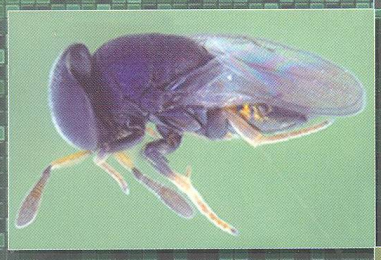
ANNUAL REPORT 2011-12



National Bureau of Agriculturally Important Insects

(Indian Council of Agricultural Research)
Bangalore 560 024, India

ANNUAL REPORT 2011-12

National Bureau of Agriculturally Important Insects

CONTENTS

1. PREFACE

India has a rich and diverse insect fauna, but its sheer size and the huge gaps in the existing knowledge of our insects have a great impact on our ability to tackle pest problems and also manage and use its insect diversity. The National Bureau of Agriculturally Important Insects (NBAII) has taken several initiatives in 2011-12 to meet these challenges and fulfill its mandate of collection, characterization, documentation of insects of agricultural importance and conservation and sustainable utilization of beneficial insects. The NBAII brought the cream of the entomological fraternity of India under one roof during the "National Meeting on Agricultural Entomology for the 21st Century: The Way Forward" held in August 2011, the deliberations of which have formed the foundation for setting the agenda for entomological research in the XII Plan. Besides this, brainstorming meets conducted on borer pests, insect genomics, and entomophilic nematodes have come up with detailed recommendations for future course of research, that are likely to get an impetus for implementation in the XII Plan.

Lack of trained scientific manpower in insect biosystematics is one of the major constraints impacting the quality of our plant protection research. The NBAII has taken steps to strengthen the ongoing research programme in insect systematics by redeploying trained insect taxonomists from other ICAR institutes. As part of NBAII's capacity building initiative in taxonomy, a training program was organized on the biosystematics of insects, mites and spiders. Explorations undertaken to Andaman & Nicobar Islands, northern and eastern India and many parts of southern India to collect insects have yielded valuable collections, augmenting our existing collections. Efforts are on to get NBAII designated as a national repository so that types and voucher specimens can be deposited at NBAII by researchers.

DNA barcoding of braconids, trichogrammatids, ants, and other insects has been done with a view to promote integration of molecular and morphological methods in insect taxonomy. The NBAII has taken a major initiative in documenting live insect genetic resources of beneficial insects maintained at different insectaries in India by putting in place the Insect Germplasm Information System (IGIS). Classical biological control of the papaya mealybug and eucalyptus gall wasp continues to be a success story, with the pest populations kept under check and no major flare ups reported from anywhere. The NAIP project on effect of abiotic stress on biocontrol agents being operated at NBAII has been one of the best performing projects in NAIP and the only one in which technologies developed are commercialized.

Under the Tribal Sub-Plan, tribals have been empowered with know-how on beekeeping and biological methods of pest management for sustainable agriculture in different parts of south India. The salient achievements of NBAII in different areas of research and development are detailed in this annual report. The NBAII is grateful to the support extended on all fronts, which has made these successes possible.

Dr S. Ayyappan, Secretary, DARE and Director-General, ICAR, has been a major guiding force for NBAII and has taken keen interest in its all round progress though it is the youngest of the National Bureaux. He was instrumental in highlighting thrust areas keeping the national scenario in view and encouraging a holistic approach involving inter-disciplinary and inter-institutional collaboration encompassing agriculture as a whole.

Dr Swapan Kumar Dutta, Deputy Director-General (Crop Sciences), ICAR, has been a great source of support and inspiration for the NBAII and the AICRP on Biological Control, for which we are grateful. He has encouraged in-depth basic research at NBAII keeping long term perspectives.

Dr T.P. Rajendran, Assistant Director-General (Plant Protection), ICAR, is always there to help us in times of need and his coordination and advice at critical junctures have been instrumental in the successes achieved by the NBAII.

The generous support extended to NBAII by **Mr Rajiv Mehrishi**, Additional Secretary, DARE and Secretary, ICAR; **Mr Pradeep Kumar Pujari**, Additional Secretary, DARE & Financial Advisor, ICAR; **Mr Devendra Kumar**, Director (Finance), ICAR; **Mr J. Ravi**, Director (Personnel), ICAR; and **Mr Sanjay Gupta**, Director (Administration), ICAR, is gratefully acknowledged.

I am grateful to **Dr B.S. Bhumannavar**, Principal Scientist, who has played a pivotal role in facilitating the various activities of NBAII, including preparation of this annual report. I also acknowledge the efforts of all the scientists of NBAII and various centres of the AICRP on Biological Control for their unstinted support in taking the NBAII forward.

N.K. Krishna Kumar
Director
National Bureau of Agriculturally Important Insects
Coordinator
AICRP on Biological Control of Crop Pests and Weeds

2. EXECUTIVE SUMMARY

The National Bureau of Agriculturally Important Insects has taken up the onerous task of documenting the vast diversity of arthropods, nematodes and associated microorganisms of agricultural importance of the country with the express purpose of identifying species for use in combating the constantly changing complement of pests and diseases which have been taking a heavy toll of our agricultural produce. The salient achievements of the various research programmes undertaken by the Bureau as well as the 20 centres operating under the All India Coordinated Research Project on Insect Pests and Weeds during 2011-12 are detailed below. The results point to the headway being made in our effort towards ensuring sustainable food production, food safety and a healthy environment.

Basic research

National Bureau of Agriculturally Important Insects

Division of Insect Systematics

Taxonomic knowledge is essential for the management of arthropods (including insects, mites and spiders), nematodes and weeds in agricultural ecosystems. It details the components of biodiversity without which it would be impossible to make decisions on the management of pests, the conservation of their natural enemies or the manipulation of pollinator diversity in agro-ecosystems. It is also essential to detect, monitor and manage alien invasive species. In this light the NBAII aims at documenting and mapping agriculturally important arthropods and related organisms from across the country so as to provide a rational basis for making informed decisions to ensure the sustainability of agro-ecosystems.

Surveys for insects and entomopathogenic nematodes

Although the study of insects of agricultural importance in our country began over a century ago they have been concentrated in certain pockets with many areas remaining largely unexplored. These areas will now be surveyed in a phased manner to enable us to gain a fuller understanding of our agriculturally important arthropods. This year the Andaman islands were identified as one such area requiring special attention for study.

Surveys were not confined to agricultural ecosystems, both natural ecosystems and urban areas were also included. In the Andaman islands, South Andaman (Sippighat, Bloomsdale, Chouldhari, Garacharma, Mt. Harriet), Middle Andaman, Baratang, Neil and Havelock islands were surveyed. The areas surveyed in mainland India were (i) Southern India: Andhra Pradesh (Hyderabad), Kerala (Thrissur, Palakkad), Tamil Nadu (Hoganekal and Kodaikanal) and extensively in various places in Karnataka (ii) Central India: Madhya Pradesh (Bhopal, Kerwa Dam) and Delhi (Aravalli ridge), and (iii) Eastern India: Odisha (Bhubaneshwar, Chilika Lake and Salia Dam).

Significant collections from these areas were made in the following groups of insects: Coccidae, Aphididae, Anthocoridae, Platygastroidea, Chalcidoidea, Microgastrinae, Trichogrammatidae and Coccinellidae.

Two new isolates each of the entomopathogenic nematodes *Heterorhabditis* sp. and *Steinernema* sp. were identified from the Andaman islands. All the four caused mortality of second and third instar grubs of the pestiferous beetle *Anomala bengalensis*.

Taxonomic studies

New species discovered / described

A new ladybird beetle *Sticholotis magnostriata* Poorani was described from Assam. *Microterys chaetococci* Hayat & Poorani (Encyrtidae), a parasitoid of *Chaetococcus* sp. on bamboo, was described from Karnataka. One new species each of *Poropoea* Foerster (Trichogrammatidae) and *Zaplatycerus* Timberlake (Encyrtidae) were described from Karnataka. Two new species of *Trichogrammatoidea*, *T. rufomaculata* Nagaraja & Prashanth and *T. brevicaudata* Nagaraja & Prashanth

have been described from Karnataka, India. Two new species of Platygastridae, *Odontacolus markadicus* Veenakumari and *Odontoscelio vikata* Veenakumari and Rajmohana, were described from southern India. Both the species are the first representatives of their genera from India. *Glyptapanteles hypermnestrae* Gupta and Pereira parasitizing larvae of *Elymnias hypermnestra* was described as new from Maharashtra, India.

DNA barcodes

Identification of insects based on morphological characters for the last 200 years has resulted in descriptions of 1.7 million species which is only 10 per cent of the total number of species estimated. In this context the identification of insects has been a monumental task, with the need for a large number of specialists and more funding than is currently being made available for the task. With the advent of molecular biology and molecular tools the identification of life forms including insects has become quick, precise and easy. Molecular systematics is not stage-specific and does not need trained taxonomists. It is rapid and helps in differentiating biotypes. The main advantage of DNA barcoding is the speed with which molecular data can be acquired. DNA barcoding is extremely useful for the unambiguous identification of biological specimens and more efficiently managing species diversity in Gene Banks. This tool is handy for the identification of invasive insect pests. DNA barcoding is a technique by which species identification is carried out by analyzing the sequences of small fragments of mitochondrial genome (cox1) as primary gene, besides ITS1, ITS2, 16sRNA, CYTB, ND5 can also be used. The mitochondrial genome has a relatively fast mutation rate and results in variation in mtDNA of different species. A 648bp region of mitochondrial cytochrome oxidase subunit I gene is used in general in DNA barcoding. In the past decade more than 100,000 insect species have been barcoded across the globe. A lot more needs to be done to generate the barcodes of Indian insects.

DNA barcodes were generated for *Trichogramma rabindrai*, *T. japonicum*, *Trichogrammatoidea armigera*, *Apanteles galleriae*, *T. agriae*, *Apanteles hyposidrae* and *Fornicia ceylonica*. Barcodes were also developed for the eucalyptus gall wasp, *Leptocybe invasa* and its natural enemies, *Quadrastichus mendeli* and *Megastigmus viggianii* based on the ITS 2 region of their mitochondrial DNA.

Molecular identification of two species of *Heterorhabditis* and eight species of *Steinernema* using multi-loci (ITS and CO genes) approach has been devised. Morphological key features have been identified for two species of *Heterorhabditis* and four species of *Steinernema* for preparation of identification keys.

Identification services

One thousand two hundred and thirty six specimens of insects including Thysanoptera, Coccidae, Aphididae, Syrphidae, Tachinidae, Tephritidae, Coccinellidae and parasitic Hymenoptera were identified for thirty three institutions including various AICRP centres, State Agricultural Universities, other universities and students.

Web-based resources

Database on agriculturally important insects

One hundred and seventy-five fact sheets on common parasitoids, predators, and weed killers have been hosted on the website of NBAII. Fact sheets on invasive pests, *Chilocorus* species of the Indian region and Aphids of Karnataka have been included in IDSource, a compilation of PestID resources hosted by USDA-APHIS and Colorado University (the only resources included from India). An image gallery was constructed for over 300 pest insects with over 2000 colour photographs.

Insect Germplasm Information System (IGIS)

Insect Germplasm Information System (IGIS) – an online computer tool has been developed for providing information about the live insect genetic resources maintained at different insectaries in India. This online database tool can cater to the needs of entomologists and the farming community. At present, passport information is available for silk worm genetic resources maintained at Central Sericulture Germplasm Research Centre (CSGRC), Hosur, Tamil Nadu and also for host insects and beneficial insects (parasitoids and predators) maintained at NBAII.

Division of Molecular Entomology

Endosymbionts of insects play a key role in the nourishment of host insects, in their ecology and evolution. Vertically transmitted symbionts can

increase in frequency by directly increasing the fitness of their hosts (nutrition, detoxification of insecticide, temperature tolerance, manipulating host reproduction and alteration of sex ratio).

Resident microflora, especially yeasts and bacteria that natural enemies harbour in the field collected populations, are determined and evaluated for their role in enhancing fitness of laboratory reared populations. Presently, the research is on isolation and characterization of endosymbionts of insect pests (like *Plutella xylostella*) and natural enemies (like *Trichogramma* spp., *Chrysoperla zastrowi sillemi* and *Cotesia vestalis*) and determining their role in fitness attributes and for tolerance to abiotic stresses - insecticides and temperature.

The future thrust areas of the division include, whole genome sequencing (*Leucinodes orbonalis*, *Thrips palmi*, *Nilaparvata lugens*), functional genomics (Genetic variation using microsatellite/SSR markers, RNAi interface in the management of insect pests and the insect vector-virus relationships (Tospo virus-thrips, Gemini viruses-whitefly, *Thrips palmi*), molecular mechanisms involved in insecticide resistance, especially *Leucinodes orbonalis*, *Pectinophora gossypiella* and *Amrasca biguttula biguttula*.

Endosymbionts

Trichogrammatids

Various endosymbionts of trichogrammatids, viz. *Pichia anomola, P. ohmeri, Candida apicola, C. pimensis, Metschnikowia reukaufii, Hanseniaspora uvarum, Wickerhamomyces anomalus, Zygosaccharomyces rouxii* and *Bacillus subtilis* were identified based on their molecular identity.

The role of endosymbiotic yeasts in fitness attributes in laboratory populations of *Trichogramma japonicum* and *T. chilonis* assessed by feeding these endosymbionts for fifteen generations indicated that per cent parasitism, per cent females and fecundity were significantly superior to control. *Wolbachia*-fed *T. brassicae* showed significant increase in female progeny and parasitism levels.

Cotesia vestalis

Presence of endosymbiotic bacterium, *Wolbachia* was detected with wsp gene in the populations. *Wolbachia* increased the fitness of the parasitoid by enhancing parasitism levels, percentage adult emergence and proportion of female progeny when compared to control. Enhanced Cytochrome P 450 monoxygenase activity (2.11- 2.791 x10^3 µm/mg/ml) was observed in populations of *C. vestalis* resistant to insecticide (fenvalerate) infected with *Wolbachia* as compared to control.

Chrysopids

The microflora isolated from the midgut and diverticulum were *Pichia anomola, P. ohmeri, Candida blankii, Candida pimensis, C. colliculosa, Paenibacillus* sp., *Enterobacter* sp. *Kodamaena ohmeri, Hanseniaspora uvarum, Wickerhamomyces anomalus* and *Zygosaccharomyces rouxii* based on their molecular identity by specific primers. TEM micrographs of midguts of the predators confirmed the presence of bacteria. The minimal media studies indicated the functional role of *Paenibacillus* sp. (isolated from pesticide tolerant strain of *C. z. sillemi* larval gut) in the degradation of acephate.

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

A total of 234 samples of soils and insect cadavers were collected from Northeast India and the Andaman islands. Sixty two samples were processed and 32 *Bacillus thuringiensis* isolates expressing bipyramidal, cuboidal, square and irregular crystal morphology were purified. Complete cds of cry1Ac gene was obtained from 13 northeast isolates. Sequencing of the gene up to 2.5 kb by primer walking was completed. PCR analysis was done for VIP3A gene in the northeast samples and only two showed expression of the gene. Among the isolates tested for toxicity against *Plutella xylostella* and *H. armigera*, the isolate TrBt4 was found effective against *P. xylostella* exhibiting LC50 of 427 µg/ml and TrBt2 isolate found most toxic to *H. armigera* exhibiting a LC50 of 265 µg/ml.

Division of Insect Ecology

Understanding the ecology of agriculturally important arthropods including pests, natural enemies and pollinators in agroecosystems is fundamental to the formulation of insect management and conservation programmes. The insect ecology division is currently involved in developing methods for monitoring the incidence of pests through pheromone technology, identifying potential natural enemies, developing production technologies for potential bioagents, evaluating their performance in

field conditions and studying the effects of climate change on pests and natural enemies.

The NBAII maintains a large repository of live insect germplasm which is made available to the academic and farming communities in accord with their requirements.

Biology and evaluation of predators

Morphometrics and biology of *Montandoniola indica*

A new anthocorid predator *Montandoniola indica* was recorded for the first time as a predator of *Gynaikothrips uzeli* infesting *Ficus retusa* in Karnataka and also on the gall forming thrips, *Liothrips karnyi* infesting black pepper leaves in Kerala. The biology and morphometrics of this anthocorid were studied. It is amenable to laboratory production.

Anthocorids against *Sitotroga cerealella*

Treatments with anthocorids were successful in reducing adult emergence from paddy infested with *Sitotroga* eggs. Treatments with *Cardiastethus exiguus* and *Xylocoris flavipes* were superior to the treatment with *Blaptostethus pallescens*. The best treatments were releases of *C. exiguus* and *X. flavipes* @ 30 nymphs per container.

Feeding potential of *B. pallescens* on cotton mealybug

Adult predatory potential and longevity of *B. pallescens* could be improved by providing cotton mealybug crawlers. The day-wise feeding potential also indicates some higher peaks of feeding during the initial days in those adults which were fed on cotton mealybug crawlers from the nymphal stage. This study indicates that prey available during the nymphal stage could have a bearing on the feeding potential of the adult stages.

Evaluation of predatory mites against thrips of chillies in polyhouses

Amblyseius swirskii (Athias-Henriot) and *Neoseiulus californicus* (McGregor), two exotic predatory mites imported by Namdhari Farm Fresh, Bangalore were evaluated against the common blossom thrips *Frankliniella schultzei* on polyhouse chilli (variety Supreme) in three of their polyhouses. A single release of the predatory mite was not effective in suppressing the population of the thrips.

New rearing techniques

Both pumpkin (*Cucurbita moschata*) and summer squash (*C. pepo*), the hosts on which scales are traditionally reared were found unsuitable for the growth and multiplication of the hemispherical scale *Saissetia coffeae*. A novel method was therefore developed to rear this scale as well as its parasitoids *Scutellista caerulea* and *Coccophagus ceroplastae* on the sprouts of potato.

Insect conservation

In situ conservation of natural enemies and pollinators in pigeonpea and sunflower ecosystems

Among the pollinators *Megachile* spp. was relatively more abundant followed by *Xylocopa* spp. in pigeonpea while in sunflower *Apis dorsata* was dominant followed by *Megachile* spp. and *Xylocopa* spp.

Field trials indicated that the pest population (*H. armigera* and 4 species of pod bugs - *Riptortus* sp, *Clavigralla* sp., *Anoplocnemis* sp. and *Nezara viridula*) was significantly low in intercropped pigeonpea. Populations of natural enemies (mainly spiders and coccinellids - *Cheilomenes sexmaculata*) were also significantly higher in intercropped pigeonpea compared to sole crop.

The weed *Spermacoce hispida* supported pollinators in pigeonpea and sunflower. *Apis cerana*, *A. florea*, and *A. dorsata* were found to visit flowers of *S. hispida* for both nectar and pollen. During the off season this is one of the dominant plants apart from *Muntingia calabura* (Singapore cherry) which helps in the conservation of bee species.

Studies on climate change

Influence of elevated levels of carbon dioxide on tritrophic interactions

Pigeonpea plants grown in Open-Top Carbon dioxide chamber (OTC) at 500 ppm carbon dioxide and two temperatures (ambient and 2°C above ambient) were compared with those grown at ambient CO_2 (380 ppm) level. The pigeonpea plants grown at 500 ppm showed profuse vegetative growth and delayed flowering as compared to those grown at ambient conditions. Laboratory studies on ovipositional preference revealed that the plants grown at 500 ppm CO_2 were preferred by *H. armigera*. Volatile profiles indicated the presence of compounds like cocaine in plants grown at 500 ppm which attracted more *H. armigera*.

Semiochemicals

Geographical variation in male response to pheromones in *Helicoverpa armigera*

Field studies conducted with different blends of 97:3, 91:9 and 85:15 of Z-11-hexadecnal: Z-9-hexadecenal revealed that males of Raichur and Patna populations responded to 91:9 ratio and Dharwad population responded to 97:3 ratio. The pheromone gland extract analysis using GCMS showed that Gulburga population has a ratio of 91:9 of Z-11-hexadecenal : Z-9-hexadecenal.

Nano formulations

Nanoparticles of *Leucinodes orbonalis* pheromone were synthesized by using ionotropic pre-gelatin, chitosan and sodium alginate. The Zeta potential showed that the nano-formulations are stable. SEM studies confirmed the particle size to be in the range of 193-891μnm. Headspace-GCMS revealed that the pheromone was encapsulated in the chitosan-alginate nanoparticles. Electroantennogram studies revealed that gelatin type A nanoparticle elicited higher response in the males of *H. armigera* than in control.

Entomofungal pathogens

Hirsutella thompsonii against citrus rust mite

Field efficacy of both host- and non-host-derived *H. thompsonii* isolates against citrus rust mite (*Phyllocoptruta oleivora*) on sweet orange was studied. Both *H. thompsonii* isolates, viz. MF(Ag)205 (host-derived) and MF(Ag)66 (non-host-derived), were able to significantly reduce the populations of the citrus rust mite even after 9 months of treatment.

Evaluation of fungal pathogens against *Aphis craccivora* on cowpea

In the field trial on cowpea aphid (*A. craccivora*), foliar spray with fungal pathogens, *B. bassiana* Bb-5, *M. anisopliae* Ma-4, *V. lecanii* Vl-8 and *P. fumosoroseus* Pfu-1 showed lower infestation of cowpea aphid (12.1-17.4% affected plants) and lower aphid population (0.16-0.21aphids/plant) compared to untreated plants (31.8% affected plants & 9.42 aphids/plant). No significant differences in the natural population of coccinellids were observed in the treated plots and untreated control indicating the safety of the fungal pathogens to the coccinellid natural enemy of the cowpea aphid.

Entomopathogenic nematodes

Mass production and exploitation of EPN

A protocol for pilot scale *in vivo* production of EPN was developed at 500 Kg per production cycle of 30-45 days. Studies on the field efficacy of EPN preparations in root grub endemic areas of arecanut in Sulya and Banakal (Western Ghats) showed that the incidence of root grubs was reduced in WP treated palms by 62-78%.

Heterorhabditis indica (Hi01) was observed to be effective in the management of *Myllocerus* weevil infestation in brinjal with least LT50 values (45.38 h). This is the first report on the efficacy of EPN against the grubs of *M. subfaciatus*.

Management of plant parasitic nematodes

Two new isolates of antagonistic fungi, *Arthrobotrys conoides* and *A. oligospora* were isolated from pasture soils. They exhibited 38-66% infection to root-knot nematode juveniles. In another experiment, integration of *Paecilomyces lilacinus* NBAII isolate PLFT5 or *Pochonia chlamydosporia* NBAII isolate PC56 at 100g/m^2 after soil solarization significantly increased nematode free plants of tobacco in nursery to the tune of 56.4 and 57.8%, respectively.

Forty-eight *Pseudomonas* isolates collected from crop rhizosphere (CRS) were tested for efficacy against egg hatching and mortality of second stage juveniles of *Meloidogyne incognita*. Four isolates of *Pseudomonas*, viz., CRS-3, CRS-6, CRS-8 and CRS-10 recorded 50-60% mortality and 42-45% inhibition of egg hatching. Morphological, biochemical and cultural characteristics of these four isolates were described.

Plant disease antagonists

Standardization of solid state fermentation conditions and development of prototypes with semi-automation for the mass production of *Trichoderma* spp.

Incubation temperatures of 26 °C and 28 °C were found optimum for mass production of *Trichoderma* spp. on solid substrates like ragi and sugarcane bagasse to get maximum viable conidial production (>1 x 10^9 CFU per g of substrate). A design of semi-automated units of tray-bed type of bioreactor for solid state fermentor was made and IP protection for the same was filed at Patent Office, Chennai (Design and development of solid state bioreactor for

the mass production of fungal bioagents 2271/CHE/2011).

Management of bacterial wilts of tomato and brinjal caused by *Ralstonia solanacearum* through *Bacillus* spp.

Combined application of talc based formulation of *B. megaterium* NBAII 63 (10^8 CFU/ml) as seed treatment (4g/kg of seed), soil application (2.5 kg/ha), seedling root dip (10g/ L of water) and foliar spray (10g/L of water) significantly reduced bacterial wilt in tomato (56%) and brinjal (62%) under field conditions. Application of *B. megaterium* increased the seedling establishment and growth in tomato and brinjal. Highest rhizosphere population of 7.1-7.4 x 10^7 CFU/g was recorded in tomato and brinjal at 40 days through the combined application.

Classical biological control

Papaya mealybug

The papaya mealybug (PMB), *Paracoccus marginatus* was successfully managed within a year of its appearance in Tamil Nadu by three exotic hymenopteran parasitoids *Acerophagus papayae*, *Anagyrus loecki* and *Pseudleptomastix mexicana* introduced with the assistance of the USAID from Puerto Rico at the initiative of this Bureau. *A. papayae* was observed to be the most effective of these parasitoids in keeping the PMB in check. Although low levels of the PMB were noticed subsequently in some areas, the reassuring presence of the introduced parasitoids indicated that they were keeping the mealybug under control.

The USDA highlighted the success of this programme for the biological control of the papaya mealybug in India in their report titled "USAID (from the American People): India" citing this as an example of a 'successful partnership demonstrating what is possible through collaborative effort'.

Recurrence of papaya mealybug, *Paracoccus marginatus*

In August 2011, the PMB rose to levels causing concern to papaya farmers in some areas of Gulbarga and Savadatti (N. Karnataka) and mulberry farmers in Chamrajnagar (S. Karnataka) in February, 2012. The mealybug was also noticed in Orissa, Tripura, Lakshadweep and Minicoy islands. While the parasitoids being maintained at NBAII were supplied directly to the aggrieved farmers in most areas they were released in other areas (Lakshadweep islands and parts of Kerala) with the assistance of KAU, Thrissur and CPCRI, Kasargod. A total of 12 lakh parasitoids were supplied by the unit during 2010-12 for release and also for further multiplication by different agencies. The parasitoids once again established their ability to contain the PMB in all the areas of release.

Management of Eucalyptus gall wasp and *Chromolaena odorata*

The parasitoid *Quadrastichus mendeli* was introduced from Israel by the NBAII to combat the gall wasp, *Leptocybe invasa,* a recent invasive of eucalyptus plantations in south India and Uttaranchal. These parasitoids, quarantined and mass multiplied at NBAII, Bangalore successfully reduced populations of the gall wasp and revived eucalyptus plantations averting a crisis for the paper mills in this region of our country.

Releases of the gall fly, *Cecidochares connexa* for the management of the weed *Chromolaena odorata* were continued in Karnataka, Kerala and Tamil Nadu. Releases were also made in Jabalpur, Madhya Pradesh. This gall fly has established in all the areas of release. Its spread and efficacy in bringing down the weed population is being monitored.

Transfer of technology to tribal areas

A new scheme to enable the transfer of technologies developed by the NBAII in tribal areas for the welfare of the tribal community was launched by the Government of India. Inputs such as bioagents, biopesticides, pheromone traps, honeybee hives and other accessories for beekeeping were supplied to them. Follow up visits are being made to assist them in the uptake of these technologies.

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

Diversity of biocontrol agents from various agroecological zones (MPKV, KAU, PAU, YSPUHF, SKUAST and AAU-A)

At MPKV (Pune), 42 species of pests and natural enemies representing 14 genera were recorded. At KAU, *Trichogramma*, *Goniozus* and braconids were collected from black headed caterpillar. An anthocorid, *Physopleurella armata* was reported for the first time from India. *Chrysoperla zastrowi*

sillemi was collected from Solan (YSPUHF) on *Trialeurodes vaporariorum* (on cucumber) and 30 species of coccinellids were collected. At SKUAST, *T. chilonis* from *Chilo partellus* and *T. kashmirica* from unidentified host on paddy were collected. At AAU (Anand), 62 species of coccinellids and 62 species of spiders belonging to 16 genera in 8 families were collected and identified.

Biological suppression of diseases (NBAII, GBPUAT, PAU, AAU-A)

Trichoderma harzianum isolate Th89 produced maximum hydrolytic enzymes under salinity stress. Talc and invert-emulsion formulation of NBAII-Th10 reduced wilt incidence in chickpea to 24% compared to control (43%). The invert-emulsion formulation of Th10 delayed the onset of *Alternaria* leaf spot damage in tomato (NS501). Isolate Th-14 was the most effective in managing wilt (*Fusarium oxysporum* f. sp. *lentis*) incidence and improving crop growth in lentil. Fusarium wilt (*Fusarium lycopersici*), damping off (*Pythium* sp.) and fruit rot (*Phytophthora parasitica*) were reduced by 73, 85 and 65%, respectively using IPM technologies and increased yield by 21.4% (GBPUAT).

Biological suppression of sugarcane pests (MPKV, TNAU)

Sugarcane woolly aphid (SWA) incidence was monitored regularly. Low incidence of SWA was recorded in Maharashtra and Tamil Nadu. At PAU, *Metarhizium* (2L and 3L /ha) treated sugarcane plots gave the lowest stalk borer incidence. At AP and TN, dead heart percentage was significantly lower in plots released with heat tolerant strain of *T. chilonis*. Eri silkworm eggs were used for mass production of *T. chilonis* and eight releases of *T. chilonis* significantly reduced *Chilo sacchariphagus* in Mandya (NBAII) and Coimbatore.

Biological suppression of cotton pests (MPKV, TNAU, PAU)

Parasitism by *Aenasius bambawalei* was recorded (60%) at MPKV. *Phenacoccus solenopsis* and *Maconellicoccus hirsutus* were recorded on cotton growing areas in Tamil Nadu. At MPKV, *Bt* cotton recorded lower incidence of aphids, jassids and thrips and mealybugs than farmers' fields.

Biological suppression of tobacco pests (CTRI)

Minimum tillage practice reduced infestation of *Rhopalosiphum maidis* on maize and *Aproaerema modicella* and *Cerotoma trifurcata* infestation in soybean.

Biological suppression of *Chilo partellus* on maize (TNAU)

Two releases of *T. chilonis* followed by release of *Cotesia flavipes* gave higher egg parasitism (19.3%) with lower dead hearts (8.4%).

Biological suppression of pests of pulses (AAU-A, MPKV, JNKVV, TNAU, PAU, MPUAT)

At all the centres, *Bt* based treatments *viz.,* NBAII-BT G4 (2%), PDBC-BT1 (2%) and IARI Bt isolate performed equally effectively against *H. armigera* and *M. testulalis*. Pigeonpea intercropped with sunflower and border crop of maize recorded the least population of pod borers.

Biological suppression of pests of oilseeds (MPKV, MPUAT, JNKVV, OUAT)

At MPKV, sprays of *M. anisopliae* were effective in suppressing the safflower aphid. First spray with *Bt* var. *kurstaki* followed by spray of *Nomuraea rileyi* and second spray with SlNPV was more effective against *S. litura* (MPUAT). At JNKVV, *M. anisopliae, V. lecanii*, Dipel and Spinosad were on par with each other with respect to *S. litura* infestation in soybean. At, JNKVV and OUAT, EPN 1 strain registered higher mortality against *S. litura* larvae.

Biological suppression of pests of coconut (CPCRI)

Six releases of *Cardiastethus exiguus* resulted in good suppression of *Opisina arenosella* (KAU). Monitoring and release of stage-specific parasitoids viz, *G. nephantidis* and *Bracon brevicornis* could reduce leaf damage (63%) and population of *O. arenosella* (91.3%).

Biological suppression of pests of tropical fruits (TNAU, MPKV, IIHR, CAU, KAU)

Application of *M. anisopliae* spray reduced mango hopper population with increased fruit set (TNAU & MPKV). At MPKV, two releases of *Scymnus coccivora* were found significantly superior against mealybug species. At Bangalore, inoculative release

of *A. papayae* at six orchards completely suppressed *P. marginatus* in 3-4 months.

Biological suppression pests of temperate fruits (YSPUHF and SKUAST)

One ichneumonid and one braconid were recovered from the parasitized larvae of codling moth (SKUAST). Average fruit damage by codling moth in orchards where *T. embryophagum* and *T. cacoeciae* were released during 2011, ranged from 42.3 to 65.5 %, as compared to 80.5 in control.

Biological suppression pests of vegetables (AAU-J, SKUAST, CAU, PAU, OUAT., MPUAT, TNAU)

Three weekly releases of *T. chilonis* reduced the larval population of *P. xylostella* in cabbage (SKUAST). Mean aphid population per plant was low in BIPM practice (PAU). Bt-NBAII was most effective against *P. xylostella* (CAU). Adoption of BIPM reduced *L. orbonalis* damage to 6.59% (IIHR). Fruit borer incidence was least in BIPM treated plots (OUAT). Thelytokous population of *T. pretiosum* reduced fruit damage in tomato (MPUAT). Release of *Blaptostethus pallescens* reduced the mite population in okra (OUAT). Release of nymphs of *B. pallescens* was effective against *Tetranychus urticae* on brinjal plants (PAU). Application of *B. bassiana* (IIHR isolate) was effective in reducing tea mosquito bug infestation in guava (IIHR).

Biological suppression of mealybugs

Mean developmental time of *Acerophagus papayae* parasitising papaya mealybug was found to be shortest (11.33 days) on papaya (TNAU).

Biological suppression of termites (IISR, TNAU, MPUAT)

Application of *M. anisopliae* against termite on sugarcane was found to be effective in all the centres.

Biological suppression of polyhouse pests (SKUAST, KAU, TNAU, YSPUHF)

Release of *B. pallescens* in rose reduced the spider mite population by 61% (SKUAST). In brinjal, the release of anthocorids reduced the mite infestation (8%) (KAU). In carnation also, the anthocorids were found to be effective against mites (TNAU & YSPUHF). Release of *Amblyseius* sp and *Stethorus pauperculus* were effective in reducing *T. urticae* in carnation (YSPUHF).

Biological suppression of storage pests (MPKV, AAU-J)

Inoculative release of *Xylocoris flavipes* against *C. cephalonica* in stored wheat and rice was significantly superior in reducing the moth emergence of *C. cephalonica* after a month.

Tribal Sub-Plan

Validation of biocontrol technologies was carried out in tribal areas on pests and diseases, of rice, chickpea, pigeonpea, potato, apple, castor, ginger, turmeric, mango and pomegranate in various centres for the benefit of tribal farmers.

Enabling large scale adoption of proven biocontrol technologies

Large scale demonstration trials were taken up against the serious pests, *viz.* maize stemborer, rice stemborer, sugarcane early shoot borer, top borer, plassey borer, coconut blackheaded caterpillar, rhinoceros beetle, at different AICRP centres (PAU, KAU, OUAT, CPCRI, MPKV, AAU-J).

