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2015-16

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(Indian Council of Agricultural Research)
Bengaluru – 560 024, India

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CONTENTS

	Prologue	v
1.	Executive Summary	1
2.	Executive Summary (Hindi)	12
3.	Introduction	22
4.	Research Achievements	27
5.	GenBank-BOLD Accessions	109
6.	Identification Services	113
7.	Extension Activities	114
8.	Awards and Recognitions	115
9.	AICRP/Coordination Unit/National Centres	118
10.	Publications	120
11.	Ongoing Research Projects	130
12.	Activities of ITMU	134
13.	Conference Papers	136
14.	Meetings and Decisions	139
15.	Participation of Scientists in Meetings	141
16.	Trainings Conducted	143
17.	Distinguished Visitors	146
18.	Mera Gaon Mera Gaurav	147
19.	Personnel	148
20.	Exhibitions	150
21.	Results Framework Document (RFD)	151

PROLOGUE

It is impossible to think about plants or animals as discrete entities without a name for each one of them. As the Chinese say, 'the beginning of wisdom is calling things by their right names'. But, what happens when you have to put a name to over 10 or 50 million species (the estimates currently accepted by both field and theoretical biologists) of which only a little over a million species of insects (which is 58 per cent of all species described so far) have currently been named. Add to this, that it has taken us over two-and-a-half centuries to name this one million species since the enterprise began with Linnaeus in 1758. It then goes without saying that the task before us of describing (or attaching a name to) the vast majority of insects that remain unknown and anonymous to us is a prodigious task. While the situation is grave all over the world, it is graver still in the tropics (where India is situated) which is home to a greater proportion of organisms (including insects) than any other region of the world.

The tropics harbour a burgeoning human population that is pushing many other forms of life to extinction, so much so that we are changing landscapes unalterably, pushing extinction rates to never before known levels, far above the long term average rate of extinction. This unprecedented impact of our species on the global environment has resulted in scientists labelling our age the Anthropocene or the Age of Man. They foresee a rapid decline in biodiversity triggered by human activity and a sixth mass extinction episode in the not so distant future, if we do not mend our callous ways. Under these circumstances taxonomists have to work swiftly if they have to catalogue fast disappearing species before they are lost forever.

In response to this sense of urgency the Indian Council of Agricultural Research (ICAR) turned the spotlight from an exclusive focus on insects as agents for the biological control of crop pests to that of insect taxonomy to enable us to discover our hidden hexapod wealth with their multifarious environmental roles. The National Bureau of Agricultural Insect Resources (NBAIR) was thus born from the embers of the Project Directorate of Biological Control (PDBC) – the institution that preceded it. Taxonomy was now to become the driving force to provide the much needed foundation for the study of insects rendering invaluable and irreplaceable services in terrestrial and freshwater ecosystems.

Agroecosystems henceforth were no more to be viewed in isolation but as interlinked with all other ecosystems with insects as the glue (in Daniel Janzen's perceptive terminology) binding them together. And insects of importance in agroecosystems were no more to be seen solely as crop pests or their natural enemies. A host of other insects rendering a range of services like pollination, nutrient cycling, maintenance of soil structure and providing nutrition to other organisms (farmed insects could be used as protein supplements in animal feed and even as rich sources of protein for humans, if we were to overcome our cultural biases to eating them) which had so far been neglected were now to become the foci of targeted studies.

It was also realised that taxonomy was no more the exclusive preserve of taxonomists. Today it is increasingly being viewed as a service discipline in addition to being the traditional research discipline of taxonomists. Applied biologists and environmental scientists require the identities of species, which forms the basis of their research endeavours. They look forward to operating taxonomic keys or using identification guides that will enable the identification of species without professional taxonomic training. Their ideal would perhaps be something like the hand held device envisaged by Janzen (the visionary American biologist, once again) that could directly read off the genome of an organism, compare it with a computerised database of all organisms on earth and display the identity of any species. With the vast majority of insects remaining to be described, named and catalogued this currently remains largely in the realm of science fiction.

With a strong contingent of taxonomists (collecting, describing and cataloguing our vast insect diversity), molecular entomologists (focussing on molecular taxonomy) and insect ecologists (working on agroecosystem services rendered by insects in addition to their function as regulators of crop pest populations) studies are underway at NBAIR to harness the power of insects to increase agricultural productivity and boost the incomes of our farming community.

Director

1. EXECUTIVE SUMMARY

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

Insect Systematics

Four new species of the genus *Diolcogaster* Ashmead, 1900 were described. *Diolcogaster andamanensis* from the Andaman Islands, and *D. duocolor*, *D. longistria* and *D. solitarium* from mainland India. The solitary larval parasitoid *D. solitarium* was reared from *Gates clarkeana* sp. (Lepidoptera: Tortricidae). Two new species of parasites, *Tetrastichus thetisae*, a gregarious parasitoid reared on *Curetis thetis* (Drury) pupa and *Sympiesis thyrsisae* (Hymenoptera: Eulophidae), reared on *Gangara thyrsis* larvae feeding on coconut were described.

Morphology, host records, and molecular phylogenetic analyses were integrated to generate boundaries between species/species-groups of the genus *Glyptapanteles*. The present study, suggests the presence of 26 additional *Glyptapanteles* species within 8 species-groups, which were previously unrecognized.

The genera *Prestwichia* and *Mirufens* were discovered from Great Nicobar. The latter was collected from leaf galls of *Dipterocarpus* sp. *Trichogrammatoidea nana* and *Trichogramma achaeae* were the first trichogrammatids to be collected from the Nicobars. A new species of *Trichogrammatoidea* resembling the unusual Chinese *T.tenuigonadium* was discovered from Mudigere in Karnataka, India.

A new species group has been proposed with five new species – *Idris adikeshavus* sp. n., *I. brevicornis* sp. n., *I. deergakombus* sp. n., *I. teestai* sp. n., and *I. lopamudra* sp. n. Ten new species of Platygastridae from India *viz. Amblyaspis khasiana* sp. n., *A. kurinji* sp. n., *Gastrotrypes longicaudatus* sp. n., *G. manii* sp. n., *Isolia kalingi* sp. n., *Synopeas* (*Sactogaster*) *ribhoiense* sp. n., *Trimorus leptoclava* sp. n., *Ptilostenius griffithi* sp. n., and *P. nicevillei* sp. n. and *Gryon ingens* sp. n. were described.

Aphid species viz., *Aphis* (*Bursaphis*) *solitaria* McVicar Baker and *Brachycaudus* (*Brachycaudina*) *napelli* (Schrank); mealybugviz., *Formicococcus formicarii* (Green) and scale, *Anomalococus crematogastri* (Green) and *P. urbicola* Cockerell were recorded for the first time form India. Similarly, *Trionymus townesi* Beardsley and *Dysmicoccus carens* Williams were recorded for the first time from Karnataka. 11 species of aphids, a species of mealybug and two species of soft scales

were added as new to the existing collection of aphids and coccids at ICAR - NBAIR.

Four terebrantian thrips species viz., *Trichromothrips arorai*, *Trichromothrips priesneri*, *Hydatothrips aureus* Bhatti and *Franklinothrips megalops* were added to the ICAR - NBAIR reference collection.

Carinostigmus griphus Krombein was recorded as new for India. *Carinostigmus congruus* (Walker) is new to Karnataka, Odisha and Goa. *Carinostigmus costatus* Krombein is new to Goa, Karnataka, Mizoram. DNA-Barcoding has been completed for species belonging to *Carinostigmus, Stigmus, Tzustigmus* and *Sphex*.

Over 40 species of Pentatomidae were added to the ICAR-NBAIR collection. *Amyotea malabarica* (Fabricius, 1775) (Hemiptera: Pentatomidae: Asopinae) and *Dardjilingia nigriventris* Yang, 1936 (Hemiptera: Heteroptera: Pentatomidae) from India were redescribed. *D. nigriventris* is recorded for the first time from Arunachal Pradesh and Manipur. The genus *Surenus* was redescribed along with the description of a new species from India.

A total of 153 specimens of Coleoptera : Lamiinae were collected from across the country. *Salpinia socia* Gahan, 1906 and *Sophronica apicalis* (Pic, 1922) have been rediscovered and reported from new localities. *Pothyne laosica* Breuning 1868 (Agapanthiini: Lamiinae) has been reported from India (Maharashtra) for the first time. The checklist, distribution records and host plants for the subfamily Lamiinae was prepared. Identification key for 20 agriculturally important cerambycid beetles and the genus and species-wise distributions of the Indian cerambycids were prepared. White stem borer, *Xylotrechus quadripes* Chevrolat 1863 a serious pest of arabica coffee has been synonymised with *Xylotrechus javanicus* (Castelnau & Gory, 1841).

Based on morphometrics, light microscopy and molecular characterization the entomopathogenic strain NBAIIO62 was identified as *Oscheius chromogensis*. It reproduced in phorid pupae.

Two strains of *Heterorhabditis indica* (NBAIIH64 and 68), five strains of *Steinernema siamkayai* (NBAIIS46, 47, 49, 51, and 54) and one strain of *S. huense* (NBAIIS55) and one strain of *S. abbasi* (NBAIIS60) were reported. *Heterorhabitis indica* was ecologically characterized. The LC_{50} and LC_{90} values indicated that *S. carpocapsae* was virulent against both third and pre-pupal stages of eggplant ash weevil, *Myllocerus subfaciatus*. Both *S. carpocapsae* and *Heterorhabitis indica* were able to reproduce in third and pre-pupal stages of ash weevil, but progeny production rate for *H. indica* was significantly higher than those of *S. carpocapsae*.

Molecular Entomology

Molecular characterization of Coleoptera (7 families), Diptera (5 families), Hemiptera (16 families), Lepidoptera (21 families), Odonata (8 families) and Ixodida (1) were done.

The identity of the insect from insect fragments found in a pharmaceutical package was established by employing mitochondrial cytochrome oxidase subunit1 (CO1) gene. The insect was found to be *Pollenia rudis* (Fabricius 1794) (Diptera: Calliphoridae).

DNA extraction, PCR amplification of partial CO1 gene from single thrips by non-destructive method was standardized.

DNA barcodes were generated for 103 agriculturally important parasitoids, predators and other insects based on COI gene & ITS-2. Parasitoids belonging to Braconidae *viz*., *Glyptapanteles* sp. (Barcode: ACZ3549) (Genbank Acc. No. KR260984), *Glyptapanteles* sp *(AAI5405) (*KT284335), *Glyptapanteles* sp (ACZ3433) (KT25318), *Microplitis maculipennis* (ACV9232) (KP759295), *Glyptapanteles creatonoti* (AAH1199) (KR021154), *Glyptapanteles* sp (ACZ3493) (KT254316), *Glyptapanteles obliquae* (Wilkinson) (ACS3730) (KR021152), *Glyptapanteles aristolochiae* (Wilkinson) (ACZ3726) (KR021156), *Glyptapanteles cf. spodopterae* Ahmad *(*ACS3730) (KR260983), *Glyptapanteles spodopterae* (ACS3730) (KR260976), *Glyptapanteles* sp (AAH1199) (KT284334), *Glyptapanteles* sp (ACZ3303) (KT254319), *Glyptapanteles obliquae* (Wilkinson) (AAH1199) (KR021152),*Glyptapanteles cf. amprosemae* Ahmad (ACZ3016) (KT284342) were characterized and barcodes generated. Phylogenetic analysis was performed on 38 species based on (COI) nucleotide sequences. Maximum likelihood and Bayesian inference methods displayed three and four major discrete *Glyptapanteles* clades, respectively.

Bayesian phylogenetic trees for 76 trichogrammatid sequences were considered to understand evolutionary relationships among the species. ITS-2 was identified as an appropriate molecular marker for identification of trichogrammatids, at species and generic levels.

Over 129 termite samples and 76 scarabaeid beetles collected were characterised based on the COI gene. Scarabaeid beetles were reared to facilitate taxonomic studies of grubs.

Microflora in gut of *Aphis gossypii*, and *A. craccivora* were identified as *Bacillus altitudinis, B. cereus, B. licheniformis, B. pumilus, B. subtilis, Corynebacterium variabile, Enterobacter cloacae, E. hormaechei, Lysinibacillus fusiformis, L. macrolides, Micrococcus luteus, Providencia stuartii* and *Stenotrophomonas maltophilia*.

Insecticide degradation assay showed *Moraxella osloensis*, *Stenotrophomonas maltophilia, Exiguobacterium indicum* and *Bacillus subtilis* as effective in degrading insecticides. Aphids collected from Dharwad were 9.7 times more resistant to imidacloprid than the Bangalore population. Green peach aphid *Myzus persicae* from Bengaluru was 13.38 times more resistant to λ-cyhalothrin 5%EC than Guntur population whilst in case of imidacloprid Guntur population was 1.107 times more resistant to imidacloprid than Bangalore population.

Insecticide resistance gene database (IRGD) for key pests has been developed in MySQL as back end and PHP as front-end. It contains 851 sequences for the pests *Aphis gossypii, Acyrthosiphon pisum, Bemisia tabaci*, *Helicoverpa armigera, Plutella xylostella, Spodoptera exigua, Spodoptera litura, Nilaparvata lugens, Myzus persicae, Tribolium*

castaneum and *Lucinodes orbonalis* with key features like Search, View, ORF Finder, etc.

Twenty five *Bacillus thuringiensis* isolates collected from Western Ghats expressed bipyramidal crystals. Four isolates from Andaman Nicobar Islands expressed bipyramidal and spherical crystals.

The trypsin activated vip3A protein (4hrs IPTG induction) caused 100% mortality of *Plutella xylostella* at 500µg concentration after 48hours. The LC_{50} value was calculated as 53.676 µg/ ml. Cry8A expressing *B. thuringiensis* (NBAIR-BTAN4) caused 100 % mortality of potato grub (*Popillia Jsp*). Bt isolate NBAIR -4 and NBAIR-1 were tested against early second instar larvae of *Tuta absoluta* by tomato leaf dip method. The former was more toxic (LC_{50} 301.3 ppm) compared to the latter (LC_{50} 373.7 ppm). Liquid formulations of NBAIR-BTG4 and standard HD-1 at 1 and 2 % did not cause mortality of *Cryptolemus montrouzieri* and *Chrysoperla carnea* .

Eighteen culturable microflora were identified from gut of dung beetle (*Onitis philemon*), eleven culturable microflora were isolated from gut of dung beetle (*Oniticellus cinctus*) and fourteen gut microflora were identified from *Holotrichia serrata.* Twenty unculturables were identified from the gut of *Onitis philemon*. Bacteria from *Onitis philemon* showed that 16 were cellulase positive and 11 were pectinase positive. Culturables from *Oniticellus cinctus* showed that 7 had cellulose as well as pectin degrading ability.

Insect Ecology

The insect repository at ICAR – NBAIR maintains over 110 live insect cultures. These cultures are supplied to farmers, students, research organisations, KVKs and commercial mass multiplication units. A total of 1314 consignments were supplied during 2015- 2016 generating a revenue of Rs 4,98,279.

Two new records of anthocorids for India viz., *Montandoniola bellatula* Yamada 2007 and *Xylocoris cerealis* Yamada and Yasunaga 2006 (from Karnataka) are reported. Of the two new species of *Orius* recorded from Karanataka, one was collected from coconut and the other from *Clerodendrum infortunatum*. Anthocorid predators *Cardiastethus exiguus, Bilia castanea, Orius maxidentex* and *Buchananiella pseudococci pseudococci* were recorded on thrips infested mulberry in Salem, Tamil Nadu .

The populations of *Aphis gossypii, Polyphagotarsonemus latus* and mealybugs were low in plants with nymphal and adult stages of the anthocorid at levels of 0.3 to 0.8 adults and 0.3 to 1.2 nymphs per bud.

Adults of *B. pallescens* released on capsicum plant raised in net house and infested by broad mites caused 80 % reduction in leaf curling. Differences in egg characters of *Blaptostethoides pacificus* and *B. pallescens* could be used for species level identification of these bugs.

Cage studies were conducted to evaluate the predatory efficiency of *A. constrictus* and *B. pallescens* on *T. absoluta* eggs. When released

in the ratio of 1 anthocorid : 10 *T. absoluta* eggs feeding by anthocorids ranged from 90 to 100% . Presence of *B. pallescens* eggs in the release site indicates their potential to establish in fields in which they are released. Cage studies were conducted to evaluate *Trichogramma* species against eggs of *Tuta absoluta* infesting tomato plant. Three species of *Trichogramma* could successfully parasitise *T. absoluta* eggs. Parasitism by *Trichogramma achaeae* was 28.8% followed by *T. pretiosum* (thelytokous) (22.7%) and *Trichogrammatoidea bactrae* (12.5%).

Bionomics of *Nesidiocoris tenuis* reared on *Tuta absoluta* had a preoviposition period of 4 days with a nymphal period of 25 days. Adult males were short lived (21 days) as compared to females (27 days). *Tuta* eggs and the per cent mined area were low in tomato plants harbouring *N. tenuis*. Number of necrotic rings per plant caused by *N. tenuis* was less (1.59) in *Tuta* infested plants compared to uninfested plants (3.45).

Incidence of papaya mealybug was below pest status in all the areas surveyed. In Andaman Islands it caused 25-30% damage on papaya and vegetable crops. Parasitisation of *Acerophagus papayae* by hyperparasitoids is on the rise in Karnataka. Incidence of *Pseudococcus jackbeardsleyi* was low compared to previous years. Natural enemies like *Cryptolaemus montrouzieri* Mulsant, *Spalgis epius* (Westwood) and gnats kept the pest under check.

The severity of banana skipper *Erionota thrax* (Hesperiidae: Lepidoptera) has come down. Root mealybugs on pepper *Formicococcus polysperes* Williams was severe in Coorg and Chickmagalur area. An outbreak of the skipper, *Hasora chromus* (Cramer) was recorded in Bangalore while a major outbreak of *Chromatomyia syngenesiae* Hardy 1849 (Agromyzidae: Diptera) was noticed on Chrysanthemum in Conoor and Ooty.

Aprostocetus sp. is a potential parasitoid of the erythrina gall wasp (*Quadrastichus erythrinae*) in India. Its identity was confirmed by molecular characterization. White gaster typical of *A. felix* males is absent in the Indian specimens studied.

Thirty six species of pollinators belonging to Apidae (17), Megachilidae (11) and Halictidae (8) were identified and added to ICAR – NBAIR insect repository. *Argyreia cuneata, Ocimum basilicum, Crotolaria retusa* and *Vitex negundo* attracted an array of pollinators and these plants can be employed for *in situ* conservation of pollinators in farm and urban habitats. DNA barcoding was done for 15 bee species.

A tick collected on the king cobra was identified as *Aponnomma laevi.* Cattle ticks, fleas from cat, sheep, dog, biting/ blood sucking midges and mosquito (*Aedes aegyptii*) were added to the repository.

The essential oil of sweet basil, eucalyptus and clove were characterized for chemical composition and cidal activity against housefly, *Musca domestica* L. (Diptera: Muscidae). Clove oil was more toxic than betel, basil and eucalyptus oil. On toxicity of essential oil to phorid fly, *Megaselia scalaris,* the LC_{50} of thymol was 5.45 µg as compared to ajowan oil 7.599 µg.

Green muscardine fungus, *Metarhizium anisopliae* and *Beauveria bassiana* caused mycosis on adult stages of house fly. The LC_{50} of *B. bassiana* on adult flies was $2.11x10^6$ spores / ml whilst in case of *M. anisopliae* it was 6.14×10^6 spores / ml.

A gel based matrix was developed for delivery of attractants of the house fly, *M. domestica*. It was effective in attracting and killing the flies compared to commercial attract- and-kill lures. Among the combinations evaluated, the gel based matrix containing food attractants of house fly with tricosene (pheromone) and imidacloprid was effective in attracting and killing over 400 flies in 4 sq. ft.

A nanomatrix was developed for delivery of pheromone 3E, 8Z, 11Z -3,8,11-tetradecatrien-1-yl acetate of American pinworm, *Tuta absoluta.* Preliminary field trials conducted at Hosur in Tamilnadu revealed that Nanomatrix lure (NML) used in tandem with sticky trap captured higher number of moths per trap (956.66 $\pm$32) than commercial lure. Sticky trap alone captured 60.66 $\pm$4.9 moths per trap. The advantage of the nanomatrix lure are that it requires a lower load of pheromone and the substrate can be reused after refilling with pheromone.

Phytoseiidae (Mesostigmata: Phyto seioidea) dominated the collection of predatory mites. The most commonly encountered phytoseiids were: *Amblyseius cucurbitae, A. herbicolus, A. paraaerialis, Euseius alstoniae, E. chitradurgae, E. coccineae, E. delhiensis, E. finlandicus, E. ovalis, E. prasadi, E. rhododendronis, Neoseiulus fallacis, N. indicus, N. longispinosus, Paraphytoseius multidentatus, Phytoseius minutus, P. swirskii, P. wainsteini, Transeius tetranychivorus, Typhlodromus homalii, T. rickeri* and *T. syzygii*.

The aphid, *Brevicoryne brassicae* on cabbage and cauliflower showed positive correlations with minimum temperature, sunshine hours of the current week as compared to the previous two weeks. Based on this, regression equations were worked out.

Among the compounds in volatile extracts of chick pea from vegetative, flowering and pod initiation stage hexanol was responsible for eliciting ovisposition response of *Helicoverpa armigera*.

An alcohol free formulation of cuelure trapped higher number of flies over the cuelure loaded in plywood pieces. A modified sticky trap with methyl eugenol was developed with good catches of *Bactrocera dorsalis.*Pheromone combined with one of the unsaturated hydrocarbon trapped an average of 1.5 males per trap in comparison to 0.75 males per trap in pheromone alone.

Endophytic ability of six strains of *Beauveria bassiana* (NBAIR-Bb-5a, 7, 14, 19, 23 and 45) was studied when applied as foliar sprays (1×10^8 conidia /ml) of oil formulation in maize and sorghum. All six strains showed varying per cent colonization ability and persistence in stem and leaf tissues in maize and sorghum. In maize, Bb-45 recorded the maximum mean colonization in older stem (46.67 %), older leaf (47.78%) and in young stem (52.22 %). In sorghum Bb-5a isolate recorded the maximum mean colonization in older stem (21.30 %) and young leaf tissues (22.22 %). Bb-5a isolate recorded the maximum

mean colonization in older stem (21.30 %) and young leaf tissues (22.22 %).

Colonization of *B. bassiana* in stem and leaf (from both old and young tissue samples) from maize and sorghum were confirmed by plating technique amd PCR amplification using *B. bassiana* specific primer.

Carboxylesterase the important enzyme involved in insecticide degradation was quantified from the various endosymbionts of *Amrasca biguttula biguttula. Bacillus pumilus* produced maximum carboxylesterase (0.309µmoles/ml) followed by *Enterobacter cloacae* (0.204µmoles/ml), *Filobasidium floriformie* (0.169µmoles/ ml) and *Bacillus licheniformis* (0.132µmoles/ml).

Six strains of nucleopolyhedrovirus (NPV) were collected across the country. NPV was isolated from the infected larvae of *Spodoptera litura* on cabbage and *Helicoverpa armigera* on bhendi.

The obligate fungal endosymbiont *Fusarium ambrosium* was isolated from the head of the tea shot hole borer, *Euwallacea fornicatus* as well as from the tea stem galleries in samples collected from the Nilgiris. The mycelium of the fungus was pale in color and cottony. The color of the thallus changes from whitish to pink. Fungus produced only club shaped multiseptate conidia. The amplification of ITS region revealed the identity of the fungus as *Fusarium ambrosium*.

ALL INDIA COORDINATED RESEARCH PROJECT ON BIOLOGICAL CONTROL

Biodiversity of biocontrol agents from various agro ecological zones

Coccinellids, (*Coccinella septempunctata*, *Menochilus sexmaculata, Scymnus* sp.) *Encarsia flavoscuttellum, Dipha aphidivora*, *Micromus igorotus*, syrphids on sugarcane woolly aphid, *Coccinella transversalis*, *M. sexmaculata, Brumoides suturalis*, *Scymnus coccivora* and *Triommata coccidivora* on custard apple mealybug colonies and *Acerophagus papayae, Pseudleptomastix mexicana, Mallada boninensis*, *Spalgis epius,Scymnus nubilus*, *Phrynocaria perrotteti* on papaya mealybug were the natural enemies recorded from Maharashtra. The chrysopid, *Chrysoperla zastrowi sillemi* was recorded in cotton, maize and french bean while *M. boninensis* was found on french beans, mango, okra, papaya and sunflower.

The natural enemy populations of aphelinid parasitoids, *Encarsia perniciosi*, *Aphytis proclia*, *Ablerus* sp. and coccinellid predator, *Chilocorus infernalis* were found on San Jose scale exclusively in unmanaged orchards of apple, apricot, plum, pear, peach, cherry, walnut and almonds in Kashmir valley as well as Laddakh. *Aphelinus mali* was found actively associated with apple woolly aphid, *Eriosoma lanigerum.* Nine natural enemies were recorded for the first time from Kashmir in association with different fruit pests. The predators recorded were *Cryptolaemus montrouzieri* and *Chrysoperla zastrowi sillemi* on mealybugs, scales and psyllids infesting brinjal, curry leaf, guava, papaya and tapioca.

Average parasitism by larval and pupal parasitoids of Codling moth was 0.63 per cent. Survey did not reveal the presence of indigenous *Trichogramma* sp.

In sugarcane ecosystem of Maharashtra, the natural enemies mainly observed were *Encarsia flavoscutellum*, *Dipha aphidivora*, *Micromus igorotus*, syrphid, *Eupeodes confrator* and spiders. The parasitoid, *Encarsia flavoscutellum* was distributed and established well in sugarcane fields and suppressed the SWA incidence.

In cotton ecosystem of Maharashtra, the natural enemies present were predatory coccinellids (*Coccinella, Menochilus, Brumoides* and *Scymnus*), chrysopids, and spiders. Whereas in Punjab, coccinellid predators such as *C. sexmaculata, C. septempunctata* and *B. suturalis* and green lace wing, *Chrysoperla zastrowi sillemi* were noticed feeding on *Phenococcus solenopsis*. The parasitization by parasitoids under field conditions varied from 40-68.2 per cent, out of which endoparasitoid, *Aenasius arizonensis* (73.2%) was predominant followed by hyperparasitoid, *Promuscidaun fasciativentris* (26.8%).

Coccinellids, *Coccinella septempunctata, Cheilomenes sexmaculata, Serangium parcesetosum, Chilocorus rubidus, Scymnus* sp. were found on mango hoppers and mealybugs. Natural infestation of *Beauveria bassiana* was observed on *Inderbela quadrinotata*. Four parasitoids belonging to families Ichneumonidae and Braconidae were collected from the mango and guava ecosystem.

Three species of parasitoids, *Tetrastichus schoenobii*, *Trichogramma japonicum* and *Telenomus* spp. were recorded on eggs of rice yellow stemborer. The coccinellid, *Micraspis vincta* was abundantly present in the rice ecosystem. Egg baiting for egg parasitoids recorded the presence of *Anagrus* sp., *Gonatocerus* sp. (Mymaridae) and *Oligosita* sp. (Trichogrammatidae). Parasitoid, *Chrysonotomyia* sp. (Eulophidae)was collected on grubs (68 per cent parasitization) and pupae (80 per cent parasitization) of the hispa beetle, *Dicladispa armigera* from Himachal Pradesh.

Trichogramma chilonis, coccinellids, *Chrysoperla,* predatory earwig, *Euborellia* sp. and spiders were the natural enemies recorded from different ecosytems of Telangana.

Surveillance for alien invasive pests

The papaya mealybug, *Paracoccus marginatus* and Jack Beardsley mealybug, *Pseudococcus jackbeardsleyi* were recorded on papaya in Tamil Nadu. In Maharastra, *Pseudococcus jackbeardsleyi* was recorded on custard apple in Pune and *P. marginatus* was observed in the papaya orchards of western Maharashtra. The incidence of papaya mealybug was low in all surveyed districts of Kerala. Stray incidences of PMB infestations were observed at two locations in Thrissur district. However, the population was very low. Tomato pinworm, *Tuta absoluta* was recorded from Maharashtra, Tamilnadu and Solan. Alien invasive insect pests like *Aleurodicus dugesii, Brontispa longissimi, Phenacoccus manihoti, Phenacoccus madeirensis* and *Frankliniella occidentalis* were not observed in any of the centres.

Biological suppression of plant diseases in field

At GBPUAT, *Trichoderma* isolates, TCMS 9 and PBAT 3 were found effective in improving plant health, reducing sheath blight and brown spot diseases and in increasing yield of rice. Whereas, *T. harzianum* (Th-3) and *P. guilliermondii* (Y-12) were found significantly better in reducing fruit rot with increased yield. In Anand, bio-efficacy of *Pichia guilliermondii*(Y12) seed treatment, seedling dip and foliar spray ($2x10^8$cfu ml^{-1}) recorded the minimum disease intensity (13.56%) and the maximum yield (38.16 q/ha). *Pseudomonas flourescens* isolates, Psf-2, Psf-173 and PBAT 3 were found effective in reducing pre-and post-emergence seedling mortality with increased plant vigour.

Biological suppression of pests in cereals and pulses

Entomofungal formulations of *Metarhizium,* Ma 35, 36 and 52 were effective against *Chilo partellus* causing 48.6 and 51.4 per cent reduction in deadhearts and stem tunnelling, respectively over the untreated control and the results were on par with whorl application of carbofuran. The strains, Ma 35 and Ma 36 caused significant increase in grain yield (4.16 and 4.25 kg/ plot), respectively as compared to control which recorded 2.85 kg/ plot. Carbofuran whorl application @ 8 kg/ha was significantly superior (4.32 kg/plot) and was on par with the strains Ma 36, Ma 35 and Ma 52

In Punjab, spraying of PDBC-BT1 (2%) and Delfin (1 or 2 kg /ha) gave the lowest pod damage in moong bean and at par with each other, followed by chlorpyriphos 20 EC @1.5 l/acre. Lower incidence of *H. armigera* larvae (0.52-0.56 /plant), damage on pod (6.79-7.60%) and grain (8-10%) were noticed in NBAII liquid formulation as against farmer's practices in Anand.

Biological suppression of pests in fruits

In mango, *Metarhizium anisopliae* @ 1x 10^9 spores/ml was found effective in suppressing the hopper population and increased fruit set (3.2 fruits / inflorescence). In apple combined effect of *Trichogramma embryophagum* and *T. cacoeciae* revealed maximum reduction of fruit damage (52.92 %) by *Cydia pomonella. Metarhizium anisopliae* (10^6conidia/cm^2) was the most effective in reducing apple root borer grubs (70.4 % mortality) and was comparable with chlorpyriphos 0.06% (85.8 per cent).

Biological suppression of pests in vegetables

In tomato, the fruit yield (291.89 q/ ha) was significantly higher in BIPM plot as compared to farmer's practice ((287.0 q/ha) with a cost benefit ratio of 1:3.2. Among the different biological control agents evaluated against *Tuta absoluta*, *Metarhizium anisopliae* @ 1.5 ml/l was the most effective one with the minimum number of larvae (2.86 larvae/ top five leaves) and fruit damage (5.32 %) with the highest fruit yield (25.84 t/ha). In brinjal two sprays of NSKE and six releases of *T. chilonis*@ 50,000 parasitoids/ha significantly reduced fruit (17.7%) and shoot (9.5%) damage by *Leucinodes arbonalis* with an increased

marketable yield of 278.4 q/ha. Release of *Cryptolaemus* @ 1500/ha significantly reduced the population of mealybug. Minimum larval population of *Plutella xyllostella* (1.90/plant) and maximum number of coccinelids (1.77/ plant) was observed in cabbage intercropped with mustard and cowpea, with highest yield of 174.9 q/ha. *Bt* formulations, NBAII BTG4 and PDBC BT1 *Bt* strains @ 2% spray were effective in reducing the larval population of diamond back moth up to 59 per cent over control. In potato, entomofungal pathogen NBAIR-Bb-5a strain reduced the infestation of *Dorylus orientalis* and *Agrotis ipsilon* with 15.5% and 17.25% infested tubers. Maximum yield of (89.5 q/ha) was obtained in plots treated with imidacloprid followed by NBAIR-Bb-5a strain (85.00 q/ha).

Biological suppression of pests in oilseeds

In Anand, *Lecanicillium lecanii*@ 40 g/ 10 litre recorded significantly minimum number of jassids (0.58 /leaf), whiteflies (2.46 /leaf), aphids (5.16 /leaf) and thrips (1.22 /leaf) on cotton. The highest seed cotton yield (18.01 q/ha) was recorded in chemical treatment and it was at par with *L. lecanii* treated cotton plots of Maharashtra.

Biological suppression of pests in tobacco

BIPM module with two rows of maize border as barrier crop, one spray of *Lecanicillium lecanii*@ 10^{13}spores /ha at 55 DAP and one spray of imidacloprid @ 0.03% at 65 DAP exhibited 95.85% reduction of infestation by tobacco aphid, *Myzus persicae* which was on par with recommended chemical control practice

Biological suppression of pests in sugarcane

In Maharashtra, the average sugarcane woolly aphid (SWA) incidence and intensity were 1.54 per cent and 1.57, respectively. The natural enemies mainly observed on SWA were *Encarsia flavoscutellum* (5.07adults/ leaf), *Dipha aphidivora*(0.6-3.0 larvae/leaf), *Micromus igorotus* (1.2-5.2 grubs/leaf), syrphid, *Eupeodes confrator* (0.4-1.0 larvae/ leaf) and spider (0.1-0.3 /leaf) during July to March, 2016.

Biological suppression of polyhouse pests

Coccinella septempunctata was found superior to *C. zastrowi* in terms of cabbage aphid suppression, as evident from statistically significant differences in aphid densities after second release of predators. Per cent reduction in aphid density were 76.52 and 63.09 for *C. septempunctata* and *C. zastrowi*, respectively over control indicated the supremacy of the former. Three sprays of abamectin 0.5 ml/lit at 15 days interval was found to be the most effective in reducing the mite population on rose (8.22 mites/ 10 compound leaves/plant) as compared to other treatments. However, four releases of predatory mites @ 10 per plant at weekly interval and three sprays of *H. thompsonii* (1 x 10^8 conidia/g) @ 5 g/litre were the next best treatments with an average 18.22 and 20.89mites/10 compound leaves/plant, respectively. The release of *B. pallescens* @ 30 nymphs per m row was found to be the most

effective in suppressing the rose mite population (7.7 mites /plant) and it was statistically at par with chemical control (4.2 mites/ plant).

Biological suppression of storage pests

Uscana sp. was evaluated against *Callosobruchus* sp. on storability of pigeon pea seeds. The results showed that increase in number of *Uscana* sp. is directly proportional to the level of parasitization. Release of 40 *Uscana* sp. + 50 eggs of *Callosobruchus* sp. recorded the highest parasitization (42 %), lowest seed infestation and the highest germination of pigeon pea seeds (82.33 %). In control, only 75% seed germination was observed.

२. निष्पादित सारांश

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

कीट प्रणालियाँ

डाइओल्कोगेस्टर असमेड, १९०० वाले वंश की चार नई प्रजाति वर्णित की गई। *डाइओल्कोगेस्टर अंडमानेन्सिस* को अण्डमान द्वीप से और *डा. डयूओकोलर, डा. लोन्गिस्ट्रिओ* तथा *डा. सोलीटेरिअम* को भारत की स्थल भूमि पर पाया गया। एकल लारवा परजीवी कीट, *डा. सोलीटेरिअम* को *गेटीस्कलेरकीआना* स्पे. (लेपिडोप्टेरा: टोरर्टीसीडे) पर पाला गया। परजीवी कीटों की दो नई प्रजातियों, *टेट्रास्टिकस थेटीसे* एक यूथचारी परजीवी कीट को *क्यूरेटिस थेटिस* (द्रुराई) प्यूपा पर तथा *सिम्पिएसिस थायर्सिसे* (हायमेनोप्टेरा: यूलोफिडे) को नारियल के वृक्ष पर भक्षण करने वाले लारवे, *गन्नोरा थायर्सिसे* पर पाले जाने को वर्णित किया गया। आकृति विज्ञान, परषोषी अभिलेखन और आण्विक फायलोजीनेटिक विश्लेषणों को समोकित करने के बाद *ग्लायप्टेपेन्टेलस* वंश की प्रजातियों के समूहों के बीच भेद का विकास किया गया। हाल ही में किए गए अध्ययन से पता चला कि ८ प्रजाति समूहों में आने वाली *ग्लायप्टेपेन्टेल्स* की २६ अतिरिक्त प्रजातियाँ उपस्थित हैं, जो कि पूर्वकाल में नहीं पहचाने गये थे।

प्रेस्टविशिआ और *मायरूफेन्स* वंशों को ग्रेट निकोबार में पाया गया। बाद में, *डिप्टेरोकार्पस* स्पे. ग्रसित गॉल वाली पत्तियों से एकत्र किया गया। *ट्रायकोग्रामेटॉयडिआ नाना और ट्रायकोग्रामा एकीये* नामक ट्रायकोग्रामेटिडस को निकोबार से पहली बार एकत्र किया गया। ट्रायकोग्रामेटांयडिए की एक नई, प्रजाति जो कि चीन देश में पाए जाने वाले *ट्रा. टेन्यूईगेनेडियम* के समान प्रतीत होती है मुदीगेरे, कर्नाटक, भारत में पाई गई।

इदरिस एडिकेसावस नामक एक नई प्रजाति समूह से पाँच नई प्रजातियाँ नामतः *इदरिस एडिकेसवस* स्पे. नियर, *इ. ब्रेविकोर्निस* स्पे. नियर पाई गई। भारत से, प्लेटीगेस्ट्रिडे की दस नई प्रजातियाँ नामतः *एम्बलायेस्पिस खासीआना* स्पे. नियर, *ए. कुरिन्जि* स्पे. नियर, *गेस्ट्रोट्रायप्स, लोन्गिकाउडेटस* स्पे. नियर, *गे. मानी* स्पे. नियर, *आयसोलिआ कालिन्गि* स्पे. नियर, *सायनोपिअस (सेक्टोगेस्टर) राइभोएन्स* स्पे. नियर, *ट्रायमोरस लेप्टोक्लेवा* स्पे. नियर, *प्टोईलोस्टेनिअस ग्रीफीथी* स्पे. नियर और *प्टो. नाइसविलेई* स्पे. नियर तथा *ग्रायोन इन्जेन्स* स्पे. नियर को वर्णित किया गया।

माहु की प्रजातियाँ नामतः *एफिस (बुरसेफिस) सोलीटेरिआ* मेक विकार बेकर और *ब्रेकीकाउडस (ब्रेकीकाउडिना) नेपेली* (स्क्रेन्क); मीलीबग *फोर्मिकोकोकस फोर्मिकारी* और शल्क कीट *ऐनोमेलोकोकस क्रीमेटोगेस्ट्री* तथा *पी. उर्बीकोला* कोकरेल को भारत में पहली बार अभिलेखित किया गया। इसी प्रकार, *ट्रायोनीमस टाउनेसी* बर्डस्ले तथा *डिसिमकोकस केरेन्स* विलियम्स को कर्नाटक से पहली बार अभिलेखित किया गया। रा. कृ. की. सं. ब्यूरो के संग्रहण में माहु की ११ प्रजातियाँ, मीलीबग की एक प्रजाति और मृदुल शल्क कीट की दो प्रजातियाँ शामिल की गई।

रा. कृ. की. सं. ब्यूरो के संदर्भ संग्रहण में थ्रिप्स की चार प्रजातियाँ नामतः *ट्राइक्रोमोथ्रिप्स अरोराई, ट्रा. प्राइएन्सेरी, हायडेटोथ्रिप्स ओरीअस* भट्टी तथा *फ्रेन्कलिनोथ्रिप्स मेगालोपस* शामिल की गई।

केरीनोस्टिग्मस ग्राइकस क्रोम्बेन को भारत में पहली बार अभिलेखित किया गया। *के. कोन्गरुस* (वाल्कर) को कर्नाटक, ओडीशा तथा गोवा राज्यों में पहली बार पाया गया। *के. कोस्टेटस* क्रोम्बेन को गोवा, कर्नाटक तथा मिजोरम राज्यों में पहली बार पाया गया। *केरिनोस्टिग्मस, स्टिग्मस, टिज्यूस्टिग्मस* के अन्तर्गत आने वाली प्रजातियों की डी एन ए बारकोडिंग की गई।

रा. कृ. की. सं. ब्यूरो के संग्रहण में पेन्टाटोमिडे की ४० से भी अधिक प्रजातियाँ शामिल की गई। *एमायोटिआ मालाबेरीका* (फेब्रीकस १७७५) (हेमिप्टेरा: पेन्टाटोमिडे:ऐसोपिने) तथा *दार्दजिलीन्गिआ नाईग्रीवेन्ट्रिस* याँग १९३६ (हेटेरोप्टेरा: पेन्टाटोमिडे) को भारत से पुन: वर्णित किया गया। *दा. नाईग्रीवेन्ट्रिस* अरूणाचल प्रदेश और मणिपुर राज्यों से पहली बार अभिलेखित किया गया। भारत में *सुरीनस* वंश के साथ एक नई प्रजाति के विवरण को पुन: वर्णित किया गया।

देश भर से कोलीओप्टेरा: लेमीने के कुल १५३ प्रतिदर्श एकत्र किए गए। *सेल्पानिआ सोसिआ.* गाहन, १९०६ और *सोफरोनिका एपिकेलिस* (पिक, १९२२) को नए क्षेत्रों से पुन: प्राप्ति तथा पाए गए। *पोथायने लाओसिका* ब्रियूनिंग १८६८ (आगापंथिनि: लेमीने) को भारत (महाराष्ट्र) में पहली बार पाया गया। लेमीने उपकुल के लिए वितरण, अभिलेखन और परपोषी पौधों की चेकलिस्ट तैयार की गई। भारतीय सीरेमबायसीड्स वाली २० कृषि प्रमुख सीरेमबायसीडस बीटलों के पहचान कुँजी और वंश तथा प्रजाति प्रकार वितरण तैयार किया गया। अरेबिका कॉफी का अत्याधिक ग्रसन करने वाला सफेद तना बेधक कीट, *जाइलोट्रेकस क्वाड्रीपस* चेवरोलेट १८६३ को *जाइलोट्रेकस जेवानीकस* (कास्टेलनाओ और गोरी, १८४१) का पर्याय पाया गया।

मॉर्फोमेट्रिक्स, प्रकाश माइक्रोस्कोपी और आण्विक लक्षण आधार पर सूत्रकृमि रोगाण्विक विभेद एन बी ए आई ओ ६२ की पहचान *आस्किअस क्रोमोजेन्सिस* के रूप में की गई। यह फोरिड प्यूपों के रूप में पुन: उत्पादित होता है।

दो विभेदों *(हेटेरोरहाब्डिटिस इन्डिका* एन बी ए आई आई ६४ और ६८), पाँच विभेदों *(स्टेइनर्नेमा सिआमकाई* एन बी ए आई आई एस ४६, ४७, ४९, ५१ और ५४) तथा एक विभेद *(स्टे. ह्यून्से* एन बी ए आई आई एस ५५) और *स्टे. अब्बासी* का एक विभेद अभिलेखित किया गया। *हेटेरोरहाब्डिटिस इन्डिका* को पारिस्थितिकी लक्षण तैयार किए गए। एल सी$_{५०}$ और एल सी$_{९०}$ मात्राओं के आधार पर संकेत पाया गया कि बैंगन की ऐश विविल, *माईलोसेरस सबकेसीएटस* के तीसरे और पूर्व-प्युपा अवस्था दोनों ही अवस्थाओं के प्रति *स्टे. कार्पोकेप्से* को विपैला पाया गया। *स्टे. कार्पोकेप्से* और *हे. इन्डिका* दोनों को ऐश विविल के तीसरे और पूर्व-प्युपा अवस्थाओं पर पुन: उत्पादित किया जा सकता है किन्तु संतान उत्पादन दर के आधार पर *हे. इन्डिका* की उत्पादन दर *स्टे. कार्पोकेप्से* की तुलना में महत्वपूर्ण रूप से अधिक पाई गई।

आण्विक कीट विज्ञान

कोलिओप्टेरा (७ कुलों का), डिप्टेरा (५ कुलों का), हेमिप्टेरा (१६ कुलों का) लेपिडोप्टेरा (२१ कुलों का), ओडोनेटा (८ कुलों का) और इक्जोडिडा (१ कुल) का आण्विक लक्षण तैयार किया गया।

सी ओ एकस १ माईटोकोन्ड्रिआ जीन के माध्यम से कीट के एक अंश से कीट की पहचान करने के लिए एक फार्मेस्यूकल पैकेज की स्थापना की गई। कीट की पहचान *पोलेनिआ रूडिस* (फेब्रीकस १७९४) (डिप्टेरा: केलीफोरिडे) के रूप में की गई। अविनाशकारी विधि के द्वारा एकल थ्रिप्स के आंशिक सी ओ १ जीन के डी एन ए निष्कर्षण, पी सी आर एम्पलिफीकेशन को मानकीकृत किया गया।

सी ओ १ जीन और आई टी एस-२ के आधार पर १०३ कृषिगत प्रमुख परजीवी कीटों, परभक्षी कीटों और अन्य कीटों का डी एन ए बार कोड तैयार किया गया। ब्रेकोनिडे नामत: *ग्लायप्टेपेन्टेलस* स्पे. (बारकोड: ए सी जेड ३५४९) (जीन बैंक खाता सँख्या के आर २६०९८४), *ग्लायप्टेपेन्टेलस* स्पे. (ए ए १५४०५) (के टी २८४३३५), *ग्लायप्टेपेन्टेलस* स्पे.

(ए सी जेड ३४३३) (के टी २५३१८), *माइक्रोप्लिटिस मेक्यूलिपेनिस* (ए सी वी ९२३२) (के पी ७५९२९५), *ग्लायप्टेपेन्टेलस क्रिएटोनोटी* (ए ए एच ११९९) (के आर ०२११५४), *ग्लायप्टेपेन्टेलस* स्पे. (ए सी जेड ३४९३) (के टी २५४३१६), *ग्लायप्टेपेन्टेलस ओबलीक्वे* (विलकिनसन) (ए सी एस ३७२०) (के आर ०२११५२), *ग्लायप्टेपेन्टेलस ऐरीस्टोलोकिए* (विलकिनसन) (ए सी एस ३७३०), (के आर ०२११५२), *ग्लायप्टेपेन्टेलस ऐरीस्टोलोकिए* (विलकिन्सन) (ए सी जेड ३७२६) (के आर ०२११५६), *ग्लायप्टेपेन्टेलस सी.एफ. स्पोडोप्टेरे* अहमद (ए सी एस ३७३०) (के आर २६०९८३), *ग्लायप्टेपेन्टेलस स्पोडोप्टेरे* (ए सी एस ३७३०) (के आर २६०९७६), *ग्लायप्टेपेन्टेलस* स्पे. (ए ए एच ११९९) (के टी २८४३३४), *ग्लायप्टेपेन्टेलस* स्पे. (ए सी जेड ३३०३) (के टी २५४३१९), *ग्लायप्टेपेन्टेलस ब्लिक्वे* (विलकिनसन) (ए ए एच ११९९) (के आर ०२११५२), *ग्लायप्टेपेन्टेलस सी एफ एम्प्रोसीमे* अहमद (ए सी जेड ३०१६) (के टी २८४३४२) की लक्षण पहचान और बारकोड तैयार किए गए। माइटोकोन्ड्रियल साइटोक्रोम ऑक्सीडेज सबयूनिट १ (सी ओ आई) न्यूक्लिओटाइड सीक्वेन्सों के आधार पर ३८ प्रजातियों का फायलोजिनेटिक विश्लेषण किया गया। अधिकतम समन्वयता और बेसिअन इन्फेरेन्स विधियों में मुख्यतः *ग्लायप्टेपेन्टेलस* क्लेडस क्रमशः तीन और चार प्रदर्शित हुए।

प्रजातियों के बीच मूल्यांकित सम्बन्धों को जानने के लिए ७६ ट्रायकोग्रामेटिड सीक्वेन्सों की सुनिश्चितता बेसिअन फायलोजिनेटिक रूपों में की गई। ट्रायकोग्रामेटिडों की प्रजाति और वंशिक स्तरों तक पहचान करने के लिए आई टी एस २ को आण्विक रूप से उचित पाया गया। सी ओ आई वंश के आधार पर दीमक के १२९ और स्केरेबीड बीटल के ७६ प्रतिदर्शों के लक्षण पहचान तैयार किए गए। स्केरेबीड बीटल के ग्रबों को वर्गीकरण अध्ययन के लिए पाला गया।

एफिस गोसीपी और *ए. क्रेकसीवोरा* की गट में उपस्थित सूक्ष्मजीवों की पहचान *बेसीलस एल्टिटयूडिन्स, बे. सीरेअस, बे. लाडकेनिफोर्मिस, बे. प्यूमिलस, बे. सब्टिलिस, कोरिनेबेक्टेरिअम वेरीएबिले, एन्टेरेबेक्टर क्लोईए, ए. हार्मेचेई, लाईसिनीबेसीलस फ्यूजिफोर्मिस, ला. मेक्रोलाईड्स, माइक्रोकस ल्यूटिअस, प्रोविडेन्सिआ स्टयूआर्टी* और *स्टेनोट्रोफोमोनाज माल्टोफिलीआ* के रूप में की गई।

कीटनाशकों के अपक्षय विश्लेषण में पाया गया कि *मोरोक्सेला ओसलोएन्सिस, स्टेनोट्रोकोमोनाज माल्टोफिलिआ, एग्जिगुओबेक्टेरिअम इन्डिकम* और *बेसीलस सब्टिलिस* को कीटनाशकों को प्रभावीरूप से अपक्षय करने वाला पाया गया। धारवाड से एकत्र किए गए माहु कीटों में बेंगलोर कीटसँख्या की अपेक्षा ईमिडेक्लोप्रिड के प्रति ९.७ गुणा अधिक सहिष्णुता पाई गई। बेंगलोर से एकत्र ग्रीन पीच माहु *माइजस पर्सिके* कीट सँख्या में गुन्टूर से एकत्र कीट सँख्या की अपेक्षा λ-साईहेलोथ्रिन ५% ई सी के प्रति १३.३८ गुणा अधिक सहिष्णुता पाई गई जबकि इमिडेक्लोप्रिड की दशा में, गुन्टूर कीट सँख्या में बेंगलोर कीट सँख्याओं की अपेक्षा १.१०७ गुणा सहिष्णुता पाई गई।

पीडकों की कुँजी के लिए माय एस क्यू एल पीछे और पी एच पी आगे की तरफ के रूप में कीटनाशक सहिष्णु जीन डाटाबेस (आई आर जी डी) तैयार किया गया। यह डाटाबेस पीडकों जैसे *एफिस गोसीपी, एसीर्थोसिकोन पाइसम, बेमेसीआ टेबेसी, हेलीकोवर्पा आर्मिजेरा, प्लूटेल्ला जाइलोस्टेल्ला, स्पोडोप्टेरा एक्जिगुआ, स्पो. लिट्यूरा, नीलपर्वता ल्यूजेन्स, माइजस पर्सिके, ट्रायबोलिअम कास्टेनीएम* और *ल्यूसीनोड्स ओरबोनेलिस* कीटों के फीचर्स कुँजी जैसे खोजना, देखना, ओ आर एफ ढूँढना, आदि के साथ ८५१ सीक्वेन्स तैयार किया गया।

बेसीलस थ्युरिन्जिएन्सिस के पच्चीस पृथकरणों को पश्चिमी घाट से एकत्र किया गया जो कि बाईपिरेमिडल क्रिस्टल प्रदर्शित करते हैं।

ट्रायस्पिन सक्रिय वी आई पी ३ ए प्रोटीन (आई पी टी जी उदभासित ३ घंटे) की ५०० माइक्रोन ग्राम सान्द्रता ४८ घन्टों के बाद *प्लूटेल्ला जाइलोस्टेल्ला* के लिए १००% घातक पाई गई।

एल सी$_{५०}$ मात्रा ५३.६७६ माइक्रोन/मिली. पाई गई। क्राय ८ ए प्रदर्शित *बे. थूरिन्जिएन्सिस* (एन बी ए आई आर - बी टी ए एन ४) को आलू की ग्रब (*पोपीलिआ जेपोनिका*) के प्रति १००% घातक पाया गया। टमाटर की फ्ती डुबोने की विधि में, बी टी पृथककरण एन बी ए आई आर - ४ और एन बी ए आई आर १ को *टयूटा एबसोल्यूटा* के दूसरे निरुपीय लारवों के प्रति परीक्षण किया गया। तुलना में, पहले वाला बी टी अधिक विषैला (एल सी$_{५०}$ ३०१.३ पी पी एम) जबकि बाद वाला कम (एल सी$_{५०}$ ३७३.७ पीपीएम) पाया गया। एन बी ए आई आर - बी टी जी-४ और मानक एच डी-१ के १ और २% वाले द्रवीय निरूपण, क्रिप्टोलीमस मोन्ट्रयूजिएरी और *क्रायसोपरला कारनिआ* के लिए घातक नहीं पाए गए।

भारतीय डंगबिटल (*ओनीटिस फिलेमोन*) की गट से अटठारह संवर्धनीय सूक्ष्मजीव, भारतीय डंग बिटल (*ओनीटिसेलस सीन्कटस*) की गट से ग्यारह संवर्धनीय सूक्ष्म जीव और *होलोट्रीकिआ सेरेटा* से चौदह गट सूक्ष्म जीव पृथककरण पहचाने गये। *ओनीटिस फिलेमोन* की गट से बीस असंवर्धनीय सूक्ष्मजीव पहचाने गए। *ओनीटिस फिलेमोन* से मिले जीवाणु मे १६ सेलुलोज पोजीटिव और ११ पेक्टिनेज पोजीटिव पाए गए। *ओनीटिसेलस सीन्कटस* से प्राप्त असंवर्धनीय में ७ सेलुलोज के साथ-साथ बेक्टिन का अपक्षय करने की क्षमता दर्शाते हैं।

कीट पारिस्थितिकीय विभाग

भा कृ अनु प - एन बी ए आई आर के कीट संग्रहण में ११० से भी अधिक जीवित कीट का रखरखाव किया गया। इनको किसानों, छात्रों, अनुसंधान संगठनों, कृषि विज्ञान केन्द्रों और व्यवसायिक रूप से बहुगुणित इकाईयों को भेजा गया। वर्ष २०१५-२०१६ के दौरान कुल १३१४ खेप भेजी गयी जिसको माध्यम से ४,९८,२७९ रूपयों का राजस्व प्राप्त हुआ।

