bihar, also recorded from south India and Sikkim
SCELIONINAE		
4	*Nixonia*	Hitherto recorded from Uttaranchal. New record for South India
PLATYGASTRINAE		
5	*Iphitrachelus*	Recorded from Andamans and Karnataka

bistrae, a single specimen of which had been collected from Bhubaneshwar was collected from Hessaraghatta. This is a Palaearctic species being recorded for the first time from anywhere in the tropics or the Oriental region. Scanning electron microscopic studies of the genitalia of *Trichogramma rabindrai* and *Trichogrammatoidea armigera* have been completed confirming their status as distinct species (Fig. 2).

Biodiversity of oophagous parasitoids with special reference to Scelionidae (Hymenoptera)

A total of 1500 parasitoids were collected, curated and preserved for future studies. So far 52 genera under five subfamilies were recorded from India. An additional five genera are now being added (Table 1) raising the total to 57 genera.

So far only three genera, *viz*., *Telenomus*, *Baryconus* and *Platyscelio* were reported from the state of Odisha. Recent surveys conducted in Bhubhaneshwar and Cuttack revealed the presence of thirty two additional genera. The thirty five genera recorded under five subfamilies from Odisha are *Baeus, Ceratobaeus, Cremastobaeus, Dicroscelio, Doddiella, Duta, Dyscirtobaeus, Encyrtoscelio, Fusicornia, Gryon, Idris, Macroteleia, Opisthocantha, Palpoteleia, Paridris, Probaryconus, Psilanteris, Scelio, Tiphodytes* (Scelioninae); *Trimorus, Xenomerus* (Teleasinae), *Paratelenomus, Psix, Trissolcus, Phanuromyia, Eumicrosoma* (Telenominae); *Platygaster, Synopeas, Leptacis, Amblyaspis* (Platygastrinae); *Isolia, Fidiobia* (Sceliotrachelinae).

Nine new species of Platygastroidea were described as new to science. *Mantibaria kerouaci* Veenakumari and Rajmohana (Fig. 3) an egg parasitoid of mantids was described. There are only three species of *Mantibaria* in the entire world. This is the first species to be described from the Oriental region.

Fig. 3. Sexual dimorphism in *Mantibaria kerouaci* (Left: Male; Right: Female)

Fig. 4. *Allotropa gundlupetensis*: Parasitoid of the Madeira mealybug (*Phenacoccus madeirensis*)

Fig. 5. *Allotropa vanajae* (Left: Female; Right: Male)

Fig. 6. *Sceliocerdo viatrix* an egg parasitoid of *Neorthacris acuticeps* on rice

Three new species of *Allotropa* (Platygastridae: Sceliotrachelinae) were described. The genus *Allotropa* are parasitoids of mealybugs. A new species, *Allotropa gundlupetensis* Veenakumari and Buhl (Fig. 4) collected from the Madeira mealybug, *Phenacoccus madeirensis*, was described. Two more species of *Allotropa*, *viz., A. vanajae* and *A. nigra* were also described (Fig. 5).

The genus *Amblyaspis* (Platygastridae: Platygastrinae) are parasitoids of Cecidomyiidae (Diptera). Five new species of *Amblyaspis viz.*, *A. fabrei, A. panhalensis, A. charvakae, A. ashmeadi* and *A. tippusultani* were described.

Sceliocerdo viatrix (Platygastridae: Platygastrinae) which are phoretic on *Neorthacris* species (Orthoptera:Pyrgomorphidae) of grasshoppers was collected from Karnataka and redescribed as the original description was inadequate (Fig. 6).

Biodiversity of aphids, coccids and their natural enemies (Hemiptera)

A total of 109 field surveys were conducted in and around Bangalore and 2541 insect specimens were collected. A total of 1630 specimens of aphids, coccids, diaspidiids, and pseudococcids were identified. Nine species of mealybugs and twenty species of aphids were identified and DNA barcodes generated. Similarly four predators and nine parasitoids were identified and characterized. *Metaceronema japonica* (Maskell), *Stictacanthus azadirachtae* (Green), *Shivaphis celti* Das and *Odonaspis greenii* Cockerell were recorded for the first time from Karnataka. *Planococcus bendovi* Williams, *Ctenochiton olivaceum* Green, *Macrosiphum euphorbiae* (Thomas) and *Milviscutulus mangiferae* (Green), were recorded for the first time from South India. *Marsipococcus iceryoides* (Green), *Ceronema fryeri* Green, *Maacoccus piperis* (Green), *Trijuba oculata* De

Table 2. New records of aphids and coccids from India

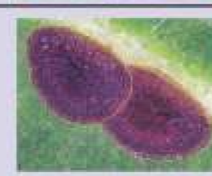
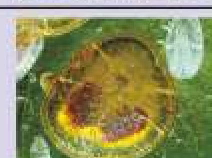
Aphid/coccid species	Family	Host plant	Figure
Astegopteryx pallida van der Goot	Aphididae	*Bambusa* sp.	
Marsipococcus iceryoides (Green)	Coccidae	*Annona reticulata*	
Ceronema fryeri Green	Coccidae	*Annona reticulata*	
Maacoccus piperis (Green)	Coccidae	*Piper nigrum*	
Trijuba oculata De Lotto	Coccidae	*Annona reticulata*	
Protopulvinaria longivalvata Green	Coccidae	*Eugenia* sp.	
Paralecanium ovatum Morrison	Coccidae	*Eugenia* sp.	
Paralecanium vacuum Morrison	Coccidae	*Annona reticulata*	
Paralecanium mancum (Green)	Coccidae	*Polyalthia longifolia*	

Table 2. (Contd...) New records of aphids and coccids from India

Aphid/coccid species	Family	Host plant	Figure
Eriococcus coccineus Cockerell	Coccidae	*Eugenia* sp.	
Duplaspidiotus claviger (Cockerell)	Diaspididae	Indet. tree	
Exallomochlus philippinensis Williams	Pseudococcidae	*Nephelium lappaceum*	

Lotto, *Protopulvinaria longivalvata* Green, *Paralecanium ovatum* Morrison, *Paralecanium vacuum* Morrison, *Paralecanium mancum* (Green), *Eriococcus coccineus* Cockerell, *Duplaspidiotus claviger* (Cockerell), *Exallomochlus philippinensis* Williams and *Astegopteryx pallida* van der Goot were recorded for the first time from India (Table 2). Twenty nine

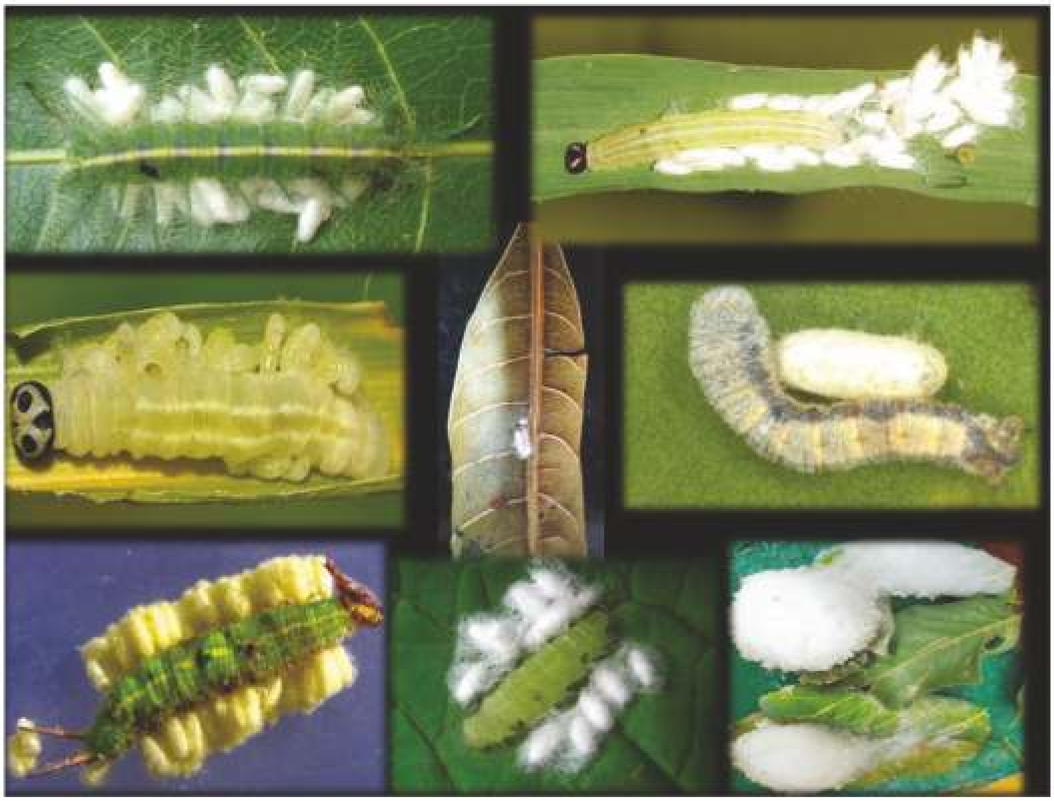


Fig. 7. Parasitized lepidopteran larvae collected from the field

species of parasitoids were recorded from 43 species of coccids of which one parasitoid was a new record from India; eight were new records from Karnataka and four were new host associations.

Biodiversity of economically important Indian Microgastrinae (Hymenoptera: Braconidae)

About 6000 specimens of parasitized insects were collected, bred, curated and preserved. 2863 specimens were identified to the genus / species level. Over 50 species were reared from about 40 hosts belonging to 9 families. In addition more than 50 masses of cocoons were collected (Fig.7).

Parasitoids were reared from the following lepidopteran families: Hesperiidae, Lycaenidae, Papilionidae, Arctiidae, Lymantriidae, Plutellidae, Noctuidae, Nolidae and Nymphalidae.

Five species of parasitic wasps associated with hesperiids from peninsular India have been documented along with the description of a new species of gregarious endoparasitoid, *Dolichogenidea cinnarae* Gupta *et al*. 2013 (Hymenoptera: Braconidae) parasitic on larvae of *Borbo cinnara* (Wallace) (Lepidoptera: Hesperiidae) (Fig. 8).

Fig. 8. *Dolichogenidea cinnarae* Gupta *et al*.

The gregarious larval parasitoid, *Cotesia erionotae* (Wilkinson) (Braconidae) and the solitary pupal parasitoid *Charops plautus* Gupta & Maheshwary (Ichneumonidae) were bred from the *Udaspes folus* (Cramer) on the host plant *Hedychium coronarium* J. Koenig. *Udaspes folus* is a new host record for the parasitic wasp genus *Charops*. *Cotesia erionotae* was bred from *U. folus* caterpillars from three states: Maharashtra, Karnataka and Kerala. An encyrtid wasp *Ooencyrtus papilionis* Ashmead was bred from eggs of *Bibasis jaina* (Moore) on the host pant *Hiptage benghalensis* (L.). This is the first documentation of a parasitic wasp from the genus *Bibasis*. *Leptobatopsis indica* (Cameron) (Ichneumonidae), often associated with *Parnara guttatus* (Bremer & Grey), was recorded from the Andaman islands.

A new species of gregarious endoparasitoid, *Parapanteles echeriae* Gupta, Pereira & Churi, 2013 bred from *Abisara echerius* Stoll (Lepidoptera: Riodinidae) on the host plant *Embelia* sp. (Myrsinaceae) is described and illustrated from Mumbai, Maharashtra, India (Fig. 9). This is the first ever record of a parasitic wasp associated with *Abisara*.

Fig. 9. *Parapanteles echeriae* Gupta *et al*.

A key to Indian species of *Parapanteles* was published.

As detailed below two new species of *Glyptapanteles* and one species of *Buluka* (Braconidae: Microgastrinae) were discovered from S. India.

Glyptapanteles clanisae Gupta 2013 (Fig. 10), a gregarious endoparasitoid, was bred from a caterpillar of *Clanis phalaris* Cramer (Lepidoptera: Sphingidae) on the host plant *Pongamia pinnata* (L.) (Leguminosae) along with a hyperparasitoid, *Eurytoma* sp. (Eurytomidae).

Fig. 10. ***Glyptapanteles clanisae*** **Gupta**

Glyptapanteles trilochae Gupta 2013, was reared from parasitized caterpillars of *Trilocha varians* (Walker) (Lepidoptera: Bombycidae) on the host plant *Ficus racemosa* L. (Moraceae) along with a hyperparasitoid, *Paraphylax* sp. (Ichneumonidae: Cryptinae). This also confirms a host range extension of Indian species of *Glyptapanteles* to Bombycidae and Sphingidae in addition to the earlier documented families (Papilionidae, Nymphalidae, Arctiidae and Noctuidae) (Fig. 11).

Fig. 11. ***Glyptapanteles trilochae*** **Gupta**

Buluka horni Gupta 2013, was collected from solitary cocoons of an indeterminate caterpillar feeding on *Mangifera indica* L. leaves (Fig. 12).

Fig. 12. ***Buluka horni*** **Gupta**

A diagnostic guide to 29 genera and 26 species of Pteromalidae was hosted on the NBAII website as 'Indian Fauna of Pteromalidae' (Fig. 15).

Collection and identification of longhorn beetles (Cerambycide: Coleoptera) of agricultural importance

Cerambycidae is one of the largest families of Coleoptera and contains more than 35,000 species under 4,000 genera in 11 subfamilies. The number of cerambycid species recorded from India is about 1500. A key to the subfamilies of Cerambycid adults has been developed with the help of published literature. A total of 31 beetle specimens were collected and curated. Five specimens were identified as *Acanthophorus serraticornis, Batocera rufomaculata, Chelidonium cinctum, Stromatium barbatum* and *Xylotrechus quadripes* (Fig. 13).

Fig. 13. ***Xylotrechus quadripes***

CHAPTER 4

Network Project on Insect Biosystematics

Field collection surveys were undertaken in Karnataka, Kerala, Andhra Pradesh, Tamil Nadu, Meghalaya, Assam, and Odisha and 120 man-days spent for insect collection. Curated and identified specimens belonging to ca. 450 species in 11 orders were added to the reference collections.

Anagyrus amnestos Rameshkumar *et al.* (Encyrtidae), a potential parasitoid of the invasive Madeira mealybug, was described from Karnataka with US collaboration (Fig. 14).

Fig. 14. *Anagyrus amnestos*, a parasitoid of the Madeira mealybug

A new species of *Calvia* (Coccinellidae) and a new genus of Miridae (Hemiptera) were documented from India. Four new species of *Dicopomorpha* Ogloblin (Mymaridae) from India were described and the Indian species keyed. *Platynaspis flavoguttatus* (Gorham) (Coccinellidae), a rare species, was redescribed and the male genitalia illustrated for the first time. Sixty-eight new distribution and host records of Indian Chalcidoidea were documented. The electronic database of NBAII's reference collection was updated with taxon/specimen-based data for groups identified up to January 2014.

The Pteromalidae (Hymenoptera:Chalcidoidea) of the North – east and the Eucharatidae (Hymenoptera:Chalcidoidea) were studied. A web portal with 38 species identification fact sheets was developed (Fig. 15).

Factsheets for 323 species of insect pests (with 1060 images) and 105 species of bioagents (with 308 images) were uploaded on NBAII's website and existing fact sheets updated with 850 new images. The web-based identification aid for Indian Genera of Mymaridae with illustrated factsheets was hosted on NBAII's website and also featured in IOBC's newsletter. Web content with an illustrated dichotomous key and factsheets was prepared for Indian genera of Diapriinae in collaboration with Dr. K. Rajmohana, ZSI, Calicut. "Aphids of Karnataka" was redone in .php format for 71 species and hosted from NBAII's website.

Biosystematics and diversity of entomogenous nematodes in India

A total of 172 soil samples were collected from Jammu and Kashmir, Tripura and Karnataka. A positive sample was intercepted with EPNs, most likely belonging to *Steinernema* sp. when analyzed by soil baiting technique using wax moth, *Galleria mellonella.*

Division of Molecular Entomology

Molecular Characterization and DNA barcoding of Agriculturally Important Parasitoids and Predators

Survey and collection

Surveys were conducted in TamilNadu, Karnataka and Punjab and several parasitoids and predators were collected for molecular studies.

Molecular characterization using cytochrome oxidase 1 gene (CO1)

Parasitoids

Sequence analysis of cytochrome oxidase 1 gene (CO1) was done and GenBank accession

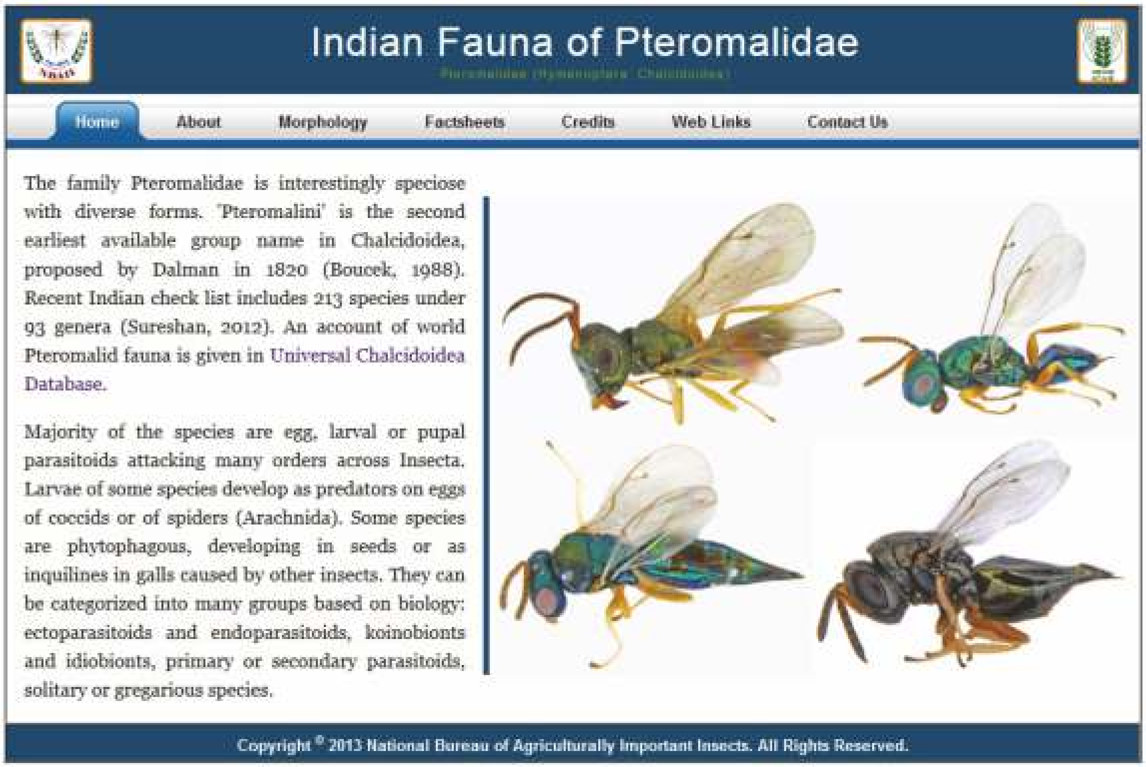


Fig. 15. Screen shot of the web portal 'Indian Fauna of Pteromalidae'

numbers were obtained for 12 parasitoids (Table 3).

Anthocorid predators

Characterization of cytochrome oxidase 1 gene (CO1) was completed and GenBank accession numbers were obtained for 5 species of anthocorid predators (Table 4).

Coccinellid predators

Analysis of cytochrome oxidase 1 gene (CO1) was completed and GenBank accession numbers were obtained for 3 coccinellid predators (Table 4).

Pollinators

Sequence analysis for cytochrome oxidase 1 gene (CO1) was done and GenBank accession numbers were obtained for 4 pollinators (Table 3).

Weed killer

Characterization of cytochrome oxidase 1 gene (CO1) was also done for the weed killer *Teleonemia scrupulosa* (KF 817579) (Table 4).

Molecular characterization and DNA barcoding of some agriculturally important insect pests

During the period more than 500 species of insects belonging to different groups were collected from different parts of the country as indicated in Fig. 16. Specimens were kept in -70°C as well as in 95% alcohol.

Fig . 16. States from where insects were collected

CHAPTER 4

Table 3. Molecular characterization of important parasitoids and pollinators

Order	Family	Scientific Name	Gen Bank Acc. No.	COI
Parasitoids				
Hymenoptera	Eulophidae	*Aprostocetus gala*	KF 817576	612 bp
Hymenoptera	Eulophidae	*Tetrastichus schoenobii*	KJ 627790	588 bp
Hymenoptera	Braconidae	*Chelonus blackburnii*	KF 365461	616 bp
Hymenoptera	Braconidae	*Bracon hebetor*	KJ 627789	651bp
Hymenoptera	Platygastridae	*Isolia indica*	KJ 489423	624 bp
Hymenoptera	Eulopidae	*Quadrastichus mendeli*	KF 879806	507 bp (ITS-2)
Hymenoptera	Eulophidae	*Aprostocetus gala*	KF958278	461 bp (ITS-2)
Hymenoptera	Scelionidae	*Sceliocerdo viatrix*	KF 938928	588 bp
Hymenoptera	Torymidae	*Megastigmus* sp. (seed feeders)	KF 938926	654 bp
Hymenoptera	Aphelinidae	*Coccophagus* sp.	KF 938924	654 bp
Hymenoptera	Encyrtidae	*Pseudleptomastix mexicana*	KF 365460	611 bp
Hymenoptera	Encyrtidae	*Leptomastix nigrocincta*	KJ 489424	597 bp
Pollinators				
Hymenoptera	Apidae	*Apis florea*	KF 817578	591 bp
Hymenoptera	Apidae	*Apis cerana indica*	KF 861941	563 bp
Hymenoptera	Apidae	*Megachile anthracina*	KF 861940	633 bp
Hymenoptera	Apidae	*Apis dorsata*	KJ 513470	621 bp

Characterization of some agriculturally important insect pests including veterinary pests using multi-locus genes

A total of 149 species, belonging to 9 orders, *viz*., Hemiptera, Diptera, Lepidoptera, Coleoptera, Hymenoptera, Mantodea, Isoptera and Araneae, Ixodida, were characterized (Table 5). All sequences agreed with Folmer's region, >550 bp with complete species information for 46 species for which Barcodes were generated. The percentage wise characterization of 162 species was Hemiptera (29.6%), Lepidoptera (22.2%), Diptera (16.7%), Coleoptera (12.3%), Hymenoptera (11.7%), Araneae (2.5%), Ixodida (1.9%), Mantodea (1.9%) and Isoptera (1.2%). Table 6 gives information about number of GenBank accession numbers and barcodes developed during the year.

DNA barcode for insects based on COX1 region

A total of 26 barcodes were obtained with barcode IDs provided (refer E publications). Distribution of inter-specific pair-wise Kimura's two parameter (K2P) distances resulting from the analysis of 45 DNA barcodes is depicted in Fig . At 95% percentiles, distribution was <2.2% from known sequences.

