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

DIRECTOR'S REPORT

XXII Biocontrol Workers Group Meeting 24-25 May, 2013

National Bureau of Agriculturally Important Insects
Bangalore 560 024

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Cover page (Top to bottom)

Zaplatycerus notialis Hayat & Poorani (Photo: J. Poorani) (Hymenoptera: Encyrtidae)

Platensina quadrula Hardy (Photo: K.J. David) (Diptera: Tephritidae)

Poropoea bella Hayat & Poorani (Photo: J. Poorani) (Hymenoptera: Trichogrammatidae)

Apanteles galleriae Wilkinson (Photo: Ankita Gupta) (Hymenoptera: Braconidae)

Cover design: Sunil Joshi

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Abraham Verghese
Director, NBAII

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Director's Report

1. Introduction

The National Bureau of Agriculturally Important Insects (NBAII) hosts the Project Coordinator's Cell of AICRP on Biological Control of Crop Pests and Weeds as its integral part and supports it with basic research. 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 impetus to the AICRP programme on biological control.

In the past three years, diversity of insects, spiders, nematodes, antagonistic and entomopathogenic organisms has been given importance and collection and cataloguing has 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 2012-13 was deliberated. With some important older programmes, new experiments were formulated with the change in agricultural scenario. As in the previous technical programme, the emphasis on monitoring invasives, pests of polyhouses and storage pests was continued. Our focus on classical biological control remained and the work on the management of exotic pests such as the mealybugs of papaya continued. It is heartening to note that there is low level of papaya mealybug incidence and also the recovery of the released parasitoid *Acerophagus* from the papaya mealybug infested fields shows the potential of classical biological control. The report of new parasitoid like *Anagyrus* sp. n. nr. *sinope* on *Phenacoccus madeirensis* will pave way for better biological control programmes. 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 2012-13 are presented below. The large scale demonstrations in different centres and those specifically in tribal areas show the potential of non-chemical management of crop pests.

2. Mandate of AICRP on biological control of insect pests, diseases and weeds

- Promotion of biological control as a component of integrated pest and disease management in agricultural and horticultural crops for sustainable crop production
- Demonstration of usefulness of biocontrol in IPM in farmers' fields.

3. Objectives

a. Development of effective biocontrol agents for use in biological suppression of crop pests and diseases
b. Evaluation of various methods of biological control in multi-location field trials
c. Development of biointensive integrated pest management strategies for cotton,

rice, sugarcane, pulses, oilseeds, potato, coconut and a few selected fruits and vegetables

d. Demonstration of usefulness of usefulness of biocontrol in IPM in farmers' fields

4. Setup

With a view to fulfill the mandate effectively and efficiently, the Bureau is functioning with the following State Agricultural Universities, ICAR Institute – based centers and some voluntary centers

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.	Jawaharlal Nehru Krishi Viswa Vidyalaya	Jabalpur
xiii.	Maharana Pratap University of Agriculture & Technology	Udaipur
xiv.	Orissa University of Agriculture & Technology	Bhubaneshwar

ICAR Institute–based centres

i.	Central Plantation Crops Research Institute	Kayangulam
ii.	Central Tobacco Research Institute	Rajahmundry
iii.	Indian Agricultural Research Institute	New Delhi
iv.	Indian Institute of Horticultural Research	Bangalore
v.	Indian Institute of Sugarcane Research	Lucknow

Voluntary Centers

i.	Directorate of Soybean Research	Indore
ii.	National Center for Integrated Pest Management	New Delhi
iii.	Directorate of Weed Science Research	Jabalpur
iv.	University of Agricultural Sciences	Raichur

5. Brief summary of Research Achievements

5.1. Basic research work National Bureau of Agriculturally Important Insects

National Bureau of Agriculturally Important Insects (NBAII) backs up the AICRP (BC) with basic and applied research and the salient achievements during the last year are given below.