भारत देश से एन्थोकोरिडस को जो नए अभिलेखन नामतः *मोन्टेन्डोनिओला बेल्लाटयूला* यामडा २००७ और *जाइलोकोरिस सेरेलिस* यामडा और यासुनाग २००६ (कर्नाटक से) पाए गये। कर्नाटक से प्राप्त *ओरीअस* की दो नई प्रजातियाँ कर्नाटक से पाई उनमें से एक नारियल से और दूसरी *क्लेरोडेन्ड्रम इन्फोर्टयूनेटम* से एकत्र की गई। सेलम, तमिलनाडु में शहतुत की थ्रिप्स से ग्रसित पन्तियों से *कार्डिआस्टेथस एक्जिगुअस, बिलिआ कास्टेनिआ, ओरीअस मेक्जिडेन्टेक्स* और *बुचेनेनीएल्ला स्यूडोकोकी* नामक एन्थोकोरिड परभक्षी कीट अभिलेखित किए गए।

जिन पौधों पर एन्थोकोरिड के निम्फ और प्रौढ उपस्थित थे उन पर *एफिस गोसीपी, पोलीकेगोटेसानीमस लेटस* और मिलीबग की सँख्या कम यानि प्रौढ़ की उपस्थिति ०.३ से ०.८ तथा निम्फों की उपस्थिति ०.३ से १.२ के स्तर तक प्रति कली की दर से पाई गई।

नेट हाऊस में ब्रोड माइट से ग्रसित शिमला मिर्च के पौधों पर *ब्ला. पेलेसेन्स* के प्रौढ़ों को छोड़ने पर पन्ती मोडक में ८०% तक कमी पाई गई। *ब्लाप्टोस्टेथॉयडस पेसीफीकस* और *ब्ला. पेलेसेन्स* के अण्डों के लक्षणों में अंतरों के आधार पर इन बगों की प्रजाति स्तर तक पहचान के लिए उपयोग किया जा सकता है।

ट्यू. एब्सोल्यूटा के अण्डों पर *ए. कोन्सट्रिक्टस* और *ब्ला. पेलेसेन्स* की परभक्षण क्षमता के मूल्यांकन का अध्ययन पिंजडों में किया गया। जब इसको १ एन्थोकोरिडः १० *ट्यू. एब्सोल्यूटा* के अनुपात में छोडा गया तब एन्थोकोरिड की भक्षण क्षमता ९० से १००% तक पाई गई। *ब्ला. पेलेसेन्स* को छोडे गए क्षेत्र में स्थापित पाया जाना का सूचक है। पिंजडों में *ट्यूटा एब्सोल्यूटा* संभाव्यता से ग्रसित टमाटर के पौधों पर *ट्यू. एब्सोल्यूटा* के अण्डों के प्रति *ट्रायकोग्रामा* प्रजातियों के अध्ययन किए गए। *ट्रायकोग्रामा* की तीन प्रजातियाँ *ट्यू. एब्सोल्यूटा* के अण्डों को सफलतापूर्वक परजीवित करती हैं। सबसे अधिक (२८.८%) परजीवीकरण *ट्रायकोग्रामा एकीए* उसके बाद *ट्रा. प्रेटिओजम* (थेलीटोकोअस) द्वारा २२.७% तथा *ट्रायकोग्रामेटॉयडिआ बेक्टरे* द्वारा न्यूनतम (१२.५%) परजीवीकरण पाया गया।

ट्यूटा एब्सोल्यूटा पर पाले गये *नेसीडीओकोरिस टेन्यूईस* का पूर्वअण्डनिक्षेपण काल ४ दिन के साथ निम्फ काल २५ दिनों का पाया गया। मादाओं का जीवनकाल अधिक (२७ दिन) जबकि प्रौढ़ नरों का जीवन काल

कम (२१ दिन) का पाया गया। टमाटर के पौधों पर *ने. टेन्यूईस* उपस्थित होने पर *ट्यूटा* के अण्डे और सूरंगों की प्रतिशतता कम पाई गई। अनोपचारित पौधो में नेक्रोटिक छल्लों की अधिकता (३.४५) जबकि *ने. टेन्यूईस* उपस्थित पौधों में प्रति पौधा इनकी सँख्या न्यूनतम (१.५९) पाई गई।

सर्वेक्षण किए गए सभी क्षेत्रों में पपीते पर मीलीबग के ग्रसन को पीडक स्थिति दर से कम पाया गया। अण्डमान द्वीप पर पपीता और सब्जी वाली फसलों पर १५-३०% ग्रसन पाया गया। कर्नाटक में हायपर परजीवी कीटों के द्वारा *एसीरोफेगस पपाये* परजीवीकरण पर बढ़ा पाया गया। पिछले वर्षों की तुलना में *स्यूडोकोकस जेकबेयर्डस्लेई* का ग्रसन कम पाया गया। प्राकृतिक शत्रु कीटों जैसे *क्रिप्टोलीमस मोन्ट्रोयूजिएरी* मूलसेन्ट, *स्पेल्जिस एपिअस* वेस्टवुड और नेटस की उपस्थिति के कारण पीड़क नियंत्रण में पाए गए।

केले के स्किपर, *ऐरिओनोटा थ्रेक्स* (हेस्पिरिडेः लेपिडोप्टेरा) का प्रकोप कम पाया गया। कुर्ग और चिकमगलूर क्षेत्रों में काली मिर्च की जड पर मीलीबग, *फोर्मिकोकस पोलीस्पेरेस* विलियम्स का प्रकोप अत्यधिक पाया गया।

बेंगलोर में, स्किपर *हेसोरा क्रोमस* (क्रेमर) अचानक अधिक पाया जबकि कण्णुर और ऊटी के क्षेत्रों में गुलदावदी पर *क्रोमेटोमायईआ सिन्जेनीसीए* हार्डी १८४९ (एग्रोमायजिडेः डिप्टेरा) को अचानक से बहुत अधिक मात्रा में पाया गया।

भारत में, एरिथ्रिना गॉल वेस्प (*क्वाड्रास्टिकस एरीथ्रिने*) के प्रति *एग्रोस्टोकेटस* स्पे. को एक संभाव्य परजीवी कीट के रूप में पाया गया। आण्विक लक्षणों के द्वारा इसकी पहचान की गई। भारतीय प्रतिदर्शों के अधध्ययन में *ए. फ्लेक्स* नरों में ब्हाईट गेस्टर लक्षण नहीं पाया गया।

परागणकर्ताओं की ३६ प्रजातियाँ जो कि एपिडे (१७), मेगाचिलिडे (११) और हेलीक्टिडे (८) से संबंधित थी उनकी पहचान की गई और एन बी ए आई आर कीट संग्रहण में शामिल किए गए। *अरगेरिआ क्यूनीएटा, ओसीमम बेसीलिकम, क्रोटोलेरिआ रेट्यूसा* और *वाईटेक्स नेग्यून्डो* को परागणकर्ता कीटों को आकर्षित करते पाया और इन पौधों को परागणकर्ता कीटों के संरक्षण के लिए प्रक्षेत्र और शहरी व्यवस्थाओं में बढ़ावा दिया जा सकता है। मधुमक्खी की १५ प्रजातियों का डी एन ए बार कोडींग किया गया।

किंग कोबरा से प्राप्त टिक कीट की पहचान *एपोनोमा लेईवी* के रूप में की गई। मवेशी टिक, बिल्ली, भेड, कुत्ते की फ्लिज, काटने/खून चूसने वाली मिजेस और मच्छर (*एडीज एजिप्टि*, को संग्रहण में शामिल किया गया।

मीठी तुलसी, नीलगिरी और लौंग सुगंधित तेल को घरेलू मक्खी, *म्यूस्का डोमेस्टिका* एल. (डिप्टेराः म्यूस्किडे) के प्रति उनके रासायनिक संस्चना और साईडल गतिविधि के रूप में विशेषताओं की पहचान की गई। पान, तुलसी और नीलगिरी तेलों की अपेक्षा लौंग के तेल का अधिक विषैला पाया गया। फोरिड मक्खी *मेगासेलीआ स्केलेरिस* के प्रति सुगंधी तेलों के विषैलेपन अध्ययन में अजवायन तेल ७.५९९ माइक्रोन ग्राम की तुलना में थायमोल की एल सी$_{५०}$ २.११ X १०^{६} बीजाणु /मिली. जबकि *मे. एनीसोप्लिए* की दशा में ६.१४ X १०^{६} बीजाणु/मिली. पाई गई।

घरेलू मक्खी, *म्यू. डोमेस्टिका* को आकर्षित करने के लिए एक जेल आधारित मैट्रिक्स विकसित की गई। बाजार में मिलने वाली मिश्रण की तुलना में इसको मक्खियों को अधिक मात्रा में आकर्षित और मारने के लिए उचित पाया गया। अनेक विकसित यौगिकों में से ट्राइकोसेन (फेरोमोन) और ईमिडेक्लोप्रिड मिश्रण वाले खाद्य पदार्थ के माध्यम से बने जेल आधारित मैट्रिक्स को मक्खी आकर्षित करने के लिए अत्यधिक प्रभावी पाया गया, यह ४ वर्गफीट क्षेत्रफल में ४०० मक्खियों को आकर्षित करके मार देता है।

अमेरीकन पिनवर्म, *टयूटा एब्सोल्यूटा* के प्रति फेरोमोन ३ई, ८जेड, ११जेड - ३,८,११ - टेट्रोडोकाट्रीएन-आई-वाई एल एसीटेट को छोड़ने के लिए एक नैनोमैट्रिक्स तैयार किया गया। होसुर, तमिलनाडु में, क्षेत्रीय परीक्षण

के माध्यम से पता चलता है कि बाजार में मिलने वाले प्रपंचों की अपेक्षा नैनोमैट्रिक्स ल्यूर (एनएमएल) को चिपकने वाले प्रपंच के रूप में प्रयेग करने पर अत्यधिक मौथ (९५६.६६ + ३२) पकडी गई। चिपकने वाली अकेले प्रपंच से ६०.६६ + ४.९ मौथ पकडी गई। इस नौनोमौट्रिक्स का एक लाभ यह है कि इसमें फेरोमोन की कम मात्रा लगती है और अधोस्तर को फिर से फेरोमोन भरकर पुनः उपयोग किया जा सकता है।

फायटोसेईडे (मीजोस्टिग्मेटाः फायटोसीओडिआ) प्रभुत्व परभक्षी माईट का एकत्रण किया गया। प्रमुखतः *एम्बलायसेईअस कुकुरबिटे, ए. हर्बिकोलस, ए. पेराएरिएलिस, यूसिअस एल्सटोनिए, यू. चित्रादुर्गे, यू. कोक्सिनिए, यू. डेल्हिएन्सिस, यू. पिनलेन्जिकस, यू. ओवेलिस, यू. प्रसादी, यू. रहोडेन्ड्रोनिस, निओसेयुलस फेलासिस, नि. इन्डिकस, नि. लोन्गिस्पिनोसस, पेराफायटोसिअस मल्टिडेन्टाटस, फायटोसिअस मिनुटस, फा. स्विर्स्कि, फा. वेन्स्डेईनी, ट्रन्सिअस टेटूनाईकीवोरस, टायललोड्रोमस होमालाई, टा. रिकेरी* और *टा. सीजीगाय* फायटोसेईडे एकत्र किए गए।

पहले दो सप्ताहों की तुलना में, वर्तमान सप्ताह के दौरान पातगोभी और फूलगोभी की फसल *ब्रेविकोरिने ब्रेसीके* माहु न्यूनतम तापक्रम, सूर्य की रोशनी के घंटों में सहसम्बन्ध सकारात्मक दर्शाता है। इससे आधार पर रिग्रेशन इक्वेशन्स कार्य करती है।

अरहर के वानस्पतिक, फूल आने और फली बनने की षटकोणीय अवस्था सभी यौगिकों वोलेटाईल अर्क *हेलीकोवर्पा आर्मिजेरा* के अण्डनिक्षेपण के लिए रोधी पाई गई।

प्लाईवुड के टुकडे प्रपंच के बनस्पत एक एल्कोहल मुक्त नियमन वाले प्रपंच अधिकतम सँख्या में मक्खियों को पकडते हैं। मिथाईल यूजिनोल वाले रूपान्तरित चिपकने वाले प्रपंच का विकास किया गया जो कि *बेक्ट्रोसीरा डोर्सेलिस* को पकडने के लिए अच्छा साबित हुआ। अनसेचुरेटड हाइडोकार्बन के साथ केरोमोन प्रपंच प्रयोग करने पर औसतन १.५ नर प्रति प्रपंच जबकि फेरोमोन प्रपंच में केवल ०.७५ नर ही पकडे गए।

ब्यूवेरीआ बेसीआना के छः विभेदों (एनबीएआईआर - ५ए, ७, १४, १९, २३ और ४५) के एन्डोफायटिक क्षमता के अध्ययन में तेलीय नियमन का पर्ण छिड़काव (१X१०^{८} कोनिडिआ/मिली) मक्का और ज्वार में किया गया। मक्का और ज्वार में सभी छः विभेद तना और पत्ती ऊतकों में कालोनी निर्माण और पर्सिस्टेन्सी में विभिन्नता पाई गई। मक्का में, पुराने तने में बीबी ४५ की कालोनी (४६.६७%), पुरानी पत्ती में (४७.७८%) और नये तने में कालोनी (५२.२२%) माध्य सँख्या अभिलेखित की गई। ज्वार में बीबी-५ए पृथककरण की अधिकतम माध्य कालोनी पुराने तने (२१.३०%) और नई पत्ती के ऊतकों (२२.२२%) पाई गई। बीबी-५ए पृथककरण की अधिकतम माध्य कालोनी पुराने तने (२१.३९%) और नई पत्ती के ऊतकों (२२.२२%) में पाई गई।

मक्का और ज्वार में *ब्यू. बेसीआना* की कालोनी निर्माण तना और पत्ती (पुराने और नए दोनों के ऊतक प्रतिदर्शों) में प्लेटिंग विधि और *ब्यू. बेसीआना* के विशिष्ट प्राईमर्स के माध्यम से निश्चितता तय की गई।

कीटनाशक का अपक्षय करने वाले प्रमुख एन्जाईम कार्बोक्सिलेस्टिएरेज की गणना की गई जो कि अम्रास्का *बिगुट्ल्ला बिगुट्ल्ला* के अनेक अन्तः सहजीवीयों से पाया गया।

बेसीलस प्युमिलस अत्यधिक कार्बोक्सिलेस्टिएरेज (०.३०९ माइक्रोन मोल्स/मिली.) इसके बाद *एन्टेरोबेक्टर क्लोएसीए* (०.२०४ माइक्रोन मोल्स/मिली), *फाईलोबेसीडिअम फ्लोरीफोर्मिए* (०.१६९ माइक्रोन मोल्स/मिली) और *बेसीलस लिकेनिफोर्मिस* (०.१३२ माइक्रोन मोल्स/मिली.) उत्पादित करते पाए गए।

सम्पूर्ण भारत वर्ष से न्यूक्लिओपोलीहेड्रोवायरस (एनपीवी) के छः विभेद एकत्र किए गये। पातगोभी से *स्पोडोप्टेरा लिट्यूरा* और भिण्डी से *हेलीकोवर्पा आर्मिजेरा* के संक्रमित लारवों से एन पी वी पृथक किये गये। नीलगिरीज से एकत्र चाय कोंपल छिद्रबेधक, *यूवेलेसीआ फोर्निकेटस* के सिर के साथ-साथ चाय तना

गैलरी प्रतिदर्शों से संभाव्य अन्तः सहजीवी *फ्यूजेरिअम एम्ब्रोजिअम* का पृथककरण किया गया। कवक के मायसीलियम का रंग हल्का पीला और रूई के समान होता है। थेलस का रंग सफेद से गुलाबी रंग में बदल जाता है। कवक केवल क्लब आकार के बहुसेपटेट कोनिडिआ उत्पन्न करता है। आईचीएस रीजन के एम्पलिफिकेशन के माध्यम से कवक की पहचान *फ्यूजेरिअम एम्ब्रोजिअम* के रूप में की गई।

जैविक नियंत्रण पर अखिल भारतीय समन्वित अनुसंधान परियोजना

अनेक कृषि पर्यावरणिक क्षेत्रों से जैविकयंत्रण कारकों की जैव विविधता महाराष्ट्र में, गन्ने के वुली माहु पर कोक्सिनेलिडो नामतः *कोक्सिनेल्ला सेपटमपन्कटेटा, मीनोकिलस सेक्समेकुलेटा, स्किमनस* स्पे., *एनकार्सिआ फ्लेवोस्कुटेलम, डाईफा एफिडीवोरा, माईक्रोमस इगोरोटस,* सिरफीड्स पाए गए, शरीफा के मीलीबग कालोनियों पर *कोक्सिनेल्ला ट्रान्सवेर्सेलिस, मी. सेक्समेकुलेटा, ब्रुमॉयडस सुचुरोलिस, स्किमनस कोक्सिवोरा* और *ट्रायओमेटा कोक्सिडिवोरा* पाए गए। पपीते के मीलीबग पर *ऐसीरोफेगस पपाए, स्यूडलिप्टोमेस्टिकस बेक्सिकाना, मलाडा बोनिएन्सिस, स्पेल्जिस एपिअस, स्किमनस न्यूबिलस, फ्रायनोकेरिआ पेरोटेटी* प्राकृतिक शत्रु कीट अभिलेखित किए गए। कपास, मक्का और फ्रेन्च बीन फसलों में क्रायसोपिड, *क्रायसोपरला जेस्ट्रोवी सिलेमी* अभिलेखित किए गए जबकि फ्रेन्च बीन, आम, भिण्डी, पपीते और सुरजमुखी की फसल में *म. बोनिएन्सिस* पाए गए।

कश्मीर घाटी के साथ-साथ लद्दाख में, सेब, अखरोट, आलुबुखारा, आडू, नाशपाती, चेरी, खुबानी और बादाम के अप्रबंधित बागानों तक में सेन जोस शल्क कीट पर एफिलीनिड परजीवी कीटों जैसे *एनकार्सिआ पर्निसिओसी, एफायटिस प्रोक्लिआ, एब्लेरस* स्पे. और कोक्सिनेलिड परभक्षी कीट, *काइलोकोरस इन्फर्नोलिस* प्राकृतिक शत्रु कीट पाए गए। सेब के वुली माहु, *एरिसोमा लेनीजीरम* पर *एफेलीनस माली* को सक्रिय रूप से सहभागी पाया गया। कश्मीर में विभिन्न फल पीडकों के साथ पहली बार नौ प्राकृतिक शत्रु कीट की सहभागिता अभिलेखित की गई। बैंगन, कडी पत्ता, अमरूद, पपीता और टेपिओका फसलें मीलीबग, शल्क कीटों और सीलिड्स ग्रसित पौधों पर *क्रिप्टोलीमस मोन्ट्रयूजिएरी* और *क्रायसोपरला जेस्ट्रोवी सिलेमी* परभक्षी कीट अभिलेखित किए गए। कोडलिन्ग मौथ का लारवों और प्यूपों का औसतन परजीवीकरण ०.६३ प्रतिशत पाया गया। सर्वेक्षण में देशी *ट्रायकोग्रामा* स्पे. की उपस्थिति नहीं पाई गई।

महाराष्ट्र में, गन्ने के परिस्थितिकी तंत्र में प्रमुखतः *एनकर्सिआ फ्लेवोस्कुटेलम, डाइफा एफिडीवोरा, माइक्रो मुसीगोरोटस,* सिर्फिड, *यूपिओडे स्कोनफ्रेटोर* और मकड़ी प्राकृतिक शत्रु कीट पाए गए। परजीवी कीट, *एनकार्सिआ फ्लेवोस्कुटेलम* गन्ने के क्षेत्रों में भली भाँति स्थापित हो गए और गन्ने के वुली माहु के ग्रसन का दमन किया।

महाराष्ट्र में, कपास परिस्थितिकी तंत्र में परभक्षी कोक्सिनेलिड, *कोक्सिनेल्ला, मीनोकाईलस* और *स्किमनस,* क्रायसोपिड्स, *ब्रुमॉयडस* और मकडियाँ प्राकृतिक शत्रु कीट पाए गए। जबकि पजाब में, कोक्सिनेलिड जैसे कि *को. सेक्समेकुलोटा, को. सेपटमपंकटेटा* और *ब्रु. सुचुरेलिस* और जालीदार पंखों वाले कीट, *क्रायसोपरला जेस्ट्रोवी सिलेमी* को *फिनोकोकस सोलेनोप्सिस* पर भक्षण करते पाया गया। क्षेत्रीय दशाओं में, परजीवी कीटों द्वारा परजीवीकरण विभिन्नताओं के साथ ४०-६८.२ प्रतिशत तक पाया गया। जिनमें से अन्तः परजीवी कीट, *एनासिअस अर्जिओनेन्सिस*, द्वारा प्रभूत्वता परजीवीकरण (७३.२%) इसके बाद हायपर परजीवी कीट, *प्रोमसकिडेओन फेस्किएटिवेन्ट्रिस* द्वारा परजीवीकरण (२६.८%) पाया गया।

आम के फुदकों और मीलीबग पर कोक्सिनेलिड, *कोक्सिनेल्ला सेप्टमपंकटेटा, कीलोमीनस सेक्समेकुलेटा, काईलोकोरस रूबीडस, स्किमनस* स्पे. पाए गए। *इन्जेरिबल एक्वाड्रिनोटेटा* पर *ब्यूवेरिआ बेसीआना* का प्राकृतिक संक्रमण पाया गया। आम और अमरूद के पारिस्थितिकी तन्त्रों से, इक्नियूमोनिडे और ब्रेकोनिडे कुलों से संबंधित चार परजीवी कीटों को एकत्रित किया गया।

धान पारिस्थितिकी तन्त्र में, धान के पीले तना बेधक के अण्डों पर *टेट्रास्टिकस स्कोनोबी, ट्रायकोग्रामा जेपोनिकम* और *टेलीनोमस* स्पे. नामक तीन प्रजातियाँ अभिलोखित की गई। धान परिस्थितिकी तन्त्र में, कोक्सिनेलिड, *माईक्रा स्पिस्विन्कटा* को बहुतायत में पाया गया। अण्ड परजीवी कीट *एनागारस* स्पे., *गोनेटोसेरस* स्पे. (मायमेरीडे) और *ओलीगोसिटा* स्पे. (ट्रायकोग्रामेटिडे) पाए गए। हिमाचल प्रदेश में, हिस्पा बीटल को परजीवी कीट, *क्रायसोनेटोमिआ* स्पे. (यूलोफिडे) को ग्रबों (६८ प्रातिशत परजीवीकरण) और प्यूपा (८० प्रतिशत परजीवीकरण) पर पाया गया।

तेलंगाना में, विभिन्न पारिश्थितिकी तन्त्रों से *ट्रायकोग्रामा किलोनिस,* कोक्सिनेलिड, *क्रायसोपरला,* परभक्षी कीट ईअर विग, *यूबोरेलिआ* स्पे. और मकडियाँ प्राकृतिक शत्रु कीटों के रूप में अभिलेखित की गई।

विदेशी कीटों की घुसपैठ के लिए अनुवीक्षण

तमिलनाडु राज्य में पपीते पर पपीता मीलीबग, *पेराकोकस मार्जिनेटस* और *जैक बेअर्डस्ले* मीलीबग, *स्यूडोकोकस जेकबेयर्डस्लेई* अभिलेखित किए गए। महाराष्ट्र राज्य के पुणे मे शरीफा पर *स्यूडोकोकस जेकबेयर्डस्लेई* अभिलेखित किया गया। और महाराष्ट्र के पश्चिमी घाट में पपीते के बागानों में *स्यू. मार्जिनेटस* पाया गया। केरल के सभी जिलों में किए गए सर्वक्षणों में पपीते के मीलीबग का ग्रसन न्यूनतम पाया गया। थ्रिसुर में, पपीते के मीलीबग का ग्रसन दो स्थानों पर पाया गया। यद्यपि, कीटों की सँख्या अत्यन्त कम पाई गई। महाराष्ट्र, तमिलनाडु और सोलन में टमाटर पिनवर्म, *टयूटा एब्सोल्यूटा* अभिलेखित किया गया। विदेशी घुसपैठी कीट पीडकों जैसे *एल्यूरीडीकस डगेस्टी, ब्रोन्टिस्पा लोन्गिसीमी, फीनेकोकस मेनीहोटी, फी. मादेइरेन्सिस* और *फ्रेन्कलीनिएल्ला आक्सीडेन्डेलिस* को किसी भी केन्द्र पर नही देखा गया।

खेत में पादप रोगों का जैविक नियंत्रण

गो ब पं कृ वि वि प्रौ, में, *ट्राइकोग्रामा* पृथककरण टी सी एम ९ और पी बी ए डी ३ को पौधों के स्वास्थ्य सुधारने, शीथ ब्लाईट और भूरे धब्बे रोगों को कम करने और धान की उपज बढ़ाने के लिए प्रभावी पाया गया। जबकि, *ट्रा. हरजिएनम* (टी एच ३) और *पी. गुलीएर्मोन्डाई* (वाई १२) को फल सड़न कम करने और उपज बढ़ाने के लिए महत्वपूर्ण रूप से उत्कृष्ट पाया गया। आनन्द में, *पीकिआ गुलीएर्मोन्डाई* (बाई १२) द्वारा बीज उपचार, नवोदभिदों को नियमन घोल में डुबोना और पर्ण छिड़काव (२ x १०^{८} सी एफ यू मिली$^{-१}$) का प्रयोग जैव क्षमता परीक्षण में रोग प्रबलता न्यूनतम (१३.५६%) और उपज अत्यधिक (३८.१६ कु. / हे.) पाई गई। *स्यूडोमोनाज फ्लूसेसेन्स* के पृथककरणों, पी एस एफ - २, पी एस एफ १७३ और पी बी ए टी - ३ का प्रयोग करने पर नवोदभिदों के निकलने से पहले और बाद में होने वाली घातकता को कम करने के साथ-साथ पौधे की ओज बढ़ाने के लिए प्रभावी पाया गया।

अन्न और दलहनी फसलों के कीटों का जैविक नियंत्रण

फसल में डेडहर्टस और तनों में सुरंगें कम करने के लिए अनोपचरित की अपेक्षा, मेटारहाईजिअम को एम ए ३५, ३६ और ५२ नामक कीटकवकीय नियमनों को *काईलो पारटीलस* के प्रति ४८.६ और ५१.४ प्रतिशत क्रमशः कम करता है और परिणाम कार्बोफ्यूरान के प्रयोग के समान पाए गए। एम ए ३५ और एम ए ३६ के विभेदों के प्रयोग करने पर दानों की उपज क्रमशः ४.१६ और ४.२५ किग्रा./प्लॉट जबकि अनोपचारित प्लॉट से केवल २.८५ किग्रा./प्लॉट पाई गई। कार्बोफ्यूरान को ८ किग्रा./हे. की दर से प्रयोग महत्वपूर्ण रूप से उत्कृष्ट उपज (४.३२ किग्रा./प्लॉट) और एम ए ३६, एन ए ३५ और एम ए ५२ विभेदों के समान पाई गई।

पंजाब में पी डी बी सी- बी टी १ (२%) और डेल्फिन (१ या २ किग्रा./हे.) के प्रयोग से मूँग बीन की फसल में फली की क्षति न्यूनतम पाई गई और एक दूसरे के समान पाई गई इसके बाद क्लोरपायरीफॉस २० ई सी की १.५ ली/एकड़ की दर से उपयोग करना पाया गया। आनन्द में, किसान द्वारा अपनाई जाने वाली प्रक्रिया की

अपेक्षा एन बी ए आई आई द्रवीय नियमन का प्रयोग करने पर *हेलीकोवर्पा आर्मिजेरा* का ग्रसन (०.५२ - ०.५६/पौधा), फली (६.७९ - ७.६०%) और दानों (७-१०%) की क्षाति न्यूनतम पाई गई।

फलों वाली फसलों मे कीटों का जैविक नियंत्रण

आम में, फुदकों की सँख्या नियंत्रण और फल बनने को बढ़ाने (३.२ फल/पुष्पक्रम) के लिए *मेटरहाईजिअम एनिसोप्लिए* का १ X १०^{९} बीजाणु/मिली. की दर से प्रयोग करना प्रभावी पाया गया। सेब में, *सायडिआ पोमोनेल्ला* द्वारा होने वाली क्षति में अधिकतम कमी (५२.९२%) करने के लिए *ट्रायकोग्रामा एम्ब्रियोफेगम* और *ट्रा. केकोएसीए* का मिश्रित रूप से प्रयोग प्रभावी पाया गया। सेब के जड़ बेधक ग्रब में कमी (७०.४% घातक) और क्लोरोपायरीफॉस ०.०६% के साथ (८५.८ प्रतिशत) तुलनात्मकता के लिए *मेटारहाईजिअम एनीसोप्लिए* (१०^{६} कोनीडिआ/सेमी^{२}) का प्रयोग अत्यन्त प्रभावी पाया गया।

सब्जियों वाली फसलों में कीटों का जैविक नियंत्रण

टमाटर में, किसानों द्वारा अपनाए जाने वाली प्रक्रियाओं से प्राप्त उपज (२८७.० कु./हे.) की अपेक्षा बी आई पी एम अपनाए गए प्लॉट से फल की उपज महत्वपूर्ण रूप से अधिकतम (२९१.८९ कु./हे.) होने के साथ १:३.२ अनुपात में लागत लाभ पाया गया। *ट्यूटा एब्सोल्यूटा* के प्रति प्रयोग किए गए विभिन्न जैविक नियंत्रण कारकों में से *मेटारहाईजिअम एनिसोप्लिए* को १.५ मिली/ली. की दर से प्रयोग करने पर लारवों की संख्या (२.८६ लारवे/उपरी पाँच पत्ती) और फल क्षति (५.३२%) न्यूनतम (५.३२%) रखने के साथ-साथ फल उपज अधिकतम (२५.८४ टन/हे.) पाने के लिए एक अत्यन्त प्रभावी जैव कारक पाया गया। बैंगन में, *ल्यूसिनोडेस आर्बोनेलिस* द्वारा फल (१७.७%) और कोंपल (९.५%) क्षति महत्वपूर्ण रूप से कम करने के साथ-साथ बाजार योग्य उपज को २७८.४ कु./हे. बढ़ी हुई प्राप्त करने के लिए एन एस के ई के दो छिड़काव और *ट्रा. किलोनिस* परजीवी कीटों को ५०,०००/हे. की दर से छः बारी में छोडना अत्यन्त प्रभावी पाया गया। मीलीबग की सँख्या महत्वपूर्ण रूप से कम करने के लिए *क्रिप्टोलीमस* को १,५००/हे. से छोड़ना प्रभावी पाया गया। पातगोभी में अन्तः फसल के रूप में सरसों और लोबिया उगाने पर *प्लूटेल्ला जाईलोस्टेल्ला* के लारवों की संख्या में कमी (१.९०/पौधा) और कोक्सिनेलिडों की अधिकतम सँख्या (१.७७/पौधा) के साथ-साथ १७४.९ कु./हे. उपज पाई गई। अनोपचरित की अपेक्षा एन बी ए आई आई बी टी जी ४ और पी डी बी सी बी टी १ बी टी नियमनों के विभेदों के २% की दर से छिड़काव करने पर डायमण्ड बेक मौथ के लारवों की ५९ प्रतिशत तक की कमी करने के लिए प्रभावी पाए गए। आलू में, एन बी ए आई आर - बी बी ५ ए विभेद वाले कीटकवकीय रोगाणु का प्रयोग करने पर *डोरील्यूसेरीएन्टेलिस* और *एग्रोटिस ईप्सिलोन* द्वारा होने वाले कन्द ग्रसनों का क्रमशः १५.५% और १७.२५% कमी पाई गई। ईमिडेक्लोप्रिड उपचारित प्लॉट से अधिकतम उपज (८९.५ कु./हे.) इसके बाद एन बी ए आई आर - बी बी ५ ए विभेद द्वारा उपज (८५.०० कु./हे.) पाई गई।

तिलहन फसलों में कीटों का जैविक नियंत्रण

आनन्द में, *लिकेनीसिलिअम लेकेनी* का ४० ग्राम/१० लीटर की दर से प्रयोग करने पर कपास मे जैसिड (०.५८/पत्ती), सफेद मक्खी (२.४६/पत्ती), माहु (५.१६/पत्ती) और थ्रिप्स (१.२२/पत्ती को महत्वपूर्ण रूप से कम सँख्या में पाया गया। महाराष्ट्र में, रासायनिक उपचार के परिणाम स्वरूप कपास के बीज की अधिकतम उपज (१८.०१ कु./हे.) पाई जो कि *लि. लेकेनी* द्वारा उपचारित कपास के प्लाट की उपज के समान पाई गई।

तम्बाकू के कीटों का जैविक नियंत्रण

बी आई पी एम पैकेज के अन्तर्गत मक्का की दो लाईन खेत के किनारों पर उगाना, रोपण के ५५ दिनों के बाद *लि. लेकेनी* का १०^{१३} बीजाणु/हे. की दर से प्रयोग और रोपण के ६५ दिनों के बाद ईमिडिक्लोप्रिड का ०.०३% की दर से एक छिड़काव करने पर तम्बाकू के माहु, *मायजस निकोटिने* की ग्रसन में ९५.८५% की

कमी देखी गई जो कि अनुशंसित रासायनिक नियंत्रण प्रक्रिया के समान थी।

गन्ने के कीटों का जैविक नियंत्रण

महाराष्ट्र में, गन्ने के वुली माहु का ग्रसन और तीव्रता क्रमशः १.५४ और १.५७ प्रतिशत पाई गई। गन्ने के वुली माहु पर मुख्यतः *एनकार्सिआ फ्लेवोस्कुटेलम* (५.०७ प्रौढ़/पत्ती), *डाइफा एफिडिवोरा* (०.६ - ३.० लारवे/पत्ती), *माइक्रोमस इगोरोटस* (१.२ - ५.२ ग्रब/पत्ती), सिरफिड, *यूपीओडेस्कोन्फ्रेटर* (०.४ - १.० लारवे/पत्ती) और मकडियाँ (०.१ - ०.३/पत्ती) नामक प्राकृतिक शत्रु कीट जुलाई-मार्च, २०१६ के दौरान पाए गए।

पोलीहाऊस कीटों का जैविक नियंत्रण

परभक्षी कीटों के दुसरी बार छोड़ने के बाद प्राप्त परिणामों में साँख्यिकी रूप से माहु घनत्वता के महत्वपूर्ण अन्तरों से ज्ञात हुआ कि पातगोभी के माहु का जैविक नियंत्रण करने के लिए *क्रि. जेस्ट्रोवी* की अपेक्षा *को. सेप्टमपंकटेटा* उत्कृष्ट पाये गये। माहु घनत्व में ७६.५२ और ६३.०९ प्रतिशत *को. सेप्टमपंकटेटा* और *क्रि. जेस्ट्रोवी* द्वारा क्रमशः कमी पाई गई जिससे *को. सेप्टमपंकटेटा* द्वारा नियंत्रण की महत्ता का पता चलता है। अन्य उपचारों की अपेक्षा एबेमेक्टिन को ०.५ मिली./लीटर की दर से १५ दिनं के अन्तर पर तीन बार छिड़काव करने पर गुलाब में थीमाईट सँख्या को कम (८.२२ माईट/१० संयुक्त पत्तियों/पौधा) करने के लिए अत्यन्त प्रभावी पाया गया। यद्यपि, परभक्षी माईट को १० माईट प्रति पौधा की दर से सप्ताह के अन्तराल पर चार बार छोडना, और *हि. थोम्पसोनाई* (१ X 10^8 कोनीडिआ/ग्रा.) को ५ ग्रा./लीटर की दर से तीन छिड़कावों को अगले उत्कृष्ट उपचार पाए गए जिनसे क्रमशः औसतन १८.२२ और २०.८९ माईट/१० संयुक्त पत्तियाँ/पौधा पाया गया। गुलाब की माईट को नियंत्रित करने के लिए *ब्ला. पेलेसेन्स* को ३० निम्फ प्रति मीटर लाईन की दर से छोड़ने पर माईट की सँख्या में कमी (७.७ माईट/पौधा) पाई गई और यह रासायनिक नियंत्रण (४.२ माईट/पौधा) से श्रेष्ठ पाई गई।

भण्डारण कीटों का जैविक नियंत्रण

अरहर के बीजों के भण्डारण के लिए *केलोसोब्रुकस* स्पे. कीट के. प्रति *उस्काना* स्पे. का मूल्यांकन किया गया। परिणाम दर्शाते हैं कि *उस्काना* स्पे. की सँख्या बढ़ाने पर परजीवीकरण के स्तर का प्रत्यक्ष आनुपातिक पाया गया। *उस्काना* स्पे. के ४० परजीवी कीटों को *केलोसोब्रुकस* स्पे. के +५० अण्डों पर छोड़ने पर आधिकतम परजीवीकरण (४२%), अरहर के बीजों पर न्यूनतम ग्रसन और अधिकतम बीजांकुरण (८२.३३%) पाया गया। अनोपचारित दशा में, बीजांकुरण केवल ७५% ही पाया गया।

3. INTRODUCTION

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

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

This shifting perspective on insects in agriculture has been mirrored in the evolution of this bureau. When the possibility of using insects instead of harmful chemicals for the management of insect pests in agriculture was realised the Indian Council of Agricultural Research (ICAR) initiated the All India Coordinated Research Project (AICRP) on Biological Control of Crop Pests and Weeds in 1977. Through initially funded by the Department of Science and Technology, Government of India the ICAR began extending full financial support to the programme from 1979. To further strengthen research on biological control the centre was upgraded to the Project Directorate of Biological Control on 19th October, 1993. With the growing realization that effective biological control was predicated on sound taxonomic and ecological knowledge the National Bureau of Agriculturally Important Insects was created on 29th June, 2009. The NBAIR was subsequently established to document the vast insect resources to enable studies on their multifarious roles in the agroecosystems of our country.

MANDATE

ICAR – NATIONAL BUREAU OF AGRICULTURAL INSECT RESOURCES
To act as a nodal agency for collection, characterization, documentation, conservation, exchange and utilization of agriculturally important insect resources (including mites, spiders and related arthropods) for sustainable agriculture.
AICRP ON BIOLOGICAL CONTROL OF CROP PESTS
Promotion of biological control as a component of integrated pest and disease management in agricultural and horticultural crops for sustainable crop production. Demonstration of usefulness of biocontrol in IPM in farmers' fields.

Notable achievements of the past

Basic and Strategic Research for Biological Control

- An expanding image gallery of agriculturally important insects is hosted on NBAIR's website with hundreds of species of insects and over 3000 photographs. The USDA and Colorado State University feature this on their site 'ID source' along with another website 'Featured Insects'.
- Fact sheets, diagnostics and illustrations on Indian Mymaridae and Pteromalidae have been developed and hosted on the NBAIR website.
- Insects in agroecosystems is hosted on the NBAIR website (URL:http://www.nbair.res.in / insectpests / index.php). It includes pests of crops and other common insects from Indian agroecosystems. About a thousand species with 3500 colour photographs are for viewing and study on the site).
- Websites on Indian Coccinellidae and Aphids of Karnataka have been constructed and hosted on the NBAIR website.
- A website featuring biocontrol introductions to India (http://www.nbair.res.in/ Introductions / Insects/index.htm) has also been hosted on the NBAIR website.
- 106 types belonging to Thysanoptera, Hymenoptera, Coleoptera and Diptera including 50 primary types in the NBAIR collections have been documented and 15 of these were digitized.
- Nine new species of Platygastroidea were described and the phoretic *Sceliocerdo viatrix* was redescribed. For the first time a parasitic wasp (*Ooencyrtus parasiticus*) was reported attacking the genus *Bibasis* (Lepidoptera: Hesperiidae). Twelve species of aphids and coccids were recorded for the first time from India. SEM studies of two species of *Trichogramma* were completed. Four new species of mymaridae were described.
- *Anagyrus amnestos*, a potential parasitoid of the invasive Madeira mealybug was described.
- Bar codes of 25 species of insect natural enemies including parasitoids, anthocorid predators, coccinellid predators, pollinators and a weed killer were developed. In addition bar codes were also developed for a total of 149 species belonging to 9 orders of insects.
- *Paracoccus marginatus* was successfully managed by the exotic parasitoid *Acerophagus papayae*. *Leptocybe invasa* was managed by the parasitoid *Quadrastichus mendeli*.
- Anthocorid predators collected on different host plants were studied for their feeding potential and amenability for culturing indoors in the search for effective agents for use in biocontrol programmes.
- *Cecidochares connexa* released for the management of *Chromolaena odorata* continues to be present in its areas of release.
- A pollinator garden has been developed that has been attracting a large number

of bees (belonging to the families Apidae, Megachilidae, Anthophoridae and Halictidae), a host of dipterans and lepidopterans.

- *Liriomyza trifolii* was found to occur at significantly higher levels when carbondioxide and temperatures were higher.
- A cost effective mass production protocol was developed for *Pseudococcus jackbeardsleyi*.
- Chitosan- aliginate nanoparticles were found to be safe to *Chrysoperla zastrowi sillemi*.
- A collection of insects of importance in veterinary and fisheries sciences has been initiated.

Applied Research (Biological Control)

- The papaya mealybug, eucalyptus gall wasp and the sugarcane woolly aphid were successfully managed by release and management of natural enemies.
- A cost-effective WP/EC based *Trichoderma* (Th-14) formulation and an efficient delivery system were developed. Rice brown spot disease severity was found to be significantly reduced by *Trichoderma* isolates TCMS 5 and TCMS 14a.
- *Metarhizium anisopliae* @2x10^8 spores / ml was found to cause mycosis in rice bugs. In sugarcane eight releases of *Trichogramma chilonis* (TTS) @50,000 / ha reduced the incidence of early shoot borer and twelve releases of *T. chilonis* @50,000 / ha reduced incidence of stalk borer.
- In soyabean SINPV sprays @250 LE / ha (1.5 x 10^{12} POBs) thrice as effective suppressing *Spodoptera litura*. Biosuppression of the safflower aphid *Uroleucon compositae* can be achieved with two sprays of *Verticillium lecanii* 1.0% WP in non-spiny safflower.
- In brinjal, shoot and fruit borer incidence can be significantly reduced with two sprays of NSKE and six releases of *T. chilonis*; *Brumus suturoides* @ 1500/ha, *Scymnus* @1500/ha and *Cryptolaemus* @ 1500/ha significantly reduced mealybug populations.
- The BIPM module developed against *Aleurodicus dispersus* on cassava was superior to farmers practice in managing this pest.
- *Neoseiulus longispinosus* @ 1:10 predator:prey ratio in carnation in polyhouses resulted in 91.2% reduction of phytophagous mites and was on par with fenazaquin (0.0025%) which caused 92.1 % reduction in the mite population.
- *Blaptostethus pallescens* @30 nymphs/m row along with chemical control (Omite 300 ml / acre) was effective in managing *T. urticae* on okra in polyhopuses.
- *Xylocoris flavipes* nymphs (30 nymphs / kg of rice) performed better than those of *Blaptostethus pallescens* in minimizing *Corcyra* moth populations in rice in storage.

Organizational set-up

Research is undertaken in the Divisions of Insect Systematics, Molecular Entomology and Insect Ecology. Research on microbial biocontrol is addressed under the AICRP on Biocontrol (Fig. 1).

ORGANISATIONAL CHART

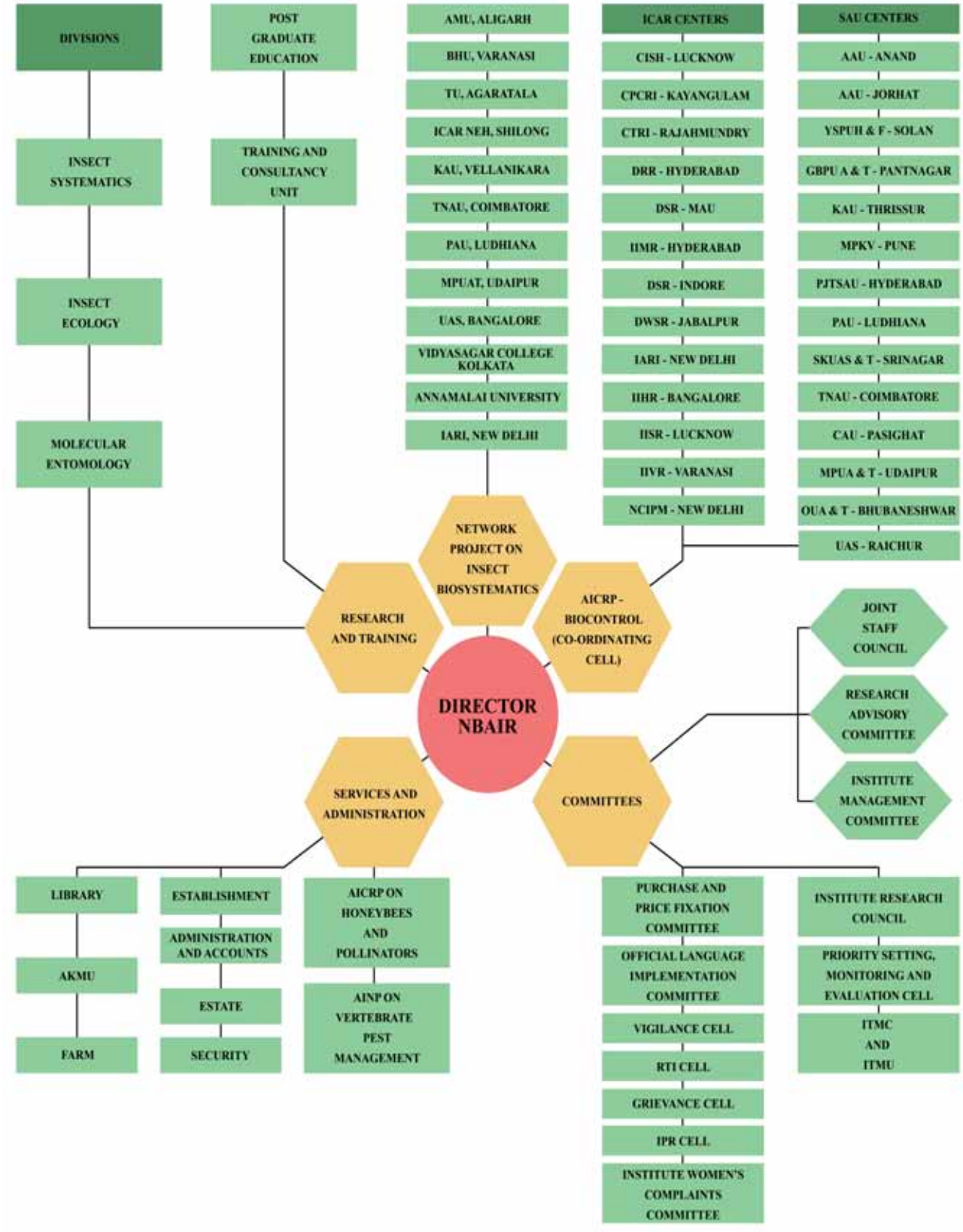


Fig. 1. Organisational Chart of ICAR - NBAIR

Financial Statement of 2015-16
National Bureau of Agricultural Insect Resources
Bengaluru

(₹ in lakhs)

Head	Plan	Non- Plan	Total
Pay & Allowances	0.00	690.51	690.51
T.A	9.77	4.98	14.75
Other Charges including equipment	163.55	122.45	286.00
Information Technology	0	0	0
Works / Petty works	73.69	15.33	89.02
HRD	1.11	0	1.11
Pension	0	17.85	17.85
Loan	0	0.45	0.45
TOTAL	**248.12**	**851.57**	**1099.69**

AICRP on Biological Control of Crop Pests
Expenditure (2015-16)
(ICAR Share only)

(₹ in lakhs)

Sl. No.	NAME OF THE CENTER	Expenditure
1	AAU, ANAND	57.18
2	AAU, JORHAT	24.50
3	ANGRAU(RARS), HYDERABAD	23.82
4	PJSTAU, TELANAGANA	23.69
5	DR.YSPUH&F, SOLAN	44.84
6	GPUAT, P'NAGAR	22.96
7	KAU, THRISSUR	43.38
8	MPKV, PUNE	43.26
9	PAU, LUDHIANA	83.36
10	SKUAT, SRINAGAR	42.22
11	TNAU, COIMBATORE	45.53
12	MPUAT, UDAIPUR	2.50
13	OUAT, B'WAR	2.22
14	CAU, PASIGHAT	1.57
15	UAS, RAICHUR	2.75
16	P.C.CELL, B'LORE	11.22
	TOTAL	475.00

4. RESEARCH ACHIEVEMENTS

National Bureau of Agricultural Insect Resources

DIVISION OF INSECT SYSTEMATICS

Surveys

Expeditions for the collection of insects were undertaken to Himachal Pradesh, Rajasthan, Gujarat, Madhya Pradesh, Tripura, Mizoram, Odisha, Karnataka, Kerala, Tamil Nadu and the Andaman & Nicobar islands. While one or two visits were made to most of the places Karnataka was surveyed more intensively with a number of collection trips being made repeatedly to various places. Collections were made from both agroecosystems and natural ecosystems. Malaise traps, yellow pan traps, light traps and sweep nets were used to collect insects. Many insects were also manually collected.

Digitization of type specimens in NBAIR reference collections

All primary types held at the NBAIR are digitized and hosted online at http://www.nbair.res.in/Type_Specimens/index.php (Fig.2). Details of original combination, current valid name, sex / stage of the type, type status, verbatim label data, and original publication are provided for the types at NBAIR. Images of the type specimen(s) featuring the diagnostic characters are provided, wherever available, for primary types. Hyperlinks are provided to the original publication in which the species description appears wherever open access is available. Information on 53 types were added this year so that currently this site holds information on 212 type specimens with 804 images.

Fig. 2. Screen shot of the site on type specimens

Biosystematics of Trichogrammatidae (Hymenoptera)

Trichogramma achaeae and *Trichogrammatoidea nana* were collected from Tripura and Great Nicobar while *Trichogramma rabindrai* was collected from the Andaman islands for the first time. A new species of *Trichogrammatoidea* closely resembling but distinct from *T. tenuigonadium* was collected from Mudigere, Karnataka. (Figs.3,4). The genera *Paratrichogramma*, *Aphelinoidea, Tumidiclava* and *Oligosita* were collected from Tripura for the first time while *Mirufens, Prestwichia, Paracentrobia* and *Oligosita* were collected from Great Nicobar.

Males of *Ufens* species have been collected for the first time. This will enable the determination of species of it

***Trichogrammatoidea* sp.**	***Ufens* sp.**	***Neocentrobiella* sp.**

Fig. 3. Species of Trichogramatidea collected from various areas in India

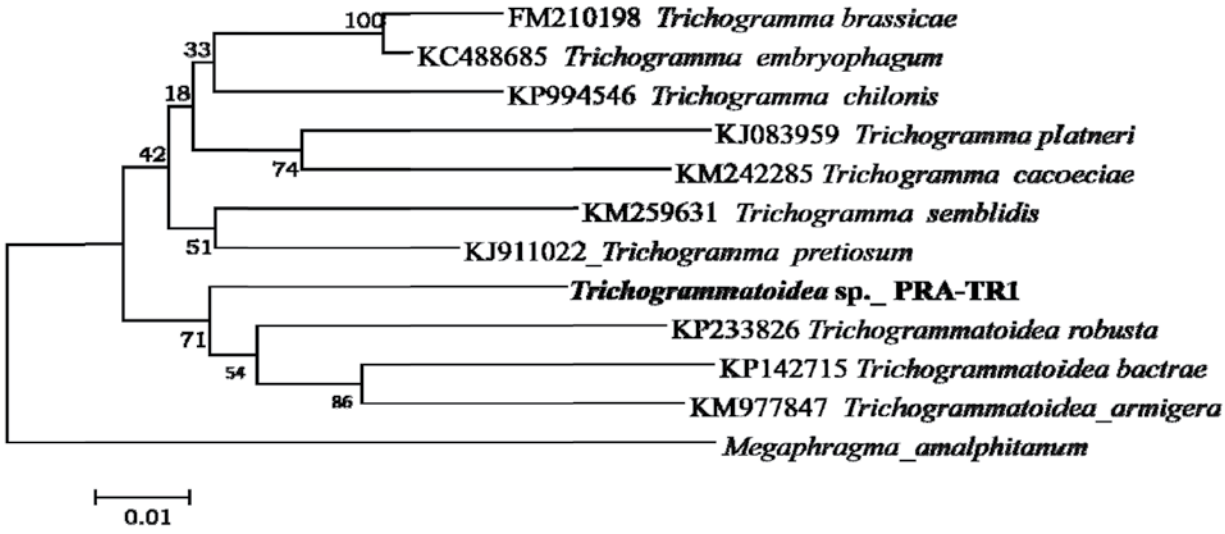


Fig.4. Phylogenetic relationship among 7 species of *Trichogramma* and 4 species of *Trichogrammatoidea* showing relationship between the new and other species of *Trichogrammatoidea* relative to *Trichogramma* and *Megaphragma*

Biosystematics of Oophagous Parasitoids with Special Reference to Platygastroidea

- Surveys were conducted for Platygastroidea in eight states *viz*., Tripura (Agartala, near Trishna WLS), Andaman and Nicobar Islands, Orissa (Bhubaneshwar, Puri Road, Joypur and Cuttack), Tamil Nadu (Thandikudi, Thadiankudisai, Ootacamund, Doddabetta, Wellington, Madurai, Kodaikanal, Hosur, Coimbatore), Kerala (Trivandrum, Peringammala, Kochukovalam), and Karnataka. In Karnataka collections were extensively made from Anekal, Attur, Hebbal, Hesaraghatta, Kanakapura, Kunigal, Mudigere, Malaimaratha, Mandya, Nandi Hills, Savandurga, Shivagange Betta, Sangama, Tumkur, etc. Different crops *viz*., rice, sugarcane, maize, pulses, vegetables and fruits in addition to forest and uncultivated fields were surveyed for insect eggs.
- Platygastrids were also collected using sweep nets, yellow pan traps and malaise traps, pitfall traps in all the above mentioned places.
- A total of 1150 parasitoids were collected, curated and preserved for future studies. So far 62 genera under four families of Platygastroidea were recorded from India under this project and an additional four genera were added raising the total to 66 genera. The four genera were *Pardoteleia, Pleistopleura, Ptilostenius, Titta* and *Nyleta.*
- The genus *Pardoteleia* Kozlov a monotypic genus was erected by Kozlov with type species *P. prater* from Vietnam. This is the first time that this genus is being reported from India. The genus *Nyleta* Dodd another monotypic genus was erected by Dodd with type species *Nyleta striaticeps* from Australia. This is the first report of this genus from Little Andaman, Andaman Islands, India. The genus *Ptilostenius* so far reported from Vietnam is reported for the first time from India. The genus is currently represented by only two species: *P. anthedon* and *P. anthedoron*, described from female specimens. The males of this genus were unknown. Two new species, *P. griffithi* and *P. nicevillei*, are described from both female and male specimens. A new species of *Trimorus* - *T. leptoclava* - with an unusual female antenna (the distal segments of the clava are not incrassate) is described. The genus *Pleistopleura* is reported for the first time from India. *Synopeas halmaherense* Buhl, which was earlier reported from Indonesia, is recorded for the first time from India.
- A new species group and fifteen new species are described.
- A new species group *Idris adikeshavus* group has been proposed with five new species – *Idris adikeshavus, I. brevicornis, I. deergakombus, I. teestai* and *I. lopamudra.*
- A new species of an unusual, sexually dimorphic species of *Gryon* – *Gryon ingens* has been described. This was reared from the eggs of *Isyndus ?heros* (Hemiptera: Reduviidae) laid on leaves of mango.

