DIRECTOR'S REPORT

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National Bureau of Agriculturally Important Insects
Bangalore 560 024

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Date: 04.06.2014 Abraham Verghese
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1. Introduction

The National Bureau of Agriculturally Important Insects (NBAII) which hosts the Project Coordinator's Cell of AICRP on Biological Control of Crop Pests as its integral part and supports it with basic research. Integrated pest management (IPM) in the days to come will be more bioagent dependent. Insecticide use is on steady decline, while interest in biocontrol and organic IPM is on the rise. NBAII and AICRP on Biocontrol are geared to address this shift. The NBAII with its revised mandate extending to insect biodiversity, systematics, ecology, molecular entomology and pollinators, with core competence in biological control and systematics gives basic and strategic leadership support to the AICRP programme on biological control of crop pests.

In the past three years, diversity of insects, spiders, nematodes, plant disease antagonistic and entomopathogenic organisms have been given importance and collection and cataloguing have been carried out covering vast geographical areas. Fresh impetus is now put into insect taxonomy and insect endosymbionts. In the last workshop a fresh insight into the technical programme for the biennial 2013-14 & 2014-15 was deliberated. Some of the less relevant programmes were dropped and new experiments were formulated with the change in agricultural pest scenario. As in the previous technical programme, the emphasis on monitoring pests of invasives, management of polyhouse and storage pests were continued. Our focus on classical biological control remained and the work on the management of exotic pests such as the mealybugs of papaya continued. Low level of papaya mealybug incidence and the recovery of the released parasitoid *Acerophagus* from the papaya mealybug infested fields shows the potential of classical biological control. Similarly the incedence of sugarcane woolly aphid was very low due to abundance of natural enemy activity. Large scale demonstrations in farmers' fields were made towards facilitating the adoption of non-chemical methods of plant protection by farmers. The results from the various experiments conducted at centres across the country during the year 2013-14 are presented below. The successful large scale demonstrations in different centres showed the potential of non-chemical management of crop pests.

2. Mandate of 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.

3. Objectives

1. Development of effective biocontrol agents for use in biological suppression of crop pests and diseases.
2. Evaluation of various methods of biological control in multi-location field trials.
3. Development of biointensive integrated pest management strategies for cotton, rice, sugarcane, pulses, oilseeds, potato, coconut and a few selected fruits and vegetable crops.
4. Demonstration of biocontrol agents and biopesticides as a component of IPM in farmers' fields

4. Setup

With a view to fulfill the mandate effectively and efficiently, the Bureau is functioning in close coordination with the following State Agricultural Universities, ICAR Institutes.

State Agricultural University–based centers

i.	Acharya N. G. Ranga Agricultural University	Hyderabad
ii.	Anand Agricultural University	Anand
iii.	Assam Agricultural University	Jorhat
iv.	Dr. Y.S. Parmar University of Horticulture and Forestry	Solan
v.	Gobind Ballabh Pant University of Agriculture and Technology	Pantnagar
vi.	Kerala Agricultural University	Thrissur
vii.	Mahatma Phule Krishi Vidyapeeth	Pune
viii.	Punjab Agricultural University	Ludhiana
ix.	Sher-e-Kashmir University of Agricultural Science & Technology	Srinagar
x.	Tamil Nadu Agricultural University	Coimbatore
xi.	Central Agricultural University	Pasighat
xii.	Maharana Pratap University of Agriculture & Technology	Udaipur
xiii.	Orissa University of Agriculture & Technology	Bhubaneshwar
xiv.	University of Agricultural science (Raichur) (Vol. Centre)	Raichur

ICAR Institute–based centres

National Center for Integrated Pest Management	New Delhi
Central Institute of Subtropical Horticulture	Lucknow
Central Plantation Crops Research Institute	Kayangulam
Central Tobacco Research Institute	Rajahmundry
Directorate of Rice Research	Hyderabad
Directorate of Seed Research	Mau
Directorate of Sorghum Research	Hyderabad
Directorate of Soybean Research	Indore
Directorate of Weed Science Research	Jabalpur
Indian Agricultural Research Institute	New Delhi
Indian Institute of Horticultural Research	Bangalore
Indian Institute of Sugarcane Research	Lucknow
Indian Institute of Vegetable research	Varanasi

5. Brief summary of research achievements

5.1. Basic research work at National Bureau of Agriculturally Important Insects

National Bureau of Agriculturally Important Insects (NBAII) backs up the AICRP on Biological control of crop pests with basic and applied research. The salient achievements of NBAII during the last year are given below.

5.1.2. Taxonomic studies on parasites and predators of insect pests

Anagyrus amnestos Rameshkumar, Noyes & Poorani (Hymenoptera: Encyrtidae) is the only parasitoid effective against the Madeira mealybug (*Phenacoccus madeirensis* Green) with high degree of host specificity. It occurs in and around Bangalore and Mudigere in Karnataka. Even at low densities of mealybug, *A. amnestos* is active, which is a promising trait. A new species of *Calvia* Mulsant (Coccinellidae) was described from north-east region. *Platynaspis flavoguttatus* (Gorham), a rare species of Coccinellidae from Karnataka was redescribed and the male genitalia were illustrated for the first time. *Aspidimerus birmanicus* (Gorham) (Coleoptera: Coccinellidae), a species hitherto known from Myanmar, Thailand and China, was recorded from Meghalaya, which constitutes a new distribution record for India. Three Chinese species, *Sumnius yunnanensis* Mader (Meghalaya), *Afissula craspedotricha* Yu (Sikkim) and *Cryptogonus hainanensis* Pang & Mao (Tripura), were recorded from India for the first time.

Described five new Indian species of parasitic wasps belonging to the subfamily Microgastrinae (Braconidae): *Buluka horni*, *Dolichogenidea cinnarae*, *Glyptapanteles clanisae*, *Glyptapanteles trilochae* and *Parapanteles echeriae*. Five species of parasitic wasps associated with hesperiids from peninsular India were documented along with the description of a new species of gregarious endoparasitoid, *Dolichogenidea cinnarae*, (Hymenoptera: Braconidae) parasitic on caterpillar of *Borbo cinnara* (Wallace) (Lepidoptera: Hesperiidae). The gregarious larval parasitoid, *Cotesia erionotae* (Wilkinson) (Braconidae) and solitary pupal parasitoid *Charops plautus* Gupta & Maheshwary (Ichneumonidae) were reared from the host *Udaspes folus* (Cramer) on the host plant, *Hedychium coronarium*. *Udaspes folus* is the new host record for the parasitic wasp genus *Charop*s. An encyrtid wasp *Ooencyrtus papilionis* Ashmead was reared from the eggs of *Bibasis jaina* (Moore) on the host pant *Hiptage benghalensis* (L.). This is the first documentation of a parasitic wasp from the genus *Bibasis*. *Leptobatopsis indica* (Cameron) (Ichneumonidae), often associated with *Parnara guttatus* (Bremer & Grey), was recorded from the Andaman Islands.

A new species of gregarious endoparasitoid *Parapanteles echeriae* Gupta, Pereira & Churi, 2013 reared from *Abisara echeria* Stoll (Lepidoptera: Riodinidae) on host plant *Embelia* sp. (Myrsinaceae) collected from Mumbai was described. This is the first record of a parasitic wasp associated with the plum judy butterfly, *Abisara echeria*.