5.1.2. New taxa described

Poropoea bella Hayat & Poorani (Trichogrammatidae) and *Zaplatycerus notialis* Hayat & Poorani (Encyrtidae) were described from Karnataka. *Coccipolipus synonychae* (Acari: Podapolipidae) was described as a parasite of the giant bamboo ladybird, *Synonycha grandis. Anagyrus qadrii* and a fortuitously introduced species of *Anagyrus* were recorded as parasitoids of the Madeira mealybug in and around Bangalore.

An image gallery was hosted on NBAII's website and 510 species have been featured so far with over 3000 photographs with details. This site and "Featured Insects", the site on insect bioagents, have been included in ID source hosted by USDA and Colorado State University. An interactive LucID Phoenix key to the genera of Mymaridae of India was prepared with fact sheets, diagnostics and illustrations for the 28 genera known so far.

Twelve new species of Braconidae: 3 (Indian) and 9 (Afro-tropical) were described . An international catalogue containing revised Microgastrinae (Hymenoptera: Braconidae) fauna of Reunion Island (Indian Ocean), key to all genera and species is provided, thirty four (34) species belonging to 13 genera were recorded along with description of nine (9) new species and new distribution records for 12 species was published. Revised Indian *Microplitis* Foerster (Hymenoptera: Braconidae): Two species, *M. bageshri* Sathe, Inamdar & Dawale and *M. dipika* (Bhatnagar) were considered *incertae sedis* in the publication. DNA barcode developed for 6 species.

Surveys were conducted for Platygastroidea in five states and union territories. A total of 1850 parasitoids were collected.. So far 41 genera under five subfamilies were recorded from India and an additional eleven genera are added, raising the total to 52 genera. A new genus *Dvivarnus* Rajmohana and Veenakumari was described under the subfamily Teleasinae. One new species under this genus *Dvivarnus punctatus* Veenakumari and Rajmohana was described. Under the subfamily Sceliotrachelinae three new species were described. *Plutomerus veereshi* Veenakumari, Buhl and Rajmohana, *Fidiobia virakthamati* Veenakumari, Buhl and Rajmohana and *F. nagarajae* Veenakumari, Buhl and Rajmohana were described. The species of *Fidiobia* are the first representatives of the genus from India.

5.1.3. Studies on *Trichogramma* and *Cotesia*

Surveys were conducted in agricultural and natural ecosystems in parts of South and Western India as well as the Andaman and Nicobar islands for their *Trichogramma/ Trichogrammatoidea* fauna. First record of *Trichogramma rabindrai* from outside Karnataka / Madhya Pradesh reported. First record of *T. bactrae* from the eggs of *Prosotas nora* (Lepidoptera: Lycaenidae) on citrus is also reported.

Continuous rearing of *T. embryophagum* for 151 generations on ESW eggs resulted in 92.2% parasitism and 70.7% adult emergence. Five releases of *T. chilonis* reared on Eri silk worm eggs were made @ 10 cards per release at 10 days intervals against paddy borers in AP. The savings in bio-control plot was Rs 1214 per acre. Six day old parasitized (by *T. chilonis*) eggs of ESW can be effectively stored for a maximum period of one week, resulting in 50% adult emergence and 87.7% female progeny.

Eighteen populations of *Cotesia vestalis*, the parasitoid of the diamondback moth were collected from different geographical locations of the country, while *Trichogramma brassicae* was collected from Karnataka region. Yeast and bacterial endosymbionts were isolated and characterized. The evolutionary relationship between the symbionts across the different populations of the parasitoids was established. *Wolbachia*, an alpha proteobacterium was found to play a major role in the alteration of sex ratio, feminization and contributed enhanced biological attributes (percent parasitisation, longevity and fecundity).

5.1.4. Biodiversity of aphids, Coccoidea and their natural enemies

A total of 296 field trips were conducted in Karnataka and a total of 2490 slides of 1298 specimens were made. There were twenty four new records during these surveys. Species of aphids viz., *Pleotrichophorus chrysanthemi* (Theobald) and *Reticulaphis foveolatae* (Takahashi) and species of invasive mealybug viz., *Pseudococcus jackbeardsleyi* Gimpel and Miller were recorded for the first time from India. Similarly, *Lohiella longicornis* (Noyes & Hayat) was recorded for the first time from India parasitizing *Drepanococcus chiton* (Green) which is also a new host association. A total of 260 specimens were identified for different SAUs, ICAR Institutes and private organizations.