Six new species of Platygastridae from India (Fig. 5). *Amblyaspis khasiana*

(Meghalaya), *A. kurinji* (Tamil Nadu, Shenbaganur), *Gastrotrypes longicaudatus* (Bengaluru), *G. manii* (Andaman Islands), *Isolia kalingi* (Orissa), *Synopeas* (*Sactogaster*) *ribhoiense* (Meghalaya) are described and illustrated.

***Amblyaspis khasiana* sp. n.**

***Amblyaspis kurinji* sp.n.**

***Gastrotrypes manii* sp.n.**

***Idris adikeshavus* sp. n.**

***Gryon ingens* sp. n. (female)**

***Gryon ingens* sp. n. (male)**

***Isolia kalingae* sp. n.**

***Synopeas halmahrense* Buhl**

Fig.5. New species of Platygastridae from India

Biodiversity of economically important Indian Microgastrinae (Braconidae)

Four new species of the genus *Diolcogaster* Ashmead, 1900 (Hymenoptera: Braconidae: Microgastrinae) (Fig.6) are described and illustrated: *Diolcogaster andamanensis* from the Andaman Islands, and *D. duocolor*, *D. longistria* and *D. solitarium* from mainland India. The solitary larval parasitoid *D. solitarium* was reared from *Gatesclarkeana* sp. (Lepidoptera: Tortricidae). A new combination, *Diolcogaster tomentosae* (Wilkinson, 1930) is proposed for the Indian species *Protomicroplitis tomentosae* (Wilkinson, 1930) along with its redescription and documentation of the gregarious cocoons associated with the pyralid (Epipaschiinae) host feeding on *Terminalia cattappa* L.

Diolcogaster andamanensis

Diolcogaster duocolor

Diolcogaster longistria

Diolcogaster solitarium

Fig.6. New species of Diolcogaster

Collection: Collection of parasitized hosts, sweep net collection, yellow pan trap and malaise trap was done from different crops and different regions of India. Nearly 5000 specimens were collected, bred, curated, and preserved. Collections include- >200 species. Collection localities (2015 -2016) (>200 collection/survey trips undertaken). Collection from following localities studied: Mizoram, Rajasthan, Gujarat, Goa & Karnataka.

Laboratory rearing- Rearing of parasitized hosts specifically lepidopteran larvae is continuously done.

Host species - Parasitoids reared from Lepidoptera host families: Erebidae (Arctiinae; Lymantriinae), Geometridae, Noctuidae (Noctuinae), Nymphalidae, Papilionidae and Sphingidae, Hesperiidae, Lycaenidae, Papilionidae, and many others (Fig.7).

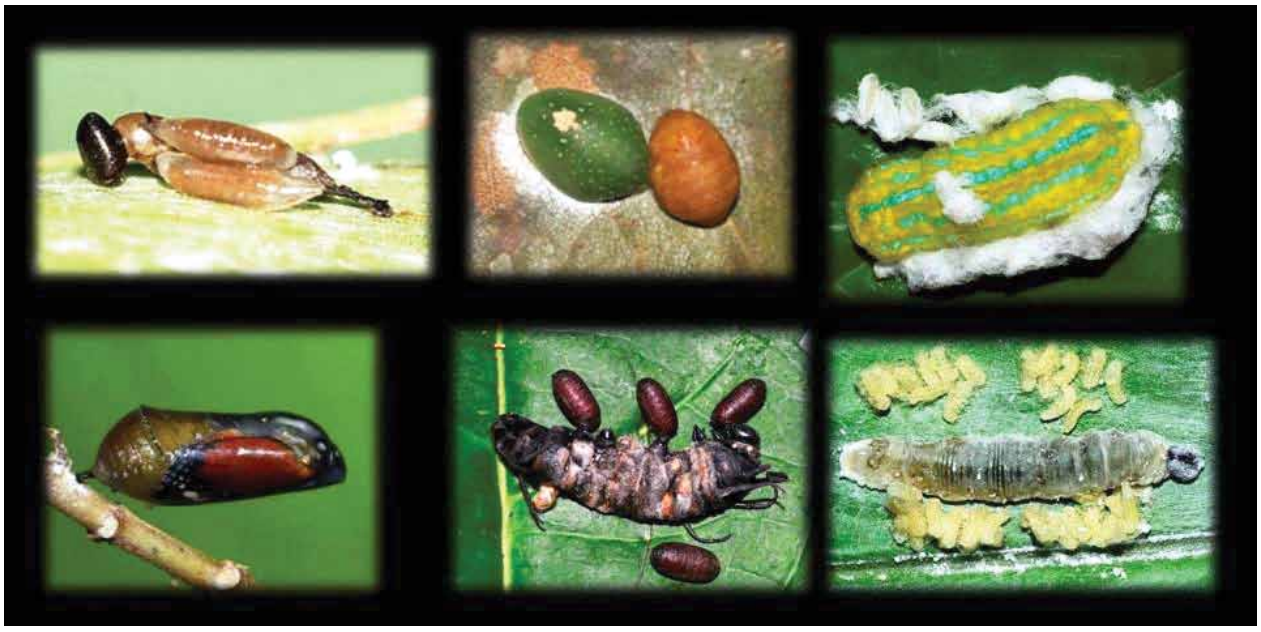


Fig.7. Parasitized butterfly stages

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

A total of 287.5 cc eggs of *Sitotroga cerealella* were multiplied from April 2015 to March 2016. Four host insects and six predators were reared continuously and were supplied to students and scientists as and when required.

A total of 2444 specimens were processed by making 650 slides. Through several field trips (local trips in and around Bangalore) collections were made and a total of 228 species of aphids, scales and mealybugs were identified.

Aphid species *viz., Aphis* (*Bursaphis*) *solitatia* McVicar Baker and *Brachycaudus (Brachycaudina) napelli* (Schrank); mealybug *viz., Formicococcus formicarii* (Green) and scale, *Anomalococcus crematogastri* (Green and *P. urbicola* Cockerell were recorded for the first time from India (Fig. 8). Similarly, *Trionymus townesi* Beardsley and *Dysmicoccus carens* Williams were recorded for the first time from Karnataka (Fig. 9).

Aphid species *viz.*, *Micromyzodium filicium* David, *Sitobion ? africanum* (Hille Ris Lambers), *Sitobion avenae* (Fabricius) *Macromyzella polypodicola* (Takahashi), *Greenidea* (*Trichosiphum*) *eugeniae* Takahashi, *Aphis caryopteridis* Holman, *Aphis verbasci* Schrank, *Myzus* (*Nectarosiphon*) *antirrhinii* (Macchiati), *Myzakkaia polygonicola* Basu, *Aphis ? rubicola* Oestlund, *Amphorophora*

ampullata Buckton, *Macrosiphoniella pseudoartemisiae* Shinji; mealybug *Adelosoma phragmitidis* Borchsenius and scale *Coccus formicarii* (Green) and *Pulvinaria floccifera* (Westwood) were added as new to the NBAIR collection.

***Aphis (Bursaphis) solitaria* McVicar Baker**

***Brachycaudus (Brachycaudina) napelli* (Schrank)**

***Formicococcus formicarii* (Green)**

***Anomalococcus crematogastri* (Green)**

Pulvinaria urbicola* Cockerell on *Solanum melongena

Pulvinaria urbicola* Cockerell infesting *Capsicum annuum

Fig. 8. First records from India

Trionymus townesi Beardsley

Dysmicoccus carens Williams

Fig. 9. First records from Karnataka

Taxonomic studies on Pentatomidae (Hemiptera: Pentatomoidea) of India with special reference to Pentatominae

Collection, identification and preservation of Pentatomidae

Around 20 collection trips were undertaken in and around Karnataka and nearly 375 specimens belonging to 40 species of Pentatomidae has been added to the collection. Apart from this, nearly 70 specimens belonging to various families such as Plataspidae, Coreidae, Scutelleridae, Reduviidae and Dinidoridae were also added to the insect collection.

DNA barcoding

17 species of Pentatomidae has been given for DNA barcoding including the three polymorphic forms of *Nezara viridula*.

Identification services

Three identification services provided to various researchers (Pune, Port Blair and Kerala), which includes the identification of 14 species belonging to Pentatomidae, Coreidae and Plataspidae.

Redescription of *Amyotea malabarica* (Fabricius, 1775) (Hemiptera: Pentatomidae: Asopinae)

Studied the variability in external colouration of adults, described and illustrated the male and female genitalia. Illustrated the habitus and external scent efferent system (Fig.10a).

Redescription of *Dardjilingia* (Hemiptera: Heteroptera: Pentatomidae) from India

Redescribed the genus *Dardjilingia* Yang, 1936 along with the redescription of the species *Dardjilingia nigriventris* Yang, 1936 with emphasis to its male and female genitalia. Illustrated the male and female genitalia, a (Fig.10b) external scent efferent system and habitus of the species. Discussed the tribal placement of the genus.

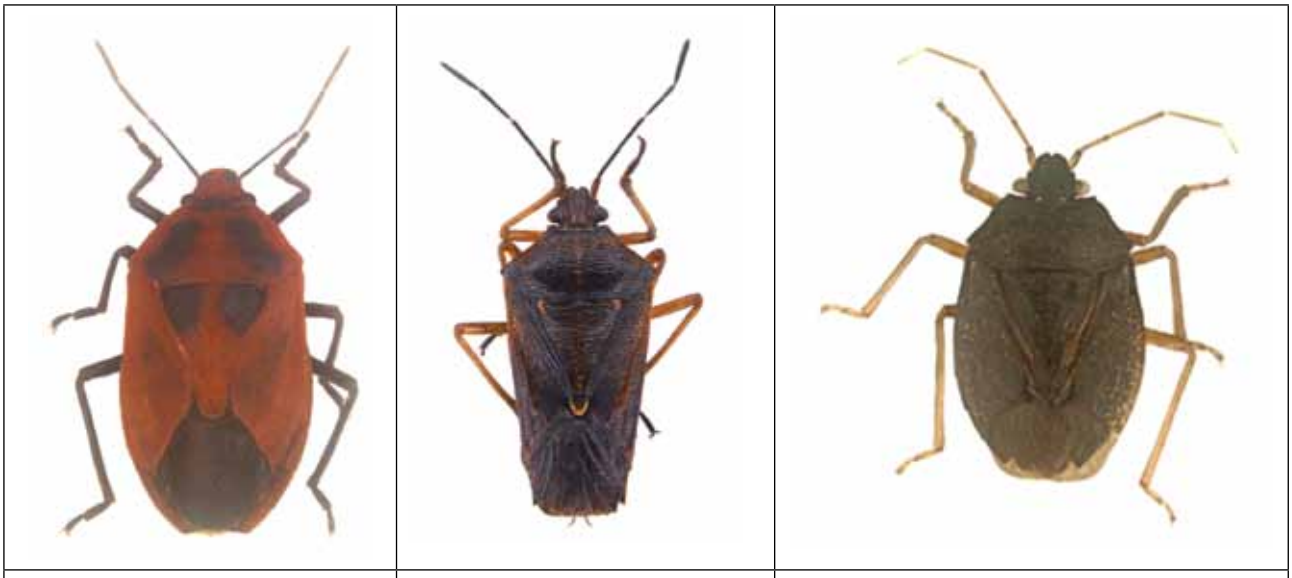
Redescription of the genus *Surenus* with description of a new species

The genus *Surenus* Distant, 1901 is redescribed (Fig.10c) along with a new species from India. Illustrated the male and female genitalia, habitus and external scent efferent

system. Discussed the tribal placement of the genus.

Improvised the dissection of male genitalia in Pentatomidae

Completely inflated phallus is important in the taxonomy of Pentatomidae and it is often difficult to inflate the same in complete form. The dissection of male genitalia and inflation of phallus in Pentatomidae usually adopted as detailed by Ahmad (1986). This method is improvised for the better inflation of phallus in Pentatomidae.



a. ***Amyotea malabarica*** | b. ***Dardjilingia nigriventris*** | c. ***Surenus sp.***

Fig. 10. Species of Pentatomidae

Biosystematics of Cerambycidae

Twenty nine field expeditions between Mar 2015 to Feb 2016 were undertaken that included Jammu, Srinagar, Ladakh, Kargil, Delhi, Almora, Pune, Mudigere, Eastern ghat hills, Thrissur, Pattambi, Peechi, and Andaman - Nicobar group of islands. Total of 153 specimens were collected. All the specimens were curated, identified and preserved at ICAR-NBAIR Museum. Five species were barcoded. *Salpinia socia* Gahan, 1906 and *Sophronica apicalis* (Pic, 1922) have been rediscovered and reported from new localities. *Pothyne laosica* Breuning 1868 (Agapanthiini: Lamiinae) has been reported from India (Maharashtra) for the first time. The checklist, distribution records and host plants for the subfamily Lamiinae has been prepared. Further, identification key for 20 agriculturally important cerambycid beetles and the genus and species wise distribution of the Indian cerambycids were prepared (Table 1).

White stem borer, *Xylotrechus quadripes* Chevrolat 1863 is the most serious pest of arabica coffee in most of the coffee growing regions of India. Now its name has been synonymised with *Xylotrechus javanicus* (Castelnau & Gory, 1841) (Fig.11).

Table 1. Representation of different subfamilies, tribes, genus and species of long-horn beetles from museum collection of the ICAR-NBAIR, against total Indian species

Subfamily	India			No. of Species in the NBAIR collections	% representation in the collections
	No. of Tribes	No. of Genus	No. of species		
Dorcasominae	2	3	4	0	0
Spondylidinae	1	4	6	0	0
Cerambycinae	26	109	349	21	6.0
Lamiinae	24	275	1103	60	5.4
Lepturinae	4	18	20	2	10
Necydalinae	1	1	3	0	0
Prioninae	10	29	56	10	17.8
Disteniinae	3	6	9	0	0
Philinae	1	2	3	1	33.3
Total	**72**	**447**	**1553**	**94**	**6.0**

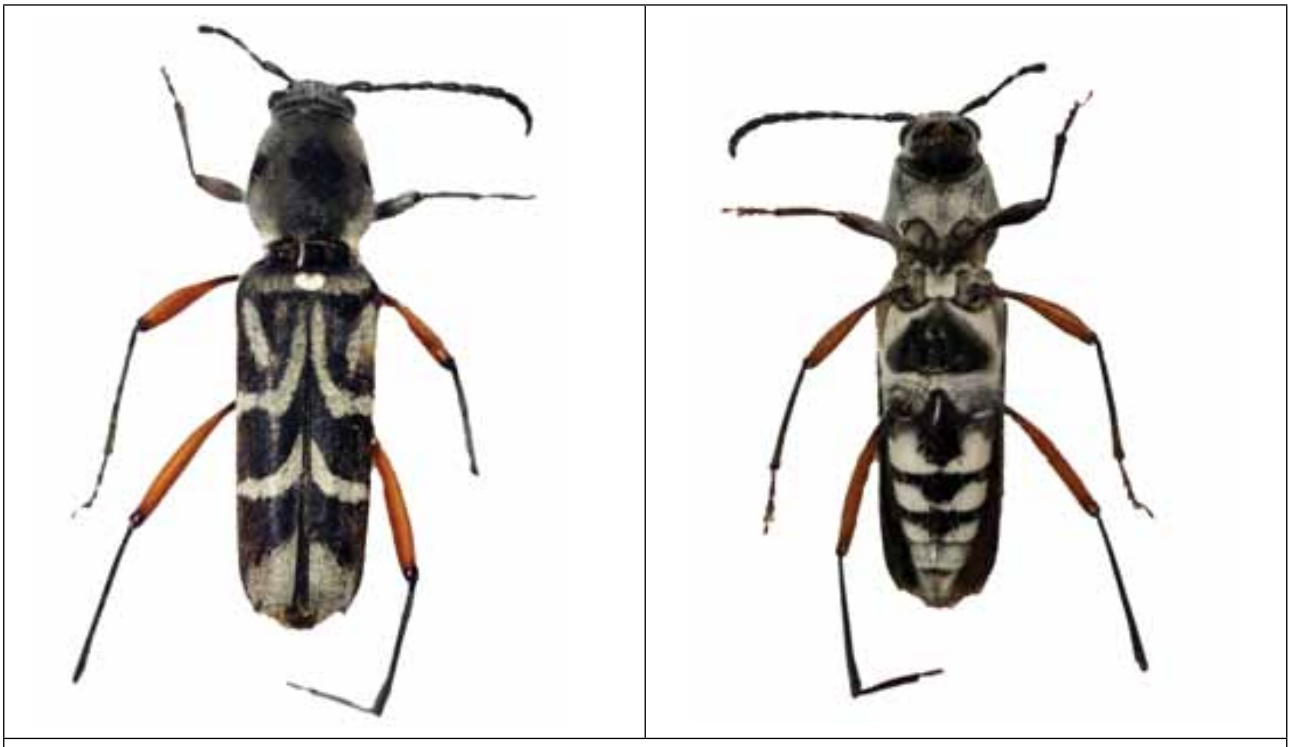


Fig. 11. ***Xylotrechus javanicus*** **(Castelnau & Gory, 1841) (Female dorsal and ventral views)**

Taxonomy and diversity of Indian Thysanoptera with special reference to Terebrantia

Extensive surveys were conducted in Karnataka (Hessaraghatta, Gadenalahalli, Nandi hills, Mudigere and Nandigrama), Tamil Nadu (Madurai and Ooty), Odisha (Bhubaneshwar) and Kerala (Vellayani, Peringammala) for collection of thrips. Collected specimens were sorted out, processed and slide mounted. Terebrantian thrips specimens belonging to the following genera were identified *viz.*, *Franklinothrips, Astrothrips, Panchaetothrips, Pseudodendrothrips, Hydatothrips, Neohydatothrips, Frankliniella, Thrips, Anaphothrips, Scirtothrips* and *Trichromothrips*. Terebrantian genus *Trichromothrips* and four species *Trichromothrips arorai* (Bhatti, 1967), *Trichromothrips priesneri* (Bhatti, 1967), *Hydatothrips aureus* Bhatti, 1973 and *Franklinothrips megalops* (Trybom, 1912) were newly added to NBAIR reference collection (Fig.12).

Trichromothrips arorai

Trichromothrips priesneri

Hydatothrips aureus

Franklinothrips megalops

Fig. 12. Species of thrips from India

Newly reported distribution reports of 12 terebrantian thrips species. Nine species viz., *Indothrips bhushani* Bhatti 1967, *Dendrothrips minutus* (Ananthakrishnan, 1961), *Neohydatothrips gracilipes* (Hood, 1924), *Jakthrips ignacimuthui* Bhatti and

Ranganath, 2006, *Megalurothrips peculiaris* (Bagnall, 1918), *Plutonothrips cus* (Bhatti, 1967), *Pseudodendrothrips suvarna* Bhatti, 1997, *Scirtothrips mangiferae* Priesner, 1932 and *Stenchaetothrips faurei* (Bhatti, 1962) were added to the fauna of Kerala. *Astrothrips stannardi* Bhatti 1967 was added to the fauna of Tamilnadu. *Hydatothrips aureus* Bhatti, 1973 and *Franklinothrips megalops* (Trybom, 1912) were newly added to the fauna of Karnataka.

Four thrips species *viz.*, *Thrips orientalis* (Bagnall, 1915) *Hydatothrips aureus* Bhatti, 1973, *Anaphothrips sudanensis* Trybom, 1911 and *Haplothrips* sp. were given for DNA barcoding.

Network Project on Insect Biosystematics

Chalcidoidea and Ichneumonoidea

Two new species of parasitic wasps were described and illustrated: *Tetrastichus thetisae* (Hymenoptera: Eulophidae) (Fig.13), a gregarious parasitoid reared from the pupa of *Curetis thetis* (Drury) (Lepidoptera: Lycaenidae) on the host plant *Derris* sp., and *Sympiesis thyrsisae* (Hymenoptera: Eulophidae), a gregarious parasitoid reared from the caterpillar of *Gangara thyrsis* (Fabricius) (Lepidoptera: Hesperiidae) on the host plant *Cocos nucifera* L. Additionally, the following host-parasitoid associations were recorded: *Amblypodia anita* Hewitson Lepidoptera: Lycaenidae) with *Parapanteles* sp. (Hymenoptera: Braconidae); *Coladenia indrani* (Moore) (Lepidoptera: Hesperiidae) with *Sympiesis* sp. (Hymenoptera: Eulophidae); *Danaus chrysippus* L. (Lepidoptera: Nymphalidae) with *Sturmia convergens* (Wiedemann) (Diptera: Tachinidae); *Idea malabarica* Moore (Lepidoptera: Nymphalidae) with *Brachymeria* sp. (Hymenoptera: Chalcididae) and *Palexorista* sp. (Diptera: Tachinidae); *Notocrypta curvifascia* Felder & Felder (Lepidoptera: Hesperiidae) with *Cotesia erionotae* (Wilkinson) (Hymenoptera: Braconidae); and *Rapala* sp. (Lepidoptera: Lycaenidae) with an inominate species close to *Aplomya* spp. (Diptera: Tachinidae). This discovery is the first record of *Tetrastichus* as parasitoid of *Curetis thetis, Sympiesis* as parasitoid of *Gangara thyrsis* and *Coladenia indrani*, *Brachymeria* and *Palexorista* as parasitoids of *Idea malabarica*, and *Cotesia erionotae* as parasitoid of *Notocrypta curvifascia*.

Cassidibracon repens	*Sympiesis thyrsisae*	*Tetrastichus thetisae*

Fig. 13. New species of parasitica wasps

Pteromalidae

Studied fauna of Pteromalidae and identified Pteromalidae specimens and published one new species *Halticoptera indica* Sureshan & Gupta in 2015-2016

1. *Nasonia vitripennis* (Walker, 1836)
2. *Trichomalopsis apanteloctena* (Crawford, 1911)
3. *Dipara* Walker
4. *Netomocera* Bouček
5. *Gastrancistrus* Westwood
6. *Pteromalus puparum* (Linnaeus, 1758)
7. *Callocleonymus* Masi
8. *Solenura ania* (Walker)
9. *Halticoptera indica* Sureshan & Gupta (Fig.14)
10. *Cheiropachus quadrum* (Fabricius)
11. *Pseudocatolaccus* nr. *nitescens* (Walker)
12. *Spanlangia* sp.

Fig. 14. *Halticoptera indica* (Pteromalidae)

Ichneumonidae*: Glyptapanteles*

The study was based on 60 populations reared from 35 host species, 100+ individual caterpillar rearings (1100 wasp specimens pinned and 2000 in alcohol) and from 12 different geographical locations of the country (11 states and one Union territory) that represent 26 provisional *Glyptapanteles* species within 8 species-groups (Table 2). Out of 60 populations, phylogenetic analyses were performed on 38 based on mitochondrial cytochrome oxidase subunit I (COI) nucleotide sequences. Maximum likelihood and Bayesian inference methods displayed three and four major discrete *Glyptapanteles* clades, respectively. In clade A very few. The other clades B and C grouped the majority of the Indian species and showed considerable host specificity in both the trees. All parasitic wasp species were gregarious in nature, except for two populations. Three different sets of data (morphology, host records, and COI) were integrated in order to generate accurate boundaries between species/ species-groups. The present study, perhaps the most comprehensive done to date in India, suggests the presence of several additional *Glyptapanteles* species, which were previously unrecognized.

Entomogenous nematodes Biosystematics and diversity in India

In total 133 soil samples were collected randomly from vegetables, banana, rubber, sugarcane, forest land of Marampally, Mudical, Vanjnadu, Kalady, Pala, Nedumudy, Changanassery, Kozhenchery, Chengannur places of Kerala. Koppa, Jayapura, Balehonnur, Rambhapuri, Ganganamakki places from

Karnataka, Kadappa, Ananthagiri, kothavalasa, Araku valley and RARS, Aanakapalle places from Andhra Pradesh. Pune from Maharashtra, J & K, Great Nicobar Island. One *Steinernema* sp. and two *Heterorhabidtis* sp. and one *Oscheius chongmingensis* were from these places.

Table 2. Species-groups of Glyptapanteles in India with total number of species currently within a group. Lepidoptera host families: "?" Unknown. MOR, DNA, BIO: degree of group support by morphological (MOR), molecular (DNA), and biological (BIO) data. "+" Strong support, "-"No support, "P" Partial support, "?" Unknown.

Species-group	Total number of morphospecies within a group	Lepidoptera host families	MOR	DNA	BIO
A3	1	?	+	+	?
A6	1	Erebidae	?	+	?
A7	2	Papilionidae	+	+	+
A8	2	Erebidae	-	-	P
B1 (B1c1, B1c2, B1c3, B1c4)	9	Erebidae, Geometridae, Nymphalidae, Sphingidae	P	P	P
B2	3	Erebidae	-	+	?
B3	7	Erebidae, Noctuidae	P	+	P
C (Cc1, Cc2)	1	Geometridae	+	+	+

Molecular characterization of entomopathogenic nematodes

Ten entomopathogenic nematodes were molecularly characterized by using the ITS regions and a fragment of 28S of the ribosomal DNA were PCR amplified. All nematodes was isolated and molecularly characterized by using the ITS regions and a fragment of 28S of the ribosomal DNA were PCR amplified. The primers used in the study were for ITS regions: 18S F 5'-TTGATTACGTCCCTGCCCTTT-3' and 26S R 5'-TTTCACTCGCCGTTACTAAGG-3' and TW81 F 5'-GTTTCCGTAGGTGAACCTGC -3' and R AB285'- ATATGCTTAAGTTCAGCGGGT -3'. For the D2D3 regions, primer D3A F 5'- GACCCGTCTTGAAACACGGA -3'and D3B R 5'-TCGGAAGGAACCAGCTACTA -3'. The amplified PCR product was checked in 1.4% agarose gel electrophoresis (Fig. 15). The sequence (1-995 bp) was subjected to BLAST at NCBI. NBAIIO62 strain showed 95% identity with *Oscheius chongmingensis* (EU273598.1), NBAIIH64 strain showed 97% and NBAIIH68 strain showed 100% identity with *Heterorhabditis indica* (GU177840.1).

The strains NBAIIS47 and NBAIIS51 showed 100% similarity between them and 97% similarity with *Steinernema siamkayai* (JF892544.1). The strains NBAIIS46, NBAIIS54 and NBAIIS55 showed 100% similarity between them and are 97% similar with *Steinernema siamkayai* (JF892544.1).

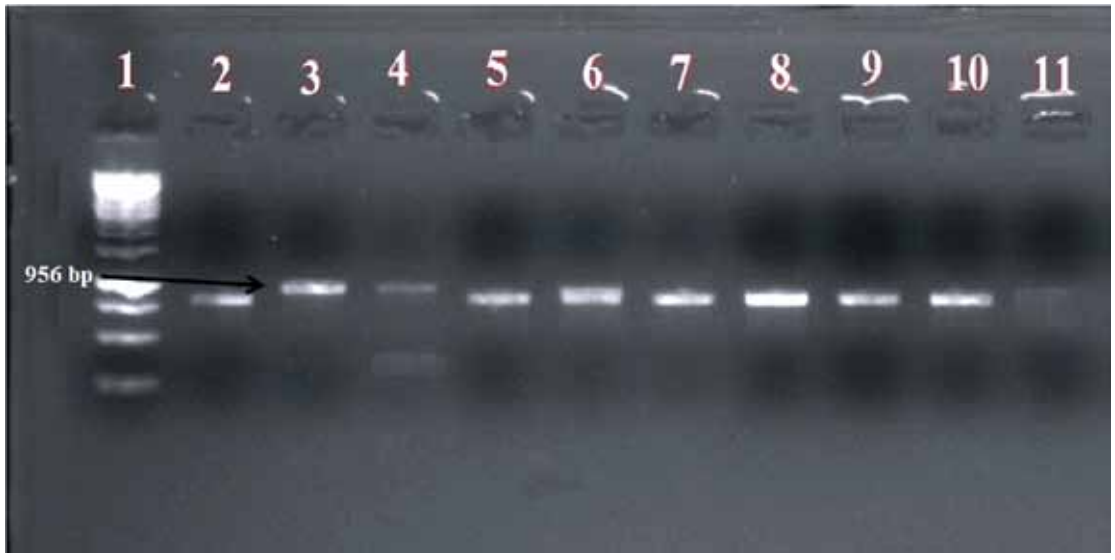


Fig . 15. PCR amplification of internal transcribed spacer (ITS) region Lane 1 1 kb Ladder, Lane2-7 *Steinernema* sp. Lane 8-9 *Heterorhabditis* sp. Lane 10 *Oscheius* sp.

The strain NBAIIS49 showed 97% identity with *Steinernema huense* (KF857581.1) whereas strain NBAIIS60 showed only 85% identity. The strain NBAIIS60 is being further subjected to molecular identification to confirm up to the species level. The sequence alignment of these strains with the closely related species was done using the default parameters of the software MEGA 7.0. The alignments were used to compare the similarities and differences in nucleotides, base composition and size of various sub-units of ITS region of the strains with other species and phylogenetic tree was constructed (Fig. 16).

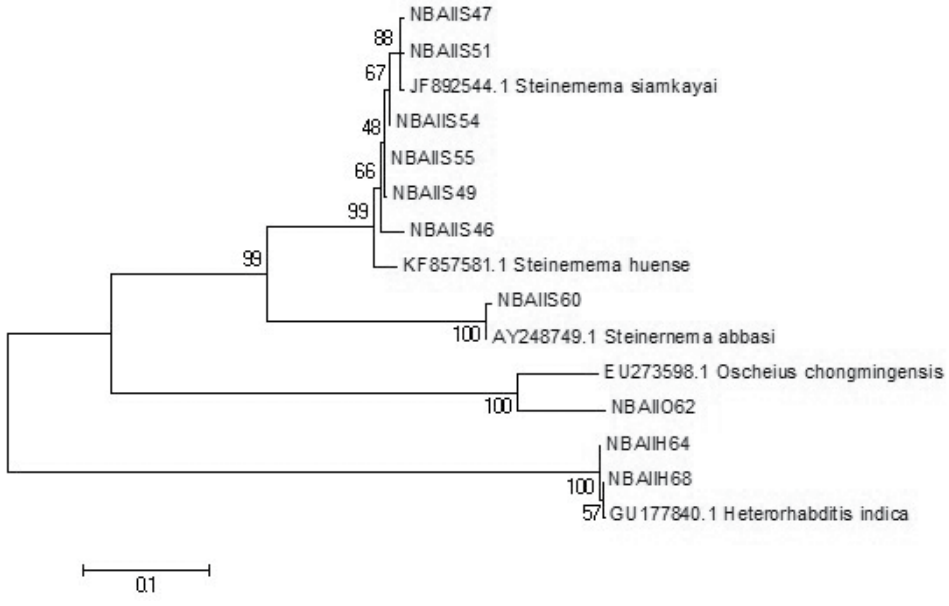


Fig. 16. Phylogenetic relationships of 7 species of *Steinernema* and 2 species of *Heterorhabditis*

Efficacy of entomopathogenic nematodes on phorids.

The pathogenicity of *Heterorhabditis indica*, *Steinernema capocapsae* and *Oscheius chongmingensis* were tested against maggots and pupae. The results showed that *Heterorhabditis indica*, *Steinernema capocapsae* and *Oscheius chongmingensis* failed to infect in maggots nevertheless *Oscheius chongmingensis* caused mortality and also reproduced in pupal stages (Fig. 17).

Fig. 17. Nematodes emerging from the pupa

Ecological characterization of *Heterorhabdtis indica*

Upon completing the maximum exposure time (48 h), 100% IJs survival was recorded at 25°C, however, no nematodes were recovered when exposed at 5 and 40°C. The maximum infectivity capacity of *H. indica* was recorded at 25 and 30°C. Even at 32°C nematodes were able to cause greater mortality but their infectivity was significantly reduced to 47%. There was no infection at 37°C. When comparing the percent penetration between 25 and 35°C, we found that almost 3-flod decrease in nematode penetration at 37°C when compared to 25°C. The nematodes were able to reproduce between 25 and 35°C, and emergence of IJs from cadavers was also observed between 25 and 35°C. We could not find difference in IJs survival between control and oxygen stress condition during 24 h of exposure. However, there was a reduction of IJs survival during 48 to 120 h. The nematode movement and infectivity to galleria larvae was significantly different with soil types (Fig. 18).

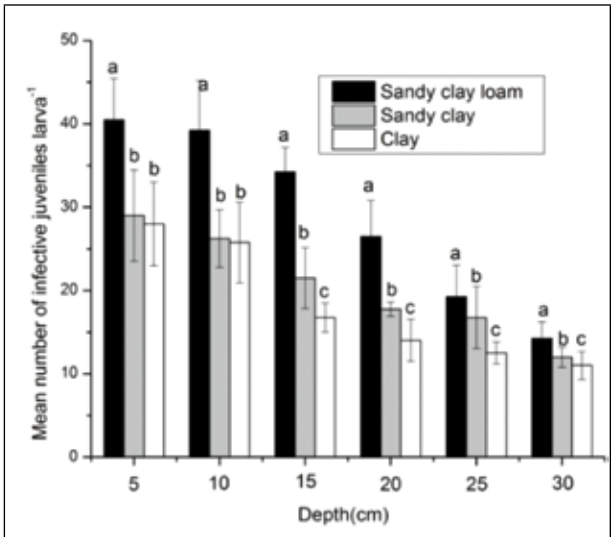


Fig. 18. Number of penetrated nematodes into wax worm hosts at different soil type and depths. Different letters on the top of error bars indicates statistically different values for different soil types at ($P < 0.05$) using Tukey's test. Error bars indicate standard error (n = 5).

Entomopathogenic nematodes: A potential biocontrol agent against Eggplant Ash weevil *Myllocerus subfaciatus* Guerin, (Coleoptera: Curculionidae)

The potential efficacy of two species of entomopathogenic nematodes (EPN), *Steinernema carpocapsae* and *Heterorhabditis indica* against third and pre-pupal stages of eggplant ash weevil, *Myllocerus subfaciatus* was tested under laboratory and semi field

conditions (Fig. 19). *S. carpocapsae* was the most effective species against pre-pupal stages (LC50 after 5 days exposure = 64 nematodes/ pre-pupa). In pot experiment among the EPN species tested *S. carpocapsae* caused significantly greater mortality (20-100%) than the *H. indica* (16-92%) against pre-pupal stages and *S. carpocapsae* caused 16-92% mortality in third instar larvae while *H. indica* caused (12-80%) mortality. Both EPN species were able to reproduce in third and pre-pupal stages of ash weevil, but progeny production rate for *H. indica* was significantly higher than those of *S. carpocapsae*. Our observations also revealed that efficacy of EPNs against *M. subfaciatus* varies with developmental stages of *M. subfaciatus* and EPN species, therefore no generalization can be made (Fig. 20).

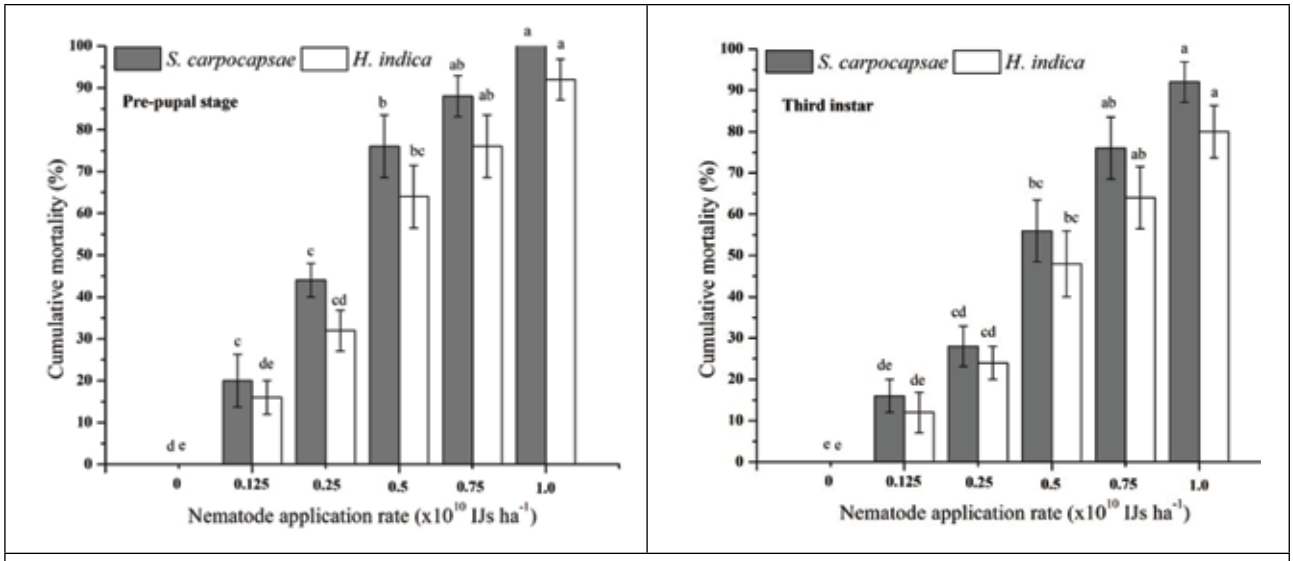


Fig. 19. Mean percentage mortality of third instars and pre-pupal stages of *Myllocerus subfaciatus* exposed for 7 days after treatment (DAT) to different rates of the entomopathogenic nematodes *Steinernema carpocapsae* and *Heterorhabditis indica* in pots with eggplant seedlings. Different letters on the top of error bars indicates statistically different values for different nematode application rate at ($P < 0.05$) using Tukey's test. Error bars indicate standard error (n = 25).

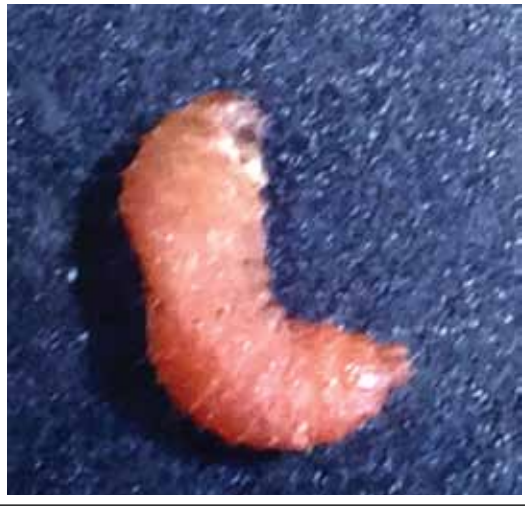


Fig. 20. Ash weevil grub infected with *Heterorhabditis indica*

Compatibility of Indian entomopathogenic nematodes with registered insecticides for *Helicoverpa armigera* (Hubner, 1809) (Lepidoptera: Noctuidae) management.

Among all insecticides tested, Fame® (Flubendiamide), King Dox® (Indoxacarb), Ballista Supar® (lambda-cyhalothrin), Attach® (Profenophos), Prolife super® (Profenophos + Cypermethrin), Monoplus® (Monocrotophos) were compatible with the both nematode species. However, IJs were able to infect *Galleria mellonella* larvae after exposure to these chemicals but their progeny production was significantly ($P < 0.05$) reduced as compared with the distilled water exposed IJs i.e. control treatment. After exposing IJs in Proclaim® (Emamectin benzoate), their survivability is not affected but infectivity of IJs was adversely affected. Both nematode species showed differential sensitivity to these insecticides, with the *H. indica* being more tolerant than *S. carpocapsae* (Table 3).

Table 3. Insecticides registered in India for *Helicoverpa armigera* in pigeon pea, toxicity classification of insecticides; The effect of the treatments on EPNs infectivity over *Galleria mellonella* larvae was classified according Peters and Poullot (2004), based on IOBC guideline

Treatment [a]	*Steinernema carpocapsae*				*Heterorhabditis indica*			
	24 h		48h		24h		48h	
	E%[b]	C[c]	E%	C	E%	C	E%	C
Proclaim®	100.0	4	100	4	100.0	100.0	100.0	4
Fame®	0.0	1	0.0	1	0.0	1	0.0	1
King Dox®	0.0	1	0.0	1	0.0	1	0.0	1
Ballista Supar®	6.7	1	33.4	2	20.0	1	26.7	1
Attach®	46.7	2	60.0	2	13.4	1	60.0	2
Prolife super®	46.7	2	66.7	2	53.4	2	66.7	2
Monoplus®	33.4	2	40.0	2	40.0	2	46.7	2

[a] a.i./ha recommended for aerial application

[b] Treatment effects: E% = 100 - (100 - corrected mortality) × (100×Red). % corrected mortality was null in all treatments and therefore it was not considered in E% calculation.

[c] Toxicity classification of insecticides by IOBC: 1– non-toxic (<30%), 2– slightly toxic (30 to 79%), 3- moderately toxic (80% to 99%) and harmful (>99%).

Fluctuating temperature: A cause for survival and development of entomopathogenic nematodes, *Heterorhabditis indica* (Poinar 1992), and *Steinernema carpocapsae* (Weiser 1955).

We determined the *Steinernema carpocapsae* and *Heterorhabditis indica* IJs survival ability by exposing the IJs to various temperatures directly without preconditioning. Results showed that the maximum exposure time (48 h) at 25 and 40°C, the percentage survival of *S. carpocapsae* ranging from 100% to 32.93%. Whereas in case of *H. indica* 100% survival was observed after exposing to the 25°C, however at 40°C, we could not notice the IJs survivability. Further, if these IJs were used as inoculum source, the percent penetration was reduced (Table 4) and, even more importantly, progeny production was very less on *Galleria mellonella*.

Table 4. Analysis of variance for survival and penetration of *Steinernema carpocapsae* and *Heterorhabditis indica* infective juveniles after exposing to different temperature regimes. Factors in the analysis include temperature regimes (T), time of exposure (Te), and nematodes species (N)

Source	Survival (%)			Penetration (%)		
	d.f.	*F* value	*P*	d.f.	*F* value	*P*
Temperature (Te)	4	1357.93	< 0.0001	3	25.61	< 0.0001
Nematode (N)	1	709.77	< 0.0001	1	7.03	0.0101
Time (T)	1	193.46	< 0.0001	1	41.77	< 0.0001
N X Te	1	3.25	0.0750	1	9.00	0.0038
N X T	4	212.52	< 0.0001	3	4.71	0.0050
T X Te	4	37.83	< 0.0001	3	5.91	0.0013
Te X N X T	4	55.40	< 0.0001	3	2.75	0.0501

Survival and reproduction entomopathogenic nematodes exposed to poultry manure

One of the eco-friendly alternate methods is by using biological agents such as entomopathogenic nematodes. It was therefore endeavored to test their survival capacity in poultry manure, since manure contains ammonia that is toxic to EPNs. In a study the survivability of *Steinernema feltiae*, *Heterorhabditis indica*, *S. carpocapsae*, *S. glaseri* and *S. abbasi* for 24 h (85.25%, 83.25%, 73%, 45%, 15.25%) 48 h (62.75%, 58%, 52.25%, 9.75%, 0%) 72 h (48.75%, 31.25%, 28%, 2.5%, 0%) and 96 h (23.75%, 12.25%, 14.25%, 0%, 0%) respectively. Further, after exposing these nematodes to manure at 24 and 48 h we have tested their virulence capacity against wax moth *Galleria mellonella*. The results of this study showed all the nematode species were able cause 100% mortality in *G. mellonella* after being exposed to the manure. However their progeny production was significantly reduced. Progeny production assay revealed that approximately 2.5 lakh IJs were harvested from the cadaver that had been killed by fresh IJs and approximately 20000 IJs were harvested from the cadaver that had been killed by IJs after exposing to the poultry manure. These data showed that poultry manure drastically reduced the survivability of nematodes and also reduce the progeny production.

Efficacy of entomopathogenic nematodes on developmental stages of house fly, *Musca domestica*

The potential efficacy of five species of entomopathogenic nematodes (EPN), *Heterorhabditis indica*, *S. carpocapsae*, *S. glaseri*, *S. abbasi* and *S. feltiae* against developmental stages of house fly was studied under laboratory condition. All the tested EPN species were not infected egg and pupal stages, while the second and third instar maggots were susceptible to all EPN species but second instar was more susceptible than third instar (Fig. 21). Among the EPN species tested, *S. carpocapsae* caused significantly greater mortality (81.25-100%) than the *H. indica* (62.5-100%), *S. glaseri* (25-100%), *S. abbasi* and *S. feltiae* (6.25-100%) against second instars of *M. domectica*. Whereas, *H. indica*

caused significantly greater mortality (18.75-100%) than the *S. carpocapsae, S. glaseri, S. abbasi* and *S. feltiae* (6.25-100%) against third instars of *M. domestica* at 50-10000 IJs/maggot. When nematodes inoculated to artificial diet and manure containing maggots, we noticed that EPN species caused up to 81.25% mortality at concentration of 10000IJs/ maggot however, in the manure 25% mortality was recorded at 256000IJs/maggot. The decrease in larval mortality in manure suggests that biocontrol of housefly by using EPNs is unlikely. This may be because of poor survival and limited movement of nematodes in poultry manure which may be due to ammonia, other toxic substances in poultry manure.

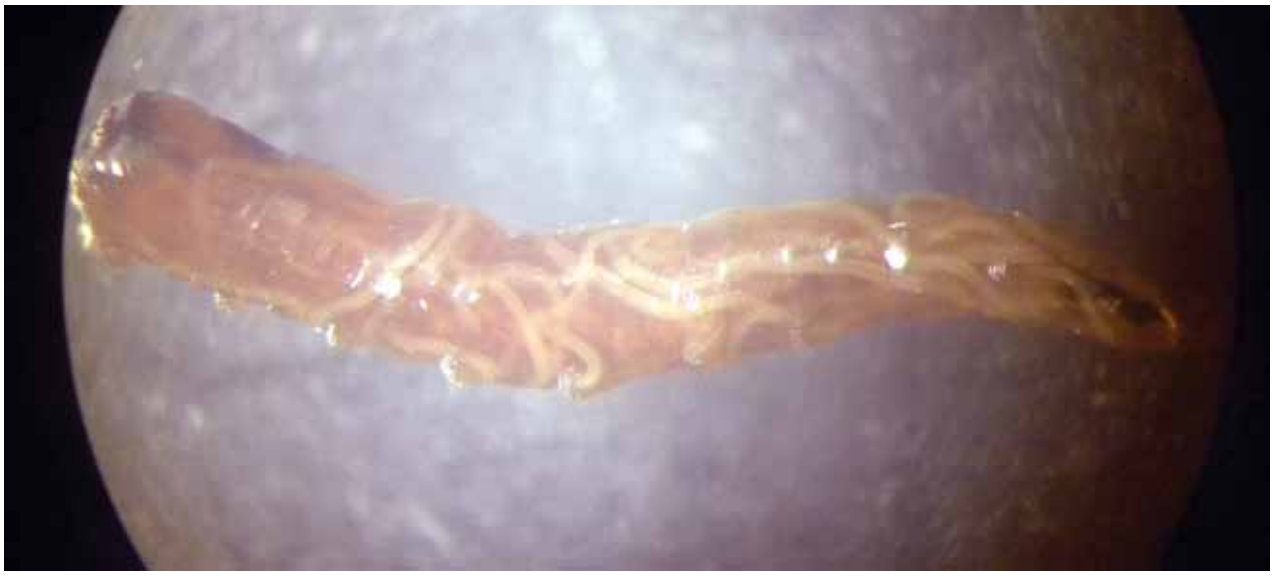


Fig 21. House fly maggot with first generation *Heterorhabditis indica*

Pathogenicity of entomopathogenic nematodes against coconut and arecanut white grubs

In laboratory assays, lethal nematode concentration for 50% grub mortality values showed that *H. indica* was the most virulent against both first and second instars grub than *S. abbasi.* Among the EPN species tested, *H. indica* caused significantly greater mortality (30-95%) than the *S. abbasi* (15-70%) against first instar grubs. Whereas, H. indica caused significantly greater mortality (20-80%) than the *S. abbasi* (5-55%) against second instars grubs at concentration of 200-3200 IJs/grub respectively. A significant differences were found in the percentage reductions of the grubs at different larval stage applications. First instar grubs were more susceptible than second instar. In field experiment, *H. indica* caused second instar grub mortality of between 63% and 81% at concentrations of 1.25 and 2.5 x 10^9 IJs/ha, respectively. The arecanut yields from the nematode-treated plots at 2.5 x 10^9 IJs/ha were at least 56 and 14% higher than those from the water control and the chlorpyrifos treated plots. The cost-benefit analysis showed that H. indica is promising agents for *L. lepidophora* grub control in arecanut fields. It is concluded that H. indica have good potential for safe management of *L. lepidophora* in arecanut production.

DIVISION OF MOLECULAR ENTOMOLOGY

Molecular characterization and DNA barcoding of some agriculturally important insect pests

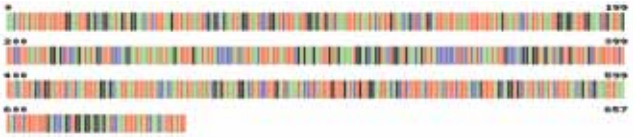
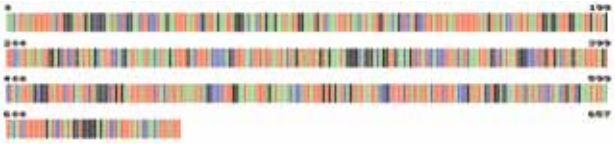
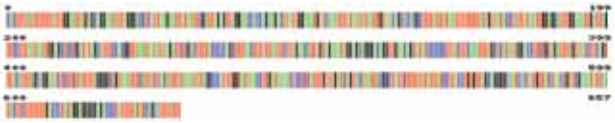
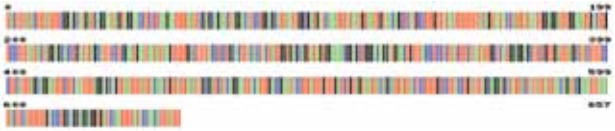
Collection of various insects was made from different parts of the country and identified insects were subjected to molecular characterization. Insect collected from Kaas Plateau, Maharashtra and from Madurai, Tamil Nadu, were subjected to community analysis. Molecular characterization of 156 insects, consisting of 71 species and 30 populations done. These insects belonged to Coleoptera (7 families), Diptera (5 families), Hemiptera (16 families), Lepidoptera (21 families), Odonata (8 families) and Ixodida (1). The species composition was Coleoptera (11 species), Diptera (7 species), Hemiptera (30 species), Lepidoptera (93 species / populations), Odonata (15 species) and Ixodida (1 species) (Table 5).

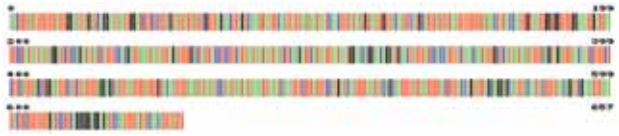
A bottle was received from a pharmaceutical company containing fragments of insect species like antennae, two leg pieces, a portion of abdomen and two intact wing pieces for identification. The wing pieces given to the taxonomists suggested that the wing fragment belonged to a calyptrate dipteran - Sarcophagidae / Calliphoridae relative. Furthermore, DNA barcoding based identification was employed to determine the identity by amplifying *COX1* mitochondrial gene, which was 658 bp size and GenBank accession number and barcode were generated, *viz*., KT368817 and VETIP006-15, respectively. Our sequence matched 100% with GenBank accession nos. GQ409351 and JF439551 and identity determined was as *Pollenia rudis* (Fabricius 1794) (Diptera: Calliphoridae). The present work highlights that DNA barcoding based identification tool a powerful and imperative in determining the identity of insect, even if a part or fragment of the specimen is available. This method can be used for insect identification wherever fragments are available, which can lead to preventive measures.

During a trip to Kaas Plateau, Satara District, Maharashtra, several insect specimens were collected, which belonged to seven insect orders, *viz*., Lepidoptera, Coleoptera, Hemiptera, Hymenoptera, Diptera, Orthoptera and Thysanoptera. Based sequence analysis ofe subunit I MT-CO1 gene,14 different insect species were identified, of which 7 could be identified up to species level, *viz*., *Adoretus duvauceli*, *Apis florae*, *Blepharella lateralis*, *Coelophora bissellata*, *Eoophyla excentrica*, *Gynaikothrips uzeli* and *Erionota torus*. The results suggested that 50% of the community could be identified to species level with MT-CO1 gene and at least about 8 specimens could be new species for India. The quantification of biodiversity also revealed that 80% of specimens were pollinators giving status to this region as “Plateau of Flowers”. It is possible to employ MT-CO1 gene for quick, reliable and authentic identification of insect biodiversity, which otherwise requires a laborious process.

GenBank accession number for 156 insect specimens and Barcodes for 14 insects were obtained from NCBI and BOLD systems, respectively.

Table 5. DNA barcodes of some insects

Sl. No.	Name of Insect, GenBank accession number and Barcode number	Barcode	Photo
Lepidoptera			
1	*Leucinodes orbonalis* KP260782_ AGIMP046-16		
2	*Maruca vitrata* KT070893_ AGIMP047-16		
Coleoptera			
3	*Oenopia mimica* KR349052_ AGIMP043-15		
4	*Oenopia sauzeti* KR349051_ AGIMP042-15		
Diptera			
5	*Pollenia rudis* KT368817_ VETIP006-15		
6	*Bactrocera cucurbitae* KP233798_ AGIMP048-16		
Hemiptera			
7	*Uroleucon sonchi* KR026974_ AGIMP049-16		

8	*Greenidea psidii* KR349049_ AGIMP050-16		
Ixodida			
9	*Rhipicephalus microplus* KP318133_ VETIP007-16		

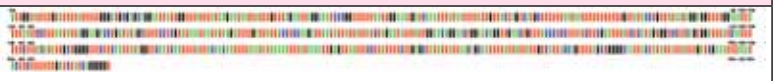
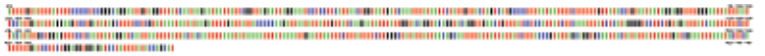
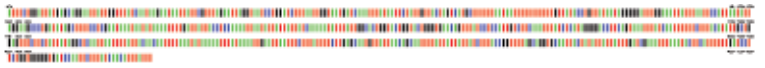
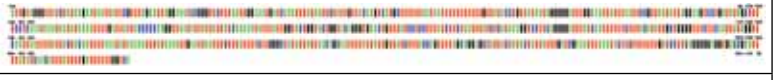
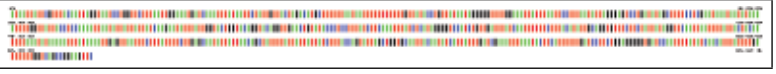
Molecular Characterization and DNA barcoding of Agriculturally Important Parasitoids and Predators

Different parasitoids, predators and other insects were collected from Andaman & Nicobar Islands, Srinagar, Pune, Anand, Varanasi, Dharmapuri and Bangalore and were used for DNA barcoding studies. Parasitoids belong to Braconidae *viz*., *Glyptapanteles* sp. (Barcode: ACZ3549) (Genbank Acc. No. KR260984), *Glyptapanteles* sp (*AAI5405) (*KT284335), *Glyptapanteles* sp (ACZ3433) (KT25318), *Microplitis maculipennis* (ACV9232) (KP759295), *Glyptapanteles creatonoti* (AAH1199) (KR021154), *Glyptapanteles* sp (ACZ3493) (KT254316), *Glyptapanteles obliquae* (Wilkinson) (ACS3730) (KR021152), *Glyptapanteles aristolochiae* (Wilkinson) (ACZ3726) (KR021156), *Glyptapanteles cf. spodopterae* Ahmad *(*ACS3730) (KR260983), *Glyptapantelesspodopterae* (ACS3730) (KR260976), *Glyptapanteles* sp (AAH1199) (KT284334), *Glyptapanteles* sp (ACZ3303) (KT254319), *Glyptapanteles obliquae* (Wilkinson) (AAH1199) (KR021152),*Glyptapanteles cf. amprosemae* Ahmad (ACZ3016) (KT284342).Phylogenetic analyses were performed on 38 based on mitochondrial cytochrome oxidase subunit I (COI) nucleotide sequences. Maximum likelihood and Bayesian inference methods displayed three and four major discrete *Glyptapanteles* clades, respectively. DNA barcode has been generated for different parasitoids and predators including indigenous and exotic species of trichogrammatids (Table 6 and Table 7).