Glyptapanteles clanisae, a gregarious endoparasitoid was reared from the caterpillar of *Clanis phalaris* Cramer (Lepidoptera: Sphingidae) on the host plant

Pongamia pinnata (L.) along with a hyperparasitoid, *Eurytoma* sp. (Eurytomidae). *Glyptapanteles trilochae* was reared from parasitized caterpillar of *Trilocha varians* (Walker) (Lepidoptera: Bombycidae) on the host plant *Ficus racemosa* L. along with a hyperparasitoid, *Paraphylax* sp. (Ichneumonidae: Cryptinae). *Buluka horni*, was collected from solitary cocoons of a caterpillar feeding on *Mangifera indica* L. leaves.

Surveys were conducted in three states *viz*., Meghalaya (Umiam and Umran), Odisha (Bhubhaneshwar, Jaraka and Cuttack) and different parts of Karnataka for collection of insects belong to Platygastroidea. A total of 1500 parasitoids were collected, curated and preserved for future studies. So far 52 genera under five subfamilies were recorded from India and an additional five genera were added now, raising the total to 57 genera. The genus *Phanuromyia* (Telenominae) is reported for the first time from India. The genus *Amitus*, parasitoid of whiteflies, was recorded only from Bihar, now it is reported for the first time from South India and Sikkim. The genus *Nixonia* which was recorded only from Uttaranchal was reported for the first time from south India.So far only three genera viz., *Telenomus, Baryconus* and *Platyscelio* were reported from the state of Odisha. Recent surveys conducted in Bhubhaneshwar and Cuttack revealed the presence of thirty two more genera under five subfamilies. Nine new species of Platygastroids *viz*. *Mantibaria kerouaci* (Scelioninae), *Allotropa gundlupetensis* (collected from Madeira mealybug, *Phenacoccus madeirensis*), *Allotropa vanajae, Allotropa nigra, Amblyaspis fabrei, Amblyaspis panhalensis, Amblyaspis charvakae, Amblyaspis ashmeadi* and *Amblyaspis tippusultani* were described.

Insect surveys were conducted in the South (Tamil Nadu: Ooty, Kotagiri; Karnataka: Tumkur, Chikkaballapur, Chintamani, Mandya, Maddur, Hessarghatta, Attur), East (Odisha: Bhubaneswar, Cuttack) and north-east (Meghalaya: Umiam, Umran) of India for the collection of Trichogrammatidae. Ten genera of Trichogrammatidae were collected. Of these, *Lathromeroidea* is a new record from south India while *Paratrichogramma* is a new record from Karnataka. *Trichogrammatoidea nana* collected from Meghalaya is the first record of the genus from north-east India. *Trichogramma cuttackensis* was collected from Bhubaneshwar which though contiguous is the only place that it is known from outside its type locality.

A total of 1630 specimens of aphids, coccids, diaspidiids and pseudococcids collected were identified at NBAII and 390 species of aphids and coccids were identified for SAUs, ICAR institutes and private organizations. *Metaceronema japonica* (Maskell), *Stictacanthus azadirachtae* (Green), *Shivaphis celti* Das and *Odonaspis greenii* Cockerell were recorded for the first time from Karnataka. *Planococcus bendovi* Williams, *Ctenochiton olivaceum* Green, *Macrosiphum euphorbiae* (Thomas) and *Milviscutulus mangiferae* (Green), were recorded for the first time from South India. *Marsipococcus iceryoides* (Green), *Ceronema fryeri* Green, *Maacoccus piperis* (Green), *Trijuba oculata* De Lotto, *Protopulvinaria longivalvata* Green, *Paralecanium ovatum* Morrison, *Paralecanium vacuum* Morrison, *Paralecanium mancum* (Green), *Eriococcus coccineus*Cockerell, *Duplaspidiotus claviger* (Cockerell), *Exallomochlus philippinensis* Williams and *Astegopteryx pallida* van der Goot were recorded for the first time from India. Twenty nine species of parasitoids were recorded from 43 species of

coccids out of these one parasitoid species was a new record from India, eight were new records from Karnataka and four were new host associations.

DNA barcoding of insect pests

During the period more than 500 insect species belonging to different groups were subjected to barcoding using primers specific to cytochrome oxidase (CO1). These insect belonged to 162 species under nine orders *viz*., Hemiptera, Diptera, Lepidoptera, Coleoptera, Hymenoptera, Araneae, Ixodida, Mantodea and Isoptera and 63 families. All sequences agreed with Folmer's region, >550 bp with complete species information for 46 species for which Barcodes were generated. The percentage wise characterization of 162 species was Hemiptera (29.6%), Lepidoptera (22.2%), Diptera (16.7%), Coleoptera (12.3%), Hymenoptera (11.7%), Araneae (2.5%), Ixodida (1.9%), Mantodea (1.9%) and Isoptera (1.2%).

DNA barcoding of parasitoids and predators

Using cytochrome oxidase 1 region (CO1), the DNA barcoding of the following parasitoids namely *Aprostocetus gala* (KF817576), *Tetrastichus schoenobii* (KJ 627790), *Chelonus blackburnii* (KF 365461), *Bracon hebetor* (KJ 627789), *Quadrastichus mendeli* (KF879806), *Aprostocetus gala* (KF958278), *Sceliocerdo viatrix* (KF 938928), *Pseudleptomastix mexicana* (KF365460), *Leptomastix nigrocincta* (KJ 489424); pollinators namely *Apis florea* (KF 817578), *Apis cerana indica (*KF 861941), *Megachile anthracina* (KF 861940), *Apis dorsata* (KJ 513470); predators namely *Amphiareus constrictus* (KF 817577), *Xylocoris flavipes* (KF 365462), *Blaptostethus pallescens* (KF365463), *Buchananiella indica* (KF 383326), *Cardiastethus affinis* (KF 383326), *Scymnus nubilus* (KF861939), *Isoliaindica* (KJ489423), *Cheilomenes sexmaculata* (KF998579) and weed killer *Teleonemia scrupulosa* (KF 817579) was done.

Diversity and predator-prey interactions of predatory anthocorids and mites

The commonly recorded anthocorids were *Cardiastethus exiguus* Poppius, *Blaptostethus pallescens* Poppius, *Cardiastethus affinis* Poppius and *Orius tantillus* (Motschulsky). Additionally, *Buchananiella crassicornis* Carayon on *Lagestromia, Orius shyamavarna* Muraleedharan and Ananthakrishnan on *Butea monosperma, Physopleurella* sp. (could be *P. armata*) from flour mill, *Buchananiella indica* Muraleedharan on Crossandra, *Amphiareus constrictus* (Stal.) on sugarcane, *Orius maxidentex* Ghauri on *Wedelia* and *Anthocoris muraleedharani* Yamada on Ficus were collected. *B. indica*, *A. muraleedharani* and *A. constrictus* were amenable to rearing on alternate laboratory hosts. Two new species of *Orius* (*Orius* sp. nov. and *Orius* sp. nr. *O. pallidicornis*) were collected from *Hibiscus* and *Butea* respectively. *Orius amnesius* Ghauri collected on rose and *Buchananiella pacificus* Herring are first records for India. For the first time, *A. constrictus,* recorded earlier as a predator of hoppers (BPH and GLH) on rice in Mandya could be reared continuously on laboratory host eggs and its biology was studied.

Insecticide resistance / insect endosymbionts

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

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

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

Studies on introduced natural enemies of exotic insect pests and weeds

Survey for invasive insects in south India revealed the occurrence of invasive Jack Beardsley mealybug, *Pseudococcus jackbeardsleyi* in Tamil Nadu, and Karnataka. Papaya, custard apple, purple martin (*Streptocarpus* sp.), *Cordyline terminalis*, Jasmine, tapioca, chrysanthemum, Indian spinach, parthenium and chrysanthemum were found to horbour this mealybug. Resource utilization by indigenous and the introduced parasitoids of eucalyptus gall wasp was found to be mutually exclusive. *Quadrastichus mendeli* preferred young larvae of *Leptocybe invasa* which were within the green galls, whereas the local parasitoid, *Megastigmus viggianii* selected larvae within the older pink and brown galls.