Table 4. Molecular characterization of important predators and a weed killer

Order	Family	Scientific Name	Gen Bank Acc. No.	COI/ ITS
Parasitoids				
Hemiptera	Anthocoridae	*Amphiareus constrictus*	KF 817577	608 bp
Hemiptera	Anthocoridae	*Xylocoris flavipes*	KF 365462	621 bp
Hemiptera	Anthocoridae	*Blaptostethus pallescens*	KF 365463	644 bp
Hemiptera	Anthocoridae	*Buchananiella indica*	KF 383326	636 bp
Coleoptera	Coccinellidae	*Scymnus nubilus*	KF 861939	603 bp
Coleoptera	Coccinellidae	*Cheilomenes sexmaculata*	KF998579	645 bp
Coleoptera	Coccinellidae	*Chilocorus* sp	KF 938927	639bp
Diptera	Drosophilidae	*Cacoxenus* sp.	KF 938925	653 bp
Weed Killer				
Hemiptera	Tingidae	*Teleonemia scrupulosa*	KF 817579	537 bp

Table 5. Insects subjected to molecular characterization

Order	Family	Species
Hemiptera	Pentatomidae	*Acrosternum grawinea*
		Bagrada hilaris
		Carbula scutellata
		Catacanthus incarnates
		Dalpnda sp.
		Eysaruris sp.
		Glaucias sp.
		Gonopsis rubescens
		Halyomorpha picus
		Menida versicolor
		Nezara viridula (2)
		Olene mendosa
		Orgyia postica
		Plautia crossota
		Sciocoris indica
	Aleyrodidae	*Aleurolobus barodensis*
	Miridae	*Helopeltis antonii*

Table 5. (*Contd..*) List of insects subjected to molecular characterization

Order	Family	Species
	Psyllidae	*Heteropsylla cubana*
	Scutelleridae	*Chrysocoris stolli*
		Scutellera perplexa
	Cicadellidae	*Dalbulus* sp.
		Hishimonus phycitis
		Orosius albicinctus
	Coccidae	*Coccus viridis*
	Pseudococcidae	*Coccidohystrix insolita*
		Ferrisia virgata
		Maconellicoccus hirsutus
		Phenacoccus madeirensis
		Phenacoccus solani
		Phenacoccus solenopsis
	Eurybrachidae	*Eurybrachys* sp.
	Monophlebidae	*Icerya purchasi*
	Lygaeidae	*Oxycarenus hyalinipennis*
	Lophophidae	*Pyrilla perpusilla*
Diptera	Tephritidae	*Bactrocera cucurbitae*
		Dioxyna sororcula
		Sphaeniscus quadrincisus
	Muscidae	*Musca* sp. (3)
	Simuliidae	*Simulium* sp. (2)
	Psychodidae	*Phlebotomus* sp. (4)
	Culicidae	*Aedes* sp.
	Ceratopogonidae	*Culicoides actoni*
		C. peregrenus
		C. schultzei
	Tabanidae	*Chrysops* sp.
Coleoptera		*Tabanus* sp.
	Cerambycidae	*Olenecamptus bilobus*
		Pseudaristobia octofasciculata
		Xylotrechus quadripes

	Curculionoidea	*Cosmopolites sordidus*
		Myllocerus dorsatus
		Myllocerus undecimpustulatus
		Myllocerus viridanus
		Sitophilus oryzae
	Chrysomelidae	*Callosobruchus chinensis*
	Tenebrionidae	*Tribolium castaneum*
	Scarabaeoidea	*Clinteria klugi*
		Heterorrhina elegans
		Oxycetonia versicolor
		Protaetia alboguttata
	Coccinellidae	*Epilachna vigintioctomaculata*
	Silvanidae	*Oryzaephilus surinamensis*
	Meloidae	*Mylabris pustulata*
	Tenebrionidae	*Luprops tristis*
Lepidoptera	Crambidae	*Chilo tumidicostalis*
		Maruca vitrata (2)
		Nymphula depunctalis
		Parotis vertumnalis
		Sylepta derogata
	Saturniidae	*Samia cynthia*
	Arctiidae	*Ceryx imaon*
	Lymantriidae	*Olene mendosa*
	Noctuidae	*Autoba olivacea*
		Polytela gloriosae
	Nolidae	*Earias vittella*
	Bombycidae	*Ocinara varians*
	Nymphalidae	*Phalanta phalantha*
	Papilionidae	*Papilio demoleus*
	Pyralidae	*Dioryctria rubella*
		Ectomyelosis ceratoniae
		Orthaga exvinacea
		Thylacoptila paurosema
	Hesperiidae	*Gangara thyrsis*
		Cyrtophora unicolor

Hymenoptera	Formicidae	*Crematogaster* sp.
		Tetraponera sp.
Mantodea	Hymenopodidae	*Ephestiasula* sp.
		Hestiasula sp.
		Elmantis sp.
Isoptera	Termitidae	*Odontotermes obesus*
		O. redemanni
Araneae	Araneidae	*Cyrtophora cicastrosa*
		C. citricola
		C. moluccensis
Ixodida	Ixodidae	*Rhipicephalus microplus*
		Rhipicephalus sp.
		Hyalomma anatolicum

Table 6. Insects for which GenBank accession numbers and Barcode IDs were obtained

Order	Family	Insect	GenBank	Barcode ID Accession
Hemiptera	Aleyrodidae	*Bemisia tabaci*	JX417980	*To be obtained*
	Aphididae	*Myzus persicae*	JX417981	*To be obtained*
	Delphacidae	*Nilaparvata lugens*	KC858992	AGIMP006-13
	Cicadellidae	*Amrasca biguttula*	KF840682	*To be obtained*
	Pyrrhocoridae	*Odontopus varicornis*	KF289771	*To be obtained*
Diptera	Tephritidae	*Acroceratitis histrionica*	KF471502	*To be obtained*
		Bactrocera correcta	KF289766	AGIMP022-13
		B. dorsalis	KF289767	AGIMP023-13
		B. zonata	KF289768	AGIMP024-13
	Agromyzidae	*Phytomyza orobanchia*	KC732453	AGIMP017-13
	Ceratopogonidae	*Culicoides innoxius*	*KF145176*	VETIP001-13
		C. huffi	*KF145177*	VETIP002-13
		C. anopheles	*KF145178*	VETIP003-13
		C. palpifer	*KF145179*	VETIP004-13
		C. circumscriptus	*KF145180*	VETIP005-13
	Calliphoridae	*Chrysomya megacephala*	*JX430024*	*To be obtained*
		Chrysomya sp.	*JX045647*	*To be obtained*

	Sarcophagidae	*Sarcophaga dux (PB-1)*	*JX430022*	*To be obtained*
		S. dux (ND-1)	*JX430021*	*To be obtained*
		Sarcophaga sp.	*JX045646*	*To be obtained*
Lepidoptera	Crambidae	*Leucinodes orbonalis* Shimoga	KF453225	*To be obtained*
		L. orbonalis Bangalore	KF453226	*To be obtained*
		L. orbonalis Chitradurga	KF453227	*To be obtained*
		L. orbonalis Neil island	KF453228	*To be obtained*
		L. orbonalis Cuttack	KF453229	*To be obtained*
		L. orbonalis Guntur	KF453230	*To be obtained*
		L. orbonalis Khammam	KF453231	*To be obtained*
		L. orbonalis Port Blair	KF453232	*To be obtained*
		L. orbonalis Kolhapur	KF453233	*To be obtained*
	Pyralidae	*Chilo auricilius*	KC306949	AGIMP003-12
		C. partellus	KC911712	AGIMP007-13
		C. sacchariphagus indicus	KC306951	AGIMP005-12
		Conogethes punctiferalis	KF114864	AGIMP012-13
		C. punctiferalis	KF114865	AGIMP013-13
		C. punctiferalis	KF114866	AGIMP014-13
		C. punctiferalis	KF114867	AGIMP015-13
		C. punctiferalis	KF114868	AGIMP016-13
		Galleria mellonella	KF289770	AGIMP026-13
		Polyocha depressella	KC306950	AGIMP004-12
		Scirpophaga excerptalis	KC306948	AGIMP002-12
		Corcyra cephalonica	KF289769	AGIMP025-13
		Helicoverpa armigera	KC911713	AGIMP008-13
	Plutellidae	*Plutella xylostella*	KC911716	AGIMP011-13
	Galleriidae	*Sesamia inferens*	KC911715	AGIMP010-13
	Noctuidae	*Spodoptera litura*	KC911714	AGIMP009-13
	Bombycidae	*Bombyx mori* PM	JX025640	BMSW002-12
		B. mori ND7	JX025639	*To be obtained*
		B. mori L14	JX025638	*To be obtained*

Coleoptera	Scolytidae	*Euwallacea fornicatus*	KC590061	AGIMP027-13
	Anobiidae	*Stegobium paniceum*	KF471501	*To be obtained*
Hymenoptera	Formicidae	*Anoplolepis gracilipes*	JN987860	ANIND016-11
		Aphaenogaster beccarii	JN886031	ANIND005-11
		Camponotus compressus	JN886027	ANIND001-11
		C. compressus GR-17	JN987857	ANIND013-11
		C. irritance	JN886033	ANIND007-11
		C. pariu	JN886032	ANIND006-11
		Leptogenys chinensis	JN886030	ANIND004-11
		Monomorium scabriceps	JN987858	ANIND014-11
		Myrmicaria brunnea	JN886029	ANIND003-11
		Oecophylla smaragdina	JN886035	ANIND009-11
		Paratrechina longicornis	JN886034	ANIND008-11
		Pheidologeton diversus	JN987859	ANIND015-11
		Plagiolepis sp.	JN886037	ANIND011-11
		Solenopsis geminata	JN886028	ANIND002-11
		Tapinoma melanocephalum	JN886036	ANIND010-11
		Technomyrmex albipes	JN886038	ANIND012-11

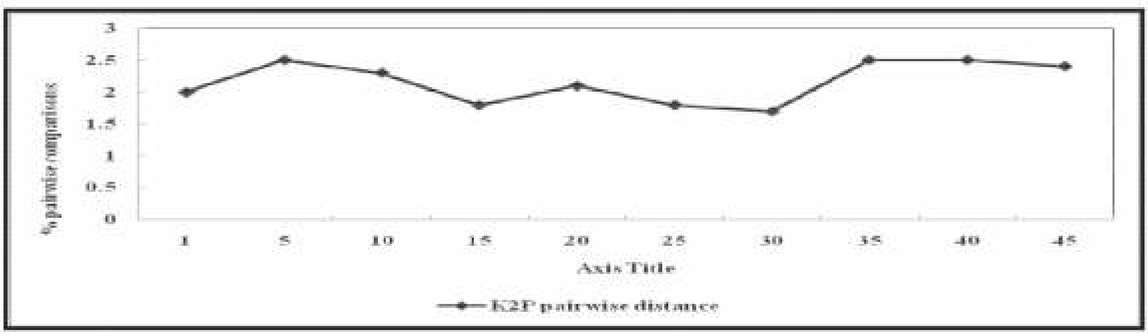


Fig. 17. Development of computational tool for prediction of insecticide resistance gene in agriculturally important insects

Table 7. Collection and isolation of *Bacillus thuringiensis*

Place	Number of samples	Number of *Bt* purified	Cry genes identified
Andamans, North East, Western Coast	352	148	Lepidoptera - *cry*1Aa, *cry*Ab, *cry*1Ac, *cry*2a, *cry*1I, vip3A (67 isolates) Coleoptera - *cry*3a, *cry*8 (7 isolates) Diptera - *cry*11, *cry* 2a, *cry*10, *cry*16, *cry*44Ba, *cry*4a (34 isolates)

Insecticide Resistance Gene Database

Agriculturally important insects like *Helicoverpa armigera*, *Aphis gossypii, Bemisia tabaci Acyrthosiphon pisum* and others developed resistance to the major groups of chemical pesticides like organo phosphorus, synthetic pyrethroids, organo chlorinates and other new groups of pesticides. Database on this aspect is necessary to know about insecticide resistant genes like Cytochrome P450, Acetylcholinesterase and Knock down resistant gene (Fig. 17). Insecticide resistant gene database (IRG) has been developed in My-SQL as back end and PHP as front-end tool to access the database. Presently, IRG contains 266 records and the home page of the database is given in Fig. 18.

Fig. 18. Home page of insecticide resistance gene database

Mapping of the cry gene diversity in hot and humid regions of India

A total of 148 *Bacillus thuringiensis* isolates were purified from soil and insect cadaver samples. Crystal morphology determined and cry gene diversity was determined for 108 isolates. The lepidopteran specific isolates expressed mostly bipyramidal shaped crystals, coleopteran specific isolates expressed spherical or rhomboidal shaped crystals and dipteran specific *Bt* isolates expressed both bipyramidal and rhomboidal shaped crystals. The majority expressed lepidopteran specific cry genes. Cry gene diversity determined included lepidopteran, coleopteran and dipteran toxic genes like *cry*1Aa, *cry*1Ab, *cry*1Ac, *cry*2a, *cry*1I, vip3A, *cry*3a, *cry*8 *cry*11, *cry*2a, *cry*10, *cry*16, *cry*44Ba and *cry*4a (Table 7). The identification of *cry*44Ba is a first report from India.

The full length gene sequencing of 1.9 kb *cry*3a (coleopteran specific gene) (Fig. 19), 2.37 kb *vip*3A (Fig. 20) (lepidopteran specific gene) and 3.686 kb *cry*1Ac (lepidopteran specific gene) was done using primer walking. The sequences were then cloned into TA vector. The construct was further subcloned into *E. coli* expression system. *cry*2A CDS (2.2 kb) was obtained from eight isolates and cloned for further studies.

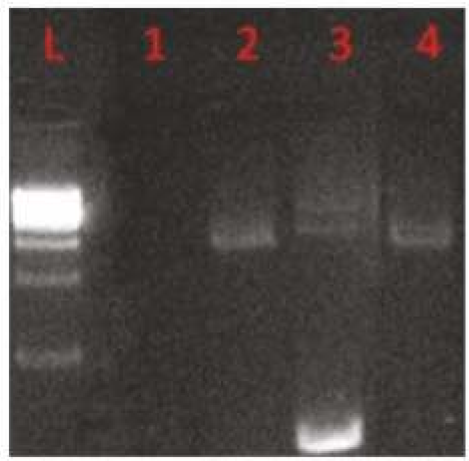


Fig. 19. Plasmid screening for effective cloning of *cry* 3a to TA cloning vector. , L- 1 kb ladder, 1- negative control, 2- *cry*3a gene from cloned TA vector, 3- negative result, 4- positive clone showing *cry*3a

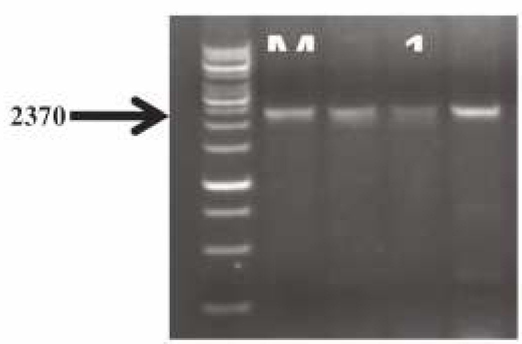


Fig. 20. Agarose gel showing amplification of 2370 bp VIP3A cloning gene analysis of Northeast Indian samples. Marker- 1kb, 1- AsBt15, 2-AsBt25, 3-Bt G-4, 4-Bt EG1

Seven isolates expressing the coleopteran specific *cry3A* gene was tested against the coleopteran pest *Sitophilus oryzae* a stored grain pest using the international standard (4AA1). *Bt*AN4 showed least LC_{50} value of 89.65 µg/ml and the standard showed LC_{50} value of 85.26µg/ml. However when the isolates were tested against another coleopteran pest *Callosobroclus chinensis Bt*AN4 showed very high toxicity and were better than the standard. The LC_{50} value recorded was 5.85 µg/ml as compared to standard (4AA1) which had a LC_{50} value of15.963 µg/ml. The *Bt*AN4 isolate was used for further cloning studies.

Genetic diversity, biology and utilization of entomopathogenic nematodes (EPN) against cryptic pests

Molecular identification and DNA Barcoding for EPN

Identity of 5 different geographical isolates of *Steinernema abbasi, S. feltiae, Heterorhabditis indica* and *H. bacteriophora* were validated and confirmed using COI, ITS and SSU RNA gene sequences and RFLP studies were carried out. 16S rRNA and Lux gene sequences of *Photorhabdus* and *Xenorhabdus* bacteria were generated and GenBank accessions obtained.

Genomes and transcriptomes

Four Indian strains of bacterial symbionts associated with EPN were accomplished for the first time for enhancing the existing efficacy of EPN against lepidopteran and coleopteran insect pests; genes and pathways related to their virulence and pathogenesis against insects were identified during NABG-NAIP overseas training on genomics and transcriptomics at WSU, Pullman USA.

Performance conditions of EPN against cryptic pests

Anomala species and *Holotrichia serrata* were found to be predominant whitegrub species in redgram of Doddaballapur region (Karnataka) (soil type lateritic soil with pH7.4, OC of 0.18%, sand:silt:clay @ 44:21:33) during Kharif season 2013. LD_{50} and LT_{50} values for *H. indica, H. bacteriophora, S. abbasi, S. carpocapsae* and *S. glaseri* were worked out against *Holotrichia serrata*. NBAII isolates of *H. indica, S. abbasi* and *S. glaseri* were effective at $2.5x10^9$ IJs/ha causing a mortality of 72-84% in soil column assay in 7days. In field WP formulations of EPN reduced the grub populations by 72-80% in 90 days of application and EPN could be retrieved 90 days after application (Fig. 21).

Field efficacy of EPN formulations against whitegrubs, *Anomala ruficapilla* and *Holotrichia* species was tested in fodder grass at Experimental Station, Doddaballapur, Bengaluru during Kahrif season 2013. WP formulations of *H. indica* and *S. abbasi* reduced 44-68% grubs in 30-45 days.

Suitability of WP formulations of EPN for delivery of EPN through drip irrigation to brinjal rhizosphere for control of ash weevil grubs

WP preparationsof three NBAII entomopathogenic nematodes were suitable for field delivery of EPN through drip irrigation to brinjal rhizosphere at NBAII Yelahanka Campus. The preparations effectively reduced incidence of *Myllocerus subfasciatus* grubs in brinjal by 68% and increased yield by 24%.

Research Report as part of NAIP-NABG Overseas training for 3 months at Washington State University, Pullman

- Datasets of Indian isolates of symbiotic bacteria of entomopathogenic nematodes (obtained previously in DBT project) were used for *in silico* analysis during the training and five studies were completed.
- Whole genomes of four bacterial isolates of NBAII were successfully *de novo* and ref sequenced, assembled, annotated and analyzed for the first time. Genome sizes ranged from 4.57 to 5.16 mb (Fig. 22).

Fig. 21. Redgram field in Doddaballapura infested with whitegrubs (left); Recovery of plant stand in treated field (right)

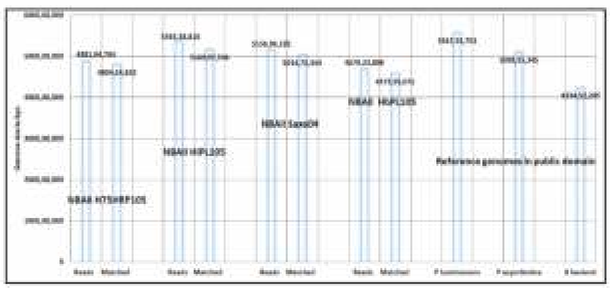


Fig. 22. Genome sizes of Indian (NBAII) strains of symbiotic bacteria associated with EPN.

- Two transcriptomes of the Indian bacterial isolates have been *de novo* sequenced and expression of genes related to virulence and pathogenesis proteins analysed (Fig. 23). The two bacteria exhibited variations in their expressed contigs.

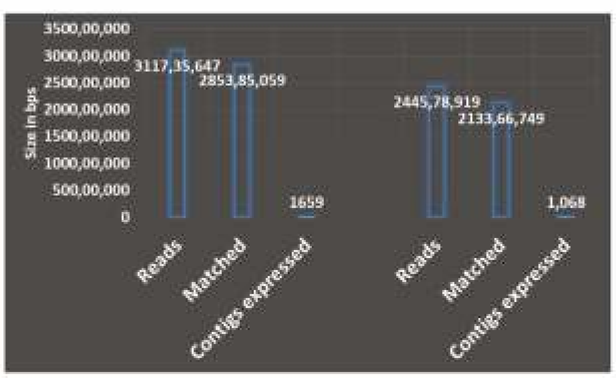


Fig. 23. Transcriptome analysis of NBAII isolates of EPN associated bacteria

- Four unique genome sequences of EPN-associated bacteria were submitted to NCBI as Bioprojects. NCBI accession numbers have been obtained.

- Seventeen short sequences from these bacterial genes were submitted to NCBI and accession numbers obtained.

- SNP analysis for the four bacterial genomes done and a baseline data base created. Of the four Indian strains of bacteria, three bacterial genomes exhibited SNPs with their respective global sequences indicating that these bacteria are unique or distinct to India, establishing that there is clear variability among the species world-wide. While one sequence exactly matched with the global sequence in NCBI genebank indicating that this Indian strain did not exhibit variability .

- Based on the information obtained from the whole genomes of these bacteria, information on the genes associated with various cellular, molecular and functional roles and their number has been obtained (Figs. 24, 25 and 26). Genes and pathways related to their virulence and pathogenesis against insects were identified.

Role of microbial flora of aphids in insecticide resistance

Live populations of aphids belonging to *Aphis gossipii*, *A. craccivora* and *Myzus persicae* were

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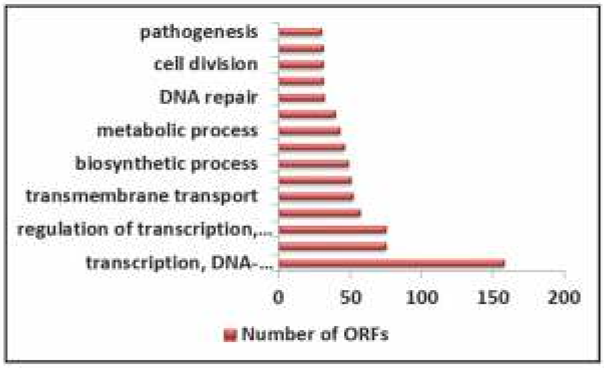

Fig. 24. Functional role of ORFs discovered from bacterial symbiont, *Xenorhabdus* sp. strain NBAII Saxe04

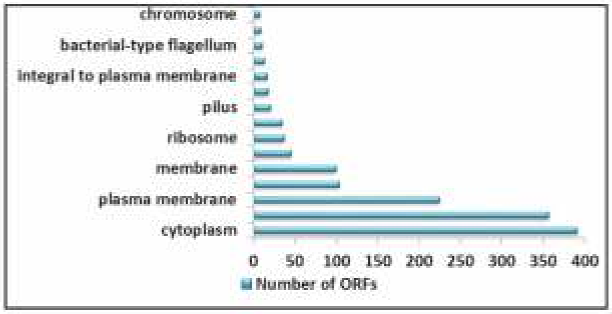

Fig. 25. Cellular role of ORFs discovered from bacterial symbiont, *Xenorhabdus* sp. strain NBAII Saxe04

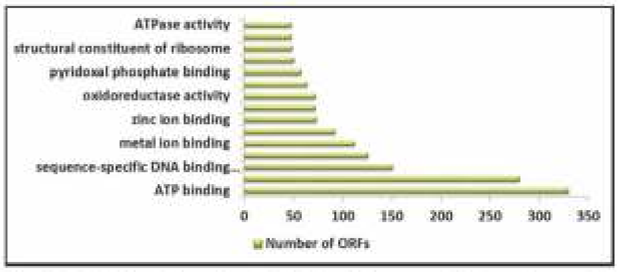

Fig. 26. Molecular role of ORFs discovered from bacterial symbiont, *Xenorhabdus* sp. strain NBAII Saxe04

collected from Karnataka on different crop plants. A total of 9 bacteria were identified as *Bacillus aryabhattai, B. cereus, B. firmus, B. horikoshii, B. jeotgali, B. massiliensis, B. subtilis, Exiguobacterium indicum, Moraxella osloensis* and *Paenibacillus lautus.* A total of 30 identified bacterial 16S rDNA sequences were deposited at GenBank and accession numbers KC465366, KC603539-KC603546 and KC707524-KC707552 were obtained. Phylogenetic affiliation of the microflora of aphids was accomplished.

Studies on *Trichogramma brassicae* and *Cotesia vestalis* interaction with their host in cabbage

Maintenance of parasitoid cultures

Twenty one populations of *Cotesia vestalis* were collected from Gujarat, Karnataka, Andhra Pradesh, Tamil Nadu, Orissa, Maharshtra, Uttara Pradesh, Himachal Pradesh, Meghalaya, Jammu & Kashmir, Punjab and Assam. The parasitoid population obtained from DBM collected on cabbage/cauliflower crops, from different locations, were maintained on mustard seedlings *Brassica juncea* raised on vermiculite in ice cream cups under laboratory conditions (at 25 ± 2^{0}C and 65% RH).

Resistance levels to insecticides

The bioassay was conducted for field collected *C. vestalis* populations using three different insecticides *i.e.* Indoxocarb, Spinosad and novoluron. Insecticide resistance level was exhibited by using Resistance ratios (RRs) in terms widely accepted as follows i.e. susceptibility (RR=1), tolerance to low resistance (RR=2-10), moderate resistance (RR=11-30), high resistance (RR=31-100) and very high resistance (>100). Based on the resistance factor (Rf) or resistance ratio (RR) the spinosad exposed CVH populations showed high resistance *i.e.* it showed 79.76 and 32.45 fold increase respectively while the rest showed tolerance to low resistance. CVH population showed moderate level of resistance to Indoxocarb with 12.92 fold increases and rest of the populations showed tolerance to low level of resistance. In case of Novoluron, CVP and CVH populations showed moderate level of resistance with 23.64 fold and 17.28 fold increase while the other showed low level of resistance. Out of the three insecticides, for Spinosad high resistance was observed. Moderate resistance was observed for Novoluron and low resistance was observed for Indoxocarb.