Furthermore, a study was conducted to identify and differentiate *Trichogramma* species and infer their evolutionary relationship based on the two molecular marker loci, internal transcribed spacer-2 (ITS-2) and cytochrome oxidase I (COI). With available related species sequences of COI and ITS-2 loci, Bayesian phylogenetic trees for total 84 and 76 Trichogrammatids sequences were considered to understand evolutionary relationship among the different species and their identification. Most of the species are correctly identified in the respective clades using the ITS-2 as compare to COI. We performed comparative assessment of mean intra- and inter- specific evolutionary distances of using COI and ITS-2 based on the Kimura-2-parameter (K2P) model.

In case of ITS-2 locus, we estimated the low intra- and high inter-specific distances for the different groups in trichogrammatids.Overall, we suggest that ITS-2 is appropriate molecular marker for our mentioned species identification in Trichogrammatids, at both species and genera level (Table 6). The following insect pests *viz*., flea beetle on solanum *Longitarsus* sp., (KU752535), leaf minor on mustard *Delia platura* (KU752538), flea beetle on turnip *Phyllotreta striolata* (KU752539), flea beetle on plum and cherry *Altica* sp. (KU752540) and the predators *viz*., green lacewing *Chrysoperla* sp., (KU752535) and syrphid fly on crucifers *Sphaerophoria philanthus* (KU752537) were characterized and obtained GenBank acc. nos. (Table 7).

Table 6 : DNA barcoding of different species of trichogrammatids using CO1 gene

Sl. No.	Scientific Name	Barcode ID	DNA barcode
1.	*Trichogramma brassicae* (Italy)	AAD6262	
2.	*T. pretiosum* (thelytokous)	ACS7056	
3.	*T. cordubensis*	ACS6228	
4.	*T. brassicae* (Italy)	AAD6262	
5.	*T. cacoeciae*	ACS7055	
6.	*T. semblidis*	ACS5856	
7.	*T. chilonis*	ACG5640	
8.	*Tr. armigera*	ACV9389	
9.	*T. pretiosum* (Colombia)	ACE5676	
10,	*T. danausicida*	ACS5878	
11.	*T. dendrolimi*	AAE8562	
12.	*T. hebbalensis*	ACS5857	

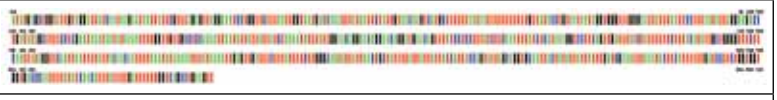
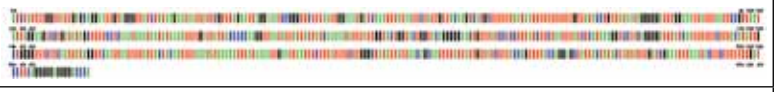
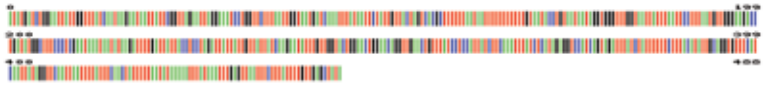
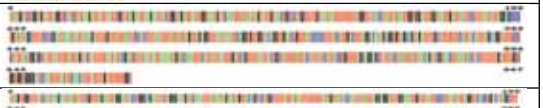
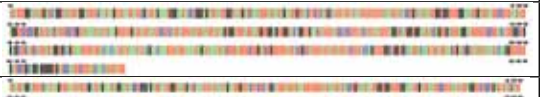
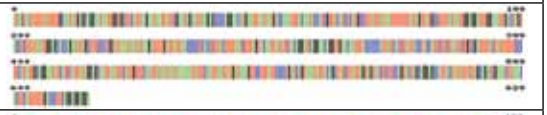
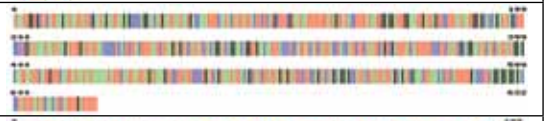
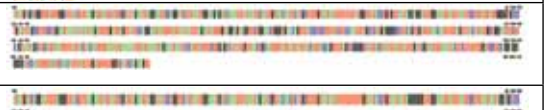
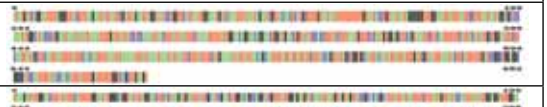
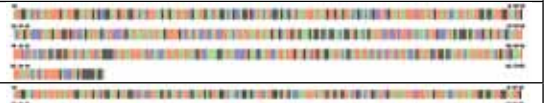
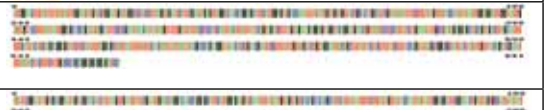
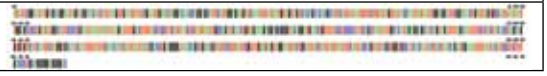
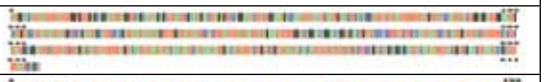
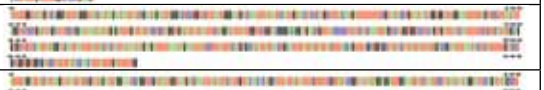
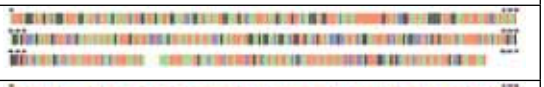
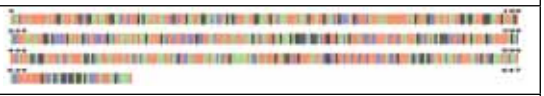
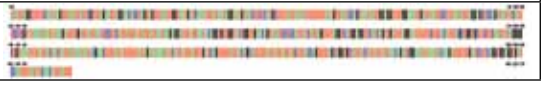
13.	*T. mwanzai*	ACS6174	
14.	*T. chilotraeae*	ACS6424	
15.	*Tr. robusta*	ACV5432	
16.	*T. evanescens* Arrhenotokous	ACS5878	
17.	*Tr. bactrae*	ACS5855	
18.	*T. japonicum*	ACV5662	
19.	*T. embryophagum*	ACS5854	
20	*T. cordubensis*	ACS6228	

Table 7. DNA Barcoding Of Agriculturally Important Insects

Sl. No.	Name of the species	Barcode ID	Gen bank Acc.no.	DNA barcode
1	*Apis dorsata*	AAB2275	KJ513470	
2	*Aphidius colemani*	AAC7809	KM054519	
3	*Aphidius ervi*	AAA4188	KM054518	
4	*Habrobracon hebetor*	AAN5769	KJ627789	
5	*Chelonus blackburni*	ACI1219	KF365461	
6	*Cotesia* sp.	ACS4950	KT308157	
7	*Glyptapanteles* sp.	ACZ2913	KP153535	
8	*Glyptapanteles* sp.	ABY9539	KR080479	
9	*Cotesia erionotae*	ACY9028	KR080481	

10	*Leiophron* sp.	ACY9005	KR809409	
11	*Microplitis maculipennis*	ACV9232	KP759288	
12	*Brachymeria tachardiae*	ACY9096	KP055618	
13.	*Lasioglossum albescens* (Smith, 1853)	AAN4354	KR076766	
14	*Lasioglossum albescens* (Smith, 1853)	ACY9356	KR076767	
15	*Lasioglossum albescens* (Smith, 1853)	ACV6441	KR076768	
16	*Lasioglossum albescens* (Smith, 1853)	ACV7852	KR076769	
17	*Macroteleia* sp.	ACS6491	KM095503	
18	*Isolia indica*	ACQ3324	KJ489423	
19	*Sceliocerdo viatrix*	ACQ1881	KF938928	
20	*Chartocerus* sp.	ACZ2667	KR809410	
21	*Coccophagus* sp.	AAL7556	*KF938924*	
22	*Myiocnema comperei*	ACQ5354	KJ955498	
23	*Orius laevigatus*	ABA3642	KM016075	
24	*Cardiastethus affinis*	ACQ3908	*KJ955496*	
25	*Amphiaerus constrictus*	ACQ3908	*KF817577*	
26	*Buchananiella indica*	ACY9057	*KF383325*	
27	*Blaptostethus pallescens*	ACI1757	*KF365463*	
28	*Xylocoris flavipes*	ACI2060	*KF365462*	

29	*Ropalidia* sp.	*ACQ1746*	KM054517	
30	*Praleurocerus viridis*	ACQ5173	*KJ955497*	
31	*Blepyrus insularis*	*ACQ5173*	*KJ850500*	
32	*Aenasius advena*	*ACQ1478*	*KJ850498*	
33	*Neastymachus axillaris*	*ACS7146*	*KM095502*	
34	*Pseudleptomastix mexicana*	*ABY0168*	*KJ955495*	
35	*Leptomastix nigrocincta*	*ACQ1256*	*KJ489424*	
36	*Megastigmus* sp.	*ACH7698*	*KF938926*	
37	*Megachile manthracina*	*ACQ5048*	*KF861940*	
38	*Pristomerus sulci*	*ACS4928*	*KM875667*	
39	*Diglyphus isaea*	*ACQ6186*	KM016074	
40	*Tetrastichus schoenobii*	*ACS4504*	*KJ627790*	
41	*Aprostocetus gala*	*ACQ6186*	KF817576	
42	*Parachrysocharis* sp.	*ACY9081*	KR080480	
43	*Curinus coeruleus*	*ACQ5004*	KJ740391	
44	*Brumoides suturalis*	*ABX2096*	KJ850497	
45	*Cryptolaemus montrouzieri*	*AAD6040*	*KM016073*	
46	*Scymnus nubilus*	*AAP7968*	*KF861939*	
47	*Hyperaspis maindroni*	AAU6400	KJ850499	
48	*Cheilomenes sexmaculata*	*ACM3340*	*KF998579*	
49	*Brachymeria* sp.	*ACY9096*	*KP055618*	
50	*Glyptapanteles* sp.	ACZ3549	KR260984	

MOLECULAR CHARACTERIZATION AND DNA BARCODING OF SUBTERRANEAN INSECTS

Scarabaeids, termites and collembolans

The collection of the beetles was restricted to the phytophagous group, belonging to the subfamilies, Melolonthinae, Rutelinae, Cetoninae and Dynastinae. The scarabaeid collections were made from various geographical locations across the country, which included the states of Andhra Pradesh (Tirupathi, Samarlakota, Anakapalli), Arunachal Pradesh (Phasighat), Gujarat (Anand), Himachal Pradesh (Shimla) , Jammu & Kashmir (Kargil), Karnataka (Shivamoga, Belgaum, Hassan, Mudigere, Sirsi, Sringeri and Udupi), Tamilnadu (Ooty, Dindigul, Dharmapuri, Hosur,Tirunelvelli, Theni), Kerala (Kannur, Thrissur and Wayanad), Meghalaya (Tondon). Telangana (Hyderabad).

The populations were collected from from cultivated fields and wetlands from three geographic locations Tirupathi (AP), Hosur (TN) and Karnataka (Bangalore, Mandya, Malur, Shivamoga, Belgaum)

Molecular characterization

The CO1 region was amplified using the CO1 forward (**F:**5'-GGTCAACAAA TCATAAAGATATTGG-3') and reverse primers (**CO1 R:** 5'-TAAACTTCAGGGTGA CCAAAAAATCA-3') for the isolated DNA from beetle samples.

The PCR products were sequenced and analysed using BLASTn and the similar sequences were found and the gaps were removed to match 100% with the other sequences and the phylogenetic relationship was assessed by constructing a phylogentic tree. The sequence data's was submitted to NCBI and accession numbers were obtained (Tables 8, 9).

Identification of scarabaeids, termites and collembolans

The beetle and termite specimens collected from different geographical locations in India, were preserved in 70% absolute alcohol and stocked at the Division of Molecular Entomology; The beetle specimens were identified at the Department of Entomology, GKVK, Bangalore and Division of Entomology, IARI, New Delhi, and the termites were identified at the Wood Biodegradation Division , Institute of Wood Science Bangalore. The collembolan samples were identified at the Apterygota section, Zoological Survey of India, Kolkata and Department of Entomology, Institute of Agricultural Sciences, BHU,Varanasi.

The adult beetles were morphologically identified based on the types of antennae, mandibles, maxillae, presence and absence of stridulatory organs and tarsal claws, while the grubs were identified based on the anal slit, raster pattern, spiracles and legs. The termites were identified based on the morphology of the soldier caste *viz.,* length of the antennae, shape of the mandibles, relative position of mandibular tooth, shape and size of the head, labrum, fontanelle and shape of postmentum and pronotum. The collembolans were differentiated based on the shape of the body (elongated, round and podomorphid) and

antennae, presence or absence of furculum , ungiculus on hind leg and collophore and abdominal chaetotaxy,

Studying the morphological characters requires laboratory rearing of the insects (Fig. 22) to enable availability of the various life stages of the pest (grubs and adults) for precise taxonomic identity. Rearing of the grubs in to adults convincingly establishes the species associated and their delineation and also facilitates molecular techniques to link identified adult specimens to unidentified larval specimens. Molecular identification is needed because larvae are difficult to rear to adults in the laboratory due to their long life cycle and high mortality and light trap catches of adult beetles cannot establish direct link between those caught and present in the ecosystem due to the mobility of the beetles. An effective and simple technique for rearing of root grubs under laboratory conditions on sliced carrots was developed.

***Holotrichia serrata* Fabricius and *Anomala dimidiata* Hope were successfully reared**

Fig. 22. Laboratory rearing of root grubs

Taxonomy and diversity of Indian Sphecidae

Around 2000 specimens were collected by 48 field survey conducted from the following states *viz*., Karnataka, Tamil Nadu, Kerala, Goa, Rajasthan, Gujarat, Odisha, Andaman Island and Mizoram using yellow pan trap and sweep net methods. Collected specimens were sorted out, processed, mounted and labeled. Generic level identification were made for the genus viz., *Sphex, Tachysphex, Trypoxylon, Sceliphron, Larra, Liris, Bembix, Cerceris, Chalybion, Carinostigmus, Stigmus* and *Tzustigmus*. Species level identification was done for Genus *Carinostigmus, Tzustigmus* and *Sphex*.

Table 8. Characterisation of some scarabaeids based on CO1 gene

S.N	Code	Identification	Sub family	Place of collection	Source	GenBank accession
Andhra Pradesh						
1	Anaka-SCG-1	*Holotrichia consanguinea*	Melolonthinae	Anakapalle	Sugarcane	KU35553
2	Samarla-SCG-1	*Holotrichia consanguinea*	Melolonthinae	Samarlakota	Sugarcane	KU35552
3	TPT-SC-5	*Protaetia*	Cetoninae	Tirupathi	Pigeon pea	KM657490
Arunachal Pradesh						
4	Phas-SC-14	*Maladera insanabilis*	Melolonthinae	Phasighat	Light trap	KU35551
5	Phas-SCG-14	*Maladera insanabilis*	Melolonthinae	Phasighat	Potato	KU35551
6	Phas-SC-1	*Protaetia*	Cetoninae	Phasighat	Light trap	1762766
7	Phas-SC-3	*Protaetia* sp.	Cetoninae	Pasighat	Lighttrap	1762769
Gujarat						
8	Guj SC-2	*Adoretus cupreus*	Rutelinae	Anand	Light trap	KT254249
9	Guj Sc-4	*Adoretus falvus*	Rutelinae	Anand	Light trap	KT254250
Himachal Pradesh						
10	Shimla-SC-1	*Anomala* sp.	Rutelinae	Shimla	Potato	1762765
Karnataka						
11	DAS-SC-1	*Anomola* sp.	Rutelinae	Dasarahalli	Light trap	KM657492
12	Shimla-SC-1	*Schizonycha* sp.	Melolonthinae	Shimoga (Karnataka)	Millets	1762749
13	DAST SC-14	*Holotrichia serrata*	Melolonthinae	Dasarahalli,	Light trap	KT254245
14	DAST SC- 16	*Protaetia cuprea ignicollis*	Cetoninae	Dasarahalli	Light trap	KT203778
15	DAST SC-19	*Anomala ruficapilla*	Rutelinae	Dasarahalli,l	Light trap	KT254246
16	Yella-Sc-1	*Exomala pallidipennis*	Rutelinae	CRPF Campus	Light trap	KU317746
17	Rajan-SCG-1	*Onthophagus nuchicornis*	Scarabaeinae	Rajankunte	Dung	KU517666
18	Nand-SC-3	*Copris tripartitus*	Scarabaeina	Nandi Hills	Cow Dung	KU665396
19	Nandi –SC-1	*Onthophagus coenobita*	Scarabaeinae	Nandi Hills	Cow Dung	KU665397
20	Doddashiv-Sc-1	*Phyllopertha horticola*	Scarabaeidae	Doddashiva	Light trap	KU317744

21	Chin-SCG-1	*Onthophagus nuchicornis*	Scarabaeinae	Chintamani	Cow dung	KU517667
22	Mudhi-SC-2	*Onthophagus auritus*	Scarabaeinae	Mudhigeri	Light trap	KU665398
23	Mudhi-SC-3	*Aethina concolor*	Nitidulinae	Mudhigeri	Light trap	KU665399
24	Mudhi	*Basilepta* sp.	Scarabaeinae	Mudhigeri	Light trap	KU665400
25	Mudhi-SC-4	*Onthophagus auritus*	Scarabaeinae	Mudhigeri	Light trap	KU665401
26	Sringeri SCG	*Leucopholis lepidophora*	Melolonthinae	Sringeri	Areca nut	KU665428
27	Shivamoga SCG	*Leucopholis lepidophora*	Melolonthinae	Shivamoga	Areca nut	KU665428
28	Thirthahalli SCG	*Leucopholis lepidophora*	Melolonthinae	Thirtahalli	Areca nut	KU665428
29	Belgaum SCG	*Leucopholis.burmeisteri*	Melolonthinae	Belgaum	Areca nut	KU665432
30	Sirsi SCG	*Leucopholis lepidophora*	Melolonthinae	Sirsi	Areca nut	KU665428
31	Chik- SCG	*Leucopholis.burmeisteri*	Melolonthinae	Chikmagalur	Areca nut	KU665432
Kerala						
32	Kannur SCG	*Leucopholis burmeisteri*	Melolonthinae	Kannur	Arecanut	KU665432
33	Thrissur SCG	*Leucopholis coneophora*	Melolonthinae	Thrissur	Coconut	KU665428
34	WayanadSCG	*Leucopholis lepidophora*	Melolonthinae	Sultan Betheri	Arecanut	KU665428
Meghalaya						
35	MGH-SC-1	*Anomola* sp.	Rutelinae	Shillong	Light trap	KM657491
36	MGH-SC-2	*Protaetia* sp.	Cetoninae	Shillong	Light trap	KM657489
Tamilnadu						
37	Anekal SC-1	*Phyllopertha horticola*	Rutelinae	Anekal SC-4	Light trap	KT203779
38	OOTY-SC-11	*Heterorrhina sp.*	Cetoninae	Ooty	Light trap	KM657485
39	Ooty-SC-14	*Protaetia* sp.	Cetoninae	Ooty	Lightb trap	KM657486
40	G-SC-1	*Protaetia* sp.	Cetoninae	Gudalur		1762776
41	G-SC-2	*Protaetia* sp.	Cetoninae	Gudalur	Light trap	1762777
42	Valam SC- 1	*Exomala pallidipennis*	Rutelinae	Valampari	Potato	KT203780
43	Then-GB-1(a)	*Anomala dimidata*	Rutelinae	Theni	Sugarcane	KU517668
44	Then-GB-1(b)	*Anomala dimidata*	Rutelinae	Theni	Sugarcane	KU517664

45	Then-GB-2(a)	*Calicnemis obesa*	Dynastinae	Theni	Sugarcane	KU517665
46	Then-GB-2(b)	*Oryctes rhinoceros*	Dynastinae	Theni	Coconut	KU517993
Uttar Pradesh						
47	Aliig-SC-1	*Apogonia* sp.	Melolonthinae	Aligarh (UP)	Millets	1762764
48	KPT-SC-1	*Alissonotum* sp.	Dynastinae	Kapatganj (UP)	Light trap	1762754

Table 9 : Characterization of some termites based on CO1 gene

S. No.	Code	Identification	Sub family	Location	Source	Genbank accession
Andhra Pradesh						
1	TPT-TE-1	*Odontermes obesus*	Macrotermitinae	Tirupathi	Forest	174056
2	Anak-TE-1	*Odontotermes obesus*	Macrotermitinae	Anakapalle	Sugarcane	KU 687341
3	Samarla-TE-1	*Odontotermes obesus*	Macrotermitinae	Samarlakota	Sugarcane	KU687342
Arunachal Pradesh						
4	Phas-T-1	*Macrognathotermes errator*	Macrotermitinae	Phasighat	Mandarin	KM657477
5	Phas-T-2	*Odontermes mathurai*	Macrotermitidae	Phasighat	Mandarin	KM657487
Karnataka						
6	DAST-3	*Euhamitermes hamatus*	Apicotermitinae	Bangalore	Neem	KM657484
7	Hebbal	*O. gurdaspurensis*	Macrotermitinae	Bangalore	Mound	KM657483
8	Attur	*O.gurdaspurensis*	Macrotermitinae	Bangalore	Mound	KM657481
9	Yellahanka	*O.gurdaspurensis*	Macrotermitinae	Yellahanka	Neem	KM657480
10	Rajan-T-2	*Microtermes mycophagus*	Macrotermitinae	Bangalore	maize	KM657479
11	Hessaraghatta	*Odontotermes longignathus*	Macrotermitinae	IIHR	Vegetable	KU687338
12	Marat TE-1	*Hypotermes xenotermitis*	Macrotermitinae	Marathahalli	Vegetable	KT274764
13	Attur TE-8	*Odontotermes longignathus*	Macrotermitinae	Attur	Vegetable	KT254244
14	Sivaganga TE-3	*Hypotermes makhamensis*	Macrotermitinae	Sivaganga	Vegetable	KT274765
15	Mys TE-2	*Hypotermes xenotermitis*	Macrotermitinae	Mysore	Teconia	KT224387
16	Thirthahalli	*Odontotermes -wallonesis*	Macrotermitinae	Thirtahalli	Arecanut	KT224388

17	Belgaum	*Odontotermes holmgren*	Macrotermitinae	Belgaum	Arecanut	KT224389
18	Sirsi	*Nasuitermes* sp.	Nasutitermitinae	Sirsi	Arecanut	KT224390
19	Mudhi	*Dicuspiditermes Krishna*	Macrotermitinae	.Mudigere	Eucalyptus	KT224391
20	Mudhi-SC-2	*Adoretus bicolor*	Rutelinae	Mudhigeri	Grapevine	KT224392
21	Mudhi-SC-3	*Odontotermes holmgren*	Macrotermitinae	Mudhigeri	Arecanut	KT224393
22	Chikmagalur	*Odontotermes -wallonesis*	Macrotermitinae	Chikmagalur	Arecanut	KT224394
23	Udupi-TE-1	*Microtermes obesi*	Macrotermitinae	Udupi	Neem	KM657488
24	Sring-TE-2	*Nasuitermes*	Nasutitermitinae	Sringeri	Arecanut	KT224395
Kerala						
25	Kannur	*Odontotermes holmgren*	Macrotermitinae	Kannur	Arecanut	KT719275
26	Thrissur	*Odontotermes longignathus*	Macrotermitinae	Thrissur	Coconut	KT719274
27	Wayanad	*Odontotermes holmgren*	Macrotermitinae	Kalpetta	Arecanut	KT719276
Meghalaya						
28	Megh-TE-1	*Odontotermes mathuri*	Macrotermitinae	Meghalaya	Pigeon pea	KM647487
Tamilnadu						
29	Ooty-TE-4	*Nasutitermes octopilis*	Macrotermitinae	Ooty	Eucalyptus	KM657478
30	Ooty TE-5	*Nasutitermes exitiosus*	Macrotermitinae	Ooty	Mound	KM 015487
31	Thangdi T-1	*Neotermes koshunensis*	Kalotermitidae	Dindigul	Guava	KM657485
32	Uddanpl-TE-1	*Hypotermes xenotermitis*	Macrotermitinae	Uddanpl	Eucalyptus	KU687340
33	Theni -1	*Nasutitermes exitiosus*	Macrotermitinae	Theni	Guava	KM657488
UttarPradesh						
34	KPT-TE-1	*Odontotermes obesus*	Kapatganj	Kapatganj	Sugarcane	KM657477

Morphological key was developed for identification of Indian species of *Carinostigmus (Carinostigmus) congruus* (Walker), *C. (Carinostigmus) costatus* Korembein, *C. (Carinostigmus) griphus* Korembein were reported from South India and the latter one is New record for India. There are two species from the genus *Tzustigmus* Finnamore were identified *viz.,Tzustigmussyam* Finnamore and *Tzustigmus veda* Finnamore, have new distribution record from Karnataka and two species from the genus *Sphex* were identified *viz., Sphex argentatus* F. and *Sphex pretiosus* sp.n. DNA extraction and molecular

Charcterization using partial COI gene were done for these identified species. GenBank accession number and BOLD BIN number were generated for all seven species.

Key for Indian *Carinostigmus*

1. Antenna 12-segmented, flagellum beneath without fringe of short erect setae; abdomen with six exposed segments, sting usually protruding between sixth tergum and sternum; last tergum with small, oval depressed pygidium… Females ……2

-Antenna 13-segmented, flagellar segments beneath with fringe of short erect, curved setae; abdomen with seven exposed segments, eighth sternum usually projecting as short blunt spine; last tergum convex, without differentiated apical area … Males…….4

2. Underside of head closely costate except small median area densely lineolate; labrum narrowly rounded at apex, sides on apical half emarginate; acetabular carina and subomalus lacking pronotal crest emarginate in middle; acetabular carina and subomalus lacking ; propodeum coarsely rugosoreticulate adjacent to enclosure and median groove; petiole stouter , about five times as long as median width, coxae black in colour; trochanters not testaceous……. …. 1. ***Carinostigmus*** (***Carinostigmus***) ***costatus*** Krombein**,**

-Underside of head moderately densely punctate especially toward middle and usually with a few parallel carinae laterally; labrum more broadly rounded at apex; pronotal crest not emarginate in middle; acetabular carina lacking propodeum usually with small smooth area adjacent to enclosure, obliquely rugose anterolaterally, rugosoreticulate posteriorly; petiole more slender; trochanters testaceous…… 3

3. Clypeus glossy, median lobe more convex, narrower at apex, the width there 0.5-0.6 times distance between inner margins of antennal sockets; declivous surface of pronotum anterior to transverse ridge smooth or with only evanescent irregular rugulae; interocular distance at anterior ocellus 1.4 times that at antennal insertions. . . . 2. ***Carinostigmus*** (***Carinostigmus***) ***congruus*** (Walker)

-Clypeus delicately shagreened basally, median lobe not so convex, broader at apex, the width there 0.7-0.8 times distance between inner margins of antennal sockets; declivous surface of pronotum anterior to transverse ridge with vertical rugae; interocular distance at anterior ocellus 1.2-1.3 times that at antennal insertions… 3. ***Carinostigmus*** (***Carinostigmus***) ***griphus*** **Krombein,**

4. Mandible with two teeth at apex; maxillary palpi elongate, extending backward to apex of fore coxae, flattened and quite broad, sides fringed with long curled setae; underside of head closely costate except irregularly rugulose on small median area; pronotal crest emarginate in middle, lateral angles spicate viewed from above; trochanters black… 1. ***Carinostigmus*** (***Carinostigmus***) ***costatus*** **Krombein.**

-Mandible with two teeth at apex; maxillary palpi slender, short, not extending backward beyond head, not fringed with

long curled setae; underside of head densely punctate except with parallel carinae laterally ; pronotal crest not or only weakly emarginate in middle, lateral angles blunt viewed from above; trochanters testaceous ……..5

5. Viewed from above head not so strongly narrowed behind eyes, width at occiput half greatest width, occipital groove narrower and not so strongly crenulate; head beneath with lateral rugae weaker or evanescent; median lobe of clypeus glossy, rarely delicately shagreened basally; pronotal ridge not emarginate in middle……**2. *Carinostigmus (Carinostigmus) congruus*** (Walker)

-Viewed from above head more strongly narrowed behind eyes, width at occiput 0.4 times greatest width, occipital groove broader and more strongly crenulate; head beneath with stronger and more numerous lateral rugae; median lobe of clypeus strongly shagreened; pronotal ridge weakly emarginated in middle **. . . 3. *Carinostigmus (Carinostigmus) griphus* Krombein**

Molecular Characterization

Standardization of methodology for DNA extraction and PCR amplification of CO-1 gene for sphecid wasps was done, and whole genomic DNA was extracted for all the identified specimens.

The protocol for DNA extraction has been modified using salting out method. The left fore-legs were used for the DNA extraction. The leg was thoroughly washed with distilled water and taken in 1.5ml eppendorf tube. 100µl of extraction buffer and 5µl of protienase K was added to it. The tubes were vortexed briefly and incubated for 48hr at 56°C. 50µl of 3M sodium acetate was added and vortxed briefly, the tubes were then transferred to -20°C for 10 mins. The content was centrifuged at 4°C for 5min at 11,000 rpm and the supernatant was transferred to a new tube, pellet was discarded. Equal volume (200 µl) of 100% freezing isopropanol was added, mixed by inversion 2 or 3 times, left at room temperature for 30min. Centrifuged at room temperature @ 10,000 rpm for 10 minutes, the supernatant was discarded. The pellet was retained and washed with 500µl of 70% ice cold ethanol and incubated for half an hour at room temperature. The sample was vortexed, centrifuged at 10,000 rpm for 8 minutes at room temperature. The supernatant was discarded and care was taken not to lose the pellet, the tube was left for air dry for overnight in a clean place. The pellet was resuspended in 50µl HPLC purified water, DNA was melted for 30 minutes to an hour at 37^0C.

PCR amplification for CO-1 gene

The isolated DNA was amplified for the mitochondrial CO1 gene fragment by using the universal primers CO-1 Forward- 5'GGTCAACAAATCATAAAGATATTGG 3'andCO-1Reverse- 5' TAACTTCAGGCTG ACCAAAAAATCA 3'. About 30 µl PCR master mixture consisting of 5µl of 10x tag buffer with 15mM $MgCl_2$, 1.0µl of dNTP's mix, 1µl of each forward and reverse primer, 1µl of *Taq* Polymerase (1U/µl), 2µl of template DNA and 2µl 25Mm $MgCl_2$. The PCR was carried out under the conditions, initial denaturation at 95^0C for 4 minutes, denaturation at 95^0C for 30 seconds, annealing at 50^0C for 1 minute, initial elongation at 72^0 C for 1:30 minute and final

extension for 7 minutes at 72^0 C. The PCR was carried out for a total of 34 cycles and final held at 4^{0}C.The amplified DNA was then checked on 1%agaroseand the gel was visualized in gel doc.

DNA barcoding of *Carinostigmus* to identify the female of *Carinostigmus congruus* (Walker)

Taxonomical study on *Carinostigmus* specimens from Karnataka, Tamil Nadu, Arunachal Pradesh, Sikkim and Assam revealed that, three species, *Carinostigmus (Carinostigmus) congruus* (Walker) (Fig.23), *Carinostigmus (Carinostigmus) costatus* Krombein (Fig.24), and *Carinostigmus (Carinostigmus) griphus* Krombein (Fig.25) were found in India. This constitutes the new record of *C. griphus* from India.

Fig. 23. *Carinostigmus congruus* (Walker)

Fig. 24. *Carinostigmus costatus* Krombein

Fig. 25. *Carinostigmus griphus* Krombein

Since the collection didn't have male *C. congruus*, in order to establish the identity of the *C. congruus,* DNA barcoding of these species using partial mitochondrial CO1 gene was done. The partial gene sequences of CO1 from male and female of *C. costatus* and *C. griphus* and female *C. congruus* were obtained (Table 10). . The sequence diversity within species varied from 0.25 to 0.5 %, wherein between species it varied from 12.28 to 13.77 % (Table 11). Analysis of the sequences revealed that the gene sequence from male and female of the same species matches 100% with each other (A1). Based on the sequence similarity the female identity of *C. griphus* and *C. congruus* was established by comparing with the sequence from the respective male counterpart and *C. congruus* femaleidentity was eventually confirmed.

The molecular phylogeny tree clearly indicates the three species as they are diverging and forming different clades in the tree (Fig. 26). *C griphus* and *C. congruus* were grouped in the same clade, indicating they are more closely related to each other than to *C. costatus*. The phylogeny tree also suggested that, there is a chance that species *C. griphus* has been present in India earlier than the *C. costatus* appeared in India , possibility are there that *C. costatus* would have entered from Srilanka to

Table 10. Sequence details of three species of *Carinostigmus* deposited in various databases

Sl.No.	Species		GenBank accession numbers	BOLD Accession Numbers
1.	*Carinostigmus congruus*	♀	KT070204	BOLD:ACD90874
2.	*C. griphus*	♂	KT070205	BOLD:ACV20062
		♀	KT070206	
3.	*C. costatus*	♂	KT070202	BOLD:ACV20072
		♀	KT070203.1	

Table 11. Analysis of sequence divergence among the three species of *Carinostigmus* (BOLD 6.2)

	n	Taxa	Comparison	Min. Dist (%)	Mean Dist(%)	Max Dist(%)	SE Dist(%)
Within Species	4	2	2	0	0.25	0.5	0.13
Within Genus	5	1	8	8.61	12.28	13.77	0.27

India or speciation would have happened before the land division of Srilanka from India. However more research needs to be performed to confirm this speciation. Nevertheless the molecular phylogeny confirms the proximity of the *C griphus* and *C. congruus*.

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

A total of 86 soil and insect samples collected from Western Ghats were analysed during the year and 25 *Bacillus thuringiensis* isolates were purified and all of them expressed

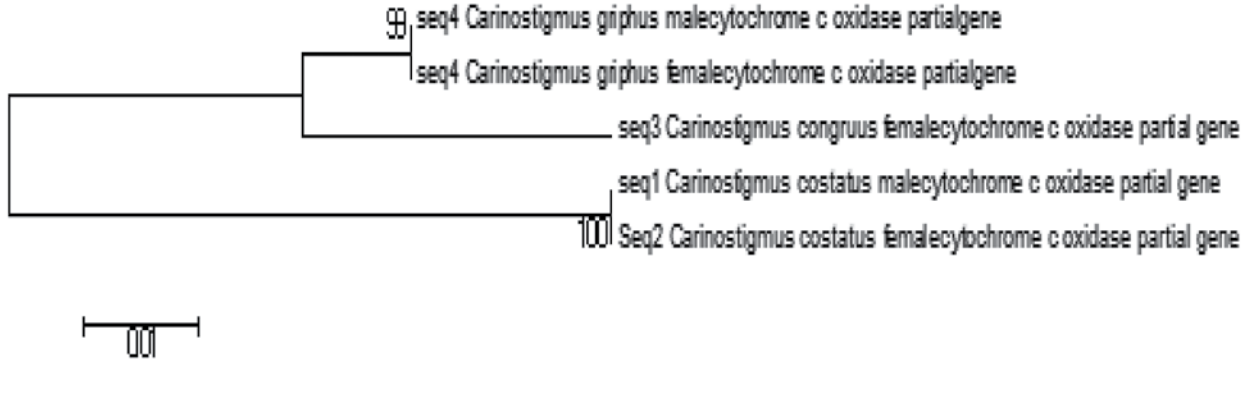


Fig. 26. Molecular Phylogeny of the three species of *Carinostigmus*

bipyrmadal crystals. Soil samples were also collected from Greater Nicobar Islands and from 16 samples 4 isolates expressing bipyramal and spherical crystals were isolated.

The trypsin activated vip3A protein (4hrs IPTG induction) was tested against *Plutella xylostella.* 100% mortality was recorded after 72hours in all the protein concentrations. The highest mortality of 100 % was recorded at 500µg concentration after 48hours. The LC_{50} value was calculated as 53.676 µg/ ml. Trypsin activated vip3A protein (16hrs IPTG induction)

was also tested and the LC_{50} was calculated as 52.87µg/ ml.

Cry8A expressing *B. thuringiensis* (NBAIR-BTAN4) was tested against the potato grub (*Popillia* Sp. Scarabeidae, Coleoptera) and 100% mortality recorded in 48h. Four NBAIR Bt isolates alongwith standard MTCC-8997 expressing the coleopteran specific protein were tested against early second instar larvae of *Tuta absoluta* by tomato leaf dip methodology. The most toxic was NBAIR-4 with LC_{50} calculated as 301.3 ppm, this was followed by NBAIR-1 which showed LC50 as 373.7 ppm. The formulations are being tested for field efficacy.

Liquid formulations of NBAIR-BTG4 and standard HD-1 were tested against *Cryptolemus montrouzieri* and *Chrysoperla carnea* at 1 and 2 % concentrations. No mortality was recorded rendering that the formulations were safe against the natural enemies.

Culturable and Unculturable Microflora associated with Soil Insects and other Arthropods

Eighteen culturable microflora were identified from gut of Indian dung beetle (*Onitis philemon*), eleven culturable microflora were isolated from gut of Indian dung bettele (*Oniticellus sinctus*) and fourteen gut microflora were identified from *Holotrichia serrata.* Twenty unculturables were identified from the gut of *Onitis philemon*.

Taxonomy classification of OTUs (operational taxonomic unit) at genus and species level was generated for the dung beetles *Onthophagus pactolus* and *Copris indicus* using QIMME analysis. Only top 10 enriched class categories were taken and these were identified as *Meiothermus, Dysgonomonas, Bacteroides, Stenotrophomonas, Citrobacter, Ocillospira, Pseudomonas, Acinitobacter* and *Spingobacterium* (Fig. 27 and 28). At genus level *Sphingobacterium* is absent in *C. indicus*. Significantly higher activity of *Oscillospora* seen in *O. Pactolus*.

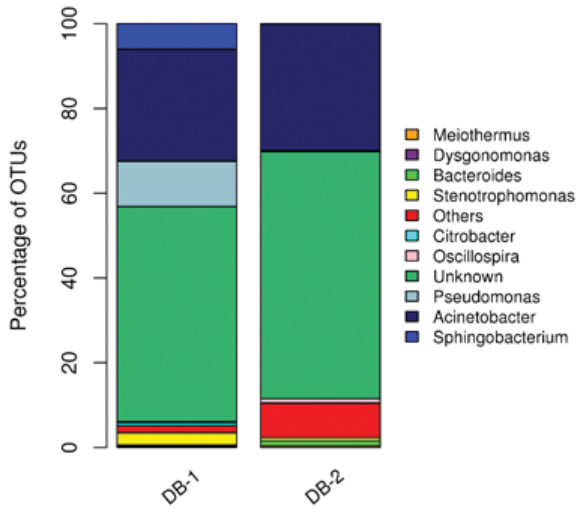


Fig. 27. Taxonomy classification of OTUs at genus level for the sample. Only top 10 enriched class categories are shown in the figure.

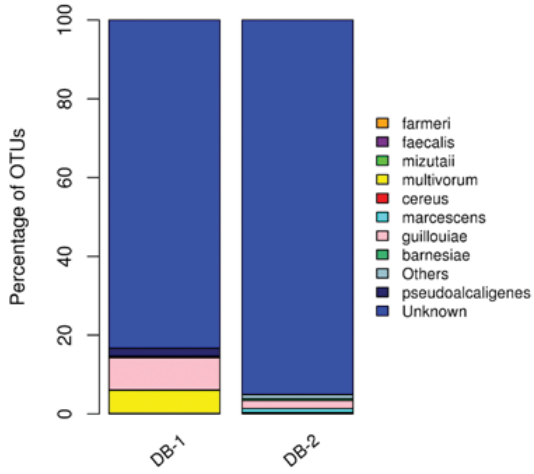


Fig. 28. Taxonomy classification of OTUs at species level for sample. Only top 10 enriched class categories are shown in the figure.

Surprisingly OTUs at species level showed that Unknown occupied maximum levels in both the species of dung beetle indicating that metagenomics and other new microbes are acitive. Another feature is *Stenotrophomonas multivorum* is active in *Onthophagus pactolus* and absent in *Copris indicus* (Fig.29).

Fig. 29. Adults of *Onthophagus* (top) and *Copris* (bottom)

Cellulase and pectinase degrading ability of bacteria isolated from two species of dung beetles were screened. Bacteria from *Onitis philemon* showed that 16 were cellulase positive and 11 were pectinase positive. Culturables from *Oniticellus sinctus* showed that 7 had cellulose as well as pectin degrading ability.

Development of database for insecticide resistance genes

Agricultural pests develope resistance against insecticides like organophosphates, synthetic pyrethroids, organo chlorinates and other new groups. Insecticide resistance is a widespread phenomenon and leads to frequent and overuse of pesticides that pose a risk to the environment and human health. Insecticide resistance gene database (IRGD) for important pests is essential to carry out molecular studies on insecticide resistant genes like Cytochrome P450, Acetylcholinesterase and Knock down resistance and Rdl (Resistant to dieldrin) gene. The database will help researchers in designing tools for overcoming insecticide

resistance. Insecticide resistant gene database (IRG) has been developed in MySQL as back end and PHP as front-end. Presently, IRGD contains 851 sequences for the pests *Aphis gossypii, Acyrthosiphon pisum, Bemisia tabaci*, *Helicoverpa armigera, Plutella xylostella, Spodoptera exigua, Spodoptera litura, Nilaparvata lugens, Myzus persicae, Tribolium castaneum* and *Leucinodes orbonalis* with key features like Search, View, ORF Finder, etc. and this database will be updated regularly. The home page of the database is given in Fig. 30.

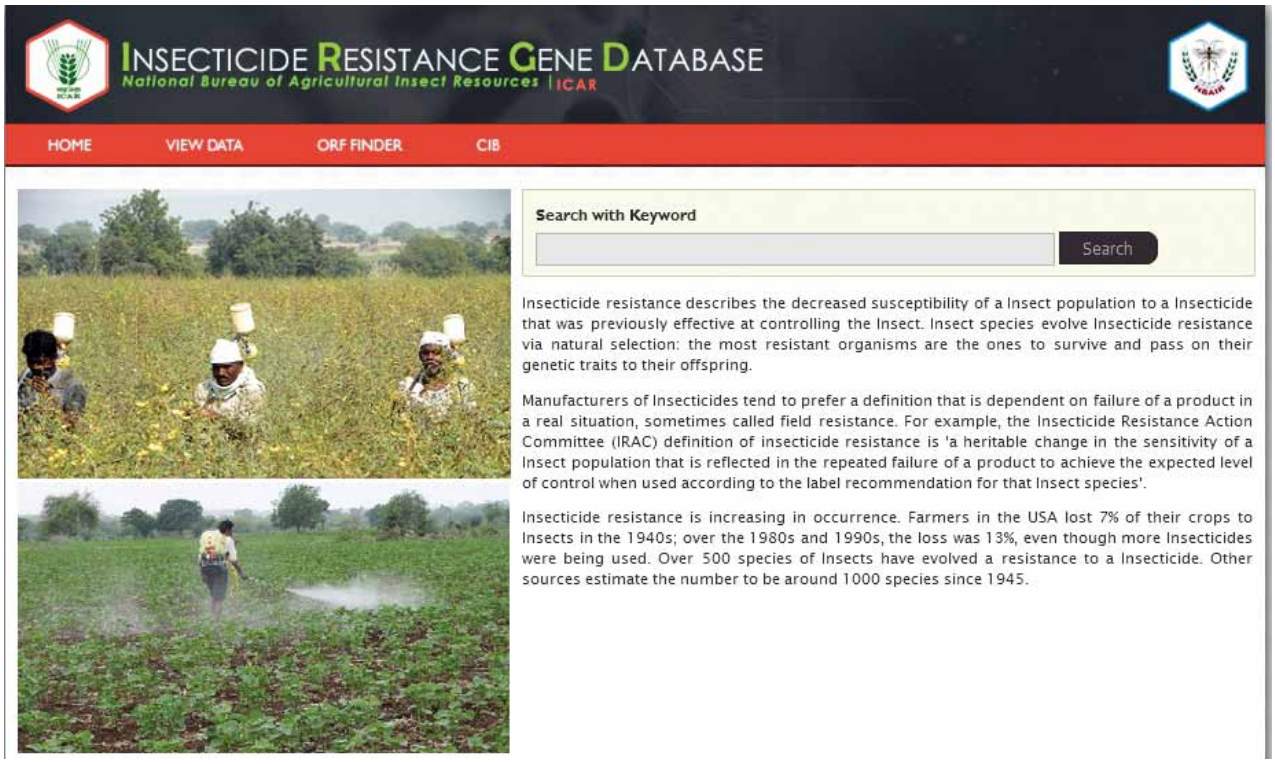


Fig. 30. Home page of insecticide resistance gene database

Role of microbial flora of aphids in insecticide resistance

Molecular identification of aphid microflora: Aphids belonging to *Aphis gossipii*, and *A. craccivora* were collected from Alesibum from Tamil Nadu, Thottibhavi and Attur, Karnataka from cotton, ragi and red gram. Aphids were identified based on taxonomic keys and based on the host plants. A total of 20 bacterial cultures from aphids belonging to *Aphis craccivira, A. fabae, A. gossypii* and *Hysteroneura setariae* were isolated in the year 2015-16 and were subjected to morphological characters and biochemical characters like protease, amylase, cellulase and ethanol production.

Among the assays 14 isolates were positive for protease, 3 for amylase, 1 for cellulase and 3 for ethanol production. The genomic DNA from isolates were subjected to amplification of 16S rDNA using universal primers, sequencing and identified using BLAST homology search as *Bacillus altitudinis, B. cereus, B. licheniformis, B. pumilus, B. subtilis,*

Corynebacterium variabile, Enterobacter cloacae, E. hormaechei, Lysinibacillus fusiformis, L. macrolides, Micrococcus luteus, Providencia stuartii and *Stenotrophomonas maltophilia*. GenBank accessions for the identified isolates were obtained (Table 12).

Insecticide degradation assays: A total of 24 bacterial flora obtained from aphids were subjected to insecticide resistance assays using Imidacloprid 17.8% SL and λ-cyhalothrin 5% EC with varying concentrations on petriplates with minimal media (Fig.31). Insecticide degradation assay showed *Moraxella osloensis*, *Stenotrophomonas maltophilia, Exiguobacterium indicum* and *Bacillus subtilis* performed better in degradation of both insecticides as revealed by their growth on the plates.

Bioassays for insecticide resistance of aphids: Leaf dip assay IRAC method No.8 was adapted to test the insecticide resistance status of aphids collected from Bengaluru, Guntur and Dharwad. The concentrations of Imidacloprid 17.8% SL used ranged from 375-600 ppm logarithmic dose and 5000-80000 ppm logarithmic dose for λ-cyhalothrin 5%EC. The petiole of the leaves was wrapped with wet cotton to prevent desiccation of the leaves. Each concentration was replicated 4-10 times. Mortality of the nymphs was recorded at 48 h after bioassay. The mortality data was subjected to probit analysis for the calculation of LC_{50}, slope and fiducial limit values. Bioassay for insecticide resistance of red gram aphid *Aphis craccivora* to imidacloprid 17.8% SL insecticide revealed that Dharwad population was 9.7 times more resistant to imidacloprid than Bangalore population (Table 13). Similarly, bioassay for insecticide resistance of green peach aphid *Myzus persicae* revealed that Bangalore population was 13.38 times more resistant to λ-cyhalothrin 5%EC than Guntur population (Fig. 32, Table 14) and Guntur population was 1.107 times more resistant to imidacloprid than Bangalore population (Table 15).

Table 12. Molecular identification of aphid microflora

S. No	Location	Lat. & Long.	Source	Isolate	Identified Organism	GenBank Accession
1	Alesibum	13°61' N 78°11' E	*Aphis craccivora*	AA3-1	*Bacillus subtilis*	KU663661
2	Alesibum	13°61' N 78°11' E	*Aphis craccivora*	AA3-4	*Bacillus cereus*	KU663662
3	Alesibum	13°61' N 78°11' E	*Aphis craccivora*	AA5-2	*Lysinibacillus fusiformis*	KU663663
4	Alesibum	13°61' N 78°11' E	*Aphis craccivora*	AA5-5	*Bacillus pumilus*	KU663664
5	Alesibum	13°61' N 78°11' E	*Aphis craccivora*	AA6-1	*Bacillus altitudinis*	KU663665
6	Alesibum	13°61' N 78°11' E	*Aphis craccivora*	AA6-2	*Micrococcus luteus*	KU663666
7	Alesibum	13°61' N 78°11' E	*Aphis craccivora*	AA6-3	*Bacillus pumilus*	KU663667
8	Alesibum	13°61' N 78°11' E	*Aphis craccivora*	AA6-4	*Micrococcus luteus*	KU663668

9	Alesibum	13°61' N 78°11' E	*Aphis craccivora*	AA6-5	*Bacillus licheniformis*	KU663669
10	Alesibum	13°61' N 78°11'E	*Aphis craccivora*	AA6-6	*Corynebacterium variabile*	KU663670
11	Attur	13°10' N 77°56'E	*Aphis craccivora*	ACGF2-1	*Bacillus subtilis*	KU867633
12	Attur	13°10' N 77°56'E	*Aphis fabae*	AFF-3ac	*Providencia stuartii*	KU867634
13	Attur	13°10' N 77°56'E	*Aphis craccivora*	ACHB-2	*Bacillus subtilis*	KU867636
14	Attur	13°10' N 77°56'E	*Aphis fabae*	AF2B-3a	*Lysinibacillus macroides*	KU867640
15	Attur	13°10' N 77°56'E	*Aphis gossypii*	AGCY-2	*Bacillus subtilis*	KU867641
16	Thottibavi	13°16'N, 77°49'E	*Hysteroneura setariae*	RAT2	*Enterobacter cloacae*	KT248838
17	Thottibavi	13°16'N, 77°49'E	*Hysteroneura setariae*	RAT3	*Stenotrophomonas maltophilia*	KT248839
18	Thottibavi	13°16'N, 77°49'E	*Hysteroneura setariae*	RAT3A	*Stenotrophomonas maltophilia*	KT248840
19	Thottibavi	13°16'N, 77°49'E	*Hysteroneura setariae*	RAT4	*Enterobacter hormaechei*	KT248841
20	Thottibavi	13°16'N, 77°49'E	*Hysteroneura setariae*	RAT5A	*Stenotrophomonas maltophilia*	KT248842

Table 13. Susceptibility status of red gram aphid *Aphis craccivora* to imidacloprid 17.8% SL insecticide (48 h bioassay data)

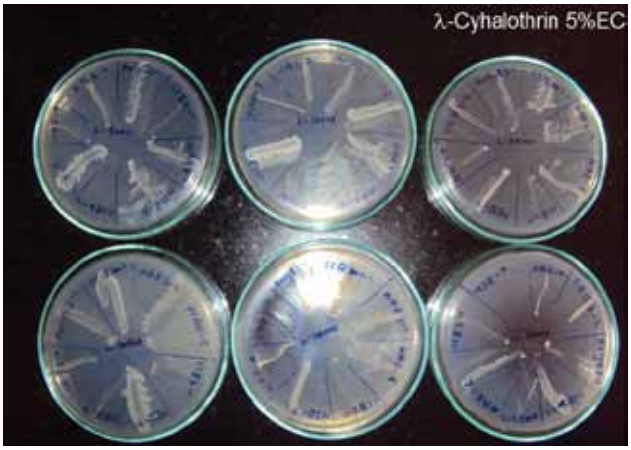
Population	LC_{50} (48 h)ppm	Slope±SE	Fiducial limits		χ^2 value(3DF)
			Lower	Upper	
Dharwad	1538.4	1.6±0.13	918.2	3957.6	19.5 (3DF)
Bangalore	158.6	1.13±0.90	89.32	363.82	7.2 (3DF)

Table 14. Susceptibility status of *Myzus persicae* to λ-cyhalothrin 5%EC insecticide (48 h bioassay data)

Population	LC_{50} (48 h)ppm	Slope±SE	Fiducial limits		χ^2 value(3DF)
			Lower	Upper	
Bangalore	4369.0	0.92±0.10	2992.6	7658.5	8.8 (3DF)
Guntur	326.5	0.56±0.09	194.78	469.02	3.4 (3DF)

Table 15. Susceptibility status of Myzus persicae to imidacloprid 17.8% SL insecticide (48 h bioassay data)

Population	LC_{50} (48 h) ppm	Slope±SE	Fiducial limits		χ^2 value(3DF)
			Lower	Upper	
Bangalore	3133.1	1.96±0.12	2773.3	3500.21	2.9 (3DF)
Guntur	3469.1	2.23±0.15	2161.8	2772.7	12.1 (3DF)



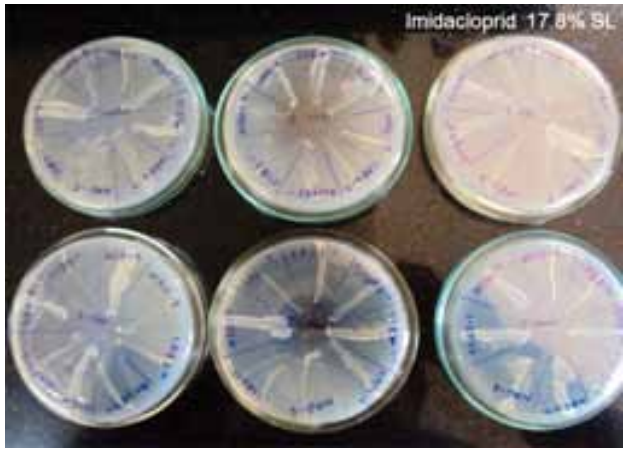


Fig. 31. Insecticide degradation assays for aphid microflora

Fig. 32. Bioassay for insecticide resistance of *Myzus persicae*

DIVISION OF INSECT ECOLOGY

Live insect repository at ICAR - NBAIR

The insect repository at ICAR – NBAIR maintains over 110 live insect cultures (Fig.33). These cultures are supplied to farmers, students, research organisations, KVKs and commercial mass multiplication units. A total of 1314 consignments were supplied during 2015- 2016 generating a revenue of Rs 4,98,279.