Erythrina gall wasp, *Quadrastichus erythrinae* was severe in Mandya and Chamarajnagar districts in *Erythrina indica*. *Aprostocetus gala* was found to be the major parasitoid of *Q. erythrinae* and 25-46% parasitization was observed. It was clearly established that *Aprostocetus gala* is not a gall former in *Erythrina* plants but a very good parasitoid of *Q. erythrinae. A. gala* was unable to parasitize *L. invasa* both in net house and field release studies.

Choromalaena weed biocontrol agent, *Cecidochares connexa* has established in the release sites and 9-12 galls were observed per 5 minutes search in 450 m around the released spot. New releases were made in Jharkhand in collaboration with Directorate of Weed Science Research, Jabalpur.

Studies on entomopathogenic nematodes (EPN)

Genomics and transcriptomics on genes and pathways related to virulence and pathogenesis of four Indian strains of bacterial symbionts associated with EPN were investigated. Demonstrated whitegrubs control in redgram and fodder grass using EPN. Licensed and transferred two technologies on production, down-stream processing and development of WP formulations of EPN and *Pochonia chlamydosporia* to Allwin Industries, Indore. EPN strains of NBAII including *Heterorhabditis indica*, *Steinernema carpocapsae, S. abhasi* were screened against *Lepidiota mansueta* in groundnut and vegetables in Majouli Island. Evaluated EPN formulations against white grubs, cutworms and termites through AINP centre at Jorhat, Assam.

A total of 172 soil samples were collected from mulberry fields of Pampore, Tral, Bandipora and Yor Khusi Pora villages of Jammu and Kashmir, forest vegetation of Monughat (Dhalali, Tripura) and coffee, arecanut, sugarcane, vegetable fields of UAS, Dharwad, Mugad, Narendra, Gamanagatti, Garag villages of Karnataka for the isolation of EPN. One positive sample was intercepted with *Steinernema* sp. when analyzed by soil baiting technique using wax moth, *Galleria mellonella.*

***Bt cry* gene diversity in hot and humid regions**

Cry2A CDS (2.2 kb) obtained from eight isolates were cloned in *E. coli* for further studies. The full length gene sequencing of 1.9 kb cry3a (coleopteran specific gene) was done. The 2.37 kb *vip3A* (lepidopteran specific gene) and 3.686 kb *cry1Ac* (lepidopteran specific gene) was done using primer walking. The sequences were then sub cloned into *E. coli* expression system. The dipteran toxic *cry2A*, *cry17A*, *cry4A* and *cry44Ba* were identified through PCR analysis. The identification of *cry44Ba* is a first report from India.

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

Evaluation of entomofungal pathogens

Among the nine entomofungal pathogens applied on polyhouse grown tomato, *Leucanicellium lecanii* (Vl-8 isolate) and *Beauveria bassiana* (Bb-9 isolate) showed significantly lower whitefly (*Bemisia tabaci*) population in tomato (15.29 & 17.21 whiteflies/plant respectively) as compared to untreated control (48.24 whiteflies/plant in tomato) indicating reduction of 68.30 & 64.32% in tomato. Among the nine entomofungal pathogens tested on capsicum, *L. lecanii* (Vl-8 isolate) and *B. bassiana* (Bb-9 isolate) showed significantly lower white fly population in capsicum (6.47 & 6.98 whiteflies/plant respectively) compared the higher whitefly population in the untreated

control (28.12 whiteflies/plant) indicating reduction of 77.00 & 75.12% respectively. With regard to yield, statistically significant differences in the yield were not observed in entomofungal pathogen treated plants and untreated control plants.

The field trial for evaluation of entomofungal pathogens on cabbage aphid (*Brevicoryne brassicae*) in cabbage (var. Saint) was carried out at NBAII Farm Attur during kharif season July-November, 2013 with nine isolates of entomopathogenic fungi. Isolates Bb-5a, Ma-6 and Vl-8 showed significantly low aphid population/leaf (4.62, 5.82 & 5.06 respectively) with a significant reduction of 60.0-68.25% over control.

Effect of elevated levels of carbon dioixide on the tritrophic interactions

The influence of elevated levels of carbon dioxide and temperature was studied in Open Top Carbon dioxide chambers (OTC) at NBAII. Significantly higher incidence of leaf miner, *Liriomyza trifolii* was noticed in tomato plants in the chambers with higher CO_2 and temperature compared to ambient conditions.

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

A plant based attractant was developed and tested for the attraction of *Bactrocera dorsalis* in the mango orchards. The dispenser attracted more fruit flies (570 fruit flies/season), mainly *B. dorsalis* as compared to methyl euginol (304 fruit flies /season).

5.2. Biodiversity of biocontrol agents from various agro ecological zones

Rice

DRR: Sweep net and light trap sampling were made in different rice fields of Pattambi, Kerala to record the pests and natural enemies. A total of 117 species belonging to 8 orders, 63 families of insects and spiders were collected and identified, of which 45 were pest species, 44 were predators, 24 were parasitoids and 4 were neutral or saprophagous group. Three stem borer species were observed in the field, the yellow stem borer, *Scirpophaga incertulus*, the white stem borer, *Scirpophaga fusciflua* and the pink stem borer, *Sesamia inferens*. Three speices of egg parasitoids were observed on eggs of *S. incertulus* and *S. fuscifluaviz*, *Tetrastichus schoenobii*, *Trichogramma japonicum* and *Telenomus* spp. The yellow hairy caterpillar *Psalis pennatula* was found in large numbers and 10 per cent larvae were parasitized by *Brachymeria* sp. In addition, natural enemies of rice pests have also been surveyed and collected from Chinsurah and Kalimpong in West Bengal. The red long winged planthopper, *Diostrombus polites* was abundant in research farm at UBKVV, Kalimpong. The dark headed borer, *Chilo polychrysus* and the grass web worm, *Herpetogramma* sp. were also recorded. The skipper *Parnara guttata* was prevalent with 75 per cent parasitisation by *Apanteles* sp. At DRR research farm, fortnightly collection by sweep nets yielded 140 species of natural enemies of which 75 were predators and 65 parasitoids.

KAU: The fungus causing mycosis in rice bugs (*Leptocorisa* sp.) was identified as *Acremonium lioliae* Latch

Vegetables

IIVR: The dominant mealy bug was *Phenacoccus solenopsis* (Tinsley) found infesting tomato, brinjal, *Capsicum*, pointed gourd and *Okra*. *Centrococcus insolitus* (Green) was recorded on brinjal. Two prominent endoparasitoids *viz*., *Aenasius bombawalei* Hayat and *Promuscidea unfasciates* Girault (Encyrtidae: Hymenoptera) of *Phenacoccus solenopsis* were noted. Tritrophic interaction was observed during the recovery of the parasitoids from different hosts and highest cumulative recovery was obtained from tomato (33.67%) followed by okra (30.45%) whereas lowest recovery (13.33%) was in case of pointed gourd.

Plantation / condiments

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

Temperate crops

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

Papaya

KAU: Survey for incidence of papaya mealy bug and its natural enemies was carried out in different districts of Kerala. The pest incidence was low in all areas due to establishement of the parasitoid. Other hosts in which papaya mealy bug infestation was noticed were tapioca and change rose (*Hibiscus mutabilis*). *Acerophagus papayae* population was found in all the areas where papaya mealybug infestation was found. Parasitisation level of *A. papayae* on tapioca was upto 27.8 per cent.