3. INTRODUCTION

Brief history

The All-India Coordinated Research Project on Biological Control of Crop Pests and Weeds was initiated in the year 1977 under the aegis of the Indian Council of Agricultural Research, New Delhi, with funds from the Department of Science and Technology, Government of India. Within two years (1979), the ICAR included the project under its research activities with full financial support. Recognition of the importance of biological control came during the VIII plan period with the up-gradation of the centre to Project Directorate of Biological Control (PDBC) with headquarters at Bangalore with effect from 19 October 1993. In the XI plan, the PDBC was reoriented into National Bureau of Agriculturally Important Insects (NBAII) on 25 June 2009. The AICRP has centres based in 14 agricultural universities and 6 ICAR institutes.

Notable achievements in the past

Basic research

- Ninety-four exotic natural enemies (NEs) have been studied for utilization against alien pests, out of which 62 could be successfully multiplied in the laboratory, 52 species have been recovered from the field, four are providing partial control, five substantial control and six are providing economic benefits worth millions of rupees. Twelve are augmented in the same way as indigenous natural enemies.
- The encyrtid parasitoid, *Acerophagus papayae*, introduced from Peurto Rico in 2010, has successfully controlled the papaya mealybug, *Paracoccus marginatus* infesting papaya, tapioca, mulberry sunflower, cotton and several crops plants in south India.
- *Trichogramma brassicae*, an egg parasitoid, introduced from Canada was successfully quarantined and found suitable for biological control of *Plutella xylostella* on cole crops recording more than 90% parasitization.
- The sugarcane woolly aphid, *Ceratovacuna lanigera* has been successfully managed by the deployment of two predators, *Dipha aphidivora* and *Micromus igorotus* and one parasitoid, *Encarsia flavoscutellum*.
- Two eulophid parasitoids, *Quadrastichus mendeli* and *Selitrichodes kryceri* introduced from Israel in 2009 have successfully established and suppressing the population of ecalyptus gall wasp, *Leptocybe invasa*.
- The predator reported earlier as *Chrysoperla carnea* has now been identified as *Chrysoperla zastrowi sillemi* through acoustic analysis of mating calls.
- DNA barcode for the invasive pest, coconut leaf beetle *Brontispa longissima* was generated for the first time in the world and will be useful for the rapid identification of the pest in the event of its invasion into our country.
- URL: http://www.nbaii.res.in/ Featured% 20insects/featured-insects.html - Factsheets on agriculturally important insects (for 155 species of common bioagents, invasives, and pests)
- URL: http://www.nbaii.res.in/ Introductions/ Insects/index.htm - Biocontrol introductions. (for ~185 species of introduced bioagents in India)
- Biosystematic studies were carried out on 275 predatory coccinellids. A website on Indian Coccinellidae featuring image galleries of common species and their natural enemies has been constructed and hosted.
- A computer-aided dichotomous key to 10 common Indian species of *Chilocorus* is hosted on the internet.
- Aphids of Karnataka - Website on aphids of Karnataka was hosted- URL: www.aphidweb.com.
- Improved laboratory techniques were developed for the multiplication of 27 egg parasitoids,

7 egg-larval parasitoids, 42 larval/nymphal parasitoids, 25 predators and seven species of weed insects.

- *Sitotroga cerealella* eggs proved to be the most suitable for rearing *Orius tantillus* and *Corcyra cephalonica* eggs for *Blaptostethus pallescens*.
- A novel technique of modified atmosphere packing of *Corcyra cephalonica* eggs followed by low temperature storage at 8±1°C has been developed to extend the shelf life.
- Tritrophic interaction studies between the egg parasitoid, *Trichogramma chilonis*, bollworm *Helicoverpa armigera* and cotton, chickpea, pigeonpea, sunflower and tomato genotypes have helped in identifying biocontrol-friendly genotypes.
- Suitable low temperatures for short-term storage of trichogrammatids, *Eucelatoria bryani, Carcelia illota, Allorhogas pyralophagus, Copidosoma koehleri, Hyposoter didymator, Cotesia marginiventris, Leptomastix dactylopii, Sturmiopsis inferens*, and *Pareuchaetes pseudoinsulata* have been determined.
- An endosulfan-tolerant strain of *Trichogramma chilonis* (Endogram) developed for the first time in the world. The technology was transferred to private sector for large-scale production.
- Strains of *T. chilonis* tolerant to multiple-insecticides and high temperature and a strain having high host searching ability have been developed for use against lepidopterous pests.
- Kairomones from scale extracts of *H. armigera* and *C. cephalonica* increased the predatory potential of chrysopids.
- Talc-based formulation of *Bacillus megaterium* has been developed for the management of bacterial wilts of tomato and brinjal.
- Isolates of *Trichoderma harzianum* tolerant to carbendazim and salinity with good biocontrol potential against four important plant pathogens have been identified.
- Two fungal (*Trichoderma harzianum*-PDBC-TH 10 and *T. viride*-PDBC-TH 23), and two bacterial antagonists (*Pseudomonas fluorescens*-PDBC-AB 2, 29 & 30 and *Pseudomonas putida*-PDBC-AB 19) of plant pathogens have been released for commercial production after intensive studies.
- Bacterial antagonists, particularly *Pseudomonas cepacia* (starin N 24), suppressed successfully *Sclerotium rolfsii* in sunflower rhizosphere as seed inocula.
- New species and strains of entomopathogenic nematodes (EPN), namely, *Steinernema abbasi, S. tami, S. carpocapsae, S.bicornutum* and *Heterorhabditis indica* have been recorded.
- Suitable media for mass multiplication of EPN were identified. *S. carpocapsae* @ 1.25-5 billion/ha proved effective against the brinjal shoot and fruit borer, *Leucinodes orbonalis*. Talc-based and alginate-capsule formulations of *S. carpocapsae* and *H. indica* were effective against *S. litura* in tobacco. A sponge formulation was found suitable for transport retaining 90% viability of *Steinernema* spp. for 3-4 months and 85% viability of *Heterorhabditis* spp. for 2 months.
- An easy and rapid technique to screen antagonistic fungi against plant parasitic nematodes has been devised to identify efficient strains. The antagonistic fungus, *Paecilomyces lilacinus* was found effective against *Meloidogyne incognita* and *Rotylenchulus reniformis* in red laterite soils and *Pochonia chlamydosporia* was effective in sandy loam soil.
- Molecular identity of native isolates of *P. chlamydosporia* was established through sequencing the β-tubulin gene (1 to 233 bases) and registered in the Genbank, NCBI, Maryland, USA.
- *Bacillus thuringiensis* isolate PDBC-BT1 caused 100% mortality of first instars of *Plutella xylostella*, *Chilo partellus* and *Sesamia inferens*. *Bacillus thuringiensis* isolate PDBC-BNGBT 1 caused complete mortality of *Helicoverpa armigera*.
- DVD films for short duration were produced on Classical Biological Control of papaya mealybug, management of sugarcane woolly aphid, management of rice insect pests and diseases through BIPM module, management of coconut black headed caterpillar, mass production and use of predatory coccinellids, mass production and delivery of *Trichoderma* spp., mass production and use of *Trichogramma* egg parasitoids.

- Licensing of know-how/product of *in vivo* production, downstream processing and development of wettable powder formulation of entomopathogenic nematode, *Heterorhabditis indica* strain NBAII Hi1 and field use for biological control of white grubs to three companies each for 2 lakhs on non-exclusive basis.
- Licensing of know-how/product of technology for liquid formulation of *Bacillus thuringiensis* to one company for 2 lakhs on non-exclusive basis.

Applied research

- Eight releases of *T. chilonis* (@ 50,000/ha at 10 days interval) during April-June and six releases of *T. japonicum* (@ 50,000/ha at 10 days interval) during May-June have proved effective in suppressing sugarcane tissue borers.
- *Beauveria bassiana, B. brongniartii* and *Metarhizium anisopliae* were effective against sugarcane white grubs.
- *Encarsia flavoscutellum, Micromus igorotus* and *Dipha aphidivora* effectively controlled the sugarcane woolly aphid.
- Application of *Heterorhabditis indica* @ 2.0 billion IJs/ha resulted in minimum population of white grubs in sugarcane.
- Biocontrol-based IPM (BIPM) modules consisting of use of moderately resistant variety, *Trichoderma viride* as seed treatment, release of *T. japonicum* @ 50,000/ha/week (6 releases), spray of *Pseudomonas fluorescens*, need-based insecticidal application and use of bird perches (10/ha) controlled the rice stem borer and increased the grain yield and net profit.
- IPM module comprising of need-based use of oxydemeton methyl (0.03%), releases of *C. carnea*, *T. chilonis* and spray of HaNPV controlled the sucking pests and boll worms and increased the yields of seed cotton and conserved natural enemies.
- BIPM package recorded significantly lower bud and boll damage, lower population of sucking pests and higher seed yield than the package with chemical agents in *Bt* cotton.
- *Bt* and HaNPV were important components of BIPM of pod borers in pigeonpea and chickpea resulting in increased grain yield.
- Release of *Telenomus remus* @ 100,000/ha and three sprays of SlNPV @ 1.5 x 10^{12} POBs/ha along with 0.5% crude sugar as adjuvant against *S. litura* in soybean resulted in 17% higher yield than in chemical control.
- Integration of *T. remus* and NSKE for the management of *S. litura* and *C. zastrowi sillemi* and *Nomuraea rileyi* (@ 10^{13} spores/ha) for the management of *Helicoverpa armigera* on tobacco were effective.
- *Ischiodon scutellaris* @ 1000 adults/ha or 50,000 larvae/ha reduced *Lipaphis erysimi* population on mustard and gave higher yield.
- Inundative releases of parasitoids *Goniozus nephantidis* and *Brachymeria nosatoi*, against *Opisina arenosella* on coconut, coinciding the first release with the appearance of the pest, have proved effective.
- Adult release of *G. nephantidis* on trunk was as good as release on crown for the control of *O. arenosella* on coconut
- *Oryctes baculovirus* has been highly successful in reducing *Oryctes rhinoceros* populations in Kerala, Lakshadweep and Andaman Islands.
- *Cryptolaemus montrouzieri* has effectively suppressed *Planococcus citri* on citrus, *Pulvinaria psidii, Ferrisia virgata* on guava, *Maconellicoccus hirsutus* on grapes and *Rastrococcus iceryoides* on mango.
- Efficacy of *Trichogramma*, *Cryptolaemus*, *C. zastrowi sillemi*, HaNPV and SlNPV has been successfully demonstrated in Punjab, Andhra Pradesh, Karnataka, Maharashtra, Gujarat and Tamil Nadu.
- *Aphelinus mali* and several coccinellid predators were found effective against the apple woolly aphid.
- San Jose scale parasitoids, *Encarsia perniciosi* and *Aphytis* sp., were well established in Jammu and Kashmir and Himachal Pradesh.
- *Trichogramma brassicae* and *Bt* were found effective against *Plutella xylostella*.

- Tomato fruit borer, *H. armigera* was effectively controlled by releases of *T. pretiosum* and *Ha*NPV.
- *Copidosoma koehleri* and *Bt* were found effective against potato tuber moth in country stores.

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 and Weeds

Promotion of biological control as a component of integrated pest and disease management in agricultural and horticultural crops for sustainable crop production.

Demonstration of usefulness of biocontrol in IPM in farmers' fields

Organisational set-up

With a view to fulfil the mandate effectively and efficiently, the NBAII is being reorganized into three divisions, *viz.* Division of Insect Systematics, Molecular Entomology and Insect Ecology. Research on microbial biocontrol is being addressed under the coordinating cell of the AICRP on Biological Control (Fig. 1).

ICAR Institute-based centres (CPCRI, Kayangulam; CTRI, Rajahmundry; IARI, New Delhi; IIHR, Bangalore; IISR, Lucknow and SBI, Coimbatore) did not maintain separate budget accounts since the Project has been merged with Non-Plan budget of the institutes.

Financial statement (2011-12) (Rs in lakhs)

NBAII, Bangalore

Head	Plan	Non-plan	Total
Pay & allowances	00.00	426.66	426.66
TA	07.99	04.99	12.98
Other charges including equipment-Lib.	118.81	81.49	200.30
Information technology	00.00	05.00	05.00
Works/petty works	07.22	9.56	16.78
HRD	00.98	-	00.98
Pension	0.00	34.29	34.29
Loan	0.00	2.94	02.94
Total	**135.00**	**564.93**	**699.93**

AICRP Centres (ICAR share only)

Name of the centre	Expenditure (Rs in lakhs
AAU, Anand	48.11
AAU, Jorhat	45.50
ANGRAU, Hyderabad	38.50
YSPUHF, Nauni, Solan	24.29
GBPUAT, Pantnagar	10.34
KAU, Thrissur	38.17
MPKV, Pune	39.04
PAU, Ludhiana	35.21
SKUAST, Srinagar	18.43
TNAU, Coimbatore	26.16
PC Cell, Bangalore	04.99
MPUAT, Udaipur	03.16
JNKVV, Jabalpur	02.86
OUAT, Bhubaneshwar	03.86
CAU, Manipur	01.38
Total	**340.00**

ORGANISATIONAL CHART

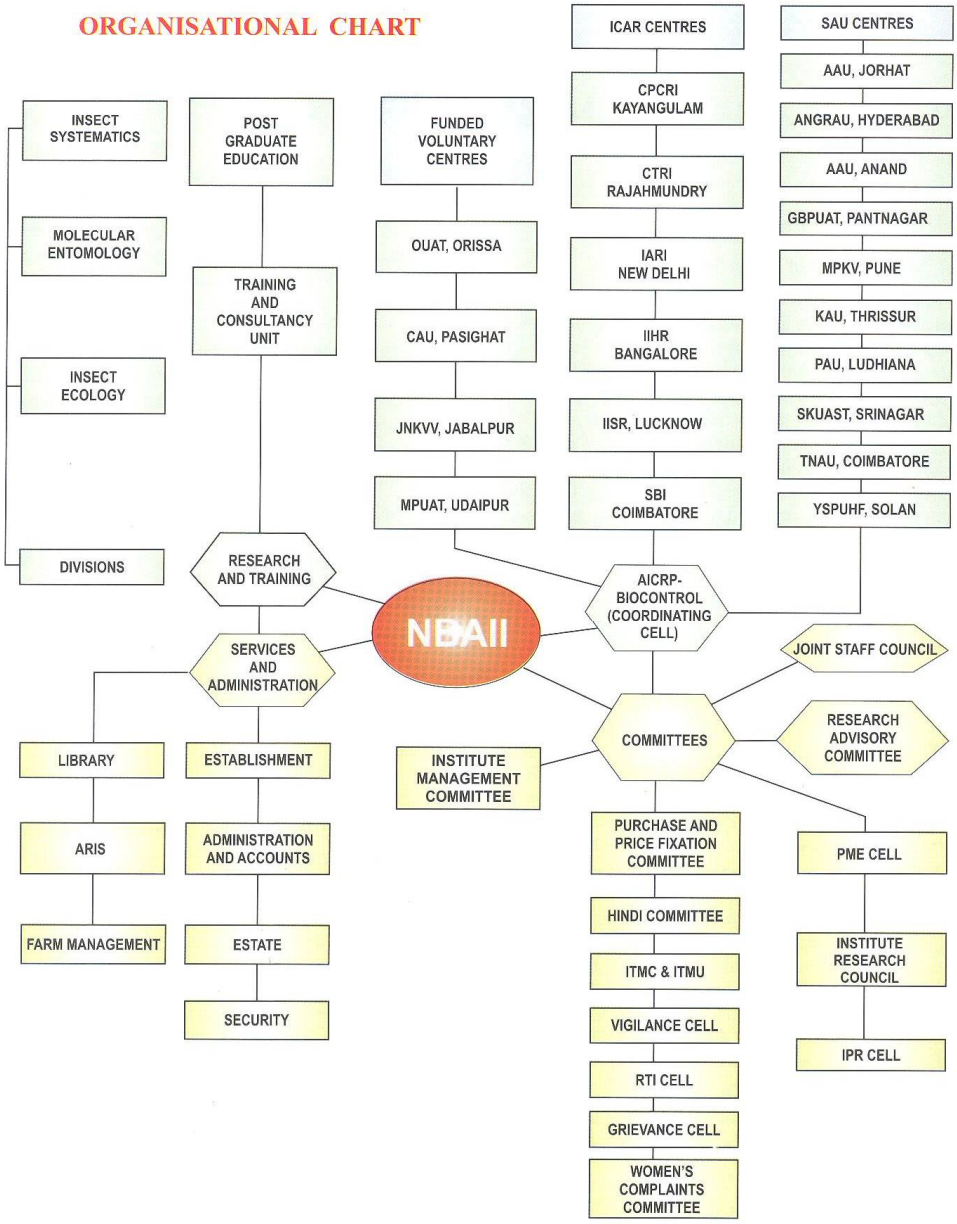


Fig. 1: Organisational chart of NBAII

4. RESEARCH ACHIEVEMENTS

4.1. National Bureau of Agriculturally Important Insects

4.1.1. Division of Insect Systematics

Taxonomic knowledge is a prerequisite for the management of arthropods, nematodes and weeds in agricultural ecosystems. It helps detail the components of biodiversity so vital for sustainable agriculture entailing the management of pests, conservation of their natural enemies and the manipulation of pollinator diversity in agro-ecosystems. It is also essential to detect, monitor and manage alien invasive species. In this light the object is to document and map the different groups of agriculturally important arthropods and related organisms from across our country.

Survey

The Andaman Islands as well as parts of South, Central and East India were surveyed for Chalcidoidea, Platygastroidea, Trichogrammatidae, Microgastrinae, Coccinellidae, Coccidae, Aphididae and Anthocoridae. In the Andaman Islands, South Andaman (Sippighat, Bloomsdale, Chouldhari, Garacharma, Mt. Harriet), Middle Andaman, Baratang, Neil and Havelock islands were surveyed.The areas surveyed in mainland India were (i) Southern India: Andhra Pradesh (Hyderabad), Kerala (Thrissur, Palakkad), Tamil Nadu (Hoganekal and Kodaikanal) and Karnataka (surveyed extensively, covering various places within the State) (ii) Central India: Madhya Pradesh (Bhopal, Kerwa Dam) and Delhi (Aravalli ridge), and (iii) Eastern India: Odisha (Bhubaneshwar, Chilika Lake and Salia Dam). Surveys were conducted in agricultural and natural ecosystems. Insects were also collected from urban areas.

New distribution records

Order Coleoptera; Family Coccinellidae

Many species of ladybird beetles are efficient predators of aphids, mealybugs and scales. Some have been used with telling success in pest management programmes around the world. Taxonomic studies on Indian Coccinellidae are in progress. *Henosepilachna verriculata* Pang & Mao, a phytophagous species, was recorded for the first time from India from Manipur. *Synonychimorpha chittagongi* (Vazirani) (Tripura), *Ortalia vietnamica* Hoang (Himachal Pradesh), *Illeis confusa* Timberlake (Manipur and Jammu & Kashmir) and *Serangium chapini* (Kapur) (Assam) are new distribution records for these states. An apparently new species of *Ortalia*, the host of which is not known, was recorded from Himachal Pradesh.

Order Hymenoptera

The Hymenoptera are perhaps the most important group of insects responsible for maintaining the diversity of agroecosystems. They are not only the most important natural enemies of insect herbivores (pests) but are also one of the most important groups of pollinators and a key group of seed dispersers.In these different roles they regulate the population size of arthropods and maintain diversity in plants. Unfortunately they also appear to be an extinction prone group with many species being susceptible to environmental disturbances.

The parasitic Hymenoptera, which constitute the largest group in this insect order, play an important role in natural and agricultural ecosystems and are a focus of our studies currently.

Superfamily Chalcidoidea

Psyllaephagus mycopsyllus Singh, *Anagyrus thailandicus* and *Neocladia narendrani* Hayat (Encyrtidae), were documented as new distribution records from Karnataka. *Cheiloneuromyia javensis* Girault (Encyrtidae) was recorded for the first time on Diaspididae from Karnataka, the earlier records being from the Andaman & Nicobar Islands, Bangladesh, and Indonesia. *Lakshaphagus fusiscapus* (Fig. 2) (on *Cerococcus* sp., from Andamans), *Astymachus felix* (on sugarcane mealybugs, from Tamil Nadu), and *Procheiloneurus javanicus* (as a hyperparasitoid associated with mealybugs, from Karnataka) were documented as new distribution records for the respective States.

Cheiloneuromyia javensis Ginault (Hymenoptera: Chalcididae) was recorded on diaspine scale, *Aulacaspis tubercularis* infesting mango.

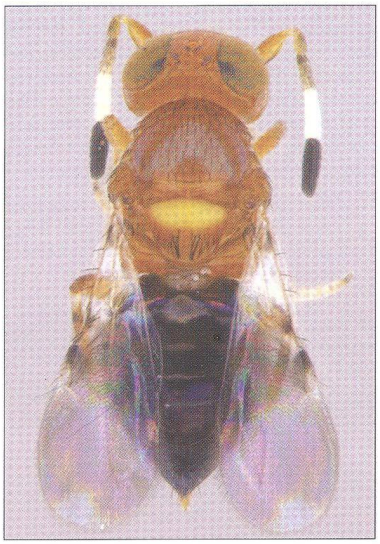


Fig. 2: *Lakshaphagus fusiscapus* from Andamans

Family Trichogrammatidae

Trichogramma achaeae and *Trichogrammatoidea bactrae* were two species recorded for the first time from agricultural fields in the Andaman islands. While both are new species records for these islands they constitute the first record of the genus *Trichogrammatoidea* from these islands. Both species are of agricultural importance and have been used widely in biological control programmes. A single specimen of *Trichogramma* belonging to the *nomlaki / drepanophorum* group was collected from a cultivated area in Bhubaneshwar. *T. bistrae* which belongs to this group has only been reported from Bulgaria and France and only a few specimens of this species exist in collections. The presence of this Palaearctic species or one closely related to it is for the first time being reported from outside its known range.

Superfamily Platygastroidea

The genera *Oxyscelio* and *Mantibaria* are reported for the first time from India. The genera *Cremastobaeus* and *Microthoron* are reported for the first time from South India. *Tiphodytes* is reported for the first time from Karnataka. So far only two genera of Platygastroidea, viz. *Telenomus* and *Gryon* were reported from the Andaman Islands. During the recent survey in February, 2012, 16 additional genera, viz. *Paratelenomus, Trissolcus, Psix, Trimorus, Xenomerus, Baryconus, Macroteleia, Baeus, Idris, Opisthacantha, Duta, Scelio, Sparasion, Ceratobaeus, Cremastobaeus* and *Psilanteris* were collected from these islands. *Allotropa* sp. (Sceliotracheliniae) was found parasitizing *Phenacoccus madeirensis* on *Cestrum nocturnum*.

Order Hemiptera

Aphids, scales and mealybugs belong to the Order Hemiptera. All of them are sucking insects which feed on plants. They are major pests of horticultural and ornamental crops. While some damage crops directly by feeding, others are dreaded vectors of plant diseases that cause immense losses to crops. Aphids and coccids are the most important groups of invasive insects.

Family Aphididae

The aphid, *Wahlgreniella nervata* (Gillette), collected on rose from Bangalore was recorded for the first time from Karnataka, India (Fig. 3).

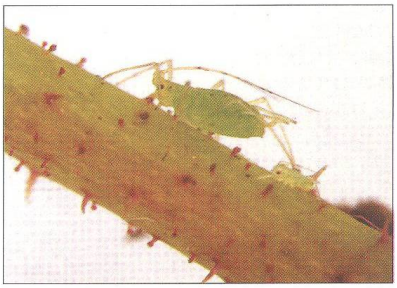


Fig. 3: *Wahlgreniella nervata* feeding on rose

Family Coccidae

Kilifia acuminata (Signoret) (Fig. 4) (infesting ornamental fern) was reported for the first time from India.

The diversity of the genus *Anagyrus*, a major parasitoid of coccids was also studied. Seventeen unidentified species of *Anagyrus* were collected from

twelve species of mealybugs infesting different host plants in Bangalore, Karnataka (Table 1).

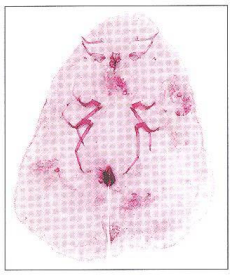


Fig. 4: Mounted female of *Kilifia acuminata*

Table 1: Species of *Anagyrus* collected from different mealybugs during 2011-12

Mealybug	Host plant
Coccidohystrix insolita	*Solanum* sp.
Maconellicoccus hirsutus	*Tamarindus indica* and *Morus alba*
Planococcus citri	*Solanum* sp.
Planococcus lilacinus	*Tectona grandis* and *Gmelina arborea*
Ferrisia virgata	*Nerium* sp. and *Psidium guajava*
Nipaecoccus viridis	*Artocarpus hetrophyllus*
Phenacoccus madeirensis	*Lantana camara*
Phenacoccus solenopsis	*Parthenium hysterophorus*
Paracoccus marginatus	*Plumeria alba*
Rastrococcus iceryoides	*Mangifera indica*, *Citrus* sp. and *Pongamia pinnata*
Crissicoccus hirsutus	*Ziziphus* sp.
Genus et. sp. indet.	*Anacardium occidentale*

Family Anthocoridae

Although bugs are predominantly a herbivorous group the anthocorids are all predators. While some of them have been used successfully in biocontrol programmes around the world others show promise for use in such programmes.

Physopleurella armata is recorded for the first time in India on coconut. *Montandoniola indica* is recorded for the first time from Karnataka as a predator of *Gynaikothrips uzeli* on *Ficus retusa*.

Taxonomic studies

Order Coleoptera; Family Coccinellidae

The genus *Stictobura*, members of which are predators of Coccoidea (scales and mealybugs) and are endemic to India, was revised. *Stictobura buruensis* Korschefsky was transferred to *Sticholotis*. *Stictobura gibbula* (Weise) was restored to *Sticholotis*, under which it was originally published. Syntypes of the species of *Stictobura* studied from the Natural History Museum, London, were designated as lectotypes to ensure stability of the names.

A new ladybird beetle *Sticholotis magnostriata* Poorani was described from Assam (Fig. 5). Members of this genus usually feed on Coccoidea, but the host of this species was not known.

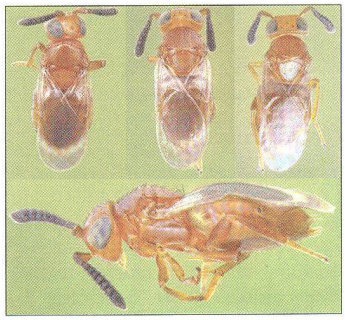


Fig. 5: *Sticholotis magnostriata* (top) and *Microterys chaetococci* (bottom)

Order Hymenoptera; Superfamily Chalcidoidea

Microterys chaetococci Hayat & Poorani (Encyrtidae) (Fig. 4), a parasitoid of *Chaetococcus* sp. on bamboo, was described from Karnataka. One new species each of *Poropoea* Foerster (Trichogrammatidae) and *Zaplatycerus* Timberlake (Encyrtidae) were described from Karnataka on indeterminate species of Attelabidae on jamun and Pseudococcidae on coconut, respectively. Two new species of *Trichogrammatoidea*, *T. rufomaculata* Nagaraja & Prashanth and *T. brevicaudata* Nagaraja & Prashanth have been described from Karnataka.

While the former is closely related to *T. fulva* the latter is related to *T. armigera*. A new species of *Trichogramma* collected from Mandya district, Karnataka is being studied and described. SEM studies have been commenced on *Trichogramma* to resolve taxonomic problems encountered in the conventional taxonomy of this group (Fig. 6).

Fig. 6: Scanning electron micrographs of male genitalia of *Trichogramma agriae*

Superfamily Platygastroidea

Two new species, *Odontacolus markadicus* Veenakumari and *Odontoscelio vikata* Veenakumari & Rajmohana, were described from south India (Fig. 7). Both the species are the first representatives of the genera from India.

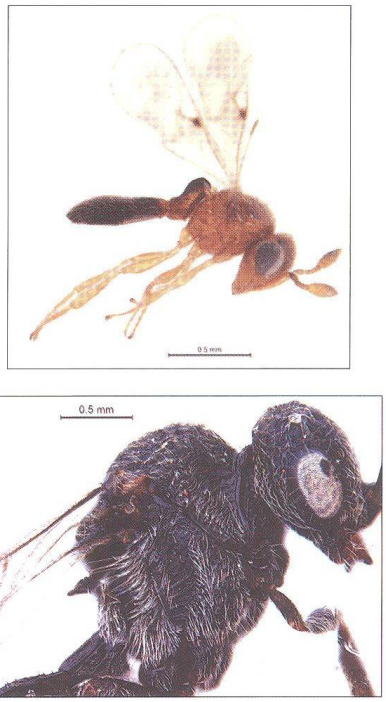


Fig. 7: *Odontacolus markadicus* (top) and *Odontoscelio vikata* (bottom)

Family Braconidae; Microgastrinae

Glyptapanteles hypermnestrae Gupta and Pereira was described as new from Maharashtra, India (Fig. 8). It was bred from parasitized larvae of *Elymnias hypermnestra* (Linnaeus) (Lepidoptera: Nymphalidae).

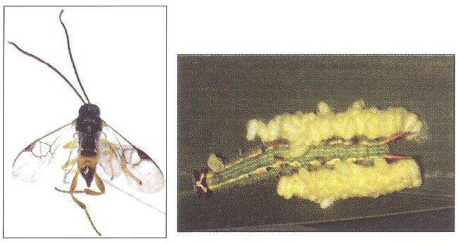


Fig. 8: Parasitized larva of *Elymnias hypermnestra* (right) and *Glyptapanteles hypermnestrae* (left)

Table 2: Diversity of anthocorids associated with different pests and host plants

Anthocorid	Host /pest	Host plant	Place
Cardiastethus exiguus	*Paracoccus marginatus* Thrips	Papaya Cashew Rose	Bangalore Puthur Bangalore
Xylocoris (*Proxylocoris* sp.) sp. (indet.)	Not known	Maize	Bangalore
Orius tantillus	Not known	Maize	Bangalore
Carayanocoris indicus	Thrips	*Cassia javanica*	Bangalore
Orius niger, *Cardiastethus exiguus* Genus et sp. indet.	*Haplothrips gowdeyi*	*Cassia javanica*	Bangalore
Cardiastethus affinis	*Hemiberlesia lataniae*	Agave	Bangalore
Montandoniola indica Genus et sp1. indet. Genus et sp2. indet.	*Gynaikothrips uzeli* Thrips *Liothrips karnyi*	*Ficus retusa* Jamun tree Pepper vine	Bangalore Bangalore Kerala
Genus et sp. indet.	Thrips	*Ficus* sp.	Bangalore
Orius sp. (indet.)	*Thrips subnudula*	*Calotropis gigantea*	Bangalore
Physopleurella armata	Not known	Coconut	Palakkad, Kerala
Orius niger, C.exiguus *Blaptostethus pallescens* Genus et sp. indet.	*Thrips subnudula* *T. hawaiiensis*	*Tecoma stans*	Bangalore
Bilia castanea	*Tetranychus urticae*	*Nyctanthes arbortristis*	Bangalore
Anthocoris muraleedharani	*Ferrisia virgata*	*Bauhinia purpurea*	Bangalore
Cardiastethus sp.	*Coccidohystrix insolita*	Pigeonpea	Bangalore
Genus et sp. indet.	Thrips	*Crotalaria juncea*	Bangalore
Genus et sp. indet.	*Megalurothrips* sp., *Planococcus citri*	*Butea monosperma*	Bangalore
Orius sp.	*Haplothrips* sp., *Microcephalothrips abdominalis,* *Thrips palmi*	*Tagetes erecta*	Bangalore
Orius sp.	*Haplothrips* sp., *Thrips palmi*	Chrysanthemum	Bangalore
Genus et sp. indet.	*Megalurothrips* sp.	Black gram	Andamans
?Cardiastethus sp.	*Orthezia* sp.	Lantana	Bangalore
Genus et sp. indet.	Eriophyid mite, Thrips	Sugarcane	Mandya
?Cardiastethus sp.	Thrips and mites	Mango inflorescence	Bangalore
Genus et sp. indet.	Mites	Cotton	Bangalore
Genus et sp1. indet. Genus et sp2. indet.	*?Gynaikothrips uzeli*	*Ficus* sp., *Ficus altissima*	Bangalore
Genus et sp. indet.		Sweepnet collection	Sippighat, Andamans

An annotated checklist of Indian Microgastrinae has been prepared. The checklist is under review. It includes 21 genera and 231 species with information on distributions and introduced species for biological control programs. Of these, 191 species are currently recognized as valid and 40 species as questionable due to lack of type specimens or erroneous identification.

New records of host insects

Apanteles folia Nixon and *Brachymeria indica* (Krausse) (Chalcididae) were reported parasitizing larvae of *Arhopala amantes* Hewitson (Lepidoptera: Lycaenidae) and pupae of *Pareronia valeria* Cramer (Lepidoptera: Pieridae), respectively, which constitute new host records.

Phenacoccus madeirensis Green and *Nipaecoccus viridis* were recorded as new hosts for *Anagyrus loecki* Noyes & Menezes which was imported from the US for the control of *Paracoccus marginatus* Williams and Granara de Willink. *Anagyrus qadrii* (Hayat et. al.) was collected for the first time on *Phenacoccus madeirensis*. *Ferrisia virgata* (Cockerell) was recorded for the first time on tubers of *Amorphophallus* sp. in storage and yam bean pods (*Sphenostylis stenocarpa*) in agricultural fields.

Many species of anthocorids were collected from cultivated and non-cultivated areas in the Andamans, Karnataka and Kerala (Table 2).

DNA barcodes

Molecular systematics is not stage-specific and does not need trained taxonomists. It is rapid and helps in differentiating biotypes. The main advantage of DNA barcoding is the speed with which molecular data can be acquired. It is extremely useful for the unambiguous identification of biological specimens and more efficiently managing species diversity in Gene Banks. This tool is handy for the identification of invasive insect pests.

DNA barcodes were generated for important parasitoids, viz. *Trichogramma rabindrai, T. agriae, T. japonicum, Trichogrammatoidea armigera, Apanteles galleriae* and *Fornicia ceylonica* Wilkinson. The following GenBank accession numbers were obtained: *Fornicia ceylonica* JN613568; *Apanteles hyposidrae* JQ308797 and *Apanteles galleriae* JN790942. Gene sequences of seven species, namely, *Apanteles hyposidrae, A. galleriae, A. machaeralis* Wilkinson, *A. taragamae* Viereck, *A. mohandasi* Sumodan & Narendran, *F. ceylonica,* and *Dolichogenidea* sp.