Documentation, production and utilisation of predatory anthocorids and mites

Diversity of Indian Anthocoridae

Two new records of anthocorids *viz.*, *Montandoniola bellatula* Yamada 2007 and *Xylocoris cerealis* Yamada and Yasunaga 2006 (Fig.34) from India are reported.

Of the two new species of *Orius* recorded from Karanataka, one was collected

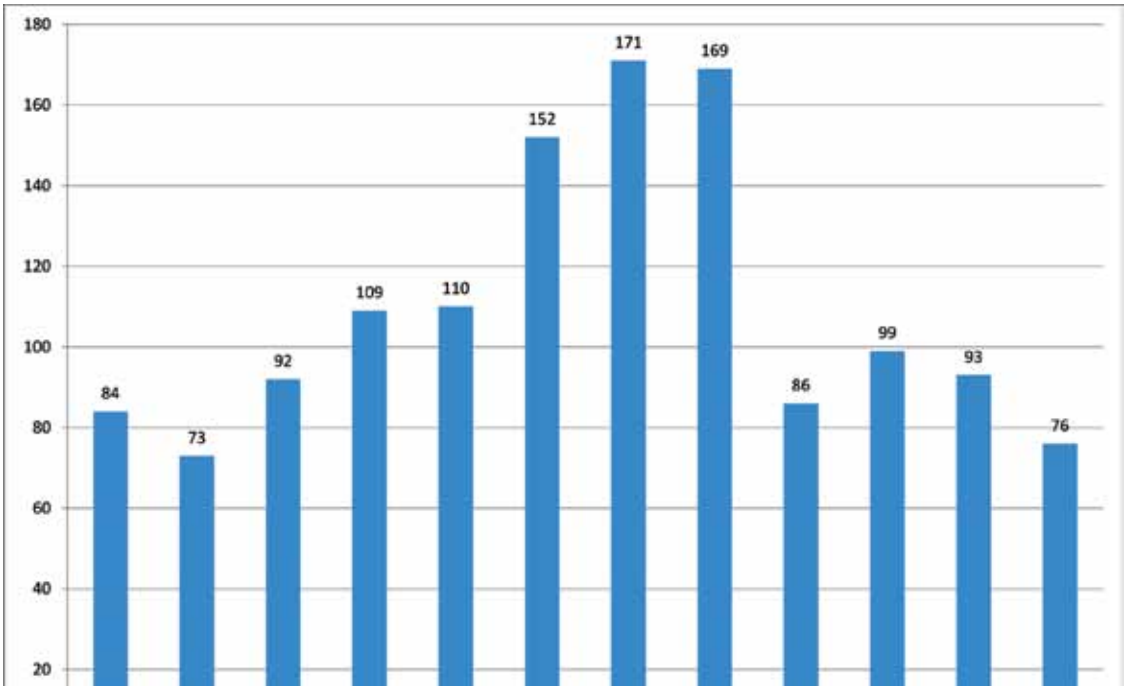


Fig. 33. Insect cultures in the insect repository

from coconut and the other from *Clerodendrum infortunatum*. Anthocorid predators *Cardiastethus exiguus, Bilia castanea, Orius maxidentex* and *Buchananiella pseudococci pseudococci* were recorded on mulberry infested by thrips in Salem, Tamil Nadu and *O. maxidentex* was recorded from Karnataka.

Population dynamics of *Orius* recorded on *Clerodendrum infortunatum*

The populations of *Aphis gossypii, Polyphagotarsonemus latus* and mealybugs were low in plants that had nymphal and adult stages of the anthocorid at the rate of 0.3 to 0.8 adults and 0.3 to 1.2 nymphs per bud respectively (Fig.35,36). Peak populations of nymphs occurred from February-March and September-October. The adult populations were at a higher during September and December. Though the poulations of aphids and broad mites was low during the period under observation, there was a close correlation between the populations of the pests and the anthocorid. Anthocorids survived high summer temperature.

Fig. 34. *Xylocoris cerealis* Yamada and Yasunaga 2006

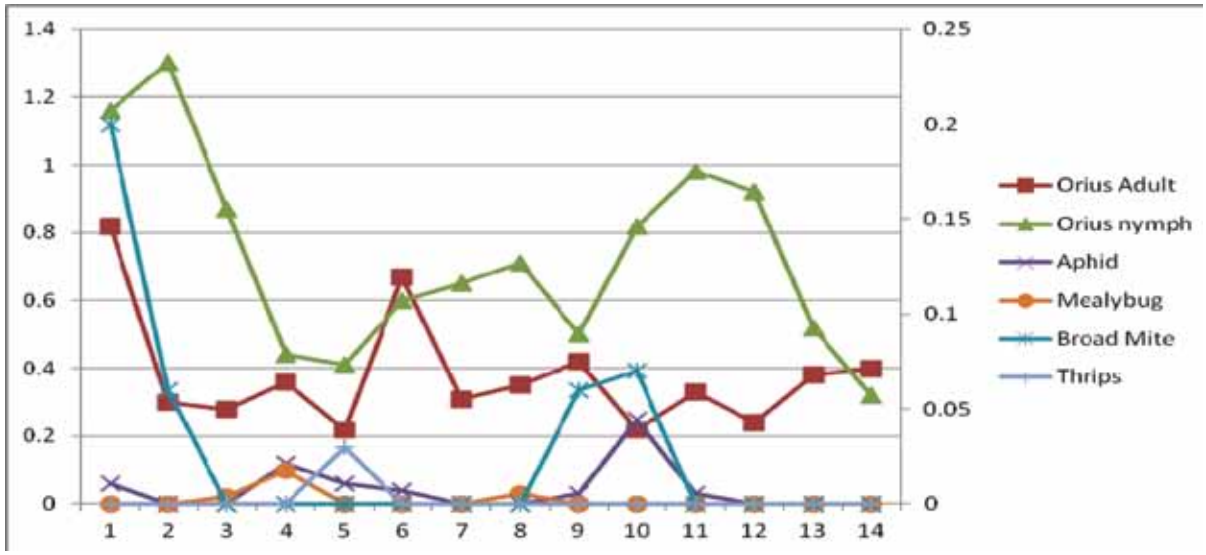


Fig. 35. Population dynamics of *Orius* on *Clerodendrum infortunatum*

Egg	Nymph	Adult

Fig. 36. Life stages of *Orius* n.sp. on *Clerodendrum infortunatum*

Fertility parameters of two litter inhabiting anthocorids

The age-specific survival and fecundity of two litter inhabiting anthocorids was studied. In *Amphiareus constrictus,* the first mortality of adult females occurred 40 days after eclosion and 100% mortality occurred at 72 days post eclosion. Egg laying started five to seven days after emergence. Female progeny were recorded from the first oviposition and continued till the parent female was 68 days old. Female progeny produced by a female in a day ranged from 0 to 3. In a generation time of 64 days, with a reproductive rate of 33.9, the intrinsic rates of increase of *A. constrictus* was 0.06**.** The doubling time, weekly multiplication rate and hypothetical F_2 females were recorded as 12.6, 1.5 and 1145.82 respectively.

The immature stages of *Buchananiella indica* occupied 20 days. The mortality ranged from 22- 40 days of adult emergence. Egg laying started two days post eclosion and female progeny produced by a female per day ranged from 0 to 1.7. Highest female progeny production was recorded when the parent female was 49 days old and ceased when it was

56 days old. With a generation time of 31 days, the reproductive rate of *B. indica* was 12.6 and the intrinsic and finite rates of increase were 0.08 and 1.08, respectively. The study indicates that *A. constrictus* has a higher reproductive rate than *B. indica,* while the finite rate of increase was comparable for the two species (Table 16;Fig 37, 38).

Table. 16. Fertility parameters of *Amphiarens constrictus* and *Buchananiella indica*

Species	R_0	T_c	r_c	r_m	T	λ	DT (days)	Hypo. F_2 ♀s	WMR
A. constrictus	33.85	55.11	0.06	0.06	64.03	1.06	12.6	1145.82	1.50
B. indica	12.6	35.89	0.07	0.08	31.09	1.08	8.66	158.76	1.71

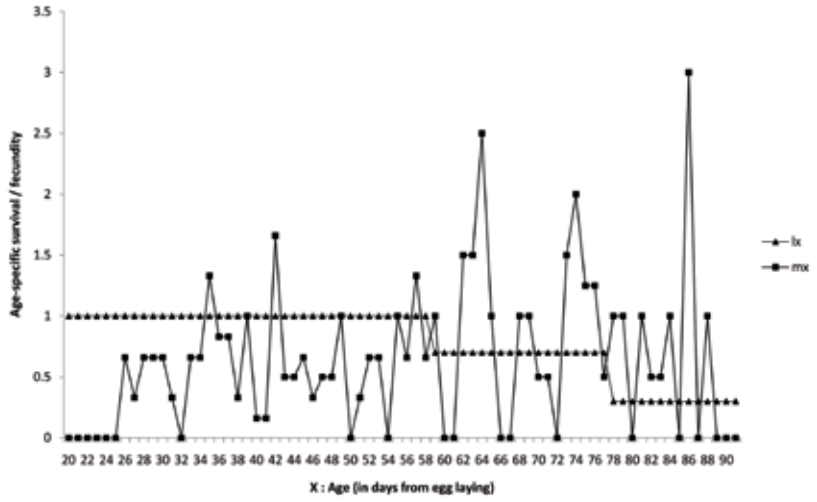


Fig. 37. Age specific survival (l_x) and fecundity (m_x) of *Amphiareus constrictus*

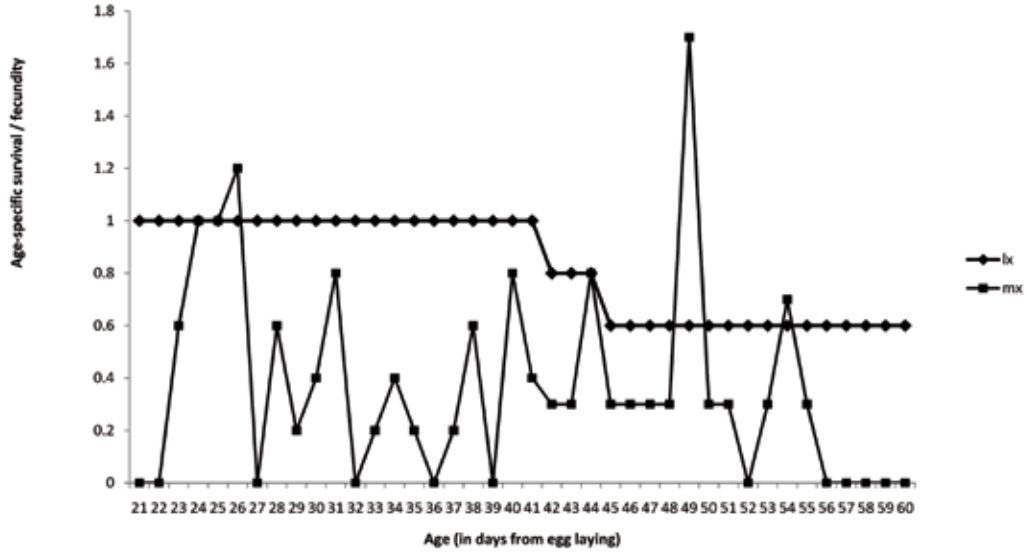


Fig. 38. Age specific survival (l_x) and fecundity (m_x) of *Buchananiella indica*

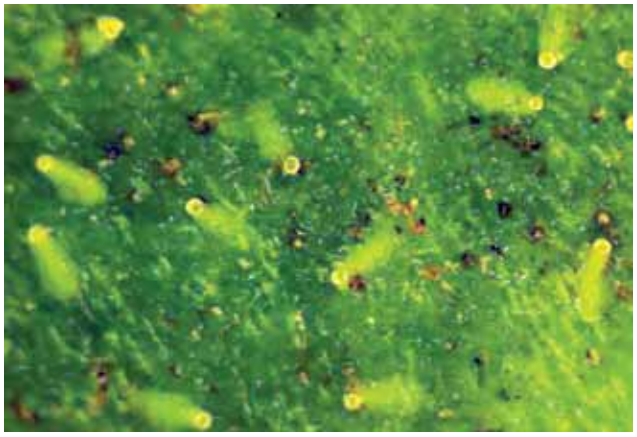
Evaluation of *Blaptostethus pallescens* against broad mites infesting capsicum

Adults of *B. pallescens* were released in net house on capsicum plant infested by broad mites. The leaf curling prior to release of *B. pallescens* was 90 and 70 % in plant receiving treatment and control respectively. The plant height was 16.2 and 15.3 cm in treatment and control respectively. Four releases of *B. pallescens* on mite infested plants caused 20 per cent curling, whilst the control plant had 100% curling. Post release, the plant height was 38.3 cm as compared to 18.7 cm in control (Fig.39).

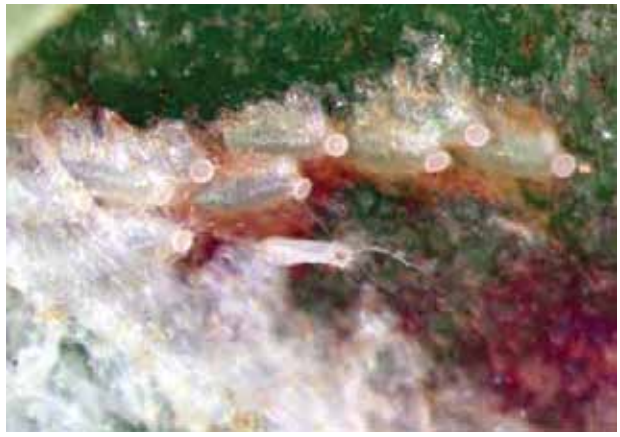
Fig. 39. Effect of *Blaptostethus pallescens* releases on A) curling of terminal leaves B) Average height - in broad mite infested chilli plants

Egg characters for identifying anthocorid predators

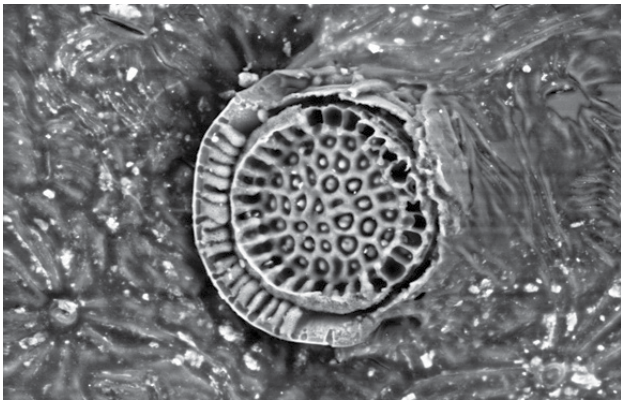
Electron microscopy and light microscopy images of *B. pallescens* and *Blaptostethus pacificus* eggs were examined to fix the characters for identification at genus level. The patterns on the follicular pits in operculum are a robust charecters for identification. Both species of anthocorids laid their eggs within the plant tissue. Electron microscopy images showed the difference in the egg architecture between the species. The egg opercula in both the species were round with a chorionic rim. The mean opercular diameter was 116.2 µm in *B. pallescens* and 152.4 µm in *B. pacificus*. The opercular region is divided into two parts: the central region and outer ring. There are 35 to 40 small open follicular pits in the central region in *B. pallescens,* while in *B. pacificus* an opaque layer covers the central region, with faint reticulations on the covering. There is an outer ring with open follicular pits in both species, the pits being wider and elongated in *B. pacificus* (9.12 and 30.6 µm, respectively) and slightly narrower and shorter in *B. pallescens* (6.57 and 12.2µm, respectively) and this could be used for identification (Fig.40).



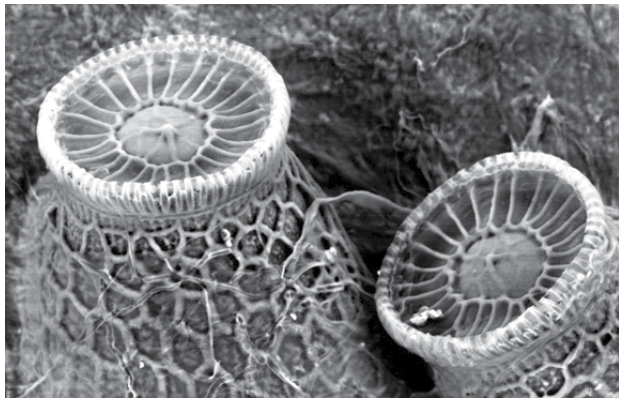
Light microscopy image of *Blaptostethus pallescens* eggs



Light microscopy image of *Blaptostethus pacificus* eggs



EM image of egg of *Blaptostethus pallescens*



EM image of eggs of *Blaptostethus pacificus*

Fig. 40. Light and electron microscopic images of eggs of *Blaptostethus* spp.

Evaluation of *Amphiareus constrictus* and *B. pallescens* against eggs of American pinworm, *Tuta absoluta* infesting tomato

Cage studies were conducted to evaluate the predatory efficiency of *A. constrictus* and *B. pallescens* on *T. absoluta* eggs. When the released in the ratio of 1 anthocorid: 10 *T. absoluta* eggs, feeding by anthocorids ranged from 90 to 100%. Presence of *B. pallescens* eggs in release site indicates their potential establish in fields in which they are released.

Evaluation of anthocorid predators against *Sitophilus oryzae* infesting maize seeds

Two experiments were conducted to evaluate the effect of anthocorids on *Sitophilus oryzae* infesting maize seeds. In one, the anthocorids (nymphal and adults stages of *Blaptostethus pallescens* and *Xylocoris flavipes*) were released after 7 days of egg laying by *S. oryzae*. The other experiment was to evaluate if the anthocorids could attack the adults / act as ovipositional deterrents. In the first experiment 30 *X. flavipes* nymphs and 40 *X. flavipes* adults were released. In case of *B. pallescens* 20, 30 and 40 nymphs were released. Release of predator caused significant reduction in pest emergence in comparison to control. In the second experiment, pest emergence was significantly reduced in the treatments with 10 *B. pallescens* nymphs, and 10 and 30 *B. pallescens* adults and 10 to 30 *X. flavipes* adults. This experiment indicates that anthocorid predators are potential bio-agents of *Sitophilus oryzae.*

Interaction between Solanum whitefly *Aleurothrixus trachoides* (Back) and predator *Axinoscymnus puttarudriahi Kapur & Munshi* on capsicum

The association between the invasive solanum whitefly, *A. trachoides* (Back) (Fig.41) and the predator *A. puttarudriahi* Kapur and Munshi (Fig.42) on capsicum was studied in natural conditions. The variance to mean ratio being greater than unity indicated an aggregated distribution of the pest and the predator. A significant positive association was observed between the pest and coccinellid predator.

Fig. 41. Pupae of white fly, *A. trachoides*

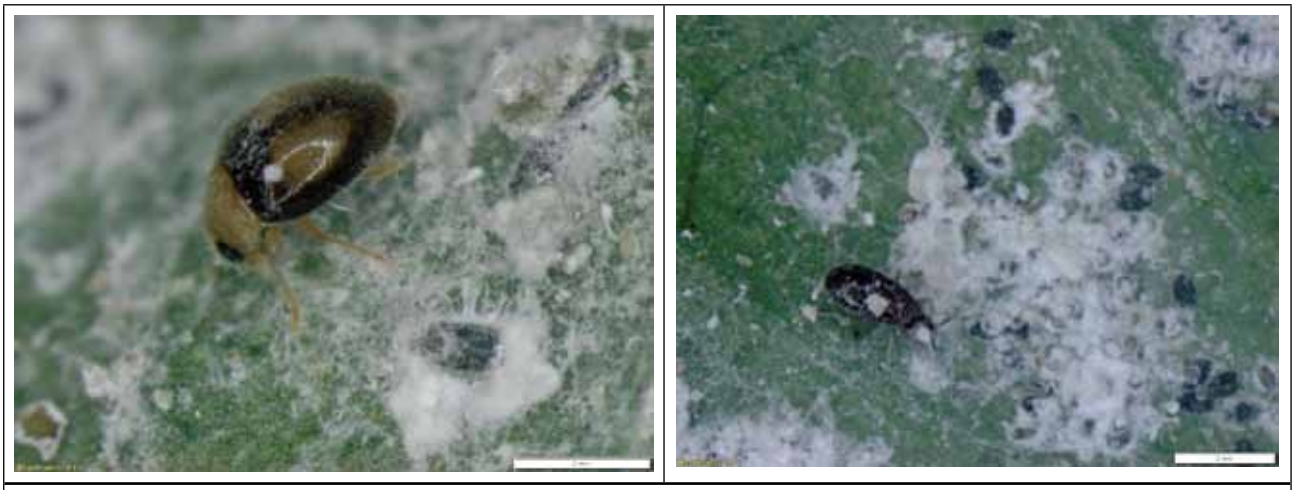


Fig. 42. Predation of *Aleurothrixus trachoides* by A) *Axinoscymnus puttarudriahi* and B) *Blaptostethus pallescens*

Evaluation of *Trichogramma* spp. on *Tuta absoluta* eggs

Cage studies were conducted to evaluate *Trichogramma* species against eggs of *Tuta absoluta* infesting tomato plant. Three species of *Trichogramma* parasitized *T. absoluta* eggs. Parasitism by *Trichogramma achaeae* was 28.8% followed by *T. pretiosum* (thelytokous) (22.7%) (Fig. 43) and *Trichogrammatoidea bactrae* (12.5%). No parasitism was recorded in the cages where *T. chilonis* was released.

Fig. 43. *Tuta absoluta* egg parasitised by *Trichogramma pretiosum*

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

36 species of non *Apis* bees belonging Apidae(17), Megachilidae (11) and Halictidae (8) were identified and submitted to the ICAR – NBAIR insect repository (Table 17). *Argyreia cuneata, Ocimum basilicum, Crotolaria retusa and Vitex negundo* were attracted to an array of pollinators and these plants could be employed for *in situ* conservation of pollinators in farm and urban habitats. DNA bar coding was done for 15 bee species.

Studies on specificity of attraction of *Tetralonia macroceps* bee to *Argyreia cuneata* was initiated. The preliminary results indicated that flower volatile profile of *Argyreia cuneata* varied with its congenor *Argyreia nervosa.* Further investigations are on to understand the specificity of this bee.

Table 17. Distribution of Non *Apis* pollinators

S. No.	Pollinator species	Host plants
1	*Amegilla confusa* (Smith, 1854): Apidae	*Ocimum basilicum* L.
2	*Amegilla violacea* (Lepeletier, 1841): Apidae	-
3	*Amegilla* sp. (*zonata* group): Apidae	*Argyreia cuneata*
4	*Braunsapis* sp.: Halictidae	*O. basilicum* L.
5	*Ceratina binghami* Cockerell, 1908: Apidae	*O. basilicum* L.
6	*Ceratina hieroglyphica* Smith, 1854 : Apidae	*O. basilicum* L.
7	*Ceratina smaragdula* (Fabricius, 1787): Apidae	*A. cuneata and O. basilicum* L.
8	*Ceratina* sp.1 : Apidae	*O. basilicum* L.
9	*Ceratina* sp.2 : Apidae	*O. basilicum* L.
10	*Coelioxys basalis* Smith, 1875: Megachilidae	*O. basilicum* L.
11	*Coelioxys confusus Smith, 1854:* Megachilidae	-
12	*Coelioxys* sp.: Megachilidae	*A. cuneata*
13	*Hoplonomia westwoodi* (Gribodo, 1894): Halictidae	*A. cuneata*
14	*Lasioglossum* (*Ctenonomia*) sp. 1: Halictidae	*Cajanas cajan* (L.) *Millsp.*
15	*Lasioglossum* sp. 2: Halictidae	*Ocimum* sp.
16	*Lithurgus atratus* Smith, 1853: Megachilidae	*A. cuneata*
17	*Megachile anthracina* Smith, 1853: Megachilidae	*C. cajan* (L.) *Millsp.*
18	*Megachile bicolor* (Fabricius, 1781): Megachilidae	*C. cajan* (L.) *Millsp.*
19	*Megachile cephalotes* Smith, 1853: Megachilidae	-
20	*Megachile disjuncta* (Fabricius, 1781): Megachilidae	*O. basilicum* L.
21	*Megachile lanata (Fabricius, 1775):* Megachilidae	-
22	*Megachile* sp.*1:* Megachilidae	*O. basilicum* L.
23	*Megachile* sp.*2:* Megachilidae	-
24	*Nomia curvipes* (Fabricius, 1793 Halictidae)	-
25	*Pachynomia* sp.*:* Halictidae	*O. basilicum* L.
26	*Scolia affinis Guerin, 1830 :* Scolidae	*A. cuneata*
27	*Seladonia propinqua (Smith, 1853):* Halictidae	-
28	*Seladonia* sp.*:* Halictidae	*Ocimum* sp.
29	*Tetralonia (Thygatina) macroceps* (Engel & Baker,2006): Apidae	*A. cuneata*
30	*Thyreus histrio* (Fabricius, 1775): Apidae	*C. cajan* (L.) *Millsp.*
31	*Thyreus massuri* (Radoszkowski, 1893): Apidae	*O. and A cuneata*
32	*Thyreus* sp*:* Apidae	*Ocimum and A. cuneata*
33	*Xylocopa aestuans* (Linnaeus, 1758) : Apidae	*Ocimum* sp.
34	*Xylocopa amethystina* (Fabricius, 1793) : Apidae	*Calotropis gigantea*
35	*Xylocopa latipes* (Drury, 1773): Apidae	*C. gigantea*
36	*Xylocopa* sp.*:* Apidae	*C. gigantea*

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

Establishment of repository of arthropods on veterinary and fisheries : A tick collected on a King cobra was identified as *Aponnomma laevi.* Cattle ticks, fleas form cat, sheep, dog, bitting/ blood sucking midges and mosquito, *Aedes aegyptii* were collected to strengthen the repository.

Table 18. Pests of economic importance in veterinary and fisheries

Insects	Collected at		Molecular barcodes
Phorid fly *Megaselia scalaris*	Karnal (HR) Shivamoga (KR)		
Rhipicephalus microplus	Pasighat (ARP) (Cow)		

Toxicity of botanicals to dipterans

The essential oil of sweet basil, eucalyptus and clove were characterized for chemical composition and cidal activity against housefly, *Musca domestica* L. (Diptera: Muscidae). Clove oil was more toxic over basil and eucalyptus oil (Table 19).

Table: 19. Fumigant toxicity of essential oils on housefly adult *(M. domestica)*

Essential oils	Toxicity LC_{50} (µl)	Lower fudicial limits	Upper fudicial limits	Chi square
Clove oil	1.362	1.17	1.53	21.55
Eucalyptus oil	3.15	2.83	3.50	9.14
Basil	1.98	1.53	2.41	8.42

The toxicity of essential oil to phorid fly, *Megaselia scalaris,* the LC_{50} of thymol was 5.45 µg as compared to ajowan oil 7.599 µg (Table 20).

Table: 20. Comparative toxicity of ajowan oil

Compound	Toxicity (µl) LC_{50}	Lower fudicial limits	Upper fudicial limits	Chi square
Ajowan oil	7.599	4.917	9.72	9.121
Thymol	5.45	3.52	7.24	7.24
Nuvan	0.5	0.32	7.12	6.53

Bioagents for management of house fly

Green muscardine fungus, *Metarhizium anisopliae* and *Beauveria bassiana* (Fig. 44, 45) were evaluated for bio efficacy against housefly. Both the pathogens were caused mycosis on adult stages.The LC_{50} of *B. bassiana* on adult flies was 2.11 $x10^6$ spores / ml whilst in case of *M. anisopliae* it was 6.14x 10^6 spores / ml.

Fig. 44. Infestation by *Beauveria bassiana*

Fig. 45. Infestation by *Metarhizium anisopliae*

Attract and kill baits for house fly

A gel based matrix was developed for delivery of attractants of house flies, *M. domestica* (Fig.46). It was effective in attracting and killing the flies compared to commercial attract and kill lures. Among the combinations evaluated, the gel based matrix containing food attractants of house fly with tricosene (pheromone) and imidacloprid was effective in attracting a killing over 400 flies in 4 sq. ft. This was followed by food attractant with imidacloprid.

Fig. 46. NBAIR gel matrix bait to manage house fly

Dispenser for delivery of *Tuta absoluta* pheromone

A nonomatrix for delivery of pheromone3E, 8Z, 11Z -3,8,11-tetradecatrien-1-yl acetate of American pinworm, *absoluta* was developed. Preliminary field trials conducted at Hosur in Tamilnadu revealed that Nanomatrix lure (NML) used in tandem with sticky trap captured higher number of moths per trap (956.66 ±32) than commercial lure (Fig. 47). Sticky trap alone captured 60.66 ±4.9 moths per trap. The advantage of the nanomatrix lure is had lower load of pheromone and the substrate can be reused after refilling with pheromone.

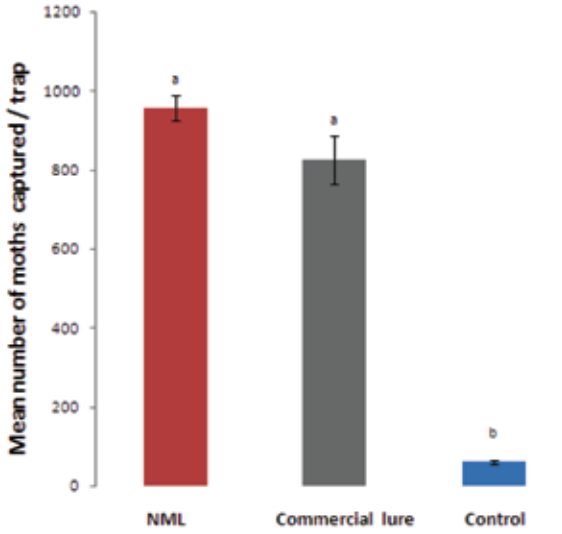


Fig. 47. Comparison of moth catches between lures
Bars having same alphabet do not differ significantly by p =0.05 DMRT.

Documenting agriculturally important mites and establishing an authentic collection

Mite samples were obtained from 30 location in 22 districts across 11 states, *viz.* Andhra Pradesh, Chattisgarh, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Maharashtra, Tamil Nadu, Telangana, Sikkim and West Bengal, and the Union Territory of Delhi.

The Phytoseiidae (Mesostigmata: Phytoseioidea) dominated the collection of predatory mites. The commonly encountered phytoseiids were: *Amblyseius cucurbitae, A. herbicolus, A. paraaerialis, Euseius alstoniae, E. chitradurgae, E. coccineae, E. delhiensis* (Fig. 48), *E. finlandicus, E. ovalis, E. prasadi, E. rhododendronis, Neoseiulus fallacis*, *N. indicus, N. longispinosus, Paraphytoseius multidentatus, Phytoseius minutus, P. swirskii* (Fig. 49), *P. wainsteini, Transeius tetranychivorus, Typhlodromus homalii, T. rickeri* and *T. syzygii*.

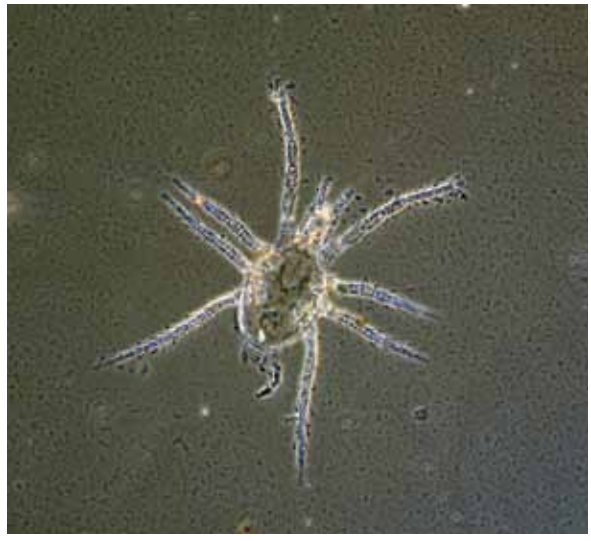


Fig. 48. *Euseius delhiensis*

Fig. 49. *Phytoseius swirskii*

Several phytoseiid mites were previously undescribed. A predator collected on chilli and provisionally identified as *Amblyseius* sp. nr. *kulini* (differs in shape of spermatheca, ventrianal shield, macrosetae on leg IV, genu length) was a new species yet to be described. A *Phytoseius* species collected on *Solanum virginianum* was provisionally identified as *Phytoseius* sp. nr. *wainsteini* (differs in spatulate macrosetae on tibia IV against pointed macrosetae and macrosetae on genu IV) before redescription.

Of the 100 different tarsonemid mites studied, many were found to be new species yet to be described: *Rhyncotarsonemus* sp. from sapota, *Rhyncotarsonemus* spp. from two unidentified plants, *Xenotarsonemus* sp. from hibiscus, *Fungitarsonemus* sp. (Fig. 50) from chilli and *Daidalotarsonemus* sp. from an unidentified plant.

Fig. 50. A new species of *Fungitarsonemus*

Diversity and predator-prey interactions in predatory mirids and geocorids

Around 100 specimens of mirids and geocorids were collected from Karnataka (Bangalore, Kunigal, Nandi Hills, chickballapur, Kanakapura), Tamil Nadu (Hosur), Himachal Pradesh (Shimla) and Arunachal Pradesh using net sweep and Yellow Pan Trap (YPT) (Table 21).

The specimens belong to genera *viz. Nesidiocoris, Cyrtorhinus, Sejanus, Campylomma, Mecistoscelis, Dortus, Fingulus, Polymerus, Lygus, Halticus, Dereaocoris,* and *Geocoris*.

Bionomics of *Nesidiocoris tenuis* reared on *Tuta absoluta* had a preoviposition period of 4 days with a nymphal period of 25 days. On longivity of adults; males were short lived (21 days) as compared to females (27 days).

Table 21. Collections of Miridae / Geocoridae from different locations

Sl.No	Place of Collection	Mode of Collection	No. of Specimens collected
1.	Karnataka (Hebbal, Yelahanka, Kunigal, Nandhi Hills, Chikballapur, Kanakpura)	YPT, Sweep Net	~70
2.	Tamil Nadu (Hosur, TNAU)	YPT	8
3.	Arunachal Pradesh	YPT	16
4.	Himachal pradesh	Sweep net	10

A greenhouse experiment was conducted to evaluate the predation of *N. tenuis* on *T. absoluta* . *Tuta* eggs and the % mined area were low in tomato plants harbouring *N. tenuis*. Number of necrotic rings per plant caused by *N. tenuis* was less (1.59) in *Tuta* infested plants compared to uninfested plants (3.45) (Fig 51, 52).

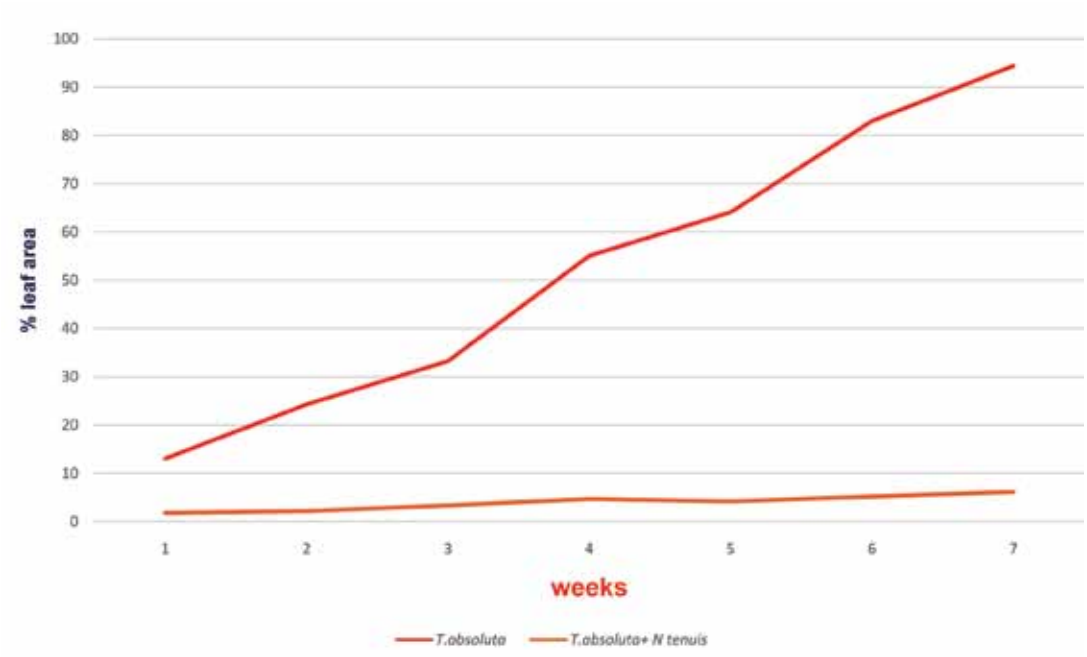


Fig. 51. Interaction of *Nesidiocoris tenuis* presence and larval feeding by *Tuta absoluta*

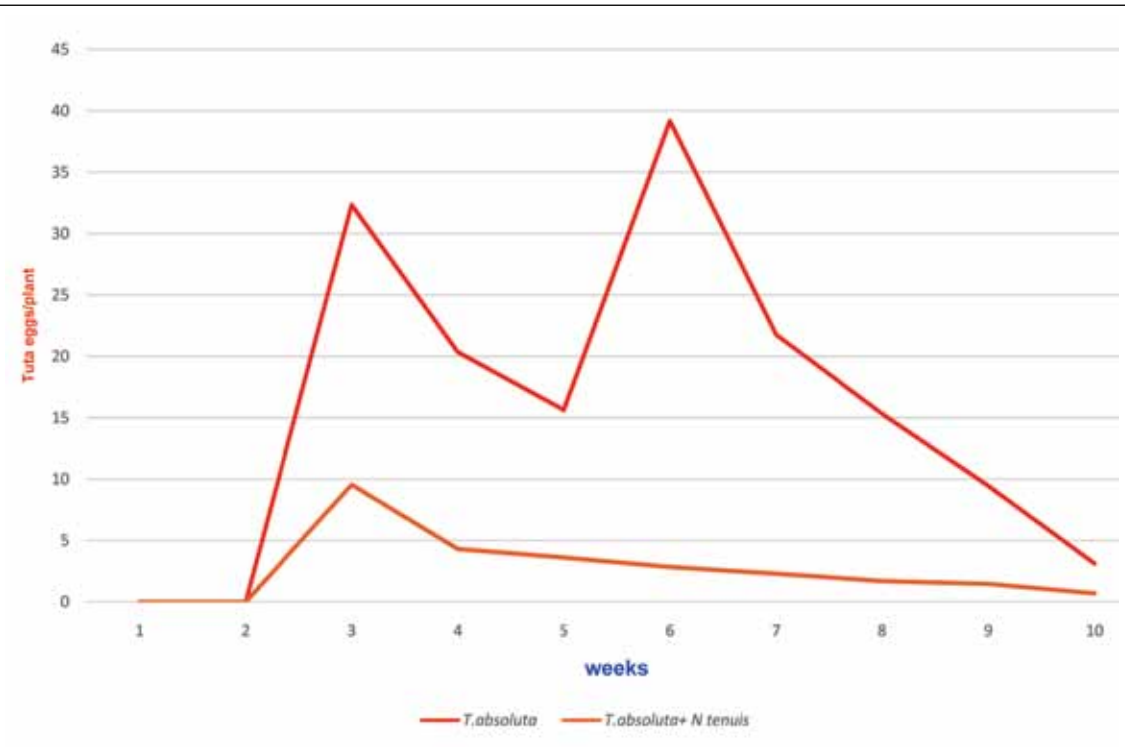


Fig. 52. Effect of *Nesidiocoris tenius* on *Tuta absoluta* egg on tomato

Climate change effect on the biodiversity and bio ecology of some important sucking pests

The population density of aphid, *Brevicoryne brassicae* on cabbage and cauliflower for the period 2014-15 was correlated with an array of weather parameters on weekly basis. Positive correlations were significant generally with the minimum temperature, sunshine hours of the current week, previous 1 & 2 weeks. Based on this regression equations were worked out (Table 22).

Table 22. Effect of weather parameters on *Brevicoryne brassicae*

Parameter	Period	Regression equation
Aphid population on cabbage	Current week	Y= 2.78.658-2.139 RH1-1.443 RH2+10.385 SSH-6.174 Evap
Aphid population on cabbage	Previous 1 week	Y= -410.151+5.861 Maxt+10.61 Mint+4.182 RH2-4.92 Evap
Aphid population on cabbage	Previous 2 week	Y=98.272-1.317 Mint-0.855 RH1+13.574RF+22.29 Evap
Aphid population on cauliflower	Current week	Y= 689.702-3.169 RH1-7.748 RH2+18.691 SSH-37.078 Evap
Aphid population on cauliflower	Previous 1 week	Y= -410.151+5.861 Maxt+10.61 Mint+4.182 RH2-4.92 Evap
Aphid population on cauliflower	Previous 2 weeks	Y= 168.690-6.775 Mint-0.849 RH1+22.675 RF+19.523 Evap

Incidence of sucking pests on brinjal at elevated levels of carbondioxide

The brinjal crop was raised at 600 ppm of CO_2 along with ambient temperature and +2° C above ambient during day and compared with the plants grown at ambient conditions.

The incidence of sucking pests was noted in all the plants. The growth of brinjal plants at 600 ppm of CO_2 with + 2 °C temperature was higher (25.5 cm) compared to 600 ppm of CO_2 & ambient temperature (14.87cm).

Incidence of sucking pests on cauliflower at elevated levels of carbondioxide

Cauliflower was raised at 600 ppm of CO_2 along with ambient temperature and +2° C above ambient during day and compared with the plants grown at ambient conditions. The growth of plants was very poor under elevated levels of carbondioxide and temperature that resulted in poor yield.The incidence of fungus, *Cladosporium cladosporoides*, a weak pathogenic was very high at field conditions on cabbage aphid.

INFLUENCE OF INFOCHEMICAL DIVERSITY ON THE BEHAVIORAL ECOLOGY OF SOME AGRICULTU RALLY IMPORTANT INSECTS

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

The volatile extracts of chick pea on different phenological state of the plant *viz.*,

vegetative, flowering and pod initiation stage was prepared in hexane and tested against the gravid female, virgin females and mated and unmated males. The studies indicated that the hexanol is involved in the ovipositional response of *H. armigera*.

Formulation of plant volatile based attractant for *Bactrocera dorsalis*

An alcohol free formulation of cuelure was field tested to attract *Bactocera cucurbitae*. A modified sticky trap with methyl eugenol was developed to manage *Bactrocera dorsalis*

A blend having pheromone and unsaturated hydrocarbon evaluated in Yelahanka and Kanpur trapped 1.5 males per trap in comparison to 0.75 males per trap in pheromone alone.

Plant oils as repellents for *Helicoverpa armigera*

A combination of plant oils was prepared and impregnated in the plywood pieces and installed @ 30 per a plot of 25 x 25 meter along with a control without any treatments. The incidence of eggs or larvae of *H. armigera* from 50 plants were observed in both the treatments. Oviposition by *H. armigera* was not affected by the treatments.

EXPLOITATION OF *BEAUVERIA BASSIANA* FOR MANAGEMENT OF STEM BORER (*CHILO PARTELLUS*) IN MAIZE AND SORGHUM THROUGH ENDOPHYTIC ESTABLISHMENT

Establishment of *Beauveria bassiana* as an endophyte in maize through aqueous conidial suspension and oil formulation (Glasshouse studies)

Glasshouse experiment was conducted to establish the endophytic ability of six strains of *Beauveria bassiana* (NBAIR-Bb-5a, 7, 14, 19, 23 and 45) in maize stem and leaf tissues (Var. Nithyashree) during different sampling periods 15, 30, 45, 60 and 75 Days after treatment (DAT), when applied through foliar sprays of aqueous conidial suspension and oil formulations. The aqueous conidial suspension and oil formulation of each strain (1 X 10^8 conidia /ml) was sprayed on maize seedlings with a hand sprayer at 15 and 30 days after germination. The control plants were sprayed with water containing 0.01% Tween 80 for aqueous conidial suspension and diluted oil devoid of conidia for oil formulation. At each sampling period, three plants were randomly selected from each treatment and were washed thoroughly under tap water. The plant bits (stem and leaf) from each treatment were surface sterilized and used for plating and PCR studies.

All six strains in both aqueous conidial suspension and oil formulation showed varying percent colonization and persistence of stem and leaf tissues.

In aqueous conidial suspension, among the six isolates tested, Bb-23 isolate recorded the maximum mean colonization in older stem (20.4%), young stem (21.3%) and older leaf (27.8%). Bb-5a isolate showed maximum mean colonization in young leaf tissues (26.9%).Bb-23 and Bb-45 showed longer persistence upto 60DAT in old stem tissues, Bb-5a and Bb-7 upto 75DAT in young stem tissues, Bb-7, 23 and 45 upto 60DAT in old leaf tissues and Bb-

45 isolate showed upto 90DAT in young leaf tissues.

In oil formulation, among six isolates tested, Bb-45 isolate recorded the maximum mean colonization in older stem (46.67 %), older leaf (47.78%) and in young stem (52.22 %). Bb-5a isolate showed maximum mean colonization in young leaf tissues (57.78 %). Bb-5a strain also showed continuous colonization upto 60 DAT in both older/young stem and leaf tissues.

In both the methods, the positive results of colonization of six strains of *B. bassiana* in stem and leaf (from both older and young tissue samples) tissues were confirmed by the PCR amplification using *B. bassiana* specific primer (Fig 53, 54 and 55). No colonization of *B. bassiana* was observed in the untreated (control) stem and leaf tissues. Recovery of *B. bassiana* from young stem/leaf tissues (developed after spraying) indicated its internal spread in the stem and leaf tissues of maize.

All the isolates except Bb-23 isolate showed significantly higher colonization of *B. bassiana* with oil formulation spray compared to aqueous conidial suspension spray in all sampled tissues. (Table 23).

The confirmation of endophytic establishment of *B. bassiana* was also done by Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM). In SEM studies, all the six isolates showed penetration of conidial germ tube into the leaf tissues after 5 days of spraying. In TEM studies, Propagules of *B. bassiana* were observed in treated leaf tissues.

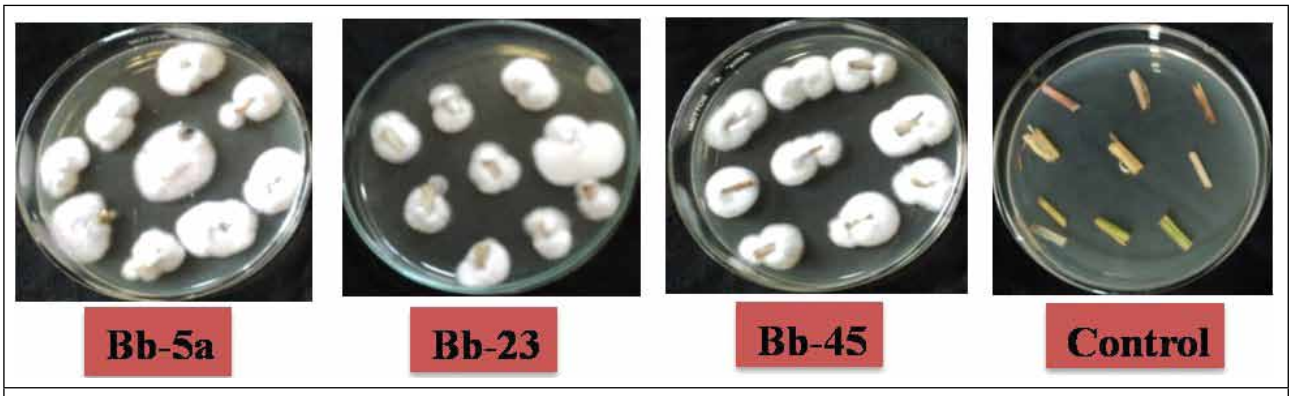


Fig. 53. Colonization of *Beauveria bassiana* in maize stem tissues

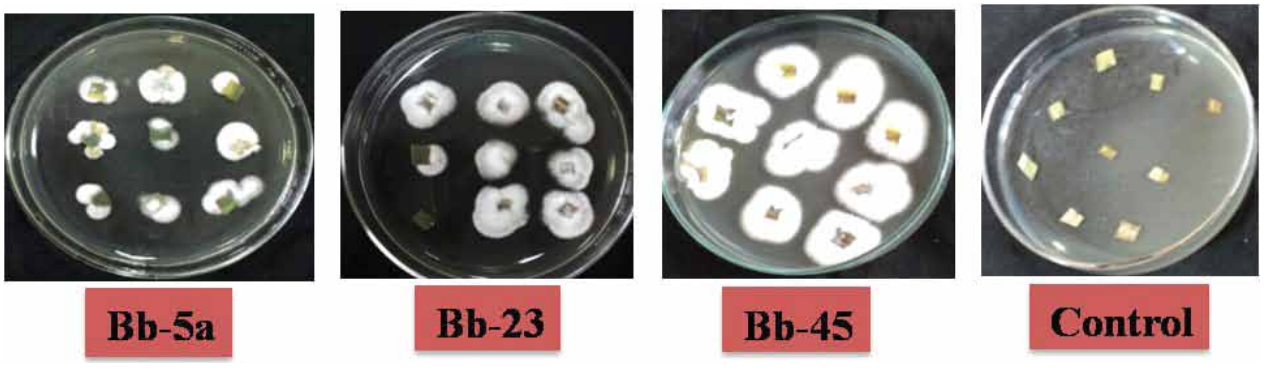


Fig. 54. Colonization of *Beauveria bassiana* in maize leaf tissues

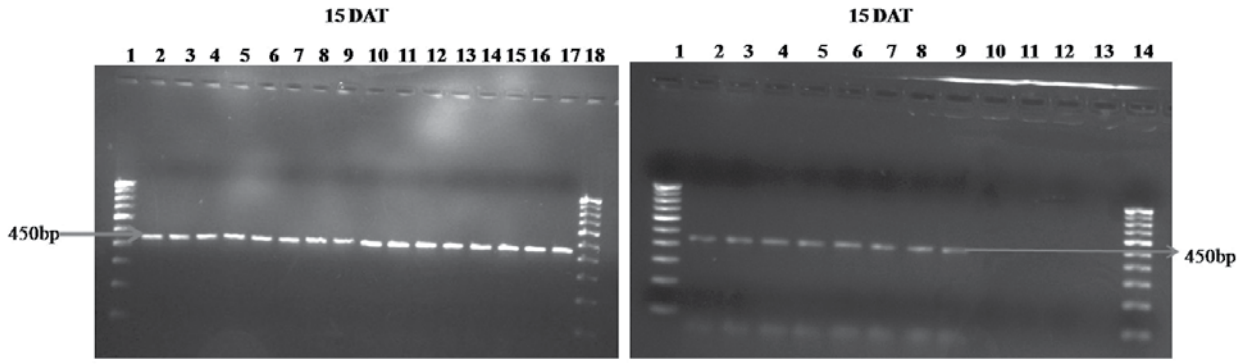


Fig. 55. PCR amplification of genomic DNA extracted from older & young stem and leaf tissues of *B. bassiana* treated maize

Lane 1 to 18: 1- 100bp ladder, 2- Bb5a older stem, 3- Bb5a young stem, 4-Bb5a older leaf, 5-Bb5a young leaf, 6-Bb7 older stem, 7-Bb7 young stem, 8-Bb7 older leaf, 9-Bb7 young leaf, 10- BB14 older stem, 11- Bb14 young stem, 12- BB14 older leaf, 13- BB14 young leaf, 14- Bb19 older stem, 15- Bb19 young stem, 16- Bb19 older leaf, 17- Bb19 young leaf, 18- 100bp ladder.

Lane 1 to 14 : 1- 100 bp ladder, 2- Bb23 older stem, 3- Bb23 young stem, 4- Bb23 older leaf 5-Bb23 young leaf, 6- Bb45 older stem, 7- Bb45 young stem, 8- Bb45 older leaf, 9- Bb45 young leaf, 10- control older stem, 11- control young stem, 12- control older leaf, 13- control young leaf, 14- 100bp ladder.

Table 23. Colonization of *Beauveria bassiana* with aqueous conidial suspension and oil formulation -mean percent colonization

Isolate	Percent colonization							
	Stem tissues				Leaf tissues			
	Older stem		Young stem		Older leaf		Young leaf	
	Aqueous conidial suspension	Oil form.	Aqueous conidial suspension	Oil form.	Aqueous conidial suspension	Oil form.	Aqueous conidial suspension	Oil form.
Bb5a	10.18^{c}	32.22^{b}	12.04^{c}	41.11^{a}	22.22^{c}	45.55^{a}	26.85^{b}	57.78^{a}
Bb7	12.02^{c}	24.44^{b}	16.67^{c}	28.89^{b}	20.37^{c}	34.44^{b}	13.89^{b}	47.78^{a}
Bb14	11.11^{c}	16.67^{b}	3.70^{d}	22.22^{b}	14.81^{c}	27.78^{b}	11.11^{c}	32.22^{b}
Bb19	7.41^{c}	27.78^{b}	9.26^{c}	28.89^{b}	6.46^{d}	34.44^{b}	12.04^{c}	32.22^{b}
Bb23	20.37^{b}	24.44^{b}	21.29^{b}	44.44^{a}	27.78^{b}	25.56^{b}	24.07^{b}	31.11^{b}
Bb45	12.96^{c}	46.67^{a}	11.11^{c}	52.22^{a}	23.15^{c}	47.78^{a}	18.52^{b}	52.22^{a}

***Values in columns followed by the different letter (a, b, c) are significantly different with each other**

Establishment of *Beauveria bassiana* as an endophyte in sorghum (Glasshouse studies)

A glasshouse experiment was conducted to establish six promising isolates of *B. bassiana* (NBAIR-Bb-5a, 7, 14, 19, 23 and 45) as endophytes in sorghum (Var. Maldandi M-35) through foliar application of aqueous conidial suspension. Two foliar sprays of the conidial suspension of each of the isolate of *B. bassiana* ($1x10^8$ conidia/ml) were given at 20 and 35 days of after germination. The colonization and persistence of the six isolates was studied in stem and leaf tissues at 15, 30, 45, 60, 75 and 90 days after treatment. Untreated plants were sprayed with sterile water containing 0.01% Tween 80. Three plants were randomly uprooted from each treatment during sampling period and washed thoroughly in tap water. The plant bits (stem and leaf) from each treatment were surface sterilized and used for plating and PCR amplification.