Cotton

UAS-R: The parasitiod of flower midge was identified as *Ecrizotomorpha* sp..

Diverse agro-eco systems

ANGRAU: Twenty two batches of *Trichogramma,* nine batches of *Chrysoperla,* five batches of *Chelonus blackburnii,* 12 batches of Coccinellids, and 19 batches of spiders were collected from Southern Telangana.

MPKV: The natural enemies recorded in Maharashtra were coccinellids, *Coccinella septempunctata* L. *Menochilus sexmaculata* (F.), *Scymnuscoccivora* Ayyar, *Encarsia flavoscutellum, Dipha aphidivora* Meyrick, *Micromus igorotus* Bank., syrphids on sugarcane woolly aphid in sugarcane, *Coccinella transversalis* F., *M. sexmaculata, Brumoides suturalis* (F.), *Scymnus coccivora* Ayyar, and *Triomata coccidivora* in mealy bug colonies on custard apple, *Acerophagus papaya, Pseudleptomastix mexicana* and *Mallada boninensis* Okam., *Spalgis epius* on papaya mealy bug and *Eublemma amabilis* on ber, the predator of lac insects. The chrysopid, *C. zastrowi sillemi* was recorded on cotton, maize, pigeon pea, French bean, brinjal and *rabi* sorghum and *Mallada boninensis* on cotton, sunflower, French bean, papaya and mango. The cadavers of *S. litura* and *H. armigera* infected with *Nomuraea rileyi*, *Metarhizium anisopliae*, *Sl*NPV, *Ha*NPV infected host insects were collected from soybean, potato, pigeon pea, capsicum, and chickpea. The armyworm larvae infected with NPV in *rabi* sorghum were collected. The invasive mealy bug, *Pseudococcus jackbeardsleyi* was recorded on custard apple in the vicinity of Pune. Papaya mealy bug, *Paracoccus marginatus* was also observed on pigeon pea and *Abution indicum* with enormous population of parasitoid *Acerophagus papaya*.

YSPUHF: One species of *Chrysoperla,* 37 species of coccinellid beetles, 20 species of hymenopteran parasitoids of *Liriomyza trifolii* and/or *Chromatomyia horticola*, three species of predatory thrips, two of anthocorid bugs, nine of syrphid predators and nine of predatory mites were collected.

Coccinellids

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

***Trichogramma* spp.**

AAU-A: Trichocards were placed in cotton, maize, tomato, groundnut and castor fields for parasitism by *Trichogramma* in different geographical areas. Similarly, eggs of host insects were collected at fortnightly interval from cotton (*H. armigera*), paddy and castor (*A. janata*). *T. chilonis* was the only Trichogramatid recorded.

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

Fazilka and Karni Khera, about 35% *Trichogramma* adults were obtained from naturally parasitized sentinel cards.

***Chrysoperla* sp.**

AAU-A: Geographic populations of green lacewing were collected. *Chrysoperla zastrowi sillemi* (Esben-Peterson) was found in all the populations

Spiders

AAU-A: A **t**otal of 207 spider specimens were collected both by pitfall trap as well as general collection from paddy ecosystem and preserved.

SKUAST: Eleven families, 25 genera and 34 species of spiders were recorded during the survey conducted in temperate rice ecosystem of Kashmir. The highest species richness was recorded in family Araneidae (seven species) followed by Tetragnathidae (five species) and Salticidae (five species). Among different foraging behaviour group of spiders, the relative abundance of visual hunters (51.62%) was recorded highest followed by web builders (30.81%) and tactile hunter (17.57%). Among the 11 families of spiders, Lycosidae (26.77%) was found the most abundant followed by Theridiidae, Salticidae and Thomisidae. The dominant spider species recorded were *Pardosa altitudis, Theridion* sp. *Araneus anantnagensis and Tetragnatha mandibulata* in temperate rice ecosystem of Kashmir.

CTRI: Biodiversity of spiders and parasitoids in tobacco nurseries planted with trap crop castor and main field was undertaken at CTRI, Rajamundry. In the main field, the Shannon index showed value of 2.83 which indicates intermediate diversity. The evenness was 0.18 indicating low inter species evenness. In the active nursery, the Shannon index showed value of 3.22 which indicates good diversity. The evenness was 0.16 indicating very low inter species evenness. There were significant differences in the number of spiders per plant in different types of tobacco. Highest number of spiders was found in Lanka followed by chewing, burley, and rustica and cigar filler. Least number of spiders was recorded in natu tobacco. There were hghly significant differences in the number of *C. sexmaculata* per plant in different types of tobacco. Highest numbers of beetles were found in Lanka followed by natu, VT 1158 cigar filler, chewing and rustica. Least number of beetles was recorded in burley tobacco. There were highly significant differences in the number of *Ischiodon scutellare* per plant in different types of tobacco. Highest numbers of beetles were found in Lanka followed by natu, cigar filler, chewing, burley and VT 1158. Least on rustica.

AAU-A: Seasonal abundance of predatory spiders in rice ecosystem was worked out using quadrate method. Overall highest species richness was observed for *Neoscona theisi* (138) and *Leucauge* sp. (134) followed by *Tetragnatha javana* (79), *Argiope sp.* (74), *Cyrtophora cicatrosa* (74), *Leucange celebesiana* (72), *Argiope anasuja* (70), *Leucauge decorate* (66).Species diversity (H') was computed using Shannon-weiner index of diversity was calculated 2.95 in Kheda whereas 2.43 in Anand district. Species

evenness using Kreb's formula came to be 0.89 of Kheda and 0.67 of Anand. Total 44 different species belonging to Araneidae, Oxyopidae, Tetragnathidae, Theridiidae, Lycosidae, Thomisidae, Gnaphosidae, Clubionidae, Sparassidae and Salticidae were identified. Among the different species of predatory spiders, Araneidae found to be predominant species followed by tetragnathidae and salticidae.

ANGRAU: Seven genera of spiders were collected during the Kharif & Rabi seasons from five locations in Rajendranagar. *Tetragnatha* was found to be the most abundant genus followed by *Oxyopes*. *Thomisus* and *Atypena* were found to be the least abundant.

***Bacillus thuringiensis* (*Bt*)**

AAU-A: Among 261 samples from 22 villages of Vadodara district, *Bt* colonies were present in 17 samples. While processing 50 samples collected from Bhavnagar district, only 4 samples yielded *Bt* colonies.

EPN

AAU-A: Soil samples were collected from different geographic locations. In Vadodara district, 261 samples were checked and four EPN like sample were sent to NBAII for identification. In Bhavanagar, out of 50 samples examined, none was harboring EPN. A new isolate of entomopathogenic nematode, *Steinernema* sp. has been recovered from a soil sample taken from mango orchard of Sitapur district, Uttar Pradesh and it has been designated as *Steinernema* sp. (strain CISH 3) (CISH).

Entomopathogenic fungi

PAU: Three isolates of entomopathogenic fungi, *Beauveria* were isolated from soil samples collected from the fields of rice, sugarcane and maize in the districts of Pathankot, Jalandhar and Hoshiarpur.

PGPR/ plant disease antagonists

CAU: Fifty one isolates of *Pseudomonas fluorescens* were collected and characterized for their plant growth promoting activity. BOX PCR using BOX A1R primer was employed to study the closeness of screened isolates. Among the isolates, Pf 14 found to produce highest amount of indole acetic acid followed by Pf 15, Pf 12 and Pf11.

PAU: Two *Bacillus* isolates were isolated from soil samples collected from the fields of radish and moong bean in districts of Jalandhar and Pathankot respectively.