5.1.5. Taxonomic studies on fruit flies (Diptera: Tephritidae) of India

Surveys conducted in Karnataka, Kerala, Tamil Nadu, Maharashtra, Andaman and Nicobar islands. 81 species were collected/studied in 33 genera and five subfamilies namely Dacinae, Tephritinae, Trypetinae, Phytalmiinae and Tachiniscinae. About 2400 specimens of fruit flies were added to NBAII collection. Four new species of *Euphranta* Loew were described from India. Four species of tribe Adramini namely *Coelotrypes latilimbatus* (Enderlein), *Dimerinogophrys parilis* (Hardy), *Dimeringophrys pallidipennis* Hardy, *Hardyadrama excoecariae* Lee and an undescribed species of *Coelopacidia* were newly recorded from India. *Ortalotrypeta ishikii* (Matsumura) and subfamily Tachiniscinae is recorded for the first time from India.

5.1.6. Diversity and predator-prey interactions with reference to predatory anthocorids and mites

An undescribed species of *Montandoniola* was recorded on *Butea monosperma, Anthocorini* gen. et. sp. from Ficus tree, *Orius maxidentex* recorded for the first time from Andaman Nicobar islands, an undescribed species of *Blaptostethoides* from sugarcane, *Xylocoris afer* was recorded for the first time in India. In Karnataka, *Cardiastethus pseudococci pseudococci* for the first time from mango inflorescence, *Cardiastethus affinis* for the first time as a predator of *Hemiberlesia lataniae* on agave.

A new method has been standardised to rear *Montandoniola indica*, a predator of pepper gall thrips, *Liothrips karnyi. Xylocoris* (*Proxylocoris*) *afer* (Reuter) was recorded for the first time in India from dry fruits of *Ficus* and *Lagerstroemia*. *Blaptostethus pallescens* was field evaluated against mulberry thrips in Salem. After three releases, the thrips count could reduce from a pre-count of 94.8 to a post count of 20.5.

5.1.7. Studies on papaya mealybug, *Paracoccus marginatus*

Recurring incidence of papaya mealybug was observed in few locations in Karnataka, Penukonda, Kothanur from Andhra Pradesh, Andaman and Nicobar Islands, Salem and Erode districts of Tamil Nadu. A total of 43 requests for *Acerophagus papayae* were received from April 2012 to February 2013. *Anagyrus loecki*, and *Pseudleptomastix mexicana* were recovered from Erode, Salem and Bangalore. *Acerophagus papayae* was found to be parasitized by *Marietta leopardine (*Hymenoptera*:* Aphelinidae*)* and *Chartocerus sp. (*Hymenoptera: Signiphoridae).

5.1.8. Biology of *Anagyrus kamali* and mass production

Biology of the endoparasitoid *Anagyrus kamali* on Pink Hibiscus Mealybug *Maeconellicoccus hirsutus* was studied. The culture obtained from Andaman Islands was used for the study. *M. hirsutus* was maintained on potato sprouts and pumpkin. Although *A. kamali* parasitized 2nd instar nymphs there was a marked preference towards the 3rd and adult female mealybugs. The total developmental period of *A. kamali* on the 2nd stage nymph ranged from 25-29 days in case of males and 30-32 days in case of females. Development was faster in later stage nymphs (22 days) and in adult female (20-21days). Longevity of males and female parasitoids varied between 30-32 days and 38-42 days respectively. Water fed or starved adults could not survive for more than 36 -48 hours. Temperature of 22-25°C was found to be optimum for survival of the parasitoid. At temperature > 25°C the longevity of adults decreased drastically.