All six strains showed varying percent colonization and persistence in stem and leaf tissues through plating technique and PCR amplification. Among six isolates tested, Bb-5a isolate recorded the maximum mean colonization in older stem (21.30 %) and young leaf tissues (22.22 %). Bb-14 isolate showed maximum mean colonization in young stem (18.52 %) and in older leaf tissues (28.70%). Bb-5a isolate also showed continuous colonization upto 60 DAT in older/young stem tissues, older leaf tissues and upto 45 DAT in young leaf tissues. Bb-14 isolate showed continuous colonization upto 75 DAT in older leaf tissues. Persistence of inoculated fungal isolates decreased with increase in age of the plant. The positive results of colonization of six strains of *B. bassiana* in stem and leaf (from both older and young tissue samples) tissues observed in plating technique were confirmed by the PCR amplification using *B. bassiana* specific primer (Fig 56, 57 and 58). No colonization of *B. bassiana* was observed in the untreated (control) stem and leaf tissues. Recovery of *B. bassiana* from young stem/leaf tissues (developed after spraying) indicated its internal spread in the stem and leaf tissues of sorghum.

The confirmation of endophytic establishment of *B. bassiana* was done by Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM). In SEM, all six isolates showed conidial germination on leaf surface and penetration into the leaf tissues after 6 days of spraying. In TEM, propagules of *B. bassiana* were observed in the treated leaf tissues.

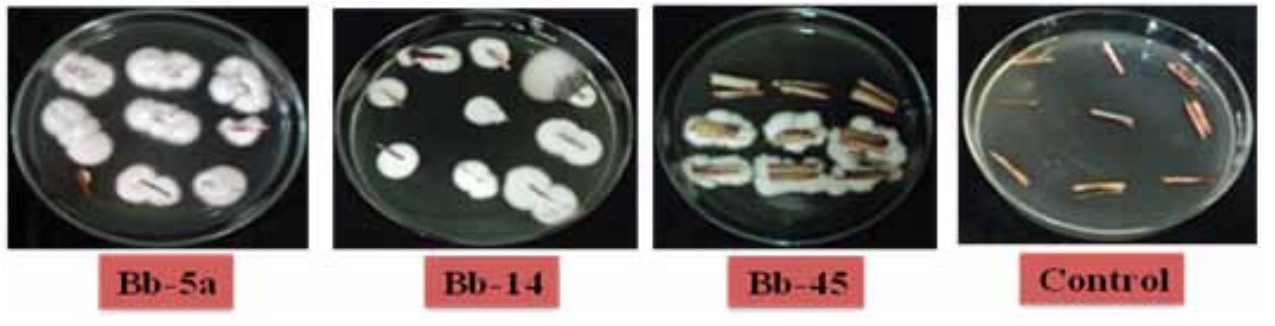


Fig. 56 Colonization of *Beauveria bassiana* in sorghum stem tissues

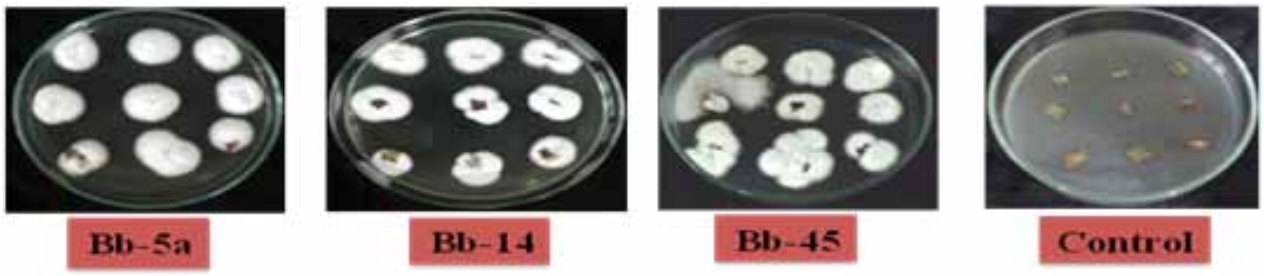


Fig. 57 Colonization of *Beauveria bassiana* in sorghum leaf tissues

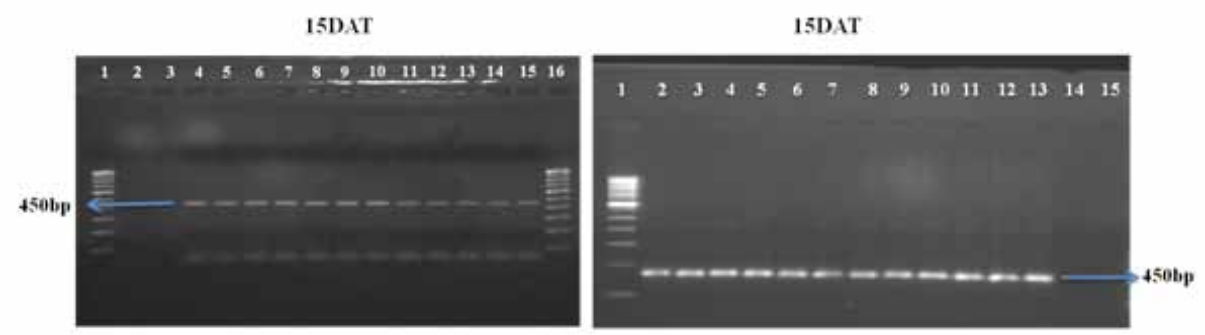


Fig. 58. PCR amplification of genomic DNA extracted from older & young stem and leaf tissues of *B. bassiana* treated sorghum

Lane 1 to 16: 1- 100bp ladder, 2- control older stem, 3- control young stem, 4- Bb5a older stem, 5- Bb5a young stem, 6- Bb7 older stem, 7- Bb7 young stem, 8- Bb14 older stem, 9- Bb14 young stem, 10- Bb19 older stem, 11- Bb19 young stem, 12- Bb23 older stem, 13- Bb23 young stem, 14- Bb45 older stem, 15- Bb 45 young stem 16- 100bp ladder.

Lane 1 to 15: 1- 250 bp ladder, 2- Bb5a older leaf, 3- Bb5a young leaf, 4- Bb7 older leaf, 5- Bb7 young leaf, 6-Bb14 older leaf, 7- Bb14 young leaf, 8- Bb19 older leaf, 9- Bb19 young leaf, 10- Bb 23 older leaf, 11- Bb23 young leaf, 12- Bb45 older leaf, 13- Bb45 young leaf, 14- control older leaf, 15- control young leaf.

Evaluation of endophytic isolates of *B. bassiana* against maize stem borer, *Chilo partellus* during kharif and rabi seasons (2015-16)

A field trial was conducted to evaluate the endophytic isolates of *Beauveria bassiana* (NBAIR-Bb-5a, 7, 14, 19, 23 and 45) through foliar applications of oil formulations against stem borer, *Chilo partellus* in maize (Var. Nithyashree) at ICAR-NBAIR, Yelahanka Research Farm, Bengaluru during kharif and rabi season of 2015-16. Two foliar sprays of the oil formulation of each isolate of *B. bassiana* (1 x 10^8 conidia/ml) were applied at 15 and 30 days after germination. Ten second instar larvae of *C. partellus* per plant were released in to the inner leaf whorl of the *B. bassiana* treated and untreated maize plants after 5 days of second spray.

Among the six isolates tested during kharif and rabi seasons, Bb-5a isolate showed significantly lower dead hearts (10.22 and 7.11 % in kharif and rabi respectively, lowest no. of exit holes (1.80 and 1.07 /plant in kharif and rabi) and lower stem tunneling (1.23 and 2.21 cm/plant in kharif and rabi), as compared to untreated control which showed higher dead hearts (23.56 and 26.78 %), exit holes (7.20 and 4.07 /plant) and stem tunneling (5.20 and 7.80 cm/plant) during kharif and rabi season respectively as represented in Table 5. Significantly higher cob yield was obtained

in the plots treated with Bb-5a (14.2 and 13.03kg/10plants in kharif and rabi) and Bb-45 (13.6 and 12.43kg/10plants in kharif and rabi) compared to the lower yield of control plot (11.8 and 10.63kg/10plants in kharif and rabi) (Table 24 and Fig 59).

Table 24. Effect of endophytic isolates of *Beauveria bassiana* on infestation of maize stem borer in Kharif and Rabi seasons

Isolate	Dead hearts (%)		Exit holes/plant		Stem tunneling/ plant (cm)		Cob yield /10 plants (Kg)	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
Bb-5a	10.22^{a}	7.11^{a}	1.80^{a}	1.07^{a}	1.23^{a}	2.21^{a}	14.20^{a}	13.03^{a}
Bb-7	16.78^{c}	13.67^{c}	4.10^{b}	2.23^{b}	2.91^{ab}	4.98^{b}	12.70^{bc}	11.53^{b}
Bb-14	20.00^{d}	16.89^{d}	5.60^{c}	2.20^{b}	3.49^{bc}	5.57^{bc}	12.00^{bc}	10.83^{b}
Bb-19	13.67^{b}	10.56^{b}	3.40^{b}	2.40^{b}	2.56^{ab}	5.25^{bc}	13.20^{ab}	12.03^{b}
Bb-23	20.11^{d}	17.00^{d}	3.60^{b}	2.07^{ab}	3.11^{b}	6.89^{bc}	12.20^{bc}	11.03^{b}
Bb-45	16.89^{c}	13.78^{c}	1.90^{a}	2.17^{b}	2.53^{ab}	5.22^{bc}	13.60^{a}	12.43^{ab}
Control	23.56^{e}	26.78^{e}	7.20^{d}	4.07^{c}	5.20^{c}	7.80^{c}	11.80^{c}	10.63^{b}
CD @ 0.05 %	**0.60**	**0.66**	**1.31**	**1.04**	**1.98**	**2.77**	**1.50**	**1.70**

Fig. 59. Extent of stem tunnelling caused by *Chilo. partellus* in treated and untreated maize plants

Evaluation of endophytic isolates of *B. bassiana* against sorghum stem borer, *Chilo partellus* in kharif season

A Field trial was conducted to evaluate the endophytic isolates of *B. bassiana* (NBAIR-Bb-5a, 7, 14, 19, 23 and 45) through foliar application of oil formulations against stem borer, *C. partellus* in sorghum (Var. Maldandi M-35) at ICAR-NBAIR, Yelahanka Research Farm, Bengaluru during kharif, 2015. Two foliar sprays of the oil formulation of each of the isolate (1 x 10^8 conidia/ml) were applied at 15 and 30 days after germination. The second instar larvae of *C. partellus* (10 larvae /plant) were artificially released in to the inner leaf whorl of the treated and untreated sorghum plants after 5 days of second spray.

Among the six isolates tested, Bb-23 and Bb-5a isolates showed significantly lesser dead hearts of 6.78 and 9.33%, exit holes (0.38 and 0.73 /plant) and lesser stem tunneling (3.75 and 4.32 cm/plant) as compared to the untreated control which recorded higher dead hearts (19.78 %), exit holes (2.10 /plant) and stem tunneling (10.18 cm/plant). The grain yield obtained in treated and untreated control were on par with each other (140-166.67 gm/10plants) as shown in Table 25 and Fig 60.

Table 25. Effect of endophytic isolates of *Beauveria bassiana* on infestation of sorghum stem borer in Kharif

Isolate	Dead hearts (%)	Exit holes/ plant	Stem tunneling/ plant (cm)	Grain yield /10 plants (gm)
Bb-5a	9.33^{ab}	0.73^{a}	4.32^{ab}	160.00
Bb-7	13.11^{bc}	1.78^{b}	7.85^{bc}	150.00
Bb-14	16.33^{cd}	1.90^{b}	8.59^{c}	143.33
Bb-19	16.44^{cd}	1.97^{b}	6.38^{abc}	146.67
Bb-23	6.78^{a}	0.38^{a}	3.75^{a}	166.67
Bb-45	13.22^{bc}	1.77^{b}	7.76^{bc}	146.67
Control	19.78^{d}	2.10^{b}	10.18^{c}	140.00
CD @ 0.05 %	1.38	0.77	4.06	63.67 (NS)

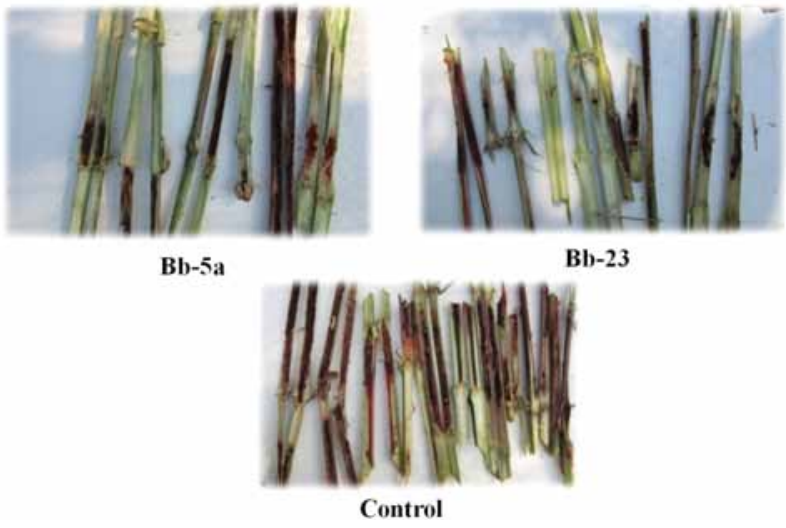


Fig. 60. Extent of stem tunnelling caused by *Chilo partellus* in treated and untreated sorghum plants

Production of enzymes by bacterial symbionts of *Amrasca biguttula biguttula* in insecticide degradation

Carboxylesterase is the important enzyme involved in insecticide degradation was quantified from the various endosymbionts of *Amrasca biguttula biguttula. Bacillus pumilus* produced maximum of carboxylesterase (0.309µmoles/ml followed by *Enterobacter cloacae* (0.204µmoles/ml), *Filobasidium floriformie* (0.169µmoles/ ml) and *Bacillus licheniformis* (0.132µmoles/ml)(Table 26). Carboxylesterase enzyme was also detected from the symbionts (Fig 61)

Table 1. Production of Carboxyl esterase from the bacterial symbionts of *A.biguttula biguttula*

Bacterial endo-symbionts	Absor-bance at 540 nm	Concentration (µmoles/ml)
Bacillus pumilus	0.906	0.309
Enterobacter cloacae	0.568	0.204
Filobasidium floriforme	0.451	0.169
Staphylococcus aureus	0.300	0.123
Bacillus licheniformis	0.330	0.132
Control	0.000	0.000

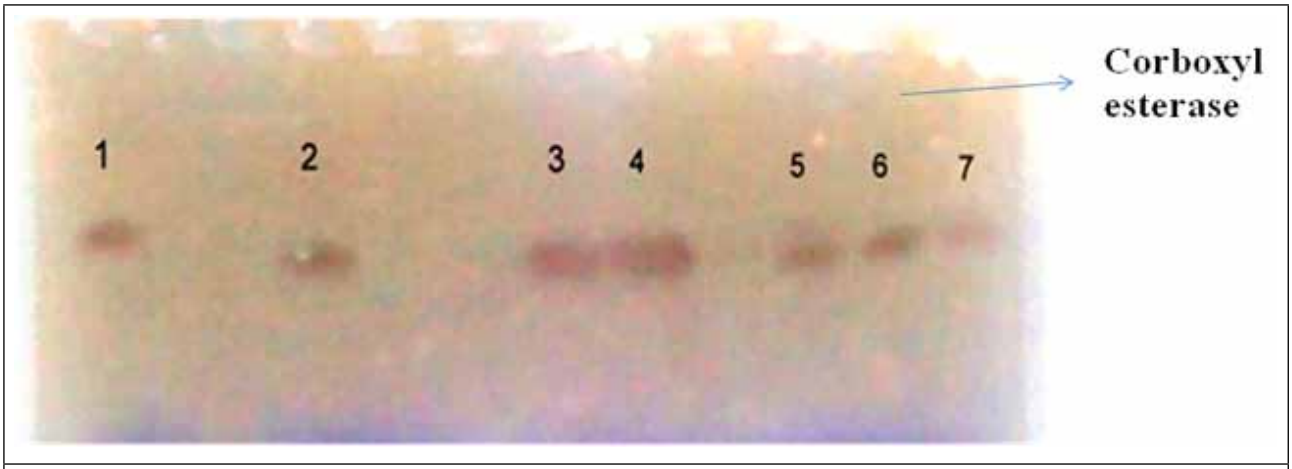


Fig.61. Native- PAGE showing the presence of carboxyl esterase enzyme from bacterial symbionts of *A. biguttula biguttula* Lane 1 : Control; Lane 2 : *Staphylococcus aureus*; Lane 3 : *Filobasidium floriforme* Lane 4 : *Bacillus licheniformis;* Lane 5 : *Bacillus pumilus;* Lane 6 : *Enterobacter cloacae;* Lane 7 : *Bacillus methylotrophicus*

Production enzymes by bacterial symbionts of *Amrasca biguttula biguttula* in insect nutrition

Production of the symbionts on host nutrition was studied. The pectinase, an important enzyme involved in insect nutrition was detected from the symbionts (*Bacillus pumilus*, *Filobasidium floriformie, B.licheniformis* and *Staphylococcus aureus)* of *A. biguttula biguttula* (Fig.62).

Characterization of viruses with special reference to Lepidoptera and Coleoptera

Six strains of Nucleopolyhedrovirus (NPV) were collected from various institutes across the country. Strains of *HaNPV* were collected from Harit Biocontrol lab Yavatmal Maharastra, KVK Puducherry, Maharanapratap University of Agriculture science and technology, Udaipur, MPKV, Rahuri.

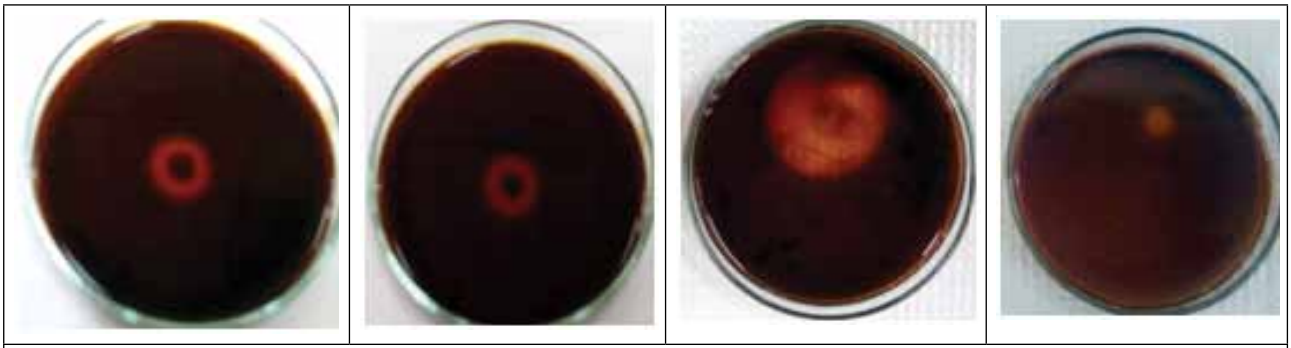
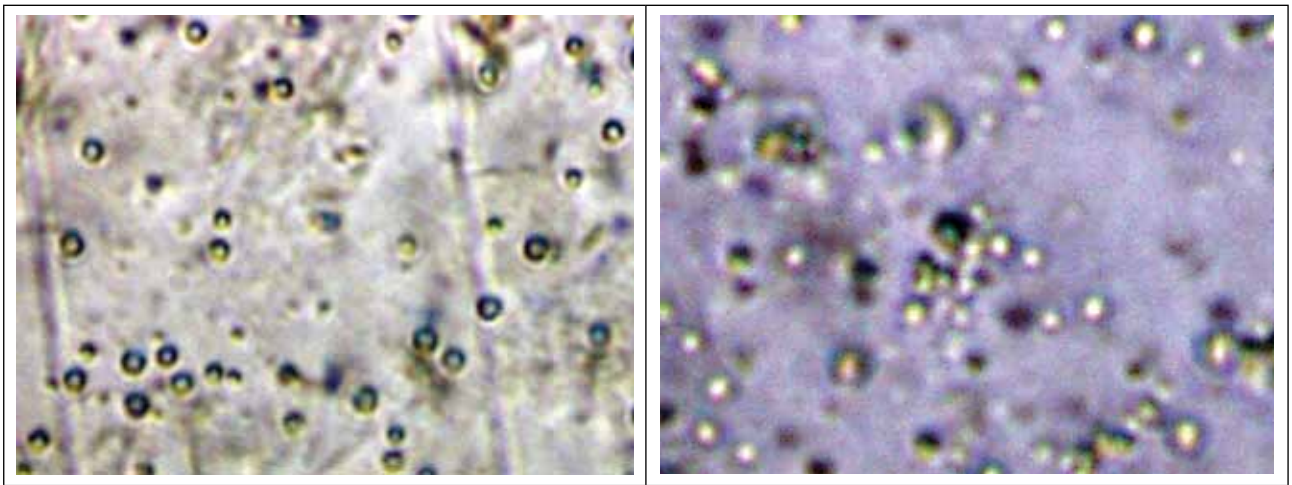


Fig.62. Production of pectinase from the bacterial symbionts of *A. biguttula biguttula*

Strains of *Sl*NPV were collected from KVK Puducherry, Maharanapratap University of Agriculture science and technology, Udaipur, MPKV, Rahuri. The collected insect viruses were maintained with a strain number. Surveys were made in around Bengaluru and collected virus infected larvae from Bhendi and cabbage. The *NPV* was isolated from the infected larvae of *Spodoptera litura* of cabbage and *Heicoverpa armigera* of Bhendi. The polyhedral occlusion bodies of all these insect viruses were viewed through light microscope (Fig.63). The size and shape of the occlusion bodies are spherical.



***Spodptera litura NPV (SlNPV)* from cabbage** | ***Helicoverpa armigera (HaNPV)* from Bhendi**

Fig. 63. Spherical occlusion bodies of Nucleopolyhedrovirus (NPV) observed under light microscope

Feasibility of suppression of Tea shot hole borer *Euwallacea fornicatus* through its mutualistic *Fusarium spp.*

Tea shot hole borers (Fig. 64) were collected from the tea gardens at Coonoor, Valparai, Gudalur, Tamilu Nadu. The obligate fungal endosymbiont *Fusarium ambrosium* (Fig. 65) was isolated from the head of tea shot hole borer *E. fornicatus* as well as from the tea stem galleries. The mycelium of the fungus was pale in color and cottony. The color of the thallus was whitish to pink. Fungus produced only club shaped multiseptate conidia. The amplification of ITS region revealed the identity of the fungus as *F. ambrosium* (GenBank Acc. No KC 6915561).



Fig. 64. Tea Shot hole borer, *Euwallacea fornicatus* damage on stem



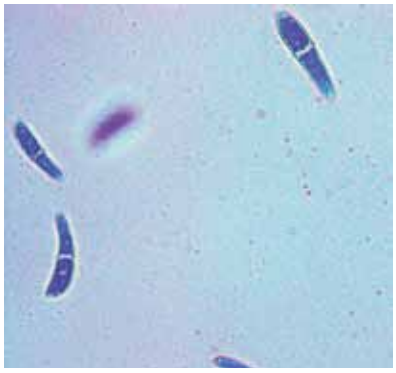


Fig. 65. The fungal endosymbionts. (a) Club shaped multiseptate conidia of *Fusarium ambrosium;* (b) *Fusarium ambrosium* in tea stem galleries

Table 27. Monitoring of papaya mealybug and its natural enemies on papaya and other alternate hosts

Location	Area of plantation(ha)	No. of plants with papaya mealybug	Damage
Mandya	8.00	12	Trace
Raichur	1.50	2	Trace
Shimoga	0.50	Nil	
Hassan	1.50	Nil	
Gulbarga	0.50	Nil	
Bangalore	0.5	2	Trace
Maddur	2.75	Nil	
Ramnagar	0.50	7	Severe in one
Chamrajnagar	5.50	2	Trace
Chitradurga	0.50	Nil	
Tumkur	1.00	Nil	
Nelamangala	2.00	2	Trace
Coimbatore	0.50	2	Trace
Nashik	1.25	Nil	
Nagpur	0.50	Nil	
Hosur	2.50	7	Severe in 2 trees
Andaman Islands	0.50	15	Severe

Survey for papaya mealybug

Incidence of papaya mealybug was below pest status in all the areas surveyed (Table 27). In Andaman Islands it caused 25-30% damage on papaya and vegetable crops.

A high level of parasitization was recorded in all the samples collected. *Acerophagus papayae* was the predominant parasitod, in addition *Pseudleptomastix mexicana*. Cultures of both parasitoids were sent to OUAT Bhuvaneshwar, Andaman Islands, Hosur, Madurai, New Delhi, Gujarat, Pondicherry, Ananthpur, in addition to local supplies in Karnataka.

Parasitization of *Acerophagus papayae* by hyperparasitoids is on rise in Karnataka. The samples collected from Nelamangala, Chamarajnagar, and Maddur had 6-7 per cent hyperparasitization by *Chartocerus sp*. and 2-3% by *Marietta leopardina*.

Host range of invasive Jack Beardsley mealybug (*Pseudococcus jackbeardsleyi* Gimpel and Miller) in Karnataka

Survey for occurrence of *P. jackbeardsleyi* was continued in Tamil Nadu, and Karnataka. In few plants it was found associated with papaya mealybug on papaya and with Madeira mealybug in *Hibiscus, Cordyline terminalis* (Agavaceae), *Diffenbachia sp.* Incidence was very low compared to previous years. Some of the local natural enemies like *Cryptolaemus montrouzieri* Mulsant, *Spalgis epius* West Wood and many species of gnats kept the pest under check. *Nephus regularis* wasa major predator on eggs of *P. jackbeardsleyi*.

Establishment of *Cecidochares connexa* gall fly

C. connexa a bioagent for management of chromolena released had established upto 15 galls per 5 minutes search in released spot in Kanakapur Road. In Puttur, Dakshina Kannada District it has spread around 6-9 km from the released spot and in Tataguni estate it has sprad to the nearby forest area. At GKVK spread was localised due to availability of host insects. Burning of the dried plants either manually or by forest fire has become the major factor for low level of spread in forest area. The gall fly has also established in Kerala and also in Tamil Nadu in the places of release.

Development of formulations of *Beauveria bassiana, Metarhizium anisopliae, Lecanicillium* spp. and *Paecilomyces fumosoroseus* for management of certain sucking pests in vegetable crops

In the Field trial at Bangalore (Karnataka), oil formulation of *Beauveria. bassiana*, Bb-5a isolate showed significantly highest reduction of 75.94% of cabbage aphid (*Brevicoryne brassicae*) and showed the highest yield (19000 kgs/ha), The untreated control plot showed the lowest yield (14500kg/ha).

Field trials with entomofungal pathogens against aphids of okra, chillies and brinjal (*Aphis gossypii*) at Bangalore (Karnataka) indicated the efficacy of *Metarhizium anisopliae* Ma-4 isolate in okra and brinjal with 71.76% & 73.96% pest reduction respectively. *L. lecanii*, Vl-8 isolate was found effective in suppressing the chilli aphid (79.88% reduction). These isolates showed significantly higher yields in the respective crops compared to the control plots.

Survey for invasive thrips *Frankliniella occidentalis*

The samples of tomato, chilli and flowers collected did not yield *F. occidentalis* (Table 28).

Fortythree samples in 13 locations in Karnataka, Tamilnadu, Maharashtra were collected for sampling for *Frankliniella occidentalis*. This invasive was not found in any of the samples.

Table 28. Sampling locations for *Frankliniella occidentalis*

Location	Samples	Presence of thrips	*Frankliniella occidentalis*
Bangalore and sorroundings	7	2	Nil
Raichur	3	1	Nil
Shimoga	5	2	Nil
Hassan	1		Nil
Gulbarga	2		Nil
Coimbatore	6	2	Nil
Chitradurga	1		Nil
Tumkur	2		Nil
Nelamangala	4	3	Nil
Nashik	3	1	Nil
Nagpur	2		Nil
Hosur	5	2	Nil
Dharmapuri	2	1	Nil

Mass production of (Girault) *Aenasius arizonensis* Hayat (Hymenoptera: Encyrtidae)

Aenasius arizonensis Hayat (Hymenoptera: Encyrtidae), a solitary endoparasitoid on *P. solenopsis*. is active in all the cotton growing areas and also on alternate hosts. Adult females have a preference to parasitize third instar nymphs. Reddish brown cocoons scattered in the mealybug colony indicates the parasitization by *A. arizonensis* and can easily be distinguished from the healthy colony. Studies on mass production of parasites using *Parthenium hysterophorus* as host revealed that the total developmental period: 16-20 days and pupal period of 6-8 days. Adult longevity: females: 13-30 days and males 8-10 days with fecundity of 130-150eggs. Females are more in number compared to males (Around 30 males to 100 females in *Parthenium* host plant). Parasitoids were supplied to farmers on request.

New invasives and host extensions

Tuta absoluta was recorded in Karnataka, Tamilnadu, Gujarat. Zoophytophagus plant bug *Nesidiocoris* sp. (Miridae) recorded to be associated with the pest. Western flower thrips *Frankliniella occidentalis* (Pergande) reported from Bengaluru earlier but the same has not been traced either in Bengaluru, or in South India in samples at randomly selected sites. The severity of banana skipper *Erionota thrax* (Hespiridae: lepidoptera) has come down. Root mealybugs on Pepper *Formicococcus polysperes* Williams and other species have become severe in Coorg and Chickmagalur area. Skipper- *Hasora chromus* (Cramer) in transient stage fluttering in and around

Bengaluru. *Chromatomyia syngenesiae* Hardy 1849 (Agromyzidae: Diptera) was found to be a major outbreak on Chrysanthemum in Coonor and Ooty areas. The skipper, common banded awl, *Hasora chromus* (Cramer) (Lepidoptera: Hesperiidae), upsurge was recorded on *Pongamia pinnata* in and around Bengaluru. Insectivorous birds were observed to feed on the caterpillars. A looper (*Cleora* sp.) (Lepidoptera: Geometridae) was found to feed extensively on neem trees in a few villages of Samsthan Narayanpur mandal of Nalgonda district in Telangana during October/November 2015. Similar damage was found in the nearby villages also. Previously this was recorded as a pest of Pigeon pea from Hyderabad.

Five mealybugs species namely *Planococcus* sp., *Planococcus citri* (Risso), *P. lilacinus* Cockerell, *Dysmicoccus brevipes* (Cockerell) and *Ferrisia virgata* (Cockerell) are known to infest the roots and basal region of stem of black pepper vines. *Formicococcus polysperes* Williams has become severe in Coorg and Chickmagalur area.

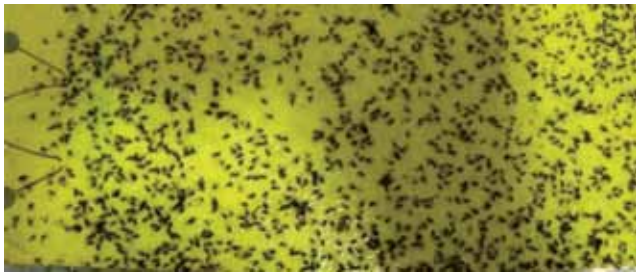
Erythrina Gall wasp *Quadrastichus erythrinae* was found in low populations in Kolar, Mandya, and Ramnagar districts. *Aprostocetus gala* was found to be the major parasitoid of *Q. erythrinae.*10-15% parasitization observed in field. It was clearly established that *Aprostocetus gala* was always found associated with *Q.erithrinae* (Fig.66). Parasitoids released on the infested plants established and adults could be recovered after 30- 45 days.

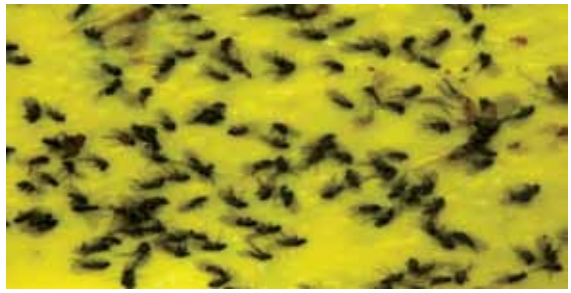
Aprostocetus sp. is a potential parasitoid of erythrina gall wasp (*Quadrastichus erythrinae*) in India. Its identity was confirmed by molecular characterization.White gaster typical of *A. felix* males is absent in Indian specimens collected.

Fig.66. *Erythrina* galls and wasps

Incidence of invasive leaf miner *Chromatomyia syngenisiae*

Severe outbreak of *Chromatomyia syngenisiae* leafminer was recorded from Coonor, Ooty and nearby areas including in poly houses across Nilgiri hills and Coimbatore. The incidence occurred in > 80 percent of the plants in the sampled area and the yellow traps were full by the end of the day of installation with adult flies. No parasitoids were recorded from the area. Release of *Diglyphus sp.* also did not bringdown the damages. *Herbertia sp.* (Pteromalidae: Hymenoptera) was collected from the mummified puparium of the leafminers (Fig. 67).





Herbertia sp.

Fig. 67. *Chromatomyia syngenisiae* and associated insects

Incidence of Thai Sac brood disease in Dakshina Kannada district of Karnataka

A survey was undertaken for the prevalence of diseases in honey bees in Dakshina Kannada district of Karnataka (Fig.68). Survey was conducted at Puttur, Sulyapadavu and Dharmastala and Sullya comprising of the major bee keeping areas in the district. The disease was rampant in the area causing losses to bee colonies as high as 35 to 50 per cent depending on the location. It was severe in Sullya, Sullyapadavu and Dharmasthala and less damage was seen (less than 10%) in Puttur. Meetings were organized at Sulyapadavu, Sullya and Dharmasthala to educate the beekeepers on preventive and management practices to overcome Thai sac brood disease (Fig.69, 70).

Fig. 68. (a) Locally made hives placed closely on ground attract pests and diseases (b) Excessive use of pesticide dusts

Fig. 69. Meeting with beekeepers at Sullya, and Mr Shyam Bhat, Director, Dakshina Kannada bee keepers Society

Fig.70. Hive and immatures of honey bees

ALL INDIA COORDINATED RESEARCH PROJECT ON BIOLOGICAL CONTROL OF CROP PESTS

Biodiversity of biocontrol agents from various agro ecological zones

Trichogramma, Chrysoperla, Cryptolaemus, spiders and entomopathogenic nematodes (EPNs) were collected from different crop ecosystems in Anand district. *Bt* isolates were obtained from 58 soil samples out of the 300 samples collected from Panchamahal district (AAU-A). Coccinellids collected on different *rabi* vegetables were *Coccinella septempunctata*, *C. transversalis, Brumoides suturalis* and *Micraspis* spp. The most dominant spider species collected from rice ecosystem were *Oxyopes* sp., *Tetragnatha* sp., *Lycosa pseudoannulata* and *Argiope catenulate* (AAU-J). Natural enemies recorded were *Trichogramma chilonis,* coccinellids, *Chrysoperla, predatory earwig, Euborellia* sp. and spiders from different ecosytems of Telangana (PJSTAU).

Field collected strains of *Trichogramma chilonis* were maintained under laboratory conditions on *Corcyra cephalonica* eggs. Test and back crosses were made between different strains of *Trichogramma chilonis* AAA10 (relatively temperature tolerant) with other high fecundity strains *viz.*, FFF1, FFF2 and FFF3 and mortality was high among the individuals in each generation. The crosses with high fecundity strains were relatively more susceptible to test temperature regimes coupled with higher percentage of arrhenotoky. Per cent arrhenotoky among the progenies also increased with increase in temperature. (IARI)

The natural enemies recorded were coccinellids, *Coccinella septempunctata*, *Menochilus sexmaculata, Scymnus* sp., *Encarsia flavoscuttellum, Dipha aphidivora*, *Micromus igorotus* and syrphids on Sugarcane woolly aphid, *Coccinella transversalis*, *M. sexmaculata, Brumoides suturalis*, *Scymnus coccivora* and *Triomata coccidivora* on custard apple mealybug colonies and *Acerophagus papaya, Pseudleptomastix Mexicana, Mallada*

boninensis, *Spalgis epius,Scymnus nubilus* and *Phrynocaria perrotteti* on papaya mealybug. The chrysopid, *Chrysoperla zastrowi sillemi* was recorded in cotton, maize and french bean while *M. boninensis* on french beans, mango, okra, papaya and sunflower. The *Cryptolaemus* adults were recovered from the pre-released plots of custard apple and papaya. Cadavers of *Helicoverpa armigera* and *Spodoptera litura* infected with EPNs were collected from soybean, potato and tomato (MPKV)

Five different entomopathogenic fungi were isolated from 31 soil samples of various crop ecosystems in Fatehgarh Sahib, Sangrur, Pathankot and Barnala districts. Five *Bacillus* bacteria were isolated from soil samples of various crop ecosystems in Barnala, Patiala, SAS Nagar, Amritsar and Ludhiana districts. EPNs had been recovered from 10 soil samples out of fifty samples collected from different locations of Punjab (PAU). The natural enemy populations of aphelinid parasitoids, *Encarsia perniciosi*, *Aphytisproclia*, *Ablerus* sp. and coccinellid predator, *Chilocorous infernalis* were found on San Jose scale exclusively in unmanaged orchards of apple, apricot, plum, pear, peach, cherry, walnut and almonds in Kashmir valley as well as Laddakh. *Aphelinus mali* was found actively associated with apple woolly aphid, *Eriosomalanigerum.* Nine natural enemies were recorded for the first time from Kashmir in association with different fruit pests (SKUAST).The predators recorded were *Cryptolaemus montrouzieri* and *Chrysoperla zastrowisillemi* on mealybugs, scales and psyllids infesting brinjal, curry leaf, guava, papaya and tapioca.

Five species of coccinellids, *Coccinella septempunctata, Cheilomenes sexmaculata, Serangium parcesetosum, Chilocorus rubidus, Scymnus sp.* were found feeding on mango hoppers and mealybugs. Natural infestation of *Beauveria bassiana* was observed on *Inderbela quadrinotata* and infested cadavers were collected and pure culture is being maintained. Four parasitoids belonging to families Ichneumonidae and Braconidae were collected from the mango and guava ecosystem (CISH).

Three species of parasitoids, *Tetrastichus schoenobii*, *Trichogramma japonicum* and *Telenomus* spp. were recorded on eggs of rice yellow stem borer. The coccinellid, *Micraspis vincta* was abundantly present in the rice ecosystem. Egg baiting for egg parasitoids recorded the presence of *Anagrus* sp., *Gonatocerus* sp. (Mymaridae) and *Oligosita* sp. (Trichogrammatidae). Parasitoid, *Chrysonotomyia* sp. (Eulophidae) was collected on grubs (68 per cent parasitization) and pupae (80 per cent parasitization) of the hispa beetle, *Dicladispa armigera* from Himachal Pradesh (IIRR).

Surveillance for alien invasive pests

The papaya mealybug, *Paracococcus marginatus* and Jack Beardsley mealybug, *Pseudococcus jackbeardsleyi* were recorded on papaya in Tamil Nadu (TNAU). In Maharastra, *Pseudococcus jackbeardsleyi*was recorded on custard apple in Pune and *P. marginatus*was observed in the papaya orchards of western Maharashtra (MPKV). The incidence of papaya mealybugwas low in all surveyed districts of Kerala. Stray incidences of PMB infestations were observed at two locations in Thrissur district.

However, the population was very low (KAU). Tomato pinworm, *Tuta absoluta* was recorded from Maharashtra, Tamilnadu and Solan. Alien invasive insect pests like *Aleurodicus dugesii, Brontispa longissimi, Phenacoccus manihoti, Phenacoccus madeirensis* and *Frankliniella occidentalis* were not observed in any of the centres.

Biological suppression of pests and diseases in field

Biological suppression of diseases

In rice, among different *Trichoderma* isolates tested, TCMS 9 and PBAT 3 were found effective in improving plant health, reducing sheath blight and brown spot diseases and in increasing yield. In pea, TCMS 9, PBAT 3 and Psf 173 reduced seed and plant mortality in field. In chickpea, Psf 2 and PBAT 3 were found very promising in reducing seed as well plant mortality in the field (GBPUAT)

Bio-efficacy of different biocontrol treatments were evaluated against anthracnose disease of chilli. Among the different tested biocontrol treatments, *Pichia guilliermondii* (Y12) seed treatment, seedling dip and foliar spray ($2x10^8$cfu ml^{-1}) was found superior to all with the minimum disease intensity (13.56%) and the maximum yield (38.16 q/ha) (AAU-A). Lowest per cent fruit rot (19.24 %) was recorded in chemical control and was followed by *P. guilliermondii* (22.15 %) and *Trichoderma harzianum* (24.25 %) treatments. Highest yield of 67.66 q/acre was recorded in chemical treatment followed by *P. guilliermondii and T. harzianum* treatments with an yield of 58.5 and 56.72 q/acre, respectively (PAU). *T. harzianum* (Th-3) and *P. guilliermondii* (Y-12) were found significantly better in reducing fruit rot with increased yield (GBPUAT).

Field evaluation of promising *Pseudomonas flourescens* for the management of pre and post emergence damping off diseases of vegetables was undertaken. In tomato, among different tested isolates, Psf-2, Psf-173 and PBAT 3 were found effective in reducing pre-and post-emergence seedling mortality with increased plant vigour. In onion, PBAT 3 was found very promising in reducing pre and post emergence mortality coupled with better plant vigour (GBPUAT).

Biological suppression of pests in cereals and pulses

Sorghum

Entomofungal formulations of *Metarhizium,* Ma 35, 36 and 52 were effective against *Chilopartellus* causing 48.6 and 51.4 per cent reduction in dead hearts and stem tunnelling, respectively over the untreated control and the results were on par with whorl application of carbofuran. The strains, Ma 35 and Ma 36 caused significant increase in grain yield (4.16 and 4.25 kg/ plot), respectively as compared to control which recorded 2.85 kg/ plot. Carbofuran whorl application @ 8 kg/ha was significantly superior (4.32 kg/plot) and was on par with the strains Ma 36, Ma 35 and Ma 52 (IIMR).

Pulses

Spraying of PDBC-BT1 (2%) and Delfin (1 or 2 kg /ha) treatments gave the lowest pod damage in moong bean and at par with each other, followed by chlorpyriphos 20

EC @1.5 l/acre (PAU). Lower incidence of *H. armigera* larvae (0.52-0.56 /plant), damage on pod (6.79-7.60%) and grain (8-10%) were noticed in NBAII liquid formulation as against farmer's practices (AAU A).

Biological suppression of pests in oilseeds

Cotton

Bio-efficacy of microbial insecticides against sucking pests in *Bt* cotton was carried out under field conditions. Significantly minimum number of jassids (0.58 /leaf), whiteflies (2.46 /leaf), aphids (5.16 /leaf) and thrips (1.22 /leaf) were registered in the treatment *Lecanicilliumlecanii* @ 40 g/ 10 litre. However, none of the tested microbial insecticides found superior to chemical ones (AAU).

Monitoring of mealybugs and other sucking pests in *Bt* cotton was undertaken under field conditions from 1st fortnight of August 2015 till January, 2016. Incidence of mealy bug was not observed on cotton till December, 2015 and incidence of sucking pests started from August, 2015 onwards. The natural enemies generally present in cotton ecosystem were predatory coccinellids, *Coccinella, Menochilus*and *Scymnus*, chrysopids, *Brumoides* and spiders. The highest seed cotton yield (18.01 q/ha) was recorded in chemical treatment and it was at par with *L. lecanii* treated plots (MPKV). In Telangana, survey for infestation and intensity of sucking pest incidence showed incidence of jassids to a greater extent followed by whiteflies and thrips (PJSTAU).

Regular surveys were carried out to monitor biodiversity and outbreaks for invasive mealy bugs on cotton. Only one mealybug species, *Phenacoccus solenopsis* on cotton was noticed from Ludhiana and major cotton growing areas of Punjab. There was no major outbreak of pests on cotton (PAU). The activity of mealybug appeared during second fortnight of October and continued till the harvest of the crop. The peak activity was noticed during second week of February with an average population of 85.42 mealybugs /plant (UAS-R). Survey conducted in Coimbatore, Erode and Tiruppur districts of Tamil Nadu on cotton host plants indicated the incidence of five species of mealybugs and *Phenacoccus solenopsis* and *Nipaecoccus viridis* were predominant (TNAU).

Regular observations were taken to monitor the biodiversity and outbreaks of sap sucking pests, mirids and their natural enemies in *Bt* and non-*Bt* cotton ecosystems. In Ludhiana, the incidence of sucking pests was less in sprayed condition as compared to unsprayed condition. Bollworm incidence was not observed on *Bt* cotton. However, on non-*Bt* cotton the mean larval population, damage in freshly shed fruiting bodies, green boll damage was comparatively more under unsprayed condition as against sprayed condition. The predator population (spiders, coccinellids, *Chrysoperla*, *Geocoris* sp. and *Zanchius*sp.) was more in unsprayed conditions as against sprayed conditions on both *Bt* and non-*Bt* cotton. During 2015, epidemics of whitefly, *Bemisia tabaci* appeared in cotton belt of Punjab (PAU). The activity of mirid bug was noticed during second fortnight of October with a peak

population during first week of December (1.33 mirid bugs/ plant) which was also coincided with the peak activity of associated predators (UAS R).

Biological suppression of pests in vegetables

Tomato

BIPM package and chemical control treatments were equally effective in reducing the sucking pests, *Helicoverpa armigera* larval population and damaged fruits. Both the treatments were significantly superior to untreated check. The highest yield was recorded in BIPM package (291.89 q/ ha) and was followed by chemical control plot (287.0 q/ha). (AAU J). Among different biocontrol agents/ biopesticides evaluated against the greenhouse whitefly, NeemBaan (1500ppm; 3ml/L) was the most effective with 60.2 per cent reduction over control and was on par with *Lecanicillium lecanii* (5g/L of 10^8 conidia/g) and *Chrysoperla* (1larva/plant) which resulted in the reduction of 57 and 50 per cent, respectively. However, none of these treatments could match the efficacy of imidacloprid (0.0075%) which reduced the whitefly population to the tune of 94.1 per cent over control. As far as the control of *T. urticae*is concerned, all the tested bioagents were only moderately effective resulting in the population reduction of the mite over control in the range of 47.9 to 54.5 per cent as against 89.9 per cent by fenazaquin (0.0025%) (YSPUHF). The cost benefit ratio in BIPM plot was 1:3.2 whereas farmer's practice with four insecticide sprays showed 1: 2.7 (TNAU).

IPM module comprised of five weekly releases of *T. Chilonis* @ 1 lakh/ha followed with 2 sprays of *Ha* NPV, first at the occurrence of pest and second spray after 15 days of first spray**.** Farmer practices included three applications of insecticides.Result indicated that the fruit damage was significantly low in IPM modules (13.8%) as against 20.6% fruit damage observed in farmer practices. The yield observed in IPM module was higher (232.34 q/ ha) (MPUAT).

Among the different biological control agents evaluated against *Tuta absoluta*, *Metarhizium anisopliae* @ 1.5 ml/l was the most effective one with the minimum number of larvae (2.86 larvae/ top five leaves) and fruit damage (5.32 %) followed by *Lecanicillium lecanii* @ 1.5 ml/l and *Beauveria bassiana* @ 1.5 ml/l. The highest fruit yield (25.84 t/ha) was also recorded on *Metarhizium anisopliae* @ 1.5 ml/l followed by *Lecanicillium lecanii* @ 1.5 ml/l and *Beauveria bassiana* @ 1.5 ml/l (UAS R).

Different biological control agents evaluated against *Tuta absoluta*. Since there was no incidence of the pest, conclusive results were not drawn and hence the study need to be repeated (IIHR).

Activity of *T. absoluta* was observed on tomato, brinjal and potato fields and the study revealed that its activity was observed from 34thStandard Meteorological Weeks (SMW) (August 3rd week) on tomato and brinjal, but mean maximum number of moths were trapped in pheromone traps during 6th SMW (February 1st week) on tomato and potato while 5th SMW (January 4th week) showed maximum population in brinjal (IGKV).

Brinjal

The shoot (9.5 %) and fruit (17.7 %) damage was minimum in BIPM package as compared to chemical control plot with 13.0 and 20.0, respectively. The yield of BIPM package was 203.5 q/ha as against 208.7 q/ha in chemical control plot and both were found to be on par with each other (AAU J). Three sprays of profenophos 0.05% at fortnightly interval was effective with the least shoot damage (5.21%) and fruit damage (7.13%) and gave maximum yield (313.9 q/ha). However, the BIPM module consisting release of *T. chilonis* @ 50,000 parasitoids/ha followed by spraying of NSKE 5% and *B. thuringiensis* @ 1 lit./ha twice at weekly interval was the next best treatment with 278.4 q/ha yield (PAU).

The minimum number of mealybug per plant (1.4) was seen in the insect treated plot after 15 days of first spray and 1.8 mealybugs per plant after 15 days of second spray with an yield of 70 t/ha. The next best treatment was release of *Cryptolaemus* @ 1500/ha with a population of mealybugs of 32.4/plant after 15 days of 1st release and 5.3/plant after 15 days of second release with an yield of 67.8t/ha. Highest number of predators were found in the treatment with *Cryptolaemus* @ 1500/ha (5.3 and 8.6/10 plants after 1st and 2nd release respectively) (TNAU).

Chlorpyriphos drenching recorded the maximum reduction of weevil population (84.06%) over control followed by soil application of EPN along with *Metarhizium anisopliae* NBAIR formulation (76.36 %) (TNAU).

Chilli

Among the different entomopathogens evaluated against chilli thrips and mites, *Beauveria bassiana* (Bb-83) IIVR strain was the most promising one with 44.34 and 64.29 per cent reduction of mites and thrips, respectively. However, none of these treatments could match the efficacy of imidacloprid 17.8 SL in reducing mite and thrips population. Bb-83 IIVR strain treated plots registered significantly highest yield (5940 kg/ha) as compared to other entomopathogens including untreated control. Whereas, Imidacloprid 17.8 SL registered significantly the highest yield of 6057 kg/ha (IIVR).

Cabbage

Minimum larval population of *Plutella xylostella* (1.90/plant) and maximum number of coccinelids (1.77/plant) was observed in cabbage intercropped with mustard and cowpea, with highest yield of 174.9 q/ha. The next best treatment was cabbage intercropped with mustard and sorghum as border crop in respect of yield (174.49 q/ha) and was followed by cabbage with sorghum as border crop (166.12 q/ha) (AAU J).

Cauliflower

NBAII BTG4 and PDBC BT1 *Bt* strains @ 2% spray were effective in reducing the larval population up to 59 per cent over control after 1st round of spray. The curd yield was maximum in insecticide treated plot (12.4t/ha) as against 11.32 to 11.86 t/ha in *Bt* strains treated plots (TNAU).

Potato

NBAIR-Bb-5a strain treated plots showed 15.5% damage by *Dorylus orientalis* and 17.25% damage by *Agrotis ipsilon* with an yield of 85.00 q/ha, although imidacloprid treated plots showed lesser tuber damage (10.25 & 9.0% respectively) with higher yield of 89.5q/ha. Significantly less incidence of *D. orientalis* and *A. ipsilon* was registered in all microbial treated plots over untreated check. Maximum number of infested tubers due to attack of *D. orientalis* and *A. ipsilon* was 34.25 and 36.5 per cent, respectively in untreated check (AAU J)

Biological suppression of pests in fruits

Mango

Field evaluation of *Metarhizium anisopliae* formulations against mango hoppers, *Idioscopus niveosparsus* was carried out and maximum fruit set of 3.2 fruits / inflorescence was recorded in liquid formulation of *M. anisopliae* treatment whereas the least fruit set of 2.3 / inflorescence was noted in untreated check. Though superior performance of imidacloprid in checking the hopper population was noted, the fruit set was comparable with *M. anisopliae* liquid formulation. The order of efficacy among the different formulations of *M. anisopliae* in checking the hopper population was liquid formulation> talc formulation > oil formulation (TNAU) (Table 29).

Table 29. Field evaluation of *Metarhizium anisopliae* formulations (IIHR) against mango hoppers

Treatments	Pretreatment count population of hoppers/inflorescence	Mango hopper population /inflorescence, 7 days after each spray			Per cent reduction over control	Fruit set / Inflorescence
		I	II	III		
Liquid formulation1ml/2L	5.4^{a}	2.8^{b}	2.0^{b}	1.3^{b}	89.21	3.2
Oil formulation 1ml/2L	5.9^{a}	4.6^{c}	3.9^{c}	3.0^{c}	77.22	2.3
Talc based formulation 10g/L	7.2^{a}	4.8^{c}	3.6^{c}	2.7^{c}	83.20	2.5
Neem oil 1%	6.4^{a}	5.2^{c}	3.7^{c}	3.0^{c}	79.00	2.3
Imidacloprid @0.3ml/L	6.8^{a}	0.4^{a}	0.0^{a}	0.0^{a}	100.00	2.5
Untreated check	5.6^{a}	7.5^{d}	9.2^{d}	12.5^{d}	-	1.6

Means followed by a common letter(s) are not significantly different by DMRT (P = 0.05)

Citrus

Bio-efficacy of EPNs against citrus trunk borer was tested under field condition at two locations. Stem injection with Dichlorvos gave the highest borehole reduction of 82.06 and 76.30 per cent at Pasighat and Rengging, respectively. Among different EPNs evaluated, CAU-1 stem injection was the most effective at Pasighat with 38.00 per cent borehole reduction. Whereas, CAUH-1 stem injection gave the maximum reduction of 34.22 per cent at Rengging (CAU).

Apple

Different biopesticides were tested for the suppression of apple root borer, *Dorysthenes*

hugelii. Among different biopesticides tested, *Metarhiziu manisopliae* (10^6 conidia/cm²) was the most effective with 70.4 % mortality of grubs and was on par with chlorpyriphos, 0.06% which resulted in 85.8 per cent mortality of the grubs (YSPUHF) (Table 30).

Table 30. Evaluation of entomopathogenic fungi and EPNs for the suppression of Apple root borer, *Dorysthenes hugelii* under field conditions

SN	Treatment	Larval mortality (%)
1	*Steinernema carpocapsae* (80 IJ/cm²)	27.9 (31.6)^b
2	*Heterorhabditis indica* (80 IJ/cm²)	42.9 (40.4)^b
3	*Beauveria bassiana* (10^6 conidia/cm²)	42.7 (40.6)^b
4	*Metarahizium anisopliae* (10^6 conidia/cm²)	70.4 (57.1)^a
5	Chlorpyriphos (0.06%)	85.8 (66.5)^a
6	Control(Untreated)	8.1 (11.6)^c
	CD(p=0.05)	(13.2)
	CV (%)	28.9

Figures in parentheses are angular transformed values

Evaluation of *Trichogramma embryophagum* and *T. cacoeciae* against Codling moth, *Cydia pomonella* on apple was carried out under field conditions. Two year investigation confirmed the superiority of *Trichogramma cacoeciae* over *T. embryophagum* with increased reduction in fruit damage. Integrated management involving one spray of Chlorpyriphos 20EC @ 1.5 ml/lit. + sequential releases of *T. cacoeciae*+ one spray of NSKE + trunk banding + disposal of infested fruits + pheromone traps resulted in 52.92 per cent reduction in damage over control (SKUAST).