Barcodes were also developed for the eucalyptus gall wasp, *L. invasa* and its natural enemies, *Q. mendeli* and *Megastigmus viggianii* based on the ITS 2 region of their mitochondrial DNA. The sequence and barcodes are given below.

***Leptocybe invasa* (556 bp) (Hymenoptera: Eulophidae: Tetrastichinae)**

CGAATTGAATTAATAAATTTAAATAATAATTTT
AATAATAATATAATTTATTATATAATAATTACTA
TTCATGCTTTATTATAATTTTTTTTATAACTATA
CCTATTATTATTGGATTAAGTAATTGATTATTA
CCTTTAATATTAATATCTTCAGATTTAATTTTT
CCTCGTTTAAATAATTTTAGATTTTGATTATTA
ATTCCATCTTTAATTTTTATAATATTAAATATAT
TATTAAATAATAATATTAATACTGGATGAACAT
TATATCCTCCTTTAATTAATCAAAATTTTATTA
CATTAAATTTTATTATTTTTTCATTACATTTAA
ATGGTTTATCTTCAATTTTTAGATCTATTAATT
TATTTCATCTATTTTTATTATTAATAATAATAAT
TTTTTTTTAAATAATTTTTCTTTAATATTTGAT
AATTATTGTTACTACAATTTTATTAATTATTTC
AATTCCTATTTTATCTAGAGCTATTACTATAAT
TATTTTAGATAATAATTTAAACATAAATTTTTT
TAATCTCAATAGGAAATGGTAAT

DNA barcode

***Megastigmus viggiani* (518 bp) (Hymenoptera: Torymidae)**

TGTGAACTGCAGGACACATGAACATCGACA
GGTCGAACGAACCATTGCGGTCCACGGATAC
GATTCCCGGACCACGCCTGGCTGAGGGTCGT
TCAACAAACTAAAACAGACTGCTCGTAAAG
TCGAGCGATTATCTTGGGCGTTCGTCGTTCTC
TGTCGGAGACAGAATAGAGCGGCGTCGCCT
GAAATGAATTTTCGTACGTACGCCTGCGAGA
GACGTATGAGAGTGTCGAGACTATTCGAATG
CGACGATCCCTTATGGACAATGTCGCGAGTC
ATCGTACGTCGAGTCCCGGAGCTCTTGCGCG
CTAAAGCGTGCCGGGCGGACCGACCGACGG
GTGGCTCGTCGATGTCCAAAACGGTTGTACG
TTTGTTCTCGCTCTCGTTGACTTACGTTATCG
CATTGCAATAAATGCAACGCAGTCCAGTTTA
CGCACGAAGGTAGATTAGCGAGAGAGCGTA
TTTAATGAAACACTGAAGCCTGCCGACATAC
GACGACCTCAGAGCAGGGCAAGACC

DNA barcode

***Quadrastichus mendeli* Kim & La Salle (530 bp) (Hymenoptera: Eulophidae: Tetrastichinae)**

TGTGAACTGCAGGACACATGTGAACATCGA
CAGTGCGAACGAACCATTGCGGTCCTCGGA
TACGATTCCCGGACCACGCCTGGCTGAGGG
TCGTTCATAAGATAAAACCAGACTGCTCGTC
TCTTTGACGAGCGTACGCTTGAGCGCTCGTC
GAGTTGTTGTTGTTGTTGTCGTCCGTGA
TGATTTTTTTTTTTATCCGACGACGCACTCCT
CGGTGTCGCTCTAAATGAATCAAACGACTTG
TCGAACGTTGCGAAAACGAACGAAAGTCA
AAGTCGTACGCACACGCAATTTCAAAAGCG
AAGCGTCTCTCACGTGCGTCGTACGTCAAG
TCCCGGAGCTCTTGTGGTCGCGCTTTCGGCG
CGCCCCGAGCGGACCGACGTCTTCCTCGTG
AGGTATGACGCGTTCGCGCGTGCCTCTGCCC
TTGACAACTGATTGTTCGGATTTCATTTGAA
AGGCTCGTTCGTGCAAATGGTATTATGTATAA
TTCTATTATATAACGACAACCTCAAAGCAGG
GCAAAACCA

DNA Barcode

Identification services

One thousand two hundred and thirty six specimens of insects including Thysanoptera, Coccidae, Aphididae, Syrphidae, Tachinidae, Tephritidae, Coccinellidae and parasitic Hymenoptera were identified for thirty three institutions including various AICRP centres, State Agricultural Universities, other universities and students.

Mass multiplication and maintenance of cultures

Different host and parasitoid cultures are being maintained in the laboratories. During the period under report, 112 live insect cultures were maintained including host insects, predators and parasitoids (list on www.nbaii.res.in). From the Mass Production Laboratories and Unit, 795 shipments of live insect cultures were supplied to different research organizations, commercial insectaries, students, AICRP centres, etc.

Species of *Trichogramma* (*T. chilotraeae, T. agriae, T. rabindrai* and two new species) and *Trichogrammatoidea* (*T. rufomaculata* and *T. brevicaudata*) are being maintained for biological and molecular studies. In addition to these, 35 cultures of other species of *Trichogramma* and *Trichogrammatoidea* collected from different hosts as well as from different geographic areas are being maintained for crossing experiments and taxonomic studies.

As *T. rabindrai* does not parasitize the eggs of *Corcyra cephalonica* or *Samia cynthia* attempts were made to culture it on alternative hosts. It could only be cultured on the eggs of *Graphium agamemnon* (Lepidoptera: Papilionidae) and *Nephele didyma* (Lepidoptera: Sphingidae). Eight generations have been completed in the laboratory.

A culture of *Callosobruchus maculatus* is being maintained for the multiplication of *Uscana* species.

Cultures of four host insects (*Aphis craccivora, Ferrisia virgata, Phenacoccus solenopsis* and *Paracoccus marginatus*) and four predators (*Cheilomenes sexmaculata, Coccinella septempunctata, Brumoides suturalis* and *Micromus timidus*) are being maintained in the laboratory.

Web resources

Database on agriculturally important insects

An image gallery (URL:http://www.nbaii.res.in/Pestsofcrops/Indian%20Insects.htm) of pests of crops and other common insects in Indian agroecosystems was constructed and hosted with over 2500 photographs to facilitate easy identification of the insects. Basic information on the taxonomic position, habitat / crops damaged and pest status is provided for all the species included (Fig. 9). This resource and the website on Aphids of Karnataka have been included in ID Source, a compilation of websites worldwide that provide identification tools to identify pests, diseases and weeds.

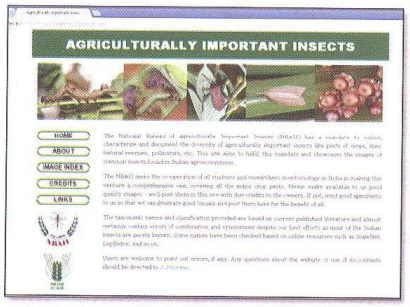


Fig. 9: Screenshot of the website on insects in Indian agroecosystems

Insect Germplasm Information System (IGIS)

Insect Germplasm Information System (IGIS) - an online computer tool has been developed for providing information about the live insect genetic resources maintained at different insectaries in India. The IGIS online database tool can cater to the needs of entomologists working on different groups of agriculturally important insects in India. At present, passport information is available for silkworm genetic resources maintained at CSGRC, Hosur, Tamil Nadu and also for host insects and beneficial insects (parasitoids and predators) maintained at NBAII.

The IGIS is user-friendly and easy to access for the submission of germplasm entries. Entomologists can log into the website: http://202.141.78.173/germplasm/ (or) through http://www.nbaii.res.in (Fig. 10). Institutes that wish to register their live insect germplasm accessions can do so by clicking the Germplasm registration option and then submit their insect germplasm entries. NBAII will then assign national accession numbers for the submissions. The application form for insect germplasm registration and guidelines are provided in the website.

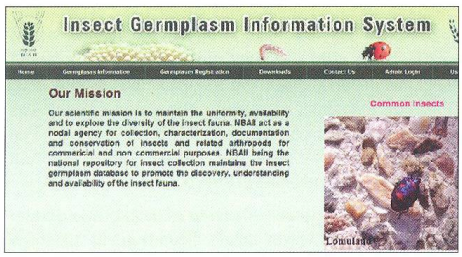


Fig. 10: Screenshot of the Insect Germplasm Registration Website

4.1.2. Division of Molecular Entomology

Recent technological advances in wet lab molecular biology and *in silico* information technology have ushered in a new era of bioinformatics making it easy for researchers to link natural biodiversity with gene pools and their utilization. NBAII envisages to apply this high-throughput knowledge in genomic analysis, functional genomics and RNAi information of insects in environmentally acceptable insect pest management, manipulation of virus-vector relationships, host-plant resistance to insect pests, management of pesticide resistance, prediction and management of invasives, molecular identification and bar coding.

Association of microbial endosymbionts with beneficial insects including parasitoids and predators is hypothesized to impart tolerance to abiotic stresses and to enhance fitness through better parasitization and production of female progeny. Projects are in progress to document such symbiotic associations in natural enemies. Culturable microbial symbionts associated with natural populations of trichogrammatids were isolated and cultured revealing that they were mainly yeast and bacteria (Fig. 11).

Mapping, documentation and characterization of endosymbionts of *Trichogramma* collected from different agro-climatic zones

Isolation of endosymbionts

Yeast and bacterial symbionts isolated from *Trichogramma* and *Trichogrammatoidea* spp. that emerged from field collected lepidopteran eggs were cultured on yeast extract peptone dextrose (YEPD) agar medium (Table 3).

Table 3: Endosymbionts isolated from species of *Trichogramma* and *Trichogrammatoidea* from different locations

Species	Crop	Location	Endosymbiont
T. chilonis	Cotton	Faridkot	*Pichia anomala*
T. chilonis	Cotton	Davanagere	*P. anomala*
T. chilonis	Sugarcane	Gurdaspur	*Candida pimensis*
T. chilonis	Sugarcane	Vadodara	*Hanseniaspora uvarum*
T. achaeae	Sugarcane	Bhubaneshwar	*C. apicola*
T. chilotraeae	Sugarcane	Hyderabad	*P. ohmeri*
T. chilonis	Castor	Jorhat	*P. anomala*
T. chilonis	Tomato	Coimbatore	*Zygosaccharomyces rouxii*
T. achaeae	Tomato	Bangalore	*Wickerhamomyces anomalus*
Tr. bactrae	Cabbage	Malur	*Metschnikowia reukaufii, Bacillus subtilis*

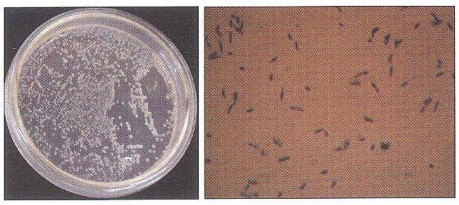


Fig. 11: Colonies of yeast and bacteria isolated from various populations

Yeast and bacterial colonies that developed were purified three times by single-colony isolation. These colonies were identified as *Pichia anomola*, *P. ohmeri*, *Candida apicola*, *C. pimensis*, *Metschnikowia reukaufii*, *Hanseniaspora uvarum*, *Wickerhamomyces anomalus*, *Zygosaccharomyces rouxii* and *Bacillus subtilis*.

Phylogenetic analysis of endosymbionts cultured from different populations of *Trichogramma*

Nucleotide sequences of ITS region of endosymbionts obtained were aligned using the CLUSTAL W algorithm and a phylogenetic tree was constructed by neighbour joining method using the distance matrix from the alignment.

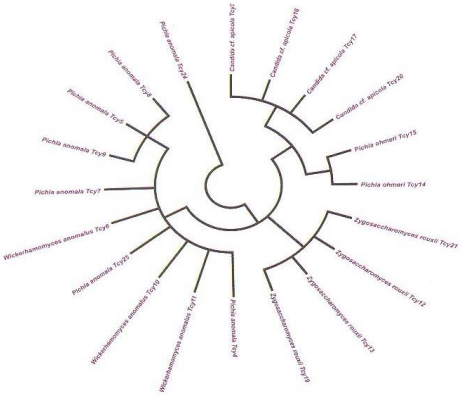


Fig. 12: Neighbour-joining tree based on nucleotide sequence alignment of ITS region of yeast endosymbionts associated with *Trichogramma*

Pichia anomola, *P. ohmeri*, *C. apicola*, *C. pimensis*, *M. reukaufii*, *H. uvarum*, *W. anomalus* and *Z. rouxii* formed different clusters, thus indicating these are different from each other (Fig. 12).

Determination of role of endosymbionts in fitness attributes of laboratory reared *Trichogramma* spp.

Endosymbionts are beneficial organisms in parasitoids which help them tolerate biotic and abiotic stresses. To determine the role of yeasts in enhancing fitness in *Trichogramma*, *M. reukaufii*, *P. ohmeri*, *W. anomalus*, *C. apicola*, and *Z. rouxii* were fed to laboratory populations of *T. japonicum* and *T. chilonis* for 15 generations.

Per cent parasitism, per cent females and fecundity in various generations of *T. japonicum* fed with different yeast symbionts were significantly enhanced compared to control (corresponding values being 30-40%, 23-49% and 28-38 /female, respectively) (Table 4). Similarly, per cent parasitism, per cent females and fecundity were greatly enhanced in *T. chilonis* (Table 5) fed with various symbionts compared to control (38% parasitism, 40% females and 28/female, respectively). These studies indicate that symbionts play a definite role in enhancing the biological fitness of laboratory populations of *T. japonicum* and *T. chilonis*.

Capsule formulations of symbionts

Viability of yeast isolates formulated in gelatin capsules (with cellulose and casein) as carriers was tested at 30-days interval. The yeast isolates remained viable (>10^5 CFU) in cellulose- and casein-based formulations even after 90 days on YPDA media.

Even after 90 days of storage, the colony count was 83-177 in cellulose and 109-189 in casein. The colony survival was low in *P. ohmeri* compared with the other four symbionts (Table 6).

Isolation and characterization of microorganisms/ endosymbionts from adult *Chrysoperla zastrowi sillemi* and *Mallada desjardinsi*

Light microscopic and TEM study revealed the presence of yeast and bacteria in the gut of adult *C. z. sillemi* (Figs 13-15). Endosymbiotic yeasts and bacteria were isolated from the midgut, fat bodies and diverticulum of natural populations of *C. z. sillemi* from cotton growing states in the country (Fig. 16). Primers, namely, Y-ITS 1F (5'-TCCGTAGGT GAACCTGCGG-3') and Y-ITS 1R (5'-GCTGCGTTCTTCATCGATGC--3') were used for the identification of yeast and 16s forward primer (5'-AGAGTTTGATCCTGGCTCAG-3') and 16s reverse primer (5'-CGGTGTGTACAAGACCC-3') were used for the identification of bacteria. Molecular characterization of six yeast isolates from *C. z. sillemi* (*W. anomalus*, *P. anomala*, *C. blankii*,

Table 4: Effect of symbionts on fitness attributes of laboratory populations of *T. japonicum*

Yeast	Parasitism (%)			Females (%)			Fecundity		
	Generations								
	F5	F10	F15	F5	F10	F15	F5	F10	F15
M. reukaufii	93	88	75	69	79	71	53	62	43
Z. rouxii	88	85	89	76	70	85	43	46	60
P. ohmeri	97	50	80	82	80	75	44	51	49
W. anomalus	85	92	75	76	77	63	57	63	51
C. apicola	85	70	80	73	77	80	40	68	40
Control (50% sucrose)	33	30	40	49	23	46	32	28	38

Table 5: Effect of symbionts on biological fitness of laboratory populations of *T. chilonis*

Yeast	No. of eggs exposed	Parasitism (%)	Females (%)	Fecundity
M. reukaufii	53	80	76	53
P. ohmeri	49	90	80	61
W. anomolus	62	75	71	46
C. apicola	54	85	78	49
P. anomala	56	73	70	50
Control (50% sucrose)	53	38	40	28

Table 6: Number of yeast colonies from the capsules formulations

Yeast	Dilution 10^{-5}					
	30 days		60 days		90 days	
	Cellulose	Casein	Cellulose	Casein	Cellulose	Casein
M. reukaufii	166	256	198	143	177	109
P. ohmeri	179	196	124	132	83	111
W. anomolus	183	201	142	151	134	127
C. apicola	192	256	144	168	112	171
P. anomala	199	261	185	203	168	189

Z. rouxii, Kodamea ohmeri and *C. pimensis*) and two endosymbiotic bacteria (*Paenibacillus* sp. and *Enterobacter* sp.) was done. *Wickerhamomyces anomalus, Torulaspora delbrueckii* (fat bodies); *W. anomalus, T. delbrueckii* & *K. ohmeri* (gut) and *W. anomalus, T. delbrueckii* and *Saccharomycetales* sp. (diverticulum) were isolated from *M. desjardinsi*. ITS-1 and 16 S RNA regions of the above were sequenced, submitted in GenBank and accession numbers obtained.

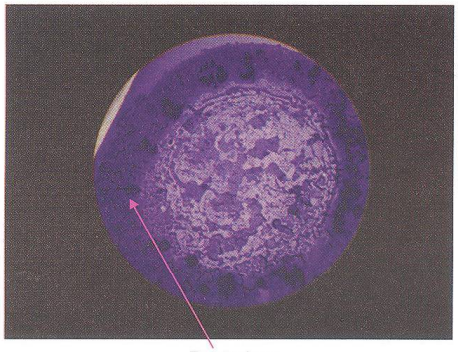


Fig. 13: Light microscopy examination of midgut and diverticulum of *C. z. sillemi* (40 X)

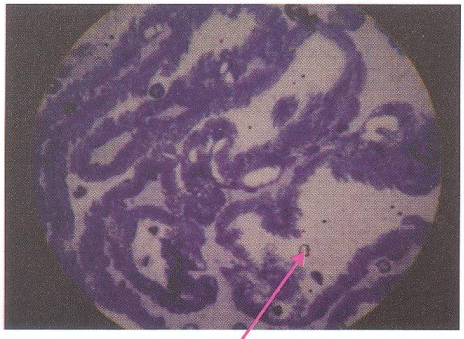


Fig. 14: Light microscopy examination of diverticulum of *C. z. sillemi* adult (40 X)

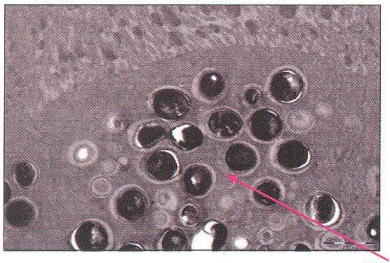
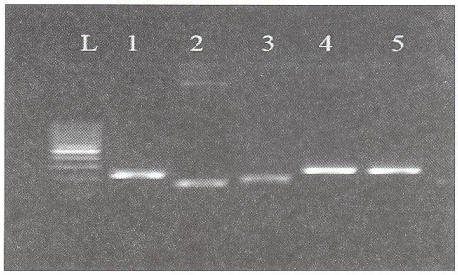


Fig. 15: TEM micrograph of adult midgut of *C. z. sillemi* (10 µm)

Fig. 16: PCR amplification of microorganisms of



***C. z. sillemi* adult**
Lane 1-midgut -175bp; Lane 2 & 3- fat body -170bp; Lane 4 & 5 diverticulum -175bp

Degradation of insecticides by microorganisms/ endosymbionts isolated from *C. z. sillemi*

Isolates of *Enterobacter* sp. and *Paenibacillus* sp. from larval gut of *C. z.sillemi* were identified by PCR assay and tested for degradation of acephate at different concentrations (25, 50, 75 and 100 ppm) using minimal media. The OD was recorded every 24 h for a period of 3 days to find the cell density. For further confirmation of the observations through OD, inoculated bacterial cultures were plated onto YPDA media for the cell count. Increase in the OD value every 24 h indicated bacterial growth utilizing acephate. This showed that bacterial symbiont/ microorganism play an important role in acephate degradation (Fig. 17).

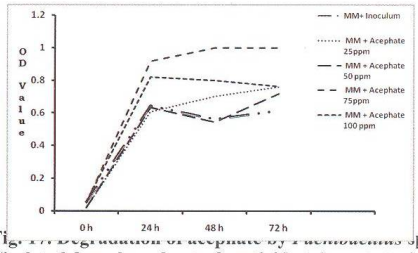


Fig. 17. Degradation of acephate by *Paenibacillus* sp. (isolated from larval gut of pesticide-tolerant strain of *C. z. sillemi*)

Isolation, characterization and identification of endosymbionts from field collected populations of *C. vestalis* and *T. brassicae*

Populations of *Cotesia vestalis*, a larval parasitoid of *Plutella xylostella*, were collected from cabbage/cauliflower fields from eight states, viz. Anand (Gujarat), Hoskote, Kolar, Malur (Karnataka),

Hyderabad, Tirupathi, Rajahmundry (AP), Salem, Coimbatore (TN), Cuttack, Ganjam (Odisha), Pune (Maharashtra), Varanasi (UP), Shillong (Meghalaya) and Jorhat (Assam).

Field collected *C. vestalis* adults were used for isolation of yeast and bacteria (Fig. 18). Identification of yeast species based on biochemical methods was done using Hi Candida Identification Kit (Table 7).

Fig. 18: Bacteria and yeast cultures isolated from *C. vestalis*

Isolation and amplification of yeast and bacterial DNA

The genomic DNA was extracted using bacterial and yeast genomic DNA miniprep. The yeast specific universal primers ITS1 and ITS4 were used to amplify the ITS region. The primers used for YITS- PCR. PCR assay was carried out using standard protocol. The primers 16S rDNA was used for amplification of bacteria.

Insect DNA isolation and detection of *Wolbachia* in *C. vestalis*

DNA of *C. vestalis* adults was extracted using Chelex 100MB. The presence of *Wolbachia* was verified by a PCR method based on the *Wolbachia* surface protein (wsp). Diagnostic PCR using the *Wolbachia*-specific primer set was performed (Fig. 19).

Fig. 19: PCR amplification of wsp gene of *Wolbachia* from *C. vestalis*

Lane M: 100bp ladder, Lane 1: Hoskote, Lane 2: Malur; Lane 3: Kolar, Lane 4: Tirupathi; Lane 5: Varanasi; Lane 6: Shillong, Lane 7: Bhubaneshwar, Lane 8: Salem, Lane 9: Hyderabad

Table 7: List of endosymbionts isolated from *C. vestalis* and *T. brassicae*

Population from	Isolated symbiont	Size (bp) of PCR product
C. vestalis		
Bangalore	*Bacillus clausi*	552
	Wolbachia	534
Bhubaneshwar	*Wolbachia*	579
	B. subtilis	676
Hyderabad	*Pichia anomola*	582
	Wolbachia	542
Salem	*Candida sp.*	564
	Wolbachia	538
Shillong	*B. clausi*	564
Tirupathi	*P. anomola*	579
	Wolbachia	550
Varanasi	*Wolbachia*	534
T. brassicae		
Bangalore	*Zygosaccharomyces rouxii*	564
	B. cereus	684
	C. apicola	576

Table 8: Fitness of *Wolbachia* spp. infected *C. vestalis*

Population	Parasitism (%)*		Adult emergence (%)*	
	Wolbachia fed	*Wolbachia* cured	*Wolbachia* fed	*Wolbachia* cured
Bhubaneshwar	88.7	79.8	72.7	67.9
Bangalore	90.4	82.3	84.1	73.3
Shillong	86.1	78.2	74.4	69.6
Tirupathi	83.8	79.1	76.6	67.4
Varanasi	78.6	73.4	76.2	70.1
Salem	79.8	74.6	73.1	69.3
Hyderabad	84.8	75.5	76.1	68.2
Control	74.8	76.8	66.4	63.4
CD (*P*=0.01%) Populations (P)		3.01*		3.67 NS
Treatments (T)		1.84*		2.25*
P x T		3.95*		6.36 NS
*Mean of 10 replications				

Determination of fitness of *Wolbachia* spp. infected *C.vestalis*

The fitness of different populations of *Wolbachia* colonized *C.vestalis* (parasitism, adult longevity, per cent adult emergence and female progeny production) was assessed by curing the *Wolbachia* with antibiotic and compared with those which were fed with *Wolbachia*. The populations fed with respective *Wolbachia* recorded significantly higher parasitism (78.9-90.4%) and adult emergence (72.7-84.1%) than the *Wolbachia* cured populations (72.4-82.3 and 67.4-73.3%, respectively). Among the different populations of *C. vestalis*, the population from Bangalore registered better attributes in terms of parasitism and adult longevity (Table 8).

The sex ratio in the infected population was 1.41 - 1.79: 1 (F:M) compared to 1 : 1.35-1.45 (F:M) in the cured populations. The increase in females over the males was 36.6% in the populations of *C.vestalis* fed with the bacteria.

Role of *Wolbachia* in insecticide resistance

Wolbachia colonized populations of *C. vestalis* were assayed for insecticide resistance (for target enzymes Cytochrome P-450) with respect to the insecticide fenvalerate and compared with cured populations.

The bioassay technique developed by IOBC/ WPRS Working Group (Hassan *et al*., 1985) was adapted and used for the assay. The surviving adults 24 hours after spray were anaesthetized with chloroform and dried for enzymatic assays. Enhanced activity of Cytochrome P 450 monoxygenase activity (1.01 x 10^3 - 2.791 x10^3 µm/mg/ml) was observed in the populations with *Wolbachia* compared to those in which *Wolbachia* was cured using antibiotic (0.133 x10^3 - 0.800 x 10^3 µm/mg/ml).

Role of *Wolbachia* in *T. brassicae*

Role of *Wolbachia* in the fitness of *T. brassicae* was assessed by feeding experiments and compared with those in which the bacterium was cured. The isolated bacterial colonies were pelleted and mixed with honey and water at 1:1:2 ratios and fed to laboratory reared *T. brassicae* adults. Adults fed with only honey served as control.

The per cent parasitism and female progeny were compared in the *Wolbachia* fed and cured parasitoids, after 10 generations of treatment through amplification of wsp gene. At the end of 10 generations there was significant increase in per cent parasitism (83) and per cent female progeny (49.6) in *Wolbachia* fed *T. brassicae* compared to the cured *T. brassicae* population (68 and 43.2, respectively).

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

A survey was conducted in the Northeastern states and Andaman Islands and a total of 234 samples of soil and insect cadavers were obtained. Sixty two samples were processed and 25 *Bacillus thuringiensis* expressing bipyramidal, cuboidal, square and irregular crystals were purified.

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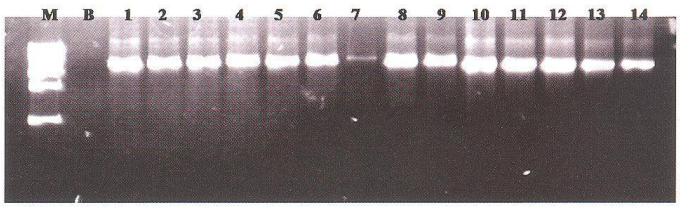


Fig. 20: Agarose gel showing amplification of 3.68 kb cry1Ac gene analysis of 1-T RBt1, 2- TRBt2, 3-TRBt3, 4-TRBt4, 5-TRBt5, 6-TRBt6, 7-TRBt7, 8-TRBt9, 9-TRBt10, 10-ASBt11, 11-TRBt8, 12-ASBt12, 13-ASBt13, 14-ASBt14

Genomic DNA was isolated and primers were designed to obtain complete cds of cry1Ac gene for cloning and toxicity evaluation. The primer was evaluated with NetPrimer software. Complete cds of 3.68 kb size gene was obtained which showed 99% match with cry1Ac complete cds (Fig. 20). Sequencing of the gene up to 2.5 kb by primer walking was carried out.

PCR analysis was done for VIP3A gene for the Northeast isolates and only two showed expression of the gene. Five sequences comprising of i. Cry1Ac of NBAIIBT-AS (JN120764.1), ii. Cry1Ab of NBAIIBT5 (JF501456.1), iii. Cry1Ab of PDBCBT1 (JF501454.1), iv. Cry1Ab of NBAIIBTAS (JF501457.1) and v. Cry1Ab of PDBCBT2 (JF501455.1) were submitted to GenBank. Selected isolates were tested for toxicity against *H. armigera* and TrBt2 was found to be the most toxic exhibiting a LC50 of 265 µg/ml followed by TrBt4 with a LC50 of 427 µg/ml.

4.1.3. Division of Insect Ecology

For the management of insect pests infesting different crops, in-depth knowledge is essential on the ecological aspects, which would include the effect of abiotic and biotic factors on the pests and the inter-relationships between the pests, host plants and natural enemies. This information could be effectively used for either conserving or augmenting populations of indigenous natural enemies and also for identifying host plants (or varieties) which are more tolerant to pests and attractive to bio-agents. NBAII maintains a large repository of live insect germplasm, which is detailed in the Insect Germplasm Registration website of NBAII. The insect ecology division concentrates on developing methods for monitoring the incidence of pests through pheromone technology, identifying potential natural enemies, developing production technologies for potential bio-agents, evaluating their performance in field conditions and studying the effects of climate change on pests and natural enemies.

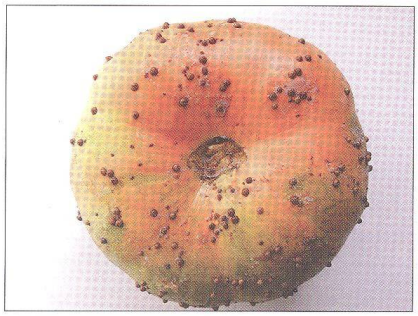
New rearing techniques

Development of mass production technique for *Saissetia coffeae* and its natural enemies

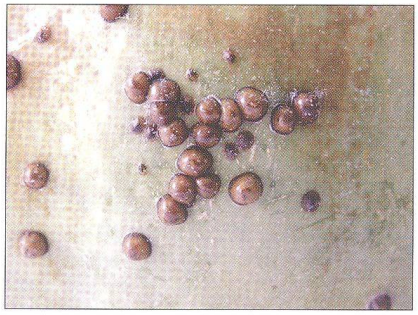
A method was devised for rearing the scale *S. coffeae* (Fig. 21) and its parasitoids, viz. *Scutellista caerulea* (Boyer de Fonscolombe) and *Coccophagus ceroplastae* (Howard) on potato sprouts as pumpkin (*Cucurbita moschata*) was found to be unsuitable for rearing *S. coffeae*, while summer squash (*Cucurbita pepo*) although supported growth and multiplication of the scale, scale colonies were sparse and life cycle was extended by many days. In this method, potatoes were made to sprout using wet sand and when the sprouts attained height of 2 inches they were infested with crawlers of *S. coffeae*. When sprouts attained a height of 6-7 inches, the sprouts along with tubers were removed from soil, shifted to acrylic cages and females were exposed to the parasitoids immediately. This method could help restrict further growth of the sprouts and retained them fresh.

Rearing of pseudococcids on different laboratory hosts

Efforts were made to rear 16 species of mealybugs on two laboratory hosts, viz. pumpkin and potato sprouts. Out of 16 species of mealybugs used in the experiment, eight species belonged to Pseudococcinae while the other eight belonged to Phenacoccinae. The hypothesis of the experiment was that those species belonging to Pseudococcinae can be reared both on pumpkin and potato sprouts, while those belonging to Phenacoccinae can be reared only on potato sprouts. Seventy five per cent of the mealybugs belonging to Pseudococcinae were amenable for rearing on pumpkin while those



Colony of *S. coffeae* on *Cucurbita pepo*



Closeup of a colony

Method of growing sprouts on sound potato (without cutting)

Colony of *S. coffeae* on potato sprout

Fig. 21: Mass multiplication of *Saissetia coffeae* on squash and potato

belonging to Phenacoccinae could not be reared on pumpkin with the exception of *P. divaricatus*. All the mealybug species belonging to both the subfamilies could be reared on potato sprouts.

Studies on biology and performance evaluation of predatory anthocorids and mites

Evaluation of anthocorid predators against *Sitotroga cerealella* eggs infesting paddy

Stored grains are damaged by several insects and mites, of which the Angoumois grain moth (*Sitotroga cerealella*) is one of the major insect pests. Chemical fumigation is generally followed for management of storage pests, which leads to hazards due to chemical pesticide residues. Biological control of storage pests using anthocorid predators is considered a safe alternative. Three species of indigenous anthocorids - *Cardiastethus exiguus, Xylocoris flavipes* and *Blaptostethus pallescens* were evaluated at three different dosages (10, 20 and 30) against 50 *S. cerealella* eggs infesting 200 g of paddy. Observations were recorded after one month on the number of moths emerging from each treatment batch and compared with a control batch which was maintained with no anthocorid release.

All the treatments were effective in reducing moth emergence and superior to control. *C. exiguus* and *X. flavipes* were more effective in comparison to *B. pallescens* (Table 9). Considering the interactions, the best treatments were *C. exiguus* and *X. flavipes* @ 30 nymphs per container.

Table 9: Effect of release of anthocorids on adult emergence of *S. cerealella*

Anthocorid species	Per cent *Sitotroga* emergence at different dosages				Mean A
	No. of anthocorids released per container				
	0	10	20	30	
Cardiastethus exiguus	44	22	8	4	19.5[a]
Xylocoris flavipes	44	18	10	5	19.3[a]
Blaptostethus pallescens	52	35	29	29	36.3[b]
Mean B	46.7[b]	25.0[a]	15.7[a]	12.7[a]	
	A	B	AxB		
CD (*P*=0.01)	13.80	15.94	27.60		

Morphometrics and biology of *Montandoniola indica*

The anthocorid, *Montandoniola indica* (Fig. 22) was recorded for the first time as a predator of *Gynaikothrips uzeli* Zimmermann infesting *Ficus retusa* in Karnataka. It was also recorded as an efficient predator of black pepper gall-forming thrips, *Liothrips karnyi* Bagnall in Kerala. The morphometrics and biology of this anthocorid were studied (Table 10). *M. indica* is amenable to laboratory production on UV irradiated *Corcyra cephalonica* eggs.

Fig. 22: Eggs, nymph and adult of *M. indica*

Eggs which were inserted into the plant tissue, with only the operculum being visible, hatched in 4-5 days. The nymphal period was 16-17 days. Five nymphal instars were identified, the mean nymphal durations being 3, 4, 3, 5 and 6 days, respectively. The morphometrics of the different life stages are presented in Table 10. The nymphs fed on a total of 27.3 eggs with a daily feeding rate of 1.56 eggs per nymph (Fig. 23). About 50% hatching was observed and 79% nymphs metamorphosed into adults. When fed on *C. cephalonica* eggs, adults lived for 16-22 days and laid a mean of 37 eggs per female. The day-wise fecundity of *M. indica* indicated that the female could lay one to four eggs per day (Fig. 24).