5.2.1 Surveillance for alien invasive pests

KAU: Mealybugs collected from different crops were identified as *Phenacoccus solenopsis* Tinsley (Host: Bhendi, Brinjal & Beet root), *Geococcus coffeae* Green (Host: Coleus) (Plate) and *Rastrococcus iceryoides* (Green) (Host: Cowpea).

KAU & CTRI: No invasive pests have been observed.

TNAU: The papaya mealybug *Paracococcus marginatus* and Jack Beardsley mealy bug *Pseudococcus jackbeardsleyi* were recorded. *Brontispa longissima*, *Aleurodicus dugesii*, *Phenacoccus manihoti* and *Phenacoccus madeirensis* were not present.

AAU-A: *Paracoccus marginatus* in papaya was observed in seven villages in Gujarat.

ANGRAU: Surveys in cotton growing areas in Telangana were conducted. *Phenococcus solenopsis* was predominant over *Meconellicoccus hirsutus. Paracoccus marginatus* was noticed in field crops. Monitoring the outbreaks of invasive mealy bugs in Kharif seasons in adjoining districts of Mahaboobnagar and Nalgonda revealed that cotton was mainly affected by *Phenococcus solenopsis* largely and *Maconellicoccus hirsutus* to certain extent.

5.3. Biological suppression of pests and diseases in field

5.3.1 Biological suppression of diseases

GBPUAT: Cost-effective WP/EC based *Trichoderma* formulations and efficient delivery systems were developed. In rice, the *Trichoderma* isolates were applied as seedling root dip treatment (10g/lit.), soil application (1kg talc based formulation of *Trichoderma* /100 kg vermicompost) and as two foliar sprays (10 g/lit) at 30 & 60 days after transplanting. The brown spot disease severity was significantly reduced by *Trichoderma* isolates TCMS 5 (17.3%), TCMS 14a (18.3%), Th 14 (19.3%), Th 82 (22.7%), Th 3 (23.3%) & Th 17 (24.0%) which were significantly lower as compared to control (48.0%).

In chickpea, soil application (1kg talc based formulation of *Trichoderma* /100 kg vermicompost/acre), seed treatment (@ 10 g/kg seeds) and two foliar sprays (@10 g/lit at 45 & 90 days after sowing) with TCMS-5 isolate showed least mortality (5.9%) followed by Th-14 (6.3%) and Th-17 (7.0%) as compared to control (15.4%) after 90 DAS.

In lentil, soil application (1kg talc based formulation of *Trichoderma* /100 kg vermicompost/acre), seed treatment @ 10 g/kg seeds and two foliar sprays @10g/lit at 45 & 90 days after sowing of various isolates were done. Among the 19 promising *Trichoderma* isolates tested, significantly higher in germination over control was observed in isolate Th-17 (28.7%) followed by TCMS-5 (28.7%) and Th-14 (21.3%).

CAU: Bio-efficacy of CHF *Pf*-1 was evaluated for the management of bacterial wilt of brinjal caused by *Ralstonia solanacearum* in Pasighat, Arunachal Pradesh.. Application of CHF *Pf*-1 as seedling dip @25g / liter for 30 minutes before transplanting + soil drenching @ 2.5g / litre at 20 days after transplanting (DAT) recorded lowest wilt incidence of 14.75% wilted plants and it was on par with soil drenching alone with CHF *Pf*-1 (18.25% wilted plants). Soil drenching with streptomycine and bleaching powder recorded 19.83% and 21.00% wilted plants respectively. The highest yield of 244.55q/ha was also recorded in CHF *Pf*-1 seedling dip + soil drench treatment.

5.3.2 Biological suppression pests in cereals, pulses and sugarcane

Maize

MPUAT: Four releases of *T. chilonis* @ 150000 parasitoids/ha in maize at 10 days intervals starting 25th days after germination was found most effective against maize stem borer.

Sorghum

DSR: Three strains each of *Metarrhizium anisopliae* and *Beauveria bassiana* were evaluated against spotted stem borer, *Chilo partellus* during Rabi 2013-14 in sorghum. Preliminary results suggest that application of *M. anisopliae* (Ma 36 @ 5ml/l) at 20, 45 DAE resulted in 18.0% reduction in dead hearts over control and was on par with whorl application of carbofuran granules @ 8 kg/ha at 20 DAE. However there were no significant differences among the fungal formulation in reducing the leaf damage.

Pigeonpea

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

AAU-A: NBAII Bt liquid formulations (PDBC-BT1 and NBAII-BTG4) and IARI *Bt* were tested against against pigeon pea pod borer (*Helicoverpa armigera*) and legume pod borer (*Maruca testulalis*). Pooled results of three years data on pod damage revealed significantly less damage (4.90 %) in plots treated with chlorpyriphos over other treatments. All the microbial insecticides found to be at par, however the plots treated with PDBC-BT1 @ 2% showed minimum (6.79%) damaged pods followed by PDBC-BT1 @ 1% (7.06%). Pooled data computed for grain yield indicated maximum yield (1841 kg/ha) in plots treated with chemical insecticide followed by NBAII-BT G4 2% (1761 kg/ha) and 1% (1680 kg/ha).

MPAUT: The per cent pod damage in chickpea was significantly lower in two sprays of HaNPV @ 250 LE/ha.

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

Sugarcane

MPKV: Sugarcane woolly aphid (SWA) incidence was low (0.88%) in western Maharashtra with 1.41 pest intensity rating. The predators observed on SWA were mainly *Encarsia flavoscutellum* (1.2-30.6 adults/leaf), *Micromus igorotus* (0.9-5.3 grubs/leaf), *Dipha aphidivora* (0.6-2.6 larvae/leaf), syrphids and spiders (MPKV).

TNAU: Survey in sugarcane indicated an incidence upto 14.8 sugarcane woolly aphids/ 6.25 sq.cm leaf area during July to December 2013. Then the incidence gradually declined to less than 4.2 SWA/ 6.25 sq.cm leaf area during February 2014.

UAS-Raichur: The incidence of SWA ranged from 5 to 10 per cent in Bidar, Gulbarga and Bellary district while its incidence was nil in Raichur and Koppal district.

5.3.3 Biological suppression pests in oilseeds and cotton

Soybean

MPKV: Spraying of *Sl*NPV @ 250 LE/ha (1.5 x 10^{12} POBs/ha) thrice at fortnightly interval was statistically superior in suppressing the infestation of *Spodoptera litura* (4.76 larvae/m row) with 78.0 per cent larval mortality and gave maximum of 21.95 q/ha yield of soybean. However, the MPKV and NBAII strains of *Nomuraea rileyi* were equally effective against *S. litura* in soybean.

DSR: Six *Beauveria bassiana* strains were evaluated at Indore against major soybean lepidopteron defoliators. Treatment with DSRBB5 recorded lower semilooper (*Chrysodeixis acuta* and *Diachrysia orichalcea*) population (0.33 per mrl) as compared to control (0.67 per mrl). Population of *Gesonia gemma* larvae was lower in all the treatments as compared to control (2.22 per mrl) and in the treatment DSRBB1 lowest population (0.22 per mrl) was recorded.

Safflower

MPKV: Three sprays of *Metarhizium anisopliae* @ 10^{13} conidia/ha at fortnightly interval was next best treatment to dimethoate@ 0.05% being superior one in suppressing the aphid population (*Uroleucon compositae*) on non-spiny variety of safflower and increased the yield (10.9 q/ha).

ANGRAU: Bio suppression of safflower aphid, *U. compositae* was achieved through two sprays of *Verticillium lecanii* 1.0 % WP in non spiny safflower. Neem oil 5% spray also proven to be promising in minimizing aphids in safflower.