Consumption rate of predatory bug, *Blaptostethus pallescens* was evaluated against European red mite (ERM), *Panonychusulmi* on apple and the average consumption of ERM eggs / nymph/day was 4.66, 6.16, 8.92 and 9.19 in relation to predator: prey ratio of 1:5, 1:10, 1:15 and 1: 20 respectively.Consumption rate of adult female of *B. pallescens* was worked out as 5.00, 8.66, 11.62 and 11.91 eggs of ERM per day in relation to identical predator prey ratio.Difference in fecundity potential between nymphs and adults was found statistically significant (t= 3.11**) when compared through Student's t-test (SKUAST).

Anthocorid bug, *Blaptostethus pallescens* was evaluated for its feeding efficiency against *Tetranychus urticae* (TRS) on apple under field conditions. Average consumption of TRS eggs / nymph/day was 7.66, 9.11, 10.77 and 10.86 eggs/day in relation to predator: prey ratio of 1:10, 1:15: 1:20 and 1:25 respectively. Consumption rate of adult female of *B. pallescens* was worked out as 9.66, 11.77, 13.11 and 13.55 eggs/ day in relation to identical predator prey ratio. Positive correlation between feeding and predator density was observed both in nymphs (r= 0.91**) as well as adult females (r= 0.89**). Difference between rate of consumption between nymphs and adults was worked out to be statistically significant (t= 4.04**) (SKUAST).

Biological suppression of pests in plantation crop

Coconut

To dispense with imidacloprid a botanical cake developed by ICAR-CPCRI was used in combination with *Heterorhabditis indica* infected *Galleria mellonella* cadavers through filter-paper delivery technique for the management of red palm weevil.Since the red palm weevil infested palms are not available in sufficient numbers at a particular time, field evaluation will be attempted in due course of time (CPCRI).

Biological suppression of pests in tobacco

BIPM module with two rows of maize border as barrier crop, one spray of *Lecanicillium lecanii*@ 10^{13}spores /ha at 55 DAP and one spray of imidacloprid @ 0.03% at 65 DAP exhibited 95.85% reduction of infestation by tobacco aphid, *Myzus persicae* which was on par with recommended chemical control practice (CTRI).

Biological suppression of pests in sugarcane

The average sugarcane woolly aphid (SWA) incidence and intensity were 1.54 per cent and 1.57, respectively in Maharashtra. The natural enemies mainly observed on SWA were *Encarsia flavoscutellum* (5.07 adults/leaf), *Dipha aphidivora* (0.6-3.0 larvae/ leaf), *Micromus igorotus* (1.2-5.2 grubs/leaf), syrphid, *Eupeodes confrator* (0.4-1.0 larvae/ leaf) and spider (0.1-0.3 /leaf) during July to March, 2016. The parasitoid, *Encarsia flavoscutellum* was distributed and established well in sugarcane fields and suppressed the SWA incidence in Solapur, Pune and Satara districts (MPKV) (Table 31). The SWA was noted in patches in Erode, Karur, Coimbatore and Namakkal areas of Tamil Nadu. The incidence of SWA was noted from November 2015 and the population escalated from January 2016 and the maximum population ranged up to 18.4 SWA/2.5 sq.cm leaf area during March 2016 in Erode district followed by Namakkal district (12.6 SWA /2.5 sq. cm) (TNAU). In Telangana,patchy appearance of SWA was noticed in a few fields of Nizamabad and adjoining areas of Medak (PJTSAU).

Biological suppression of polyhouse crop pests

Coccinella septempunctata was found superior to *C. zastrowi* in terms of cabbage aphid suppression, as evident from statistically significant differences in aphid densities after second release of predators. Per cent reduction in aphid density were 76.52 and 63.09 for *C. septempunctata* and *C. zastrowi*, respectively over control indicated the supremacy of the former. Differences in per cent reduction in aphid density when compared for the two predators were found statistically significant after first to fifth release (SKUAST).

Three sprays of abamectin 0.5 ml/lit at 15 days interval was found to be the most effective in reducing themite population on rose (8.22 mites/ 10 compound leaves/plant) as compared to other treatments. However, four releases of predatory mites @ 10 per plant at weekly interval and three sprays of *H. thompsonii* (1 x 10^8 conidia/g) @ 5 g/litre were

Table 31. Effect of natural enemies on incidence of sugarcane woolly aphids in Maharashtra

Districts surveyed	SWA incidence (%)	Pest intensity rating (1-6)	Natural enemies/leaf				Spiders
			D. aphidivora	*M. igorotus*	*E. flavoscutellum*	*E. confractor*	
Pune	1.0	1.0	0.8	3.8	2.3	0.6	0.1
Satara	1.6	2.0	1.6	3.8	8.0	0.6	0.1
Sangli	2.3	2.0	1.8	4.8	7.0	0.6	0.3
Kolhapur	2.4	2.0	3.0	5.2	5.8	0.3	0.3
Ahmednagar	0.8	1.0	0.6	1.2	1.6	0.4	0.1
Solapur	2.1	2.0	1.2	2.6	10.2	1.0	0.3
Nashik	0.6	1.0	0.6	1.2	0.6	0.2	0.1
Average	**1.54**	**1.57**	**1.37**	**3.22**	**5.07**	**0.52**	**1.8**
Range	**0.6–2.4**	**1 -2**	**0.6-3.0**	**1.2–5.2**	**0.6 -10.2**	**0.4- 1.0**	**0.1-0.3**

Pest Intensity Rating **1**=0, **2**= 1-20, **3**= 21–40, **4**=41–60, **5**=61–80, **6**=81-100 % leaf covered by SWA.

the next best treatments with an average 18.22 and 20.89mites/10 compound leaves/ plant, respectively (MPKV). The release of *B. pallescens* @ 30 nymphs per m row was found to be the most effective in suppressing the rose mite population (7.7 mites /plant) and it was statistically at par with chemical control (4.2 mites/ plant) (PAU).

Biological suppression of storage pests

Uscana sp. was evaluated against *Callosobruchus* sp. on storability of pigeon pea seeds. The results showed that increase in number of *Uscana* sp. is directly proportional to the level of parasitization. Release of 40 *Uscana* sp. + 50 eggs of *Callosobruchus* sp. recorded the highest parasitization (42 %), lowest seed infestation and the highest germination of pigeon pea seeds (82.33 %). Whereas in control, only 75% seed germination was observed.

5. GENBANK / BOLD ACCESSIONS (2015-16)

DESCRIPTION	ACCESSION NUMBER
Termite (CO1)	
Odontermes obesus	174056
O. obesus	KU 687341
O. obesus	KU687342
Macrognathotermes errator	KM657477
Odontermes mathurai	KM657487
Euhamitermes hamatus	KM657484
O. gurdaspurensis	KM657483
O.gurdaspurensis	KM657481
O.gurdaspurensis	KM657480
Microtermes mycophagus	KM657479
Odontotermes longignathus	KU687338
Hypotermes xenotermitis	KT274764
Odontotermes longignathus	KT254244
Hypotermes makhamensis	KT274765
H. xenotermitis	KT224387
Odontotermes wallonesis	KT224388
O. holmgren	KT224389
Nasuitermes sp.	KT224390
Dicuspiditermes krishna	KT224391
Adoretus bicolor	KT224392
Odontotermes holmgren	KT224393
O. wallonesis	KT224394
Microterme sobesi	KM657488
Nasuitermes	KT224395
Odontotermes holmgren	KT719275
O. longignathus	KT719274
O. holmgren	KT719276
Nasutitermes octopilis	KM657478
N. exitiosus	KM 015487
Neotermeskos hunensis	KM657485
Hypotermes xenotermitis	KU687340
Nasutitermes exitiosus	KM657488
Specidae (CO1)	
Carinostigmus congruus	BOLD:ACD90874
C. griphus	BOLD:ACV20062
C. costatus	BOLD:ACV20072
Insect Pests (CO1)	
Leucinodes orbonalis	KP260782_ AGIMP046-16
Maruca vitrata	KT070893_ AGIMP047-16

Oenopia mimica	KR349052_AGIMP043-15
Oenopia sauzeti	KR349051_AGIMP042-15
Pollenia rudis	KT368817_VETIP006-15
Bactrocera cucurbitae	KP233798_ AGIMP048-16
Uroleucon sonchi	KR026974_ AGIMP049-16
Greenidea psidii	KR349049_ AGIMP050-16
Rhipicephalus microplus	KP318133_VETIP007-16
Trichogrammatids (CO1)	
T. brassicae (Italy)	AAD6262
T. pretiosum (thelytokous)	ACS7056
T. cordubensis	ACS6228
T. brassicae (Italy)	AAD6262
T. cacoeciae	ACS7055
T. semblidis	ACS5856
T. chilonis	ACG5640
Tr. armigera	ACV9389
T. pretiosum (Colombia)	ACE5676
T. danausicida	ACS5878
T. dendrolimi	AAE8562
T. hebbalensis	ACS5857
T. mwanzai	ACS6174
T. chilotraeae	ACS6424
Tr. robusta	ACV5432
T. evanescens Arrhenotokous	ACS5878
Tr. bactrae	ACS5855
Trichogramma japonicum	ACV5662
Other Insects (CO1)	
Apis dorsata	AAB2275; KJ513470
Aphidius colemani	AAC7809; KM054519
Aphidius ervi	AAA4188; KM054518
Habrobracon hebetor	AAN5769; KJ627789
Chelonus blackburni	ACI1219; KF365461
Cotesia sp.	ACS4950; KT308157
Glyptapanteles sp.	ACZ2913; KP153535
Cotesia erionotae	ACY9028; KR080481
Leiophron sp.	ACY9005; KR809409
Microplitis maculipennis	ACV9232; KP759288
Brachymeria tachardiae	ACY9096; KP055618
Lasioglossum albescens (Smith, 1853)	AAN4354; KR076766
Isolia indica	ACQ3324; KJ489423
Sceliocerdo viatrix	ACQ1881; KF938928
Chartocerus sp.	ACZ2667; KR809410
Myiocnema comperei	ACQ5354; KJ955498

Orius laevigatus	ABA3642; KM016075
Cardiastethus affinis	ACQ3908; *KJ955496*
Amphiareus constrictus	ACQ3908; *KF817577*
Buchananiella indica	ACY9057; *KF383325*
Blaptostethus pallescens	ACI1757; *KF365463*
Xylocoris flavipes	ACI2060; *KF365462*
Ropalidia sp.	*ACQ1746;* KM054517
Praleurocerus viridis	ACQ5173; *KJ955497*
Blepyrus insularis	*ACQ5173; KJ850500*
Aenasius advena	*ACQ1478; KJ850498*
Neastymachus axillaris	*ACS7146; KM095502*
Pseudoleptomastix mexicana	*ABY0168; KJ955495*
Leptomastix nigrocincta	*ACQ1256; KJ489424*
Megastigmus sp.	*ACH7698; KF938926*
Megachile manthracina	*ACQ5048; KF861940*
Pristomerus sulci	*ACS4928; KM875667*
Diglyphus isaea	*ACQ6186; KM016074*
Tetrastichus schoenobii	*ACS4504; KJ627790*
Aprostocetus gala	*ACQ6186; KF817576*
Parachrysocharis sp.	*ACY9081; KR080480*
Curinus coeruleus	*ACQ5004; KJ740391*
Brumoides suturalis	*ABX2096; KJ850497*
Cryptolaemus montrouzieri	*AAD6040; KM016073*
Scymnus nubilus	*AAP7968; KF861939*
Hyperaspis maindroni	AAU6400; KJ850499
Cheilomenes sexmaculata	*ACM3340; KF998579*
Brachymeria sp.	*ACY9096; KP055618*
Glyptapanteles sp.	ACZ3549; KR260984
Microbial 16s rDNA sequences (insect associated)	
Microbes Associated with Dung Beetles	
Enterobacter cloacae	KU041594
Uncultured alpha proteobacterium clone Pau21	KT251052
Uncultured bacterium clone Pau19	KT251051
Uncultured *Microbacterium* sp.	KT251050
Uncultured bacterium clone Pau17	KT251049
Uncultured Lachnospiraceae	KT251048
Uncultured bacterium clone Pau13	KT251047
Uncultured bacterium clone Pau10	KT251046
Uncultured bacterium clone Pau9	KT251045
Uncultured bacterium clone Pau7	KT251044
Uncultured bacterium clone Pau4	KT251043
Uncultured bacterium clone SJTU	KT071712
Acidovorax ebreus	KU041595
Citrobacter amalonaticus	KT956222

Bacillus sp.	KU041593
Bacillus stratosphericus	KU041592
B. cereus	KU041591
Enterobacter cloacae strain	KU041590
Rhodococcusrhodochrous	KU041588
Lysinibacillus fusiformis	KU041587
Rhodococcus equi	KU041586
Lysinibacillus sphaericus	KU041585
Azotobacter vinelandii	KU041584
Arthrobacter luteolus	KU041583
Bacillus altitudinis	KU041582
Citrobacter amalonaticus	KT956239
Acinetobacter baumannii	KT956238
Aeromonas caviae	KT956237
Providencia rettgeri	KT956234
Morganell amorganii	KT956232
Aeromonas dhakensis	KT956231
A. hydrophila	KT956230
Citrobacter freundii	KT956229
C. amalonaticus	KT956226
Microbes Associated with Aphids	
Bacillus subtilis	KU663661
B. cereus	KU663662
Lysinibacillus fusiformis	KU663663
Bacillus pumilus	KU663664
B. altitudinis	KU663665
Micrococcus luteus	KU663666
Bacillus pumilus	KU663667
Micrococcus luteus	KU663668
Bacillus licheniformis	KU663669
Corynebacterium variabile	KU663670
Providencia stuartii	KU867634
Lysinibacillus macroides	KU867640
Stenotrophomonas maltophilia	KT248840
Enterobacter hormaechei	KT248841

6. IDENTIFICATION SERVICES

The ICAR – NBAIR offers identification services to institutions, scientists, students and other individuals. The services offered are for groups in which expertise is available in the bureau. For other groups we interphase with experts within the country and obtain the identities. Groups for which no expertise is available in the country the specimens are maintained in the museum for future studies.

Hymenoptera (Braconidae, Ichneumonidae, Pteromalidae, Eulophidae, Chalcididae, Encyrtidae, Eupalmidae, Aphelinidae and Bethylidae) (Ankita Gupta)

ICAR-Central Institute for Arid Horticulture, Bikaner ; Krishi Vigyan Kendra, Balasore, Orissa; Rajshree Sugars & Chemical Limited, Villupuram, Tamilnadu ; AICRP on biological control of crop pests and weeds, Rajendranagar-Hyderbad ; ICAR-Central institute for arid horticulture, Bikaner ; ICAR-IIHR, Hesaraghatta; Director, NBAIR- Pawan Kumar Sharma; Director, NBAIR- Ezhil kumara; Director ,NBAIR- Arpitha Bhat; ICAR-IIHR, Hesaraghatta; Assam Agricultural University, Jorhat; EIB lab, NBAIR, Bangalore; G.K.V.K , Bangalore; Shivaji university, Kolhapur; University of Agricultural Sciences, Dharwad; Central agricultural university, Umiam-Meghalaya; University of agricultural & horticultural sciences, Shivamogga; Navsari agricultural university, Navsari-Gujarat ; Sacred heart college (Dept of Zoology) Cochin; G.K.V.K Bangalore; University of Agricultural sciences, Raichur ; AICRP on biological control of crop pests & weeds, Rajendranagar-Hyderbad ; AICRP on groundnut and oil seeds, Dharwad; Krishi vigyan kendra Balasore-Orissa; AICRP on fruits, PAU, Ludhiana,Punjab ; C.S.R.T.I., Mysore; Dr. Y. S. Parmar university of horticulture & forestry, Nauni, Solan, HP; Dept of zoology, Modern college Ganeshkhind, Pune; College of agriculture, V.C. Farm, Mandya; ICAR Research complex for NEH region, Umiam-Meghalaya; University of horticultural science, Bagalkot.

Hemiptera (Aphids, mealybugs and scale insects) (S.Joshi)

294 species were identified for SAUs, ICAR institutions and private organizations through 72 identification services.

Hemiptera (Pentatomidae) (S.Salini)

University of Agricultural Sciences, Dharwad; Mahatma Phule Krishi Vishwavidyalaya, Pune; Kerala Agricultural University, Vellayani; Central Island Agricultural Research Institute, Port Blair

Hymenoptera (Trichogrammatidae) (Prashanth Mohanraj)

Punjab Agricultural University, Ludhiana; Tamil Nadu Agricultural University, Coimbatore; University of Agricultural & Horticultural Sciences, Mudigere.

Thysanoptera (R.R.Rachana)

Indian Institute of Horticultural Research, Hessaraghatta; University of Agricultural sciences, Dharwad; RFRS, Vengurle.

7. EXTENSION ACTIVITIES

Live insect cultures

During 2015 16, 103 live insect cultures were maintained. 1314 consignments of insects were supplied to various institutions, students, extension agencies, farmers and private entrepreuners (Fig. 71) and a revenue of Rs.4,98,279 /- was generated.

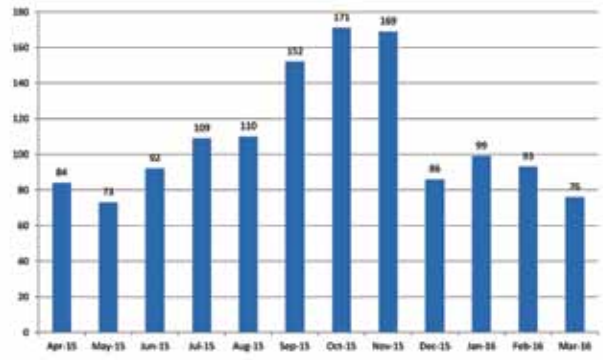


Fig.71. Live insect cultures maintained and supplied (2015-2016)

Microbial cultures

A total of 87 shipments of microbial biocontrol agents were made during 2016-17 (Fig.72) generating a revenue of 3.49 lakh rupees. Also quality analysis of six biocontrol formulations was done and Rs. 18,000/- revenue earned.

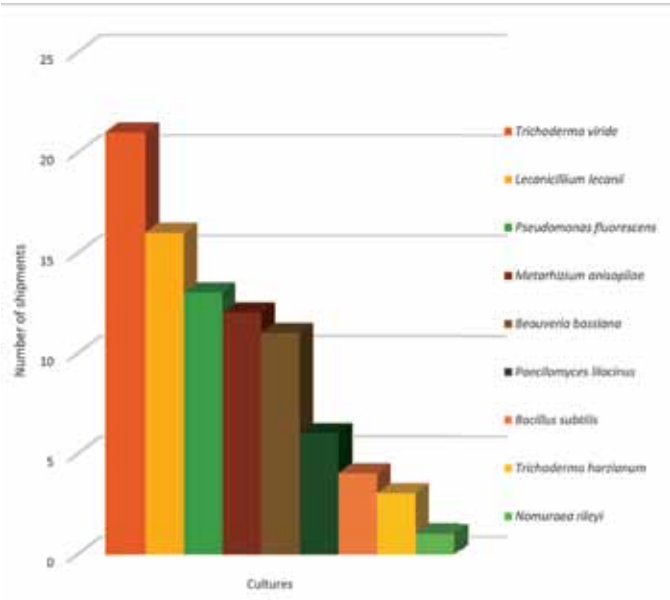


Fig. 72 Shipment of microbial biocontrol agents made during 2016-17

8. AWARDS AND RECOGNITIONS

Dr S.K. Jalali

Guest of Honour at "Model Training course on Production and Popularization of Biological Control Agents to Enhance Pulse Production: An Eco-friendly Approach" at IIPR, Kanpur.

Dr Chandish R. Ballal

NBAIR Scientific Excellence A ward, September 2015.

IMC mumber of NBAIM, Mau, 2013-16.

Councillor. Plant Protection Association of India. 2014-16.

Best Poster A ward, Conference on National Priorities in Plant Health Management, College of Agriculture, Tirupati, 4-5 February 2016.

Invited Speaker, IV Congress on Insect Science: Entomology for Sustainable Agriculture, PAU, Ludhiana, 16-17 April 2015.

Resource Person, Refresher Course in Environmental Sciences, Kannur University, 17 November 2016.

Resource Person, Refresher Course in Environmental Sciences, Kerala University, Thiruvananthapuram, 12 January 2016.

Invited Speaker, Researc and PG Department of Zoology, Government Victoria College, Palakkad, 12 February 2016.

External Examiner for Ph.D. student, Kalyani University.

Dr Kesavan Subaharan

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

Served as an examiner for thesis titled Impact of fortification chlorogenic acid and vitamin C rich botanical extract on growth and cocoon parameters of silkworm *Bombyx mori* L. submitted by Divya Manjunath Naik, University of Agricultural Sciences, Dharwad.

Served as an examiner for thesis titled Studies on Biology, Development and Food Volatiles of *Sitophilus Oryzae* L. Feeding on Sorghum Plants and Split Pulses submitted by S. VIJAY (ID.No.12-603-017) Tamil Nadu Agricultural University, Coimbatore.

Served as an interview panel member for selection of scientist in Insect Genetics at Silk Board, Bangalore.

Served as an outside expert for the selection of research associate position at ICAR - Indian Institute of Horticultural Research, Bengaluru on 06.02.2016.

Served as an outside expert for the selection of Senior Research Fellow under NICRA Project at ICAR - Indian Institute of Horticultural Research, Bengaluru on 06.02.2016

Passed the Post Graduate Diploma in Intellectual Property Rights.

Member of site visit committee of Biotechnology Industry Research Assistance Council (BIRAC) Department of Biotechnology to evaluate the proposal submitted by KN industries, Hyderabad to DBT.

Screening committee member of CCRS proposal submitted to Department of Biotechnology, Govt. of India

Served as Co convener for workshop organized jointly by ICAR and NIAS on Human wildlife conflict on agro pastoral context from 11-12.12.2015.

Dr T. Venkatesan

Award of Excellence, NBAIR, September 2015.

Travel Grant, Department of Science & Technology, Government of India, for attending 6th International Conference on Barcode of Life, University of Guelph, Canada, 17–22 August 2015.

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

Consulting Editor, Editorial Board, The Journal of Environmental Biology, Lucknow.

External Expert to conduct interview to select scientists (Entomology), Central Sericulture Research and Training Institute, Bengaluru.

Recognized as External Examiner for Ph.D, at Dept. of Zoology, Delhi University, Delhi.

Recognized as an External Examiner for M.Sc (Ag) & Ph.D students, Dept. of Entomology, TNAU, Coimbatore.

Recognized as Co-Chairman, to organize National Science Day on 27/02/2016 at ICAR-NBAIR, Bengaluru.

Elected as Vice President, Society for Biocontrol Advancement (SBA), Bengaluru from 2015 to till date.

Dr P. Sreerama Kumar

Ambassador nomination, Society for Invertebrate Pathology, USA.

Vice-President, Society for Biocontrol Advancement, Bengaluru.

Dr S. Sivakumar

Travel Grant Award from Department of Biotechnology, Govt of India, for attending and presenting a paper at the III World Biodiversity Congress, Serbia, 26–30 October 2015.

Young Scientist Award from Global Scientific Research Foundation, India and Nature Conservation Institute of Serbia at the III World Biodiversity Congress, Serbia, 26–30 October 2015.

Co-chairperson, Technical Session, III World Biodiversity Congress, Serbia, 26–30 October 2015.

External Examiner for a Ph.D. student's thesis viva, Department of Plant Pathology, TNAU, Coimbatore.

External Examiner for a Ph.D. student's of thesis viva, Faculty of Agriculture and Animal Husbandry, Gandhigram Rural Institute – Deemed University, Gandhigram.

Best Paper Award at the National Seminar on Mitigation of chemical residues in farm products-strategies, opportunities and challenges held at Faculty of Agriculture and Animal Husbandry Gandhigram Rural Institute- Deemed University, Gandhigram, 18–19 February 2016.

Lead Talk at the National Seminar on Mitigation of chemical residues in farm products-strategies, opportunities and challenges held at Faculty of Agriculture and Animal Husbandry Gandhigram Rural Institute- Deemed University, Gandhigram, 18–19 February 2016.

Dr Ankita Gupta

Award of Excellence, NBAIR, September 2015.

Best Poster Award, III World Biodiversity Congress, Serbia, 26–29 October 2015.

Best Poster Award, Conference on National Priorities in Plant Health Management, Tirupati, 4–5 February 2016.

Dr Jagadeesh Patil

Young Scientist Award 2015, Venus International Foundation, Chennai, December 2015.

Ph.D. Guide, Biotechnology, Jain University, Bengaluru

9. AICRP/COORDINATION UNIT/NATIONAL CENTRES

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

Headquarters

ICAR- National Bureau of Agricultural Insect Resources, Bangalore	Basic Research

State Agricultural University–based Centres

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

Maharana Pratap University of Agriculture & Technology, Udaipur	Vegetables, whitegrubs, termites
Orissa University of Agriculture & Technology, Bhubaneshwar	Rice, vegetables
University of Agricultural Sciences (Raichur), Raichur	Oilseeds, pulses
ICAR Institute–based centres	
ICAR- Central Institute of Subtropical Horticulture, Lucknow	Mango
ICAR- Central Plantation Crops Research Institute, Kayangulam	Coconut
ICAR- Central Tobacco Research Institute, Guntur	Tobacco and soyabean
ICAR- Directorate of Seed Research, Mau	Pigeonpea, sorghum
ICAR- Indian Institute of Millet Research, Hyderabad	Sorghum
ICAR- Directorate of Soybean Research, Indore	Soyabean
ICAR- Directorate of Weed Science Research, Jabalpur	*Chromolaena odorata*
ICAR- Indian Agricultural Research Institute, New Delhi	Basic Research
ICAR- Indian Institute of Horticultural Research, Bangalore	Fruits and Vegetables
ICAR- Indian Institute of Rice Research, Hyderabad	Rice
ICAR- Indian Institute of Sugarcane Research, Lucknow	Sugarcane
ICAR- Indian Institute of Vegetable Research, Varanasi	Natural enemies of vegetable Pests
ICAR- National Centre for Integrated Pest Management, New Delhi	IPM of Whitegrubs in coconut

10. PUBLICATIONS

Peer-reviewed articles

NBAIR

Antony J.C. and Pratheepa, M. 2015. Rule based induction model to study the population dynamics of soybean semilooper *Geosonia gemma* (Swinhoe) in Maharashtra. *Legume Research* (In Press)

Archana, M., D-Souza, P., Jalali, S. K., Renukaprasad and Ojha, R. 2014. Molecular identification of commonly prevalent *Culicoides* in South India. *Journal of Veterinary Parasitology*, 28: 33-36.

Ballal, C. R., Gupta, A., Mohan, M., Lalitha, Y. and Verghese, A. 2016. The new invasive pest *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in India and its natural enemy complex. *Current Science* (Accepted) in Press

Ballal, C. R., Joshi, S., Bhaskaran, T. V. and Lakshmi, L. 2015. Feasibility of continuous rearing of a potential ichneumonid parasitoid *Campoletis chlorideae* Uchida. *Journal of Biological Control*, 29: 75-84.

Ballal, C. R., Yamada, K. and Joshi, S. 2016. Morphology and biology of the litter-inhabiting *Buchananiella indica* Muraleedharan (Hemiptera: Anthocoridae). *Entomon*, 41(1): In press

Benoit J. B., Z. N. Adelman, K. Reinhardt, A. Dolan, M. Poelchau, E. C. Jennings, E. M. Szuter, R. W. Hagan, H. Gujar, J. Shukla, F. Zhu, M. Mohan, D. R. Nelson, A. J. Rosendale, C. Derst, V. Resnik, S. Wernig, P. Menegazzi, C. Wegener, N. Peschel, J. M. Hendershot, W. Blenau, R. Predel, P. R. Johnston, P. Ioannidis, R. M. Waterhouse, R. Nauen, C. Schorn, M.-C. Ott, F. Maiwald, J. S. Johnston, A. D. Gondhalekar, M. E. Scharf, B. F. Peterson, K. R. Raje, B. A. Hottel, D. Armisén, A. J. Johan Crumière, P. N. Refki, M. E. Santos, E. Sghaier, S. Viala, A. Khila, S.-J. Ahn, C. Childers, C.-Y. Lee, H. Lin, D. S. T. Hughes, E. J. Duncan, S. C. Murali, J. Qu, S. Dugan, S. L. Lee, H. Chao, H. Dinh, Y. Han, H. Doddapaneni, K. C. Worley, D. M. Muzny, D. Wheeler, K. A. Panfilio, I. M. Vargas Jentzsch, E. L. Vargo, W. Booth, M. Friedrich, M. L. Porter, J. W. Jones, O. Mittapalli, C. Zhao, J.-J. Zhou, J. D. Evans, G. M. Attardo, H. M. Robertson, E. M. Zdobnov, J. M. C. Ribeiro, R. A. Gibbs, J. H. Werren, S. R. Palli, C. Schal and S. Richards. 2015. Unique features of the bed bug, a global human ectoparasite, identified through genome sequencing. *Nature Communications* (in press)

Bhagat, D., Bhaktavatsalam, N. and Ramu, G. 2015. Effect of volatiles from leaves of rice cultivars on the foraging behaviour of *Trichogramma* Spp. (Hymenoptera: Trichogrammatidae). *Oryza*, 51(3): 255-257.

David, K. J. and Singh, S. K. 2015. Two new species of *Euphranta* Loew (Diptera: Tephritidae: Trypetinae) and an updated key for the species from India. *Zootaxa*, 3914: 64-70.

Dheemanth, L., Srinivasa Murthy, K., Venkatesan, T. and Jalali, S. K. 2015. Molecular characterisation of common predatory anthocorids. *Journal of Biological Control*, 29 (1):8-13.

Firake, D. M., Joshi, S., Behere, G. T., Momin, G., Thakur, A. and Nagachan, S. V. 2015. First report of mealybug Formicococcus polysperes (Hemiptera: Pseudococcidae) infesting ginger in India. *Entomological News*, 125 (3): 179-185.

Gupta, A. and Jose´ L. Ferna´ndez-Triana. 2015. Four new species of the

genus *Diolcogaster* Ashmead, 1900 (Hymenoptera: Braconidae: Microgastrinae) from South East Asia with a key to the Indian species. *Systematic Parasitology*, 90: 285-300. 10.1007/s11230-014-9546-8

Gupta, A., P. M. Sureshan, A. Rameshkumar, V. Naveen and Sanjeev, U. (2015): On a collection of Pteromalidae (Hymenoptera: Chalcidoidea) from North- East India with description of a new Halticoptera Spinola species, *Oriental Insects*, 1-14. DOI: 10.1080/00305316.2015.1101722.

Gupta, A., Gawas, S. M. and Bhambure, R. 2015. On the parasitoid complex of butterflies with descriptions of two new species of parasitic wasps (Hymenoptera: Eulophidae) from Goa, India. *Systematic Parasitology*, 92: 223–240.

Gupta, A., Yeshwanth, H. M., Hansson, C. and Venkatesan, T. 2015. *Neochrysocharis* nr. *diastatae* (Howard) (Hymenoptera: Eulophidae) parasitic on eggs of *Letana* Walker (Orthoptera: Tettigoniidae) in India: first record of host association. *Journal of Biological Control*, 29: 121-124.

Gupta, A., Rameshkumar, A. and Naveen, V. 2015. First record of the genus *Callocleonymus* Masi (Hymenoptera: Chalcidoidea: Pteromalidae: Cleonyminae) from India. *Journal of Biological Control*, 29: 1-2.

Gupta, A. and Naveen, V. 2015. A new species of genus *Cassidibracon* Quicke (Hymenoptera: Braconidae: Braconinae) with new host record from India. *Journal of Biological Control*, 28: 122-125.

Guruprasad, N. M., Harish, B. M., Jalali, S. K. and Puttaraju, H. P. 2015. Characterization of *Wolbachia* cell division protein (ftsz) gene for potential management of Uzifly *Exorista sorbillans* (Diptera: Tachinidae). *Journal of Entomology and Zoology Studies*, 3: 57-61.

Hayat, M. and Veenakumari, K. 2015. Description of four new species of brachypterous Encyrtidae (Hymenoptera: Chalcidoidea from India. *Zootaxa*, 3990 (2): 2259-271.

Hosamani, M., Basagoudanavar, S. H., Sreenivasa, B. P., Inumaru, S., Ballal, C. R. and Venkataraman, R. 2015. Eri silkworm (*Samia ricini*), a non-mulberry host system for AcMNPV mediated expression of recombinant proteins. *Journal of Biotechnology*, 216: 76-81.

Jalali, S. K. and Venkatesan, T. 2015. Quantification of diversity of agriculturally important insect through DNA barcoding. *Genome*, 58(5): 231.

Jalali, S. K., Ojha, R., Gupta, A. and Venkatesan, T. 2015. Identification of a calliphorid Fly, *Pollenia Rudis* (Diptera: Calliphoridae) based on its fragments through DNA barcoding. *International Journal of Agriculture, Environment and Biotechnology*, 8(4): 991-994.

Jayanthi, P.D.K., Aurade, R. M., Kempraj, V., Roy, T. K., Shivashankara, K. S., Verghese, A. 2015. Salicylic Acid Induces Changes in Mango Fruit that Affect Oviposition Behavior and Development of the Oriental Fruit Fly, *Bactrocera dorsalis*. *PLoS ONE* 10(9): e0139124. doi:10.1371 \

Jayanthi, P. D. K., Ravindra, M. A., Vivek, K. and Verghese, A. 2015. Aromatic fruits as baits for the management of fruit-piercing moths in pomegranate exploiting of olfaction. *Current Science*, 109: 1476-1479.

Joshi, S. and Rumki Sangma, 2015. Natural enemies associated with aphids and coccids from India. *Journal of Biological Control*, 29 (1): 3-7.

Kulkarni, N., Srujana Sripathi and Deepa Bhagat. 2015. Nanocellulose: ageless bionanomaterial in agriculture. *Eduved International Journal of Interdisciplinary Research*, 2(6):8-17.

Kumar, M., Saravanan, P. and Jalali, S. K. 2016. Expression and purification of virus like particles (VLPs) of foot-and-mouth disease virus in Eri silkworm (*Samia cynthia ricini*) larvae. *Virus Disease*, 27: 84-90.

Kumara, A.D.N.T., Chandrashekharaiah, M., Subaharan, K. and Chakravarthy, A. K. 2015. Periodicity of adult emergence and sexual behaviour of coconut black headed caterpillar, *Opisina arenosella* Walker (Lepidoptera: Oecophoridae). *Phytoparasitica*, 43: 701–712.

Lalitha, Y. and Ballal, C. R. 2015. Influence of seasons and inoculum dosages on the production efficiency of *Corcyra cephalonica* Stainton. *Journal of Biological Control*, 29 (1): 25-30.

Malathi, V. M., Jalali, S. K., Sidde Gowda, D. K., Mohan, M. and Venkatesan, T. 2015. Establishing the role of detoxifying enzymes in field-evolved resistance to various insecticides in the brown planthopper (*Nilaparvata lugens*) in South India. *Insect Science* (2015) 0, 1–12, DOI 10.1111/1744-7917.12254

Nadda, G. and Joshi, S. 2015. First report of Aphid, *Liosomaphis ornate* Miyazaki, 1971 (Hemiptera: Aphididae) from India. *Halteres*, 6: 51-55.

Ojha, R., Jalali, S. K., Poorani, J. and Srinivasa Murthy, K. 2016. Genetic variation among different Indian populations of cabbage diamondback moth (*Plutella xylostella*; Lepidoptera: Plutellidae) based on mitochondrial DNA. *Molecular Entomology*, 7: 1-7.

Pashte, V. V., Shylesha, A. N. and Bhat, N. S. 2014. Effectiveness of Attractants and Scents in enticement of *Apis cerana* on Sesamum crop. *Environment and Ecology*, 33 (4):1504-1507

Pashte, V. V., Shylesha, A. N. and Badge, A.S. 2015. Effect of Honey Bee Pollination, Bee Attractants and Scents on Yield of Sesamum. *International Journal of Ecology and Environmental Sciences*, 41 (1-2): 87-93.

Patil J., Rajkumar and Subaharan, K. 2015. Synergism of Entomopathogenic Nematode and Imidacloprid: A Curative Tool to Coconut white grub, *Leucopholis coniophora* (Coloeptera: Melolonthinae). *Vegetos*, 1: 184-190.

Poorani, J., Jalali, S. K. and Ojha, R. 2015. Morphological characters and DNA barcodes to separate *Oenopia sauzeti* Mulsant and *O. mimica* Weise (Coleoptera: Coccinellidae), two externally similar lady beetles from the Indian subcontinent. *Entomon*, 40: 235-242.

Rachana. R. R., Jayasimha. G. T., Richa, V. and Manjunatha. M. 2016. Evaluation of fungal pathogens, *Fusarium semitectum* Berk and Ravenel and *Hirsutella thompsonii* Fisher against red spider mite, *Tetranychus neocaledonicus* (Andre) of okra under laboratory and greenhouse conditions. *Journal of Applied and Natural Science*, 8: Issue 1.

Ramanujam, B., Poornesha, B., Yatish, K. R. and Renuka, S. 2015. Evaluation of pathogenicity of different isolates of *Metarhizium anisopliae* (Metchnikoff) Sorokin on maize stem borer *Chilo partellus* (Swinhoe) using laboratory bioassay. *Biopesticides International*, 11: 89-95.

Ramya, S. L., Venkatesan, T., Murthy, K. S. and Jalali, S. K. and Abraham Verghese. 2016. Detection of carboxylesterase and

esterase activity in culturable gut bacterial flora isolated from diamondback moth, *Plutella xylostella* from India and its possible role in indoxacarb degradation. *Brazilian Journal of Microbiology*, http://dx.doi.org/10.1016/j.bjm.2016.01.012

Ramya, S. L., Venkatesan, T., Murthy, K. S., Jalali, S. K. and Abraham Verghese. 2016. Degradation of acephate by *Enterobacter asburiae* (PX–E), *Bacillus cereus* (PX–B.C.Or) and *Pantoea agglomerans* (PX-Pt.ag.jor) isolated from diamondback moth *Plutella xylostella*. *Journal of Environmental Biology*, (in press)

Rangeshwaran, R., Velavan, V., Frenita, D. L., Surabhi Kumari, Shylesha, A. N., Mohan, M., Satendra Kumar, Sivakumar. G. 2016. Cloning, expression and bioassay of Vip3A protein from an indigenous *Bacillus thuringiensis* isolate, *Journal of Pure and Applied Microbiology* (in press)

Rawat, N., Sandhya, Subaharan, K., Eswaramoorthy, M and Kaul, G. 2016. Comparative in vivo toxicity assessment places multiwalled carbon nanotubes at a higher level than mesoporous silica nanoparticles. Toxicology and Industrial Health 1–11 © The Author(s) 2016 Reprints and permissions: sagepub.co.uk/journalsPermissions.nav DOI: 10.1177/0748233715622307

Rebjith, K. B, Asokan, R., Hande, H. R., Krishna Kumar, N. K., Krishna, V., Vinuah, J. and Bakthavatsalam, N. 2015. RNA interference of obodrant binding protein 2 (OBP-2) of the cotton aphid, *Aphis gossypii* (Glover) resulted in altered electrophysiological responses. *Appl J Biochem Biotechnolgy*, DOI 10.1007/s12010-01501869-7.

Reddy, G.N. and Jalali, S. K. 2015. Identification of most suitable species of *Trichogramma* for the management of *Earias vittella* (Fabricius) on Okra. *Mysore Journal of Agricultural Sciences*, 49: 329-331.

Reddy, G.N. and Jalali, S. K. 2015. Efficacy of different strategies for management of shoot and fruit borer, *Earias vittella* (Fabricius) on Okra. *Trends in Biosciences*, 8 (16): 110-114.

Reddy, P. V. R., Rajan, V. and Verghese, A. 2015. A non-meat based artificial diet and protocol for mass rearing of *Chrysomya megacephala* (Fab.) (Diptera: Calliphoridae), an important pollinator of mango. *Current Science*, 108: 17-19.

Reddy, P. V. R., Rashmi, T. and Verghese, A. 2015. Foraging activity of Indian honey bee, *Apis cerana* in relation to ambient climate variables under tropical conditions. *Journal of Environmental Biology*, 36: 577-581.

Renuka, S. and Ramanujam, B. 2016. Fungal endophytes from maize (*Zea mays* L.): Isolation, identification and screening against Maize stem borer, *Chilo partellus*. *Journal of Pure and Applied Microbiology* 10 (1). Accepted for publication

Renuka, S., Ramanujam, B., Poornesha, B. 2015. Screening of *Beauveria bassiana* (Balsamo) Vuillemin isolates against maize stem borer, *Chilo partellus* (Lepidoptera: Pyralidae) and the effect of solid substrates on conidial production and virulence. *Journal of Pure and Applied Microbiology* 9 (4): 2979-2986.

Salini, S. and Viraktamath, C. A. 2015. Genera of Pentatomidae (Hemiptera: Pentatomidea) from south India-an illustrated key to genera and checklist of species. *Zootaxa,* 3924(1): 1-76.

Shashank, P. R., Ojha, R., Venkatesan, T., Jalali, S. K. and Bhanu, K. R. M. 2015. Molecular characterization of brinjal shoot

and fruit borer, *Leucinodes orbonalis* (Guenée) (Lepidoptera: Crambidae) based on mitochondrial marker cytochrome oxidase I and their phylogenetic relationship. *Indian Journal of Experimental Biology*, 52: 51-55.

Sheoran, N., Agisha Valiy Nadakkakathb, Vibhuti Munjala, Aditi Kundu, Kesavan Subaharan, Vibina Venugopal, Suseelabhai Rajamma, Santhosh J. Eapen, Aundy Kumar. 2015. Genetic analysis of plant endophytic *Pseudomonas putida* BP25 and chemo-profiling of its antimicrobial volatile organic compounds. *Microbiological Research*, 173: 66–78.

Shrivastava, P., Kumar, R., Mahesh S. Yandigeri, Nityanand Malviya and Arora, D. K. 2015. Isolation and characterization of Streptomycetes with plant growth promoting potential from mangrove ecosystem. *Polish Journal of Microbiology*, 64(4): 339-349.

Shrivastava, P., Kumar, R. and M. S. Yandigeri. 2016. *In vitro* biocontrol activity of halotolerant *Streptomyces aureofaciens* K20: A potent antagonist against *Macrophomina phaseolina* (Tassi) Goid. *Saudi Journal of Biological Sciences*, http://dx.doi.org/10.1016/j.sjbs.2015.12.004

Sivakumar, G., Rangeshwaran, R., Yandigeri, M. S., Mohan, M., Venkatesan, T. and Verghese, A. 2016. Diversity of culturable Gut bacteria associated with the field populations of cotton leafhopper *Amrasca biguttula biguttula* (Ishida) in India, *Indian Journal of Agricultural Sciences* (Accepted for publication in February 2016 issue)

Sreerama Kumar, P. 2015. Endophytes of invasive weeds: pertinence to classical biological control in India. *Journal of Biological Control*, 29(3): 115–120.

Sreerama Kumar, P. and Verghese, A. 2015. *Cyrtobagous salviniae* – godsend in God's own country. *Antenna*, 39(4): 175–177.

Sridhar, V., Venkatesan, T., Yan Tomason, Jalali, S. K., Behera, G., Shanthi, R. M., Ravinder Kumar, Padma, N., Gopinath, V. and Umesh Reddy. 2016. *In silico* mining of microsatellites and analysis of genetic diversity among inter and intra-generic aphids of sub-family, Aphidinae. *Entomologia Experimentalis et Applicata*, (in Press).

Srikanth, J., Mahesh, P., Salin, K. P. and Poorani, J. 2015. Occurrence of the hispa, *Asamangulia cuspidata* and its parasitoids in South India. Current Science, 109:

Srinatha, H. S., Jalali, S. K., Sriram, S. and Chakravarthy, A. K. 2015. Isolation of microbes associated with field-collected populations of the egg parasitoid, *Trichogramma chilonis* capable of enhancing biotic fitness. *Biocontrol Science and Technology*, 25: 789–802.

Srinivasa Murthy, K., Choubey, B. K., Syeda Lubna, Kumar, A.R.V., Venkatesan, T., Jalali, S. K. and Verghese, A. 2015. Diversity and characterization of phytophagous scarabaeids. *Annals of Biological Research,* 6 (12): 5-15

Srinivasa Murthy, K., Ramya S. L., Venkatesan, T., Jalali, S. K. and Verghese, A. 2015. Insecticide degradation by gut bacteria in *Cotesia vestalis* Haliday, a potential parasitoid of diamond back moth, *Plutella xylostella* (Linnaeus). *Asian Journal of Science and Technology*, 6 (11):1960-67

Srinivasa Murthy, K., Syeda Lubna Banu, Kumar, A.R.V., Venkatesan, T., Jalali, S.K. and Verghese, A. 2015. *In-vitro* rearing of root grubs. *International Journal of Current Research*, 7(12): 24650-24655.

Veenakumari, K., Khan, F. R. and Prashanth Mohanraj. 2015. Three new species of Telasinae (hymenoptera: Platygastridae) from India. *Entomologists Monthly Magazine*. 150: 227-238.

Veenakumari, K., Mohanraj, P. and Khan, F. R. 2015. 'The *adikeshavus*-group': A new species group of *Idris* Förster (Hymenoptera, Platygastridae) from India, with descriptions of five new species. *Deutsche Entomologische Zeitschrift* 62(2), 247-260.

Veenakumari, K., Rajmohana, K. and Prashanth Mohanraj. 2016. An unusual, new, sexually dimorphic species of Gryon Haliday (Hymenoptera: Scelionidae) from India. *Oriental Insects* (accepted).

Veereshkumar, Belavadi, V. V. and Ankita Gupta 2015. Parasitisation of leaf-cutter bees (Megachilidae: Apoidea) by *Melittobia*. *Entomon*, 40: 105-112.

Venkatesan, T., Reetha, B., Jalali, S. K., Lalitha, Y., Ballal, C. R., Ravi P. More and Abraham Verghese. 2015. Molecular Identification of Egg parasitoid, *Trichogramma* species of India using COI and ITS-2 regions and their phylogeny relationship. *Genome*, 56: 291-292.

Venkatesan, T., Sridhar, V., Yan Tomason., Jalali, S. K., Behera, G., Shanthi, R. M., Ravinder Kumar, Padma., N., Gopinath, V. and Umesh Reddy. 2015. Use of expressed sequence tag microsatellite markers for population genetic research of *Helicoverpa armigera* (Lepidoptera: Noctuidae) from India. *Canadian Entomologist*, 1–13. oi:10.4039/tce.2015.47.

Verghese, A., Subaharan, K. and Sreerama Kumar, P. 2015. New, safer molecules and biocontrol technologies for integrated pest management in crops. *Current Science*, 109(10): 1766–1767.

Yandigeri, M.S., Nityanand Malviya, Manoj Kumar Solanki, Shrivastava P., G. Sivakumar. 2015. Chitinolytic *Streptomyces vinaceusdrappus* S5MW2 isolated from Chilika lake, India enhances plant growth and biocontrol efficacy through chitin supplementation against *Rhizoctonia solani*. *World Journal of Microbiology and Biotechnology*, 31(8):1217-25.

BOOKS/ BOOK CHAPTERS/ TECHNICAL BULLETINS/ FOLDERS/ TRAINING MANUALS/ POPULAR ARTICLES

NBAIR

Agarwal, Abraham Verghese, Sindhu Radhakrishnan and Kesavan Subaharan. 2016. Human Animal Conflict in Agro-Pastoral Context: Isses & Policies. ICAR - National Agricultural Science Fund, New Delhi, India. p.58.

Bakthavatsalam, N and Kesavan Subaharan 2016. Chemical ecology in pest control. In: integrated Pest Management in the Tropics (Ed) Dharan. P.Abrol New India Publishing Agency, New Delhi, pp.627-685.

Jalali, S. K., Ojha, R. and Venkatesan, T. 2015. DNA Barcoding for Identification of Agriculturally Important Insects, pp. 13-23. In: A. K. Chakravarthy (ed.), New Horizons in Insect Science: Towards Sustainable Pest Management, DOI 10.1007/978-81-322-2089-3_29, © Springer India 2015.

Jalali, S. K., Prashanth Mohanraj, Lakshmi, B. L. 2016. Trichogrammatids. *Ecofriendly Pest Management for Food Security*, pp. 139-181. http://dx.doi.org/10.1016/B978-0-12-803265-7.00005-1

Mohan, M., Bakthavatsalam, N., Kesavan Subaharan and Abraham Verghese. 2015. The South American Tomato Leafminer,

Tuta absoluta : Monitoring and Management, Extension folder, ICAR - NBAIR, Bengaluru.

Mohan, M., Bakthavatsalam, N.,Kesavan Subaharan, Narasa Reddy and Abraham Verghes. 2015. Thakkaliyil Suranga poochi. Extension folder, ICAR - NBAIR, Bengaluru. (Tamil).

Sreerama Kumar, P. 2015. Bringing together safer molecules and biocontrol technologies. *Biocontrol News and Information*, 36(3): 28N.

Sreerama Kumar, P. 2015. Schoolchildren and morning walkers learn about biological control. *Biocontrol News and Information*, 36(4): 36N–37N.

Sreerama Kumar, P. and Verghese, A. 2015. Recent successes in biological control in India, pp. 73–76. In: Manjunath, T.M., Angadi, S., Hittalamani, S.V. and Narayana Swamy, S. (eds) *Sangama – A Souvenir*, UAS-B Global Alumni Meet, 27–28 December 2015, UAS-B Alumni Association, Bengaluru, India.

AAU–Jorhat

Saikia, D.K., Borkakati, R.N. and Das, P. 2016. Comparative study of BIPM package of rice over farmers' practice. *Pestology*, XL (2): 56-58.

ANGRAU–Anakapalle

Visalakshi, M. and Sireesha, A. 2015. Study on influence of tillage methods on productivity of maize. Indian Journal of Agricultural Research. 49(5): 452–455.

Visalakshi, M., Bhavani, B. and Prasada Rao, K. 2015. Efficacy of insecticide + fungicide combinations in the management of early shoot borer and smut in sugarcane. *Pestology* 39(10): 39–41.

Visalakshi, M. 2015. Knowledge, adoption and economics of intergrated pest management in paddy in Vizianagaram district, Andhra Pradesh. *The Andhra Agricultural Journal*, 61(4), 879–884.

Visalakshi, M., Bhavani, B. and Govinda Rao, S. 2015. Field evaluation of entomopathogenic fungi against white grub, *Holotrichia consanguinea* Blanch in sugarcane. *Journal of Biological Control*, 29(2): 103–106.

Visalakshi, M. and Bhavani, B. 2015. Field efficacy of *Beauveria bassiana* and *Metarhizium anisopliae* against white grub damaging sugarcane in Andhra Pradesh. *Sugar Journal*, 2015: 153–157.

GBPUAT–Pantnagar

Pandey, V., Ansari, M.W., Tula, S., Yadav, S., Sahoo, R.K., Bains, G., Badal, S., Chandra, S., Gaur, A.K., Kumar, A., Shukla, A., Kumar, J. and Tuteja, N. 2016. Dose-dependent response of *Trichoderma harzianum* in improving drought tolerance in rice genotypes. *Planta*, 1–14.

Negi, Y., Prabha, D., Garg, S.K. and Kumar, J. 2015. Biological control of ragi blast disease by chitinase producing *Pseudomonas fluorescens* strains. Organic Agriculture : DOI 10.1007/s13165-015-0142-2

Rai, D., Tewari, A.K. and Bisht, K.S. 2015. Evaluation of different concentrations of Jaggery (as a cheaper carbon source) for growth and sporulation of *Trichoderma harzianum*. *Trends in Biosciences*, 18 (8): 4868–70.

Rai, D., Bisht, K.S. and Tewari, A.K. 2016. *In-vitro* effect of newer fungicides

on mycelial growth in biocontrol fungus *Trichoderma* (Th14). *Journal of Hill Agriculture, Environment & Food Science*, 7(1):

IIVR–Varanasi

Halder, J. and Rai, A.B. 2016. Suitability of different prey aphids on the growth, development and reproduction of *Chrysoperla zastrowi sillemi* (Esben-Petersen) (Chrysopidae: Neuroptera), *Proceedings of the Zoological Society*, 69(1): 89–95.

KAU–Thrissur

Aswin, T., Bhaskar, H. and Subramanian, M. 2015 Efficacy of novel acaricide molecules and botanicals against rice leaf mite *Oligonychus oryzae* (Hirst) (Prostigmata: Tetranychidae) *Journal of Tropical Agriculture*, 53(2): 187–190.

MPUAT–Udaipur

Kalyan, R.K., Ameta, O.P., Ameta, G.S., Rana, B.S. and Jain, H.K. 2015. Estimation of losses in soybean due to insect pests. *Indian Journal of Applied Entomology*. Pp 30.

Ahir, K.C., Rana, B.S., Ameta, O.P. and Mordia, A. 2015. Seasonal incidence of major insect pests of groundnut. *Indian Journal of Applied Entomology*. Pp 55.

Saini, A., Rana, B.S., Ameta, O.P. and Mordia, A. 2015. Seasonal incidence of major insect pests infesting Chilli. *Indian Journal of Applied Entomology*. Pp 78.

TNAU–Coimbatore

Ranjith, M., Bajya, D.R., Manoharan, T., Sridharan, S. and Kuttalam, S. 2015. Repellent efficacy of *Crotalaria burhia* and *Anacardium occidentale* against *Odontotermes obesus* (Isoptera: Termitidae) under laboratory condition. *The Indian Journal of Agricultural Sciences*, 85(9): 1234–1236.

Sridharan, S., Chandrasekhar, K. and Ramakrishnan, N. 2015. Effect of mineral oil and its combinations against leafhopper, *Amrasca biguttala biguttala* in okra. *Indian Journal of Plant Protection*, 43(2): 133–142.

Ramakrishnan, N. and Sridharan, S. 2015. Eco-safe biopesticides to manage psyllids, *Diaphorina citri* in curry leaf, *Murraya koenigii. Indian Journal of Plant Protection,* 43(3): 294–298.

Awasthi, N.S., Sridharan, S. and Padmanban, B. 2015. Analysis of technology gap and relative importance of banana pseudostemborer *O. longicullus* Oliver in Tamil Nadu. *Indian Journal of Ecology*, 43 (Special issue-1): 506–511.