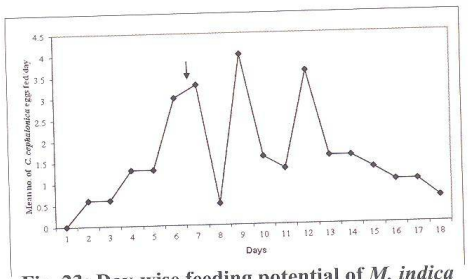


Fig. 23: Day-wise feeding potential of *M. indica* nymph on *C. cephalonica* eggs
(Arrows indicate the days on which moulting was observed)

Table 10: Morphometrics of *M. indica* stages

M. indica stage	Operculum diameter (µm)	Length (µm)	Width (µm)
Egg	111.12	490.36	144.96
First instar nymph		836.11	278.61
Fourth instar nymph		1948.86	688.96
Adult male		2082.79	709.27
Adult female		2142	806.45

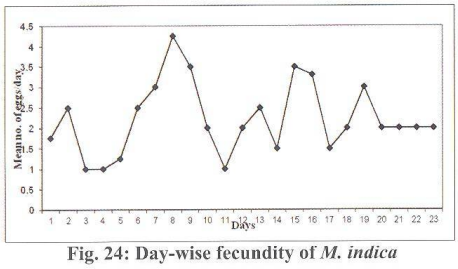


Fig. 24: Day-wise fecundity of *M. indica*

Comparative feeding potential of anthocorid *Blaptostethus pallescens* adult when fed on cotton mealybug *Phenacoccus solenopsis* from nymphal stage vis-a-vis from adult stage

It was observed that by providing crawlers of cotton mealybug (CMB) right from the nymphal stage, the predatory potential of the adult *B. pallescens* could be improved. The total feeding potential and longevity of such adults habituated to the mealybug hosts from the nymphal stage were significantly superior to those which were fed on *P. solenopsis* crawlers only from the adult stage (Table 11). Some higher peaks of feeding were observed (Fig. 25) during the initial days in those adults which were fed on mealybug crawlers from the nymphal stage.

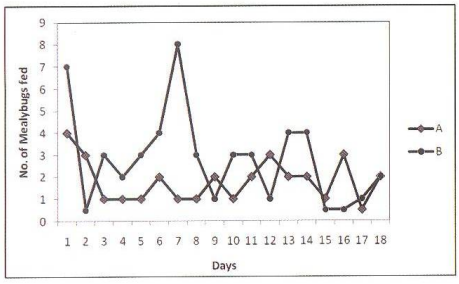


Fig. 25: Comparative day-wise feeding potential of *B. pallescens* adult when fed on CMB from adult stage (A) and from nymphal stage (B)

Nymphal feeding potential of *Anthocoris muraleedharani* and determining the nymphal instars

The duration of the nymphal instars, pattern of feeding, total nymphal feeding and per day feeding were studied for the anthocorid predator, *A. muraleedharani*. Five nymphal instars were observed, the durations being 3-4, 2-3, 4-5, 4-5 and 6-7 days, respectively. Each nymph fed on 55 CMB crawlers on average with a per day feeding of 3 crawlers. Certain peaks in feeding were observed, while at the time of moulting, a lower rate of feeding was observed except during the first moult (Fig. 26).

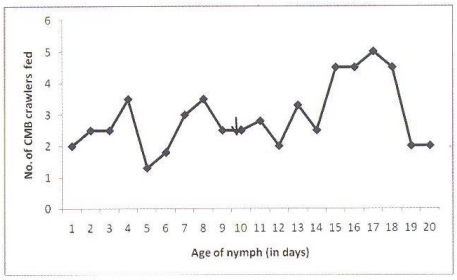


Fig. 26: Feeding potential of *A. muraleedharani* nymph (arrows indicate the points when moulted skins were observed)

Evaluation of predatory mites against thrips and mites infesting polyhouse chilli

Exotic predatory mites *Amblyseius swirskii* (Athias-Henriot) and *Neoseiulus californicus* (Mc Gregor) imported by Namdhari Farm Fresh, Bangalore were evaluated during November-February on polyhouse chilli (variety Supreme) in three of their polyhouses. During this period, infestation by tetranychid mites could not be detected. However, infestation by *Frankliniella schultzei* (Trybom) was observed to be severe. A single release of predatory mites was made

Table 11: Feeding potential and longevity of *B. pallescens* on *P. solenopsis*

Treatment	Total feeding (No. of crawlers)	Per day feeding (No. of crawlers)	Adult longevity (Days)
Fed on CMB from adult stage	22.83	1.93	14.17
Fed on CMB from nymphal stage	38.70	2.25	17.00
CD ($P=0.05$)	13.89	NS	1.82

in each polyhouse after one and a half to two months from the date of transplantation. Observations were recorded at fortnightly intervals on the number of thrips per leaf and flower and number of predatory mites per leaf and flower.

The number of thrips per leaf ranged between 0 and 1.2 and the number of thrips per flower between 0 and 4.6 till 2nd week of January. Though a single release of predatory mites was made, they established well. Beyond the 2nd week of January, there was a drastic increase in the thrips population (17.5 to 29 per flower). This steep increase in thrips population was observed to be accompanied by a decrease in the predatory mite population from the 2nd week of January (Fig. 27). The predatory mites are known to be more effective in warmer weather conditions. The dip in the predatory mite population during the 2nd week of December could be due to the decrease in temperature. The data also indicates that it would be useful to make an additional release of predatory mites during the second week of December and evaluate its effect on the thrips population.

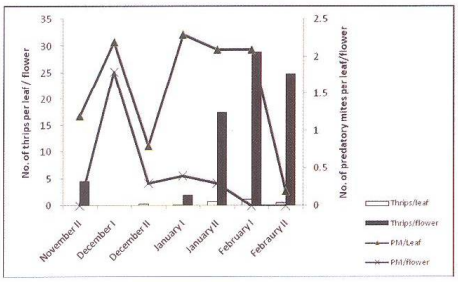


Fig. 27: Populations of thrips and predatory mites on chillies in polyhouse

Conservation of natural enemies and pollinators

In situ conservation of natural enemies and pollinators in pigeonpea and sunflower

Among various pollinators on pigeonpea, *Megachile* spp. was the most dominant one followed by *Xylocopa* spp. whereas on sunflower it was *Apis dorsata* followed by *Megachile* spp. and *Xylocopa* spp.

A replicated field trial was conducted in Kharif 2011 at NBAII Research Farm. Pigeonpea (cv. TTB-7) was intercropped with marigold (cv. Local) and sunflower (cv.KBSH-53) (10:2 rows) and a sole crop of pigeonpea was laid out (Fig. 28). Population of pests (*Helicoverpa armigera* and 4 species of pod bugs - *Riptortus* sp., *Clavigralla* sp., *Anoplocnemis* sp. and *Nezara viridula*) was significantly higher on sole pigeonpea compared to both marigold and sunflower intercropped pigeonpea (Table 12). Population of natural enemies, mainly spiders and *Cheilomenes sexmaculata*, was also significantly higher in intercropped pigeonpea compared to sole crop (Table 13) (Fig. 29).

Fig. 28: Field view of the intercropping trial of pigeonpea

Table 12: *Helicoverpa armigera* and pod bugs in different intercrops as compared to sole crop of pigeonpea

Treatment	Number of *H. armigera* larvae/10 plants (mean of 10 replications)					Number of pod bugs/10 plants (mean of 10 replications)				
	Aug	Sept	Oct	Nov	Dec	Aug	Sept	Oct	Nov	Dec
Pigeonpea +Marigold (10:2)	6.2 b	7.2^{b}	6.5^{b}	7.6^{b}	3.6^{c}	7.3^{b}	8.2^{b}	9.1^{b}	8.3^{b}	10.2^{b}
Pigeonpea +sunflower (10:2)	4.1^{b}	3.9^{c}	3.1^{c}	4.6^{c}	6.4^{b}	6.8^{c}	5.1^{c}	6.3^{c}	8.9^{b}	8.4^{c}
Pigeonpea (sole)	9.4^{a}	10.8^{a}	10.1^{a}	12.3^{a}	12.6^{a}	10.2^{a}	12.3^{a}	16.3^{a}	18.1^{a}	21.8^{a}

Fig. 29: Marigold and sunflower attracting bees and natural enemies

Weed flora associated with pigeonpea harbouring pollinators and natural enemies

Spermacoce hispida, a weed associated with pigeonpea, was confirmed as a useful plant in supporting pollinators which are common to pigeonpea and sunflower. Three bee species, *Apis cerana* (8-9 sec/flower), *A. florea* (11-14 sec/flower) and *A. dorsata* (3-5 sec/flower) were found to visit flowers of *S. hispida* for both nectar and pollen. During the off season, *S. hispida* and *Muntingia calabura* (Singapore cherry) help in conservation of bee species.

Effect of elevated levels of CO_2 on pigeonpea and *Helicoverpa armigera*

Plant parameters of pigeonpea at elevated levels of carbon dioxide

With the advances in industrialisation, the global carbon dioxide level has increased from 280 ppm to 391ppm which is one of the contributing factors for global warming and climate change. The increased levels of CO_2, though initially favours plant growth, when coupled with increase in temperatures has a detrimental effect on the physiology of several crops. The changes in CO_2 directly or indirectly affect the biology, ecology and behaviour of insect pests, natural enemies and pollinators. Studies were initiated to document the effect of elevated levels of Co_2 on the biology and behaviour of *Helicoverpa armigera* through the crop.

A trial was conducted on the effect of elevated levels of carbon dioxide (CO_2) on pigeonpea (cv. TTB-7) grown under elevated levels of CO_2 in open top carbon dioxide chambers. Pigeonpea plants were grown under three conditions: Elevated (500±25 ppm) CO_2+ambient temperature (24±2 ^{o}C), (500 ppm) CO_2 + 2 ^{o}C above ambient temperature, and ambient CO_2 (380±25 ppm) and temperature. All standard agronomical practices were followed.

The mean height of plants was maximum at 500 ppm CO_2+2 °C (207.8 cm), followed by 500 ppm CO_2 (180.3 cm) and ambient CO_2 and temperature conditions (132.63 cm). Similarly, the mean number of leaves / plant was highest at 500 ppm + 2°C (569.12), followed by 500 ppm of CO_2 (435.43) and ambient conditions (409.43) (Table 14). There was a delay of 15 days in flowering and pod formation in plants grown at 500 ppm of CO_2+2°C though the pod yield was higher (25.55 q/ha) than that at ambient conditions (19.44 q/ha) (Table 14).

Volatile profile of pigeonpea plants grown at elevated levels of CO_2

The volatile profile of pigeonpea plants grown at 500 ppm CO_2 was compared with that at ambient conditions using GCMS. µ-Copaene and an array of volatiles were detected in plants grown at 500 ppm of CO_2 which may be responsible for attracting females.

Ovipositional behaviour of *H. armigera* on pigeonpea grown at elevated levels of CO_2

The ovipositional behaviour of *H. armigera* was studied in the laboratory by allowing 10 gravid

Table 13: Influence of intercrops on spider and coccinellid numbers in pigeonpea

Treatment	Number of spiders /10 plants						Number of coccinellids /10 plants					
	Aug	Sept	Oct	Nov	Dec	Jan	Aug	Sept	Oct	Nov	Dec	Jan
Pigeonpea +Marigold (10:2)	7.6^{a}	4.1^{b}	8.3^{a}	6.6^{a}	6.9^{a}	9.5^{a}	6.4^{a}	7.8^{a}	9.5^{a}	11.1^{a}	13.9	15.4^{a}
Pigeonpea +sunflower (10:2)	8.3^{a}	5.7^{a}	5.6^{b}	2.3^{b}	6.3^{a}	6.9^{b}	3.6^{b}	7.5^{a}	7.8^{b}	8.3^{b}	14.5	15.1^{a}
Pigeonpea (sole)	4.4^{b}	2.3^{c}	3.2^{c}	1.2^{c}	5.3^{b}	5.7^{b}	3.3^{b}	3.9^{b}	4.5^{c}	5.9^{c}	13.6	13.5^{b}
CD (P=0.05)	1.1	0.6	0.6	0.6	1.2	1.4	1.1	1.6	1.9	1.7	-	1.0

Table 14: Profiles of plants grown at different levels of CO_2 and temperature

Treatment	Mean height (cm)*	No. of leaves/plant*	No. of flowers/plant*	Pod yield (q/ha)
Ambient CO_2 (500 ppm) and temperature (24±2°C)	132.63	409.43	68.8	19.44
Elevated CO_2	180.30	435.43	0.4	13.05
Elevated CO_2 + 2° C above ambient temperature (24±2°C)	207.8	569.16	23	25.55
CD (P=0.05)	23.25	78.20	14.50	
CV%	23.97	32.33	113.3	

*mean of 30 plants

females overnight to oviposit on a bouquet of pigeonpea twigs grown at different levels of CO_2 and temperature in acrylic chambers (60x30x30 cm). Least number of eggs were laid on plants grown at ambient conditions when compared to those plants grown at 500 ppm of CO_2+2°C above ambient temperature (Table 15).

Table 15. Oviposition by *H. armigera* on pigeonpea plants grown at elevated levels of CO_2

Treatment	No. of eggs laid
Ambient CO_2 (500 ppm) and temperature (24±2°C)	81.42
Elevated CO_2 (500 ppm) + ambient temperature (24±2°C)	251.48
Elevated CO_2 500 ppm +2° C above ambient temperature (24±2°C)	358.85
CD (P=0.01)	179.08
CV%	50.43

Polymorphism in pheromone perception in males of different populations of *H. armigera*

Field efficacy of pheromone blend ratios of *H. armigera*

Males of *H. armigera* were found to show polymorphism in their perception to the commercially used pheromone blend of Z-11-hexadecenal : Z-9-hexadecenal at the ratio of 97:3. Earlier electrophysiological and behavioural studies have shown that different populations use different blends.

In continuation to the earlier work, five field trials were conducted during 2011-12 at Bangalore, Raichur, Dharwad, Guntur and Patna to study the efficacy of different pheromone blends in the ratio of 97:3, 91:9 and 85:14 Z-11-16-Ald and Z-9-16-Ald respectively. Generally, the incidence of *H. armigera* on cotton was very low in all the locations. Raichur and Patna populations responded better to 91:9 compared to 97:3, whereas Dharwad population responded better to 97:3 (Table 16).

Wind tunnel studies on response of different geographical populations of *H. armigera* to pheromone blends

Laboratory studies were conducted to find the attraction of males of different populations of *H. armigera* to the blends of 85:15, 91:9 and 97:3. Zone resident analysis was done where the highest value indicated highest response of the males. The populations from Coimbatore and Nanded showed highest response to 91:9 blend and Raichur and Gulburga populations responded better to 97:3, though statistically not much significance was observed (Table 17).

GCMS studies on pheromone gland extraction of different populations of *H. armigera*

The extracts of pheromone glands of females from different populations of *H. armigera* were collected in hexane and analyzed through GCMS. The Gulburga population showed more than 10% of Z-9-16-Ald compared to 3% in commercial formulation (Fig. 30).

Table 16: Effect of pheromone blend ratios on trap catches of *H. armigera* (Dharwad population)

Week	No. of males per trap caught in blends			
	91:9	85:15	97:3	Mean
I	0.05	0.19	0.33	0.19
II	0.37	0.47	0.52	0.45
III	0.90	0.81	0.71	0.81
IV	1.80	1.09	13.33	5.40
V	1.47	1.71	1.23	1.47
VI	6.00	5.90	7.34	6.41
VII	7.95	8.76	6.23	7.64
VIII	4.61	6.23	4.38	5.07
IX	4.09	3.38	3.42	3.36
X	2.61	2.57	2.62	2.60
XI	2.57	2.38	2.19	2.38
Mean	2.94	3.04	3.85	
CD (*P*=0.05)	Between blends 0.405 Between dates 0.776 Interaction 1.345			

Table 17: Behavioural response of males of different geographical populations of *H. armigera* to different pheromone belnd ratios in wind tunnel studies

Blend ratio	Lab	Gulburga	Coimbatore	Raichur	Rajkote	Nanded	Nagpur	Mean
91:9	6.714	5.571	6.428	4.714	5.143	7.571	6.142	6.04
85:15	5.571	6.286	5.714	6.000	6.000	6.000	6.000	5.94
97:3	4.857	7.285	4.857	7.285	6.857	7.142	6.000	6.33
Mean	5.71	6.38	5.66	5.99	6.00	6.90	6.04	
CD (*P*=0.01)	Between blend 1.052 Between population 1.607 Interaction 2.787							

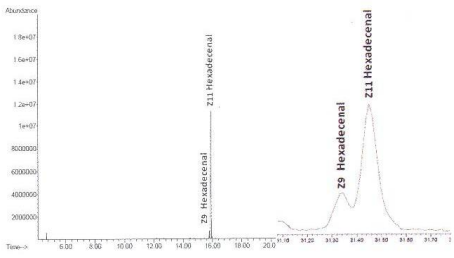


Fig. 30: GCMS profile of pheromone gland extract of *H. armigera*

Formulations of pheromones of important borers, other crop pests and kairomones for natural enemies using nanotechnology

Leucinodes orbonalis pheromone immobilized in chitosan-alginate nanoparticles

Nanoparticles of *L. orbonalis* pheromone were synthesized using ionotropic pre-gelatin followed by polycationic cross-linking with chitosan and sodium alginate. Pheromone loaded ALG-CS nanoparticles (particle size in the range of 200-600nm) and Zeta potential showed that nanoformulations are stable (Fig. 31). Morphology was studied using SEM which confirmed particle size in the range of 193-891nm. Release pattern of nanoformulation recorded

with Headspace-GCMS showed that the pheromone was encapsulated in the chitosan-alginate nanoparticles. The liquid nanoformulation was converted into solid using spray drier.

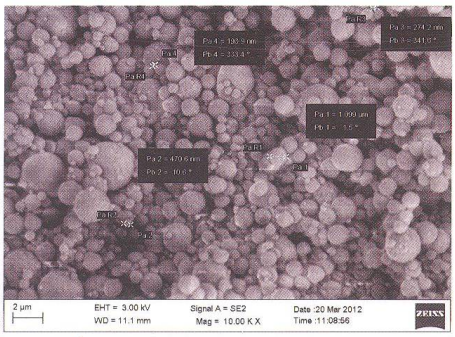


Fig. 31: SEM of nanoparticles of *L. orbonalis* pheromone

Helicoverpa armigera pheromone immobilized in gelatin nanoparticles

Gelatin nanoparticles of *H. armigera* pheromone (HAP) were synthesized by two step desolvation method. Three different nanoformulations, NF1, NF2 and NF3, were synthesized in which the Gelatin type A was kept constant at 200 mg, HAP was kept constant at 20 µl, temperature was kept constant at 40°C whereas the crosslinker, glutaraldehyde was varied to 15 µl (NF1), 20 µl (NF2) and 30 µl (NF3). The particle size analysis showed that with increase of quantity of crosslinker, nanoparticle size decreased (Table 18). This showed that quantity of crosslinker glutaral-dehyde controls the size of gelatin nanoparticle.

Electroantennogram studies with two-day old males of *H. armigera* indicated that control (gelatin nanoparticles without pheromomone) elicited least response. Formulation 1 elicited significantly higher response than honey. Other formulations elicited lower response (Table 19).

Table 19: Electroantennogram response of male *H. armigera* to nanoformulations of pheromone

Treatment	Amplitude (-mV)		
	ER1	ER2	ER3
Air	0.09	0.09	0.06
Honey 1	0.18	0.18	0.20
Formulation 1	0.60	0.61	0.60
Formulation 2	0.08	0.09	0.05
Formulation 3	0.07	.07	.033
Control	0.04	0.04	0.04
Honey 2	0.05	0.05	0.2
CD (*P*=0.01)	0.11	0.11	0.15
CV	32.86	29.30	37.80

ER1= Gelatin type A was 400mg, HAP, 20 µl and gluteraldehyde at 10 µl, 20 µl and 30 µl respectively in formulations 1, 2 and 3.

ER2= Gelatin type A was 200 mg gluteraldehyde 20 µl and HAP at 10 µl, 15 µl and 20 µl respectively in formulations 1, 2 and 3.

ER3=Gelatin type B 200 mg, HAP 20 µl gluteraldehyde 10 µl, 20 µl and 30 µl respectively in formulations 1, 2 & 3.

Phytophagous mites as a source of microbes for harnessing in pest management

Evaluation of microbial associates of rust mites for their biocontrol potential

Acremonium, Beauveria, Hirsutella, Lecanicillium and *Paecilomyces* were found to be the dominant pathogens of citrus rust mite, *Phyllocoptruta oleivora* (Ashmead). There was 10% incidence of *Hirsutella thompsonii* in sweet orange groves that received no pesticide sprays. There were no bacterial or viral associations with the mite. Microbial associates of the oriental red mite, *Eutetranychus orientalis* (Klein), and false spider mite, *Brevipalpus phoenicis* (Geijskes), were also recorded.

Field bioefficacy of both host- and non-host-derived *H. thompsonii* isolates against *P. oleivora* on orange

Table 18: Effect of crosslinker glutaraldehyde in particle size

Sample name	Glutaraldehyde (µl)	Size(nm) Index	Polydispersity (mV)	Zeta potential
NF1	15	675.6	0.331	-38.65
NF2	20	539.5	0.333	-38.11
NF3	30	375.0	0.251	-38.48

Table 20: Field bioefficacy of host- and non-host-derived *H. thompsonii* isolates against *P. oleivora* on sweet orange

Treatment	No. of live mites (± SE)/4-mm diameter of the fruit surface				
	Pre-treatment	21 DAT	3 MAT	6 MAT	9 MAT
MF(Ag)205	14.7 ±0.19 a	1.7±0.13 a (-88.4)	3.5±0.14 a (-76.2)	3.9±0.15 a (-73.5)	5.0±0.24 a (-66.0)
MF(Ag)66	15.2±0.14 a	1.9±0.06 a (-87.5)	4.7±0.29 a (-69.1)	4.0±0.06 a (-73.7)	5.0±0.32 a (-67.1)
Control	15.4 ±0.24 a	16.1±0.14 b (+4.5)	14.0±0.06 b (-9.1)	15.0±0.26 b (-2.6)	16.7±0.30 b (+8.4)

Note: DAT= Days after treatment; MAT= Months after treatment.
Data in each column were subjected to one-way ANOVA after square-root transformation. Means in each column followed by the same letter did not differ significantly at $P < 0.05$, Tukey's HSD. Figures within parentheses indicate per cent decrease (-) or increase (+) over pre-treatment within a row.

and sweet orange (Fig. 32) was studied at the Biocontrol Research Farm, Yelahanka, Bangalore. The two fungal isolates, MF(Ag)205 (host-derived) and MF(Ag)66 (non-host-derived), were multiplied separately and mycelial suspensions (2×10^6 colony-forming units/ ml) were evaluated in the trial. Post-treatment counts of live mites were taken at regular intervals. The host-derived isolate was slightly better than the other isolate in terms of reduction in mite density at 3 months after treatment (76.2% compared with 69.1%) (Table 20). The presence of *H. thompsonii* in association with the dead mites on unharvested fruits indicated the establishment of the fungus in the grove.

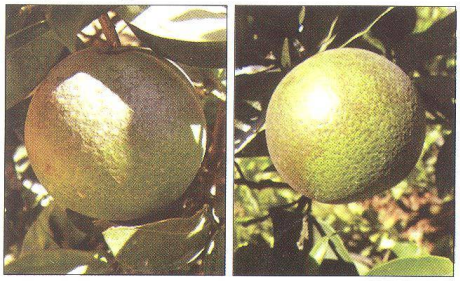


Fig. 32: Sweet oranges infested with *Phyllocoptruta oleivora*

Field evaluation of entomofungal pathogens

Field evaluation of entomofungal pathogens against cowpea aphid (*Aphis craccivora*)

Four promising isolates of entomofungal pathogens (*B. bassiana* Bb-5, *M. anisopliae* Ma-4, *V. lecanii* Vl-8 and *P. fumosoroseus* Pfu-1) were field evaluated against *Aphis craccivora* infesting cowpea (var. KBC-2) at NBAII Farm, Attur during Rabi, 2011. All the four entomofungal pathogens were equally effective in reducing the aphid population (0.16-0.21 aphids/plant) compared to the control (9.42 aphids/plant). No significant differences were observed in the natural population of coccinellids in the treatment and control plots indicating the safety of fungal pathogens to coccinellids.

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

Four promising isolates of entomopathogenic fungi (*B. bassiana* Bb-5, *M. anisopliae* Ma-4, *V. lecanii* Vl-8 and *P. fumosoroseus* Pfu-1) were evaluated against *B. tabaci* infesting capsicum (var. Indra) and tomato (cv. Lakshmi) in the polyhouse at NBAII Farm, Attur during April-June 2011. *Paecilomyces fumosoroseus* (Pfu-1 isolate), *B. bassiana* (Bb-5a isolate) and *V. lecanii* (Vl-8 isolate) treatments were significantly superior in reducing the whitefly population in capsicum (2.42-3.23 whiteflies/plant) and tomato (7.14-7.23 whiteflies/plant) in comparison to control (7.48 whiteflies/plant in capsicum and 13.42 whiteflies/plant in tomato).

Studies on entomopathogenic nematodes

Mass production and exploitation of entomopathogenic nematodes against white grubs from diverse habitats

Entomopathogenic nematodes are soil-dwelling beneficial nematodes which are well documented to parasitize insects across different genera and orders, and cause insect mortality in 48-72 h. Among seven insect families of entomogenic nematodes, nematodes belonging to Heterorhabditidae and

Steinernematidae have been utilized commercially for field control of insect pests, especially soil-dwelling pests including whitegrubs, molecrickets, cutworms, *Spodoptera* spp. etc. Heterorhabditid and steinenrnematid nematodes in association with specific symbiotic bacteria bring about rapid insect host mortality. At NBAII, the research programme on EPN addresses the documentation of diversity of EPN in Indian subcontinent, large-scale field use of EPN and protocols for commercial production.

A protocol for pilot scale *in vivo* production of EPN was developed at 500 kg per production cycle of 30-45 days. *Heterorhabditis indica* and *Steinernema carpocapsae* obtained from *Galleria mellonella, C. cephalonica* and *Leucopholis lepidophora* exhibited better infectivity in shorter duration against *G. mellonella* and *L. lepidophora,* compared to the progeny obtained from *H. armigera, S. litura* and *P. xylostella.* It indicated that the insect host from which the EPN have multiplied had an effect on their infectivity. Field application of WP EPN @ 2.5 x10^9 IJs/ha in root grub (Fig. 33) endemic areas of arecanut in Western Ghats (Sulya and Banakal) in June-July could reduce the incidence of root grubs by 62-78%.

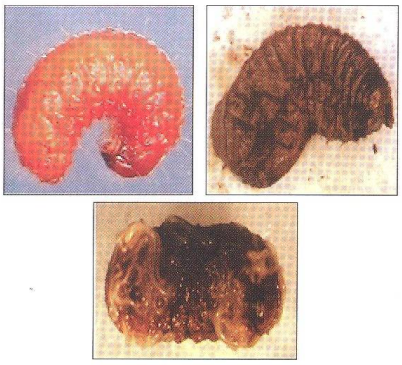


Fig. 33: EPN infected whitegrubs of arecanut

Bioefficacy of EPN isolates for the management of *Myllocerus subfasciatus* in brinjal

Bioefficacy of seven isolates of EPN, *S. abbasi* (Sa01, Sa04), *S. carpocapsae* (Sc04), *S. glaseri* (Sg01), *H. indica* (Hi01, HiMah), and *H. bacteriophora* (Hb05) were examined against *M. subfasciatus*. Lethal concentrations of EPN ranged between 21.4 and 27.4 IJs/cc soil for effecting 50% grub mortality in 96h. Lethal time for effecting 50% grub mortality ranged between 45.38 and 55.94 at 40 IJs/cc soil (1.5x10^9 IJs/ha) (Table 21). LC and LT values were least in treatments with *H. indica* Hi01 followed by *S. glaseri* Sg01 and *S. abbasi* Sa01. Among five soils tested (alluvial, black cotton, loamy sand, red laterite and carbon rich mountain), mortality of grubs was highest in loamy sand (90%), followed by mountain (82-94%) and alluvial (80-92%) soils in 96h post application at 40 IJs/cc soil. Contents of clay, sand, and silt exhibited negative, positive, and no effect on bioefficacy of EPN isolates, respectively. This is the first report on the efficacy of EPN to the grubs and pupae of *M. subfasciatus* (Figs 34 & 35).

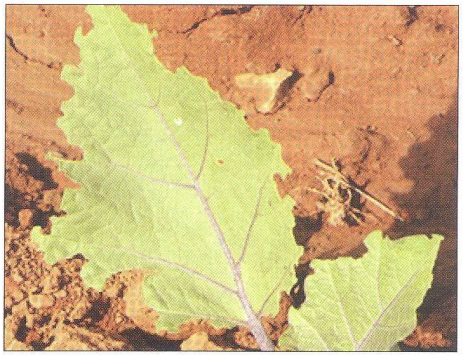


Fig. 34: Leaf margins of brinjal damaged by adults of *M. subfasciatus*

Fig. 35: *H. indica* NBAII isolate Hi01 infected grubs and pupa of *M. subfasciatus*

Two new isolates each of *Heterorhabditis* and *Steinernema* species were identified from the Andaman Islands. All the four caused mortality of second and third instar grubs of *Anomala bengalensis*.

Molecular identification of two species of *Heterorhabditis* and eight species of *Steinernema* using multi-loci (ITS and CO genes) approach has been devised. Key morphological features have been identified for two species of *Heterorhabditis* and four species of *Steinernema* for preparation of identification keys.

Table 21: Lethal time for mortality of *M. subfasciatus* grubs when treated with local EPN isolates (40IJs/cc soil) by soil column assay

Treatment/Nematode isolate	Lethal time	Hours	Class limits (95%)		Slope	Standard error	Chi-Square
			Lower	Upper			
S. abbasi NBAII Sa01 (En01)	50	47.92	41.26	54.05	-2.346	0.413	1.555
	90	74.10	66.36	86.69			
S. abbasi NBAII Sa01 (En04)	50	55.72	47.49	63.44	-1.921	0.351	2.753
	90	92.88	82.11	111.59			
S. carpocapsae NBAII Sc04 (En04)	50	45.82	38.40	52.38	-2.008	0.379	0.984
	90	75.07	66.67	88.99			
S. glaseri NBAII Sg01	50	48.39	41.28	54.88	-2.151	0.386	1.399
	90	77.22	68.88	90.93			
H. indica NBAII Hi01	50	45.38	38.51	51.56	-2.204	0.405	0.991
	90	71.77	64.00	84.54			
H. indica NBAII HiMah	50	49.17	41.37	56.10	-1.961	0.362	0.535
	90	81.31	72.29	96.19			
H. bacteriophora NBAII Hb05	50	55.94	48.99	62.63	-2.378	0.394	1.244
	90	86.05	77.28	100.41			

Biocontrol of plant diseases

Biocontrol of bacterial wilts of tomato and brinjal caused by *Ralstonia solanacearum* using *Bacillus megaterium*

Combined application of talc based formulation of *B. megaterium* NBAII 63 (10^8 CFU/ml) as seed treatment (4g/kg of seed), soil application (2.5 kg/ha), seedling root dip (10g/ L of water) and foliar spray (10g/L of water) significantly reduced bacterial wilt in tomato (56%) (Table 22) and brinjal (62%) under field conditions. Application of *B. megaterium* increased the seedling establishment and growth in tomato and brinjal. Highest rhizosphere population of 7.1-7.4 x 10^7 CFU/g was recorded in tomato and brinjal at 40 days through the combined application.

Biological control of plant parasitic nematodes using antagonistic fungi

Effect of antagonistic fungi against plant parasitic nematodes infesting FCV tobacco seedlings

Two new isolates of antagonistic fungi, *Arthrobotrys conoides* and *A. oligospora* were isolated from

Table 22: Efficacy of talc-based formulation of *B. megaterium* on establishment and growth of tomato in field

Treatment	Seedling establishment (%)	Root length (cm)	Shoot length (cm)	Fresh weight (g)	Dry weight (g)	Wilt incidence (%)
Seed treatment (ST)	80.0	20.3	61.2	36.1	11.3	33.3
Seedling root dip(SRD)	79.0	20.4	60.3	34.3	10.8	37.4
Soil application(SA)	79.0	20.4	61.3	34.5	10.8	36.4
Foliar spray(FS)	77.0	21.1	59.3	33.4	10.5	39.5
ST+ SRD+SA+FS	88.0	26.2	74.1	43.2	13.5	22.3
Streptomycin sulphate	91.0	15.00	56. 5	30.1	10.0	15.4
Control	62.0	13.00	33.2	18.2	7.80	50.7
CD (*P*=0.05)	2.12	0.95	2.31	1.21	1.31	1.23

pasture soils. They exhibited 38-66 per cent infection to root-knot nematode juveniles. The temperature optima were 26 to 34°C for mycelial growth and 26 to 38°C for spore germination. Passport data information for these two isolates were developed and added to the database.

Performance conditions for *P. lilacinus* PL55 and *P. chlamydosporia* PC56 were standardized in laterite, sandy loam and loamy soils (with pH 6.4, 6.8 and 7.6, respectively, and organic carbon at 0.65, 0.82 and 0.48, respectively). Spore germination and mycelial growth were recorded in 32-44 h at 32-33°C; while root colonization (48-52%) and nematode egg mass infection (38-46%) were observed at 36-42 DAT on tomato.

Integration of *P. lilacinus* NBAII isolate PLFT5 or *P. chlamydosporia* NBAII isolate PC56 @ 100g/m^2 after soil solarization significantly increased nematode free plants of tobacco in nursery to the tune of 56.4 and 57.8%, respectively (Table 23).

Crop rotation with marigold followed by application of WP formulations of *P. chlamydosporia* (100g/m^2) in coloured capsicum in polyhouses reduced root-knot nematode infection in the first year.