Esterase activity in insecticide resistance

Esterase activity in pesticide (Indoxocarb 14.5%

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SC, Spinosad 45% SC, Novoluron 10% EC) exposed populations were determined (Fig 27). Out of 10 field collected populations, Indoxocarb exposed CVP population showed 2.4 fold higher esterase level than the lab population, in same way Indoxocarb exposed CVT, CVH, CVA, CVD, CVV and CVJ populations showed 2.3, 2.15, 2.0 fold higher esterase level. The novoluron exposed CVH population showed 2.6 fold elevated esterase activity where as populations from CVP, CVV and CVA showed 2.2 fold esterase activities. CVC and CVT showed 2 fold and 1.4 fold higher esterase activities than that of lab population. Spinosad exposed CVP population showed 10.32 fold higher esterase activity, 7.74 fold increased activity was found in CVT and CVD populations whereas CVV population showed 7.4 fold increases in esterase when compared with lab populations. Here the lab population refers to the population which is having least esterase activity.

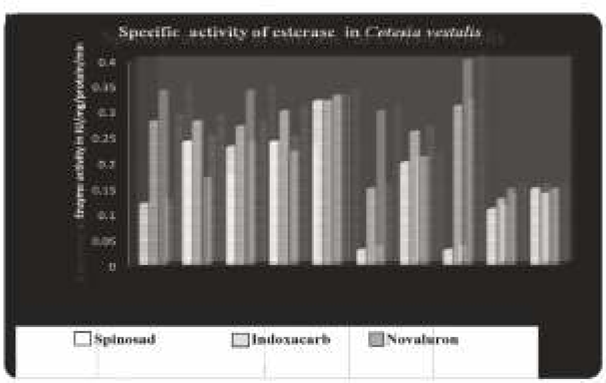

Fig. 27. Specific activity of esterase in field collected *Cotesia vestalis*

Esterase patterns in *C. vestalis* were determined in 8% polyacrylamide gel. In all of the *C. vestalis* populations from different regions of India screened in this study, a total of 5 á-esterase bands were detected. Out of all, CVH population showed greatest activity with thick bands, in which the novoluron exposed one expressed three bands, rest all including CVD and CVH1 population showed only two bands (Fig. 28). In the same wayCVB and CVV population also expressed two bands Insecticide exposed CVJ samples showed slightly higher expressions with three thick bands but untreated one did not express any bands. Novoluron exposed CVA population showed greater activity with very thick bands but the untreated sample showed no bands. CVP samples showed enhanced esterase activity with three bands but the control did not express any activity. CVT samples showed esterase activity with expression of two thick bands but in the control, esterase bands were not expressed.

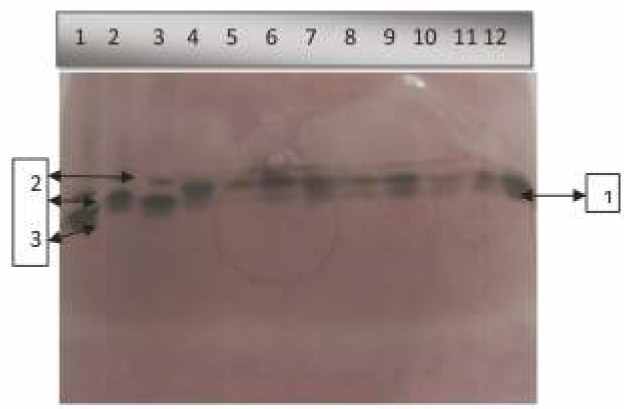

Fig. 28. Native polyacrylamide gel electrophoresis (PAGE) of insect crude homogenates, stained for esterases activity with the substrate a-napthyl acetate.1-4 (Novoluron, Spinosad, Indoxocarb & Control) CVH population, 5-8 (Novoluron, Spinosad, Indoxocarb & Control) CVD population, 9-12 (Novoluron, Spinosad, Indoxocarb and Control) CVH1 population

Diversity of gut flora in different populations of *Cotesia vestalis*

A total of 11 microflora were isolated and identified from the gut of *Cotesia vestalis* collected from various places in India (Table 8).

Insecticide degradation studies by the bacterial flora isolated from *Cotesia vestalis*

LC-MS studies to detect the concentration of insecticides degraded and to elucidate the final degradative product structure

Liquid Chromatography - Mass Spectrometry (LC-MS) is applied for the analysis of thermally

Table 8. Culturable bacteria identified in various populations of *Cotesia ?vestalis* using 16S rRNA technique

Strain name	Bacteria	Place of collection	GenBank Acc. No
Cp-Ps.sp	*Pseudomonas* sp.	Shillong (Assam)	KC441059
CpG-13	*Enterobacter cancerogenus*	Anand (Gujarat)	KC139361
CpR-12	*Bacillus* sp.	Rajahmundry (Andhra Pradesh)	KC139360
Cp-B.sp1	*Bacillus* sp.	Nawanshahr (Punjab)	KC512245
Cp-Pt.a	*Pantoea agglomerans*	Palani (Tamil Nadu)	KC512244
Cp-b.sp2	*Bacillus* sp.	Solan (Himachal Pradesh)	KC512246
Cp-Bt	*Bacillus thuringiensis*	Jorhat (Assam)	KC512243
Cp-Bc	*Bacillus cereus*	Delhi	KC582828
Cp-Pt.a1	*Pantoea* sp.	Bhubaneshwar (Orissa)	KC582827
Cp-Ps.pt1	*Pseudomonas putida*	Hoskote (Karnataka)	KC589741
Cp-Bs.sp3	*Bacillus* sp.	Tirupati (Andhra Pradesh)	KC582829

unstable molecules in complex samples. LC-MS works on soft ionization technique and is useful for detection of non volatile compounds, vitamins, amino acids, protein and peptides. The technique was used to detect the degradation of insecticides by gut microflora of the parasitoid. Two gut microflora *Bacillus* and *Enterobacter cancerogenus* were evaluated for their role in degradation of the insecticide Acephate (O,S-Dimethyl acetylphosphoramidothioate). The LCMS analysis indicated ability of *Bacillus* sp. to degrade Acephate (183.16 g/mol) into des-O-methyl acephate (143.2 g/mol) based on the spectrum formed (Fig. 29). The area of the spectrum decreased which indicated degradation of the compound. The mass spectrum of the control sample showed molecular weight of 183 which matched with the standard acephate mass spectrum. Similarly *E. cancergenus* formed a degradation product. The chromatogram revealed reduced peak in comparison to control which indicated degradation.

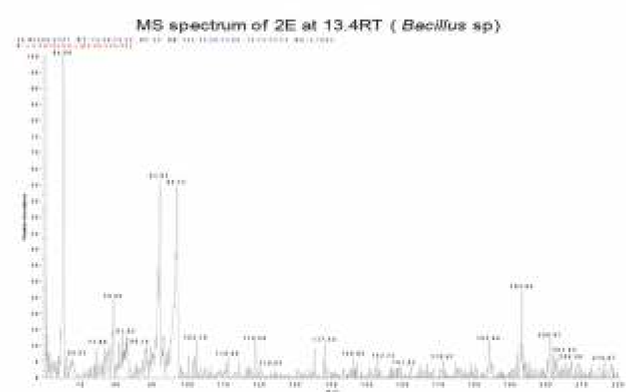

Fig. 29. Mass spectrum of 2E (MM+ Acephate 300ppm+ *Bacillus* sp.)

Division of Insect Ecology

Diversity of anthocorid predators

Anthocorid predators were collected from different host plants: *Cardiastethus exiguus* from *Adenanthera pavoni, Delonix regia,* rose, *Butea monosperma, Caesalpinia pulcherrima, Aegle marmelos*; *Blaptostethus pallescens* & *Cardiastethus affinis* from *Spathodea campanulata, Orius tantillus* from sugarcane;

Buchananiella crassicornis from *Lagerstromia*; *Orius maxidentex* from *Wedelia*; and *Orius shyamavarna* from *Butea monosperma*. *Physopleurella* sp. (could be *P. armata*) were collected from infested flour in a warehouse. *Buchananiella indica* collected from crossandra and *Amphiareus constrictus* collected from sugarcane and *Anthocoris muraleedharani* collected from ficus were amenable to rearing on alternate laboratory host eggs. *Blaptostethoides pacificus* from sugarcane and *Orius amnesius* from rose are first records for India. Two new unidentified species of *Orius* were collected from hibiscus and *Butea*.

Biology and feeding potential of *Amphiareus constrictus*

The anthocorid predator *Amphiareus constrictus* was collected for the first time from sugarcane in Mandya, Karnataka. This predator was earlier recorded as a predator of hoppers (BPH and GLH) on rice in Mandya in 1976. This is the first attempt at its mass rearing in the laboratory. This anthocorid was amenable to production using UV-irradiated *Corcyra cephalonica* eggs. The total developmental period was 16.4 days. Male longevity was 55.7 days and female longevity was 55.3 days. Fecundity was 84.7 eggs per female. The total feeding during nymphal stage was 35.2 eggs. Adult female could feed on 93.5 eggs throughout its life time and per day it could feed on 2.7 eggs.

Studies on anthocorid predator *Buchananiella indica*

Buchananiella indica was collected from dry flowers of crossandra in Karnataka. This anthocorid is amenable to laboratory rearing on alternate laboratory host eggs. As on date, it has been reared for more than 10 generations in the laboratory. The biology of *B. indica* was studied in the laboratory. The incubation period was 4.2 days and nymphal period 15.8 daysThe adult male and female *B. indica* lived for 30 and 31.2 days, respectively and the fecundity was 33 eggs per female. Nymphal feeding potential was 2.57 eggs per day and total 29, adult feeding was 2.23 eggs per day and total 79.83.

Evaluation of predatory mites against chilli thrips

A net house experiment was conducted to evaluate predatory mite releases against thrips infesting chilli. Prior to treatment, per cent curling was 65.2 and 46.3 in treatment and control, respectively (Table 9). After the first and second releases, per cent curling was 0.1 and 0.2, respectively in treatment and the corresponding values in the control were 66.9 and 82.3 %, respectively. The pre-treatment counts of thrips per leaf were 1.3 and 1.5, respectively in treatment and control. The first post treatment counts were 0.1 and 2.7 thrips per leaf in treatment and control, respectively and 0.0 and 1.7, respectively in the second post-treatment count. At the end of the experiment, 100 % of the treated plants bore flowers and fruits, while in control 50% had flowers, 16.7% with flowers and fruits and 30% of the plants were dead.

Table 9. Effect of release of predatory mites on chilli thrips

Treatment	% curling of terminal leaves		No. of thrips per leaf	
	Treated	Control	Treated	Control
Pre-treatment	65.2[a]	46.3[a]	1.3[a]	1.5[a]
Post-treatment 1	0.10[a]	66.9[b]	0.1[a]	2.7[b]
Post-treatment 2	0.2[a]	82.3[b]	0.0[a]	1.7[b]

Effect of constant temperature regimes on the biological parameters of *Xylocoris flavipes*

The effect of temperature on the warehouse pirate bug *Xylocoris flavipes* was studied. Considering the nymphal survival and fecundity, constant temperatures of 17 and 36 °C are not suitable for rearing *X. flavipes* and 22 and 27°C are the optimum temperatures. The developmental threshold temperatures for incubation, nymphal and total development were 7.85, 12.28 and 11.8,

CHAPTER 4

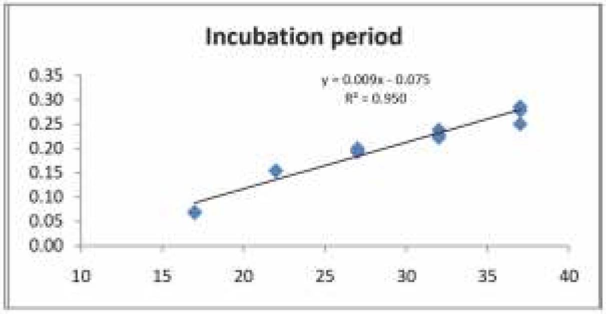

Fig. 30. Egg stage: Lower threshold temperature: 7.85°C; upper threshold: 37.6°C & thermal requirement: 104.17DD

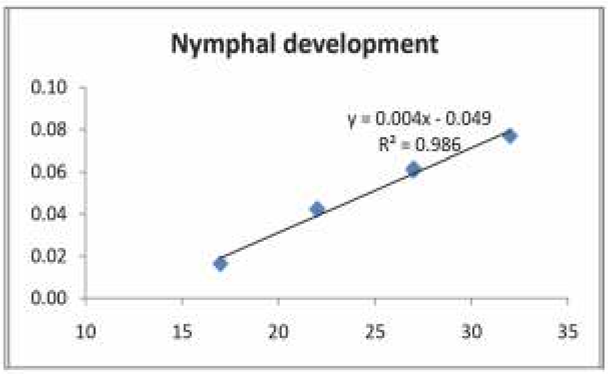

Fig. 31. Nymphal stage: Lower threshold temperature: 12.28°C; upper threshold: 31.5°C & thermal requirement: 250 DD

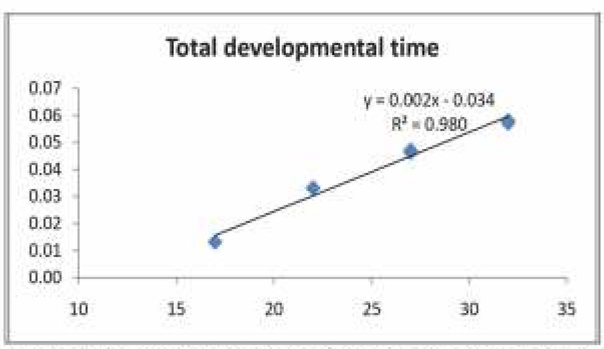

Fig. 32. Total development: Lower threshold temperature: 11.8°C; upper threshold: 32.08°C & thermal requirement: 344.83 DD

respectively and upper threshold temperatures 37.6, 31.5 and 32.1°C, respectively, indicating that the egg stage is least heat-sensitive (Figs 30, 31 & 32).

Maintenance and supply of live insect germplasm

During 2013-14, 109 species/strains of live insects were maintained continuously. 980 consignments of live insect cultures were supplied and a revenue of Rs 3,26,353 was generated.

Diversity of bioagents and their amenability to rearing

Trichogramma danaidiphaga (ex sphingid eggs infesting *Calotropis* in Kerala) was able to parasitise *Corcyra* eggs in the lab. *Telenomus* sp. (ex egg masses of *Mythimna* on sugarcane in Karnataka) was amenable to rearing on *Spodoptera litura* eggs. *Anastatus acherontiae* (ex eri silkworm eggs on sugarcane in Karnataka) was amenable to rearing on eri silkworm eggs. *Anastatus bangaloriensis* (ex mantid egg mass on sugarcane in Karnataka) was amenable to rearing on eri silk worm eggs.

Ovipositional behaviour of *Helicoverpa armigera* on pigeonpea plants grown under elevated levels of CO_2

A trial was conducted on the behaviour and biology of *Helicoverpa armigera* on pigeonpea grown under elevated levels of CO_2 in open-top carbon dioxide chambers.

The females of *H. armigera* preferred to lay more eggs on the pigeonpea plants grown at 500 ppm of CO_2 + 2°C compared to plants grown at ambient conditions (Table 10).

Volatile profile of pigeonpea grown under elevated levels of CO_2

The volatile profile of pigeonpea plants grown under 500 ppm CO_2 was analysed using GCMS. Plants grown at 500 ppm of CO_2 showed the presence of compounds like á copaene in addition to an array of volatiles, which may be responsible for the attraction of females.

Incidence of *Liriomyza trifolli* on tomato grown under elevated levels of CO_2

Tomato plants were grown in open-top CO_2 chambers with different levels of CO_2. The incidence of *Liriomyza trifolii* was significantly higher in the chambers with elevated levels of CO_2 and temperature (Table 11).

Table 10. Ovipositional preference of *Helicoverpa armigera* to the pigeon pea inflorescence/young pods in dual choice test

Treatment	Mean no. of eggs in ambient CO_2	Mean no. of eggs in 500 ppm CO_2	Mean no. of eggs laid in 500 ppm CO_2 +2°C
Ambient vs elevated CO_2	196.6	417.4	
Ambient vs elevated CO_2 + 2°C	317.6		575.0
Elevated CO_2 vs elevated CO_2 +2°C		393.7	358.7

Table 11. Incidence of *Liriomyza trifolii* on tomato grown under different levels of carbon dioxide and temperature

Treatment	Per cent leaves infested	
	Observation-1	Observation-2
Ambient temperature and CO_2	8.2	10.6
Carbon dioxide 500 ppm and ambient temperature	11.4	20.9
Carbon dioxide 500 ppm + 2 °C above ambient	14.0	22.2

Plant-based formulation to attract *Bactrocera dorsalis*

A plant-based attractant was developed and evaluated in three field trials for comparison with methyl eugenol. The new formulation was more effective than methyl eugenol in terms of trapping the fruit fly *Bactrocera dorsalis*.

Plant volatile-based deterrent for *Helicoverpa armigera*

Three formulations of plant-derived volatile compounds were tested for their efficacy as deterrents for *Helicoverpa armigera* on chickpea. All the new compounds showed good ovipositional deterrence compared with control.

Monitoring of papaya mealybug and its natural enemies on papaya and other hosts

Based on the samples received from various sources and also the survey conducted for the incidence of papaya mealybug in Karnataka it was observed that the infestation was very low, sporadic and below pest status.

Occurrence of papaya mealybug on papaya, weeds and other host plants in Karnataka

Incidence of papaya mealybug was very low in Karnataka. Damage in the score of 3 (1- 5 scale) and below only were observed sporadically in homesteads. Surveys in 25 papaya orchards revealed the presence of *Acerophagus papayae* in all the places whereever papaya mealybug was observed. *Spalgius epius* was also recorded.

On *Hibiscus* the papaya mealybug was found invariably associated with *Maconellicoccus hirsutus*, *Phenacoccus solenopsis* and *Ferrisia virgata*. On tapioca, it was found associated with *P. madeirensis*. *Acerophagus papayae* parasitized up to 72% on hibiscus.

About 84–86% parasitization was observed on *Parthenium* and 72–79% on *Sida acuta* and *Acalypha*. In a laboratory study, it was confirmed that there was no significant variation in parasitization by *A. papayae* on papaya mealybug grown on different weed species. Per cent parasitization by

Table 12. Parasitization of *Paracoccus marginatus* by *Acerophagus papayae* in field collected samples

Month	Number of fieldsamples observed	Parasitization (%)
March 2013	9	72.4
April	6	86.5
May	12	87.2
June	5	65.5
July	9	62.2
August	7	64.5
September	5	66.2
October	3	65.5
November	2	69.8
December	4	68.4
January 2014	3	55.7

Table 13: Distribution of *Acerophagus papayae* to farmers

Month	Number of people requesting culture	Number of parasitoids issued
March 2013	3	1000
April	0	0
May	2	1000
June	5	3000
July	9	4500
August	6	3000
September	5	4500
October	3	1500
November	2	1000
December	4	2500
January 2014	3	2000

A. papayae of *P. marginatus* is given in Table 12.

Supply of host insects and natural enemies

Acerophagus papayae cultures were sent to Nashik, Rajahmundry, Bhubaneswar, Guwahati, Madurai, Puducherry, Kayangulam, Rayakottai, Anantapur, Chittoor in addition to local supplies in Karnataka (Table 6). Cultures of gall fly *Cecidochares connexa* were also supplied to researchers for field releases across the country. Parasitoids of *Leptocybe invasa* were given to several paper mills and also to state departments of horticulture and forestry for releases in their states. In addition, cultures of *Pseudleptomastix mexicana* and *Anagyrus loecki* were also supplied to KVKs, universities departments and ICAR institutes for maintenance and mass production from their end (Table 13)

Host range of invasive Jack Beardsley mealybug in Karnataka

Survey for invasive insects in south India revealed the occurrence of *Pseudococcus jackbeardsleyi* in Tamil Nadu and Karnataka. It was found with papaya mealybug on papaya (Fig. 33) in Bangalore. It was also found on flowers of custard apple (*Annona squamosa*), purple martin (*Streptocarpus* sp.) and jasmine. Along with papaya mealybug it was found on papaya, tapioca, chrysanthemum and Indian spinach (*Basella alba*). It is associated with *Phenacoccus solenopsis* on parthenium and chrysanthemum (Fig. 34).

Ever since the first report of this invasive mealybug, the host range is expanding day by day in India. As in case of the other invasive species observed *P. solenopsis* or *Paracoccus marginatus*, in the beginning the establishment on weeds and ornamental crops was fast and coexistence with several other sucking pests was observed. This invasive mealybug is a very slow establishing species and is expanding slowly. Some of the local natural enemies like *Cryptolaemus montrouzieri*, *Spalgis* *epius* and unidentified species of gnats are keeping its spread under check.

in pots can also be used for mass production of parasitoids.

Fig. 33. Jack Beardsley mealybug on papaya (left) associated with papaya mealybug (centre). Female with ovisac (right)

Fig.34. *Pseudococcus jackbeardsleyi* on chrysanthemum (left) associated with aphids (centre). Adult female (right)

Mass production of *Pseudococcus jackbeardsleyi* on potato sprouts and pumpkin

Rearing on raw papaya fruits: *P. jackbeardsleyi* can easily be mass-produced on raw papaya fruits. Fresh smaller size (diameter 2-4 inches) papayas which are not mature are selected for rearing the mealybug. Within 28 to 32 days the whole papaya will be covered with mealybugs. Raw papaya can support only one or two generations of the mealybug.

Rearing of *P. jackbeardsleyi* on pumpkin: Green pumpkins supported mealybug growth much better than the bottlegourd.

Although many methods and host plants were tried for the mass production of the host mealybug *P. marginatus*, rearing on potato sprouts was found to be easy and cost-effective (Fig. 35). The same method was used for mass rearing jackbeardsley mealybug as well. Between 14 and 20 days, infested potatoes can be removed and set-up in cages to be used for the rearing of the parasitoids. Potato plants

Eucalyptus gall wasp management

Leptocybe invasa, the eucalyptus gall wasp, was effectively managed by the release of *Quadrastichus mendeli*. The indigenous parasitoid *Megastigmus viggiani* was also supportive in bringing down the population of the gall wasp, with15–20% parasitization. It has been established in Uttar Pradesh, Punjab and Uttaranchal. *Megastigmus* was more effective than *Q. mendeli* in north India.

Interaction of indigenous and introduced parasitoids of eucalyptus gall wasps

Interaction of indigenous and introduced parasitoids of eucalyptus gall wasps was studied and it was found that resource utilization by both the parasitoids was mutually exclusive (Table 7). *Quadrastichus mendeli* preferred young larvae of *L. invasa* which were within the green galls, whereas the local parasitoid *Megastigmus viggianii* selected larvae within the older pink and brown galls.

Fig. 35. ***Psuedococcus jackbeardsleyi*** **on raw papaya fruits and potato sprouts (top row). Establishment of** ***Psuedococcus jackbeardsleyi*** **on fully ripe and mature green pumpkins (bottom row)**

Erythrina gall wasp managment

Incidence of the erythrina gall wasp, *Quadrastichus erythrinae*, was found to be severe in Mandya and Chamarajnagar districts of Karnataka. *Aprostocetus gala* was found to be the major parasitoid of *Q. erythrinae*. Up to 46% parasitization was observed in the field. It was clearly established that *Aprostocetus gala* is not a gall former in *Erythrina* plants but a very good parasitoid of *Quadrastichus erythrinae*. *Aprostocetus gala* was unable to parasitize *Leptocybe invasa* in both nethouse and field studies.

Establishment of *Cecidochares connexa*

The biocontrol agent *C. connexa* released to manage the weed *Chromolaena* at different places has established. An average of 9–12 galls were found in 5 minutes search in a 450 m area around the released spot. New releases were made in

Table 14. Interaction of *Quadrastichus mendeli* and *Megastigmus viggianii* parasitoids of gall wasp *Leptocybe invasa*

Quadrastichus mendeli	*Megastigmus viggianii*
Only females	Both sexes present
Prefer only young green 35-40 days galls of *L. invasa*	Prefer only brown and red 45-65 days galls of *L. invasa*
No parasitoid emergence from galls aged above 95 days	No parasitoid emergence noticed before 75day old galls
Mutually exclusive utilization of resources observed and the parasitoids are complementary to each other	

Jharkhand in collaboration with Directorate of Weed Science Research, Jabalpur.