Cotton

MPKV: The mealy bug *Phenacoccus solenopsis* was observed at low intensity on cotton during 2013-14, but, it was noticed on parthenium, hibiscus, marigold and tomato in Pune region. It was reported in Dhule, Jalgaon and Nandurbar districts during November - December 2013 in association with *Aenasius bambawalei* Hayat. The incidence of sucking pests *viz*., aphids were recorded from 33rd MW, jassids, thrips and white flies observed from 36th MW and mites from 39th MW. Peak incidence of jassids and thrips was noticed during 46th MW and white flies in 47th and 48th MW. Aphid population was maximum during 47th MW. Natural enemies *viz.,* coccinellids (*M. sexmaculata, C. septempunctata*) and spiders were recorded from 1st week of October to 4th week of November 2013 and chrysopid *C. zastrowi sillemi* observed from 39th MW. The infestation of leaf minor (1-2 %) was observed in trial plot of cotton.

5.3.4 Biological suppression pests in vegetables

Tomato

MPAUT: The microbial insecticides comprising of two sprays of Btk @ 1kg/ha and two sprays of HaNPV @ 250 LE/ha produced higher tomato fruit yield.

TNAU: In the Biointensive IPM field, the population of sucking pests *viz.*, aphids, thrips, leafhoppers and whiteflies and fruit borer *viz*., *Helicoverpa armigera* incidence were significantly lower when compared to farmers practice. The incidence of fruit borer was 6.4 to 8.6% in BIPM as compared to 14.2 to 15.8% in farmers practice at 75 to 105 DAT. The fruit yield (36.80t/ha) was significantly higher in BIPM plot as compared to farmers practice (32.45t/ha) with a cost benefit ratio of 1:3.2. Abundance of *Chrysoperla* and coccinellids were noticed in BIPM demonstration plot.

Brinjal

MPAUT: Two sprays of NSKE and six release of *Trichogramma chilonis* in brinjal significantly reduced the fruit and shoot damage and sucking pest incidence.

OUAT: The biointensive IPM practice produced net return over the farmers practice in the range of ₹1,06,830 to ₹ 1,24,800 indicating the superiority of IPM package over the farmers' practice.

TNAU: Among the biocontrol agents, *Brumus suturoides* @ 1500/ha, *Scymnus*@ 1500/ha and *Cryptolaemus* @ 1500/ha significantly reduced the population of mealybug over control. The entomopathogen *Verticillium lecanii* sprayed plot was less effective and on a par with control.

MPKV: The BIPM module consisting release of *T. chilonis* @ 50,000 parasitoid/ha followed by spraying of NSKE 5% and *B. thuringiensis* @ 1 lit./ha twice at weekly interval starting from 45 days after transplanting was found to be significantly effectively

over other modules in suppressing the shoot (10.6%) and fruit (15.3%) infestation and increased the marketable fruit yield of brinjal (217.8 q/ha). Three sprays of profenophos 0.05% at fortnightly interval was the superior treatment in suppressing thrips population (3.2 thrips/plant) on onion with 1 rating of white patches. However, three sprays of *M. anisopliae* @ 10^8 cfu/ml showing 7.8 thrips/plant and 1.4 rating of white patches on leaves was the next best treatment.

Cauliflower:

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

Potato

AAU-J: Local and NBAII entomopathogenic fungal strains were evaluated against soil insects in potato. Imidacloprid @ 20 g ai/ha was found to be the best and could significantly reduce the infestation of potato tubers by *Dorylus orientalis* (10.25) and *Agrotis ipsilon* (11.25). Out of different bio insecticides, *Ma*-4 , *Bb*-23 and *Bb*-5a of NBAII strains showed good results in reducing the infestation of *D. orientalis* with 19.0, 19.25, 19.75 % infested tubers compared to the local strains of AAU (*M.a*, Biometa and *Bb*-Biosona) and *Ma*-35, where the per cent infested tubers was 21.5 and 23.5 and 23.75, respectively. Imidacloprid @ 20g ai/ha (11.25%) and malathion @40kg/ha dust (13.50%) significantly reduced the population of cutworm, *Agrotis ipsilon*. Maximum yield (83.90 q/ha) was obtained in the plots treated with imidacloprid @20 g ai/ha followed by *Ma*-4 NBAII strain (83.12 q/ha), and malathion dust (79.37 q/ha) and the treatments were found to be at par with each other.

5.3.5 Biological suppression pests in fruit crops

Mango

MPKV: Spraying of *Metarhizium anisopliae* @ 1 x 10^9 spores/ml with adjuvant (sunflower oil 1 ml/l + Triton X 100 @ 0.1 ml/l) during offseason in December followed by four sprays of the entomopathogenic fungi at weekly interval during flowering (January-February) found significantly effective in suppressing the hopper population (10.6 hoppers/inflorescence) and increased fruit set (11.8 fruits/inflorescence) in mango.

TNAU: Talc formulation of *Metarhizium anisopliae* of IIHR strain @ 1kg/100L recorded 77.1 per cent mortality of mango hoppers which was significantly superior to other formulations *viz*., liquid and oil formulations which recorded 71.13 and 63.73 per cent mortality of adult mango hoppers over untreated control respectively.
IIHR: The efficacy of oil, water and talc based formulations of *M. ansiopliae* in addition to chemical control were tested against mango inflorescence hopper *Idioscopus*

nitidulus. Significant reduction in hopper population was found in Imidacloprid @ 0.3ml/l sprayed trees followed by Nimbicidin @0.3 % spray. Liquid and talc formulations of *M. anisopliae* were on par in reducing the hopper population.

KAU: Oil formulation of *M. anisopliae* was found superior than the talc and liquid formulations of *M. anisopliae* against mango hopper and it was on par with Nimbicidin. There was no significant difference between treatments in fruit set.

Custard apple

MPKV: Release of *Scymnus coccivora* @ 10 grubs per tree twice at monthly interval was found effective in reducing the mealy bugs *Maconellicoccus hirsutus. hirsutus* and *Ferrisia virgata* and increased the yield of marketable custard apples (34.9 kg/tree). It was at par with *Cryptolaemus montrouzieri* @ 5 grubs per tree.

Papaya

MPKV: Papaya mealy bug incidence was noticed 12.8 to 21.0% with 2.1 to 2.8 pest intensity rating in five districts of Maharashtra. Besides eight predators, the parasitoid *Acerophagus papayae* and *Pseudleptomastix mexicana* were observed in the mealy bug colonies. The pest incidence was recorded from April to December 2013 with peak (14.6-25.0%) in June in the fortnightly visited orchards.

Citrus

CAU: Field evaluation on bio-efficacy of EPNs including five local collections *viz*. CAU-1, CAU-2, CAU-3, CAUH-1 and CAUH-2 as stem injection @50 ijs/ml of water and as cadaver application (wrapping two cadaver by muslin cloth and binding at one meter height from the ground level) against citrus trunk borer, *Anoplophora versteegi* were carried out at two locations *viz.* Pasighat and Ringging of Arunachal Pradesh. CAU-1 stem injection (37.22 and 36.43% reduction at Pasighat and Rengging respectively) and CAUH-1 stem injection (33.90 and 36.75% reduction at Pasighat and Rengging respectively) were observed as the best treatments. However, EPNs were found inferior to stem injection with dichlorvos 0.05 per cent. The stem injections of the EPNs were found more effective than their respective cadaver treatments.