Screening of *Pseudomonas* spp. against root-knot nematode, *Meloidogyne incognita*

Forty-eight *Pseudomonas* isolates collected from crop rhizosphere (CRS) were tested for efficacy against egg hatching and mortality of second stage juveniles of *M. incognita*. Four isolates of *Pseudomonas*, viz. CRS-3, CRS-6, CRS-8 and CRS-10 recorded 50-60% mortality and 42-45% inhibition of egg hatching. Morphological, biochemical and cultural characteristics of these four isolates were described. These isolates were observed to colonize the roots of tomato, brinjal and cowpea. Among the twenty NBAII *Pseudomonas* isolates tested against *Fusarium oxysporum*, 2 isolates, viz. CRSRPF7 and CRSGR3ARS3 showed 58% inhibition.

Table 23: Effect of antagonistic fungi in integration with soil solarization on FCV tobacco seedling growth

Treatment	Germination count	Seedling height (cm)	Seedling weight (g)	Healthy transplants count (60 DAS)	Total healthy transplants yield	% increase over check
Paecilomyces lilacinus (PDBC strain) 10^8 spores @ 100g/ m^2	21.7	12.2a	150.0ab	455.0b	632.0c	52.5
Pochonia chlamydosporia (PDBC strain) 10^8 spores @100g/ m^2	22.3	12.5a	154.0ab	450.3b	636.0c	53.5
Soil solarization alone	23.0	12.6a	160.7b	442.0b	600.0b	44.8
Paecilomyces lilacinus+ soil solarization	22.3	15.0b	171.6b	450.0b	648.0cd	56.4
Pochonia chlamydosporia + soil solarization	23.3	15.9b	173.3b	456.0b	654.0d	57.8
Carbofuran @ 10 g/m^2	24.3	14.8b	162.0b	441.0b	650.0cd	56.8
Untreated check	22.0	11.4a	140.0a	320.0a	414.3a	-
CD (*P*=0.05)	NS	2.16	17.8	16.7	18.8	

Mass production of antagonists

Standardization of solid state fermentation conditions for the mass production of *Trichoderma spp.*

For the confirmation of suitable growth conditions in the solid state fermentation employed for the mass production of *T. harzianum*, the effect of different incubation temperatures (24, 28, 30, and 32 °C) was studied with ragi and sugarcane bagasse as substrates. The CFU counts were estimated at 5, 10 and 15 days of inoculation. Highest CFU *T. harzianum* was observed at 26 and 28°C (above 10^9 CFU/g) respectively after 15 days of incubation (Table 24). At 30 and 32 °C, the CFU counts were low as compared to those at 26 and 28 °C.

In another experiment sugarcane bagasse was used as substrate. The optimum incubation temperature was 28°C. Incubation at 32°C resulted in a significant drop in the CFU count and CFU counts recorded at 26 or 28 °C on 10th and 15th day were on par (Table 25). There were no significant differences in CFU counts when incubated at 26 or 28°C. Sugarcane bagasse as inert support in the solid state fermentation employed for mass production of *T. harzianum* could result in high CFU counts (>10^9 CFU g-1) within 10 days of incubation, indicating that sugarcane bagasse can be optimally used for SSF enabling low cost mass multiplication of fungal bioagents.

Classical biological control

Recurrence of the papaya mealybug

The papaya mealybug (PMB), *Paracoccus marginatus* was successfully managed within a year of its appearance in Tamil Nadu in 2008 by three exotic hymenopteran parasitoids, *Acerophagus papayae*, *Anagyrus loecki* and *Pseudleptomastix mexicana* that were introduced from Puerto Rico at the initiative of this Bureau. *A. papayae* was observed to be the most effective of these parasitoids in keeping the PMB in check. Although low levels of the PMB were noticed subsequently in some areas the reassuring presence of its parasitoids indicated that they were keeping the mealybug under control. In August 2011, however, the PMB rose to levels causing concern to papaya farmers in some areas of Gulbarga and Savadatti (N. Karnataka) and mulberry farmers in Chamrajnagar (S. Karnataka) in February,

Table 24: Effect of incubation temperature on biomass production (CFU/g of substrate) of *T. harzianum* in SSF with ragi as solid substrate

Temp (°C)	5th day	10th day	15th day	Mean
24	8.69	8.99	8.74	8.81a
26	8.80	9.02	9.22	9.01a
28	8.83	9.03	9.29	9.05a
30	8.76	8.91	8.65	8.77a
32	8.44	8.32	8.22	8.33b
Mean	8.70	8.86	8.82	

CD (*P*=0.01): Days: NS, Temp.: 0.45

Table 25: Effect of incubation temperature on biomass production (CFU/g of substrate) of *T. harzianum* in SSF with sugarcane bagasse as solid substrate

Temp (°C)	5th day	10th day	15th day	Mean
24	8.228	9.143	9.085	8.819
26	8.716	9.243	9.209	9.056
28	8.477	9.203	9.297	8.993
30	8.086	8.418	8.286	8.263
32	7.820	8.009	8.045	7.958
Mean	8.265	8.803	8.784	

CD (*P*=0.01): Temperature: 0.87; Days: 0.51; interaction: 0.61

2012. The mealybug was also noticed in Orissa, Tripura, Lakshadweep and Minicoy islands. While the parasitoids being maintained at NBAII were supplied directly to the aggrieved farmers in most areas they were released in other areas (Lakshadweep islands and parts of Kerala) with the assistance of KAU, Thrissur and CPCRI, Kasargod. The parasitoids once again established their ability to contain the PMB in all the areas of release.

Superparasitism in *Acerophagus papayae*

Ability of insect parasitoids to parasitize larger individuals of the same species and effective utilization of host to produce more number of individuals is an evolved character by certain parasitoids known as superparasitism. Studies conducted at the quarantine facility at NBAII revealed that *A. papayae* prefers the second and third instars or the adult female of the PMB although it is capable of parasitising and developing successfully in all stages. As noticed in earlier studies the sex ratio was female biased when larger mealybugs were parasitised. Studies conducted at NBAII were however the first to reveal that *A. papayae* were capable of superparasitism in the PMB (Fig. 36). Up to 12 parasitoids were recorded emerging from an adult female of *P. marginatus*. Low population levels of the host *P. marginatus* induced superparasitism by *A. papayae* apparently as a survival mechanism by this highly specific parasitoid.

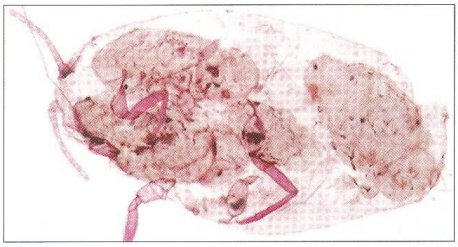


Fig. 36: A number of parasitoid embryos of *A. papayae* within adult female *P. marginatus*

The USDA highlighted the success of the programme for the biological control of the papaya mealybug in their report titled "USAID (from the American People): India" citing this as an example of a 'successful partnership demonstrating what is possible through collaborative effort".

Management of Eucalyptus gall wasp using *Leptocybe invasa*

The outbreak of the Eucalyptus gall wasp, *L. invasa* was suppressed by the exotic parasitoid *Quadrastichus mendeli* (Fig. 37) introduced by the NBAII from Israel. After the completion of studies establishing the safety of this parasitoid at the quarantine facility at NBAII, permission was obtained from the Government of India for limited area release of the parasitoid in Karnataka, Kerala, Tamil Nadu, Andhra Pradesh and Orissa.

Fig. 37: *Quadrastichus mendeli*

The parasitoids mass produced at NBAII in the galls of *Eucalyptus camaldulensis* (Fig. 38), a susceptible variety, were supplied to the nurseries being maintained by paper mills which were members of the Indian Paper Manufacturers' Association (IPMA) as well as to the Institute of Forest Genetics and Tree Breeding (IFGTB), Coimbatore for further multiplication and distribution to farmers. The continuous production and supply of the parasitoids during 2010-12 helped bring down the population of the gall wasp to insignificant levels in all the states of release.

Fig. 38: Galls on eucalyptus suitable for oviposition by *Q. mendeli*

During the latter part of 2011 severe incidence of the gall wasp was reported from North India. Parasitoids were supplied by this Bureau to the Forest Research Institute, Dehradun and to private nurseries for release in all the affected areas of Uttaranchal.

Management of *Chromolaena odorata* using *Cecidochares connexa*

The *Chromolaena* gall fly (*Cecidochares connexa*) continued to be released for the management of the pernicious weed *Chromolaena odorata* at this Bureaus' initiative. The gall fly has now established in Karnataka, Kerala, Tamil Nadu and Jabalpur. While it was observed to have spread from 500 to 750 m in all directions from its earlier sites of release, its spread in the newer areas of release is being monitored.

Parasitization of the gall fly larvae by *Ormyrus* sp. was very low, not exceeding 4% in any area indicating that it was not a major cause impeding the spread of the gall fly.

Transfer of technology to tribal areas

In order to improve the socio-economic status of the tribal farmers, the Government of India proposed that each organization spend about 10% of the total budget for the welfare of the tribal community. The technologies developed at the institute are directly taken to them with the materials required for proper implementation of the technology along with technical support as and when required. This support will help them to gain the knowledge about the technology and also assimilation of the same at the earliest thereby improving their economic status.

Under the Tribal Sub-Plan the technologies developed at NBAII were demonstrated to tribals in selected areas of south India. Inputs such as bioagents, biopesticides, pheromone traps, honeybee hives and other rearing accessories for beekeeping were supplied to them. Follow-up visits are being made to assist them in the uptake of these technologies (Figs 39a & 39b).

Fig. 39a: Tribal Sub-Plan programmes

Fig. 39b: Tribal Sub Plan programme at Yellapur, south Canara, Karnataka

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

Biological suppression of diseases and nematodes

Among selected abiotic stress tolerant (i.e. moisture stress and salinity with pH >8.5) isolates of *Trichoderma harzianum*, isolate Th-89 was observed to produce maximum hydrolytic enzymes. (GBPUAT) (Table 26).

The talc formulation of *Trichoderma* was observed most effective in limiting fusarial wilt and improving plant growth parameters in chickpea followed by invert emulsion and carbendazim (GBPUAT). Treatment with invert-emulsion or talc formulations as seed and soil application resulted in significantly reduced incidence of chickpea *Fusarium* wilt (24-28%) compared to control (43.3% and 25.4% respectively) (Table 27). In tomato (NS501) plants treated with invert-emulsion formulations IEF1 and IEF2 as seed treatment and seedling dip, the incidence of *Altenaria* leaf spot was delayed and the disease severity was also less on 0-5 scale in kharif 2011. At 75 DAP, the disease severity increased in control (2.2 out of 5), while in *Trichoderma* treated plots it was 1.3-1.6 (Table 28) and in carbendazim treated plot it was 1.9 (NBAII).

Table 26: Enzymes produced by selected abiotic stress tolerant *T. harzianum* isolates in liquid medium

S. No.	Isolate (U/ml)*	Chitinase (U/ml)	Glucanase (U/ml)	Glucosidase (U/ml)	Cellulase (U/ml)	Protease
1	Th-13	0.62	0.53	0.16	1.06	0.13
2	Th-14	1.47	0.64	0.43	1.41	1.18
3	Th-19	0.73	0.68	0.38	1.37	0.18
4	Th-33	0.67	0.48	0.34	0.98	0.17
5	Th-50	0.73	0.63	0.41	1.55	0.16
6	Th-56	0.86	0.43	0.21	0.85	0.16
7	Th-69	0.73	0.48	0.37	1.06	0.12
8	Th-75	0.84	0.60	0.29	1.08	0.17
9	Th-82	0.83	0.61	0.31	1.22	0.18
10	Th-89	1.61	0.74	0.47	1.41	0.18
LSD (*P*=0.05)		0.02	0.05	0.01	0.31	0.04
CV (%)		1.40	0.52	1.84	15.3	1.59

*(U/ml) = One unit of total enzyme activity corresponding to one 1µ mol of reducing sugar

Table 27: Effect of talc and invert emulsion formulations of *T. harzianum* on *Fusarium* wilt incidence in chickpea and yield

Treatment	Incidence %	Root weight per plant	Shoot weight per plant	Yield per plot kg per ac	Rhizosphere population of antagonists*
Control	43.33	2.01	8.12	88.0	-
Th10 talc	25.42	3.52	10.21	112.0	68%
IEF1	28.32	3.01	9.78	155.2	81%
IEF2	24.17	3.21	11.21	107.2	76%
Bavistin	37.08	4.21	12.49	99.2	-
LSD (*P*=0.05)	3.56	NS	NS	10.12	

* % of root bits colonized while plating on TSM 60 days after sowing

Table 28: Yield and rhizosphere colonization of tomato plants treated with different formulations of *T. harzianum*

Treatment kg per ac	Yield per plot antagonists*	Rhizosphere population of DAT	*Alternaria* leaf blight at 75
Control	129.36	-	2.2
Th10 talc	149.35	79%	1.6
IEF1	144.50	76%	1.9
IEF2	136.45	84%	1.5
Bavistin	133.62	-	1.3
LSD (*P*=0.05)	7.82	-	0.36

* % of root bits colonized while plating on TSM 60 days after sowing

Field evaluation of promising strains of *Trichoderma* spp. under rain fed conditions under multi-location testing at different locations revealed isolates Th-1, Th-11, Th13, Th-19 and Th-75 were the best in reducing the brown spot disease incidence (*Bipolaris oryzae*), in rice (GBPUAT). Isolate Th-14 was observed most effective in managing wilt (*Fusarium oxysporum* f. sp. *lentis*) incidence and improving crop growth in lentil and chickpea.

Fusarium wilt and *Macrophomina* root rot incidence was lower in bioagent-treated pea compared to untreated and appreciably higher yield of 65-70 q / ha was recorded in bioagent treated plots whereas the control plots recorded 40-50 q /ha pod yield (GBPUAT). In large scale demonstration trials using *Pseudomonas fluorescens* PBAP-27 and *T. harzianum* PBAT-43, there was less bacterial leaf blight incidence in rice and yield was significantly higher compared to farmers' practice (GBPUAT). *Fusarium* wilt (*Fusarium lycopersici*), damping off (*Pythium* sp.) and fruit rot (*Phytophthora parasitica*) were reduced by 73, 85 and 65%, respectively, using IPM technologies and the yield increased by 21.4 %. In capsicum, wilt and damping off were reduced by 65 and 80% respectively with increased yield of 24.6% over farmers' practices (GBPUAT).

Diversity of biocontrol agents from various agroecological zones

The insect pests of crops and biocontrol agents including parasitoids, predators, entomopathogenic nematodes and microorganisms associated with them and weeds were collected on field and horticultural crops to record the diversity of bioagents from different agro-ecological zones.

At MPKV 42 species of pests and natural enemies representing 14 genera were recorded. The pests included the sucking pests of cotton, sugarcane woolly aphids, pod borers in pulses, thrips and mites on chilli, mealybugs on custard apple, grape vine and papaya and mango hoppers. Natural enemies of sugarcane woolly aphid, viz. *Dipha aphidivora* and *Encarsia flavoscutellum* and some unidentified chrysopids were collected from Jorhat, Golaghat, Sivasagar and Nagon districts. At KAU, natural enemies, viz. *Trichogramma, Goniozus* and braconids were collected from black headed caterpillar. An anthocorid, *Physopleurella armata* was reported for the first time from India. *Chyrsoperla zastrowi sillemi* was collected from Solan (YSPUHF) on *Trialeurodes vaporariorum* (on cucumber). Thirty species of coccinellids were collected of which *Coccinella septempunctata, Hippodamia variegata, Cheilomenes sexmaculata, Oenopia* spp. and *Chilocorus nigrita* were dominant. *Orius spp., Anthocoris* spp., *Scolothrips,* staphylinid beetles and one predatory midge were also collected from greenhouses. Parasitoids of pea leaf miners, *Diglyphus* and *Quadrastichus* were recorded in Bilaspur of HP. At PAU, seven *Bt* isolates were obtained from vegetables and sugarcane. At SKUAST, *T. chilonis* from *Chilo partellus* and *T. kashmirica* from unidentified host on paddy were collected. Spiders were collected from many centres and sent to NBAII for further identification. At AAU (Anand), 62 species of coccinellids and 62 species of spiders belonging to 16 genera in 8 families were collected and identified with the help of Dr. B. H. Patel. Sixteen spider species belonging to 8 families were also from Kerala (KAU). Soil samples and insect bait samples for the isolation of EPNs, fungal and bacterial antagonists were collected by the centres and sent to NBAII for further isolation and identification of bioagents.

Biological suppression of sugarcane pests

Sugarcane woolly aphid (SWA) (*Ceratovacuna lanigera*) incidence was monitored regularly. Low incidence of SWA was recorded during the survey in ten districts of Maharashtra (Pune, Satara, Sangli, Kolhapur, Ahmednagar, Nashik, Nandurbar, Dhule, Jalgaon and Aurangabad) during 2011-12. Predators *Dipha aphidivora, Micromus igorotus,* syrphids, spiders and parasitoid *Encarsia flavoscutellum* were recorded (MPKV). In Tamil Nadu only sporadic incidence of SWA was noticed in all the places surveyed (Erode, Cuddalore, Coimbatore, Salem, Karur, Vellore and Tirunelveli) and the occurrence of *D. aphidivora* and *M. igorotus* was observed along with the population of SWA (TNAU) (Table 29).

The lowest stalk borer incidence (10%) was recorded in *Metarhizium* (2L and 3L /ha) treated sugarcane plots compared to control (25%) (PAU). Incubation temperature range of 15-20°C was observed to be the most optimal for all the entomopathogenic fungi (EPF) while 35°C reduced the efficacy of the EPF against *G. mellonella* (SBI).

In other two trials at Katturu at Andhra Pradesh and Vellore, Tamil Nadu, dead heart percentage was significantly lower in plots released with heat tolerant strain of *T. chilonis* compared to control. Similarly cane count in the plots showed significant difference in one of the three trials with the heat tolerant

Table 29. Effect of natural enemies on incidence of sugarcane woolly aphids in Maharashtra

District	SWA incidence (%)	Pest intensity rating (1-6)	Natural enemies recorded	
			D. aphidivora	*M. igorotus*
Pune	0.78	1.8	1.6	3.9
Satara	0.65	1.6	1.2	3.2
Sangli	0.57	1.6	1.4	3.8
Kolhapur	0.74	1.8	1.3	4.1
Ahmednagar	0.25	1.1	0.7	1.3
Aurangabad	0.14	1.1	0.2	1.6
Jalgaon	0.21	1.3	1.7	2.6
Dhule	0.32	1.5	1.2	1.5
Nandurbar	0.23	1.2	0.4	1.2
Nashik	0.28	1.6	1.3	2.4
Mean		0.42	1.46	1.12.56

Table 30. Demonstration of *T. chilonis* (Temp. tolerant strain) against *C. infuscatellus* at village Chachrari (Dist. Kapurthala) during 2011

Treatment	Incidence of C. *infuscatellus* (%)	Reduction over control (%)	Yield (q/ha)	BC ratio
T. chilonis (Temp. tolerant strain) 37° C	4.8[a]	58.6	734.6[a]	20.5:1
Chemical control (Padan @25kg/ha)	4.6[a]	60.3	736.8[a]	8.5:1
Control	11.6[b]	---	681.2[b]	-

Note: 8 releases of *T. chilonis* were made @50,000/ha at 10 days interval during April to June; Padan 4G@ 25kg/ha was applied after 45 days of planting. Values in a column followed by the same alphabets do not differ significantly.

strain being the best of the three treatments (SBI) (Table 30).

Eri silkworm eggs were used as a factitious host for mass production of *T. chilonis* in the laboratory. The efficacy of *T. chilonis* produced using eri silkworm eggs was compared with the parasitoids produced using *C. cephalonica* eggs for field evaluation against sugarcane internode borer (*Chilo sacchariphagus*). At Mandya (NBAII) and Coimbatore (TNAU), after eighth release @ 20,000/acre, *T. chilonis* reared on eri silkworm eggs significantly reduced the incidence of internode borer as compared to release of *T. chilonis* reared on *C. cephalonica* eggs (Fig. 40).

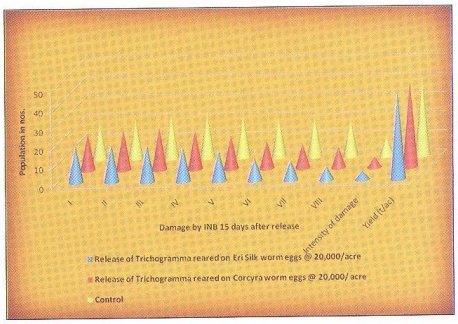


Fig. 40: Field evaluation of *T. chilonis* (produced on eri silkworm eggs) against *C. sacchariphagus*

Biological suppression of cotton pests

Mealybug incidence on cotton was monitored in a field trial (research farm of Botany Section, College of Agriculture, Pune) and incidence was noticed during the 4th week of November 2011. Parasitism by *Aenasius bambawalei* was recorded in December 2011 and it increased to the extent of 60 per cent in the first week of January 2012 (Table 31). The natural enemies recorded were parasitic dipteran flies, aphelinids and encyrtids like *Anagyrus* sp. and predatory coccinellids (*Coccinella, Brumoides* and *Scymnus*), chrysopids, *Spalgis epeus*, anthocorids and spiders (MPKV).

Two mealybug species, the solenopsis mealybug, *Phenacoccus solenopsis* and the pink hibiscus mealybug, *Maconellicoccus hirsutus* were recorded in all cotton growing areas. Earlier, *P. solenopsis* was predominant in many places of Tamil Nadu and slowly replaced by *P. marginatus* especially in Coimbatore, Erode and Tiruppur districts (TNAU). In Ferozepur district of Punjab, the results of survey for cotton mealybug showed that there was low incidence of the pest and maximum parasitism by *Aenasius bambawalei* (36.2%) in the first fortnight of July (PAU).

The *Bt* cotton plot of var. Ankur, Bollgard II was separately maintained on the research farm of College of Agriculture, Pune. The incidence of aphids, jassids, thrips and mealybugs and their natural enemies were recorded. The incidence of sucking pests was comparatively lower in Bt cotton plots during this year in farmers' fields (MPKV).

Biological suppression of tobacco pests

Minimum tillage practice reduced infestation of maize aphid, *Rhopalosiphum maidis* compared to recommended practice (CTRI, Rajahmundry). Minimum tillage reduced the leaf webber *Aproaerema modicella* and leaf beetle (*Cerotoma trifurcata*) infestation in soybean at vegetative, flowering and pod formation stages compared to recommended tillage. However, hairy caterpillar (*Spilarctia casignata*) and green stink bug (*Nezara viridula*) infestation was high in plots with minimum tillage.

Diversity of insect and spider fauna was richer and equally distributed on soybean than maize. In soybean or maize ecosystems, Hemiptera, Coleoptera and Arachnida in the recommended tillage plots showed higher diversity values. In case of Hymenoptera and Lepidoptera minimum tillage plots carried better diversity as indicated by Shannon-Wiener index. Shannon-Wiener index was calculated using the formula:

Σ pi log pi Where i= the species surveyed, p= # each species (ni) divided by total # of species (N) = ni / N

Biological suppression of *Chilo partellus* on maize

Field evaluation of *C. flavipes* and *T. chilonis* showed that two releases of *T. chilonis* @ 2,50,000/ha at weekly interval followed by release of *C. flavipes* @ 5000/ha, resulted in significantly higher per cent of egg parasitism (19.3) with lower per cent of dead hearts (8.4) compared to farmers' practice wherein lower per cent of egg parasitism (2.8) with higher per cent of dead hearts (11.6) were observed (TNAU).

Biological suppression of pests of pulses

NBAII *Bt* formulations were evaluated for managing *H. armigera* and *Maruca vitrata* and observations recorded at 14 DAT indicated that all the *Bt* based treatments performed equally effectively and were found comparable with chlorpyriphos. Pod damage

Table 31: Monitoring biodiversity and outbreaks for invasive mealybugs on cotton

Period of observations		Mealybug infestation (*P. solenopsis*)	Parasitism by *A. bambawalei*	Predators/ plant
July	I	Low	36.2	0.1
	II	low	14.8	0.3
August	I	Medium	20.4	0.8
	II	Low	10.4	1.0
Sept.	I	Low	12.8	0.6
	II	Low	5.6	0.4
October	I	V. Low	2.6	0.3
	Mean	14.7	0.5	

recorded at harvest showed that the treatments of NBAII-BT G4 (2%), PDBC-BT1 (2%) and IARI Bt isolate @ 1 and 2% were equally effective and exhibited pod damage ranging from 4.9 to 5.8% (AAU-A). Grain yield data indicated that maximum yield (1852 kg/ha) was recorded in plots treated with chlorpyriphos followed by NBAII-BT G4 (2%) (1775 kg/ha).

At MPKV, the field evaluation showed that *Bt* strains NBAII-BTG4 and PDBC-BT1 were on par with chemical treatment (chlorpyriphos (0.05%)) with respect to larval population, pod damage and yield.

Among biocontrol treatments, PDBC BT 1 (2%), NBAII-BTG 4 (2%) and *B. bassiana* (2 kg/ha) resulted in minimum pod and grain damage and higher yield and were on par with chlorpyriphos (0.4%) and all the treatments were significantly superior to untreated control (JNKVV). Evaluation of different Bt liquid formulations, two doses of *B. bassiana*, NSKE (5%) and chlorpyriphos (0.04%) showed that PDBC-BT1 (2%), IARI Bt isolate (2%) and chlorpyriphos (0.04%) were highly effective in reducing the larval population of *H. armigera* and *M. vitrata* in all stages, i.e. preflowering, post flowering and pod emergence with lesser pod and seed damage and recording higher yield (TNAU). The population of *H. armigera* larvae was lowest (0.2) in NBAII-BTG4 (2%) treated plot and was on par with NBAII-BTG4 (1%), PDBC-BT1 (1%), PDBC-BT1 (2%), and chlorpyriphos (0.2%) which were significantly better than other treatments (PAU).

Pigeonpea intercropped with sunflower and border crop of maize recorded the least population of pod borers and the per cent reduction in pod damage was 48.3 over sole pigeonpea crop (MPUAT). The results of Field Level Demonstration (FLD) conducted at Ulagadam (Tamil Nadu) revealed (Fig.41) that pigeonpea intercropped with sunflower and maize or sorghum as border crop recorded significantly lower larval population of *H. armigera* and *M. vitrata* compared to pigeonpea as sole crop. Natural enemy population was remarkably higher in pigeonpea intercropped with sunflower and maize or sorghum as border crop than pigeonpea as sole crop. *Chrysoperla, Cheilomenes* and *Ischiodon* populations and *Campoletis* parasitism were higher in intercropped pigeonpea than sole crop (TNAU).

In studies on influence of crop habitat diversity (pigeonpea sole, pigeonpea bordered with maize and sorghum) on biodiversity of natural enemies of insect pests of pigeonpea conducted at JNKVV, five natural enemies were recorded on pigeonpea which included *C. sexmaculata, Cotesia* sp., spiders, dragonfly and mud wasps. Maximum populations of all the natural enemies were observed on sole pigeonpea crop followed by pigeonpea crop bordered with maize and sorghum, respectively.

Significantly least number of *H. armigera* larvae (0.06 larva/plant), minimum number of damaged pods (1.77%) and least number of dried plants (5.09%) due to wilt were recorded in BIPM module compared to farmers' practice (FP) or control. Significantly highest (940 kg/ha) grain yield was harvested from the BIPM module in comparison to FP (873 kg/ha) and untreated check (651 kg/ha) (AAU-A).

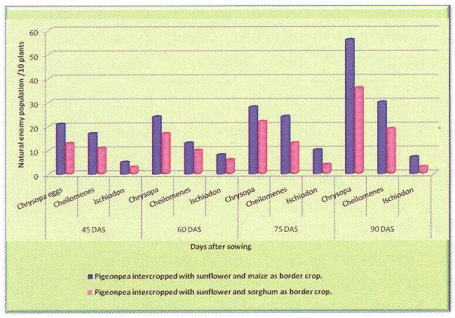


Fig. 41: Activities of natural enemies on the intercrop

Biological suppression of pests of oilseeds

Sprays of *M. anisopliae* @ 10^{13} conidia/ha (av. 8.1 surviving aphids/5 cm shoot/plant) were on par with three sprays of dimethoate @ 1.45 ml/L at fortnightly interval in suppressing the safflower aphid *Uroleucon compositae* population (MPKV).

First spray with *Bt* var. *kurstaki* @ 1 kg /ha, followed by spray of *Nomuraea rileyi* @ 1.5 x 10^{13} conidia/ha and second spray with SlNPV @ 1.5x10^{12} POBs/ha was more effective in reducing *S. litura* population (MPUAT). Three sprays of SlNPV @ 1.5 x 10^{12} POBs/ha was found statistically effective in suppressing the larval population of *S. litura* with 76.0 per cent mortality and gave maximum yield (22.2 q/ha) of soybean (MPKV). Treatments *M. anisopliae* @ 10^{13} spores/ha, *V. lecanii* @ 10^{13} spores/ha, Dipel @ 1 kg/ha and Spinosad 45% SC @ 73 g a. i. /ha were on par with each other with respect to *S. litura* infestation in soybean and were significantly better than control (JNKVV) (Table 32).

Table 32: Efficacy of Entomopathogens against tobacco caterpillar *S.litura* infesting soybean

Treatment	*S. litura* larval population / mrl * 1				
	Pre-treatment	3 DAS	7 DAS	10DAS	Mean
B. bassiana	4.7 L (2.1)	5.3 (2.3)	4.0 (2.0)	0.7 (0.08)	3.1 (1.8)
M. anisopliae	5.0 (2.2)	5.0 L (2.2)	4.8 (2.2)	2.1 (1.5)	4.0 (2.0)
V. lecanii	6.0 H (2.4)	5.7 (2.4)	5.2 (2.3)	2.3 (1.5)	4.4 (2.1)
Bacillus thuringiensis var. *kurstaki*	5.7 (2.4)	5.5 (2.3)	3.1 L (1.8)	0.6 L (0.8)	3.1 L (1.8)
Dipel @ 1 kg /ha	5.7 (2.4)	5.7 (2.4)	5.5 (2.3)	2.3 (1.5)	4.5 (2.1)
Spinosad 45%SC @ 73 g a.i. /ha	5.7 (2.4)	5.7 (2.4)	5.7 (2.4)	2.2 (1.5)	4.5 (2.1)
Control	5.3 (2.3)	6.0 H (2.4)	6.5 H (2.5)	5.5 H (2.3)	6.0 H (2.4)
Mean	5.4 (2.3)	5.5 (2.4)	5.0 (2.2)	2.3 (1.4)	4.3 (2.1)
SEM	(0.1)	(0.04)	(0.04)	(0.06)	(0.02)
LSD (*P*=0.05)	(NS)	(NS)	(0.13)	(0.18)	(0.06)
CV (%)	(7.3)	(3.0)	(3.2)	(7.0)	(1.7)

Screening entomopathogens against *S. litura* and semiloopers in soybean revealed that among microbial insecticides, all the EPN strains registered higher mortality in *S. litura* larvae than *Bt* (56.4%), the highest being with EPN 1 (62.8%). (DSR, JNKVV). In case of *S. litura*, incidence in SlNPV treatment was on par with quinalphos followed by *Bt* and *B. bassiana*. Against leafminer, *Bt* treatment was on par with quinalphos. *Bt* treatment resulted in 26.76 q/ha yield that was on par with quinalphos (27.98 q/ha) (OUAT).

Biological suppression of pests of coconut

The population of *Opisina arenosella* reduced significantly after six releases of *Cardiastethus exiguus* @ 50 numbers / palm made at the crown region (KAU). Monitoring and release of stage-specific parasitoids, viz, *G. nephantidis* and *B. brevicornis* could reduce leaf damage to the tune of 63% and population of *O. arenosella* to the tune of 91.3% in a period of eight months (CPCRI).

In a pilot programme in Edava Panchayat of Trivandrum district, a community based participatory management methodology was followed to scale up the adoption of *M. anisopliae* among small and marginal coconut farmers (208 ha). Farm level production technology developed by CPCRI was facilitated through educated rural women farmers.

Biological suppression of pests of tropical fruits

Application of *M. anisopliae* @ $1x10^9$ spores/ml spray during off season (Neelam variety) plus three sprays during season at weekly interval recorded low mango hopper population (31.6/ inflorescence) with increased fruit set (474.1/tree) (TNAU). At MPKV also the same trend was observed. The mean surviving population was recorded to the extent of 12.0 hoppers per inflorescence during flowering as against 57.9 hoppers per inflorescence in untreated control. The fruit set per inflorescence was 11.6 fruits in this treatment as against 6.3 fruits in untreated control.

Two releases of *Scymnus coccivora* @ 10 grubs per infested tree at monthly interval during July-August 2011 were found significantly superior in suppressing the population of mealybug species, *M. hirsutus* (10.9 mealybugs/fruit) and *F. virgata* (1.2 mealy bugs/fruit) in custard apple orchards and increased the yield of marketable fruits (35.2 kg/tree) (MPKV) (Table 33).

The incidence of PMB was noticed to the extent of 6.0 to 28.5 per cent in Pune, Jalgaon, Dhule, Nandurbar and Kolhapur districts covering western Maharashtra plain, Central Maharashtra Plateau and Sub-montane zones of Maharashtra. The population of the parasitoid, *A. papayae* was high in Dhule (12.5 adults/leaf) than other districts.

Parthenium (*Parthenium hysterophorus* L.), milk weed (*Euphorbia heterophylla* L.), kena weed or day flower (*Commelina benghalensis* L.), tandulja (*Amaranthus dubius* L.) and shoe flower (*Hibiscus rosa-sinensis* L.) were identified as weed hosts of PMB, while guava (*Psidium guajava* L.), teak

(*Tectona grandis* L.), safed chafa (*Plumeria alba*) and mulberry (*Morus* sp.) were cultivated hosts for PMB (MPKV).

Surveys for *P. marginatus* and its natural enemies on papaya and other economically important alternate hosts in four agro-ecological zones of Tamil Nadu in two seasons indicated that *P. marginatus* incidence and intensity of damage were maximum on tapioca with 12 to 72% incidence and 2-4 grade. During Rabi season, spiralling whitefly replaced *P. marginatus*. It was observed that *A. papayae* and *S. epeus* were associated with *P. marginatus*. Several alternate hosts were recorded for papaya mealybug which include 3 Solanaceae, 2 Malvaceae, 2 Fabaceae and one each in Euphorbiaceae, Apocynaceae and Asteraceae (TNAU).