5.1.9. Madera mealybug *Phenacoccus madeirensis*

Phenacoccus madeirensis was recorded on 7.5 ha cotton crop from Bandipur and Gundlupet on *Cestrum nocturnum,* C. *diurnum, Acalypha, Hibiscus rosasinensis, Lantana camara, Clerodendron viscosum, Solanum melongena* and *S. tuberosum*,

Crossandra sp. Tapioca and mulberry plants were found to be the alternate hosts of *P. madeirensis*. Several natural enemies were observed feeding on *P. madeirensis.* Main predators were *Cacoxenus perspicax* (Drosophillidae: Diptera) and several Cecidomyiidae. *Cryptolaemus montrouzieri* and *Scymnus sp.* were predominantly feeding on *P. madeirensis.*

5.1.10. Laboratory rearing of *Leucinodes orbonalis* and insecticide resistance monitoring studies

An attempt was made to address the deficiencies in existing artificial diets for rearing *L. orbonalis* larvae. The nutritional and phagostimulancy improvements in diet combinations developed herein are useful for rearing of *L. orbonalis* larvae under laboratory conditions. The study on insecticide resistance revealed up to six fold variation in insecticide susceptibility with respect to fenvalerate, phosalone and emamectin benzoate.

5.1.11. Studies on endosymbionts

Culturable microflora associated with the sixteen populations of *Amrasca biguttula biguttula* (Cotton leafhoppers**)** from various cotton growing areas of the country were characterized through morphological and molecular methods. More than 40 different microflora were identified through 16S rDNA analysis and 7 microflora were identified from *Nilaparvata lugens.* Fourteen culturable microflora associated with eight populations of *Aphis gossypii*, *A. craccivora* and *Myzus persicae* were identified and *Bacillus* was the dominant genus found invariably in all aphid species.

5.1.12. Selection of superior strain of predators *viz*., *Chrysoperla zastrowi sillemi* (Esben- Petersen) and *Cryptolaemus montrouzieri* (Mulsant)

Genetic stocks of twelve different geographical populations of *C. z. sillemi* and 6 different populations of *C. montrouzieri* were maintained. Studies on biological attributes of different populations of *C. montrouzieri* at variable temperatures (32-40 ºC) revealed that most of the populations survived for 60 days and Coimbatore and Shimoga populations survived for 70 days. Studies on fixing field release schedule of pesticide tolerant and susceptible strain of *C. z. sillemi* revealed that there was 84 % survival in pesticide tolerant strain and 33 % in susceptible population and 84%, 98% and 98% on 1, 2 and 3 days after spray, respectively.

Field evaluation of pesticide tolerant strains against sucking pests of cotton revealed that two releases of PTS (Cza-8) at 15 days interval in combination with two sprays of acephate (0.67g/li) (13.4aphids/plant) were effective against *A. gossypii*, *Thrips tabaci* and also had highest cotton yield (1533 kg/ha). Pesticide tolerant strain of *C. z. sillemi* (Cza-8) (tolerant to Op, ocl and synthetic pyrethroids) was mass produced and 12,000 nos. were supplied for field release against sucking pests of capsicum in UP. 5,000 nos. were supplied to contain tea mosquito bug in Assam.

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

Three new isolates of *Heterorhabditis* spp. and *Steinernema abbasi* were recorded from diseased grubs collected from north Karnataka-Maharashtra border and added to NBAII collections. Totally eight new EPN strains isolated and catalogued. Identity of 10 different geographical isolates of *S. abbasi, S. feltiae, H. indica* and *H. bacteriophora* was validated and confirmed using COI, ITS and SSU RNA gene sequences and RFLP studies were carried out. DNA Barcoding for eight *Steinernema abbasi*, *Heterorhabditis indica* and *H. bacteriophora* was done for the first time from India for NBAII isolates using COI gene.