Awasthi, N.S. and Sridharan, S. 2015. Screening of botanicals for their repellent properties to banana pseudostem borer *Odoiporus longicollis* oliver. *The Ecoscan*, 7 (Special issue 2015): 147–152.

Sridhar, K., Sridharan, S. and Muthukumar, M. 2016. Screening of bioenergy sweet sorghum genotypes for their resistance to shootfly *Atherigona Soccata* (Rodani) under field conditions. *Trends in Biosciences*, 8(21): 5866–5883.

Sridhar, K., Sridharan, S. and Muthukumar, M. 2016. Screening of sweet sorghum genotypes for their resistance to stem borer *Chilo partellus* (Swinhoe) under field

condition. *Progressive Research*, 10 (Special V): 759–766.

Shanmuga Prema, M., Sridharan, S. and Kuttalam, S. 2016. Fipronil 80WG: A promising phenyl pyrrozole insecticide to manage thrips damage in grapes. *Annals of Plant Protection Sciences*, 24(1): 61–66.

Shanmuga Prema, M. and Sridharan, S. 2016. Management of rice leaf folder with Fiprnil 80WG – a novel phenyl pyrrosole pesticide. *Progressive Research*, 10 (Special II): 1019–1022.

PAU–Ludhiana

Devi, M.S. and Kaur, R. 2015. Effect of different artificial diets on the adult's biological attributes of sugarcane stalk borer, *Chilo auricilius* Dudgeon and evaluation of their costs. *Journal of Applied and Natural Science*, 7(1): 88–81.

Sharma, S. and Aggarwal, N. 2015. Dispersal ability and parasitisation performance of *Trichogramma* spp (Hymenoptera: Trichogrammatidae) in organic *basmati* rice. *Journal of Environmental Biology*, 36: 1345–1348.

Shera, P.S. and Arora, R. 2016. Comparative study on oviposition and larval preference of spotted bollworm, *Earias vittella* on *Bt* and non-Bt cotton. *Journal of Environmental Biology* 37(1): 121–127.

Shera, P.S. and Arora, R. 2016. Comparative survival and development of spotted bollworm, *Earias vittella* (Fabricius) on *Bt* and isogenic non *Bt* cotton genotypes under field cage conditions. *Journal of Cotton Research and Development*, 30(1): 97–103.

Shera, P.S. and Arora, R. 2016. Survival and development of spotted bollworm, *Earias vittella* (Fabricius) (Lepidoptera: Nolidae) on different transgenic *Bt* and isogenic non-Bt cotton genotypes. *Phytoparasitica* DOI 10.1007/s12600-016-0505-6.

YSPUHF–Solan

Gavkare, O. and Sharma, P.L. 2015. New record of *Nesidiocoris tenuis* (Reuter) (Hemiptera: Miridae) associsted with *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae) on tomato from Maharastra, India. *Journal of Biological Control*, 28(2): 117–118.

Gavkare, O., Sharma, P.L. and Japoshvili, G. 2015. Parasitization of the Potato Aphid, *Macrosiphum euphorbiae* (Thomas), by *Aphelinus asychis* Walker in Greenhouses in India. *Journal of Agricultural and Urban Entomology*, 31(1): 47–51.

Sharma, P.L., Chauhan, U. and Sharma, K.C. 2015. Studies on the diversity of predatory coccinellid beetles (Coleoptera) in different agro-climatic zones of Himachal Pradesh. *The Bioscan*, 10(3): 981–985.

Suman, S. and Chauhan, U. 2015. Survey of thrips (Thysanoptera) and their natural enemies in vegetables from mid hills of Himachal Pradesh. *The Ecoscan*, 9(3&4): 713–715.

Suman, S. and Chauhan, U. 2015. Survey of thrips fauna and their theirnatural enemies in different fruit crops under mid

hills of Himachal Pradesh. *Journal of Insect Science*, 28(2): 202–207.

Books/ book chapters/ technical bulletins/ folders/ training manuals/ popular articles

AAU–Anand

Raghunandan, B.L. 2015. Role of soil yeast in relation to plant health. *Popular Kheti*, 3(4): 94–95.

Raghunandan, B.L. and Mohannaik, G. 2015. Seed biopriming – promising strategy to enhance plant growth and yield. *Readers Shelf*, 12(6): 18–19.

AAU–Jorhat

Borkakati, R.N. 2016. Poramporagata Paddhatire Dhankhetir Keet-Potanga Niyantran. *Asomiya Khabar* (28 March): 9.

Borkakati, R.N. and Saikia, D.K. 2016. Dhanani Potharat Jaibik Niyantrak Trichogramma-r Prayug. *Asomiya Khabar* (14 March): 9.

Borkakati, R.N. 2016. Sashyarakhyar Babe Ecological Engineering-r Xuprayug. *Asomiya Khabar* (7 March): 9.

Borkakati, R.N. 2016. Aloo Khetir Krishke Mon Dibologia. *Asomiya Khabar* (1 February): 9.

Borkakati, R.N. and Saikia, D.K. 2015. Sashyarakhyar Babe Ecological Engineering-r Xuprayug. *Prantik* (16 April): 41.

MPKV–Pune

Bankar, S.P., S.M.Galande and Shinde, Y.A. 2015. Efficacy of various insecticides against pod borer, *Maruca vitrata* infesting cowpea. *Pestology*. 39(5): 45– 50.

PAU–Ludhiana

Shera, P.S., Sharma, S. and Sangha, K.S. 2015. Biological control: An integral component of IPM in sugarcane. *Progressive Farming*, 51(7): 4–5.

Sharma, S., Shera, P.S. and Sangha, K.S. 2015. Ganne de hanikarak kiriyan de sarvpakhi roktham vich mittar kiriyan da yogdan. *Changi Kheti*, 51(7): 3–6.

Sharma, S., Shera, P.S. and Sangha, K.S. 2016. *Haari de mitar kiriyan nal jaan pachaan. Changi Kheti*, 16–18.

Shera, P.S., Sharma, S. and Sangha, K.S. 2016. Identification of natural enemies of insect pests in rabi crops. *Progressive Farming*, January, 17–19

TNAU–Coimbatore

Sridharan, S., Kuttalam, S. and Saravanan, P.A. 2015. Potential biocontrol agents in pest management (Tamil). *Valarum Velanmai*, 47–50.

Saravanan, P.A., Sridharan, S. and Kuttalam, S. 2015. Biological control of pests in sugarcane (Tamil). *Valarum Velanmai*, 11–13.

Saravanan, P.A., Sridharan, S. and Kuttalam, S. 2015. Biological control of pests in brinjal (Tamil). *Valarum Velanmai*, 19–21.

11. ONGOING RESEARCH PROJECTS

A. Institute projects for the year 2015-16

S. No.	Name of the project	Principal Investigator
DIVISION OF MOLECULAR ENTOMOLOGY		
1	Molecular characterization and DNA barcoding of some agriculturally important insect pests (01.04.2013 to 31.09.2018)	Dr S. K. Jalali
2	Molecular characterization and DNA barcoding of agriculturally important parasitoids and predators (01.06.2013 to 31.05.2018)	Dr T. Venkatesan
3	Molecular characterization and DNA barcoding of subterranean insects (01.04.2014 to 31.03.2019)	Dr K. Srinivasa Murthy
4	Mapping of the Cry gene diversity in hot humid regions of India (01.04.2011 to 31.03.2017)	Dr R. Rangeshwaran
5	Culturable and unculturable microflora associated with soil insects and other arthropods (01.04.2013 to 31.03.2016)	Dr R. Rangeshwaran
6	Role of microbial flora of aphids in insecticide resistance (01.10.2012 to 31.03.2016)	Dr Mahesh Yandigeri
7	Development of computational tools for prediction of insecticide resistance gene for agriculturally important insects (01.04.2012 to 31.03.2016)	Dr M. Pratheepa
8	Distribution of abiotic stress tolerant genes / alleles across insect orders (01.04.2014 to 31.03.2017)	Dr M. Pratheepa
9	Taxonomy and Diversity of Indian Sphecidae (01.09.2014 to 31.03.2020)	Dr R. Gandhi Gracy
DIVISION OF INSECT ECOLOGY		
10	Documentation, production and utilisation of predatory anthocorids and mites (24.03.2012 to 31.03.2017)	Dr Chandish R. Ballal
11	Influence of infochemical diversity on the behavioural ecology of some agriculturally important insects (01.04.2013 to 31.03.2017)	Dr N. Bakthavatsalam
12	Climate change effect on the diversity and bioecology of some important sucking pests (01.04.2014 to 31.03.2019)	Dr N. Bakthavatsalam
13	Exploitation of *Beauveria bassiana* for the management of maize stem borer (*Chilo partellus*) and tomato fruit borer (*Helicoverpa armigera*) through endophytic establishment (01.04.2014 to 31.03.2017)	Dr B. Ramanujam
14	Introduction and studies on natural enemies of some new insect pests and weeds (27.08.2010 to 31.03.2016)	Dr A. N. Shylesha
15	Pollinator diversity in different agro climatic regions with special emphasis in non-*Apis* species (01.04.2012 to 31.03.2017)	Dr T. M. S. Swamy

16	Documenting agriculturally important mites and establishing an authentic collection (01.04.2014 to 31.03.2019)	Dr P. Sreerama Kumar
17	Chemical characterization and ethology of economically important dipteran pests of veterinary and fisheries (09.10.2014 to 09.10.2017)	Dr K. Subaharan
18	Characterization of viruses with special reference to Lepidoptera & Coleoptera (24.11.2015 to 31.03.2021)	Dr G. Sivakumar
19	Microflora associated with insecticides resistance in cotton leafhoppers (*Amrasca biguttula biguttula*) (01.04.2012 to 30.09.2015)	Dr G. Sivakumar
20	Synthesis of nanomaterials to act as sensor for semiochemicals in pest management (01.07.2013 to 31.07.2017)	Dr Deepa Bhagat
21	Diversity and predator-prey interactions in predatory mirids and geocorids (01.10.2015 to 31.03.2019)	Dr Richa Varshney
DIVISION OF INSECT SYSTEMATICS		
22	Biosystematics of Trichogrammatidea (Hymenoptera) (01.04.2013 to 31.05.2017)	Dr Prashanth Mohanraj
23	Biosystematics of oophagous parasitoids with special reference to Platygastroidea (Hymenoptera) (01.09.2008 to 31.03.2018)	Dr K. Veenakumari
24	Biosystematics of aphids, coccids and diversity of their natural enemies (01.04.2009 to 31.03.2017)	Dr Sunil Joshi
25	Mechanism of insecticide resistance in *Leucinodes orbonalis* (01.10.2012 to 31.03.2016)	Dr M. Mohan
26	Biosystematics and diversity of agriculturally important Cerambycidae (01.10.2013 to 31.03.2017)	Dr M. Mohan
27	Biosystematics and diversity of entomogeneous nematodes in India (01.04.2012 to 31.03.2017)	Dr Jagadeesh Patil
28	Taxonomic Studies On Fruit Flies (Diptera: Tephritidae) of India (01.04.2012 to 31.03.2017)	Dr K. J. David (Study leave)
29	Taxonomic studies on pentatomidae (Hemiptera: pentatomoidea) of India with special reference to pentatominae (14.03.2012 to 31.03.2020)	Dr S. Salini
30	Biodiversity of economically important Indian microorganisms (Braconidae) supported by molecular phylogenetic studies (21.09.2010 to 31.03.2016)	Dr Ankita Gupta
31	Digitization of type specimens in NBAII reference collection (01.04.2013 to 31.03.2018)	Dr Ankita Gupta
32	Taxonomy and diversity of Indian Thysanoptera with special reference to Terebrantia (01.10.2015 to 31.03.2021)	Ms. Rachana, R. R.

B. Externally funded projects for the year 2015-16

S. No.	Name of the project	Principal Investigator
DIVISION OF MOLECULAR ENTOMOLOGY		
1	**NFBSFARA:** Identification of nucleopolyhedrovirus (NPV) encoded protein and small RNAs and the feasibility of their expression in plant to control *Helicoverpa* (01.01.2011 to 31.03.2016)	Dr S. K. Jalali
2	**CRP:** Consortium Research Project (CRP) on Genomics (01.04.2015 to 31.03.2017)	Dr S. K. Jalali
3	**ICAR:** Intellectual property management & transfer/ commercialization of Agricultural Technology Scheme (06.06.2008 to 31.03.2017)	Dr T. Venkatesan
4	***ORP-SP:*** ICAR-Outreach Programme on Management of Sucking Pests in Horticultural Crops (02.01.2015 to 31.03.2017)	Dr T. Venkatesan
5	**CRP on Bioinformatics – ICAR:** Centre for Agricultural Bioinformatics (CABin) (01.01.2015 to 31.03.2017)	Dr T. Venkatesan
6	**AMAAS:** Culturable and unculturable microbial diversity of aphids and their role in insecticide resistance and other fitness attributes (01.04.2014 to 31.03.2017)	Dr Mahesh Yandigeri
DIVISION OF INSECT ECOLOGY		
7	**DBT:** Studies on extending the shelf life and improving the delivery methods of trichogrammatid egg parasitoids for promoting their commercial mass production in India (01.07.2013 to 31.07.2016)	Dr Chandish R. Ballal
8	**CST:** Studies on pest status and ecofriendly management of thrips (*Pseudodendrothrips mori*) (Thysanoptera: Thripidae) on Mulberry in Tamil Nadu (09.10.2014 to 31.10.2016)	Dr Chandish R. Ballal (Co-CPI)
9	**ICAR-CABI:** The study of biological control of invasive plant species & Indian natural enemies (01.07. 2014 to 31.07.2016)	Dr Chandish R. Ballal
10	**CRP:** Consortium Research Platform (CRP) on Borer in Network Mode (01.04.2014 to 31.03.2017)	Dr N. Bakthavatsalam
11	**CSRTI**: Investigation on semiochemicals of the silkworm uzifly *Exorista bombycis* (01.01.2015 to 31.12.2016)	Dr N. Bakthavatsalam
12	**CSRTI:** Identification, characterization, synthesis and field evaluation of sex pheromone of the mulberry leaf roller, *Diaphania pulverulentalis* (Lepidoptera: Pyralidae) (21.01.2016 to 20.01.2018)	Dr N. Bakthavatsalam
13	**DBT:** Plant-derived botanicals from herbs/shrubs of Indo-Burma biodiversity hotspot for control of stored grain insect pests (20.03.2015 to 31.03.2018)	Dr N. Bakthavatsalam
14	**Coffee Board:** Ecofriendly approaches for the management of Coffee white stem borer, Xylotrechus quadripes Chev. (Coleoptera: Cerambycidae) (01.07.2012 to 30.06.2015)	Dr N. Bakthavatsalam

15	**ICAR Extra Mural Project:** Formulation of pheromones for important agricultural pests (21.01.2016 to 31.03.2017)	Dr N. Bakthavatsalam
16	**AMAAS:** Development of formulations of *Beauveria bassiana, Metarhizium anisopliae* and *Lecanicillium* spp. for management of certain sucking pests in vegetable crops (01.04.2014 to 31.03.2017)	Dr B. Ramanujam
17	**DBT**: Controlled release dispensers for delivery of semiochemicals (25.11.2014 to 24.11.2017)	Dr K. Subaharan
18	**ICAR Extramural project:** Development of Stable, Low cost, Essential Oil based mosquito repellent formulations (01.01.2016 to 31.03.2017)	Dr K. Subaharan
19	**NTRF:** Feasibility of suppression of Tea Shot Hole Borer Euwallacea fornicates through its mutualistic Fusarium spp. (01.01.2016 to 31.12.2018)	Dr G. Sivakumar
20	**IISc**: Characterization, functionalisation and assembly of nanosensors and their applications (03.08.2012 to 31.08.2015)	Dr Deepa Bhagat
21	**DBT**: Nanoparticles for enhancing shelf life/storage and field application of semiochemicals (05.07.2010 to 09.07.2015)	Dr Deepa Bhagat
22	**CRP:** Consortium Research Platform (CRP) on Nanotechnology project (18.11.2014 to 31.03.2017)	Dr Deepa Bhagat
DIVISION OF INSECT SYSTEMATICS		
23	**CRP:** Consortium Research Platform (CRP) on Agro biodiversity (14.08.2015 to 31.03.2017)	Dr Prashanth Mohanraj
24	**ORP:** Open Research Platform on Management of Sucking Pests of Horticultural Crops - Taxonomy of Aphids and Coccids (04.01.2012 to 31.03.2017)	Dr Sunil Joshi
25	**DST:** Diversity and distribution entomopathogenic nematodes in coconut and arecanut ecosystems (16.05.2014 to 15.05.2017)	Dr Jagadeesh Patil
26	**ICAR:** Network project on Insect biosystematics (09.04.2012 o 31.03.2017)	Dr Ankita Gupta

12. ACTIVITIES OF ITMU

Technologies transferred

1. Novel insecticidal WP formulations of *Heterorhabditis indica*
2. Dorsa lure- Plant volatile dispensers for increasing the trap efficiency for mango fruit flies"
3. A simple technique of rearing brinjal shoot and fruit borer
4. A Herbal based repellant for termites on woody trees – Repter
5. A) Herbal swabber for the management of white stem borer *Xylotrechus quadripes* in Coffee (organic).

   B) Booster for boosting plant health in coffee (not for certified organic coffee)
6. Novel wettable powder formulation of *Pochonia clamydosporia*
7. Liquid formulation of *Bacillus thuringiensis*
8. Protocol for designing lure for impregnating parapheromone 4[4-acetoxy) phenyl-butanone to attract male flies of *Bactrocera* spp attacking cucurbit crops for monitoring its population – (CUELURE)

Events organized

1. Guest lecture on Bioresources, Access And Benefit Sharing" By Dr. R. Vasudeva, Professor, College of Forestry, SIRSI, UAS (D), Karnataka on 28th July 2015.
2. One-day collaborative Workshop with WTO & IPR Relay Cell, Visvesvaraya Trade Promotion Centre (Govt of Karnataka Centre for Export Promotion), Department of Industries & Commerce, which will be held on 5 August, 2015.

ICAR-NBAIR-Industry Interface Meet at ICAR-NBAIR on 11/03/2016

Achievements of ITMU under NAIF Project

1. Total technologies developed at ICAR-NBAIR : 21
2. New technologies developed in 2015-16 : 7
3. Number of technologies commercialized in 2015-16 : 9
4. Technology brochures prepared during 2015-16 : 18

Patents filed

1. Method for continuous rearing of an anthocorid predator *Blaptostethus pallescens* : (Dr. Chandish R. Ballal)
2. DORSA LURE- Plant volatile composition to increase the trap efficiency for mango fruit flies: Dr. N. Bakthavatsalam and team
3. EUGALURE: A dispenser for the monitoring of eucalypts gall wasp, *Leptocybe invasa* (Dr. N. Bakthavatsalam and team)
4. Protocol for designing lure for impregnating parapheromone 4[4-acetoxy) phenyl-butanone to attract male flies of *Bactrocera* spp attacking cucurbit crops for mass trapping and monitoring its population thereof: Dr. N. Bakthavatsalam and team)
5. A herbal based repellent for termites on woody trees – Repter (Dr. N. Bakthavatsalam and team)

Revenue generated during 2015-16

Revenue generated through sale of technologies	: Rs 15,00,000/-
Revenue through training	: Rs 75,029/-
Revenue generated through sale of macrobials	: Rs 4,98,000/-
Revenue generated through sale of microbials	: Rs 3,97,000/-
Revenue generated through sale of publications	: Rs 2,360/-
Total revenue generated	: Rs 24,73,000/-

13. CONFERENCE PAPERS

Archana, M., Desouza, P.E., Patil, J. 2015. Efficacy of entomopathogenic nematodes (Rhabditida: Steniernematidae and Heterorhabditidae) on developmental stages of House fly, *Musca domestica*. International on Biodiversity, Agriculture, and Environment and Forestry, 11-12 December 2015, Fortune Hotel Sullivan Court, Ooty.

Archana, M., Desouza, P.E. and Patil, J. 2016. Exposition of entomopathogenic nematodes (Rhabditida: Steinernematidae and Heterorhabditidae) to poultry Manure: a cause for survival and reproduction. XXV National Congress of Veterinary Parasitology and Animal Symposium, 17–19 February 2016, Department of Parasitology, Madras Veterinary College, Vepery, Chennai.

Gupta, A. and Verghese, A. 2015. Butterfly parasitoids in peninsular India: diversity estimates, host specificity and potential threats. pp. 119. III World Biodiversity Congress 26-29th October Mokra –Gora Serbia.

Lalitha, Y., Ballal, C.R. and Gupta, A. 2016. Interaction between *Anastatus acherontiae* and *Anastatus bangalorensis* (Hymenoptera: Chalcidoidea) two potential parasitoids of Litchi stink bug *Tessaratoma javanica* Thunberg In Conference on "National Priorities in Plant Health Management", held on 4th–5th February, 2016 at S. V. Agricultural College, Tirupati, Andhra Pradesh.

Patil, J. 2015. Guest lecture on Entomopathogenic nematodes for the management of insect pests at UAHS, Shivamogga, Karnataka on 18th September 2015.

Patil, J. 2015. Management of white grub in arecanut plantation. In: one day meet on arecanut farmers at UAHS, Shivamogga, Karnataka.

Patil, J. 2016. Biostatistics with reference to Insect Bioinformatics In: "Recent advances in Insect Bioinformatics and its applications in Pest management" held at NBAIR during 15th to 20th February 2016.

Patil, J., Manjunatha T Gowda., Vijayakumar. R. and Abraham Verghese. 2015. Ecological characterization of Heterorhabditis indica, A warm adapted entomopathogenic nematode form India. Oral presentation in "International on Biodiversity, Agriculture, and Environment and Forestry" held from 11-12 December 2015 in Fortune Hotel Sullivan Court, Ooty. Organized by Association for the Advancement of Biodiversity Science.

Pratheepa, M., Verghese, A. and Bheemanna, H. 2016. Weighted Association rule mining for the occurrence of the insect pest *Helicoverpa armigera* (Hübner) related with abiotic factors on cotton. Proceedings of the 10thINDIACom; INDIACom-2016; IEEE Conference ID: 37465 2016 3rd International Conference on "Computing for Sustainable Global Development", 16 th - 18thMarch, 2016 Bharati Vidyapeeth's Institute of Computer Applications and Management (BVICAM), New Delhi (INDIA).

Ramanujam, B., Poornesha, B., Avinash, T.G., Renuka, S., Shylesha, A.N. and Rangeshwaran, R. 2015. Endophytic establishment of *Beauveria bassiana* (Balsamo)

Vuillemin in sorghum. Paper presented at 56th Annual Conference of Association of Microbiologists of India" during December 7-10, 2015 at Jawaharlal Nehru University, New Delhi. AMP no.47 p.252.

Renuka, S., Ramanujam, B. and Poornesha, B. 2015. Endophytic colonization of Entomopathogenic fungus *Beauveria bassiana* (Balsamo) Vuillemin in Maize (*Zea mays* L.). Paper presented at "56th Annual Conference of Association of Microbiologists of India" during December 7-10, 2015 at Jawaharlal Nehru University, New Delhi. AMP no.48 p.253.

Sivakumar, G., Ballal, C.R., Rangeshwaran, R., Surabhi Kumari. 2015. Diversity of endosymbionts imparting insecticide resistance in leafhopper *Amrasca biguttula biguttula* (Ishida) through 16s rRNA gene sequencing" presented in the III World Biodiversity Congress held at Serbia from 26 to 30 October 2015.

Sivakumar, G., Rangeshwaran, R., Ballal, C.R. and Verghese, A. 2016. Bacterial symbionts mediated functions in cotton leafhopper " presented in the National Seminar on Mitigation of chemical residues in farm products-strategies, opportunities and challenges held at Faculty of Agriculture and Animal Husbandry Gandhigram Rural Institute- Deemed University Gandhigram from 18 to 19 February 2016.

Sreerama Kumar, P. 2016. Phytoplasmas in India: it's high time we identified the insect vectors, p. 164. In: Khetarpal, R.K., Mondal, K.K., Dubey, S.C., Rao, G.P., Celia Chalam, V., Singh, N., Kamil, D., Bashyal, B.M., Jambhulkar, P.P., Prakash, G., Singh, D. and Sharma, P. (eds) International Conference on Plant, Pathogens and People — Challenges in Plant Pathology to Benefit Humankind, Indian Phytopathological Society, New Delhi, India, 23–27 February 2016.

Surabhi Kumari, Rangeshwaran, R. And Shylesha, A.N. 2015. Occurrence of cellulolytic and pectinolytic bacteria in the gut of Indian dung beetles" presented in the International Symposium on " Biodiversity, Agriculture, Environment and Forestry held at Ooty from 11- 12 December 2015.

Venkatesan, T., Reetha, B., Jalali, S.K., Lalitha, Y., Ballal, C.R., More, R.P. and Abraham Verghese. 2015. Molecular Identification of Egg parasitoid, *Trichogramma* species of India using COI and ITS-2 regions and their phylogeny relationship. Presented at 6th International Conference on Barcode of Life Conference at University of Guelph, Canada at during 17th to 22nd August 2015.

Venkatesan, T. 2016. An Over view of Technologies ready for commercialization. Presented at ICAR-NBAIR-Interphase Meet, held at ICAR-NBAIR, Bangalore on 11th March 2016. Organized by IIMU-NBAIR and Society for Biocontrol Advancement, Bangalore.

Venkatesan, T. and Pratheeba. 2016. Detection of Insecticide Resistance in *Meconellicoccus hirsutus* and quantification of detoxification of enzymes. Presented at Annual Review Meeting ORP on Management of sucking pests, held at IIHR, Bangalore during 13th February, 2016.

Venkatesan, T. 2016. Annual Progress Report on Network Project on Agricultural

Bioinformatics and Computational Biology presented at Steering committee, CABin, IASRI, New Delhi during 24th Feb 2016.

Verghese, A. and Venkatesan, T. 2016. Biological control of insect pests of citrus-status and way forward. Presented at National Symposium on Sustainable Citrus Production: Way forward: Theme: Precision citriculture for food safety and Nutritional Security under changing climate held at ICAR-Central Citrus Research Institute, Nagpur during 27-19 Nov 2015uring 24th to 26th Feb 2016. pp. 185-188.

Kesavean Subaharan 2016. Chemo ecological approaches in pest management presented during science day at ICAR-NBAIR on 28.02.2016.

Kesavan Subaharan 2016. Exploiting trophic interactious in pest management. Presented at centre for Research in Medical Entomology, ICMR, Madurai on 10.2.2016.

Kesavan Subaharan 2015. Advances in chemo ecological methods for pest management. Invited lecture delivered in round table on scope of semiochemicals for borer pest managemet held at ICAR-NBAIR Bengaluru on 6.8.2015.

14. MEETINGS AND DECISIONS

XIX Research Advisory Committee Meeting

The 19th meeting of the Research Advisory Committee (RAC) of the National Bureau of Agricultural Insect Resources was held on 1st April, 2015, in the conference hall of the NBAIR. The following members of the RAC attended the meeting.

1.	Dr. C. A. Viraktamath	Chairman
2.	Dr. M. Venkat Rajam	Member
3.	Dr. Abraham Verghese	Member
4.	Dr. S. K. Jalali	Member Secretary

The research achievements and progress for the year 2014-15 were presented by the Heads of Divisions. **In addition, there were presentations on the achievements** of Institute Technology Management Unit (ITMU) and revenue generation through technologies, and on the invasive pests *Tuta absoluta* and *Frankliniella occidentalis*.

General recommendations

1. A core committee to be formed alert and plan methods of management of invasive insects.
2. In the case *Trichogramma*, apart from SEM studies of male genitalia, SEM studies on additional characters such as antennae, mesosoma, etc. to be explored for species characterisation.
3. Research attempts should be made to find a solution for long term permanent preservation of mites either through permanent slides in Canada balsam or through dry / wet preservation and in combination with SEM images.

Division-wise specific recommendations

Division of Insect Systematics

- Initiate biosystematics work on thrips especially in the light of report of *Frankliniella occidentalis*.

Division of Insect Ecology

- Work on *Tuta absoluta* needs to be intensified including the work on microbials like entomopathogenic fungi.

Division of Molecular Entomology

- Attempt to be made to standardize the procedure for characterization of termites from museum specimens of UAS.
- Some novel / potent Cry genes to be provided for transformation work.

XXIX Institute Research Council Meeting

The 29th Institute Research Council Meeting of the ICAR-NBAIR, Bengaluru was held on 27th, 28th and 29th April 2015, under the Chairmanship of Dr. Abraham Verghese, Director, NBAIR. The scientists presented achievements in their projects during 2014-15. The following points emerged after detailed discussions:

General recommendations

- Complete listing of agriculturally important insects may be taken up in CRP on Bioinformatics project.

- Molecular entomology scientists to focus on creating molecular phylogeny based on sequences obtained at family / genus level.
- Publications to be taken up seriously.
- Contractual worker employments to be optimized.
- Scientists to propose external funded projects.
- A mail to be sent to Dr. M. Nagesh to give RPP III for the project "Genetic diversity, biology and evaluation of EPN against cryptic pests" immediately.
- Dr. Ankita Gupta to keep updating the databases and type specimens developed by Dr. J. Poorani on a regular basis.
- All Heads to ensure that ATR of previous IRC and comments of 29th IRC included by the scientists in the respective RPP II before sending it to PME Cell. The RPP II should be submitted within one month, i.e., by 29th May 2015.
- The scientists where the projects are closed should submit the copy of RPP-III to PME Cell as well as must upload in PIMS and where ever commercialization is possible include RPP-IV also on or before 29.05.2015.

XXX Institute Research Council Meeting

The 30th Institute Research Council Meeting of the ICAR-NBAIR, Bengaluru was held on 4th November, 2015, under the Chairmanship of Dr. Abraham Verghese, Director, ICAR-NBAIR, Bengaluru. After the Director's introductory remarks two new projects were presented by Dr. Richa Varshney (Diversity and predator-prey interactions in predatory mirids and geocorids) and Ms. Rachana, R. R. (Taxonomy and diversity of Indian Thysanoptera with special reference to Terebrantia). The following general points emerged after detailed discussions:

General Comments:

- The house felt that DDG (CS) may be requested to visit NBAIR in near future.
- Include Dr. Richa Varshney as Co-PI in the Institute project titled "Documentation, Production and utilization of predatory anthocorid and mites" of Dr. Chandish R. Ballal.
- All the Heads should ensure maximum use of field/crop facilities at the farm.

XXXI Institute Research Council Meeting

The 31st Institute Research Council Meeting of the ICAR-NBAIR, Bengaluru was held on 24th November, 2015 at Attur Campus, Yelahanka, under the Chairmanship of Dr. Abraham Verghese, Director, ICAR-NBAIR, Bengaluru. The Director welcomed the scientists to the 31st IRC and he emphasized about DDG's visit. After his introductory remarks new projects were presented by Dr. G. Sivakumar (Characterization of viruses associated with Lepidoptera and Coleoptera) and Dr. S. Salini (Taxonomic studies on Pentatomidae (Hemiptera: Pentatomoidea) of India with special reference to Pentatominae). The following general comments were made:

General Comments:

- Include Dr. S. Salini as Co-PI in the Institute project titled "Molecular characterization and DNA barcoding of some agriculturally important insect pests" of Dr. S. K. Jalali.

15. PARTICIPATION OF SCIENTISTS IN MEETINGS

Abroad	
Dr Abraham Verghese Dr G. Sivakumar	III World Biodiversity Congress, Serbia, 26–30 October 2015.
Dr S.K. Jalali Dr T. Venkatesan	VI International Conference on Barcode of Life, University of Guelph, Canada, 17–21 August 2015.
India	
Dr Chandish R. Ballal	IV Congress on Insect Science: Entomology for Sustainable Agriculture, Punjab Agricultural University, Ludhiana, 16–17 April 2015.
	Round Table Series I on *Conogethese punctiferalis* and Allied Species, Indian Institute of Horticultural Research, Bengaluru, 22 May 2015.
	Sensitisation Workshop on 'Mera Gaon Mera Gaurav', University of Agricultural Sciences, Bengaluru, 3 October 2015.
	Review Meeting on Insect-Pests' Outbreak in Soybean and Cotton, NASC Complex, New Delhi, 27 October 2015.
	Brainstorming on IPM in Major Crops, NASC Complex, New Delhi, 16–17 February 2016.
	Institute Management Committee Meeting, National Bureau of Agriculturally Important Microorganisms, Mau, 9 March 2016.
Dr S.K. Jalali	Production and Popularization of Biological Control Agents to Enhance Pulse Production: An Eco-friendly Approach, Indian Institute of Pulses Research, Kanpur, 22 February 2016.
Dr T. Venkatesan	Annual Review Meeting of ORP on Management of Sucking Pests, Indian Institute of Horticultural Research, Bengaluru, 13 February 2016.
Dr P. Sreerama Kumar	VI International Conference: Plant, Pathogens and People — Challenges in Plant Pathology to Benefit Humankind, Indian Phytopathological Society, NASC Complex, New Delhi, 23–27 February 2016.
Dr K. Srinivasamurthy	Competency Development for Human Resource Development of Nodal Officers of ICAR, National Academy of Agricultural Research Management, Hyderabad, 10–12 February 2016.
	National Level Agriculture Fair-cum-Exhibition "Krishi Unnati", Indian Agricultural Research Institute, New Delhi, 19–21 March 2016.
Dr K. Subaharan	AICRP on Palms workshop, Central Coastal Agricultural Research Institute, Goa, 27 May 2015.
	Group meeting for Consortia Formation on Developing a Concept for Veterinary and Fisheries Pest Management, NBAIR Yelahanka Campus, 05 July 2015.
	Round Yable on Cashew Stem and Root Borer Management, Directorate of Cashew Research, Puttur, 19 August 2015.

Dr G. Sivakumar	III World Biodiversity Congress, Serbia, 26–30 October 2015.
	National Seminar on Mitigation of Chemical Residues in Farm Products – Strategies, Opportunities and Challenges, Gandhigram Rural Institute – Deemed University, Gandhigram, 18–19 February 2016.
Dr Jagadeesh Patil	International Symposium on Biodiversity, Agriculture, Environment and Forestry, Association for the Advancement of Biodiversity Science, Fortune Hotel Sullivan Court, Udhagamandalam, 11–12 December 2015.
Dr S. Salini	International Conference on Biodiversity and Evaluation: Perspectives and Paradigm Shifts, Department of Zoology, Sree Sankara College, Kalady, 2–3 December 2015.
	National Conference on Insect Diversity Studies: Where Does India Stand in the Global Map?, Central University of Kerala, Entomological Society of India, Professor T.C. Narendran Trust for Animal Taxonomy, Kasaragod, 29–31 March 2016.
Dr Chandish R. Ballal Dr S.K. Jalali Dr B. Ramanujam	XXV Biocontrol Workers' Group Meeting, Tamil Nadu Agricultural University, Coimbatore, 2–3 June 2015.
Dr T. Venkatesan Dr R. Rangeshwaran Dr M. Pratheepa	Steering Committee Meeting of Network Project on Agricultural Bioinformatics and Computational Biology, CABin, Indian Agricultural Statistics Research Institute, New Delhi, 24–26 February 2016.
Dr P. Sreerama Kumar Dr K. Srinivasamurthy Dr R. Rangeshwaran Dr K. Subaharan Dr Ankita Gupta	Workshop on Human–Wildlife Conflict in Agro-pastoral Context, National Institute of Advanced Studies, National Agricultural Science Fund, NBAIR, Bengaluru, 11–12 December 2015.
Dr Chandish R. Ballal Dr Deepa Bhagat	Nanotechnology in Agriculture: A Focus on Insects and Insect Resources, NBAIR, Bengaluru, 19 March 2016.
All scientists	WTO Training Workshop on Important International Agreements and Treaties for Exploitation of Biological Resources, Visvesvaraya Trade Promotion Centre (Government of Karnataka), NBAIR, Bengaluru, 05 August 2015.
All scientists	ICAR–NBAIR–Industry Interface Meet, Institute Technology Management Unit, NBAIR, Bengaluru, 11 March 2016.

16. TRAININGS CONDUCTED

S. No	Trainees from	Particulars of training	Date & duration	Co-ordinator/ resource person	Number of participants
1	SRFs – Outreach project on management of sucking pests NRC on Pomegranate, Solapur	Mass production of Biocontrol agents and isolation techniques	15.4.2015 to 20.4.2015	Dr. Chandish R. Ballal Dr. T. Venkatesan Dr. G. Sivakumar Dr. A.N. Shylesha Dr. B. Ramanujam	2
2	Mr. Sridhar Bioseed Research India (BRI)-ICRISAT Insect rearing Lab Patancheru Medak Dist (Telangana)	Mass rearing of Insect Pests	25-5-2015 to 26-5-2015	Dr. Chandish R. Ballal/ Dr. Y. Lalitha	2
3	Krishi Vigyan Kendra Ganagvati 583 227 University of Agricultural Sciences, Raichur (Assistants of Mr.Badari Prasad, SMS –Ag. Ent.,	Mass multiplication of predator *Cryptolaemus montrouzieri*	27-5-2015 to 28-5-2015	Dr. Chandish r. Ballal/ Dr. Y. Lalitha	2
4	Krishi Vigyan Kendra Ganagvati 583 227 University of Agricultural Sciences, Raichur (Assistants of Mr.Badari Prasad, SMS –Ag. Ent).,	Mass multiplication of predator *Cryptolaemus montrouzieri*	27-5-2015 to 28-5-2015	Dr. Chandish R. Ballal Dr. Sunil joshi Dr. Y. Lalitha	2
5	Smt. L.Beenakumari, Smt. B.Smitha and Sri. Mathew Abraham Extension officers from Kerala Centre for Pest Management, Moncombu Alapuzha- 688 503, Kerala	Identification of insect pests, preservation, archiving, IPM techniques, EPN etc.,	16.7.2015 to 18.7.2015	Dr. Prashant Mohanraj Dr Ankita, Dr. Chandish Ballal, Dr. Sunil Joshi Dr Ramanujam, Dr. Rangeshwaran Dr. N. Bakthavatsalam	3

6	Ms. Apoorva, V. Department of Studies and Research in Microbiology Mangalore University PG centre Chikka Aluvara Kodugu - 57123	Training on Insect Pathology	10-6-2015 to 9.7.2015	Dr. B. Ramanujam	1
7	Dr. B.K.Shivanna Professor & University Head, Zonal Agricultural & Horticultural Research Station Savalnga Road Navile, Shimoga-577 225	Training on EPN multiplication	18-6-2015 to 19-6-2015	Dr. Jagadeesh Patil	1
9	Dr. P.Giribabu Scientist (Nematology) NRC on Banana Trichy	Training on EPN molecular characterisation and diagnostics	1-9-2015 to 5.9.2015	Dr. Jagadeesh Patil	1
10	Dr. Lavanya Scientist NIPHM Hyderabad	Training on mass production of certain parasitoids	28-9-2015 to 29-9-2015	Dr Chandish R. Ballal Dr K.Srinivasa Murthy	1
11	Ms. A.Rama Devi Mr. Nagalaton Kasar Ms.Preethi Ghosh PG students from Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia 741 252 (WB)	Training on identification of fruit flies and mango hoppers and their Biology	1-12-2015 to 4-12-2015	Dr. David Dr. Abraham Verghese	3
12	Horticulture officers/ Extension officers Directorate of Horticulture Karnataka	Training programme on Mass production of Biocontrol agents-for management of insect pests of crops	19-20th January 2016	Dr Chandish Ballal	26

13	Technical staff from RARS, Anakapalle (AP) under AICRP-BC	Training on mass production of *Trichogramma* and Entomopathogenic fungi for sugarcane pests	21-23rd March 2016	Dr Chandish Ballal Dr. B.Ramanujam	2
14	Extension personnel, farmers and students	Monitoring and management of tomato pin worm, *Tuta absoluta*	11.8.2015	Kesavan Subaharan, M. Mohan N. Bakthavatsalam	100

ARS Trainees (2015-16) – Subject Matter Training

S. No	Trainee from	Co-ordinator/ Resource person	Date & Duration
1	Dr. Mallikarjun Scientist , NRCP	Dr. Chandish R. Ballal	21.5.2015 to 10.6.2015
2	Dr. Bandi Sanjay, IIPR, Kanpur	Dr.Chandish R. Ballal	21.5.2015 to 10.6.2015
3	Mr.Samadhan Bagul NBAIM, Mau	Dr. B. Ramanujam	25.5.2015 to 24.7.2015
4	Mr.Samadhan Bagul NBAIM, Mau	Dr. G. Sivakumar	25.7.2015 to 24.8.2015
5	Mr. B. Naveen kumar Patil, NRRI, Cuttack	Dr. S.K. Jalali, Dr Chandish R. Ballal, Dr N. Bakthavatsalam, Dr T. Venkatesan and Dr. R. Gandhi Gracy	01.09.2015 to 30.11.2015

17. DISTINGUISHED VISITORS

1. Dr. C.A. Viraktamath, Chairman, RAC of this Bureau and former Professor, Division of Entomology, UAS, Bengaluru visited NBAIR on1st April, 2015.
2. Dr. M. Venkatarajam, Member RAC of this Bureau visted NBAIR on 1st April, 2015.
3. Honourable Union Agriculture Minister, Shri Radha Mohan Singh visited NBAIR on 2nd April, 2015.
4. DR. Raghavendra Bhat, Director, NIANP, Bengaluru visited on 2nd April, 2015.
5. Dr. H. Rahman,Director, PD-ADMAS, Bengaluru visited on 2nd April, 2015.
6. Dr. Venkataraman, Joint Director, IVRI, Bengaluru visited on 2nd April, 2015.
7. Shri. Sunil Kumar Singh, Additional Secretary & Financial Advisor (DARE/ ICAR) visited NBAIR on 1st October, 2015.
8. Mr. E.P Suresh Kumar, Deputy Superintendent of Police, CBI Bengaluru visited NBAIR on 31st October, 2015
8. Dr. Subba Rao, veteran entomologist visited NBAIR, on 10th November, 2015
10. Dr. Jeet Singh Sandhu, Deputy Director General (CS), ICAR, New Delhi visited NBAIR on 19/11/2015.
11. Dr. S. Ayyappan, DG (ICAR) and Secretary (DARE) visited NBAIR on 11-12 December, 2015.
12. Dr. Baldev Raj, Director, NIAS, Begaluru visited NBAIR on 11-12 December, 2015.
13. Dr. V.S. Ramamurthy, Former Secretary, Department of Science and Technology visited NBAIR on 11-12 December, 2015.

13 Dr. P.K. Agrawal, Director NASF, New Delhi visited NBAIR on 11-12 December, 2015.

14. Dr. S. Ayyappan, Former DG (ICAR) and Secretary (DARE) visited NBAIR on 25th February, 2016.

18. MERA GAON MERA GAURAV

Six teams of scientists / Technical officers have adopted a total of 30 villages in Karnataka and the bordering State of Tamil Nadu. Awareness has been created amongst farmers on eco-friendly management of pests. Based on the needs of farmers the following inputs have also been provided: Tricho-cards have been provided to farmers of Modur village of Kunigal taluk for management of lepidopteran pests infesting paddy, brinjal and sugarcane; to Mandya for management of paddy borers; to mulberry farmers of Kanakapura for management of leaf folder; *Goniozus* for management of black-headed caterpillar to Modur; *Zygogramma* for management of *Parthenium* to Modur , Hiriyur and Tumkur; *Chrysoperla* for management of sucking pests in rural Bengaluru; *Cryptolaemus* for management of mealybugs in Gulbarga; Coorg, rural Bangalore, Madanapalli (AP) and *Cryptolaemus* and *Chrysoperla* to farmers in Chennai. Novel insecticidal WP formulations of *Heterorhabditis indica* were distributed to sugarcane farmers of Mandya for management of white grubs and other soil insects. Technology on trapping of adult males of the tomato pinworm *Tuta absoluta* was demonstrated to the tomato farmers of Kolar and Krishnagiri. Mosaic virus was observed as a major problem on cassava in Krishnagiri and on 2nd December 2015, a Kisan Goshti was arranged in Krishnagiri, wherein the mosaic virus resistant clones of Cassava supplied by ICAR-CTCRI, Thiruvananthapuram were distributed to farmers. Field days were conducted on 6th of October and 29th of December 2015 on management of tomato pinworm and IPM in vegetables in three villages in Krishnagiri. On 21st December 2015, demonstrations were arranged on the utility of parasitoids for management of papaya mealybug and Tricho cards for management of lepidopteran pests in different crops in Neralaghatta and Gandarajupura of rural Bangalore, Karnataka. Besides, mobile based advisories were provided to farmers, literature (in local language) on pest management was provided and advisories in local language on management of various local pests have been put up on NBAIR website (http://www.nbair.res.in/mgmg.php).

Interaction with farmers at a demonstration on the use of WP formulation of the entomopathogenic nematode, *H. indica*

Distribution of WP formulation of *H.indica*

19. PERSONNEL

S. No.	Name	Designation
	Scientists	
1.	Dr Abraham Verghese	Director
2.	Dr Prashanth Mohanraj	Principal Scientist (Agri. Ento.) & Head, Division of Insect Systematics
3.	Dr Chandish R. Ballal	Principal Scientist (Agri. Ento.) & Head, Division of Insect Ecology
4.	Dr S. K. Jalali	Principal Scientist (Agri. Ento.) & Head, Division of Molecular Entomology
5.	Dr N. Bakthavatsalam	Principal Scientist (Agri. Ento.)
6.	Dr B. Ramanujam	Principal Scientist (Plant Pathology)
7.	Dr K. Veenakumari	Principal Scientist (Agri. Ento.)
8.	Dr A. N. Shylesha	Principal Scientist (Agri. Ento.)
9.	Dr T. Venkatesan	Principal Scientist (Agri. Ento.)
10.	Dr T. M. Shivalingaswamy	Principal Scientist (Agri. Ento.)
11.	Dr P. Sreerama Kumar	Principal Scientist (Plant Pathology)
12.	Dr K. Srinivasa Murthy	Principal Scientist (Agri. Ento.)
13.	Dr Sunil Joshi	Principal Scientist (Agri. Ento.)
14.	Dr R. Rangeshwaran	Principal Scientist (Agri. Microbiology)
15.	Dr Kesavan Subaharan	Principal Scientist (Entomology)
16.	Dr G. Sivakumar	Senior Scientist (Microbiology)
17.	Dr Mahesh Yandigeri	Senior Scientist (Microbiology)
18	Dr M. Mohan	Senior Scientist (Agri. Ento.)
19.	Dr M. Pratheepa	Senior Scientist (Computer Application)
20.	Dr Deepa Bhagat	Senior Scientist (Organic Chemistry)
21.	Dr Jagadeesh Patil	Scientist (Nematology)
22.	Dr R. Gandhi Gracy	Scientist (Agri. Ento.)
23.	Mr K. J. David	Scientist (Agri. Ento.)
24.	Dr S. Salini	Scientist (Agri. Ento.)
25.	Dr Ankita Gupta	Scientist (Agri. Ento.)
26.	Dr Richa Varshney	Scientist (Agri. Ento.)
27.	Ms R. R. Rachana,	Scientist (Agri. Ento.)

28.	Mr Navik Omprakash Samodhi	Scientist (Agri. Ento.)
29.	Ms R. S. Ramya	Scientist (Agri. Ento.)
30	Ms Daliyamol	Scientist (Plant Pathology)

	Technical Officers / Assistants	
31.	Ms Shashikala S. Kadam	Chief Technical Officer
32.	Dr Y. Lalitha	Assistant Chief Technical Officer
33.	Mr B. K. Chaubey	Assistant Chief Technical Officer
34.	Mr Satandra Kumar	Assistant Chief Technical Officer
35.	Mr P. K. Sonkusare	Senior Technical Officer (T6)
36.	Ms B. L. Lakshmi	Senior Technical Officer (T6)
37.	Ms L. Lakshmi	Senior Technical Officer (T6)
38.	Mr H. Jayaram	Senior Technical Officer (T6)
39.	Ms S. K. Rajeshwari	Technical Officer (T5)
40.	Mr P. Raveendran	Technical Officer (T5)
41	Dr A. Raghavendra	Technical Assistant (Laboratory Technician)
42.	Mr Umesh Kumar Sanjeev	Technical Assistant (Laboratory Technician)
43.	Mr M. Chandrappa	Technical Assistant (Driver)
44.	Mr R. Narayanappa	Technical Assistant (Generator Operator)
45.	Mr P. Madanathan	Technical Assistant (Driver)
	Administrative Staff	
46.	Ms S. Rama	Senior Administrative Officer
47.	Mr T. A. Vishwanath	Finance & Accounts Officer
48.	Mr K. N. Visweswara	Private Secretary to Director
49.	Mr Ajit Desai	Assistant Administrative Officer
50.	Ms S. Kaveriamma	Personnel Assistant
51.	Mr M. Eswar Reddy	Assistant
52.	Ms Dipanwita Deb	Assistant
53.	Ms Uma	Junior Stenographer
54.	Ms Nazia Anjum	Upper Divisional Clerk
55.	Ms P. Anitha	Lower Divisional Clerk
	Supporting Staff	
56.	Mr Ramakrishnaiah	Skilled supporting staff
57.	Mr V. Anjenappa	Skilled supporting staff
58.	Mr Pamulu Nagaiah	Skilled supporting staff

20. EXHIBITIONS

The NBAIR participated in the following exhibition/melas to showcase research technologies developed at the institute.

- Agriculture Exhibition from 20th to 21stAugust, 2015 at Motihari, Bihar
- INSECT WORLD exhibition at Cubbon park on 27th September, 2015
- KrishiMela at GKVK, Bangalore from 19th to 22nd November, 2015
- 'JAI KISAN JAI VIGYAN' exhibition at Cubbon park on 27th December, 2015
- Agriculture Exhibition at IIPR, Kanpur on 13/3/2016
- KrishiUnnatiMelaat IARI, New Delhi from 19th to 21st March, 2016

Agriculture Exhibition at Motihari, Bihar from 20th to 21st August, 2015

KrishiUnnatiMela at IARI, New Delhi from 19th to 21st March, 2016

INSECT WORLD exhibition at Cubbon park on 27th September, 2015

JAI KISAN JAI VIGYAN' exhibition at Cubbon park on 27th December, 2015

21. RESULTS FRAMEWORK DOCUMENT (RFD) for 2014-2015

Sl No	Mandatory Objectives	Weight (%)	Actions	Success Indicators	Unit	Weight	Target/ Criteria/ Value					Achievements	Perfomance Raw Weighted score		Percent achievements agaisnt target values of 90 % column	Reasons for shortfall or excessive achievement , if applicable
							Excellent	Very Good	Good	Fair	Poor					
							100%	90%	80%	70%	60%					
1	Augmentation of genetic resources of agriculturally important insects*.	40	Collection and characterization of agriculturally important insects	Insect collections made	Num	15	972	810	648	486	324	**1132**	100	15	**139.7**	Efforts made beyond specialisation to augment collection
				Insect specimens identified	Num	15	11880	9900	7920	5940	3960	10320	100	15	**104.24**	
				GeneBank accessions, gene sequences & Barcodes developed	Num	10	648	540	432	324	216	**552**	100	10	**102.22**	
2	Conservation, evaluation, utilization and supply of agriculturally important insects.	30	Ex situ conservation	Insect species conserved	Num	15	508	423	338	253	168	**443**	100	15	**104.35**	
			Evaluation of bioagents	Evaluation experiments conducted*	Num	5	32 #	27	22	17	12	**28.0**	100	5	**103.7**	Stepped due to greater awareness in control of borer complex and root grubs, woolly aphid etc.,
			Supply	Insect species supplied	Num	10	551	459	389	275	783	**782**	100	10	**170.39**	Demand driven . Increasingly large numbers were requested

Sl No	Mandatory Objectives	Weight (%)	Actions	Success Indicators	Unit	Weight	Target/ Criteria/ Value					Achievements	Perfomance Raw Weighted score		Percent achievements agaisnt target values of 90 % column	Reasons for shortfall or excessive achievement , if applicable
							Excellent	Very Good	Good	Fair	Poor					
							100%	90%	80%	70%	60%					
3	Capacity building and dissemination of technology	**10**	Impartation of training on insects & dissemination of technology	Human resource development	Num	10	26	22	18	14	78	**23**	100	10	**104.5**	
*	Publication/ Documentation	5	Publication of research articles in the journals having NAAS rating of 6.0 and above	Research articles published	Num	3	30	27	24	21	18	**31**	100	3	**114.85**	NIL
			Timely publication of institute Annual Report (2013-14)	Annual Report Published	Date	2	30.06. 2014	2.7.14	4.7.14	4.7.14	9.7.14	**16.6. 2014**	100	2	**100**	NIL
*	Fiscal resource management	2	Utilisation of released plan fund	Plan fund utilized	%	2	98	96	94	92	90	**96**	97	1.94	**100**	NIL
*	Efficient functioning of RFD	3	Timely Submission of draft RFD (2014-15) for approval	On- time submission	Date	2	May 15 2014	May 16 2014	May 19 2014	May 20 2014	May 21 2014	May 15 2014	100	2	**100**	NIL
			Timely submission of RFD results (2014-15)	On -time submission	Date	1	May 1 2014	May 2 2014	May 3 2014	May 6 2014	May 7 2014	**May 1 2014**	100	1	**100**	NIL

Sl No	Mandatory Objectives	Weight (%)	Actions	Success Indicators	Unit	Weight	Target/ Criteria/ Value					Achievements	Perfomance Raw Weighted score		Percent achievements agaisnt target values of 90 % column	Reasons for shortfall or excessive achievement , if applicable
							Excellent	Very Good	Good	Fair	Poor					
							100%	90%	80%	70%	60%					
*	Enhanced Transparency/ Improved service delivery of Ministry / Department	3	Rating from independent Audit of implementation of Citizens Charter (CCC)	Degree of implementation of commitments in CCC	%	2	100	95	90	85	80	**100**	100	2	**100**	NIL
			Independent Audit of implementation of Grievence Redress Management (GRM) system	Degree of success in implementing GRM	%	1	100	95	90	85	80	**100**	100	1	**100**	NIL
	Administrative Reforms	7	Update departmental strategy to align with revised priorities	Date	%	2	Nov 1 2014	Nov 2 2014	Nov 3 2014	Nov 4 2014	Nov 5 2014	**Nov 2 2014**	100	2	**100**	NIL
			Implement agreed milestones of approved Mitigating strategies for reduction of potential risk of corruption (MSC)	% implementation	%	1	100	90	80	70	60	**100**	100	1	**100**	NIL
			Implement agreed milestones for implementation of ISO9001	% implementation	%	2	100	95	90	85	80	**95**	100	2.0	**100**	NIL
			Implementation agreed milestones of approved innovation action plan (IAPs)	% implementation	%	2	100	90	80	70	60	**100**	100	2	**100**	NIL

*Percent achievable Targets = Consolidated Achievements / Targets under 90% column X 100

Total Composite Score: 99.94

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

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