Biology of *Anagyrus amnestos:* Major parasitoid of *Phenacoccus madeirensis*

The biology of *Anagyrus amnestos* was studied and the different attributes are presented in Table 15.

Table 15: Biology of *Anagyrus amnestos* on *Phenacoccus madeirensis*

Attribute	
Fecundity	56-95/Female
Developmental period (male)	16-21 days
Developmental period (female)	15-18days
Longevity (male)	18-20 days
Longevity (female)	30-32 days
Active temperature range	20-31°C
Host stage preference instar	3rd and final
Super parasitism with 4-7 /host	Observed
Mean per cent parasitization	45-72% Density dependent More at low host density

Collection, documentation and identification of non-*Apis* bees on different host plants

Over 200 specimens of bees belonging to Apidae, Megachilidae, Anthophoridae and Halictidae were collected on different host plants and curated for further studies.

Nest-building activity of a megachilid (*Megachile lanata*) was studied in detail and documented (both photographs and video). This species an important pollinator of pigeon pea and sunhemp. The bee nested in a hollow stem of bamboo.

Megachile anthracina, a major pollinator of sunhemp uses pigeonpea and *Cassia* leaves for building its nest.

Milletia pinnata (Fabaceae) which flowers during February- March observed to attract many megachilids apart from *Apis* and other bees. *Vitex negundo* (Verbenaceae) is known to attract smaller Xylocopid bees. Both the plants provide rich nectar and pollen for their survival in summer.

A species of *Tetralonia* (Apidae), pollinator of *Argyreia cuneata* (Convolvulacaeae) was recorded. This bee species appears to be host specific. These wild bees are very important in pollination of crops belonging to Convolvulaceae and Malvaceae where the population of *Apis* spp. is not present or is inadequate. The frequency of visits and time spent in each flower and other parameters were studied.

Establishment of a 'Pollinator Garden'

A "Pollinator Garden" has been developed in about 0.7 acres at the Yelahanka campus. This garden has over 70 species of plants belonging to diverse families (trees, shrubs, herbs and climbers) which are known to be attractive to diverse pollinator groups like bees, butterflies, flies, beetles, ants and even birds! This garden aims to attract and support a wide range of pollinators during the season to aid pollination in cultivated crops.

Characterization of gut microflora of leaf hoppers

A total of 37 culturable gut bacteria and a culturable yeast were characterized and identified from 15 live populations of leafhoppers (*Amrasca biguttula biguttula*, *Empoasca* spp., *Nephotettix nigropictus* and *Bothrogonia*) and a planthopper (*Nilaparvata lugens*), which have been exposed to different insecticides. All the organisms were characterized through morphological and molecular methods.

The bacteria associated with *A. b. biguttula* were *Microbacterium imperial, Bacillus aryabhattai, Staphylococcus epidermidis, Janibacter anopheles, Bacillus cereus,* *Staphylococcus aureus, Micrococcus luteus, Agrococcus terreus, Bacillus cereus, Staphylococcus warneri, Staphylococcus hominis, Staphylococcus arlettae, Pseudomonas stutzeri, Bacillus pumilus* and *Enterobacter* spp.

The bacterium *Enterobacter cloacae* and the yeast *Filobasidium floriforme* (Fig. 36) were associated with *N. lugens*.

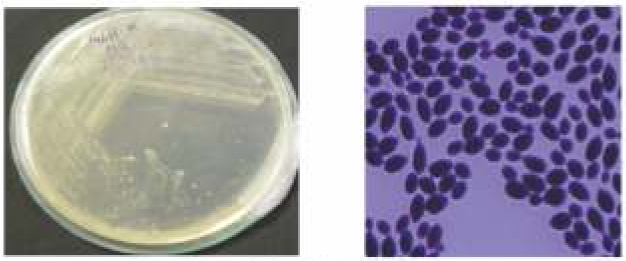

Fig. 36. *Filobasidium floriforme*

The culturable bacteria associated with *N. nigropictus* were *Enterobacter cloacae, Stenotrophomonas maltophilia, Bacillus firmis, Enterobacter cloacae, Kocuria kristinae, Stenotrophomonas maltophi* and *Bacillus flexus*.

The culturable bacteria associated with *Empoasca* spp. are *Bacillus stratosphericus* and *Micrococcus* spp.

Lysinibacillus fusiformis was isolated and characterized from *Bothrogonia* sp.

Detection of *Wolbachia* from the leafhoppers *Bothrogonia* and *Amrasca biguttula biguttula*

Wolbachia was detected in two leafhopper species, *viz. Bothrogonia* sp. and *A. biguttula biguttula* (Fig. 37).

Growth of *Enterobacter cloacae* in the minimal broth under different concentrations of acephate

Maximum growth of *Enterobacter cloacae* was recorded in the minimal broth after 3 days of inoculation in all concentrations of acephate as compard to control. The maximum OD value recorded was 1.0 at 3 days after inoculation under 50 ppm concentration of acephate as compared to control where it was 0.8. (Fig 38).

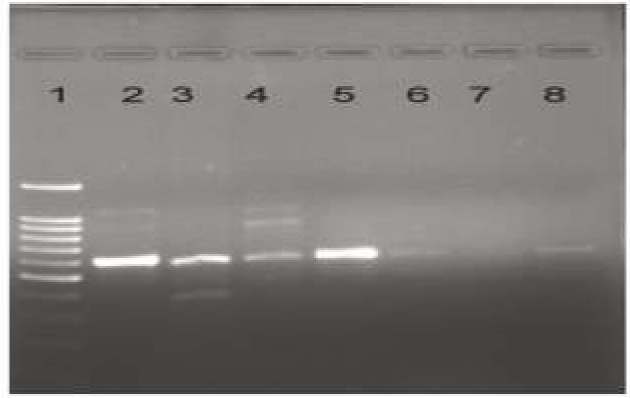

Fig. 37. Lane 1: 100-bp marker, Lane 2: Positive control, Lane 3: *Bothrogonia* spp., Lane 4: *A.biguttula biguttula* Lane 5: SLH, Lane 6: AVLH, Lane 7: LH-K1, Lane 8: LH-K4

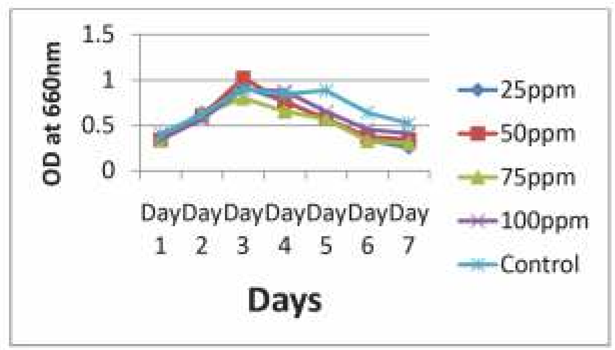

Fig. 38. Growth of *Enterobacter cloacae* in the minimal broth under different concentrations of acephate

Growth of *Bacillus pumilus* in the minimal broth under different concentrations of acephate

Maximum growth of *Bacillus pumilus* was recorded in the minimal broth after 3 days of inoculation in all concentrations of acephate as compard to control. The maximum OD value recoded was 0.8 at 3 days after inoculation under 50 ppm concentration of acephate as compared to control where it was 0.6. (Fig. 39).

Cage studies to identify viruliferous leafhoppers and/or planthoppers from direct field collections

Sweep-net samples of all the dominant captured species were taken from the canopies of both crops and weeds in the morning hours from April 2013 to March 2014. Leafhoppers and planthoppers were

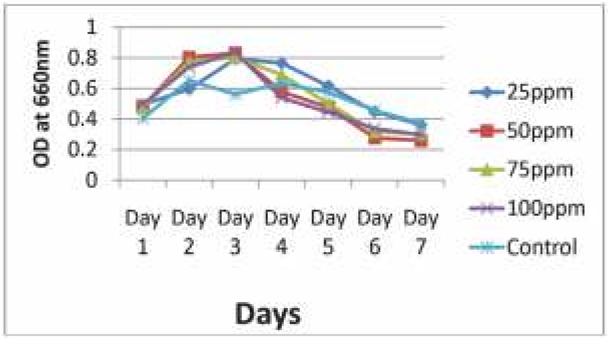

Fig. 39. Growth of *Bacillus pumilis* in the minimal broth under different concentrations of acephate

sorted to species, or at least genus, and caged in groups of five insects on healthy sesame, brinjal and periwinkle seedlings in the greenhouse for at least 48 h. Plants were allowed to grow on greenhouse benches for at least one month to observe for symptoms. Out of the 15 species of leafhoppers belonging to 5 subfamilies of Cicadellidae tested, only *Batracomorphus angustatus*, *Cicadulina bipunctata*, *Exitianus indicus*, *Hecalus* sp., *Hishimonus phycitis*, *Nirvana pallida* and *Orosius albicinctus* were found to be viruliferous based on symptom production in brinjal, sesame and/or periwinkle. Though other leafhoppers were absolutely nonviruliferous, *Austroagallia sinuata* showed inconsistent transmission. Three planthoppers, including a *Stenocranus* sp., were not found to be carrying phytoplasmas.

Understanding the feeding processes of putative insect vectors

A comparative analysis of the mouthparts of *Hishimonus phycitis* and *Orosius albicinctus* indicated only minor perceptible differences between the two. The salivary glands of both species resembled that of other deltocephaline leafhoppers, though the paired principal glands were larger in *H. phycitis*. In general, on both sesame and brinjal, exploratory probing of *H. phycitis* was more pronounced than that of *O. albicinctus*. The latter was found to restrict itself to test probing on brinjal. The salivary flanges or feeding marks left by *H. phycitis* on both sesame and brinjal were similar.

Molecular identification and DNA barcoding of three leafhopper species

For molecular identification of leafhopper species, their DNA was isolated, the mitochondrial cytochrome oxidase I (COI) gene was amplified through PCR and the resultant product was sequenced. DNA barcoding was completed for *Nirvana pallida*, *H. phycitis* and *O. albicinctus*, and the nucleotide sequences were submitted to GenBank (KJ465911, KJ465912 & KJ465913).

Effect of entomofungal pathogens on *Bemisia tabaci* infestation in tomato and capsicum under protected cultivation

Entomofungal pathogens were evaluated against *Bemisia tabaci* on tomato (cv. NS501) and capsicum (cv. Indria) during February-May 2013. Four rounds of foliar sprays with oil formulations of fungal pathogens at a spore dose of $1 x 10^8$ spores/ml were applied at 15-day intervals during March-April 2013. Among the nine entomofungal pathogens tested, *Lecanicillium lecanii* (Vl-8 isolate) and *B. bassiana* (Bb-9 isolate) showed significantly lower whitefly population on tomato (15.29 & 17.21 whiteflies/plant, respectively) compared with untreated control (48.24 whiteflies/plant in tomato), indicating a reduction of 68.3 and 64.3% (Table 16). Vl-8 treated plants showed significantly higher yield (5.06 kg/plant) than untreated control (3.42 kg/plant). The yields recorded in the plants treated with other fungal pathogens were on par with control.

Among the nine entomofungal pathogens tested, *L. lecanii* (Vl-8 isolate) and *Beauveria bassiana* (Bb-9 isolate) showed significantly lower whitefly population on capsicum (6.47 & 6.98 whiteflies/plant, respectively) than the untreated control (28.12 whiteflies/plant) indicating a reduction of 77.0 & 75.1%, respectively (Table 16). However, there was no significant effect on the yield.

Field evaluation of entomofungal pathogens against cabbage aphid (*Brevicoryne brassicae*)

Entomofungal pathogens were evaluated

CHAPTER 4

Table 16. Effect of fungal pathogens on whitefly (*Bemisia tabaci*) on tomato and capsicum

Isolate	Tomato			Capsicum		
	No. of whiteflies/ plant	% reduction overcontrol	Yield (kg/plant)	No. of whiteflies/ plant	% reduction over control	Yield (kg/plant)
Bb-9	17.21[c]	64.32	4.89[ab]	6.98[a]	75.12	2.42
Bb-36	36.08[b]	25.21	3.98[ab]	20.18[b]	30.24	1.94
Bb-68	31.84[b]	34.00	4.06[ab]	17.36[b]	38.27	1.78
Ma-6	30.42[b]	36.94	4.26[ab]	16.23[b]	42.29	1.92
Ma-41	28.46[b]	41.00	4.62[ab]	12.53[b]	55.45	2.19
Ma-42	34.92[b]	27.61	4.01[ab]	19.98[b]	28.95	1.86
Vl-8	15.29[c]	68.30	5.06[b]	6.47[a]	77.00	2.56
Vl-12	29.92[b]	37.98	4.36[ab]	15.16[b]	46.09	2.09
Vl-32	26.93[b]	44.17	4.79[ab]	13.19[b]	53.10	2.37
Control	48.24[a]	-	3.42[a]	28.12[c]	-	1.68
CD@5%	9.23	-	1.64	7.66	-	NS

against *Brevicoryne brassicae* on cabbage (cv. Saint) during July-November 2013. Three rounds of foliar sprays of oil formulations of fungal pathogens at a spore dose of $1x10^8$ cfu/ml were applied at monthly intervals during August, September and October 2013. Among the nine fungal pathogen isolates tested, Bb-5a, Ma-6 and Vl-8 isolates showed significantly low aphid population/leaf (4.62, 5.82 and 5.06, respectively) with a reduction of 60.0-68.25% over control (Table 17). However, the entomopathogens did not have any direct effect on the yield.

Chemical profiling of *Bactrocera dorsalis* and *B. caryeae* using proton NMR spectroscopy

About nine species of *Bactrocera* are known to occur in India. Metabolite signatures (NMR) provide a valuable method for identifying the larval stages of different species by means of tissue extracts. Therefore, we tried this method to differentiate the larval stages of *B. dorsalis* from those of *B. caryeae*. With ^{1}H NMR spectral analyses, we obtained chemical shift (α) values in *B. dorsalis* of α0.84(m), α0.85(d), α1.25(s), α1.28(s), α1.37(s), α1.42(s), α1.58(s), α2.16(s) whereas in the case of *B. caryeae* the values obtained were α 0.96(q), 1.25(s), 1.32(d), 1.45(q), 1.54(m), 1.68(s), 1.71(t), 1.75(s), 2.07(t), 2.16(s), 2.34(t), 4.09(d), 4.30(t), 4.99(q), 5.16(q),7.52(m). The data showed that there are two different sets of peaks in the two species.

Non-target effects of chitosan-alginate nanoparticles on the biology of *Chrysoperla zastrowi sillemi*

The effect of continuously feeding the larvae of *Chrysoperla zastrowi sillemi* with *Corcyra cephalonica* eggs mixed with chitosan alginate nanoparticles was studied for over 10 generations and the results indicated that there was no significant difference in the biological parameters, viz. percentage hatching, pupal formation, adult male and female survivability,

Table 17. Effect of fungal pathogens on incidence of cabbage aphid *Brevicoryne brassicae*

Isolate	Pre-count (aphids/leaf)	Post-count (aphids/leaf)	% reduction		Yield/ha (kg)
			Over control	Over Pre-treatment	
Bb-5a	11.97[a]	4.62[c]	68.25	61.41	17168
Bb-9	12.07[a]	10.53[a]	27.63	12.76	16378
Bb-68	13.50[a]	9.14[bc]	31.19	32.30	16124
Ma-4	16.60[a]	8.18[bc]	45.79	50.73	16796
Ma-6	16.73[a]	5.82[c]	60.00	65.22	16974
Ma-41	17.03[b]	8.09[bc]	44.40	52.50	16746
Vl-8	16.00[a]	5.06[c]	65.23	68.32	17080
Vl-12	15.33[a]	7.98[bc]	45.16	47.95	16264
Vl-32	17.57[a]	10.02[a]	31.14	42.98	16428
Control	16.40[a]	14.55[a]	-	11.29	16238
CD@5%	7.22	5.32			NS

fecundity, in comparison with control. In the morphometrics and longevity of male and female adults of F1 to F10 generations also showed nonsignificant results. On histopathological examination of the control and treatment adult male and female insects showed no observable change in the head and mouth parts (Fig. 41), insect muscle, midgut from F1 to F10 generations. Thus, based on the above observations, it may be concluded that the feeding of the nanoparticles mixed diet had no adverse effect on the adult male and female insects for 10 generations when compared to insects fed with normal diets.

Characterization, functionalisation and assembly of nanosensors and their applications: IISc, Bangalore Funded

Pheromone nanosensors are required for early detection of pest (Fig. 40), to measure the concentration of pheromones in the field and to release pheromones from devices in appropriate quantity and time. The chemically functionalized nanosensor devices were fabricated with the IISc, group. These nanosensor devices conform to the acceptability of food for human consumption by following the food safety and standards authority of India (FSSAI) as per Chapter IV (20, 21). These nanosensors have no direct contact with food articles. These inventions also strictly follow the FAO/WHO food standards and follow the guidelines of the Hazards and Critical Control Points (HACCP) analysis, and Codex Alimentarius Commission. The ISO 22,000 uses the HACCP which ensures food safety for the entire farm to fork chain.

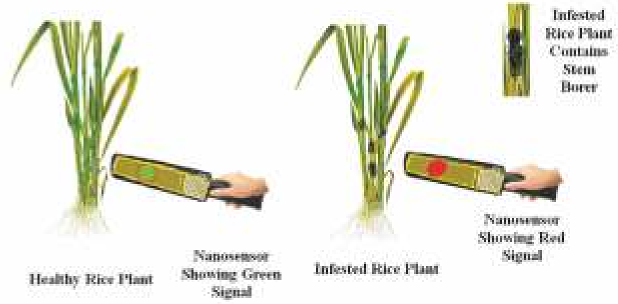

Fig. 40. Schematic representation of nanosensor utilizing volatiles of stem borers

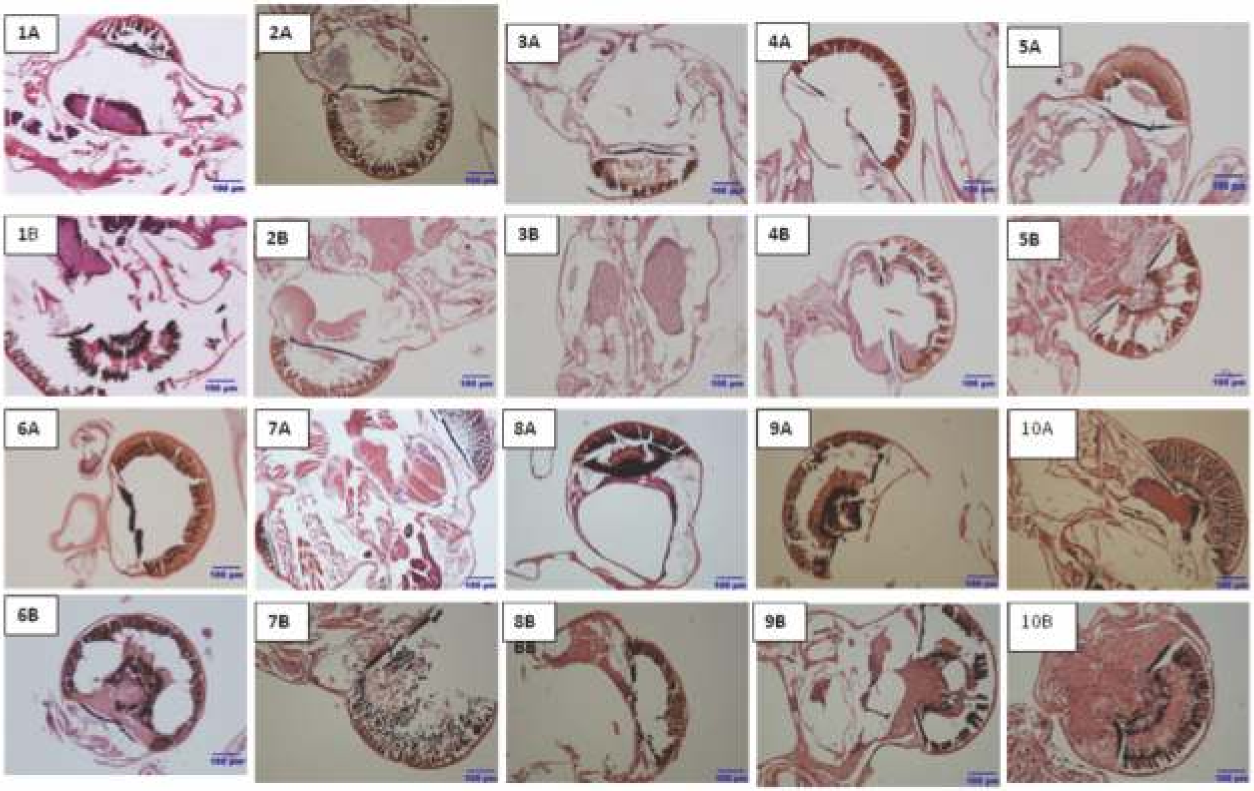

Fig. 41. A. Female mouth (Control), B. Female mouth (Treated) (H&E, scale bar = 100µm)

ALL INDIA COORDINATED RESEARCH PROJECT ON BIOLOGICAL CONTROL

Biodiversity of biocontrol agents from various agro ecological zones

Twenty two batches of *Trichogramma,* 9 batches of *Chrysoperla,* 5 batches of *Chelonus blackburnii,* 12 batches of coccinellids, and 19 batches of spiders were collected from South *Telangana* (ANGRAU). The natural enemies recorded were coccinellids, *Coccinella septempunctata, Menochilus sexmaculata, Scymnus coccivora*, *Encarsia flavoscutellum, Dipha aphidivora*, *Micromus igorotus*, syrphids on sugarcane woolly aphid in sugarcane, *Coccinella transversalis*, *M. sexmaculata, Brumoides suturalis*, *Scymnus coccivora,* and *Triomata coccidivora* in mealy bug colonies on custard apple, *Acerophagus papayae, Pseudleptomastix mexicana* and *Mallada boninensis, Spalgis epius* on papaya mealy bug and *Eublemma amabilis* on ber, a predator of lac insects.. The *Cryptolaemus* adults were recovered from the pre-released plots of custard apple. Amongst the target pests, *Pseudococcus jackbeardsleyi* was recorded on custard apple in the vicinity of Pune. Papaya mealybug, *Paracoccus marginatus* was also observed on pigeon pea and *Abutilon indicum* with enormous population of parasitoid *Acerophagus papaya* (MPKV).One species of *Chrysoperla,* 37 species of coccinellid beetles, 20 species of hymenopteran parasitoids of *Liriomyza trifolii* and/or *Chromatomyia horticola,* 3 species of predatory thrips, 2 of anthocorid bugs, 9 of syrphid predators and 9 of predatory mites were collected (YSPUHF).

The natural population of C. *montrouzieri* was observed throughout the year in a density dependent manner. Fifteen species of lady bird beetles were collected from different parts of East Siang District of Arunachal Pradesh (CAU).

The egg parasitoid was recovered from eggs of sugarcane top borer collected from Paddi Khalsa (Jalandhar) was identified as *Trichogramma japonicum*. About 7.5 to 35.8% of natural parasitization with *Trichogramma* was obtained on sentinel cards collected from the fields of maize at Hoshiarpur and Ludhiana. In the cotton fields at Fazilka and Karni Khera, about 35% *Trichogramma* adults were obtained from naturally parasitized sentinel cards (PAU).

Rice

A total of 117 species belonging to 8 orders, 63 families of insects and spiders were collected and identified, of which 45 were pest species, 44 were predators, 24 were parasitoids and 4 were others. Three species of egg parasitoids *Tetrastichus schoenobii*, *Trichogramma japonicum* and *Telenomus* spp were observed on eggs of *S. incertulus* and *S. fuscifluaviz*,. The yellow hairy caterpillar *Psalis pennatula* was found in large numbers and 10 per cent larvae were parasitized by *Brachymeria* sp. In addition, natural enemies of rice pests have also been surveyed and collected from Chinsurah and Kalimpong in West Bengal. The red long winged planthopper, *Diostrombus polites* was abundant in Kalimpong. The dark headed borer, *Chilo polychrysus* and the grass web worm, *Herpetogramma* sp. were also recorded. The skipper *Parnara guttata* was prevalent with 75 per cent parasitisation by *Apanteles* sp. Fortnightly collection at DRR farm yielded 140 species of natural enemies of which 75 were predators and 65 parasitoids. The fungus causing mycosis in rice bugs (*Leptocorisa* sp.) was identified as *Acremonium lioliae* (KAU).