Six papaya orchards in Karnataka with low to very heavy infestation of *P. marginatus* were chosen for inoculative release of *A. papayae* numbering 100-1000 adults / orchard. The parasitoid was recovered

Table 33: Effect of release of predators for the control of mealybugs in custard apple

Treatment	Mealybug population/fruit				Pest intensity rating	Yield (kg/tree)
	Pre-count		Mean surviving population*			
	M. hirsutus	*F. virgata*	*M. hirsutus*	*F. virgata*		
S. coccivora @ 5 grubs/tree	24.8^{a}	10.0^{a}	16.6^{b}	3.6^{b}	1.6	31.7^{a}
S. coccivora @ 10 grubs/tree	26.5^{a}	8.5^{a}	10.9^{a}	1.2^{a}	1.1	35.2^{a}
V. lecanii @ 10^{13} conidia/ha	25.6^{a}	9.2^{a}	17.4^{b}	4.8^{b}	1.8	31.3^{a}
C. montrouzieri @ 5 grubs/tree	27.3^{a}	8.5^{a}	12.7^{a}	1.9^{a}	1.2	33.9^{a}
Untreated control	26.2^{a}	8.8^{a}	40.9^{c}	21.9^{c}	2.7	27.1^{b}
LSD (*P*=0.05)	(NS)	(NS)	(0.28)	(0.52)		5.48

*Cumulative mean of four observations recorded at 15 and 30 days after 1st and 2nd releases of the predator/spray of fungal pathogen.

Table 34: Evaluation of potential of *A. papayae* in controlling papaya mealybug

Location/ Variety	% infestation before release	Date of releases	No. of parasitoids released	Remarks
Hessaraghatta Arka Prabhath	12/ 150 8.00	22.02.2011	200	By May, in three months, complete control was observed
Baglur Red Lady	82/118 69.49	07.06.2011 17.06.2011 27.06.2011	500 1000 500	Establishment of parasitoid after one month, spread was observed in two months and complete control by November
Baglur Red Lady	24/208 23.00	06.07.2011 28.07.2011 05.08.2011	150 100 250	Establishment of parasitoid in four months
Doddabalapur Red Lady	26/217 11.98	02.08.2011 23.08.2011	200 300	By 8th Dec 2011, no fresh infestation was observed. Complete control was observed.

15 days after release indicating the establishment. Complete control of *P. marginatus* was observed in 3-4 months time. The infestation did not increase more than 3% in one of the orchards. About 60-80% control in all the orchards was obtained in 3 months time (IIHR) (Table 34).

Evaluation of seven strains (collections) of entomopathogenic nematodes (EPNs), viz. NBAII-01, NBAII-04, CAU-1, CAU-2 and CAU-3, CAUH-1 and CAUH-2 against citrus trunk borer *Anoplophora versteegi* revealed that at 72 hrs, mortality ranged from 72 to 88 per cent and at 96 H all the grubs died (CAU).

The infestation of papaya mealybug was medium in Androth island in Lakshadweep. *Acerophagus papayae* was released in the infested areas in Kavaratti and Agathi islands and the parasitoids established very well and suppressed the population of *P. marginatus* (KAU).

Biological suppression pests of temperate fruits

Evaluation of predatory mite, *Neoseiulus longispinosus* alone and in combination with horticultural mineral oils (HMO), and azadirachtin (1500 ppm a.i.; 3ml/l) in comparison to fenazaquin (0.0025%) revealed that there was lower mite infestation in plants treated with neem @ 3ml/l (19.8 mites/ plant), compared to 31.0 mites/ plant in untreated plots (YSPUHF) (Table 35)

Table 35: Evaluation of predatory mite in combination with horticultural mineral oils (HMO) against phytophagous mites on apples

Treatment module	Average mite population/leaf	
	Before treatment	15 days after final treatment
N. longispinosus (150/plant) (3 releases)	18.4	8.2 (2.84)ab
HMO (1.0 %) (3 sprays)	17.9	14.2 (3.71)bc
HMO (1.0 %)+ *N. longispinosus* (2 releases)	19.0	10.0 (3.13)b
NeemBaan (1500 ppm; 3 ml/l) (3 spray)	18.7	19.8 (4.42)c
Fenazaquin (0.0025%) (3 sprays)	19.1	4.0 (1.97)a
Control (Untreated)	17.2	31.0 (5.53)d
LSD (*P*=0.05)	NS	(0.89)
CV (%)		42.9

Figures in parentheses are square root transformed values

Table 36: Impact of field releases of *T. embryophagum* and *T. cacoeciae* on per cent apple fruit damage by codling moth at Kargil during 2011

Location	Damage on tree (%)	Dropped fruits (%)	Average damage (%)	% Reduction in damage over control
Mangmore	25.14 (29.29)^{b}	92.16 (73.9)^{a}	58.65 (50.0)^{c}	21.8 (14.11)^{b}
Shanigund	23.3 (28.3)^{b}	78.2 (62.8)^{c}	48.4 (44.0)^{d}	32.1 (34.2)^{e}
Hardas (Gongkuk)	26.2 (30.0)^{b}	90.5 (72.8)^{a}	58.3 (49.8)^{c}	22.1 (27.1)^{d}
Bagh-e- Khomini	9.34 (16.8)^{c}	75.3 (60.7)^{c}	42.3 (40.5)^{e}	38.1 (40.3)^{f}
Kharrol	41.1 (40.1)^{d}	89.9 (71.5)^{ab}	65.5 (54.1)^{b}	13.7 (20.5)^{c}
Hardas (Gond)				
Untreated Check	65.8 (54.6)^{a}	95.2 (77.62)^{a}	80.5 (64.12)^{a}	0.0 (2.8)^{a}
LSD (*P*=0.01)	8.2	5.84	4.29	4.92

- Figures in each column represent mean of 10 observations
- Values in parentheses are arc sin transformations
- Similar alphabets in a column indicate values statistically on par

One ichneumonid and one braconid were recovered from the parasitized larvae of codling moth (SKUAST). Average fruit damage by codling moth in orchards where *T. embryophagum* and *T. cacoeciae* were released during 2011 ranged from 42.3 to 65.5 per cent, as compared to 80.5 in untreated control (Table 36).

Biological suppression pests of vegetables

The yield of cabbage was maximum (171.5q/ha) in IPM package followed by conventional practice (169.0 q/ha) which was significantly higher than that of control plots (96.0 q/ha) (AAU-J) (Table 37). Three weekly releases of *T. chilonis* reduced the larval population of *P. xylostella* in cabbage (SKUAST). Mean aphid population per plant was low in BIPM practice (*C. z. sillemi* @ 5 larvae/ plant at weekly interval + econeem @ 20-25 ml/acre @ 20-25 ml/acre at 10 days interval + planting of mustard crop as trap crop) and it was significantly better than control in suppressing aphid population during the winter season (PAU). Bt-NBAII sprayed at 5ml/L. of water was observed as the most effective treatment with average *P. xylostella* population of 0.33 and 0.20 larvae/leaf in 1st and 2nd spray, respectively and it was comparable to 0.05 per cent profenophos (CAU).

Adoption of BIPM reduced brinjal fruit borer (*L. orbonalis*) damage to 6.59% compared to control (31%) with corresponding increase in yield (45 t/ha) compared to control (31t/ha) (IIHR). Fruit borer incidence was least in BIPM treatments (17.5 to 19.1%) at different locations compared to control plots (29.8 to 33.7%) (OUAT). Thelytokous population of *T. pretiosum* is capable of exerting better control of fruit damage in tomato compared to arrhenotokous populations (MPUAT). IPM package was on par with chemical control alone in the management of *Amrasca biguttula* and *Bemisia tabaci* populations in okra with yield of 97q/ha compared to 69.6q/ha in control (AAU-J).

Release of *Blaptostethus pallescens* @ 10 per plant reduced the mite population in okra to 279.25 mites/10 plants compared to 390.00 mites/10 plants in control plots (OUAT) (Table 38). When 6-7 day-old nymphs of *B. pallescens* were released twice at weekly interval on brinjal plants under polyhouse condition, the population of *T. urticae* was significantly reduced (PAU). The mean population of onion thrips, *Thrips tabaci* per plant varied from 6.0 to 29 in the biological control treatments. The per cent thrips population reduction over control varied from 38 to 58 per cent in plots with anthocorid release. Neem soap and acephate recorded 34 to 38% reduction in thrips population over control (IIHR).

Application of *B. bassiana* (IIHR isolate) was on par with lambda cyhalothrin, acetamipirid and neem soap in reducing tea mosquito bug infestation in guava (IIHR). At Coimbatore (TNAU), acetamiprid 0.2 g/l and cyhalothrin 0.5ml/l were found significantly superior in reducing the tea mosquito bug population followed by *B. bassiana* (IIHR) strain.

Table 37: Developing bio-intensive IPM package for the pests of cabbage

Treatment	*B. brassicae*/ leaf		*P. brassicae*/plant*		*P. xylostella*/plant*		Yield (q/ha)
	Pre count	Post count*	Pre count	Post count*	Pre count	Post count*	
IPM plot	16.6	5.82[b]	2.16	1.48[b]	3.72	1.92[b]	171.5[b]
Farmers' Practice (Chemicalcontrol)	21.04	6.0[b]	2.16	1.52[b]	4.04	2.2[b]	169.0[b]
Untreated control	24.9	29.97[a]	2.36	3.28[a]	4.2	5.0[a]	96.2[a]
Sed±	2.21	0.78	0.13	0.15	0.27	0.32	4.7
LSD (*P*=0.05)	5.11	1.80	0.29	0.34	0.63	0.73	10.83
CV (%)	16.76	11.28	8.98	10.96	10.8	16.55	5.1

*Mean of 3 observations

Means followed by same letters are not significantly different

Table 38: Evaluation of anthocorid predators against *T. urticae* on okra

Treatment	Mite population before release*	Mite population 7 days after release*	Mite population 15 days after release*	No. of leaves with webbings**	Marketable yield(q/ha)
B. pallescens @ 10 per plant	380.50 (2.58)	279.25 (2.45)	145.50 (2.16)	16.50 (4.12)	131.5
B. pallescens @ 20 per plant	378.75 (2.58)	212.50 (2.33)	126.50 (2.10)	12.25 (3.57)	138.4
B. pallescens @ 30 per plant	369.50 (2.57)	176.50 (2.25)	98.50 (1.99)	13.50 (3.74)	142.6
Chemical control	390.50 (2.59)	87.75 (1.94)	43.25 (1.64)	8.50 (3.00)	156.9
Untreated control	388.25 (2.59)	390.00 (2.59)	412.50 (2.62)	29.75 (5.50)	110.3
LSD (*P*=0.05)	NS	(0.18)	(0.15)	(0.09)	9.61

Figures in parentheses are * Log x transformation, ** $\sqrt{(x+0.5)}$ transformation

Biological suppression of mealybugs

Influence of host plants on parasitisation by *A. papayae*, was studied by releasing mealybugs on six host plants, viz. papaya, cotton, mulberry, tapioca, marigold and teak followed by release of 20 pairs of *A. papayae*. The mean developmental time of *A. papayae* parasitising papaya mealybug on papaya was 11.33 days (minimum) and 12.33 days, 12.66 days, 13.66 days 14.83 days and 15.16 days on teak, cotton, mulberry, marigold and tapioca, respectively (TNAU).

For the utilization of indigenous strains of *Anagyrus* spp. for the management of *M. hirsutus* on fruit and ornamental crops, surveys showed no emergence of *A. kamali* from pink mealybug at Coimbatore but other parasitoids, *viz*., *Leptomastix dactylopii*, *Elasmus* sp., cecidomyiid fly and predators viz., *Spalgis epeus, Cryptolaemus montrouzieri, Scymnus coccivora, Brumoides suturalis, Cheilomenus sexmaculata, Coccinella transversalis* and *Ischiodon scutellaris* were recorded while in MPKV, Pune, *Triommata coccidivora* and *Anagyrus* sp. and some unidentified species emerged from the mealybug colonies.

Biological suppression of termites

Bioefficacy of *M. anisopliae* (strains 1, 2, 3, 4) was tested for the suppression of termite incidence in sugarcane (cv. CoLk 8102). Cane damage in entomopathogenic fungi treated plots was 20-25% compared to 37% in control while in chemical treated plots it was 13% (IISR) (Table 39). Application of *M. anisopliae* @ $5x10^{13}$ spores/ha FYM enriched and

Table 39: Effect of *M.anisopliae* on germination, incidence of termites and yield

Treatment	Germination (%)	Incidence of termites (%)		Yield (t/ha)
		Bud damage (May)	Cane damage (at harvest)	
M. anisopliae (strain 1)	25.2 (30.10)	23.64 (29.07)	33.46 (35.32)	52.32
M. anisopliae (strain 2)	23.2 (28.78)	25.20 (30.10)	29.13 (32.64)	51.34
M. anisopliae (strain 3)	26.72 (31.10)	20.43 (26.85)	27.64 (31.73)	53.43
M. anisopliae (strain 4)	24.69 (29.71)	22.21 (28.09)	28.48 (32.23)	52.87
Chlorpyriphos 20EC @ 1 kg a.i. /ha	31.2 (33.93)	12.72 (20.84)	21.26 (27.42)	56.27
Control	19.8 (26.38)	36.87 (37.36)	39.20 (38.74)	47.20
LSD (P=0.05)	2.01	1.67	1.69	1.75

Figures in parentheses are arc sine transformation

Table 40: Evaluation of *B. pallescens* against spider mites

Treatment	Average mite population/leaf	
	Before treatment	15 days after treatment
B. pallescens (1:20)	16.4	20.8 (4.55)[c]
B. pallescens (1:10)	15.7	14.0 (3.68)[b]
Profenophos (0.05%)	18.2	3.2 (1.77)[a]
Control	13.6	36.6 (6.03)[d]
LSD (*P*=0.05)	NS	(0.72)
CV (%)		26.7

Figures in parentheses are square root transformed values

M. anisopliae @ $5x10^{13}$ spores/ha recorded comparatively lesser mortality and yield was on par with chlorpyriphos treatment (TNAU). Similarly application of FYM enriched with *M. anisopliae* $5x10^{13}$ spores/ha reduced termite incidence in maize to 4.6% compared to 21.5% in control (MPUAT)

Biological suppression of polyhouse pests

Release of anthocorid predator, *B. pallescens* against spider mites in polyhouse on roses at the rate of 20 anthocorids per plant reduced the mite population by 61% and it was on par with abamectin application (60%) (SKUAST). In brinjal also the release of anthocorids reduced the mite infestation (8%) compared to control (21%) (KAU). In carnation also the same effect could be recorded though the performance of anthocorids was less than that of chemical application but significantly better than control and yielded 2400 stalks of flowers compared to 1800 stalks in control (TNAU). At YSPUHF, *B. pallescens* (1:20 and 1:10) released carnation plots had lower mite population (20.8 and 14.0 mites/leaf, respectively) than untreated control, but significantly higher than profenophos treatment (0.05%) where the mite population was only 3.2 mites/leaf (Table 40).

Application of *Coccinella septempunctata*, *C. undecimpunctata* and *Chrysoperla* reduced the cabbage aphids by 54.14, 57.1 and 39.11 per cent respectively when evaluated under polyhouse conditions (SKUAST).

Among biocontrol agents, release of predatory mite, *Amblyseius* sp. @ 10 and 5 mites/ plant and release of coccinellid beetle, *Stethorus pauperculus* were effective in reducing two spotted-spider mite, *T. urticae* in carnation under polyhouse condition. Application of Neem Baan (3ml/L) resulted in 77.8 per cent reduction of mite population that was on par with *Neoseiulus longispinosus* released at predator: prey ratios of 1:10 and 1:20 (YSPUHF).

Biological suppression of storage pests

Inoculative release of *Xylocoris flavipes* @ 30 nymphs/10 kg stored wheat was significantly superior in reducing the moth emergence of *C. cephalonica* after a month (av. 18.6 moths/ container), followed by the treatment with *X. flavipes*

Table 41: Effect of anthocorids on infestation of *C. cephalonica* in stored wheat

Treatment	No. of *C. cephalonica* moths emerged		
	Trial 1	Trial 2	Mean
B. pallescens @ 10 nymphs/10 kg wheat	58.2[c]	59.0[b]	58.6[d]
B. pallescens @ 30 nymphs/10 kg wheat	29.7[a]	30.5[a]	30.1[b]
X. flavipes @ 10 nymphs/10 kg wheat	39.5[b]	42.2[b]	40.9[c]
X. flavipes @ 20 nymphs/10 kg wheat	26.2[a]	29.5[a]	27.9[b]
X. flavipes @ 30 nymphs/10 kg wheat	19.2[a]	18.0[a]	18.6[a]
Untreated control	89.5[d]	87.5[c]	88.5[e]
LSD (*P*=0.01)	1.22	1.27	0.45

Table 42: Effect of anthocorid predators against storage pests of rice

Treatment	Mean no. of *Corcyra* moths emerged	Mean no. of living anthocorids (nymphs)
B. pallescens @ 10 nymphs	43.8	0
B. pallescens @ 20 nymphs	38.5	0
B. pallescens @ 30 nymphs	28.8	0.75
X. flavipes @ 10 nymphs	38.3	3.25
X. flavipes @ 20 nymphs	27.8	6.75
X. flavipes @ 30 nymphs	22.3	11.75
Untreated	57.3	0
S. Ed±	1.86	0.73
CV (%)	7.18	32.08
LSD (*P*=0.05)	3.91	1.53

@ 20 nymphs/10 kg wheat and *B. pallescens* @ 30 nymphs/10 kg wheat. The mean moth emergence in untreated control was 88.5 per container (MPKV) (Table 41).

X. flavipes @ 30 nymphs/ kg rice effectively suppressed the population of rice moth, *C. cephalonica* under storage conditions. *X. flavipes* released @ 30 nos./bin performed better followed by *X. flavipes* @ 20nos./bin (KAU). Inoculative release of *X. flavipes* @ 30 nymphs per kg of stored rice could reduce the emergence of *C. cephalonica* moths (22.3 moths/container) followed by *X. flavipes* @ 20 nymphs / container (Table 42). Maximum number of living nymphs of *X. flavipes* was also found in the treatments with 30 nymphs (11.75) and 20 nymphs (6.75) (AAU-J). *X. flavipes* was better than *B. pallescens* in controlling rice moth infestation.

Inoculative release of *X. flavipes* @ 30 nymphs per bin of rice reduced significantly the emergence of *C. cephalonica* moths followed *B. pallescens* @ 30 nymphs per bin of rice. The *C. cephalonica* moth emergence was maximum (89) in untreated control. It was noticed that the number of live anthocorid nymphs and adults was maximum (49.4) from *X. flavipes* @ 30 nymphs released bins followed by *X. flavipes* @ 20 and 10 nymphs (TNAU). It was noticed that the number of live anthocorid nymphs and adults was maximum (49.4) from *X. flavipes* @ 30 nymphs released bins followed by *X. flavipes* @ 20 and 10 nymphs.

Tribal Sub-Plan

Validation of biocontrol technologies was carried out in tribal areas under TSP programme on various crops, *viz.*, chickpea (for *Fusarium* wilt management at AAU-A, JNKVV), pigeonpea pest complex (MPUAT), rice (KAU), potato (CAU), apple (for codling moth at SKUAST), castor (ANGRAU), ginger and turmeric (OUAT), mango (for hoppers at TNAU) and pomegranate (RKN at MPKV, AAI-A) for the benefit of tribal farmers.

Enabling large scale adoption of proven biocontrol technologies

The following large-scale demonstration trials were taken up at different AICRP centres during 2011-12.

- Demonstration of biocontrol based IPM in rice at Chaggran in district Hoshiarpur in 25 ha (PAU), at Rajabahar of Jorhat district in 100 ha (AAU-J), at Thrissur in 500 ha (KAU)
- Demonstration of biological control of maize stem borer at village Chaggran in Hoshiarpur district on 10 ha area (PAU)
- Large scale demonstration of biocontrol for suppression of plassey borer, *Chilo tumidicostalis* using *T. chilonis* in 150 ha at Dergaon of Golaghat district (AAU-J)
- Demonstration of temperature tolerant strain of *T. chilonis* against early shoot borer (ESB) in Suru planting of sugarcane (MPKV)
- Large-scale demonstration of the use of *T. chilonis* against early shoot borer and internode borer of sugarcane in farmers' field Nimapara, Puri district (OUAT)
- Large-scale demonstration of effectiveness of *T. chilonis* (tts) against early shoot borer, *C. infuscatellus* over an area of 1000 acres in

collaboration with two sugar mills of the state.

- Large-scale demonstrations on effectiveness of *T. japonicum* against top borer, *S. excerptalis* in Paddi Khalsa (Distt Jalandhar) (PAU).
- Large scale demonstration of effectiveness of *T. japonicum* against top borer, *S. excerptalis* over an area of 1000 acres in collaboration with Doaba Cooperative Sugar Mills Ltd., Nawanshahar and Morinda Cooperative Sugar Mills Ltd., Morinda (PAU).
- Demonstration of biological control of maize stem borer *C. partellus* using *T. chilonis* and *C. flavipes* in Hoshiarpur district on 10 ha area (PAU).
- Validation of integrated biocontrol technology against *Oryctes rhinoceros* infesting coconut in 100 ha in Alappuzha district of Kerala (CPCRI).
- Biocontrol of *O. rhinoceros* with *Metarhizium anisopliae* var. *major* at Thrissur in 5ha (KAU).

5. TECHNOLOGY ASSESSED, TRANSFERRED AND MATERIALS DEVELOPED

DNA sequences generated and deposited with GenBank

Deepa, M.H., Divya, R.M., Rajeshwari, R., Jalali, S.K., Venkatesan, T. and Sriram, S. 2011. Characterization of yeast endosymbionts from *Trichogramma chilonis* - JF803488.

Divya, R.M., Deepa, M.H., Rajeshwari, R., Jalali, S. K., Venkatesan, T. and Sriram, S. 2011. Characterization of yeast endosymbionts from *Trichogramma chilonis* - JF803489.

Divya, R.M., Deepa, M.H., Rajeshwari, R., Jalali, S. K., Venkatesan, T. and Sriram, S. 2011. Characterization of yeast endosymbionts from *Trichogramma chilonis* - JF803490.

Divya, R.M., Deepa, M.H., Rajeshwari, R., Jalali, S.K., Venkatesan, T. and Sriram, S. 2011. Characterization of yeast endosymbionts from *Trichogramma chilonis* - JF803491.

Deepa, M.H., Divya, R.M., Rajeshwari, R., Jalali, S.K., Venkatesan, T. and Sriram, S. 2011. Molecular characterization of endosymbionts (Bacteria) in *Trichogramma chilonis* - JF736840.

Deepa, M.H., Divya, R.M., Rajeshwari, R., Jalali, S.K., Venkatesan, T. and Sriram, S. 2011. Molecular characterization of endosymbionts (Bacteria) in *Trichogramma chilonis* - JF736841.

Deepa, M.H., Divya, R.M., Rajeshwari, R., Jalali, S.K., Venkatesan, T. and Sriram, S. 2011. Molecular characterization of endosymbionts (Bacteria) in *Trichogramma chilonis* - JF736842.

Divya, R.M., Deepa, M.H., Rajeshwari, R. and Jalali, S.K. 2011. Molecular characterization of endosymbionts in *Trichogramma chilonis* of sunhemp - JF728870.

Deepa, M.H., Divya, R.M., Rajeshwari, R., Jalali, S.K., Venkatesan, T. and Sriram, S. 2011. Molecular characterization of bacterial endo-symbionts in *Trichogramma chilonis* - JF728871.

Hemalatha, B.N., Venkatesan, T., Jalali, S.K. and Sriram,S. 2011. *Wickerhamomyces anomalus* strain CZS1-Y1 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, complete sequence; and 5.8S ribosomal RNA gene, partial sequence (397 bp) - JQ061140

Hemalatha, B.N., Venkatesan, T., Jalali, S.K. and Sriram, S. 2011.*Wickerhamomyces anomalus* strain CZS1-Y2 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, complete sequence; and 5.8S ribosomal RNA gene, partial sequence (634 bp) - JQ061141.

Hemalatha, B.N., Venkatesan, T., Jalali, S.K. and Sriram, S. 2011. *Wickerhamomyces anomalus* strain CZS2-Y5 internal transcribed spacer 1 and 5.8S ribosomal RNA gene, partial sequence - JQ241273

Hemalatha, B.N., Venkatesan,T., Jalali, S.K. and Sriram, S. 2011. *Candida apicola* strain CZS2-Y6 18S ribosomal RNA gene and internal transcribed spacer 1, partial sequence (300 bp) - JQ241274 .

Hemalatha,B.N., Venkatesan,T., Jalali, S.K. and Sriram, S. 2011. *Candida blankii* strain CZS3-Y1 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, complete sequence; and 5.8S ribosomal RNA gene, partial sequence - JQ340778.

Hemalatha, B.N., Venkatesan, T., Jalali, S.K. and Sriram, S. 2011. *Candida blankii* strain CZS3-Y3 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, complete sequence; and 5.8S ribosomal RNA gene, partial sequence - JQ340779.

Hemalatha, B.N., Venkatesan, T., Jalali, S.K. and Sriram, S. 2011. *Wickerhamomyces anomalus strain*

CZS5-Y1 18S ribosomal RNA gene,partial sequence; internal transcribed spacer 1, complete sequence; and 5.8S ribosomal RNA gene, partial sequence - JQ340780.

Hemalatha, B.N., Venkatesan, T., Jalali, S.K. and Sriram, S. 2011. *Wickerhamomyces anomalus* strain CZS5-Y2 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, complete sequence;and 5.8S ribosomal RNA gene, partial sequence - JQ340781.

Hemalatha, B.N., Venkatesan, T., Jalali, S.K. and Sriram, S. 2011. *Wickerhamomyces anomalus* strain CZS5-Y3 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, complete sequence;and 5.8S ribosomal RNA gene, partial sequence - JQ340782.

Hemalatha, B.N., Venkatesan, T., Jalali, S.K. and Sriram, S. 2011. *Zygosaccharomyces rouxii* strain CZS7-Y1 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, complete sequence; and 5.8S ribosomal RNA gene, partial sequence - JQ410172.

Hemalatha, B.N., Venkatesan, T., Jalali, S.K. and Sriram, S. 2011. *Zygosaccharomyces rouxii* strain CZS7-Y3 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, complete sequence; and 5.8S ribosomal RNA gene, partial sequence - JQ410174.

Hemalatha, B.N., Venkatesan, T., Jalali, S.K. and Sriram, S. 2011. *Wickerhamomyces anomalus* strain CZS8-Y2 18S ribosomal RNA gene, partial sequence; internal transcribed spacer 1, complete sequence; and 5.8S ribosomal RNA gene, partial sequence - JQ410176.

6. EDUCATION AND TRAINING

Name	Training programme	Duration	Place
International			
Dr T. Venkatesan	Allele mining- Mining of microsatellites and functional genes	21.3.2011 to 20.6.2011	West Virginia State University, West Virginia, USA
Dr Deepa Bhagat	Nanotechnology- Synthesis of nanosensors	5.2.2011 to 5.5.2011	University of California, Davis, USA
National			
Dr Rajkumar	Structure, functions and dynamics of bio-molecules used in pest management of horticultural crops	10.5.2011 to 23.5.2011	CTCRI Regional Station, Bhubaneshwar
Dr M. Pratheepa	High performance bio-computing & drug design	12.9.2011 to 22.9.2011	IASRI, New Delhi
Mr H. Jayaram	Workshop-cum-training on strategies for implementation of Koha implementation under e-Granth project-NAIP	6.9.2011 to 7.9.2011	UAS, Bangalore
Dr Ankita Gupta	Microsoft Office Access	28.9.2011 to 30.9.2011	ISTM, New Delhi
Dr Deepa Bhagat Ms Gandhi Gracy Dr Ankita Gupta Dr Rajkumar	Molecular mechanisms involved in conferring abiotic stress tolerance to the biological control agents *Chrysoperla*, *Trichogramma*, *Trichoderma* and *Pseudomonas*	1.12.2011 to 21.12.2011	NBAII, Bangalore
Dr Deepa Bhagat	Nanocellulose and its composites in agriculture	10.10.2011 to 24.10.2011	CIRCOT, Mumbai
Dr M. Pratheepa	Open access to academic knowledge	2.11.2011	IISc, Bangalore
Dr G. Sivakumar	Refresher course on agricultural research management	19.1.2012 to 8.2.2012	NAARM, Hyderabad
Mr P. K. Sonkusare	Data mining using SAS	6.2.2012 to 11.2.2012	IASRI, New Delhi

7. AWARDS AND RECOGNITIONS

NBAII, Bangalore

- The University of Mysore has recognized NBAII as its affiliate Institute for conducting research leading to Ph. D. degree in the fields of Zoology, Biotechnology and Microbiology.

Dr B.S. Bhumannavar

- Vice-President, Society for Biocontrol Advancement, Bangalore.
- Nodal Officer for Project Information and Management System of ICAR (PIMS-ICAR)
- Nodal Officer for Results Framework Document (RFD) of NBAII
- Vigilance Officer, NBAII
- Chairman, PME Cell, NBAII
- Nodal Officer for HYPM
- Member Secretary, RAC, NBAII
- Member Secretary, QRT, NBAII

Dr T. Venkatesan

- Recognized as guide for Ph.D. (Biotechnology) by University of Mysore, Mysore.
- Recognized as an advisory member for M.Sc. (Ag.) student by the Department of Entomology, UAS, Bangalore.

IIHR, Bangalore

Dr A. Krishnamoorthy

- Chief Editor, Journal of Horticultural Sciences, Society for Promotion of Horticulture, Bangalore.
- President, Association for Advancement of Pest Management in Horticultural Ecosystems, Bangalore.
- Vice-President, Society for Biocontrol Advancement, Bangalore.
- Appointed as Nodal officer to conduct ARS/NET exams by ASRB in 2011.

MPKV, Pune

Dr R.V. Nakat

- Awarded *Adarsha Shikshak Puraskar* by Shivpratap Pratisthan, Pune, on the occasion of Teachers' Day on 5 September 2011.

CTRI, Rajahmundry

Mr S. Gunneswara Rao

- Awarded Ph.D. degree by Acharya Nagarjuna University, Nagarjuna Nagar, Guntur.

8. LINKAGES AND COLLABORATION IN INDIA AND ABROAD INCLUDING EXTERNAL PROJECTS

Research projects funded by lateral sources operating at NBAII

NAIP

- Effect of abiotic stresses on the natural enemies of crop pests: *Trichogramma*, *Chrysoperla*, *Trichoderma* and *Pseudomonas* and mechanism of tolerance to these stresses (Collaborating centres - DOR, CRIDA, Vittal Mallya Science Research Foundation, Bangalore and Mysore University).
- Estblishment of National Agricultural Bioinformatics Grid (NABG) in ICAR.

DBT

- DNA-based early detection of post-harvest diseases in mango, banana and management using consortia of bioagents (NBAII work-Isolation of pathogens and microflora from fruit surfaces of mango for post harvest management) (in collaboration with TNAU, Coimbatore)
- Development of fungal bionematicides: Scale-up, post-harvest processing, storage stability, toxicology and field evaluation.
- Genetic and functional analysis of novel genes from *Photorhabdus luminescens* and *Xenorhabdus nematophilus,* symbiotic bacteria associated with entomopathogenic nematodes for insect pest management.
- Nanoparticles for enhancing shelf-life/storage and field application of semiochemicals

ICAR Cess-Fund

- Network Project on Insect Biosystematics.
- TMC MM1 3.3: Development, validation, utilization and/or commercialization of bio-pesticides and bio-inoculants.
- ICAR Network Project: Outreach programme on diagnosis and management of leaf spot diseases of field and horticultural crops (Sub-project: Biological control of *Colletotrichum* diseases of chillies).
- PhytoFuRa – An outreach programme of IISR on *Phytophthora, Fusarium* and *Ralstonia* diseases of horticultural and agricultural crops.

AMAAS (ICAR)

- Microbial control of insect pests – II.

IPR

- Intellectual Property Management and Transfer/Commercialization of Agricultural Technology Scheme (upscaling of existing component, i.e. Intellectual Property Rights (IPR) under ICAR Headquarters scheme on management on information services).

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

- Identification of nucleopolyhedrovirus (NPV) encoded proteins and small RNAs and the feasibility of their expression in plant to control *Helicoverpa* (Lead centre: ICGEB, New Delhi).

Institute of Forest Genetics and Tree Breeding

- Influence of eucalyptus species on the natural enemy incidence on the gall wasp *Leptocybe invasa*.

9. AICRP / COORDINATION UNIT / NATIONAL CENTRES

With a view to fulfill the mandate of the AICRP on Biological Control effectively and efficiently, the NBAII is functioning with the following ICAR Institute-based and State Agricultural University-based centres.

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
State Agricultural University-based centres	
Acharya N.G. Ranga Agricultural University, Hyderabad	Sugarcane, cotton 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 Sciences & Technology, Srinagar	Temperate fruits and vegetables
Tamil Nadu Agricultural University, Coimbatore	Sugarcane, cotton, pulses and tomato
Voluntary centres (partially funded)	
Jawaharlal Nehru Krishi Viswavidyalaya, Krishi Nagar, Adhartal, Jabalpur	Pulses
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

10. LIST OF PUBLICATIONS

Research papers published in refereed scientific journals

NBAII, Bangalore

Ankita Gupta and Peter Smetacek, 2011. A new larval host record for *Sphingomorpha chlorea* (Cramer) (Insecta: Lepidoptera: Noctuidae) from Karnataka, India. *Journal of Threatened Taxa*, 3: 1553-1554.

Ankita Gupta and Veenakumari, K. 2011. A new record of *Chrysochalcissa oviceps* Bouček (Hymenoptera: Torymidae) from eggs of Heteroptera from Karnataka, India. *Journal of Biological Control,* 25: 148-149.

Bakthavatalam, N., Ravi, G., Deepa Bhagat and Tandon, P.L. 2011. Electrophysiological response of *Tetrastichus schoenobii* Ferriere (Hymenoptera: Eulophidae) an egg parasitoid of rice stem borer, *Scirpophaga incertulas* (Walker) (Lepidoptera: Crambidae) to the extracts of plants collected from rice ecosystem. *Journal of Biological Control*, 25: 98-102.

Basha, H., Hemannavar, V., Ramanujam, B., Rangeshwaran, R. and Sriram, S. 2011. Screening of chilli microflora and other biocontrol agents for their antagonistic effects on *Colletotrichum* spp. infecting chillies. *Journal of Plant Protection Sciences*, 2: 38-44.

Charles, V., Puneeth, P., Vijayan, V. A. and Jalali, S. K. 2011. Genetic aspects of insecticide tolerance in *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae) strains. *Journal of Biological Control*, 25: 207-213.