Apple

SKUAST: Field releases of *Trichograma embryophagum + T. cacoeciae* @ 100,000/ha against codling moth *(Cydia pomonella*) in apple orchards of Kargil recorded 23.5 % reduction of fruit damage. However, the combined effect of *Trichograma embryophagum, T. cacoeciae* and pheromone trap revealed 27.66% reduction of fruit damage at Kargil. Mass trapping of codling moth (*Cydia pomonella*) through pheromone traps in apple orchards of Kargil recorded highest population (48.5/ trap) in Mangmore in the month of July.

YSPUHF: Among different biopesticides, *Metarhizium anisopliae* (10^6 conidia/cm^2) was the most effective in controlling apple root borer, *Dorysthenes hugelii* resulting in 82.6 per cent mortality of the larvae and was on par with chlorpyriphos (0.06%) which killed 87.5 per cent of the grubs.

Pineapple

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

Banana

KAU: *Beauveria bassiana* and *Metarhizium anisopliae* in different spore loads were evaluated against grubs and adults of pseudostem weevil. *B. bassiana* (10^8 spores/ml) and *M. anisopliae* (10^8 spores/ml) were found causing good mycosis on grubs of banana pseudostem weevil.

5.3.6 Biological suppression pests in plantation crops

Tea

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

Coconut

CPCRI: Coconut leaf eating caterpillar (*Opisina arenosella*) infestation was noticed in Trivandrum during April 2013 with 74.4% leaf damage. The damage was brought down to 16.7% over a period of nine months by release of larval parasitoids,*Goniozus nephantidis* and *Bracon brevicornis.* Demonstration on integrated management of *O.arenosella* at Arsikere, Karnataka revealed significant recovery of palms.Training on farmer–participatory production of *Metarhizium anisopliae* for biological suppression of coconut rhinoceros beetle was imparted with emphasis on women groups (Three groups from two districts of Kerala). Awareness programmes through field based farmers interactive meetings (Nine programmes) and mass media utilization were done for technology transfer.

Tapioca

TNAU: BIPM module evaluated against *Aleurodicus dispersus* on cassava recorded a lower population of *A. dispersus* (76.93 per 5 plants) as compared to farmer's practice (226.11 per 5 plants) and untreated check (320.96 per 5 plants). The per cent reduction of *A. dispersus* population over control was maximum in BIPM module (74.81) than the farmer's practice (29.43). Maximum yield was recorded from BIPM module (36.79 t/ha) as compared to untreated check (21.60 t/ha). The net profit and benefit cost ratio (BCR) were also higher in BIPM module (1 : 3.34) than the farmer's practice (1: 2.41).

5.3.7 Biological suppression of polyhouse crop pests

MPKV: The average initial root-knot nematode population in gerbera field ranged from 520 to 680 IJs/200 cm^3 of soil. The treatment of *Paecilomyces lilacinus* @ 20 kg/ha found to be the most effective in reducing the root-knot nematode population (64.3 %) and gall index (52%) which was at par with the treatment of *Arthrobotrys oligospora* @ 20 kg/ha in reducing the root knot nematode population (60%) and gall index (38 %).

YSPUHF: Release of predatory mite, *Neoseiulus longispinosus* at 1:10 predator: prey ratio in carnation resulted in 91.2 per cent reduction of phytophagous mite population over untreated control and was also on par with fenazaquin (0.0025%) which caused 92.1 per cent reduction.

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

SKUAST: The efficacy of predatory mite (*Neoseiulus longispinosus*) against phytophagous mite in rose under polyhouse condition was evaluated. Maximum reduction of 69.6 % of european red mite (*Panonychus ulmi* Koch) was observed after 4^{th} release of 30 predatory mites/plant. Minimum leaf damage/10plants was recorded after 4^{th} release of 30 predatory mites/plant/release. Maximum yield/plot (1173 cut flowers) was recorded in the treatment of 30 predatory mites/plant/release which was statistically on par with Azadurachtin 3ml/L treated plots.

Maximum reduction (68.2%) of cabbage aphid in polyhouse was achieved by five weekly releases of 2^{nd} instar grubs of *Coccinella septumpunctata* @ 5/plant. The minimum percentage of leaf infestation was recorded with the release of 2^{nd} instar of *C. septempunctata* @ 5/plant. The maximum yield/plot was 23.75kg recorded against Dichlorovas @ 1ml/L which was statistically on par with the release of 2^{nd} instar grubs of *C. septempunctata* @ 5/plant (23.50 Kg).

5.3.8 Biological suppression of storage pests in rice

AAU-J: Release of anthocorid predator, *Xylocoris flavipes* @ 30 nymphs per kg of corcyra infested stored rice (12.75 moths/jar) was significantly superior to all other treatments in reducing the emergence of *Corcyra* moths.

ANGRAU: Release of anthocorid bugs in rice bins could effectively control the *Corcyra* c*ephalonica* larvae. Nymphs of the bug *Xylocoris flavipes* performed better than those of *Blaptostethus pallescens* in minimizing the moths. Survivability of *X. flavipes* was more in the treatments where 20 nymphs were released followed by the bins where 30 nymphs were released.

5.4 Large scale demonstration of proven biocontrol technologies

Rice

AAU-J: No significant differences was observed in *Nephotettx* sp. population and per cent leaf damage by *Cnaphalocrocis* sp. in BIPM plot as well as farmers' practice. The mean incidence of dead heart and white ear was 2.77% and 2.7% in BIPM package as compared to farmers practice (3.90% and 3.21% respectively). Maximum mean yield was contributed by BIPM package with 4757.0 kg/ha, significanltly superior to the farmers practice (3875.0 kg/ha).

KAU: Large scale adoption of proven biocontrol technologies in rice was carried out in 100 ha area in Thrissur district. The yield data shows that there was no significant difference in grain weight in BIPM and conventional farming. Coccinellid population was significantly high in BIPM. BIPM in paddy is practiced in all the districts of Kerala.

PAU: BIPM practice (7 releases of *T. chilonis* and *T. japonicum* each @ 1, 00,000/ha) has proved as effective as chemical control for management of leaf folder and stem borer of basmati rice. The cost benefit analysis indicated a net return of Rs. 1, 01,775/- in BIPM package as compared to Rs. 1, 07,070/- in farmer's practice.

GBPUAT: During Kharif season 2013, large scale field demonstration of bio-control technologies was conducted in 31 farmers fields covering an area of 42 hectares in different villages of Nainital district. The Pant bioagent-3 ((PBAT-3) was colonized on FYM/ vermicompost (5-10 tons/ha) and applied in soil followed by seed treatment (10 g/kg seed), seedling dip treatment (10g/lit. water) and need-based foliar sprays of PBAT-3 (10g/lit. water). By adopting bio-control technologies an average yield of 45q/ha was obtained as compared to conventional farmer's practices (38 q/h).

Sugarcane

MPKV: Eight releases of *T. chilonis* TTS @ 50,000 parasitoids/ha at weekly interval starting from 45 days after shoot emergence in farmers field was found effective in

reducing the infestation of early shoot borer (6.8%) and increased tillers as well as cane yield (144.3 MT/ha).

OUAT: Regular release of *T.chilonis* against early shoot borer and internode borer of sugarcane in Farmers' fields resulted lower incidence of early shoot borer (7.2 to 8.7%) as compared to 27.4 to 35.8% in the fields where no parasitoids have been released and farmers took their own control measures of pesticide application. Similarly, internode borer incidence was also least in parasitoid released plots (11.84-14.38%) as compared to 27.45% and 33.33% in farmers practice. Top shoot borer incidence was also least in parasitoid released fields (2.8-4.2%) as compared to 7.3-9.1% incidence in the fields where no parasitoid has been released. The yield was higheer (144.7-155.2 t/ha) in parasitoid released plots whereas it was 109.5-111.6 t/ha in farmers practice.