Vegetables

Phenacoccus solenopsis was the dominant mealy bug infesting tomato, brinjal, *Capsicum*, pointed gourd, okra and *Centrococcus insolitus* on brinjal. Two prominent endoparasitoids *viz*., *Aenasius bombawalei* and *Promuscidea unfasciativentris* (Hymenoptera: Encyrtidae) of *Phenacoccus solenopsis* were noted. Tritrophic interaction (Host plant – *P. solenopsis* – parasitoids) was observed during the recovery of the parasitoids from different hosts and highest cumulative recovery was obtained from tomato (33.67%) followed by okra (30.45%) (IIVR).

Plantation / condiments

The earwig, *Auchenomus hincksi* (Dermaptera: Labiidae) was noticed as egg predator of banana pseudo stem weevil. The earwigs *Paralabis dohrni*, *Charhospania nigriceps*, and *Euborellia shabi* (Dermaptera: Labiidae) were found feeding on eggs and early instar grubs of the banana rhizome weevil, *C. sordidus*. The coccinellid predators collected on the banana aphid were *Pseudaspidimerus trinotatus, Scymnus pyrocheilus*, *Jaurovia soror, Scymnus* spp., *Cheilomenes sexmaculata* and *Sticholotis* sp. In pepper, spiders like *Bavia kairali*, *Oxyopes javanus* and *Oxyopes swetha* were found predating on pollu beetle (KAU).

Papaya

In Kerala the papaya mealy bug was low due to well established parasitoid *A. papayae*. The pest was also noticed in tapioca and *Hibiscus mutabilis*. Parasitisation level of *A. papayae* on tapioca was upto 27.8 per cent (KAU).

Cotton

The parasitoid of flower midge was identified as *Ecrizotomorpha* sp. (UAS-R).

Spiders

A total of 207 spider specimens was collected both by pitfall trap as well as general collection from rice ecosystem (AAU-A). Eleven families, 25 genera and 34 species of spiders were recorded in Kashmir. The highest species richness was recorded in family Araneidae (7 species) followed by Tetragnathidae (5 species) and Salticidae (5 species). The relative abundance of visual hunters (51.62%) was highest. The dominant spider species recorded in Kashmir were *Pardosa altitudis, Theridion* sp. *Araneus anantnagensis and Tetragnatha mandibulata* (SKUAST).

Seasonal abundance of predatory spiders in rice ecosystem was worked out using quadrat method. Overall highest species richness was observed for *Neoscona theisi* (138) and *Leucauge* sp. (134) followed by *Tetragnatha javana* (79), *Argiope sp.*(74), *Cyrtophora cicatrosa* (74), *Leucange celebesiana* (72), *Argiope anasuja* (70) and *Leucauge decorate* (66). Shannon-Weiner index of diversity was calculated as 2.95 in Kheda and 2.43 in Anand district. Among the different species of predatory spiders, Araneidae was predominant followed by Tetragnathidae and Salticidae (AAU-A). Seven genera of spiders were collected during the *Kharif* and *Rabi* seasons from five locations in Rajendranagar. *Tetragnatha* was found to be most abundant genus followed by *Oxyopes*. *Thomisus* and *Atypena* were found to be least abundant (ANGRAU).

Temperate fruits

Forty species of natural enemies of 16 temperate fruit insect pests were recorded from Kashmir. Among 40 species of natural enemies, 17 species were parasitoids and 23 species were predators. *Aphidus* sp. was recorded from apple aphid, *Aphis spiraecola* and *Trioxys* sp. from Walnut aphid, *Calipteras juglandis*. Twenty three predators of temperate fruit insect pests were recorded which belongs to coccinellids, chrysopids, spiders, and syrphid flies (SKUAST).

EPN

One entomopathogenic nematode, was isolated from a mango orchard in Sitapur district, Uttar Pradesh and it has been designated as *Steinernema* sp. (strain CISH 3) (CISH).

PGPR/ plant disease antagonists

Fifty one isolates of *Pseudomonas fluorescens* were collected and characterized for their plant growth promoting rhizobacteria (PGPR) activity. BOX PCR using BOX A1R primer was employed to study the closeness of screened isolates. Among the isolates tested Pf 14 was found to produce highest amount of Indole Acetic Acid (CAU).

Surveillance for alien invasive pests (all centres)

The papaya mealybug *Paracococcus marginatus* and Jack Beardsley mealybug *Pseudococcus jackbeardsleyi* were recorded (TNAU). In cotton growing areas of Telangana *Phenococcus solenopsis* was predominant over *Meconellicoccus hirsutus. Paracoccus marginatus* was noticed in field crops (ANGRAU).

Survey in sugarcane indicated an incidence of up to 14.8% by sugarcane woolly aphid (SWA) / 6.25 sq.cm leaf area during July to December 2013 (TNAU). The incidence of SWA ranged from 5 to 10 % in Bidar, Gulbarga and Bellary districts while its incidence was nil in Raichur and Koppal districts (UAS-R). Papaya fields in seven villages were found infested with *Paracoccus* mealybug (AAU-A).

Invasive pests were not found in tobacco agro-ecosystem (CTRI). Mealybugs collected from different crops were identified as *Phenacoccus solenopsis* (Host: Bhendi), *P. solenopsis* (Host: Brinjal), *P. solenopsis* (Host: Beet root), *Geococcus coffeae* (Host: *Coleus*) and *Rastrococcus iceryoides* (Host: Cowpea). No invasive pests have been reported (KAU).

Biological suppression of pest and diseases in field

Biological suppression of diseases and nematodes

Cost-effective WP/EC based *Trichoderma* (Th-14) formulations and efficient delivery system were developed. Significantly higher sporulation was observed in *Jhangora* grains amended with 5% jaggery ($3.2x10^{10}$ spores/g). Among liquid media, maximum sporulation was observed in jaggery medium ($3.94x10^8$). Jaggery and NH4SO4 were found as the best carbon and nitrogen sources for maximum sporulation ($1.6 x 10^9$ and $1.5x10^9$ spores/ ml respectively). PDB and jaggery medium with a pH of 5.5 amended with sugar (2%) as carbon and NH4SO4 (0.01%) as nitrogen sources along with MgSO4 (0.05%) and NaCl (0.1%) as a source of micronutrients significantly increased the sporulation. (GBPUAT).

The wheat plants treated with inducer rhizobacteria (seed and soil treatment) and artificially inoculated with the pathogen (*Bipolaris sorokiniana*) showed less disease severity as compared to control. Maximum decrease in disease severity was observed in the PFa-50 (51.34%)(GBPUAT).

Field evaluation of promising *Trichoderma* isolates for the management of soil-borne and foliar diseases in different crops was undertaken. In rice the brown spot disease severity was significantly reduced by *Trichoderma* isolates TCMS 5 (17.3%) and TCMS 14a (18.3%) as compared to check (48.0%). Fungicide compatibility test with *Trichoderma* showed that mancozeb, Captaf, Thiram, chlorothalonil and copper hydroxide were compatible with the test antagonist up to 100 µg a.i. /ml, as these fungicides did not affect the growth of test antagonist. The growth inhibition by these fungicides observed was from 2.3-39.1 per cent (GBPUAT).

Bio-efficacy of CHF *Pf*-1 was evaluated against bacterial wilt of brinjal caused by *Ralstonia solanacearum.* Application as seedling root dip @25g / L of water dipping for 30 minutes before transplanting +soil drenching@ 2.5g / L of water at 20 days after transplanting (DAT) recorded lowest wilt incidence with14.75% wilted plants compared to streptomycin (19.83%). The highest yield of 244.55q/ha was also recorded in CHF *Pf*-1 treatment (CAU).

Biological suppression of pests in cereals and pulses

Rice

The incidence of yellow stem borer, green leafhopper (GLH) and other foliar pests were significantly less in IPM package with significant increase in yield over the farmers' practice. In IPM package, the dead heart, white ear, leaf folder, case worm, skipper and GLH population were significantly lower than that of the farmers' practice (OUAT). Cage studies were conducted for evaluating the effectiveness of different entomopathogens against rice bug adults and nymphs. Only *Metarhizium anisopliae* @ $2x10^8$ spores/ ml & $2x10^9$ spores/ ml was found causing mycosis on rice bugs (KAU).

Sugarcane

Sugarcane woolly aphid incidence was low (0.88%) in western Maharashtra. The predators mainly observed on SWA were *Encarsia flavoscutellum* (1.2-30.6 adults/leaf), *Micromus igorotus* (0.9-5.3 grubs/leaf), *Dipha aphidivora* (0.6-2.6 larvae/leaf), syrphids and spiders (MPKV). Eight releases of *T. chilonis* (tts)@ 50,000 per ha at 10 days interval during mid-April to end June reduced the incidence of early shoot borer by 54.9 % and top borer by 52.2%. 12 releases of *T. chilonis* @ 50,000 per ha at 10 days internal during July to October reduced the incidence of stalk borer by 52.3 % (PAU).

Sorghum

Application of *Metarrhizium anisopliae* (Ma 36 @ 5ml/l) at 20, 45 DAE during Rabi 2013-14 resulted in 18.0% reduction of deadhearts over control and was on par with whorl application of carbofuran granules @ 8 kg/ha at 20 DAE(DSR).

Pigeonpea/pulses

Spraying of *Bt* strain NBAII-BTG4 @ 2% thrice at fortnightly interval was statistically comparable with chlorpyriphos 0.05% in reducing pod damage (11.8%) of *H. armigera* and *Maruca testulalis* and increased the yield (14.8 q/ha) of pigeon pea (MPKV).

Pooled results of three years data on pod damage revealed that significantly least damage (4.90 %) was observed in plots treated with chlorpyriphos. However the plots treated with PDBC-BT1 @ 2% showed minimum (6.79%) damaged pods. Pooled data computed for grain yield indicated that maximum (1841 kg/ha) yield was registered in plots treated with chemical insecticide followed by NBAII-BT G4 2% (1761 kg/ha) and 1% (1680 kg/ha) (AAU-A).

Among all the bioagents tested against pod borer, the NBAII - BTG 4 *Bt* @ 2g/lit was found effective which recorded 10.84 per cent pod damage and it was statistically superior over other bioagents. The treatment recorded significantly higher grain yield of 14.88 q/ha than other treatments (UAS-R).

Biological suppression of pests in oilseeds

Soybean

Spraying of *Sl*NPV @ 250 LE/ha (1.5 x 10^{12} POBs/ha) thrice at fortnightly intervals was statistically superior in suppressing the infestation of *Spodoptera litura* (4.76 larvae/m row)with 78.0 per cent larval mortality and gave maximum of 21.95 q/ha yield of soybean (MPKV).

Safflower

Three sprays of *Metarhizium anisopliae* @ 10^{13} conidia/ha at fortnightly intervals was the next best treatment to dimethoate@ 0.05% being superior in suppressing the aphid population and increased the yield (10.9 q/ha) (MPKV).Bio suppression of safflower aphid, *Uroleucon compositae* was achieved through two sprays of *Verticillium lecanii* 1.0 % WP in non spiny safflower. Neem oil 5% spray also proven to be promising (ANGRAU).

Cotton

In Pune the mealy bug *Phenacoccus solenopsis* was observed at low intensity on cotton during 2013-14, but, it was also noticed on parthenium, hibiscus, marigold and tomato. It was also in association with *Aenasius bambawalei* during November - December 2013.With regard to incidence of sucking pests peak incidence of jassids and thrips was noticed during 46th MW and white flies in 47th and 48th MW. Aphid population was maximum during 47th MW. Natural enemies *viz.*, coccinellids (*M. sexmaculata*, *C. septempunctata*) and spiders were recorded from 1st week of October to 4th week of November 2013 and *C. zastrowi sillemi* observed from 39th MW (MPKV).

Biological suppression pests in vegetables

Tomato

Btk @ 1kg/ha and two sprays of *Ha*NPV @ 250 LE/ha produced higher tomato fruit yield (MPAUT). The incidence of fruit borer was 6.4 to 8.6% in BIPM as compared to 14.2 to 15.8% in farmers practice at 75 to 105 DAT. The fruit yield (36.80t/ha) was significantly higher in BIPM plot as compared to farmers practice (32.45t/ha) with a cost benefit ratio of 1:3.2. Abundance of *Chrysoperla* and coccinellids was noticed in BIPM demonstration plot (TNAU).

Brinjal

Two sprays of NSKE and six release of *Trichogramma chilonis* in brinjal significantly reduced the fruit and shoot damage by sucking pests (MPAUT). The biointensive IPM practice produced net return over the farmers practice in the range of ₹1,06,830 to 1,24,800 indicating the superiority of IPM package over the farmers' practice (OUAT). Among the biocontrol agents, *Brumus suturoides* @ 1500/ha, *Scymnus*@ 1500/ha and *Cryptolaemus* @ 1500/ha significantly reduced the population of mealybug over control (TNAU).

The BIPM module consisting of release of *T. chilonis* @ 50,000 parasitoid/ha followed by spraying of NSKE 5% and *B. thuringiensis* @ 1 L./ha twice at weekly intervals starting from 45 days after transplanting was found to be significantly effective in suppressing the shoot (10.6%) and fruit (15.3%) infestation and increased the marketable fruit yield of brinjal (217.8 q/ha) (MPKV).

Cabbage

Maximum reduction (68.2%) of cabbage aphid in polyhouse was achieved by five, weekly releases of 2nd instar grubs of *Coccinella septumpunctata* @ 5/plant. The maximum yield/plot was 23.75 kg when treated with Dichlorovas @ 1ml/L which was statistically similar to *C. septempunctata* treated plot (23.50 Kg) (SKUAST).

Cauliflower

Bt formulations *viz.*, PDBC - BT 1 and NBAII BTG 4 @ 1 and 2% were significantly superior in reducing the larval population of diamondback moth by 85.48 to 90.88% over control. The highest yield of 17.8 t/ha was recorded in NBAII - BTG 4 @ 2% spray which was on par with other Bt formulations and chlorpyriphos treatment (TNAU).

Potato

Local and NBAII entomopathogenic fungal strains were evaluated against soil insects in potato. Imidacloprid @ 20 g ai/ha could significantly reduce infestation of potato tubers by *Dorylus orientalis* (10.25 %) and *Agrotis ipsilon* (11.25 %). Out of different bio insecticides, *Ma*-4,*Bb*-23 and *Bb*-5a of NBAII strains showed good results in reducing the infestation of *D. orientalis* with 19.0, 19.25, and 19.75 % infested tubers. Imidacloprid @ 20g ai/ha (11.25%) and malathion @ 40kg/ha dust (13.50%) significantly reduced the population of cutworm, *Agrotis ipsilon*. Maximum yield (83.90 q/ha) was obtained in the plots treated with imidacloprid followed by *Ma*-4 NBAII strain (83.12 q/ha), and malathion dust (79.37 q/ha) and the treatments were found to be at par with each other (AAU-J).

Biological suppression of pests in fruit crops

Mango

Spraying of *Metarhizium anisopliae* @ 1 x 10^9 spores/ml with adjuvant (sunflower oil 1 ml/L + Triton X 100 @ 0.1 ml/L) during offseason in December followed by four sprays of entomopathogenic fungi at weekly intervals during flowering (January-February) was found significantly effective in suppressing the hopper population (10.6 hoppers/ inflorescence) and increased fruit set (11.8 fruits/ inflorescence) in mango (MPKV). Talc formulation of *M. anisopliae* (IIHR strain) @ 1kg/100L recorded 77.1 % mortality of mango hoppers (TNAU). At IIHR, Bangalore different formulations of *M. anisopliae* along with chemical and botanical insecticides were evaluated against mango hoppers. Significant reduction in hopper population was found in Imidacloprid @ 0.3ml/L sprayed trees followed by Nimbicidin @0.3 % sprayed trees. Liquid and talc formulations of *M. anisopliae* were on par in reducing the hopper population and these treatments were significantly superior to control. There was no significant difference between treatments in fruit set (KAU).

Custard apple

Release of *Scymnus coccivora* @ 10 grubs per tree twice at monthly intervals was found effective in reducing the mealybugs *M. hirsutus* and *F. virgata* and increased the yield of marketable custard apples (34.9 kg/tree)(MPKV).

Papaya

Papaya mealybug incidence was 12.8 to 21.0% in five districts of Maharashtra. Besides eight predators, the parasitoid *Acerophagus papayae* and *Pseudleptomastix mexicana* were observed in the mealy bug colonies. The pest incidence was recorded from April to December 2013 with peak (14.6-25.0%) in June (MPKV).

Citrus

Field evaluation of EPNs including five local collections as stem injection @50 ijs/mL of water and as cadaver application against citrus trunk borer, *Anoplophora versteegi* were carried out at two locations *viz.* Pasighat and Ringging of Arunachal

Pradesh. CAU-1 stem injection showed 37.22 and 36.43 per cent reduction at Pasighat and Rengging, respectively. However, EPNs were found inferior to stem injection with dichlorvos 0.05 per cent and stem injections were more effective (CAU).

Apple

Field releases of *Trichograma embryophagum* + *T. cacoeciae* @ 100,000/ha against codling moth (*Cydia pomonella*) in apple orchard of Kargil recorded maximum mean reduction of fruit damage (23.5 %). However, the combined effect of *Trichograma embryophagum, T. cacoeciae* and pheromone trap revealed maximum reduction of fruit damage (27.66%) at Kargil. Mass trapping of codling moth (*Cydia pomonella*) through pheromone traps in apple orchards of Kargil recorded highest population (48.5/ trap) in Mangmore in the month of July (SKUAST).Among different biopesticides, *Metarhizium anisopliae* (10^6 conidia/cm²) was the most effective in controlling apple root borer, *Dorysthenes hugelii* resulting in 82.6 % mortality of larvae and was on par with chlorpyriphos (0.06%) which killed 87.5 % of the grubs (YSPUHF).

Pineapple

Beauveria bassiana, Metarhizium anisopliae and *Lecanicillium leacanii* were evaluated against pineapple mealybug, *Dysmicoccus brevipes* (Cockerell). Mycosis was noticed only in treatments with *L. leacanii* @ 10^8- 10^9 spores/ ml(KAU).

Banana

Beauveria bassiana(10^8 spores/ml) and *Metarhizium anisopliae* (10^8 spores/ml) were found causing good mycosis on grubs of banana pseudostem weevil (KAU).

Biological suppression of pests in plantation crops

Tea

Beauveria bassiana (IIHR isolate) was evaluated against tea mosquito bug, *Helopeltis theivora*. Thiamethoxam @ 30 gm ai/ha was found superior to *B. bassiana* (IIHR strain) in reducing the *H. theivora* population in tea after 30 days of second spray. No significant difference was noticed in reducing the *H. theivora* population with *B. bassiana* IIHR strain (15.75/10 plants) pestoneem (16.25/10 plants) and commercial formulation of *B.bassiana* (17.25 /10 plants) (AAU-J).

Coconut

Coconut leaf eating caterpillar (*Opisina arenosella*) infestation in Trivandrum during April 2013 with 74.4% leaf damage was brought down to 16.7% over a period of nine months by release of larval parasitoids, *Goniozus nephantidis* and *Bracon brevicornis.* Awareness programmes through field based farmers interactive meetings (nine programmes) and mass media utilization were done for technology transfer (CPCRI).

Tapioca

BIPM module evaluated against *Aleurodicus dispersus* on cassava recorded a lower population of *A. dispersus* (76.93 per 5 plants) as compared to farmer's practice (226.11 per 5 plants) and untreated check (320.96 per 5 plants). Maximum yield was recorded from BIPM module (36.79 t/ha) as compared to untreated check (21.60 t/ha). The net profit and benefit cost ratio (BCR) were also higher in BIPM module (1:3.34) than the farmer's practice (1:2.41). *Encarsia guadalupae* was found to be the most effective parasitoid in the reduction of *A. dispersus* population both after first (82.6 per cent) and second releases (96.0 per cent) followed by *E.* sp. nr. *meritoria* in both the releases (79.6 and 92.2 per cent, respectively) (TNAU).

Biological suppression of polyhouse crop pests

The average initial root-knot nematode population in gerbera field ranged from 520 to 680 IJs/200 cm3 of soil. Treatment with *Paecilomyces lilacinus* @ 20 kg/ha was found to be most effective in reducing the root-knot nematode population (64.3 %) and gall index (52%)(MPKV).

Release of predatory mite, *Neoseiulus longispinosus* at 1:10 predator: prey ratio in carnation resulted in 91.2 % reduction of phytophagous mite population over untreated control and was also on par with fenazaquin (0.0025%) which caused 92.1 % reduction (YSPUHF). In rose treatment with *N. longispinosus* caused maximum reduction (69.6 %) of European red mite (*Panonychus ulmi* Koch) after 4th release of 30 predatory mite/plant. Maximum yield/plot (1173 cut flowers) was recorded in 30 predatory mites/plant/release which was statistically similar to Azadirachtin 3ml/L treated plots (SKUAST).

Blaptostethus pallescens @ 30 nymphs/ m row along with chemical control (Omite 300 ml/ acre) was found effective in managing two-spotted spider mite, *T. urticae* on okra under net house condition (PAU).

Spalgis epius (Lepidoptera: Lycaenidae) is a potential biological control agent of mealy bugs of various species. Fertilized eggs could be obtained under enclosed conditions in net house of 14m x 6m. Oviposition behaviour of *S. epius* in relation to host plants showed that the order of preference was Annona, guava and hibiscus. No egg could be recorded from potato sprouts and pumpkins. Pale green eggs were laid singly on all the host plants exposed. Females preferred to lay eggs in spaces in between the mealybug infestations (IIHR).

Biological suppression of storage pests in rice

Release of anthocorid predator, *Xylocoris flavipes* @ 30 nymphs per kg of stored rice (12.75 moths/jar) was significantly superior to all other treatments in reducing the emergence of *Corcyra* moths. Maximum number of living nymphs were recorded from the treatment of *X. flavipes* @ 30 nymphs/ jar (14.25) followed by *X. flavipes* @ 20 nymphs/ jar (9.50)(AAU-J). Release of anthocorid bugs in rice bins could effectively control the *Corcyra cephalonica* larvae. Nymphs of the bug *Xylocoris flavipes* performed better than those of *Blaptostethus pallescens* in minimizing the moths. Survivability of *X. flavipes* was more in the treatments where 20 nymphs were released followed by the bins where 30 nymphs were released (ANGRAU).