Gracy, R.G., Shivalingaswamy, T.M., Satpathy, S. and Rai, A.B. 2011. Okra shoot and fruit borer, *Earias vittella* (F.), a new host record for the egg parasitoid, *Trichogramma chilotraeae* Nagaraja & Nagarkatti from India. *Journal of Biological Control,* 25: 146-147.

Gupta, T., Ballal, C.R. and Joshi, S. 2011. Preferential feeding of an anthocorid predator *Blaptostethus pallescens* on different stages of cotton mealybug. *Journal of Environmental Entomology,* 33: 423-428.

Jaydeep Halder, Kodandaram, M.H., Rai, A.B. and Shivalingaswamy, T. M. 2011. Effect of systemic insecticides against three aphid species on vegetable crops. *Annals of Plant Protection Sciences,* 19: 206-207.

Madhusudan, S., Jalali, S.K., Venkatesan T. and Lalitha, Y. 2011. Insecticide resistance variation in *Helicoverpa armigera* (Hübner) in cotton and tomato crops. *Journal of Insect Science*, 24: 135-141.

Madhusudhan, S., Jalali, S.K., Venkatesan, T., Lalitha, Y. and Srinivas, R.P. 2011. 16s rRNA gene based identification of gut bacteria from laboratory and wild larvae of *Helicovpera armigera* (Lepidoptera: Noctuidae) from tomato farm. *The Bioscan*, 6: 175-183.

Narendra Kumar, J. B., Gopinath, O.K., Sreenivas, B.T., Divya, S.H., Shylesha, A.N., Vinod Kumar, Shekhar, M.A. and Qadri, S.M.H. 2011. Mass production of *Acerophagus papayae* to contain papaya mealybug. *Indian Silk*, 2: 4-6.

Patil, S., Sriram, S. and Savitha, M.J. 2011.Evaluation of non-pathogenic *Fusarium* for antagonistic activity against *Fusarium* wilt of tomato. *Journal of Biological Control*, 25: 118-123.

Patil, S., Sriram, S., Savitha, M.J. and Arulmani, N. 2011. Induced systemic resistance (ISR) in tomato by non-pathogenic *Fusarium*. *Archives of Phytopathology and Plant Protection*, 44: 1621-1634.

Prashanth Mohanraj and Veenakumari, K. 2011. Butterflies of the Andaman and Nicobar islands: History of collection and checklist. *Zootaxa,* 3050: 1-36.

Qadri, S.M.H., Rabindra, R.J., Shekhar, M.A. and Shylesha, A.N. 2010. Tackling papaya mealybug

in mulberry to sustain sericulture. *Indian Silk*, 1(5-6): 4-5 & 9

Ramakrishnan, S. and Nagesh, M. 2011. Integration of soil solarisation with nematode egg parasitic fungi, *Pochonia chlamydosporia* and *Paecilomyces lilacinus* for the management of root-knot nematode, *Meloidogyne incognita* in tobacco nursery. *Journal of Biological Control*, 25: 2011.

Ramanujam, B., Balachander, M., Roopa, G., Rangeswaran, R. and Pritam Karmakar. 2011. Chitinase activity and virulence of different isolates of *Beauveria bassiana*, *Metarhizium anisopliae* and *Lecanicillium* spp. *Journal of Biological Control*, 25: 223-228.

Ramanujam, B., Balachander, M., Roopa, G., Rangeswaran, R. and Pritam Karmakar. 2011. ITS sequencing of Indian isolates of *Lecanicillium* species. *Journal of Biological Control*, 25: 337-341.

Ramanujam, B., Prasad, R.D., Sriram, S. and Rangeshwaran, R. 2010. Mass production, formulation, quality control and delivery of *Trichoderma* for plant disease management. *The Journal of Plant Protection Sciences*, 2: 1-8.

Rangeshwaran, R., Veenakumari, K., Pritam Karmakar, Ashwitha, K., Sivakumar, G. and Satendar Kumar, 2011. Characterization and evaluation of two indigenous *Bacillus thuringiensis* isolates (NBAII-BTAS and NBAII-BTG4) against *Helicoverpa armigera*. *Journal of Biological Control*, 25: 286-293.

Satpathy, S., Kumar, A., Shivalingaswamy, T. M. and Rai, A.B. 2012. Effect of prey on predation, growth and biology of green lacewing, *Chrysoperla zastrowi sillemi* (Esben-Petersen) (Neuroptera: Chrysopidae). *Indian Journal of Agricultural Sciences*, 82: 55-58.

Shivalingaswamy, T. M., Kumar, A., Satpathy, S. and Rai, A.B. 2011. Pea leafminer, *Chromatomyia horticola* infestation in different cultivars. *Insect Environment*, 17: 17-18.

Sivakumar, G., Rangeshwaran, R. and Sriram, S. 2011. Screening and identification of potential *Bacillus* spp. for the management of bacterial wilt of brinjal (egg plant). *Journal of Biological Control*, 25: 229-235.

Sreerama Kumar, P. and Leena Singh. 2012. A simple method of storing nonsynnematous and synnematous isolates of *Hirsutella thompsonii* while conserving their pleomorphism, pathogenicity and genetic purity. *Folia Microbiologica*, 57: 15-19.

Srinivasa Murthy, K., Rajeshwari, R., Venkatesan, T. and Nesil Liz Baby. 2011. Detection and characterization of *Wolbachia* in *Cotesia plutellae* Kurdjumov (Braconidae: Hymenoptera), a parasitoid of the Diamond back moth, *Plutella xylostella* (Linn.). *Journal of Biological Control*, 25: 213-216.

Srinivasa Murthy, K., Rajeshwari, R., Jalali, S.K. and Venkatesan, T. 2011. Host searching efficiency of *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) an important parasitoid of the maize stem borer *Chilo partellus* Swinhoe. *Indian Journal of Fundamental and Applied Life Sciences*, 1:71-74.

Sriram, S., Roopa, K.P. and Savitha, M.J. 2011. Extended shelf-life of liquid fermentation derived talc formulations of *Trichoderma harzianum* with the addition of glycerol. *Crop Protection*, 30: 1334-1339.

Sriram, S. and Savitha, M.J. 2011. Enumeration of colony forming units of *Trichoderma* in formulations – precautions to be taken to avoid errors during serial dilution. *Journal of Biological Control*, 25: 64-67.

Veenakumari, K. and Prashanth Mohanraj. 2011. *Odontacolus markadicus* sp. nov. (Hymenoptera: Platygastroidea: Platygastridae) – As addition to the platygastrid fauna of India. *Journal of Biological Control*, 25: 188-192.

Veenakumari, K., Prashanth Mohanraj and Peigler, R. 2011. First description of a female of *Antheraea meisteri* Brechlin and notes on some pre-imgaines of three recently described species of Saturniidae (Lepidoptera) from the tropical moist forests of the Andaman Islands. *Journal of the Lepidopterists' Society*, 65: 94-100.

Veenakumari, K., Rajmohana, K. and Prashanth Mohanraj. 2011. Description of *Odontoscelio vikata* sp. nov. (Hymenoptera: Platygastroidea: Platygastridae) from India. *Hexapoda*, 18: 87-92.

Venkatesan, T., Baby Nesil Liz, Jalali, S.K., Shylesha, A.N. and Rabindra, R.J. 2011. Characterization and identification of *Acerophagus papayae* an introduced parasitoid of papaya mealybug through DNA barcode. *Journal of Biological Control,* 25: 11-13.

CPCRI, Kayangulam

Chandrika Mohan, Rajan, P. and Anithakumari, P. 2012. Ecofriendly biocontrol methods for management of rhinoceros beetle – safe, simple and free of chemical pesticides. *Indian Naleekera Journal,* 3: 22-24.

Josephrajkumar, A., Rajan, P., Chandrika Mohan and Krishnakumar, V. 2011. Report on the palm aphid, *Cerataphis brasiliensis* on 'Kalparaksha' coconut cultivar. *Phytoparasitica,* 39: 389-391.

Sneha Soman and Chandrika Mohan 2011. Compatibility of *Metarhizium anisopliae* (Metsch.) Sorokin with some chemical and botanical pesticides used in coconut pest management. *Journal of Plantation Crops,* 39: 196-200.

GBPUAT, Pantnagar

Bhaduria, B.P., Singh, P. K., Zaidi, N.W. and Kumar, J. 2011. Biocontrol efficacy of *Beauveria bassiana* against *Spodoptera litura. Annals of Plant Protection Sciences,* 19 : 216-218.

Negi, Y., Garg, S.K., and Kumar, J. 2011. Genetic diversity among cold-tolerant fluorescent *Pseudomonas* isolates from Indian Himalayas and their characterization for biocontrol and plant growth promotion activities. *Journal of Plant Growth Regulation,* 30: 128-143.

Rawat, L., Singh, Y., Shukla, N. and Kumar, J. 2011. Alleviation of the adverse effects of salinity stress in wheat (*Triticum aestivum* L.) by seed biopriming with salinity tolerant isolates of *Trichoderma harzianum. Plant and Soil,* 347: 387-400

Shukla, N., Awasthi, R.P., Rawat, L., and Kumar, J. 2012. Biochemical and physiological response of rice (*Oryza sativa* L.) as influenced by *Trichoderma harzianum* under drought stress. *Plant Physiology and Biochemistry,* 54: 78-88.

IIHR, Bangalore

Ganga Visalakshy, P. N., Mani, M., Krishnamoorthy, A. and Gopalakrishna Pillai, K. 2010. Epizootics of *Entomophthora* sp. on mango inflorescence hopper, *Idioscopus nitidulus* (Walker). *Journal of Biological Control*, 24: 274–275.

Ganga Visalakshy, P.N. and Krishnamoorthy, A. 2010. Distribution of eggs and larvae of *Leucinodes orbinalis* Guenee (Lepidoptera: Pyralidae) in relation to different plant parts. *Entomon*, 35: 1-2.

IISR, Lucknow

Srivasatava, D.C., Baitha, A., Singh, M.R. and Bajpai, P.K. 2012. Natural parasitisation and incidence of sugarcane top borer, *Scirpophaga excerptalis* Walker. *International Sugar Journal*, 114:197-202.

Baitha, A, Sinha, O.K., Maurya, B.L. and Rajak, D.C. 2011. Age preference of females on biological attributes in *Tetrastichus howardi* (Olliff. (Eulophidae: Hymenoptera). *Journal of Plant Protection and Environment*, 8: 45-48.

MPKV, Pune

Nakat, R.V., Pokharkar, D.S., Dhane, A.S. and Tamboli, N.D. 2012. New record of *Acerophagus papayae* (N. & S.) on papaya mealybug, *Paracoccus marginatus* (W. & G.) in India. *Journal of Agriculture Research and Technology*, 37: 165-167.

PAU, Ludhiana

Joshi, N., Virk, J.S. and Sharma, S. 2011. Fixing economic threshold level for initiation of HaNPV application for the control of *Helicoverpa armigera* on chickpea under Punjab conditions. *Pest Management and Economic Zoology,* 17: 195-201.

Joshi, N. and Virk, J.S. 2011. Field evaluation of eco-friendly biocontrol package for the managementof pod borer, *Helicoverpa armigera* Hubner, and fusarium wilt in chickpea, *Cicer arietinum. Archives of Phytopathology and Plant Protection,* 44: 1815-21.

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CPCRI, Kayangulam

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11. LIST OF APPROVED ONGOING PROJECTS/ EXPERIMENTS

National Bureau of Agriculturally Important Insects

I. Basic research

1. Cataloguing of insect fauna of India, with emphasis on minor orders
2. Biosystematics of *Trichogramma* and *Trichogrammatoidea*
3. Introduction and studies on natural enemies of some new exotic insect pests and weeds
4. Biodiversity of oophagous parasitoids with special reference to Scelionidae (Hymenoptera)
5. Biodiversity of economically important Indian Microgastrinae (Braconidae) supported by molecular phylogenetic studies
6. Development of production protocols and evaluation of mite and anthocorid predators
7. Biodiversity of aphids, coccids and their natural enemies
8. Polymorphism in pheromone reception in *Helicoverpa armigera*
9. Influence of elevated levels of carbon dioxide on the tritrophic interactions in some crops
10. Semiochemicals for the management of coleopteran pests
11. Formulations of pheromones of important borer and other crop pests and kairomones for natural enemies using nanotechnology
12. Attractants for natural enemies of rice pests for use in the conservation of natural enemies
13. Studies on bee pollinators in crop ecosystems with special reference to pulses and oilseed crops
14. *In situ* conservation of natural enemies and pollinators in pigeonpea and sunflower ecosystems
15. Isolation, identification and characterization of endosymbionts of trichogrammatids and their role on the fitness attributes
16. Studies on molecular characterization and identification of endosymbionts of chrysopid predators and their role on the biological attributes
17. Studies on *Trichogramma brassicae* and *Cotesia plutellae* interaction with their host in cabbage ecosystem
18. Molecular characterization of Indian coccinellids
19. Phytophagous mites as a source of microbes for harnessing in pest management
20. Interactions of microbial control agents in diverse soil types
21. Standardization of solid state fermentation conditions and development of prototypes with semi-automation for the mass production of *Trichoderma* spp., *Metarhizium anisopliae* and *Beauveria bassiana*
22. Management of bacterial wilts of tomato and brinjal caused by *Ralstonia solanacearum* through *Bacillus* spp.
23. Evaluation of fungal pathogens on *Aphis craccivora* in cowpea and *Bemisia tabaci* in tomato and capsicum
24. Isolation, characterization and toxicity of indigenous *Bacillus thuringiensis* strains against lepidopterous pests
25. Bio-intensive management of root-knot nematode/ *Fusarium* disease complex in tomato and okra using PGPR
26. Mass production and exploitation of entomopathogenic nematodes against white grubs from diverse habitats
27. Nematode-derived fungi and bacteria for exploitation in agriculture
28. Database on entomopathogenic nematodes

AICRP on Biological Control

I. Biodiversity of biocontrol agents from various agro-ecological zones

Trichogramma - all centres

Chrysoperla - All centres

Goniozus and Braconid species (KAU, ANGRAU, CPCRI, TNAU, OUAT, AAU-J)

Cryptolaemous - All centres (except SKUAS & T)

Spiders - All centres

Insect-derived EPNs - All centres

Soil samples for isolation of antagonistic organisms - All centres

Anthocorids - All centres

Biodiversity of insect pests and their natural enemies in horticultural ecosystems (YSPUH & F)

Biodiversity and conservation of natural enemies in coriander (MPUAT)

Isolation of native *Bt* isolates from soil (AA-A, NBAII, IARI, PAU)

Surveillance for alien invasive pests in vulnerable areas (All centres)

II. Biological suppression of pests and diseases in field

Plant diseases and nematodes

A. Biological control of plant diseases using antagonistic organisms

1. Screening of selected abiotic stress tolerant (i.e. drought, salinity) isolates of *Trichoderma* sp. for their potential to produce hydrolytic enzymes under *in vitro* conditions (GBPUAT)
2. Development of oil-based formulations of selected isolates of *Trichoderma harzianum* and study of their shelf life (GBPUAT)
3. Field evaluation of invert-emulsion formulations of *T. harzianum* for the management of foliar and soil borne diseases of tomato (PAU) and chickpea (AAU-A, GBPUAT).
4. Field evaluation of promising strains of *Trichoderma* spp. under rain fed conditions under multi-location testing at different locations (GBPUAT, AAU-A, PAU, NBAII)
5. Large scale field demonstration of biocontrol technologies (GBPUAT)
6. Monitoring for emergence of newer pests and diseases of various crops in district Udham Singh Nagr and Nainital of Uttarakhand (GBPUAT).
7. Isolation, identification and characterization of indigenous strains of *Pseudomonas fluorescens* and *Bacillus* strains effective against *Fusarium* wilt in pigeonpea (AAU-A).

B. Validation of biocontrol technologies for management of crop pests and diseases under Tribal Sub-Plan (TSP)

1. Pigeonpea

   a) *Fusarium* wilt management on pigeonpea (AAU-A, JNKVV)

   b) Validation of pigeonpea pest complex under TSP (MPUAT)
2. Validation of biocontrol technologies in rice under TSP (KAU)
3. Validation of biocontrol technologies for potato pests and diseases under TSP (CAU)
4. Validation of bio-intensive management of codling moth, *Cydia pomonella* on apple, in the tribal aras of Leh and Kargil under TSP (SKUAST)
5. Validation of biocontrol technologies for management of pests and diseases of castor under TSP (ANGRAU)
6. Validation of biocontrol technologies for lmanagment of pests and diseases of ginger and turmeric under TSP (OUAT)
7. Validation of biocontrol technologies for management of mango hopper with *Metarhizium anisopliae* under TSP (TNAU)

C. Biological control of plant parasitic nematodes using antagonistic organisms

1. Demonstration of biocontrol practices for management of root-knot nematode in pomegranate (1ha) (MPKV, AAU-A, NBAII)

III. Biological suppression of sugarcane pests

1. Monitoring the sugarcane woolly aphid incidence and impact assessment of natural enemies on its biosuppression (MPKV, TNAU, UAS-Raichur).
2. Evaluation of entomopathogenic fungi against stalk borer of sugarcane (PAU).

3. Interaction of entomopathogenic fungi with other soil fungi in sugarcane agro-ecosystem (SBI).
4. Field trials on the evaluation of heat tolerant strain of *Trichogramma chilonis* for the management of shoot borer (SBI).
5. Field evaluation of *Trichogramma chilonis* produced using eri-silkworm eggs as factitious host (TNAU, ANGRAU, CAU, NBAII).

IV. Biological suppression of cotton pests

1. Monitoring the biodiversity and outbreaks of invasive mealybugs on cotton (MPKV, TNAU, PAU)
2. Monitoring the biodiversity and outbreaks of sap sucking pests, mirids and their natural enemies in *Bt* cotton ecosystem (MPKV).

V. Biological suppression of tobacco pests (CTRI)

1. Isolation and identification of indigenous pathogens of tobacco stem borer and their utilization along with other pathogens for suppression of tobacco stem borer
2. Influence of cropping rotations and tillage operations in tobacco on the diversity of plant and soil dwelling faunal assemblages.

VI. Biological suppression rice pests

1. Seasonal abundance of predatory spiders in rice ecosystem (AAU-A, AAU-J, ANGRAU, CAU, KAU, OUAT, TNAU).
2. Laboratory evaluation of fungal pathogens on gundhi bug, *Leptocorisa* sp. (KAU, CAU).
3. Evaluation of IPM for upland rice pests and diseases (CAU).

VII. Biological suppression of pests of maize

1. Evaluation of *Cotesia flavipes* and *Trichogramma chilonis* against maize stem borer, *Chilo partellus* (TNAU).

VIII. Biological suppression of pulse crop pests

1. Evaluation of NBAII liquid formulations (PDBC-BT1 and NBAII-BTG4) and IARI *Bt* against pigeonpea pod borer (*Helicoverpa armigera*) and legume pod borer (*Maruca testulalis*) (AAU-A, MPKV, JNKVV, ANGRAU, TNAU, PAU, UAS-Raichur).
2. Influence of crop habitat diversity on biodiversity of natural enemies in pigeonpea through FLD/OFD (TNAU, ANGRAU, MPUAT & JNKVV).
3. Demonstration of bio-intensive pest management practices in chickpea (AAU-A).

VIII. Biological suppression of oilseed crop pests

1. Biological suppression of *Uroleucon carthami* on safflower (MPKV, ANGRAU)
2. Evaluation of entomophagous pathogens against soybean insect pest complex (MPUAT, MPKV, JNKVV).
3. Screening of EPN against *Spodoptera litura* on soybean (DSR, JNKVV).
4. Biological control of groundnut pests -rabi, 2011-13 (OUAT).

IX. Biological suppression of coconut

1. Surveillance and need-based control of coconut leaf caterpillar, *Opisina arenosella* in Kerala (KAU, CPCRI).
2. Scaling up utilization of *M. anisopliae* through technology transfer (CPCRI).
3. Entomopathogenic nematodes for management of red palm weevil (*Rhynchophorus ferrugineus*) (CPCRI, NBAII, TNAU, ANGRAU).

X. Biological suppression of pests in tropical fruits

1. Field evaluation of *Metarhizium anisopliae* formulation against mango hoppers (IIHR, KAU, TNAU, ANGRAU, MPKV)
2. Biological suppression of mealybug, *Maconellicoccus hirsutus* and *Ferrisia virgata* with *Scymnus coccivora* on custard apple (MPKV).
3. Survey and record of incidence of papaya mealybug and its natural enemies on papaya and other alternate hosts (Tritrophic interaction) (MPKV, KAU, OUAT, TNAU, IIHR, NBAII).
4. Establishment of *Acerophagus papayae* on *Paracoccus marginatus* in Lakshadweep and their impact. While visiting Lakshadweep, collection of natural enemies from other crops may be made (KAU, OUAT, NBAII).
5. Evaluation of entomopathogenic fungi against citrus trunk borer, *Anaplophora versteegi* (CAU).

XI. Biological suppression of pests of temperate fruits

1. Evaluation of entomopathogenic fungi and EPNs for the suppression of apple root borer, *Dorysthenes huge* under field conditions (YSPUHF).

2. Evaluation of predatory mite in combination with horticultural mineral oils (HMO) for the management of phytophagous mites on apple (YSPUHF).
3. Survey for identification of suitable natural enemies of codling moth (SKUAST).
4. Field evaluation of *Trichogramma embryophagum* and *T. cacoeciae* against the codling moth, *Cydia pomonella* on apple (SKUAST).
5. Observations on the natural enemies of seed infesting chalcid, *Eurytoma* of apricots in Laddakh (SKUAST).

XII. Biological suppression of pests of vegetable crops

1. Developing biointensive IPM package for the pests of cole crops (YSPUH & F, AAU-J, SKUAST, PAU).
2. Characterization of toxicity of Bt isolates against pests of cole crops (IARI).
3. Evaluation of microbial pesticides against diamond back moth, *Plutella xylostella* (CAU).
4. Validatin of different BIPM modules against shot and fruit borer, *Leucinodes orbonalis* on brinjal (IIHR, MPKV, JNKVV, OUAT).
5. Field evaluation of thelytokous and arrheno-tokous strains of *Trichogramma pretiosum* against *Helicoverpa armigera* on tomato (MPKV).
6. Validation of BIPM of major insect pests in tomato at farmers' field (MPUAT).
7. Development of biocontrol based IPM module against insect pests of okra (AAU-J).
8. Evaluation of anthcorid predators against mite, *Tetranychus urticae* on brinjal and okra (OUAT, PAU).
9. Biological suppression of onion thrips, *Thrips tabaci* with predatory anthcorid and microbial agents (MPKV, IIHR).
10. Biological control of cowpea aphid (KAU).
11. Survey for parasitoids of *Liriomyza trifolii*, the serpentine leaf miner (KAU).
12. Evaluation of *Encarsia guadeloupae* against spiraling whitefly on cassva (TNAU).
13. Evaluation of entomopathogens against sucking pests of ornamentals/ vegetables (JNKVV).
14. Identification of major aphid parasitoids and their extent of parasitism in mustard and cabbage (MPUAT).

XIII. Biological control of tea mosquito bug

1. Population dynamics of tea mosquito bugs in tea and its natural enemies (AAU-J).
2. Evaluation of *Beauveria bassiana* (IIHR isolate) against tea mosquito bug in guava (IIHR, TNAU) and in tea (AAU-J).

XIV. Biological control of mealybugs

1. Survey for mealybugs and their natural enemies on horticultural crops- papaya, hibiscus, tapioca, brinjal, tomato, okra (AAU-J).
2. Influence of host plants on parasitisation by *Acerophagus papayae* (TNAU).
3. Utilization of indigenus strains of *Anagyrus* spp. for the management of pink hibiscus mealybug, *Maconellicoccus hirsutus* on fruit and ornamental crops (TNAU, IIHR, MPKV, NBAII).

XV. Biological control of termites

Testing the bioefficacy of entomopathogenic fungi in suppression of termite incidence (Sugarcane- AAU-A, ANGRAU, SBI, IISR, TNAU; Maize- MPUAT, AAU-A).

XVI. Biological suppression of pests in polyhouses

1. Evaluation of anthocorid predator, *Blaptostethus pallescens* against spider mites in polyhouses (SKUAST- Demonstration) (KAU, ANGRAU, TNAU, USPUHF, AAU-A).
2. Evaluation of efficacy of predators against cabbage aphids in polyhouses (SKUAST).
3. Evaluation of predatory mite, *Neoseiulus longispinosus* against phytophagus mite in rose under polyhouse condition (YSPUHF, SKUAST).
4. Evaluation of biological control agents against carnation spider mite under polyhouse conditions (TNAU).
5. Evaluation of biocontrol agents against sap sucking insect pests of ornamentals in polyhouses (YSPUHF, ANGRAU, KAU, JNKVV).
6. Biological management of root knot nematode infesting tomato, carnation and gerbera in polyhouses (KAU, MPKV, GBPUAT, AAU-A, ANGRAU, TNAU, SKUAST).

XVII. Biological suppression of storage pests

1. Evaluation of anthocorid predators against storage pests of wheat (MPKV, PAU).
2. Evaluation of anthocorid predators against storage pests in rice (KAU, TNAU, ANGRAU, AAU-J, SKUAST).

XVIII. Biological suppression of weeds

1. Biocontrol of *Chromolaena odorata* in forest area of Chattisgarh utilizing *Cecidochares connexa* by inoculative release (DWSR).

XIX. Enabling large-scale adoption of proven biocontrol technologies

1. Rice (AAU-J, KAU, PAU, OUAT)

2. Sugarcane

i. Large-scale demonstration of biocontrol for the suppression of Plassey borer, *Chilo tumidicostalis* using *Trichogramma chilonis* (AAU-J)

ii. Enabling the uptake of biocontrol based ecofriendly technologies in sugarcane for the management of early shoot borer and internode borer (ANGRAU) (for only one year, 2012-13) (BCRL to provide the pheromone traps)

iii. Demonstration of temperature tolerant strain of *Trichogramma chilonis* against early shoot borer in Suru planting of sugarcane (MPKV).

iv. Large-scale demonstration on the use of *Trichogramma chilonis* (temperature tolerant strain) for the suppression of early shoot borer and internode borer of sugarcane in farmers' field (OUAT) (50 ha.).

v. Enabling large scale adoption of approved biocontrol technology in sugarcane in collaboration with sugar mills (PAU).

3. Maize

I. Demonstration of biological control of maize stem borer, *Chilo partellus* using *Trichogramma chilonis* and *Cotesia flavipes* (PAU).

4. Coconut

I. Large area field validation of integrated biocontrol technology against *Oryctes rhinoceros* (CPCRI, KAU).

12. CONSULTANCY, PATENTS AND COMMERCIALISATION OF TECHNOLOGY

NBAII

- Quality testing of several biopesticides
- EAG and GC-MS analysis for samples received from various organizations
- Bioassay of *Bt* proteins against lepidopteran pests
- Mass production and supply of trichogrammatids and coccinellids for biological control of various pests
- Mass production and supply of *Trichoderma*, *Pseudomonas*, etc. for management of plant diseases
- Mass production and large scale supply of host insects like *Corcyra cephalonica*, *Spodoptera litura*, *Helicoverpa armigera* for research and commercial units

Patents filed

- Design and development of solid state bioreactor for the mass production of fungal bioagents (2271/CHE/2011; 4 July 2011).
- Development of novel wettable powder formulation of *Paecilomyces lilacinus* strain NBAII PLFT5 (PL55) and method thereof for scale-up production and downstream processing for commercial use (29 March 2012).

Technology sold

- Licensing of Know-how/product of *In vivo* production, downstream processing and development of wettable powder formulation of entomopathogenic nematode, *Heterorhabditis indica* strain NBAII Hi1 and field use for biological control of white grubs to M/s Venkateshwara Chemicals, Secunderabad, for 2 lakhs on non-exclusive basis.
- Licensing of Know-how/product of *In vivo* production, downstream processing and development of wettable powder formulation of entomopathogenic nematode, *Heterorhabditis indica* strain NBAII Hi1 and field use for biological control of white grubs to M/s Sri Biotech Laboratories India Ltd., Hyderabad, for 2 lakhs on non-exclusive basis.
- Licensing of Know-how/product of *In vivo* production, downstream processing and development of wettable powder formulation of entomopathogenic nematode, *Heterorhabditis indica* strain NBAII Hi1 and field use for biological control of white grubs to M/s Multiplex Bio-Tech Pvt. Ltd., Bangalore, for 2 lakhs on non-exclusive basis.
- Licensing of know-how/product of technology for liquid formulation of *Bacillus thuringiensis* to M/s Agro Bio-tech Research Centre Ltd., Kottayam, for 2 lakhs on non-exclusive basis.

13. MEETINGS HELD AND SIGNIFICANT DECISIONS MADE

Institute Research Council Meeting

The Institute Research Council Meeting of the NBAII, Bangalore, was held on 18 June 2011 under the Chairmanship of Dr R.J. Rabindra, Director, NBAII.

Dr S. Sriram and Dr. R. Rangeshwaran presented the plan of work of the following new projects (RPF-I). The following observations emerged after the detailed discussions:

1. There were no comments in the RPF-I presented by Dr S. Sriram. In the project presented by Dr Rangeshwaran, the following changes have been suggested by the IRC.

- Reduce the number of treatments to the manageable level.
- Compatibility between *Pseudomonas* and *Bacillus* to be checked before imposing the treatments.

2. It was agreed for the merger of the project "Studies on bee pollinators in crop ecosystems with special reference to pulses and oilseed crops' handled by Dr D. Sundararaju (now superannuated) with the project 'In situ conservation of natural enemies and pollinators in pigeon pea and sunflower ecosystem' handled by Dr. T. M. Shivalingaswamy.

3. It was agreed for the closure of the project 'Establishment of *Puccinia spegazzinii* on *Mikania micrantha',* as the main objective of importation, quarantine and field release of the rust of *Puccinia spegazzinii* had been completed. The rust fungi did not establish in the field and there is no further collaboration with CABI for further import of rust fungus. The scientist has been advised to submit RPF-III.

4. The proposal of Dr. M. Nagesh for the extension of his two projects 'Nematode-derived fungi and bacteria for exploitation in agriculture' (extension till 31.3.2012) and 'Mass production and exploitation of entomopathogenic nematodes against white grubs from diverse habitats' (extension till 31.3.2012) was discussed. The scientist has been advised to provide adequate justification.

5. Dr S. Sriram and Dr R. Rangeshwaran were asked to submit their RPF-I after suitable modification in line of suggestions.

Institute Management Committee Meetings

The XXI IMC meeting was held on 12 November 2011 at NBAII under the chairmanship of Dr N. K. Krishna Kumar, Director. The other members who attended the meeting were Dr V. J. Shivankar, Dr. K. S. Varaprasad, Dr R. P. Gupta, Dr. B. Mallik, Dr. P. V. Veera Raju, Dr K.P. Jayanth, Dr N.G. Lakshminarayana, Dr. A. Krishnamoorthy, Shri. S. Bilgrami and Dr. J.N.L. Das. Presentations on the following topics were made to the IMC members.

1. Classical biological control of eucalyptus gall wasp, *Leptocybe invasa* (Eulophidae: Hymenoptera) with the exotic parasitoid, *Quadrastichus mendeli* from Israel.
2. Commercialization of different technologies at NBAII.
3. Production protocols for the predatory anthocorids.
4. A brief account of utilization of Institute budget and tribal sub-plan.

The IMC recommended the following

The IMC appreciated the efforts taken by the NBAII to import the parasitoids for the management of Eucalyptus gall wasp. The IMC appreciated the action taken on the commercialization of different technologies at NBAII.

1. The IMC approved for the extension of services of Dr P.V. Mahalakshmi and Dr Vishwanath N. Patil, the AMAs for a period up to 31.3.2013.

2. The IMC also approved three additional hospitals (i) Maiya Multispeciality Hospital, Jayanagar, Bangalore, ii) K. K. Hospital, No. 9 A1/A2, A Sector, Yelahanka New Town, Bangalore and iii) Lokhandes Hospital, 3 AC, 902, 3rd A Cross, 9th A Main, Kalyananagar I Block, HRBR Layout, Bangalore) one diagnostic centre (Doctors Diagnostic Centre, No.83, N. K. Complex, Kammanahalli Main Road, Bangalore) and one AMA (Dr L. S. Vijayakumar, MBBS, MD Sri Seshakamal Clinic, No.11/37, Kathiriguppa, Main Road, Banashankari III Stage, Bangalore) for NBAII staff treatment.
3. The IMC approved the proposal of mobile insect collection laboratory under equipment during the XII Plan.

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

NBAII, Bangalore

Dr N. K. Krishna Kumar

- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- Brainstorming Session on Insect Genomics, NBAII, Bangalore, 24 October 2011.
- Seminar on Plant Genomics – Genotyping and Marker Aided Selection, Genotypic Technology Private Limited, UAS Alumni Association Convention Hall, Bangalore, 13 February 2012.

Dr B. S. Bhumannavar

- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.

Dr N. Bakthavatsalam

- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.

Dr J. Poorani

- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.

Dr Prashanth Mohanraj

- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.

Dr K. Veenakumari

- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.

Dr A.N. Shylesha

- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.

Dr S.K. Jalali

- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.
- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- Brainstorming Session on Insect Genomics, NBAII, Bangalore, 24 October 2011.

Dr B. Ramanujam

- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.

Dr K. Srinivasa Murthy

- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.
- Colloquium on Research Areas in Insect Bio-informatics, NBAII, Bangalore, 28 July 2011.
- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- Brainstorming Session on Insect Genomics, NBAII, Bangalore, 24 October 2011.
- Seminar on Plant Genomics – Genotyping and Marker Aided Selection, Genotypic Technology Private Limited, UAS Alumni Association Convention Hall, Bangalore, 13 February 2012.

Dr T. Venkatesan

- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.
- Colloquium on Research Areas in Insect Bio-informatics, NBAII, Bangalore, 28 July 2011.
- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- Brainstorming Session on Insect Genomics, NBAII, Bangalore, 24 October 2011.
- Seminar on Plant Genomics – Genotyping and Marker Aided Selection, Genotypic Technology Private Limited, UAS Alumni Association Convention Hall, Bangalore, 13 February 2012.

Dr R. Rangeshwaran

- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.

Dr C.R. Ballal

- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.
- Colloquium on Research Areas in Insect Bio-informatics, NBAII, Bangalore, 28 July 2011.
- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- International Symposium on Mass Production and Commercialization of Arthropod Biological Control Agents, Beijing, China, 21-24 October 2011.

Dr G. Sivakumar

- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.
- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.