Tomato

AAU-A: Large scale field demonstrations on the use of Trichocards for control of *Helicoverpa armigera* was conducted in 61 tomato growers of the Anand region. Using this technology in tomato, the chemical insecticide sprays were reduced to 2-3 from 6-7 sprays. There is huge demand for Trichocards from the farmers of this area as they want to reduce the chemical pesticides.

Pea

GBPUAT: During Rabi 2013-14, large scale field demonstrations of biocontrol technologies were conducted on pea (Arkil variety) in 20 farmer's fields in Golapar-Chorgalia, in Nainital district covering an area of about 30 acres. The Pant bioagent-3 ((PBAT-3) was colonized on FYM/ vermicompost (5-10 tons/ha) and applied in soil followed by seed biopriming (10 g/kg seed). During the year the farmers used biocontrol agent for the management of wilt problems. Due to the successive application of biocontrol agents, the yield of green pea was recorded to the tune of 35-45 q/acre as compared to conventional farmers practices (25-30 q/acre).

Time to time demonstration and training programmes were conducted at farmer's field as well as on university campus. A total of 770 farmers were trained in nine training programmes on various crops viz. wheat, rice, tomato, pulses and vegetables for successful application of biocontrol technologies under organic farming/IDM. During large scale field demonstrations, seven quintals of bioagent (PBAT-3) was distributed to the farmers.

Coconut

CPCRI: Area wide demonstration of biocontrol technology under taken in southern Kerala covering 1500 ha for the management of coconut rhinoceros beetle resulted in 57.3 to 69.6 % reduction in leaf damage over a period of 18 months.

6. Director's and Monitoring Team Visit to AICRP centers

S. N	Dates	Visit of Director/ NBAII Scientist	Place of visit	Highlights of visit
1.	28-4-2013	Dr.N. Bakthavastalam P.S, NBAII	AAU, Jorhat	Reviewed the progress of work of AICRP centre at AAU, Jorhat
	1-6-2013	Dr. A. Verghese Director, NBAII	KAU, Trissur	Reviewed the progress of work of AICRP centre at KAU, Trissur
2.	29-9-13 to 30-9-13	Dr. T. Venkatesan P.S, NBAII	PAU, Ludhiana	Reviewed the progress of work of AICRP centre at PAU, Ludhiana
3.	13-11-13 to 14-11-13	Dr. A. Verghese Director, NBAII	MPKV, Pune	Reviewed the progress of work of AICRP centre at MPKV, Pune
4.	19-11-13 to 21-11-13	Dr. P.Mohan Raj P.S, NBAII	OUAT, Bhubaneswar	The AICRP (BC) trials laid out at the OUAT campus were damaged by the cyclone and hence they would be taken up again. Visited fields of rice, sugarcane and brinjal where large scale demonstrations were being undertaken in farmers fields and were all damaged by the cyclone with rice and brinjal being affected the most.
5	3-12-13 to 4-12-13	Dr. A. Verghese Director, NBAII	OUAT, Bhubaneswar	Reviewed the progress of work of AICRP centre at OUAT, Bhubaneswar
6	7-1-2014	Dr. A. Verghese Director, NBAII	TNAU, Coimbatore	Reviewed the progress of work of AICRP centre at TNAU, Coimbatore
	17-1-14 to 19-1-14	Dr. B. Ramanujam P.S, NBAII	AAU-Anand	Reviewed the progress of work at AICRP Centre, Anand. In the field trials on Collar rot of groundnut, the disease has

				not been observed and hence PI suggested the closure of the project. Advised the PI to take up TSP project from next year onwards (2014-15) Participated in farmers meeting held at Runaj village where IPM in tomato is implemented. There is huge demand for *T. chilonis* from the farmers of this area. Advised the PI to take up large-scale demonstration of IPM technology in tomato pests in Runaj village of Anand district.
7.	7-3-2014	Dr. A. Verghese Director, NBAII	KAU, Trissur	Reviewed the progress of work of AICRP centre at KAU, Trissur
8.	20-3-14	Dr. A. Verghese Director, NBAII	ANGRAU, Hyderabad	Reviewed the progress of work of AICRP centre at ANGRAU, Hyderabad
9	24-3-14 to 25-3-14	B. Ramanujam P.S, NBAII	GBPUAT, Pantnagar	Reviewed the progress.Visited large-scale demonstration plots of Rice, peas, tomato in Haldwani District and interacted with the farmers who indicated that diseases in these crops have come done drastically because of antagonists. Discussed about the preparation of TSP project for the centre. Advised to prepare a new project on Biocontrol of chilli anthracnose

7. Publications: During the year 2013-14, a total of 235 research papers/ symposium papers/reviews/technical bulletins, etc., were published by the different centers as given below.

Center	Research papers in journals	Papers in Symposia/ Seminars etc.	Books/Book chapters/ Tech. Bulletin/ Popular articles	Total
NBAII, Bangalore	61	44	29	**134**
AAU, Anand	5	-	1	**6**
AAU, Jorhat	-	1	6	**7**
GBPUAT, Pantnagar	6	12	1	**19**
KAU, Thrissur	-	1	-	**1**
MPKV, Pune	0	5	4	**9**
PAU, Ludhiana	-	4	2	**6**
SKUAST, Srinagar	6	-	2	**8**
TNAU, Coimbatore	6	3	2	**11**
YSPUHF, Solan	1	1	0	**2**
CPCRI, Kayangulam	7	-	-	**7**
IIHR, Bangalore	1	7	1	**9**
UAS-R	5	9	2	**16**
Total	**98**	**87**	**50**	**235**

8. Profile of experiments and demonstrations carried out during 2013-14

Crop/Insect	Experiments	Large scale Demonstrations
Biodiversity of biocontrol agents	3	-
Antagonists for crop diseasemanagement	9	3
Rice	2	4
Maize	1	1
Sorghum	1	-
Sugarcane	2	5
Cotton	2	0
Tobacco	2	0
Pulses	3	0
Oil seeds	5	0
Coconut	3	1
Tropical fruits	8	0
Temperate fruits	3	0
Vegetables	15	1
Tea mosquito bug	1	0
Mealybugs	1	0
Storage pests	1	0
Weeds	1	0
Polyhouse crops	7	0
Total	**70**	**15**

9. Enabling large scale adoption of proven biocontrol technologies

Following large scale demonstration trials were taken up at different AICRP centres during 2013-14.

1. Rice

AAU-J, KAU (Adat model), OUAT (Large scale adoption of proven bio control technologies), PAU (Biocontrol-based IPM for Basmathi Rice)

2. Sugarcane

i. Demonstration of temperature tolerant strain (TTS) of *Trichogramma chilonis* against early shoot borer (ESB) in *Suru* planting of sugarcane (MPKV, PAU)

ii. Use of *Trichogramma chilonis* for the suppression of stalk borer, *Chilo auricilius* in collaboration with sugar mills(PAU)

iii. Demonstration on the use of *Trichogramma japonicum* for the suppression of top borer, *Scirpophaga excerptalis*(PAU)

iv. Large-scale demonstration on the use of *T.chilonis* against early shoot borer and internode borer of sugarcane in farmers' field (OUAT)

3. Maize

Demonstration of biological control of maize stem borer, C*hilo partellus* using *Trichogramma chilonis* (PAU)

4. Coconut

Large area field validation of integrated biocontrol technology against *Oryctes rhinoceros* (CPCRI)

5. Brinjal

BIPM in Brinjal (OUAT)