GENBANK ACCESSIONS OBTAINED AND DNA BARCODES DEVELOPED

Table 18. GenBank accessions obtained by NBAII

Organism	GenBank Accession Number
DNA Barcodes of insect pests (cox1) gene	
Culicoides innoxius	voucher AIN26002BLRVET01 (KF145176).
Culicoides huffi	voucher AIN26002BLRVET01 (KF145177).
Culicoides anopheles	voucher AIN26002BLRVET01(KF145178)
Culicoides palpifer	voucher AIN26002BLRVET01 (KF145179).
Culicoides circumscriptus	voucher AIN26002BLRVET01 (KF145180).
Amrasca biguttula biguttula	voucher GSV-1-NBAII (KF840682).
Bemisia tabaci	isolate ZSI-1 (JX417980)
Chrysomya megacephala	isolate MH2 (JX430024)
Myzus persicae	isolate ZSI-2 (JX417981)
Sarcophaga dux	isolate PB1 (JX430022)
Sarcophaga dux	isolate ND1 (JX430021)
Bactrocera correcta	voucher AIN26NBAII001 (KF289766)
Bactrocera dorsalis	voucher AIN26NBAII001 (KF289767)
Bactrocera zonata	voucher AIN26NBAII001 (KF289768)
Corcyra cephalonica	voucher AIN27NBAII001 (KF289769)
Galleria mellonella	voucher AIN27NBAII002 (KF289770)
Chilo partellus	(KC911712)
Helicoverpa armigera	(KC911713)
Nilaparvata lugens	voucher AIN18001AP1 (KC858992)
Spodoptera litura	(KC911714)
Phytomyza orobanchia	voucher AIN26002MP001 (KC732453)
Odontopus varicornis	voucher AIN19NBAII001 (KF289771)
Euwallacea fornicatus	voucher AIN22019TN1 (KC590061)
Chilo auricilius	voucher AIN27002CaLKO (KC306949)
Chilo sacchariphagus indicus	voucher AIN27004CsiLKO (KC306951)
Polyocha depressella	voucher AIN27003PdLKO (KC306950)
Scirpophaga excerptalis	voucher AIN27001SeLKO (KC306948)
Chrysomya sp.	OR-2012 isolate VET 24 (JX045647)
Sarcophaga sp.	OR-2012 isolate VET 16 (JX045646)
Plutella xylostella	KC911716
Sesamia inferens	(KC911715)
Leucinodes orbonalis	isolate Shimoga (KF453225)
Leucinodes orbonalis	isolate Bangalore (KF453226)
Leucinodes orbonalis	KF453228\
Leucinodes orbonalis	isolate Cuttack (KF453229)
Leucinodes orbonalis	isolate Guntur (KF453230)
Leucinodes orbonalis	isolate Khammam (KF453231)
Leucinodes orbonalis	isolate Port Blair (KF453232)
Leucinodes orbonalis	isolate Kholhapur (KF453233)
Conogethes punctiferalis	voucher AIN27008HaCa (KF114864)
Conogethes punctiferalis	voucher AIN27009HaGing (KF114865)
Conogethes punctiferalis	voucher AIN27010RaiCa (KF114866)
Conogethes punctiferalis	voucher AIN27011WayCad (KF114867)
Conogethes punctiferalis	voucher AIN27012BelCa (KF114868)
DNA Barcodes of natural enemies and pollinators (cox1) gene	
Apis dorsata	KJ513470

CHAPTER 5

Megachile anthracina	KF861940
Apis florea	KF817578
Apis cerana indica	F861941
Leptomastix nigrocincta	KJ489424
Megastigmus sp.	KF938926
Isolia indica	KJ489423
Sceliocerdo viatrix	KF938928
Cheilomenes sexmaculata	KF998579
Chilocorus sp.	KF938927
Scymnus nubilus	KF861939
Teleonemia scrupulosa	KF817579
Aprostocetus gala	KF817576
Aprostocetus gala	KF817576
Bracon hebetor	KJ 627789
Tetrastichus schoenobii	KJ 627790
Cacoxenus sp.	KF938925
Coccophagus sp.	KF938924
Amphiareus constrictus	KF817577
Xylocoris flavipes	KF365462
Buchananiella indica	KF383325
Blaptostethus pallescens	KF365463
Chelonus blackburnii	KF365461
Buchananiella indica	KF383326
Xylocoris flavipes	KF365462
Blaptostethus pallescens	KF365463
Amphiareus constrictus	KF817577
Diolcogaster sp. on *Terminalia catappa*	KC867699
Glyptapanteles clanisae Gupta from *Clanis phalaris*	KC990832
Microplitis (=*Snellenius*) *maculipennis* (Szepligeti)	KC867698
Dolichogenidea cinnarae	KC867700
Dolichogenidea cinnarae	KC953855
Endosymbionts of *Cotesia vestalis* (16s RNA)	
Pantoea sp.	KC582827
Pseudomonas sp.	KC4410591
Pseudomonas putida	KC589741
Pantoea sp.	KC582827
Bacillus cereus	KC582828
Bacillus sp.	KC582829
Bacillus sp.	KC512245
Bacillus sp.	KC512246
Bacillus sp.	KC139360
Enterobacter cancerogenus	KC139361
Uncultured *Pseudomonas* sp. clone CV-2	KC733870
Uncultured *Pseudomonas sp.* clone CV-4	KC733872
Uncultured *Pseudomonas* sp. clone CV-5	KC733873
Uncultured *Pseudomonas* sp. clone CV-6	KC733874
Phytoplasma	
Phytoplasma	KF709193
Endosymbionts of *Amrasca biguttula biguttula* (16s rRNA gene)	
Bacillus pumilus CLHA	KF958277

Enterobacter cloacae CLHR	KF971357
Enterobacter cloacae CLHK	KF971358
Filobasidium floriforme GLHK	KF971359
Bacillus licheniformis LH-H6	KJ148626
Staphylococcus aureus LH-Y1	KJ148627
Staphylococcus epidermidis LH-Y4	KJ398217
Janibacter anophelis LH-Y5	KJ398237
Bacillus aryabhattai LH-Y6	KJ398238
Bacillus cereus LH-Y7	KJ398239
Staphylococcus aureus LH-Y8	KJ398240
Micrococcus luteus LH-Y9	KJ398241
Staphylococcus aureus LH-Y11	KJ398242
Micrococcus luteus LH-Y12	KJ398243
Microbacterium imperiale LH-Y2	KJ398244
Bacillus aryabhattai LH-Y3	KJ398245
Agrococcus terreus LH-Y13	KJ197167
Bacillus cereus LH-H1	KJ197166
Bacillus subtilis LH-G1	KJ197168
Paenibacillus sp. LH-G4	KJ197169
Bacillus cereus LH-Ka1	KJ197170
Micrococcus sp. LH-Ka2	KJ197171
Staphylococcus warneri LH-Ka3	KJ197172
Staphylococcus hominis LH-Ka4	KJ197173
Bacillus stratosphericus LH-Ka5	KJ197174
Staphylococcus arlettae LH-Ka6	KJ197175
Staphylococcus hominis LH-Ka8	KJ197177
Pseudomonas stutzeri LH-Ka9	KJ197178
Bacillus pumilus LH-Ka10	KJ197179
Enterobacter sp. LH-Bac-C	KJ361468
Bothrogonia japonica RH	KJ361467
Bacillus subtilis A3-H2	KJ472525
Staphylococcus epidermidis A1-H5	KJ486551
Bacillus cereus A1-H6	KJ486552
Staphylococcus pasteuri A1-H7	KJ486553
Bacillus subtilis A4-H3	KJ486554
Bacillus amyloliquefaciens A1-H1	KJ534596
Bacillus altitudinus A3-H3	KJ534597
Rhodococcus equi A3-H4	KJ534598
Bacillus horikoshii A3-H4	KJ534599
Comamonas sp. A4-H2 (KJ534600)	
Vip 3A gene	
Bacillus thuringiensis strain TRBT-19	KC596007
Bacillus thuringiensis strain AgBT-15	KC596008
Bacillus thuringiensis strain BT D-2	KC596009
Bacillus thuringiensis strain NE-60	KC596010
Bacillus thuringiensis strain AgBT-25	KC596011
Bacillus thuringiensis strain BTEG-1	KC596012
Bacillus thuringiensis strain C3	KC596013
Bacillus thuringiensis strain TrBt 10	KC596014
Cry 11a gene	
Bacillus thuringiensis strain AsBT-12	KC596015
Bacillus thuringiensis strain BT-3	KC596016

Bacillus thuringiensis strain TrBt 10 *Bacillus thuringiensis* strain AgBT-6 *Bacillus thuringiensis* strain AgBT-4	KC596017 KC596018 KC596019
Cry 3a gene *Bacillus thuringiensis* strain BTAN 4 *Bacillus thuringiensis* strain BTAN-5 *Bacillus thuringiensis* strain TrBt 10 *Bacillus thuringiensis* strain TrBt 17 *Bacillus thuringiensis* strain ASBT 21 *Bacillus thuringiensis* strain ASBT20 *Bacillus thuringiensis* strain ASBT 24	 KC416617 KC416618 KC416619 KC416620 KC416621 KC416622 KC416623

Table 19. Insects and their Barcodes

GenBank Accession No.	DNA BARCODE	Barcode No. at BOLD
Amrasca biguttula KF840682		*AGIMP028-13*
Nilaparvata lugens KC858992		*AGIMP006-13*
Polyocha depressella KC306950		*AGIMP004-12*
Culicoides innoxius KF145176		*VETIP001-13*
Culicoides huffi KF145177		*VETIP002-13*
Culicoides anopheles KF145178		*VETIP003-13*

GenBank Accession No.	DNA BARCODE	Barcode No. at BOLD
Culicoides palpifer KF145179		*VETIP004-13*
Culicoides circumscriptus KF145180		*VETIP005-13*
Chilo partellus KC911712		*AGIMP007-13*
Helicoverpa armigera KC911713		*AGIMP008-13*
Spodoptera litura KC911714		*AGIMP009-13*
Sesamia inferens KC911715		*AGIMP010-13*
Plutella xylostella KC911716		*AGIMP011-13*
Conogethes punctiferalis Hassan castor KF114864		*AGIMP013-13*

GenBank Accession No.	DNA BARCODE	Barcode No. at BOLD
Conogethes punctiferalis Hassan ginger KF114865		*AGIMP016-13*
Conogethes punctiferalis Raichur castor KF114866		*AGIMP012-13*
Conogethes punctiferalis Wayanadu cardamom KF114867		*AGIMP015-13*
Conogethes punctiferalis Belgaum castor KF114868		*AGIMP014-13*
Euwallacea fornicates KC590061		*AGIMP018-13*
Phytomyza orobanchia KC732453		*AGIMP017-13*
Bactrocera correcta KF289766		*AGIMP022-13*
Bactrocera dorsalis KF289767		*AGIMP023-13*

GenBank Accession No.	DNA BARCODE	Barcode No. at BOLD
Bactrocera zonata KF289768		*AGIMP024-13*
Corcyra cephalonica KF289769		*AGIMP025-13*
Galleria mellonella KF289770		*AGIMP026-13*
Odontopus varicornis KF289771		*AGIMP027-13*

Insect Identification Services

The NBAII extends its services for the identification of insects to institutions, students and other individuals. This facility is however largely available for those insect groups in which taxonomic expertise is available at NBAII. Insects are also identified by networking with taxonomists from other parts of the country and the world.

Ichneumonoidea and Chalcidoidea (Ankita Gupta)

Y.S.R Horticultural University, Andhra Pradesh; NRC citrus, Nagpur; Calicut University, Calicut; UAS, Dharwad; DOR, Hyderabad; Directorate of Cashew Research, Puttur; IIHR, Bangalore; IGKV, Raipur, Chhattisgarh; Central Sericultural Research & Training Institute, Pampore, Srinagar; PCI Private Limited, Bangalore; National Research Centre for Grapes, Pune; , IIHR, Chettahalli; SKUAST-J, Main Campus, Chatha, Jammu; students from the University of Agricultural Sciences, Bangalore.

Aphididae, Diaspididae, Coccidae, Pseudococcidae (Sunil Joshi)

Central Sugarcane Research Station, Padegaon, Satara Dt, Maharashtra; CSIR- Institute of Himalayan Bioresource Technology, Palampur, Himachal Pradesh; Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, Maharashtra; National Research Centre for Orchids, Pakyong, Sikkim; Institute of Wood Science & Technology, Malleshwaram, Bangalore; College of Horticulture, Mudigere; Directorate of Groundnut Research, Junagadh, Gujarat; Dupont India Pvt. Ltd., Gurgaon, Haryana; Punjab Agricultural University, Ludhiana, Punjab; Central Plantation Crop Research Institute, Kasargod, Kerala; Sugarcane Breeding Institute, Coimbatore, T.N.; Sugarcane Breeding Institute, Coimbatore, T.N.; Univ. of Agricultural Sciences, GKVK, Bangalore; Anand Agricultural University, Anand, Gujarat; National Research Centre for Citrus, Nagpur, MS; Tamil Nadu Agricultural University, Thanjavur, T.N.; Indian Institute of Horticultural Research, Hessarghatta, Bangalore; Central Silk Board, Berhampore, West Bengal; Kerala Agricultural University, Thrissur, Kerala; Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra; University of Agricultural Sciences, Dharwad; Krishi Vigyan Kendra, Bangalore Rural; Central Horticultural Experiment Station, Chettahalli, Kodagu; ICRISAT, Patancheru, A.P.; Assam Agricultural university, Jorhat, Assam; National Research Centre for Grapes, Pune, Maharashtra; Assam Agricultural university, Jorhat, Assam; Plant Quarantine Station, Bangalore (MSIL Building), Bangalore; Central Silk Board, (REC), Srivilliputtur, Virudunagar, T.N.; Pest Control India, Bangalore; Regional Plant Quarantine Station, Chennai; Mumbai trees group, Goregaon, Mumbai.

Coleoptera (Coccinellidae, Curculionidae), Chalcidoidea (Encyrtidae, Aphelinidae, Chalcididae, Eulophidae), Hemiptera (Pentatomidae, Aphididae, Coccoidea) and Diptera (Tachinidae, Syrphidae) (J. Poorani)

UAS, Bangalore; Tripura University, Agartala; TNAU, Coimbatore, Tamil Nadu; Du Pont India; YSPUHF, Solan, Himachal Pradesh; AAU, Jorhat, Assam; Agri. College, Bijapur, Karnataka; UAS, Shimoga, Karnataka; ICIPE, Nairobi, Kenya; CCS Agrl. University, Hissar; Bihar Agricultural University, Sabour, Bhagalpur ; NRC Citrus, Nagpur; MPKV, Pune, Maharashtra: Govt. Degree College, Talwari, Chamoli, Uttarakhand; ARS, Dharwad, Karnataka; BCRL, Bangalore, Karnataka; ZSI-WRC, Pune, Maharashtra; BHU, Varanasi, Uttar Pradesh; IWST, Bangalore, Karnataka; UAS, Dharwad; , PAU, Ludhiana, Punjab; NRC Grapes, Pune, Maharashtra; NRC Grapes, Pune, Maharashtra; Eastern University, Sri Lanka; DRR, Hyderabad, Andhra Pradesh; students, journalists and photographers.

Diptera (Tephritidae) (K.J. David)

IIHR, Bangalore; National Institute of Plant Health Management, Hyderabad.

Hymenoptera (*Trichogramma; Trichogrammatoidea*) (Prashanth Mohanraj)

Indian Agricultural Research Institute, New Delhi; N.M.College of Agriculture,Navsari Agricultural University, Gujarat.

EXTENSION ACTIVITIES

Supply of live insects

A total of 980 consignments of host insects and natural enemies were supplied to KVKs, commercial units, students and research organisations generating a revenue of Rs 3,26,353 /- (Fig. 42).

Fig. 42. Monthly supply of live insects during 2013 - 2014

Supply of microbials and EPNs

A total of 48 microbials and EPNs comprising *Trichoderma harzianum*, *T. viridae*, *Pseudomonas fluorescens*, *Beauveria bassiana*, *Verticillium lecanii*, *Metarhizium anisopliae*, *Bacillus subtilis*, *Paecilomyces fumoroseus*, EPN infected *Galleria mellonella* as well as plant pathogens were shipped during the year generating a revenue of Rs. 2,16,500 /- . Thirteen commercial microbial formulations were subjected to quality analysis generating a revenue of Rs. 29, 211 /-. The total revenue generated was Rs. 2,45,711 /-.

A field day on utility of stress tolerant natural enemies was organised for farmers in Dharmapuri, Tamil Nadu on 22.02.2014

AWARDS AND RECOGNITIONS

Abraham Verghese was recognized as a Member, Board of Management, University of Agricultural and Horticultural Sciences, Shimoga

Abraham Verghese was awarded Fellow of Association for the Advancement of Biodiversity Science (FAABS)

Abraham Verghese was recognized as a Faculty in Jain University, Bangalore

Abraham Verghese was recognized as a Member, Post Graduate Centre for the revision of food and agriculture syllabus, Kuvempu University, Mysore

Abraham Verghese was nominated as Editor for the journal 'Insect Environment'

Abraham Verghese served as Editorial Advisor for the 'Newsletter for Birdwatchers' and the journal 'Current Biotica'

Abraham Verghese was member of IMC and RAC of NCIPM New Delhi

Abraham Verghese was member of IMC, NRC Pomegranate, Sholapur

Ballal C R, Joshi S, Bhaskaran T V, Lakshmi L, 2013, received the Best Paper Award for the paper entitled "Production protocols for indigenous ichneumonid parasitoids *Campoletis chlorideae* Uchida and *Eriborus argenteopilosus* (Cameron)" presented during the IOBC *MRQA 13th workshop on "Emerging Opportunities for the Mass Production and Quality Assurance of Invertebrates"*, Bangalore, India, 6-8 November, 2013.

Deepa Bhagat, Bakthavatsalam N, Srinivasa R, 2013, received Best Paper Presentation Award at the International Conference on water quality and management for climate resilient agriculture, 28th - 31st May, 2013 at Jain Irrigation, Jalgaon, Maharastra for the paper entitled "Release pattern of an infochemical, linalool under simulated climate change scenario" .

Deepa Bhagat was conferred a 'Fellow of CHAI' by the Confederation of Horticulture Associations of India, New Delhi, India.

Deepa Bhagat was recognized as Convener for the technical session entitled " Water needs for crop production and tools for enhancing productivity of water" during the International conference on water quality and management for climate resilient agriculture, 28th - 31st May, 2013 at Jain Irrigation, Jalgaon, Maharastra.

Ganga Visalakshy P N, Darshana C N, Swathi C, Krishnamoorthy A, 2013, received the Best Paper Award for the paper titled "Efficacy of formulations of *Metarhizium anisopliae* for the control of mango inflorescence hopper", presented at the symposium *Emerging Trends in Eco-friendly Pest Management, Centre for Plant Protection Studies,* Tamil Nadu Agricultural University,Coimbatore , 22-24 January, 2013.

Ganga Visalakshy P N, Swathi C, Darshana C N, 2013, received the Best Paper Award for the paper titled "Eco- friendly management of tea mosquito bug *Helopeltis antonii* on horticultural crops – possible alternatives" presented at the *International Conference on Plant Biochemistry, Biotechnology on Food and Nutritional Security and XII Convention of Indian Society of Agriculture Biochemists* , 11-14 December, Sri Venkateswara University, Tirupati.

Hemalatha B N, Venkatesan T, Jalali S K, Reetha B, Abraham Verghese, 2013, received the Best Paper Award for the paper titled " Endosymbiotic yeast, a dietary source for improved production of *Chrysoperla zastrowi sillemi"* presented at the 13th Workshop of the IOBC Global Working Group on Mass Rearing and Quality Assurance, Mövenpick Hotel & Spa, Bangalore, India, November 6–8, 2013.

Jalali S K, Venkatesan T, Rangeshwaran R, Sriram S, Srinivasamurthy K, Sivakumar G and Abraham Verghese were honored with the Team Award by the Society for Biocontrol, Bangalore for 'Development and Adoption of Stress Tolerant Natural Enemies Technologies' under NAIP-ICAR during the Field Day held at KVK, Dharmapuri, Tamil Nadu on 22nd February, 2014 .

Joshi S, Ballal C R, Lakshmi B L, 2013, received the Best Poster Award for the paper entitled "Development of a novel mass production technique for *Brumoides suturalis* (Fabricius) (Coleoptera: Coccinellidae), a predator of mealybugs" presented during the IOBC *MRQA 13th workshop on "Emerging Opportunities for the Mass Production and Quality Assurance of Invertebrates"*, Bangalore, India, 6-8 November, 2013.

Lalitha Y, Ballal C R, Patel V N, 2013, received the Best Paper Award for the paper entitled 'Quality assessment of mass reared *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae) based on field performance' presented during the *IOBC MRQA 13th workshop on "Emerging Opportunities for the Mass Production and Quality Assurance of Invertebrates"*, Bangalore, India, 6-8 November, 2013.

Nakat R V, MPKV Pune was conferred the " Krishi Gourav Puraskar Award" of Bharat Krishik Samaj , Maharashtra at Jalgaon, on 18.01.2013.

Ramya S L, Venkatesan T, Jalali S K, Srinivasa Murthy K, 2014, received the Best Poster Award for the paper titled "Biochemical mechanism of insecticide resistance in field populations of diamondback moth, *Plutella xylostella"* at the 2nd International Conference on Agricultural and Horticultural Sciences, at Hyderabad during 3-5 November, 2014.

Venkatesan T, Mahiba Helen S, Jalali S K, Srinivasa Murthy K, Lalitha Y, 2013, received the Best Paper Award for the paper titled "Rearing and evaluation of pesticide tolerant populations of *Chrysoperla zastrowi sillemi*. p.57-58. *In:* 13th Workshop of the IOBC Global Working Group on Mass Rearing and Quality Assurance, Bangalore, India, November 6–8.

Bakthavatsalam N acted as Chairman, Institute Review Committee of Indian Cardamom Research Institute, Myladumpara on 26.11.2013.

Bakthavatsalam N acted as external expert in the Selection Committee at the Institute of Wood Science & Technology, Bangalore.

Bakthavatsalam N acted as expert for review of work done by DBT Women Science Fellows.

Ballal C R acted as IMC member of NBAIM, Mau.

Ballal, C R acted Councillor for Plant Protection Association of India, 2014 – 2016.

Murthy K S was honored as a Fellow by the Society for Plant Protection Sciences, New Delhi.

Murthy K S was recognized as a Guide, Department of Zoology, University of Mysore, Mysore.

Ramanujam B was recognized as a Member of Board of Studies, Department of Microbiology, Sri Krishnadevaraya University, Anantapuramu, Andhra Pradesh.

Rangeshwaran R was recognized as a Guide, Department of Microbiology, University of Mysore. Also recognised as Guide, Department of Microbiology, Jain University, Bangalore.

Venkatesan T was recognized as a Guide, Department of Biotechnology, Jain University, Bangalore.

EXTERNALLY FUNDED PROJECTS

DBT project

1 Nanoparticles for enhancing shelf life/storage and field application of semiochemicals (29/9/2010 To 29/9/2013)

2 Characterisation, Functionalisation and Assembly of nanosensors and Their Applications as Pheromone Sensor for Pest Management (3/8/2012 To 31/8/2015)

3 Studies on extending the shelf life and improving the delivery method of trichogrammatid egg parasitoids for promoting their commercial mass production in India (01.04.2013 – 31.03.2016)

IPR Project

4 Intellectual Property Management and Transfer/ commercialization of Agricultural Technology Scheme (upscalling of existing component i.e. Intellectual Property Rights (IPR) under ICAR Headquarters Scheme on Management on Information Services

5 ICAR- National Fund for Basic, Strategic and Frontier Application Research in Agriculture-Funded Project

6 Identification of nucleopolyhedrovirus (NPV) encoded protein and small RNAs and the feasibility of their expression in plant to control *Helicoverpa*

NAIP project

7 Effect of abiotic stresses on the natural enemies of crop pests *Trichogramma, Chrysoperla, Trichoderma* and *Pseudomonas* and mechanism of tolerance to these stresses (19/7/2008 To 30/6/2014)

8 National Agricultural Bioinformatics Grid for Insect Domain (31/3/2010 To 30/6/2014)

AMAAS project (ICAR)

9 Microbial Control of Insect Pests-II (AMAAS project continued) (1/4/2007 - 31/3/2017)

ICAR Cess fund

10 Network Project on Insect Biosystematics-NBAII (9/4/2012 To 31/3/2017)

Institute of Forest Genetics and Tree Breeding

11 Influence of eucalyptus species on the natural enemy incidence on the gall wasp *Leptocybe invasa.* (01.06.2011 – 31.03.2014)

Coffee Board

12 Ecofriendly approaches to the management of coffee white stem borer, *Xylotrechus quadripes* Chev. (01.07.2012 – 31.03.2015)

AICRP / COORDINATION UNIT / NATIONAL CENTRES

Large scale demonstrations and field testing of biological control technologies developed at NBAII are undertaken by the following ICAR institutes and State Agricultural Universities.