- Brainstorming Session on Insect Genomics, NBAII, Bangalore, 24 October 2011.
- Refresher Course on Agricultural Research Management, NAARM, Hyderabad, 19 January 2012 to 8 February 2012.

Dr Rajkumar

- Training Programme on Structure, Functions and Dynamics of Bio-molecules Used in Pest Management of Horticulture Crops at RC-CTCRI, Bhubaneswar, 10-23 May 2011.
- Winter School on Molecular Mechanisms Involved in Conferring Abiotic Stress tolerance to the Biological Control Agents *Pseudomonas* spp. *Chrysoperla,* etc., NBAII, Bangalore, December 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.
- Colloquium on Research Areas in Insect Bioinformatics, NBAII, Bangalore, 28 July 2011.
- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- Brainstorming Session on Insect Genomics, NBAII, Bangalore, 24 October 2011.
- National Symposium on Nematodes: A challenge under changing climate and agricultural practices, 16th to 18th Nov. 2011 held at Kovalam, Trivandrum, Kerala.

Dr T. M. Shivalingaswamy

- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.

Dr Ankita Gupta

- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.

Dr Sunil Joshi

- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.

Dr S. Sriram

- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.

Dr P. Sreerama Kumar

- National Information Day and Training on European Union's Seventh Framework Programme (FP7) of Food, Agriculture and Fisheries, and Biotechnology, Indian Institute of Technology Madras, Chennai, 19 August 2011.
- Seminar on Plant Genomics – Genotyping and Marker Aided Selection, Genotypic Technology Private Limited, UAS Alumni Association Convention Hall, Bangalore, 13 February 2012.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.
- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.

- XII Biennial Group Meeting of the All-India Network Project on Agricultural Acarology, Kerala Agricultural University, Thrissur, 27-28 January 2012.

Dr Deepa Bhagat

- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.

YSPUHF, Solan

Dr Usha Chauhan

- XX Biocontrol Workers' Group Meeting, NBAII, Bangalore, 27-28 May 2011.
- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.

Dr P.L. Sharma

- XX Biocontrol Workers' Group Meeting, NBAII, Bangalore, 27-28 May 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.

Dr Chandrika Mohan

- XX Biocontrol Workers' Group Meeting, NBAII, Bangalore, 27-28 May 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.
- Sensitization Workshop on Approved Use of Pesticides, National Institute for Plant Health Management, Hyderabad, 18 June 2011.
- National Meeting on Agricultural Entomology for 21st Century: The Way Forward, NBAII, Bangalore, 25-26 August 2011.
- Training programme on Consortium of e-Resources in Agriculture, CPCRI, Kasaragod, 15 September 2011.
- National Workshop on Conservation of Biodiversity- Unsolved Problems, their Policy and Individual Responsibility, Malabar Christian College, Calicut, 23 September 2011.
- XX Biennial group meeting of AICRP (Palms) at CPCRI, Kasaragod during 15-17 October 2011.
- Stakeholders Meet on Plant Health in Relation to Planting Material Production in Coconut Root Wilt Disease Prevalent Tracts, CPCRI (RS), Kayamkulam, 15 December 2011.
- Platform Discussion on Research Programme ORP on Sucking Pests, CTCRI, Trivandrum, 16 December 2011.

CTRI, Rajahmundry

Dr S. Gunneswara Rao

- XIV National Symposium on Tobacco, CTRI, Rajahmundry, 20 December 2011.

IIHR, Bangalore

Dr P.N. Ganga Visalakshy

- ICAR Challenge Programme on Insect Borers, NBAII, Bangalore, 9 November 2011.
- International Conference and Exhibition on the Art and Joy of Wood , FAO and IWST, Bangalore, 19-22 October 2011.
- National Seminar on Current Trends in Biotechnological Strategies for Ecofriendy Crop Protection, Department of Zoology, University of Madras, Chennai, 16-17 December 2011.

Dr A. Krishnamoorthy

- National Symposium on Harnessing Biodiversity for Biological Control of Crop

Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.

- XII Plan Stakeholders Meet, ICAR research Complex, Goa, 10 February 2012.
- National Dialogue on Citrus Improvement, Production and Utilization, NRC for Citrus, Nagpur, 27-29 February 2012.

KAU, Thrissur

Dr K.R. Lyla

- XX Biocontrol Workers' Group Meeting, NBAII, Bangalore, 27-28 May 2011.
- XII Biennial Group Meeting of All India Network Project on Agricultural Acarology, Kerala Agricultural University, Thrissur, 26-28 January 2012.

Ms C.V. Vidya

- XII Biennial Group Meeting of All India Network Project on Agricultural Acarology, Kerala Agricultural University, Thrissur, 26-28 January 2012.

PAU, Ludhiana

Dr J. S. Virk

- III Congress on Insect Science, PAU, Ludhiana, 18-20 April 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.
- Research and Extension Specialists Workshop for Rabi Crops, PAU, Ludhiana, 18-19 August 2011.
- Kisan Mela, PAU, Ludhiana, 22-23 September 2011.
- Research and Extension Specialists Workshop on Vegetable, Fruit and Flower Crops, PAU, Ludhiana, 8-9 November, 2011.
- Annual Review Meeting of Network Project on Insect Biosystematics, PAU, Ludhiana, 26- 27 March 2012.
- Kisan Mela, PAU, Ludhiana, 21-22 March 2012.

Dr Neelam Joshi

- III Congress on Insect Science, PAU, Ludhiana, 18-20 April 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.
- Research and Extension Specialists Workshop for Rabi Crops, PAU, Ludhiana, 18-19 August 2011.
- Kisan Mela, PAU, Ludhiana, 22-23 September 2011.
- Research and Extension Specialists Workshop on Vegetable, Fruit and Flower Crops, PAU, Ludhiana, 8-9 November, 2011.
- Annual Review Meeting of Network Project on Insect Biosystematics, PAU, Ludhiana, 26- 27 March 2012.
- Kisan Mela, PAU, Ludhiana, 21-22 March 2012.
- International Conference on Microbial Biotechnology for Sustainable Development, Punjab University, Chandigarh, 3-6 November 2011.
- International Conference of Entomology, Punjabi University, Patiala, 17-19 February 2012.

Dr Rabinder Kaur

- III Congress on Insect Science, PAU, Ludhiana, 18-20 April 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.
- Research and Extension Specialists Workshop for Rabi Crops, PAU, Ludhiana, 18-19 August 2011.
- Kisan Mela, PAU, Ludhiana, 22-23 September 2011.
- Research and Extension Specialists Workshop on Vegetable, Fruit and Flower Crops, PAU, Ludhiana, 8-9 November, 2011.

- Annual Review Meeting of Network Project on Insect Biosystematics, PAU, Ludhiana, 26- 27 March 2012.
- Kisan Mela, PAU, Ludhiana, 21-22 March 2012.
- ICAR-NAIP-CAZRI-Sponsored National Training Course on Nanoparticle Production, Characterization and Utilization in Agriculture, CAZRI, Jodhpur, February 23- 3 March 2012.

Dr Naveen Agarwal

- III Congress on Insect Science, PAU, Ludhiana, 18-20 April 2011.
- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, Bangalore, 25-26 May 2011.
- Research and Extension Specialists Workshop for Rabi Crops, PAU, Ludhiana, 18-19 August 2011.
- Kisan Mela, PAU, Ludhiana, 22-23 September 2011.
- Research and Extension Specialists Workshop on Vegetable, Fruit and Flower Crops, PAU, Ludhiana, 8-9 November, 2011.
- Annual Review Meeting of Network Project on Insect Biosystematics, PAU, Ludhiana, 26- 27 March 2012.
- Kisan Mela, PAU, Ludhiana, 21-22 March 2012.

SKUAST, Srinagar

Dr M. Jamal Ahmad

- XX Biocontrol Workers' Group Meeting, NBAII, Bangalore, 27-28 May 2011.
- Kisan Mela, DEE, SKUAST-K, Shalimar Campus, Srinagar, 3 October 2011.
- I Jammu & Kashmir Agricultural Science Congress, SKUAST-K, Shalimar Campus, Srinagar. 8-10 September 2011.
- Apple Conference, DEE, SKUAST-K, Shalimar campus, Srinagar.

TNAU, Coimbatore

Dr M. Kalyanasundaram

- National Seminar on Current Trends in Biotechnological Strategies for Eco-friendly Crop Protection, University of Madras, Chennai, 16-17 December 2011.

15. WORKSHOPS, SEMINARS, SUMMER INSTITUTES, TRAINING PROGRAMMES, ETC.

Group meeting

- XX Biocontrol Workers' Group Meeting, NBAII, Bangalore, 27-28 May 2011.

Symposium

- National Symposium on Harnessing Biodiversity for Biological Control of Crop Pests, Society for Biocontrol Advancement, NBAII, Bangalore, 25-26 May 2011.

Training programmes

NBAII, Bangalore

- Mass Production of *Helicoverpa armigera* and *Spodoptera litura,* 25-26 April 2011: Mr S. Santosh Kumar, Ph. D. Scholar, GIS, GITAM University, Visakhapatnam.
- Quality Control Aspects of Bio pesticides (*Trichoderma* sp., *Pseudomonas* sp., *Paecilomyces* sp., *Bt*, *Metarhizium* sp., and *Beauveria* sp.), 4-8 July 2011: Ms V.P. Kalai Selvi, Assistant Director, Department of Agriculture, Hyderabad.
- Mass Production of Quality Predatory Coccinellids with Special Reference to *Cryptolaemus montrouzieri,* 25 July 2011: Mr Ramesh Ippikoppa, Mr U. Premchand and Mr Mohammed Azhar Bintory, College of Horticulture, Bagalkot.
- Mass Production of Quality *Trichoderma*, *Pseudomonas*, *Verticillium* & *Beauveria,* 7-9 September 2011: Mr M.N. Sudheer, Ambalathara, Thiruvananthapuram.
- Mass Production of Quality Predatory *Chrysoperla* sp., Entomopathogenic fungi (*Metarhizium*, *Beauveria*, *Verticillium* and *Nomuraea*), *Bacillus thuringiensis* and *Trichoderma viride*: Two Project Assistants from Ramakrishna Mission, Kolkata.
- Hands-on Training in the Area of Biotechnological Tools, 5 December 2011-24 March 2012: Ten students of Agricultural College, Hassan.
- Professional Attachment Training on Management of Insect Pests Through Pheromones, Three months from 27 January 2012: Dr Vallepu, Scientist (Probation), CPRI, Shimla.
- Professional Attachment Training on Mass Production of Natural Enemies Against Pests of Citrus and Taxonomic Identification and Documentation of Insect Pests of Citrus, Three months from 27 December 2011: Ms. Anjitha Alexander, Scientist (Probation), NRCC, Nagpur.

AAU, Jorhat

- Seven training programmes were conducted on IPM with special reference to use of bioagents biopesticides in vegetables (Kharif & Rabi), rice and sugarcane in different villages benefitting 327 farmers (246 men and 81women).

ANGRAU, Hyderabad

- Training imparted to students of B.Sc. (Ag.), M.Sc.(Ag.) and Ph.D. students of College of Agriculture, Rajendranagar, Hyderabad on different methodologies in rearing of different natural enemies and culturing & field use of microbial formulations.

CPCRI, Kayangulam

- Training Programme on Eriophyid Mite and Rhinoceros Beetle of Coconut - Technological Updates of Biocontrol Aspects, 19-21 January 2012: Entomologists of AICRP Palms Centres (Aliyarnagar, Ambajipeta and Ratnagiri).
- Method Demonstration on Rat Control in Coconut Garden, 25 October 2011: Farmers sponsored by ATMA 2011-12, Pallippuram Grama Panchayat, Vypin.
- Agricultural Officers (60) were trained on IPM of coconut sponsored by Kerala Centre for Pest Management, Moncompu, Alappuzha.

- Training on Integrated Pest Management in Scientific Coconut Cultivation, 19 November 2011: Farmers from Thalavady.
- Training on Pest and Disease Management in Coconut Cultivation, 20 December 2011: Farmers from Ernakulam.

CTRI, Rajahmundry

- Conducted three training programmes for tobacco farmers and Tobacco Board field staff on IPM aspects.

IISR, Lucknow

- Training on Biocontrol of Insect Pests of Sugarcane, 8 July 2011: Sugarcane development officers.
- Training on Techniques of Mass Production of Rice Grain Moth, *Corcyra cephalonica,* 27 April 2011: Sugarcane development officers of DSCL Group of Sugar Industries.

KAU, Thrissur

- Training Programmes on Mass Production of Biocontrol Agents, 18, 22 & 28 June 2011 and 7 February 2012: Agricultural officers, Communication Centre, Mannuthy and Biocontrol Laboratory, Androth Island.
- Two Training Programmes on Biological Control of Papaya Mealybug: Farmers at Thrissur and Androth Island.
- Seven Training Programmes on IPM of Major Pests of Vegetables, Coconut and Paddy Including Biological Control: Farmers and Agricultural Officers at Thrissur, Koorkkenchery and Ernakulam.

MPKV, Pune

- Model Training Course on Mass Multiplication of Bio pesticides and Bioagents, 13-20 December 2011: 30 In-service personnel sponsored by the Directorate of Extension, GOI, New Delhi.
- Training on Integrated Pest Management and Role of Bioagents in Crop Pest Management, 21 September 2011: 25 Extension Workers from RAMETI Institute, Department of Agriculture, Maharashtra, Pune.

SKUAST, Srinagar

- Demonstration on the Spot Use of Apple Trunk Banding for Trapping and Killing of Overwintering Codling Moth: Kargil and Leh.
- Demonstration on the Spot Use of Pheromone Traps in Mass Destruction of Codling Moth: Kargil and Leh.
- Demonstration on the Spot Significance of Debarking of Apple Trees for Destruction of Overwintering Codling Moth: Kargil and Leh.
- Information on Disposal of Codling Moth-Infested Fruits to Reduce Pest Problem: Apple orchardists.

TNAU, Coimbatore

- Biological Control of Papaya Mealybug, 1 July 2011: 60 papaya farmers from Kodumudi village at Mr Thangavelu Gounder Thottam.
- Mass Production and Use of Entomopathogens, 4 July 2011: 20 Agricultural Officers from State Department of Agriculture.
- Biological Control in Protected Cultivation, 17 July 2011: 30 Horticultural Officers from all over the State at Ooty.
- Mass Production of Papaya Mealybug Parasitoids- Field Release and EvaluationTechniques, 18 July 2011: 100 farmers at Thayanur.
- Biological Control of Papaya Mealybug, 26 July 2011: 400 farmers at KVK, Namakkal.
- Mass Production of Papaya Mealybug Parasitoids, 6 August 2011: 5 SPAC tapioca officials.
- Biological Control of Mango Pests, 17 October 2011: 75 farmers at Thali village, Krishnagiri district.
- Evaluation and Impact Assessment of Papaya Mealybug Parasitoid Release, 30 September 2011: KVK scientists of TNAU.
- Mass Production of Biocontrol Agents- Field Release and Evaluation Techniques, 22 February 2012: 22 scientists from all over India during CAFT programme.
- Biological Control of Mealybug in Guava, 1 December 2011: 100 farmers at Pollachi.
- Role of Biocontrol in IPM, 22 December 2011: 80 officials of Syngenta Agrochemicals at Pune.

- Biological Control Awareness Meeting to Tribal Farmers and Free Distribution of Biocontrol Agents, 9 March 2012: 100 tribal farmers from Karumanthurai village, Salem district.
- Biological Control of Coconut Insect Pests, 10 March 2012: 125 coconut farmers from Batlagundu, KVK, Gandhigram.
- Biological Control Awareness Meeting to Tribal Farmers and Free Distribution of Biocontrol Agents, 22 March 2012: 100 tribal farmers from Pollachi district.

YSPUHF, Solan

- Demonstration Trials on the Management of Two-Spotted Spider Mite with the Help of Predatory Mite and Biopesticides on Carnation in Polyhouse, 2011-12: Mahog Baag, Chail, Solan; on Capsicum: Kotla, Dharampur.
- Training on Mass Multiplication and Use of Predatory Mite, *Neoseiulus longispinosus* (Evans) for the Management of Two-Spotted Spider Mite, *Tetranychus urticae* Koch on Crops Grown under Polyhouse Conditions, 31 March - 2 April 2011 and 14-16 September 2011.

Radio talks

AAU, Jorhat

- Dr D. Saikia: Insect pest management of Rabi vegetables, 14 December 2011, AIR, Dibrugarh.

MPKV, Pune

- Mr N.D. Tamboli: Control of fruit borers in different fruit crops, 2 April 2011, 'Maze Ghar Maze Shet' programme.
- Mr A.S. Dhane: Integrated pest management in vegetable crops, 24 July 2011, 'Maze Ghar Maze Shet' programme.
- Mr N.D. Tamboli: Integrated pest management on cotton, 27 July 2011, 'Maze Ghar Maze Shet' programme.

PAU, Ludhiana

- Insect pests of sugarcane and their management, 14 May 2011.

Television programmes

AAU, Jorhat

- Dr D.K. Saikia: An interaction programme with farmers' on IPM of vegetables and horticultural crops, 19 March 2012, Doordarshan, Dibrugarh.

MPKV, Pune

- Dr D.S. Pokharkar: Biological control of insect pests in kharif crops, 15 August 2011, Sahyadri Channel, Doordarshan, Mumbai.

PAU, Ludhiana

- Sugarcane insect pests and their management, 16 April 2011.

16. DISTINGUISHED VISITORS

NBAII, Bangalore

- Dr Prakash Arora, Special Secretary (Agriculture) W.P. Gover visited on 23 jne 2011 and showed keen interest in insect barcoding.
- Dr Kumar, Member (ICAR) visited on 23 July 2011 and showed keen interest in classical biological control of papaya mealybug.
- Dr S. Rao, Varanasi, SeaAla, USA, visited different laboratories on 31 January 2012.
- Dr N. D. Raghavan, Former Vice-Chairman, CAT, Bangalore, visited different laboratories on 28 April 2012.
- Dr T.K. Srinivasa Gopal, Director, CIFT, Kochi visited on 1.5.2012

MPKV, Pune

- Dr N.G. Thry Dong, Cameroon, visited the Biocontrol Lab on 26 May 2011 and observed the mass production of bioagents.
- Dr A.S. Patil, CEO, India Bio and Agro Pacific Pvt. Ltd., Baner, Pune, visited the Biocontrol Lab on 26 May 2011 and discussed the mass production programme of bioagents, demonstrations on action research and ongoing research activities.
- Dr T.A. More, Vice-Chancellor, MPKV, Rahuri, along with ICAR Monitoring Team of Dr C. Devakumar, ADG (APD), Mr V.P. Kothiyal, Director of Works, Dr T. Rai, Representative of ADG (PI & M) and Mr Devendra Kumar, Director, Finance, ICAR, New Delhi, visited on 9 September 2011 and reviewed the facilities generated at this station and ongoing research activities.
- Dr R.B. Thakare, Vice-President, Bharat Krishak Samaj, Maharashtra (Former World Bank Advisor) and Senior Advisor, Raisoni Group of Institutes, Nagpur, Dr Suchitra Godbole, Head, Department of Microbiology and Biotechnology, RGI, Nagpur, visited the Biocontrol Lab on 12 September 2011.
- Dr S.G. Borkar, Chairman, Monitoring Team & Head, Dept. of Plant Pathology and Agricultural Microbiology, MPKV, Rahuri, Dr Kamble, Deputy Director of Research, MPKV, Rahuri, Dr P.A. Nawale, Associate Director of Research, NARP (PZ), Pune, Members of the Monitoring Team of University visited the centre on 28 September 2011 and reviewed the progress of research work. They appreciated the contribution of the scientists in the research work done on biological control of papaya mealybug at this centre.
- Mr Arjan Schmitman, Delft., The Netherlands visited the Biocontrol Lab on 2 March 2012 and observed the mass production of bioagents and research activities.

TNAU, Coimbatore

- Dr Alka Gupta, Communication Specialist, IPM-CRSP, USAID, visited the Biocontrol Laboratory on 24 August 2011.
- Honourable Minister for Agriculture and Pro-Chancellor of TNAU visited the Biocontrol Laboratory on 21 December 2011 and discussed with the scientists about papaya mealybug biocontrol.
- Three member team from Ghana headed by Dr Holger Khal visited the Biocontrol Laboratory on 23 January 2012 and interacted with the scientists regarding the papaya mealybug management.
- Dr Kusumakar Sharma, Assistant Director-General (HRD), Education Division, ICAR, New Delhi, visited the Biocontrol Laboratory on 21 February 2012

- Five members from Afghanistan visited the Biocontrol Laboratory on 29 February 2012 and learned mass production and release of biocontrol agents.
- Dr S. Sithanantham, Director, Sun Agro Biotech Research Centre, Chennai, visited the Biocontrol Laboratory on 1 March 2012.

SKUAST, Srinagar

- Mr James Chang, Director, Cultural Division, Tapei Economic and Cultural Centre, New Delhi.
- Dr Yuan- Huei Chang, Director of Science and Technology, Taipei.
- Prof. Alauddin Ahmad, Former Vice-Chancellor, SKUAST-K, Srinagar.

17. PERSONNEL

National Bureau of Agriculturally Important Insects, Bangalore

Dr N.K. Krishna Kumar	Director (w.e.f. 1.7.2011)
Dr R.J. Rabindra	Director (up to 31.6.2011)
Dr B.S. Bhumannavar	Principal Scientist
Dr D. Sundararaju	Principal Scientist (up to 30.4.2011)
Dr N. Bakthavatsalam	Principal Scientist
Dr B. Ramanujam	Principal Scientist
Dr Prashanth Mohanraj	Principal Scientist
Dr K. Veenakumari	Principal Scientist
Dr J. Poorani	Principal Scientist
Dr Chandish R. Ballal	Principal Scientist
Dr M. Nagesh	Principal Scientist
Dr A.N. Shylesha	Principal Scientist
Dr S.K. Jalali	Principal Scientist
Dr T.M. Shivalingaswamy	Senior Scientist
Dr T. Venkatesan	Senior Scientist
Dr P. Sreerama Kumar	Senior Scientist
Dr K. Srinivasa Murthy	Senior Scientist
Dr S. Sriram	Senior Scientist
Dr Sunil Joshi	Senior Scientist
Dr R. Rangeshwaran	Senior Scientist
Dr G. Sivakumar	Senior Scientist
Dr M. Pratheepa	Scientist (SS)
Dr Deepa Bhagat	Scientist (SS)
Ms R. Gandhi Gracy	Scientist
Dr Ankita Gupta	Scientist
Dr Rajkumar	Scientist
Mr K.J. David	Scientist
Ms S. Salini	Scientist

Central Tobacco Research Institute, Rajahmundry

Mr S. Gunneswara Rao	Scientist (SG)

Central Plantation Crops Research Institute, Regional Station, Kayangulam

Dr Chandrika Mohan	Senior Scientist

Indian Agricultural Research Institute, New Delhi

Dr G.T. Gujar	Principal Scientist

Indian Institute of Sugarcane Research, Lucknow

Dr Arun Baitha	Senior Scientist

Indian Institute of Horticultural Research, Bangalore

Dr M. Mani (up to 30.6.2011)	Principal Scientist
Dr A. Krishnamoorthy	Principal Scientist
Dr P.N. Ganga Visalakshy	Senior Scientist

Sugarcane Breeding Institute, Coimbatore

Dr N. Geetha	Senior Scientist

Anand Agricultural University, Anand

Dr D.M. Korat	Principal Research Scientist
Dr Babubhai H. Patel	Associate Research Scientist
Dr J.J. Jani	Assistant Research Scientist

Acharya N. G. Ranga Agricultural University, Hyderabad

Dr S.J. Rahman	Principal Scientist
Ms G. Anitha	Scientist

Assam Agricultural University, Jorhat

Dr A. Basit	Principal Scientist
Dr D.K. Saikia	Principal Scientist

Dr Y.S. Parmar University of Horticulture & Forestry, Solan

Dr Usha Chauhan	Senior Entomologist
Dr P.L. Sharma	Entomologist

Govind Ballabh Pant University of Agriculture & Technology, Pantnagar

Dr J. Kumar	Professor

Kerala Agricultural University, Thrissur

Dr K.R. Lyla	Professor

Mahatma Phule Krishi Vidyapeeth, Pune

Dr D.S. Pokharkar	Entomologist
Dr R.V. Nakat	Assistant Entomologist

Punjab Agricultural University, Ludhiana

Dr Jaspal Singh Virk	Senior Entomologist
Dr Neelam Joshi	Microbiologist
Dr Rabinder Kaur	Assistant Entomologist
Mr Sudhendu Sharma	Assistant Entomologist

Sher-e-Kashmir University of Agriculture & Technology, Srinagar

Dr M. Jamal Ahmad	Associate Professor
Dr Sajad Mohi-ud-din	Assistant Professor

Tamil Nadu Agricultural University, Coimbatore

Dr P. Karuppuchamy	Professor
Dr M. Kalyanasundaram	Professor

Jawaharlal Nehru Agricultural University, Jabalpur

Dr S.B. Das	Senior Scientist (Entomology)

Maharana Pratap University of Agriculture & Technology, Udaipur

Dr B.S. Rana	Associate Professor

Central Agricultural University, Pasighat

Dr K. Mamocha Singh	Associate Professor

Orissa University of Agriculture & Technology, Bhubaneshwar

Dr B.K. Mishra	Entomologist

18. INFRASTRUCTURE DEVELOPMENT AT NBAII

Infrastructure at NBAII

Facilities have been created for housing a VIP Dining hall, a separate space for library and separate space for administration along with adequate furniture.

Equipment

The laboratories were further strengthened with the acquisition of several equipments like column chromatography unit, PCR, preparatory gel electrophoresis unit.

Library

The library has a collection of 2,024 books, 1,537 bound volumes of journals, 64 bulletins and several miscellaneous publications including several reprints on various aspects of biological control. Eleven foreign and eight Indian journals were subscribed for. Online version of the Plant Protection Database has been updated up to June 2012.

National Insect Reference Collection

The PDBC has 25,000+ authentically identified specimens belonging to 235 families under 18 orders. The collection includes representatives of the orders Hymenoptera, Coleoptera, Hemiptera, Orthoptera, Strepsiptera, Thysanoptera, Neuroptera, Diptera, Lepidoptera, etc., encompassing crop pests, parasitoids and predators. A sizeable reference collection of Thysanoptera with 1,500 slides has been added. NBAII's reference collection of insects has been electronically catalogued in a retrievable form.

Farm development

A new laboratory complex with six laboratories with a conference hall is under construction. Several plants have been planted for the conservation of beneficial arthropod fauna at the farm.

19. EMPOWERMENT OF WOMEN

During 2011-12, the participation of women in different training programmes was as follows:

Quality control aspects of biopesticides (*Trichoderma* sp., *Pseudomonas* sp., *Paecilomyces* sp., *Bt*, *Metarhizium* sp. and *Beauveria* sp.) (4-8 July 2011)

Ms. V. P. Kalai Selvi, Assistant Director, Department of Agriculture, Hyderabad, Andhra Pradesh.

Hands-on training on biotechnology (December 2011-March 2012)

Ms Ranjitha, B.Sc. (Biotech.), College of Agriculture, Hassan.

Ms Sandhya, B.Sc. (Biotech.), College of Agriculture, Hassan.

Proceedings of National Meeting on Agricultural Entomology for 21 Century: The Way Forward: NBAII, Bangalore, 25-26 August 2011

Background

The plant protection scenario in the country is undergoing a sea change in the 21 century. The advent of transgenic crops, increased awareness of the environmental hazards of agro-chemicals in general and pesticides in particular, the ever increasing damage by insect transmitted plant viruses, threat perspective from invasive alien insects and invertebrates are matters of great concern. A number of fields such as mapping the bio-diversity of insects, climate change and its influence on pollinators / beneficial arthropods/ pests, parasitoids of animals have to be focused more. The emergence of new fields of science such as nano-technology, gene silencing, bioinformatics, etc. have to be discussed by subject matter specialists taking the views of entomologists of eminence, if collective wisdom has to be garnered for the betterment of plant protection. Confounding this there is a need for trained quality human resources in fields such as insect systematics, physiology, ecology that will increase in the years to come as a consequence of experienced scientists retiring from active service. As we move from public to a PPP mode in addressing IPM, there is an increased need from the industry for quality HR.

Proceedings

More than 300 agricultural entomologists, selected nematologists and pathologists representing all parts of India from ICAR, SAU, and other private and public sector participated in the two day brain-storming session to prioritize researchable issues in the area of agricultural Entomology and plant protection for the 12th Five Year Plan Period at NBAII, Bangalore on 25 and 26 August, 2011 (appendix I). The venue was the Auditorium of Veterinary Council, Hebbal, and Bangalore.

Dr N. K. Krishna Kumar, Director, NBAII, Bangalore welcomed the fraternity of Entomologists and other plant protection experts gathered. Introducing the theme of the meeting he said The National Meeting is a brainstorming exercise to identify the crucial areas for frontier research in Entomology during forthcoming XII Plan. There is a need to take stock of the existing scenario, identify the missing links and plan for the future to meet the challenges in Agricultural Entomology and related disciplines.

The inaugural session of the brain storming session was held under the chairmanship of Dr S. Ayyappan, Director-General, ICAR and Secretary, DARE. Deputy Director General (CS), Dr G.K. Veeresh, Former Vice Chancellor, UAS, Bangalore; Dr B. Senapati, Former Vice Chancellor; Dr S. K. Datta, Dr S.N. Puri, Vice-Chancellor Central Agricultural University, Manipur; Dr Narayanagowda, Vice Chancellor, UAS, Bangalore OUAT; Dr G.C. Tewari, Vice Chancellor, CSA University for Agriculture and Technology, Kanpur; Dr B. V. Patil, Vice Chancellor, UAS, Raichur; and other eminent entomologists, Dr T.P. Trivedi, Project Director (DKMA); Dr T.P. Rajendran, Asst. Director General (PP); Dr O. M. Bambawale, Director, National Centre for Integrated Pest Management, New Delhi; Dr R. Ramani, Director, Indian Institute of Natural Resins and Gums, Ranchi; Dr Amrik Singh Sidhu, Director, Indian Institute of Horticultural Research, Bengaluru; Dr K. R. Kranthi, Director, Central Institute for Cotton Research, Nagpur; Dr R.J.R. Rabindra, Former Director, NBAII, graced the occasion. The dignitaries released 5 noteworthy publications on

a) DNA Barcode for Agriculturally Important Insects
b) DNA Barcode for important Sap Sucking Insect Pests of Horticultural Crops
c) Molecular Identification of Insects
d) Molecular identification and diversity of cardamom thrips, Sciothrips cardamomi (Thripidae: Thysanoptera)

the next two days deliberations and discussions in this National meeting on Agricultural Entomology for 21st Century should give way forward for finalizing the broad researchable issues in the XII plan.

There were six sessions (excluding the inaugural open session and plenary) covering a whole range of thematic areas. They are:

i) Insect Biodiversity & Systematics Including Molecular Systematics/Bar coding
ii) Pollination Ecology & Crop Production
iii) Management of Alien Invasive Pests & Quarantine
iv) Pest Management and Food Safety
v) Molecular Entomology
vi) Veterinary Entomology and Parasitology

Recommendations of the National Meeting on Agricultural Entomology for the 21st Century held at NBAII, Bangalore on 25-26 August, 2011

It was agreed that the existing entomological research in ICAR institutes need a make-over. The following new programmes need to be incorporated, to optimally utilize, the entomologists of all crop institutes and certain identified KVK.

1) Network Research programmes:

a. Network project on identification and management of stored pests of commodities may be developed on priority.
b. Existing network project on management of sucking pests in horticultural crops should be expanded to sucking pest of all agriculture crops by expanding the scope of the project.
c. A network project on documentation, identification and management of invasive species from outside and within the country may be considered.
d. Effect of climate change on pollinators and beneficial arthropods (insects, spiders, nematodes etc.) was suggested to be addressed through a network project.
e. Network project on management of insecticide resistance in major crop pests (insects, mites and natural enemies).
f. Network project on management of RNAi technology-based host plant resistance, on PPP mode
g. Gene discovery for xenobiotic-supported resistance against pest through transgenic crops was envisaged.
h. The network project on veterinary entomology including pests, parasites and vectors broadly encompassing insects, mites, ticks, helminthes etc.
i. A network project on mapping the biodiversity of arthropods and nematodes of uncovered agro-ecological zones including Andaman & Nicobar Islands, Sub-Himalayan regions, north-east India and temperate regions under AICRP on Plant parasitic Nematodes.
j. On a PPP mode, research network on gene discovery and endosymbionts.
k. A national ICAR consortium on molecular systematic / bar-coding and constant updating of molecular technologies is required.
l. Network on synthesis and evaluation of semio-chemicals and pheromones (aggregation and sex) for field bio-efficacy to design suitable IPM.

2) Infrastructure:

a. Arthropod repository facility - for long term maintenance of types/voucher specimens and the collection of agriculturally important Arthropods/Nematodes.
b. Insect Museum - for display of agriculturally important arthropods and their roles in agro-ecosystems.
c. Centralized Infrastructure for Insect/arthropod molecular systematics.
d. Additional quarantine and phyto-sanitary facilities in every state through SAU to prevent inter-state movement of pests.
e. Additional land with irrigation required for NBAII to effectively implement research programmes.

3) Capacity Building:

a. Entomologists with knowledge in systematics based at all ICAR Institutes to become a part of NBAII + additional scientists for n bio-systematic research on spiders and acarines in addition to insects.
b. Systematics of nematodes (including nematodes of veterinary importance) to be encouraged at NBAII with creation of additional staff.

c. To enhance expertise of existing taxonomists they may be sent to centres of excellence (National/International) in their respective groups.

d. ICAR / GoI have international collaboration network with various countries and country blocks through bilateral and other types of agreements. Specific proposals for capacity building in bioinformatics, animal genomics, nano-technology in pesticide formulation.

e. Winter/summer schools to be routinely organized for enhancing capacity in various aspects of molecular entomological topics at ICAR Institutes/SAU, as per availability of expertise.

f. Modernization of facilities for screening crop accessions to different pests.

g. Separate efforts for HRD in traditional/molecular systematic for pests/nematodes/vectors of veterinary importance including the documentation of their biodiversity.

h. Networking of existing national collections at IARI, New Delhi, FRI, Dehradun and ZSI, Kolkatta and Networking of all taxonomists in ICAR, SAU and armature collectors

4) General:

a. Strengthening research infrastructure and skill for research in frontier science under Bioinformatics and nanotechnologies may be taken up in all Bureaus.