Headquarters

National Bureau of Agriculturally Important Insects, Bangalore	Basic Research

ICAR Institute-based Centres

Central Tobacco Research Institute, Rajahmundry	Tobacco and Soybean
Central Plantation Crops Research Institute, Regional Centre, Kayangulam	Coconut
Indian Agricultural Research Institute, New Delhi	Basic Research
Indian Institute of Horticultural Research, Bangalore	Fruits and Vegetables
Indian Institute of Sugarcane Research, Lucknow	Sugarcane
Sugarcane Breeding Institute, Coimbatore	Sugarcane
National Centre for Integrated Pest Management, New Delhi	IPM Related Research

State Agricultural University-based Centres

Acharya N.G. Ranga Agricultural University, Hyderabad	Sugarcane, coconut and vegetables
Anand Agricultural University, Anand	Cotton, pulses, oilseeds, vegetables and weeds
Assam Agricultural University, Jorhat	Sugarcane, pulses, rice and weeds
Dr Y.S. Parmar University of Horticulture & Forestry, Solan	Fruits, vegetables and weeds
Govind Ballabh Pant University of Agriculture & Technology, Pantnagar	Plant disease antagonists
Kerala Agricultural University, Thrissur	Rice, coconut, weeds, fruits and coconut
Mahatma Phule Krishi Vidyapeeth, Pune	Sugarcane, cotton, soybean and guava
Punjab Agricultural University, Ludhiana	Sugarcane, cotton, oilseeds, tomato, rice and weeds
Sher-e-Kashmir University of Agricultural Science & Technology, Srinagar	Temperate fruits and vegetables
Tamil Nadu Agricultural University, Coimbatore	Sugarcane, cotton, pulses and tomato

Voluntary Centres (partially funded)

Maharana Pratap University of Agriculture & Technology, Udaipur	Vegetables, white grubs and termite
Orissa University of Agriculture & Technology, Siripur, Bhubaneswar, Khurda	Rice and vegetables
Central Agricultural University, College of Horticulture & Forestry, Pasighat	Rice and vegetables

Voluntary Centres

Chaudhary Charan Singh Haryana Agricultural University, Hisar	Sugarcane
College of Agriculture, Kolhapur	White grubs and weeds
National Research Centre for Soybean, Indore	Soybean
National Research Centre for Weed Science, Jabalpur	Weeds
Navsari Agricultural University, Navsari	Sugarcane and coconut
Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar	Vegetables
University of Agricultural Sciences, Bangalore	Cotton and pigeonpea
University of Agricultural Sciences, Dharwad	Cotton and chickpea
Vasantdada Sugar Institute, Pune	Sugarcane

PUBLICATIONS

Peer Reviewed Articles

NBAII, Bangalore

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22nd Biocontrol workers' group meeting held at NBAII, Bangalore from 24-25 May, 2013

ONGOING RESEARCH PROJECTS

Institute Projects

No.	Project Title (Start Date To End Date)	PI
1.	Biodiversity of Aphids, Coccids and their Natural Enemies (27/8/2010 to 31/3/2016)	**Sunil Shankar Joshi**
2.	Biodiversity of Oophagous Parasitoids with Special Reference to Scelionidae (1/9/2008 to 31/3/2018)	**Veenakumari Kamalanathan**
3	Biosystematics and Diversity of Agriculturally Important Cerambycidae (3/10/2013 to 31/3/2017)	**Muthugounder Mohan**
4	Biosystematics and Diversity of Entomogeneous Nematodes in India (1/4/2012 to 31/3/2015)	**Jagadeesh Patil**
5	Biosystematics of Trichogrammatidae (10/4/2013 to 31/5/2017)	**Prashanth Mohanraj**
6	Development of Computational Tool for Prediction of Insecticide Resistance Gene in Agriculturally Important Insects (1/4/2012 to 31/3/2015)	**Pratheepa M.**
7	Digitization of Type Specimens in NBAII Reference Collections (1/4/2013 to 31/3/2015)	**Janakiraman Poorani**
8	Distribution of Abiotic Stress Tolerant Genes / Alleles Across Insect Orders (10/4/2014 To 31/3/2017)	**Pratheepa M.**
9	Diversity and Predator-prey Interactions With Special Reference to Predatory Anthocorids and Mites (24/3/2012 to 31/3/2017)	**Chandish R. Ballal**
10	Diversity of Economically Important Indian Microgastrinae (Braconidae) supported by Molecular Phylogenetic Studies (21/9/2010 to 21/9/2015)	**Ankita Gupta**
11	Exploitation of *Beauveria bassiana* for Management of Maize Stem Borer (*Chilo partellus*) and Tomato Fruit Borer (*Helicoverpa armigera*) through Endophytic Establishment (5/4/2014 to 31/3/2017)	**Bonam Ramanujam**
12	Genetic Diversity, Biology and Utilization of Entomopathogenic Nematodes (EPN) against Cryptic Pests (1/4/2012 to 31/3/2015)	**Mandadi Nagesh**
13	Influence of Infochemical Diversity on the Behavioural Ecology of Some Agriculturally Important Insects (3/10/2013 to 31/3/2017)	**N. Bakthavatsalam**

14	Insect Vector Components Influencing Phytoplasma Diseases (1/4/2012 to 31/3/2015)	**Sreerama Kumar Prakya**
15	Introduction and Studies on Natural Enemies of some new Exotic Insect Pests and Weeds (27/8/2010 to 31/3/2015)	**Shylesha Arakalagud Nanjundaiah**
16	Mapping Of The Cry Gene Diversity In Hot And Humid Regions Of India (1/4/2011 to 31/3/2015)	**Rajagopal Rangeshwaran**
17	Mechanism of Insecticide Resistance in *Leucinodes orbonalis, Leucopholis coneophora* (1/10/2012 to 31/3/2016)	**Muthugounder Mohan**
18	Microflora Associated with Insecticides Resistance in Cotton Leafhopper (*Amrasca biguttula biguttula*) (4/1/2012 to 31/3/2015)	**Gopalsamy Sivakumar**
19	Molecular Characterization and DNA Barcoding of some Agriculturally Important Insect Pests (6/4/2013 to 30/9/2018)	**Sushil Kumar Jalali**
20	Molecular Charatcerization and DNA Barcoding of Agriculturally Important Parasitoids and Predators (3/10/2013 to 31/3/2018)	**Thiruvengadam Venkatesan**
21	Molecular Profiling of Subterranean Insect Diversity (5/4/2014 to 31/3/2019)	**Srinivasamurthy Kotilingam**
22	Pollinator Diversity in Different Agro-Climatic Regions with Special Emphasis on Non-*Apis* Species (1/4/2012 to 31/3/2015)	**Shivalingaswamy Maharudrappa Timalapur**
23	Role of Microbial Flora of Aphids in Insecticide Resistance (1/10/2012 to 31/3/2016)	**Mahesh Shankarappa Yandigeri**
24	Semiochemicals for the Management of Coleopteran Pests (1/9/2010 to 31/3/2015)	**N. Bakthavatsalam**
25	Synthesis of Nanomaterials to Act as a Sensor for Semiochemcials in Pest Management (4/11/2013 to 31/7/2017)	**Deepa Bhagat**
26	Taxonomic Studies on Fruit Flies (Diptera: Tephritidae) of India (1/4/2012 to 31/3/2017)	**K . J. David**
27	Taxonomic Studies on Pentatomidae (Hemiptera: Pentatomoidea) of India with Special Reference to Pentatominae (14/3/2012 to 31/3/2017)	**S. Salini**

ACTIVITIES OF ITMU

Technologies Developed (2013-14)

S No	Technology
1	Promising antagonist of *Trichoderma harzianum* for management of chilli anthracnose disease
2	Powder based formulation of *Pseudomonas fluorescens* a DAPG producing abiotic stress tolerant isolate for rainfed and stressed agricultural soils
3	Closed system for mass production of predatory mites
4	A dispenser for the monitoring of Eucalyptus gall wasp , *Leptocybe invasa*
5	A plant volatile based attractant for enhanced attraction of fruit fly

Technologies Commercialized (2013-14)

S.No	2013-2014
1	Pesticide tolerant strain of predator *Chrysoperla zastrowi sillemi*
2	Multiple insecticide tolerant strain of egg parasitoid *Trichogramma chilonis*
3	High temperature tolerant strain of egg parasitoid *Trichogramma chilonis*
4	Novel insecticidal WP formulations of *Heterorhabditis indica* strain NBAII Hi1 for the biological control of white grubs and other soil insect pests
5	Novel wettable powder formulation of *Pochonia chlamydosporia* as bionematicide & methods thereof for scale-up production & down-stream processing for biological control of plant parasitic nematodes
6	Liquid formulation of *Bacillus thuringiensis* (NBAII-Bt1)
7	Bioformulation of salinity tolerant *Trichoderma harzianum* with biocontrol potential
8	Bioformulation of carbendazim tolerant *Trichoderma harzianum* with biocontrol potential
9	Promising plant growth promoting strain of *Bacillus megaterium* for vegetable crops

Revenue Generation

Source	2013-14 (Rs. in lakhs)	
Commercialisation of IP Protected Technologies		**11.25**
Commercialisation of non- IP Protected Technologies	Sale of bioagents	
	a) Macrobials	2.82
	b) Microbials	2.0
	Royalty	0.35
	Publications	0.35
	Fees and subscriptions	1.72
	Other Income	7.61
	Total	**14.95**
	Grand Total	**26.20**

NBAII Industry Meet

The Institute Technology Management Unit, NBAII and Zonal Technology & Management Unit, CIFT, Cochin in association with Society for Biocontrol Advancement, Bengaluru organized one day NBAII-Industry Interface Meet on 7th December 2013 at Bengaluru. The main objective was to showcase, promote and commercialize the biocontrol technologies such as *Trichogramma*, *Chrysoperla*, predatory mites and formulations of *Trichoderma*, *Psuedomonas*, *Bacillus,* Bt, EPN and others developed at this bureau to the industries, NGOs and other agripreneurs who are engaged in production of various biocontrol agents and formulations. The meet was attended by 50 industries and there were more than 100 participants. The meeting gave a bigger platform for NBAII to showcase technologies in the biocontrol market and increased our brand value.

M/s. Allwin Industries Pvt. Ltd., Indore, Madhya Pradesh (above) and
M/s. Agri Biocare Pvt. Ltd., Kerala (below) purchasing technologies developed at NBAII

CONFERENCE PAPERS

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MEETINGS AND DECISIONS

Institute Research Council

The Institute Research Council meeting of the NBAII, Bangalore was held from 9-10th May, 2013 and 4th June 2013, under the Chairmanship of Dr. Abraham Verghese, Director, NBAII, Bangalore. All the projects were discussed and the following recommendations made.

1. Gap identification and prioritisation of biodiversity of Agriculturally Important Insects (AII).
2. The work on biodiversity and conservation of AII to be intensified; suitable diversity indices and species richness to be reflected.
3. All coordinating centres must be contacted for sending insect specimens to NBAII.
4. Explore possibility to obtain specimens of spiders collected by Dr. Patel (Anand).
5. Proper proforma for submission of voucher specimens to be made. Time for identification of specimens to be indicated by the taxonomy unit. Consulting fees for identification services may be charged; this may be discussed in ITMU.
6. A note to be given for design and other facilities required for the museum at NBAII by the Systematics Division.
7. The commercial potential of yeasts identified as symbionts to be explored.
8. All taxonomists to give one set of insects collected to the Division of Molecular Entomology for barcoding. Common insects may be given to the Scientist-in-charge, farm for display.
9. All scientists who have projects with barcode objective to be included in two newly approved projects on barcoding as Co-PIs after date of approval, *i.e.*, June 2013 and objectives in their respective projects to be deleted. The portion of the work in existing projects to be carried out by respective scientists in these two new projects (Ankita Gupta, Prashanth Mohanraj, K. Veenakumari, Chandish R. Ballal, M. Nagesh, M. Mohan).
10. All data should be subjected to proper statistical analysis. Help of ARIS cell to be taken.

Research Advisory Committee

The 18th meeting of the Research Advisory Committee (RAC) was held on 1st March 2014 at NBAII, Bangalore.The meeting was chaired by Dr .C. A.Viraktamath and attended by the members Dr.P.K.Chakrabarty, Dr.Balwinder Singh, Dr. M. Venkat Rajam, Dr.K.P.Jayanth, Shri N.G. Lakshminarayan, Dr.Abraham Verghese and Dr.S.K. Jalali (Member –Secretary). The Heads of the three Divisions presented the salient achievements made in the various research projects during 2013 – 2014.The Chairman and members of the RAC were appreciative of the progress made in the research projects. The recommendations are detailed below.

RAC Recommendations

1. NBAII should have a scanning electron microscope (SEM) and ICAR may be approached for a special additional provision for this in the XII plan EFC.
2. Efforts may be made to have an inventory of potential invasives and availability of natural enemies in view of the responsibility given to NBAII for import and export of natural enemies.
3. As considerable effort has been made to develop excellent products for entomofungal organisms like *Metarhizium anisopliae* and

Lecanicillium lecanii, NBAII should approach DBT for funds to generate toxicological data, which will enable commercialization of these products.

4. NBAII should come out with pictorial field guides besides brochures on mass production of natural enemies.

5. NBAII should develop collaborative linkages for work on GM crops and other transformation work particularly in the light of research being carried out at NBAII on identification of insecticide resistance and bacterial toxin genes as well as endosymbionts of insects.

6. One scientist specialized in biotechnology may be posted at NBAII to take forward the advances being made in molecular entomological work.

7. Information system to be updated on a daily basis, which should also include information on invasives.

8. NBAII should serve as a hub for monitoring the import/export of insects.

9. Scientists trained abroad in specialized fields may be allowed to continue their work on the same lines on which they undergo training (within the mandate of NBAII) so that the time and money spent for foreign training is not wasted.

10. Royalty for commercialisation of EPNs and other technologies may be enhanced to at least 3%.

11. The repository of NBAII should be modernised to conform to international standards in view of it being designated a National Repository by the National Biodiversity Authority with designated scientists as Museum Keeper and Museum Curators.

12. Type specimens of species described by NBAII scientists should be deposited in the central repository of NBAII at one place.

13. Mealybugs affecting avenue trees and their natural enemies may be identified to help their management.

14. Illustrated field guides may be prepared for agriculturally important insects.

15. Work should be intensified to find out threshold levels for phytoplasma transmission through qPCR.

16. Work on management of chilli anthracnose at present restricted to South India should be extended to other chilli-growing areas in the rest of India such as Rajasthan, Punjab and Gujarat through AICRP-BC.

17. Work on biological control of stink bug of litchi may be taken up on a priority basis.

18. Technology for biocontrol in protected cultivation may be worked out.

19. Diversity of Bt toxin gene repository to be maintained with NBAII identity. Protocols to be devised to develop formulations containing new toxin genes for field evaluation.

20. PCR conditions may be changed to study the degenerative processes of the toxin genes.

21. To develop molecular signatures for all promising strains identified / developed / commercialized including stress resilient strains and isolates of fungal bionematicides.

22. Work on DNA barcoding to be intensified with a view to catch up with world scenario.

23. Studies on role of microflora / symbionts in host manipulation, strain variation, detoxifying enzymes, development of biotypes and insecticide resistance through aposymbionts may be intensified.

PARTICIPATION OF SCIENTISTS IN CONFERENCES, MEETINGS, WORKSHOPS, SYMPOSIA IN INDIA AND ABROAD

Symposia/Conferences/Seminars/Workshops attended
Abraham Verghese
Acarology session during the XVII Group Meeting of All India Network Project on White grubs and other Soil Arthropods held on July 11-12, 2013 at Rajasthan Agricultural Research Institute, Durgapur, Jaipur
Annual Conference of Vice chancellors of Agricultural Universities and ICAR Directors held at Baramati and Pune, Maharashtra from 19th to 21st January, 2014.
Annual Group Meeting of AICRP on Cashew held from 6th to 7th January, 2014 at Bidhan Chandra KrishiViswaVidyalaya, Kalyani, West Bengal.
Brainstorming session on Cassava Mosaic Disease and its Management at CTCRI, Trivandrum on 18th May, 2013.
Executive Development Programme on Leadership Development held from 25th to 29th June, 2013 at NAARM, Hyderabad.
Interactive Workshop on Administrative and Financial matters for the ICAR institutes located in Southern Region held at NAARM, Hyderabad from 9th to 10th December, 2013.
International Conference on Biodiversity, Bio-resources and Biotechnology held on 30th January, 2014 at Mysore.
Meeting on repeat study on assessment of post harvest losses of major horticultural crops, Animal and Fishery Products in Indiaat NASC complex, New Delhi on 29th August, 2013.
National Workshop on Problems and prospect of seed potato production system in India on 20th September and Group Meeting of AICRP Potato held on 21st Sep., 2013 at Central Potato Research Station, Patna.
National Conference on Biodiversity Conservation and Sustainable Management held at Kuvempu University, Shankaraghatta, Shimoga District on 25th March, 2014.
National level symposium on Emerging Trends in Eco-friendly Insect Pest Management held at TNAU Coimbatore on 24th Jan, 2014.
National Symposium on Recent Advances in Beneficial Insects at IINRG, Ranchi on 27th Nov., 2013.
National Consultation Meeting on Jackfruit jointly organized by ICAR and Kerala Agricultural University at Banana Research Station, on 1st June, 2013, Kannara, Kerala
National Citrus Meet held at NRC for Citrus on 12th August, 2013, Nagpur.
Participated in the Annual Group Meeting of All India Coordinated Research Project on Palms at Indira Gandhi KrishiVishwavidyalaya, Krishi Nagar, Raipur on 23rd and 24th July, 2013.
Workshop-cum-demonstration and Brainstorming Session on Bioremediation and Biocontrol Technologies for Weed Management organized by the Punjab State Council for Science and Technology, Chandigarh from 27th to 28th March, 2014.
Deepa Bhagat
Institute Management Committee Meeting of the National Centre for Integrated Pest Management, Pusa campus, 24th October, 2013, New Delhi.
Scientific meeting on "Nanotechnology in Agriculture -2013" at the Centre for Nano Science and Engineering, IISc, Bangalore 25th September 2013.IEEE workshop on Nanotechnology & Sensors at

CeNSE, IISc, Bangalore from 19th – 21st September, 2013.Brain storming session on "Prioritizing research areas on Nano-Bio-Information technology for development of North-Western Himalayan states & strengthening efforts in frontier sciences and practicing Hi-tech Research" from 12th -13th July, 2013 at Department of Molecular Biology & Genetic Engineering, CBSH, G.B.P.U.A & T., Pantnagar.Brain storming session on "Nanotechnology in Agriculture: Scope and its Current Relevance" on 23rd April, 2013 at NAAS Complex, New Delhi.
Chandish R. Ballal Fruit Growers' Meet – Growers' Researchers' interface meet at Attur Farm, NBAII on 22nd October, 2013. KVK National Conference at UAS, GKVK, Bangalore on 23rd October, 2013 and gave a lead presentation.National Business Meet on Plant Protection in protected cultivation of vegetables and flowers at Movenpick, Bangalore – 6th and 7th March, 2014.
K.S.Murthy NAIP Consultation Meeting on December 19, 2013at National Institute of Animal Nutrition *and Physiology,* Bangalore. 5th Consortium Advisory Committee Meeting of NAIP project on 8th November 2013 at NBAII.
M.Nagesh Workshop on "Strategic areas for research collaborations in the area of biological control, product develop. and technology transfer for pest management", organized by DOR, Hyderabad, July, 26-27, 2013.
Chandish R Ballal, T. Venkatesan, R. Rangeshwaran, K. Srinivasamurthy, G. Sivakumar, Abraham Verghese, Y.Lalitha Jagadeesh Patil, B.Ramanujam, A.N.Shylesha, Ankita Gupta Chandrikamohan (CPCRI), P.N.Gangavisalakshy (IIHR), R. V. Nakat(MPKV) Workshop of the IOBC Global Working Group on Mass rearing and Quality Assurance. Emerging opportunities for the Mass Production & Quality Assurance of Invertebrates. November, 6-8th 2013.Movenpick Hotel & Spa, Bangalore.
Chandish R. Ballal, Prashanth Mohanraj, T. Venkatesan, R. Rangeshwaran, K. Srinivasamurthy, G. Sivakumar, Abraham Verghese, Jagadeesh Patil, B.Ramanujam, A.N.Shylesha, M.Nagesh NBAII- Industry Meet on 7th Dec,2013, at Bengaluru
S.K. Jalali, T. Venkatesan, G. Sivakumar, Abraham Verghese Field day and Famers meet" on the success stories of stress tolerant biocontrol agents (under NAIP project) on 22nd February 2014.
All scientists XXII Biocontrol Workers' Group Meeting of the AICRP on Biological Control of Crop Pests, Diseases and Weeds" organised by NBAII at the Yelahanka Campus, Bangalore, 24-25 May 2013.
P. Sreerama Kumar National Symposium on Pathogenomics for Diagnosis and Management of Plant Diseases, 24-25th October, 2013. Central Tuber Crops Research Institute, Thiruvananthapuram, Workshop-cum-Demonstration & Brainstorming Session on Biointerventions: Focus- Bioremediation and Biocontrol Technologies for Weed Management", Organised by Punjab State Council for Science & Technology and Punjab Agricultural University, Hotel Chandigarh Beckons, Chandigarh, 27 March 2014
M Pratheepa Attended training on CLC Bio software (Phase-I) attended at IASRI, New Delhi during 26-30 August, 2013. Attended HPC administration training at NBFGR,Lucknow during 28-30 October, 2013.

B.Ramanujam	
National Business Meet on Plant Protection in Protected Cultivation of Vegetables and Flowers organized by IIHR, Bangalore on 6-7, March, 2014 and presented a invited talk on Biocontrol methods of management of diseases in protected cultivation.	
R. Rangeshwaran	
National meeting on Microbial Culture Collection, NBAIM, Mau, 10-12-13.	
T.M. Shivalingaswamy	
Advisory Council Meeting of the NBAFARA project at Bareilly 17 July 2013	
T.Venkatesan	
Meeting on Operational Research Project (ORP) on sucking insects at IIHR, Hessaraghatta, Bangalore on 24th August 2013.CAC meeting on "NAIP Workshop under component 4 project "Effect of Abiotic stresses on the Natural Enemies of Crop Pests: *Trichogramma*, *Chrysoperla*, *Trichoderma* & *Pseudomonas* & mechanism of tolerance to these stresses" at NBAII, Bangalore on 5th Nov. 2013.	
S.J.Rahman (ANGRAU)	
International Trade Fair and Directional Programme on Agriculture at HYTEX, Madhapur from 25-28, April, 2013	
P.N.Gangavisalakshy (IIHR)	
International Conference on Plant Biochemistry, Biotechnology on Food and Nutritional Security and XII Convention of Indian Society of Agriculture Biochemists (Dec 11-14, 2013). SVU, Tirupati	
C.V. Vidya (KAU), M.Kalyanasundaram (TNAU)	
National symposium on Emerging Trends in Eco-friendly Insect Pest Management held on 22nd to 24th January, 2014 at Tamil Nadu Agricultural University, Coimbatore.	
Neelam Joshi (PAU)	
International Conference in Entomology at Punjabi University, Patiala from 21-23rd February 2014	
Dr Usha Chauhan(YSPUHF)	
Asia Pacific Regional Symposium on "Entrepreneurship and Innovation in Organic farming," at Bangkok,Thailand w.e.f.2nd to 4th December,2013	
Overseas training	
M Nagesh, Principal Scientist	
NAIP-National Agricultural Bioinformatics Grid overseas HRD and capacity building in Bioinformatics, genomics, transcriptomics, from NBAII Domain for 3 months during September through November 2013. Genomics and Biotechnology Lab., Dept of Horticulture, Washington State University, Pullman, USA.	
M Mohan	
NAIP Open International Training on Biomolecules (Crop Science) from Sept. 18, - Dec. 16, 2013 under Department of Entomology, College of Agriculture, University of Kentucky, Lexington, USA.	
Mahesh S Yandigeri	
NAIP Opened International Training on Microbial Taxonomy from September 18 to December 16, 2013 at University of California Riverside and Agricultural Research Service, United States Department of Agriculture, Riverside, California, USA on the research topic Metagenome of 'Wolbachia' endosymbiont associated with tomato psyllid using BAC Libraries.	

Institute Training Programmes

Sl. No.	Programme	Course Coordinator	Duration
1	Development of DNA barcode of coconut lacebug *Stephanitis typicus* and *Proutista moesta*	T. Venkatesan	29.03.2013 to 06.04.2013
2	Mass production and quality control of *Trichoderma* and *Pseudomonas*	R. Rangeshwaran	18.06.2013
3	Mass production of biocontrol agents for the management of insect pests for Officers of Karnataka Department of Horticulture	C. R. Ballal	22.08.2013 to 23.08.2013
4	Detection and measurement of insecticide resistance including molecular aspects in insect pests	M. Mohan	02.09.2013 to 11.09.2013 23.08.2013
5	DNA isolation and PCR techniques	T. Venkatesan	07.09.2013 to 13.09.2013
6	DNA barcoding	S. K. Jalali	21.11.2013 to 23.11.2013
7	Rearing of biocontrol agents for NIPHM Scientist	C. R. Ballal	21.11.2013 to 23.11.2013
8	Eco-friendly management of white grubs and other soil arthropods using entomopathogenic nematodes	M. Nagesh	06.12.2013 to 13.12.2013
9.	Mass production of biocontrol agents for the management of insect pestsfor Officers of Karnataka Department of Horticulture	C. R. Ballal	28.01.2014 to 29.01.2014
10	"Bioinformatics: *In Vitro* to *In Silico* Approaches in Entomology" under the NAIP-NABG project was imparted to scientists of ICAR & State Agricultural Universities	M. Nagesh and M. Pratheepa	18.11.2013 to 30.11.2013

DISTINGUISHED VISITORS

NBAII

1. Dr. K. Bolckmans, Koppert Biological Systems, The Netherlands visited the NBAII and interacted with the scientists on 08.11.2013
2. Dr. C. Caceres, International Atomic Energy Agency, Vienna, Austria visited the NBAII and interacted with the scientists on 08.11.2013
3. Dr. P. De Clercq, Department of Crop Protection, Ghent University, Ghent, Belgium visited the NBAII and interacted with the scientists on 08.11.2013
4. Dr. C.J. Geden, USDA, ARS, Gainesville, Florida, USA visited the NBAII and interacted with the scientists on 08.11.2013
5. Dr.R.Gnaneswaran, Department of Zoology, University of Jaffna, Sri Lanka visited the NBAII and interacted with the scientists on 08.11.2013
6. Dr.T.Groot, Koppert Biological Systems, The Netherlands visited the NBAII and interacted with the scientists on 08.11.2013
7. Dr.J.Klapwijk, Koppert Biological Systems, The Netherlands visited the NBAII and interacted with the scientists on 08.11.2013
8. Dr. M. Manduchi, Bioplanet S.C.A, R&D, Italy visited the NBAII and interacted with the scientists on 08.11.2013
9. Dr.P.Maneesakorn, Plant Protection Research and Development Office, Department of Agriculture, Bangkok, Thailand visited the NBAII and interacted with the scientists on 08.11.2013
10. Dr.A.Pekas, R&D Senior Scientist, Biobest Belgium NV, Westerlo, Belgium visited the NBAII and interacted with the scientists on 08.11.2013
11. Dr. M. Prishanthini, Department of Zoology, Eastern University, Sri Lanka visited the NBAII and interacted with the scientists on 08.11.2013
12. Dr.S. Steinberg, BioBee Sde Eliyahu Ltd., R&D, Israel visited the NBAII and interacted with the scientists on 08.11.2013
13. Dr.R. Timmer, Radbout, Koppert Biological Systems, The Netherlands visited the NBAII and interacted with the scientists on 08.11.2013
14. Dr. L. Van den Driesche, R&D Senior Scientist, Biobest Belgium NV, Westerlo, Belgium visited the NBAII and interacted with the scientists on 08.11.2013
15. Dr.M. Vinobaba, Department ofZoology, Eastern University, Sri Lanka visited the NBAII and interacted with the scientists on 08.11.2013
16. Dr.A.Winotai, Plant Protection Research and Development Office, Department of Agriculture, Bangkok Thailand visited the NBAII and interacted with the scientists on 08.11.2013
17. Dr.R.S.Paroda, Former Secretary, DARE and DG(ICAR) chaired a meeting of the National Advisory Board for the Management of Genetic Resources and visited the laboratories on 10-11, October, 2013
18. Dr.S.Ayyappan, Secretary, DARE and DG (ICAR) inaugurated the 'Pollinator Garden' at the Yelahanka campus on 22.10.2013
19. Dr.N.K.Krishnakumar, DDG(Horticulture) visited the 'Pollinator Garden' and the laboratories at Yelahanka on 22.10.2013
20. Dr.Swapan Kumar Datta, DDG(Crop Science) inaugurated the 'Centre for Insect Bioinformatics (A High Performance Computing Facility)' on 23.10.2013

21. Dr.C.Chattopadhyay, Director, NCIPM, New Delhi visited the laboratories and farm at Yelahanka on 19.03.2014
22. Dr.M.S.Ladaniya, Director, NRC for Citrus, Nagpur visited the laboratories at Hebbal and Yelahanka on 19.03.2014
23. Dr.P.K.Chakrabarty, ADG (PP), ICAR, New Delhi inaugurated the 'Insectarium' and participated as a Member of the XVIII RAC meeting of the Bureau on 01.03.2014
24. Dr.C.A.Viraktamath, Chairman, RAC of this Bureau and Former Professor, Division of Entomology, UAS, Bangalore chaired the XVIII meeting of the Research Advisory Committee on 01.03.2014
25. Dr.Balwinder Singh, Professor and Head, Department of Entomology, PAU, Ludhiana visited the laboratories on 01.03.2014

AICRP Centres

AAU, Anand

1. Dr. B. Ramanujam, Principal Scientist, NBAII, Bangalore visited on 17-19 Jan. 2014

AAU, Jorhat

1. Dr. N. Bakthavastalam, Principal Scientist, NBAII, Bangalore visited on 28-04-2013.
2. Director of Research AAU, Jorhat visited Biological control laboratory, Department of Entomology, AAU, Jorhat on 12th July , 2013.
3. A group of students (28 nos) from Kokrajhar Govt. College from Department of Zoology visited the biological control laboratory on 20.8.2013.
4. A group of farmers (65 Nos) from Golaghat district visited the laboratory on 03.11.2013.
5. A team of Probationary officers (32 nos) from Tea Board visited the biological control laboratory on 10.11.2013.
6. Research Monitoring Team, AAU, Jorhat visited biological control laboratory on 21.02.2014

ANGRAU, Hyderabad

1. Dr. G.S. Dhillon, Vice Chancellor, PAU, Ludhiana visited on 25.10.2013 for active collaboration between ANGRAU Centre and PAU for commercialization of Technologies.
2. Dr. Abraham Verghese, Director, NBAII, Bangalore visited on 20.3.2014 for reviewing the progress of work; he also visited the experimental plots at ARS, Tandur (Rangareddy Dist.), A.P.

GBPUAT, Pantnagar

1. Dr. B. Ramanujam, Principal Scientist, NBAII, Bangalore visited on 17-19 January, 2014.

MPKV, Pune

1. Dr. Mohamed Saeed Alkhalila, AAU, Sudan visited the laboaratory on 01.4.2013 and discussed mass culturing of bioagents and other activities of the Biocontrol Laboratory.
2. Dr. (Ms.) Chandish Ballal, Principal Scientist, Head, Division of Ecology, NBAII, Bangalore visited the laboratory on 18.4.2013 and observed the mass culturing of bioagents and host insects and assessed the progress of research.
3. Dr. P. P. Dhar, Professor (Agril. Entomology), BCKVV, Nadia (W.B.) visited the Biocontrol Laboratory on 26.4.2013 and discussed aspects of the mass production of bioagents and entomofungal pathogens as well as other research activities.
4. Dr. B. R. Kawathekar, Retd. Professor (Agril. Entomology), MAU, Parbhani visited the Biocontrol Laboratory on 15.05.2013.
5. Dr.Anand Narangalkar, Head, Dept. of

Entomology, Dr. B. S. K. K. V., Dapoli visited the Biocontrol Laoratory on 20-21[st] July, 2013.

6. Dr. U. M. Waghmare, Head, Dept. of Entomology, M. K. V., Parbhani visited the Biocontrol Laboratory on 3.08.2013.

7. Dr. R. S. Pandit, Department of Zoology, University of Pune along with 15 M.Sc. students visited this laboratory on 05.08.2013 for observing work on the mass production of bioagents.

8. Dr. Kusumkar Sharma, ADG (HRD) ICAR, New Delhi visited the Biocontrol Laboratory on 14[th] September, 2013 and observed the research activities of the Centre.

9. Prof. M. M. Anwar, Former Director, N.R.C. on Seed Spices and Prof. of Research Management, NARAM, Hyderabad visited the Biocontrol Laboratory on 10[th] October, 2013 and observed the research activities of the Centre.

10. Dr. G. Subbaiah, Associate Dean, College of Agriculture, Bapatla (A.P.) reviewed the bioagent production activity in this laboratory on 08.11.2013.

11. Dr. P. Rajendra Prasad, Professor and Head, Department of Entomology, S. V. Agriculture College, Tirupathi (A.P.) visited the Biocontrol Laboratory on 08.11.2013 and reviewed the work on production of bioagents and their use in IPM of various crops.

12. Prof. R. Subhash Reddy, Agriculture Microbiology, ANGRAU, Rajendranagar, Hyderabad visited the Biocontrol Laboratory and discussed the use of bioagents in IPM programmes on 08.11.2013.

13. Dr. Abraham Verghese, Project Coordinator and Director, NBAII, Bangalore visited the Biocontrol Laboratory on 13 - 14 November, 2013 and reviewed the progress of research work assigned to the centre for the year 2013-14. He along with staff of the project visited the experimental plot as well as the papaya orchards surrounding Pune for observing the PMB infestation and its natural enemies.

14. Shri. P. A. Sathe, Regional Deputy Director (Sugar), Pune visited the Biocontrol Laboratory on 13.11.2013 and reviewed the use of bioagents in IPM on sugarcane.

15. Mr. Alex Taa, Koppert Biological Systems, India visited the Biocontrol Laboratory on 20.11.2013 and exchanged information on role of bioagents in IPM of various crops.

16. Dr. Ram Niwas, Professor and Head, Department of Meteorology, CCS, HAU, Hissar visited the Biocontrol Laboratory on 06.12.2013.

17. Mr.Uday Narayan Bhat, Koppert Biological Systems, India visited the Biocontrol Laboratory on 13.12.2013 and had discussions on the collaborative trials in polyhouse crops, A. C. Pune.

18. S.Permalloo, Divisional Scientific Officer, Entomology Division, Ministry of Agro-Industry and Food Security, Reduit, Mauritius visited the Biocontrol Laboratory and discussed the use of bioagents in IPM programmes with special emphasis on the control of the papaya mealy bug in Mauritius with the staff of this centre on 19.12.2013.

19. Dr. G. Prasad Rao, Dean (Retd.), KAU visited the Biocontrol Laboratory and discussed the use of bioagents in IPM programmes on 23.12.2013.

20. Dr. H.R. Sardana, Principal Scientist, NCIPM, Pusa, New Delhi visited the Biocontrol Laboratory on 09.01.2014.

21. Shri. Shivaji Chamkire and Shri. K.D. Lambe,

Influx AgroTech Pvt. Ltd., Pune visited the Biocontrol Laboratory on 10.01.2014.

KAU, Thrissur

1. Dr. N.K. Krishnakumar, Deputy Director General (Hort.), ICAR, New Delhi visited the scheme on 13.03.2014.
2. Dr. Abraham Verghese, Director, NBAII, Bangalore visited the scheme on 01.06.2013 and 06.032014.
3. Dr. Chandish Ballal, Principal Scientist & Head, Division of Ecology, NBAII visited the scheme on 12.11.2013.
4. Dr. K. Prathapan, Director, State Horticulture Mission, Kerala visited the scheme on 30.12. 2013.

PAU, Ludhiana

1. A delegation from the University of Faisalabad, Pakistan visited the laboratory on 30 November, 2013.
2. Students of the B. Sc. (Agri.) degree programme from the Baba Farid College, Bathinda, visited the laboratory on March 30, 2013.
3. Dr. T. Venkatesan, Principal Scentist, NBAII, visited the laboratory from 29-30 September, 2013.

OUAT, Bhubaneswar

1. Dr. PrashantMohanraj, Principal Scientist, NBAII, Bangalore visited the Biocontrol Laboratory from 19-21 November 2013.
2. Dr. Abraham Verghese, Director, NBAII, Bangalore reviewed the work done under the AICRP on Biocontrol from 3-4 December, 2013.

TNAU, Coimbatore

1. Dr. T.P. Rajendran, ADG (PP), ICAR, New Delhi visited Biocontrol Laboratory of the Department on 20.06.2013.
2. Dr.N.K.Krishnakumar, DDG (Hort.), ICAR, New Delhi visited on 22.01.2014 to inaugurate the National Symposium on "Emerging Trends in Eco-friendly IPM" on January 22, 2014.
3. Dr.Abraham Verghese, Director, NBAII, Bengaluru visited the Biocontrol, Biosystematics, Pheromone and Toxicology laboratories of the Department on 24.01.2014. He presented a lead paper at the National Symposium on "Emerging Trends in Eco-friendly IPM" conducted from 22-24 January, 2014.
4. Dr. J. Poorani, Pricipal Scientist, NBAII, Bangalore visited the Department on 22.01.2014 and presented a lead paperat the National Symposium on "Emerging Trends in Eco-friendly IPM"
5. Dr.S.Chelliah, Former Director, TRRI and Director of Research, TNAU visited on 27.1.2014 to deliver a motivation lecture to staff and students.
6. Dr.S.Sithanantham, Director, SABRC visited the Department at frequent intervals to discuss collaborative projects in biological control.
7. Dr. Stephen Samuel, Entomologist, Regional Coffee Research Station, Thandigudi visited the Department on 3.3.2014.

PERSONNEL

Sl.No.	Name	Designation
1.	Dr. Abraham Verghese	Director
2.	Dr. Prashanth Mohanraj	Principal Scientist (Agri. Ento.)
3.	Dr. (Ms.) Chandish R. Ballal	Principal Scientist (Agri. Ento.)
4.	Dr. N. Bakthavatsalam	Principal Scientist (Agri. Ento.)
5.	Dr. B. Ramanujam	Principal Scientist (Plant Pathology)
6.	Dr. (Ms.) K. Veena Kumari	Principal Scientist (Agri. Ento.)
7.	Dr. (Ms.) J. Poorani	Principal Scientist (Agri. Ento.)
8.	Dr. M. Nagesh	Principal Scientist (Nematology)
9.	Dr. A. N. Shylesha	Principal Scientist (Agri. Ento.)
10.	Dr. S. K. Jalali	Principal Scientist (Agri. Ento.)
11.	Dr. T. Venkatesan	Principal Scientist (Agri. Ento.)
12.	Dr. P. Sreerama Kumar	Principal Scientist (Plant Pathology)
13.	Dr. K. Srinivasa Murthy	Principal Scientist (Agri. Ento.)
14.	Dr. T. M. Shivalingaswamy	Principal Scientist (Agri. Ento.)
15.	Dr. Sunil Joshi	Principal Scientist (Agri. Ento.)
16.	Dr. R. Rangeshwaran	Principal Scientist (Agri. Microbiology)
17.	Dr. G. Siva Kumar	Senior Scientist (Microbiology)
18.	Dr. Mahesh Yandigeri	Senior Scientist (Microbiology)
19.	Dr. M. Mohan	Senior Scientist (Agri. Ento.)
20.	Ms. M. Pratheepa	Scientist SS (Computer Application)
21.	Dr. (Ms.) Deepa Bhagat	Scientist SS (Organic Chemistry)
22.	Dr. Gandhi Gracy	Scientist (Agri. Ento.)
23.	Dr. Ankita Gupta	Scientist (Agri. Ento.)
24.	Dr. K. J. David	Scientist (Agri. Ento.)
25.	Dr. S. Salini	Scientist (Agri. Ento.)
26.	Dr. Jagdesh Patil	Scientist (Nematology)
Technicians		
1.	Ms. Shashikala S. Kadam	Chief Technical Officer
2.	Dr. (Ms.) Y. Lalitha	Assistant Chief Technical Officer
3.	Mr. B. K. Chaubey	Assistant Chief Technical Officer

4.	Mr. Satandra Kumar	Assistant Chief Technical Officer
5.	Mr. P. K. Sonkusare	Senior Technical Officer
6.	Ms. B. L. Lakshmi	Senior Technical Officer
7.	Ms. L. Lakshmi	Senior Technical Officer
8.	Ms. S. K. Rajeshwari	Technical Officer
9.	Mr. H. Jayaram	Technical Officer
10.	Ms. R. Rajeshwari	Senior Technical Assistant (Laboratory Technician)
11.	Mr. P. Raveendran	Senior Technical Assistant (Laboratory Technician)
12.	Mr. P. Ramakrishna	Technical Assistant(Laboratory Technician)
13.	Dr. A. Raghavendra	Technical Assistant (Laboratory Technician)
14.	Mr. M. Chandrappa	Technical Assistant (Driver)
15.	Mr. R. Narayanappa	Technical Assistant (Generator Operator)
16.	Mr. P. Madanathan	Technical Assistant (Driver)
Administrative		
1.	Mr. J. N. L. Das	Administrative Officer
2.	Mr. T. A. Vishwanath	Finance & Accounts Officer
3.	Mr. P. Vanaraju	Assistant Administrative Officer
4.	Mr. K. N. Visweswara	Personal Secretary to Director
5.	Ms. S. Kaveriamma	Personal Assistant
6.	Mr. Ajit Desai	Assistant
7.	Mr. Eswar Reddy	Assistant
8.	Ms. Dipanwitha Deb	Assistant
9.	Ms. Uma	Junior Stenographer
10.	Ms. Nazia Anjum	Lower Divisional Clerk
11.	Ms. P. Anitha	Lower Divisional Clerk
12.	Mr. A. Vijaykumar	Lower Divisional Clerk
Supporting		
13.	Mr. Ramakrishnaiah	Skilled supporting staff
14.	Mr. V. Anjenappa	Skilled supporting staff
15.	Mr. C. Anjenappa	Skilled supporting staff
16.	Mr. Pamulu Nagaiah	Skilled supporting staff
Emeritus Scientist		
1.	Dr. M. Mani	

Infrastructure developed

Center for Insect Bioinformatics

The Center for Insect Bioinformatics was established at NBAII (Fig. 43). It is a High Performance Computing Facility for complicated and time consuming data analysis. The High Performance Computing facility at NBAII consists of 16 nodes of Linux based cluster with one master node. The storage capacity of each cluster is 96 GB and the master node with 40 TB and the total storage capacity is around 126 TB. Workstations have also been connected with this high performance computing facility with high-end software like CLC Genomics workbench, Discovery Studio, Geneious-R7, Codon-Code Aligner, DNAstar for advanced analysis in insect genomics, proteomics, interactomics and systems biology data.

Installation of Fermentors

Two fermentors (10L and 100L) were installed for the purpose of standardization of pilot scale production of microbial biocontrol agents (Fig. 44). This will also facilitate the training of entrepreneurs in mass production technology.

Fig.43. The High Performance Computing Facility at NBAII

Fig.44. Fermentors of different capacities at the NBAII Yelahanka campus

CHAPTER 20

EMPOWERMENT OF WOMEN

Women farmers from Kanakapura, Mandya and Hassan were given hands-on training in solid state mass production of the biocontrol agent *Trichoderma harzianum*. They were also exposed to simple production technology of *Pseudomonas*. The women were invited through the NGO 'Green Foundation' based in Kanakapura, Bangalore Rural District.

Women farmers learning the solid state fermentation technology for *Trichoderma*

EXHIBITIONS CONDUCTED / PARTICIPATED

The NBAII participated in the following exhibitions / melas to showcase research technologies of NBAII

- The 8th KVK National Exhibition at GKVK, Bangalore from 23-25 October, 2013.
- *Krishi Mela* held at UAS, Bijapur from 5-6 January, 2014.
- *Krishi Vasant* held at CICR, Nagpur from 9-13 February, 2014.
- *Pusa Krishi Vigyan Mela* held at IARI, New Delhi from 26-28 February, 2014

Dr. S. Ayyappan, Director General, ICAR inaugurating the NBAII exhibition during the entrepreneur's meeting held at NBAII research complex, Attur, Bangalore on 22nd October 2013

Sri H.R. Bhardwaj, Honourable Governor of Karnataka, showing keen interest in the exhibits at NBAII stall during the 8th KVK National Exhibition held at GKVK, Bangalore

Sri S.R. Patil, Minister of IT, BT and Science & Technology, Govt. of Karnataka, showing keen interest in NBAII research activities during Krishi Mela at UAS, Bijapur

Dr. S. Ayyappan, Director General, ICAR, visiting the NBAII stall during 'Krishi Vasant' at CICR, Nagpur

Annual Performance Evaluation Report of RFD for the year 2013-2014

S. No.	Objectives	Weight	Actions	Success Indicators	Unit	Weight	Target / Criteria Value: Excellent 100%	Very Good 90%	Good 80%	Fair 70%	Poor 60%	Consolidated Achievements	Raw score	Weighted Score	Percent achievements against Target values of 90% Col.*	Reasons for short falls or excessive achievements, if applicable
1	Augmentation of genetic resources of agriculturally important insects*.	48	[1.1]. Collection and characterization of agriculturally important insects	[1.1.1] Insect collections made	No.	20	850	765	680	595	510	837	100	20	109.41	
				[1.1.2] Insect specimens identified	No.	18	11000	9900	8800	7700	6600	14470 $	100	18	146.16	$
				[1.1.3]Gen Bank accessions, gene sequences & Barcodes developed	No.	10	555	500	450	400	350	577	100	10	114.66	
2	Conservation, evaluation, utilization and supply of agriculturally important insects.	30	[2.1] Ex situ conservation	[2.1.1] Insect species conserved	No.	12	500	450	400	350	300	517	100	12	114.88	
			2.2] Evaluation of Bioagents	[2.2.1] Evaluation experiments conducted	No.	10	150	135	120	105	90	158	100	10	117.03	
			2.3] Supply	[2.3.1] Insect species supplied	No.	8	550	495	440	385	330	539	100	8	108.88	
3	Capacity building and dissemination of technology	10	[3.1] Impartation of training on insects & dissemination of technology	[3.1.1] Trainings conducted/ organised	No.	10	15	13	11	10	9	27#	100	10	207.69	#

$ More number of collections was made in greater frequency due to invasive threats.

More number of trainings were conducted based on the demand for the management of pests of coconut, invasive pests and mass rearing techniques

Continued.....................

S. No.	Objectives	Weight	Actions	Success Indicators	Unit	Weight	Target / Criteria Value						Raw score	Weighted Score	Percent achievements against Target values of 90% Col.*	Reasons for short falls or excessive achievements, if applicable
							Excellent 100%	Very Good 90%	Good 80%	Fair 70%	Poor 60%	Consolidated Achievements				
4	Efficient functioning of RFD	12	[4.1] Timely Submission of draft RFD (2014-15) for approval	[4.1.1] On-time sub-mission	Date	2	March 23 2014	March 26 2014	March 27 2014	March 28 2014	March 29 2014	10th Feb 2014	100	2	100.0	
			[4.2] Timely submission of RFD results (2013-14)	[4.2.1] On-time sub-mission	Date	1	May 1 2014	May 2 2014	May 3 2014	May 4 2014	May 5 2014	30th April 2014	100	1	100.00	
	Administrative Reforms		[4.3] Implement ISO 9001	[4.3.1] Prepare an ISO 9001 action plan	Date	1	June 4 2014	June 5 2014	June 6 2014	June 7 2013	June 8 2014		50	0.5	50.00	Action plan initiated
				[4.3.2] Implemen-tation of ISO 9001 action plan	Date	2	March 25 2014	March 26 2014	March 27 2014	March 28 2014	March 29 2014		50	1	50.00	Imple men tation would take another six months
			[4.4] Implement imitigating strategies for reducing potential risk of corruption	[4.4.1]% implemen tation	%	2	100	95	90	85	80	100	100	2	100	
	Improving internal efficiency / responsiveness service delivery of Ministry Department		[4.5] Implemen tation of Sevottam	[4.5.1] Independent Audit of Implemen tation of Citizens Charter	%	2	100	95	90	85	80	100	100	2	100	

S. No.	Objectives	Weight	Actions	Success Indicators	Unit	Weight	Target / Criteria Value					Consolidated Achievements	Raw score	Weighted Score	Percent achievements against Target values of 90% Col.*	Reasons for short falls or excessive achievements, if applicable
							Excellent 100%	Very Good 90%	Good 80%	Fair 70%	Poor 60%					
				[4.5.2] Independent Audit of Implementation of Public Grievance redressal system)	%	2	100	95	90	85	80	100	100	2	100	

* Per cent of Achievable Targets = Consolidated Achievements /Targets under 90% Column * 100

Total composite score : 98.5

Procedure for computing the Weighted and Composite Score

1. Weighted Score of a Success Indicator = Weight of the corresponding Success Indicator x Raw Score / 100
2. Total Composite Score = Sum of Weighted Scores of all the Success Indicators
3. Raw score for achievement = Obtained by comparing achievement with agreed target values. Example : Values between 80% (Good) and 70% (Fair), the raw score is 75%

Departmental rating	Value of Composite score
Excellent	100-96%
Very Good	95-86%
Good	85-76%
Fair	75-66%
Poor	65% and below


The 4th meeting of the National Advisory Board for Management of Genetic Resources under the chairmanship of Dr. R.S. Paroda was held at NBAII from 10 to 11 October, 2013


Dr. S. Ayyappan, Secretary DARE and DG, ICAR and Dr. N.K. Krishnakumar, DDG (Hort.) visiting the 'Pollinator Garden' on 22.10.2013 at the Yelahanka campus of NBAII

Dr. Swapan Kumar Datta, DDG (CS) inaugurating the high performance computing facility on 23.10.2013

13th workshop of the IOBC on mass rearing and quality assurance of parasitoids and predators was organised by NBAII at Bengaluru between 6 to 8 November, 2013


Dr. P.K. Chakrabarty ADG (Plant Protection) and Dr. C.A. Viraktamath, Chairman, RAC inaugurating the 'Insectarium' on 1st March, 2014

National Bureau of Agriculturally Important Insects
(Indian Council of Agricultural Research)
Bengaluru 560 024, India