NBAII isolates of *H. indica, S. abbasi* and *S. glaseri* were effective at $2.5x10^9$ IJs/ha causing a mortality of 80-96% of white grubs. in soil column assay in 7days. Application of wettable powder preparations/formulations of *H. indica, S. abbasi and S. glaseri* at 2.0 $x10^{13}$ IJs/ha at transplanting reduced incidence of grubs of *Myllocerus subfasciatus* in brinjal (Purple Round) by 44-68% in field and improved yield by 18-24% over control. Application of WP formulations of three entomopathogenic nematodes compared to use of *Galleria* cadaver preparations reduced incidence of grubs of *Myllocerus subfasciatus* in brinjal by 68% and increased yield by 24%. *H. indica* in combination with *M. anisopliae* gave 73% control of grubs in soil observed at 90 and 120 days of crop growth. Demonstrated efficacy of EPN formulations against *Leucopholis burmeisteri, Phyllophaga* sp., and *Phyllognathus dionycius* in sugarcane (3 acres each) in 3 villages in Malkapur area of Kolhapur district of Maharashtra. WP formulations of *H. indica* NBAII Hi01, *S. abbasi* NBAII Sa01, *S. carpocapsae* NBAII Sc04, *S. glaseri* Sg01 recovered tillering, cane length, reduced grubs by 48-64% & persisted for 240days in west UP, Maharashtra, Belgaum. Mass produced *H. indica, S. abbasi* and *S. carpocapsae* and supplied their sponge and talc formulations to 14 centres of AICRP Biological control of crop pests, diseases, weeds & nematodes and 10 centres of AICRP white grub and soil arthropod pests.

Technologies related to *in vivo* production of *Heterorhabditis indica* strain NBAIIHi1 were sold to three entrepreneurs including Camson Biotech Ltd., Bangalore, and FARMER, Ghaziabad, generating revenue of Rs. 3.5 lakh.

5.1.14. Studies on *cry* gene diversity

Seven isolates were characterized for the coleopteran specific *cry*3A gene and the complete coding sequence (1.9kb) of *cry*3A and was amplified in 2 isolates. Another coleopteran toxic cry gene (*cry*8a) was characterized in 8 isolates. Sequence analysis of vip3A gene (broad spectrum lepidopteran activity) was completed in 8 isolates. Crude preparations of *vip*3A protein obtained form 20 isolates were tested against *Spodoptera litura* and the protein from two of the isolates (EG1 and BtAN4) showed high toxicity with a LC_{50} value of 9.09 and 9.92 µg/ml respectively.

5.1.15. Evaluation of fungal pathogens on *Aphis craccivora* in cowpea and *Bemisia tabaci* in tomato and capsicum

A field trial for evaluation of entomofungal pathogens on cowpea aphid (*Aphis craccivora*) in cowpea (variety, KBC-2) was carried out. Among the nine isolates tested, Ma-6 & Ma-41 of *M. anisopliae*, Vl-32 of *Lecanicillium lecanii* and Bb-68 of *B. bassiana* reduced 65.60-76.61% of aphids/plant. Evaluation of entomofungal pathogens on *Bemisia tabaci* infestation in tomato (variety, NS501) and capsicum (var. Indira) was carried out in polyhouse. Foliar spray with *B. bassiana* (Bb-9 isolate) reduced 69.29 & 71.17% whitefly population in tomato and capsicum respectively.

5.1.16. Management of pests with pheromone nanogels

Novel nanogels were synthesized in collaboration with Deptment of Organic Chemistry, IISc, using supramolecular self-assembly principles to increase the field-life of various nanogel-absorbed pheromones employed to disrupt the lifecycle of harmful crop pests. Nanogels were also used to prolong the effectiveness of kairomones.

Biosafety of nanoparticles in terms of their effects on natural enemies was established. Non-target effects of chitosan alginate nanoparticles on the biology of *Chrysoperla zastrowi sillemi* were studied through the F1 generations, and it was concluded that there were no lethal effects.

5.2. Biodiversity of biocontrol agents from various agroecological zones

5.2.1. Biodiversity studies (AICRP centres)

***Trichogramma*:** Trichocards with eggs of *Corcyra cephalonica* were placed in cotton, paddy, maize, sugarcane, groundnut and castor fields for parasitism by *Trichogramma* in different geographical areas and collected after 3 days from the fields and observed in the laboratory for emergence of *Trichogramma*. Similarly, eggs of host insects were collected at fortnightly interval from cotton (*H. armigera*), paddy and castor (*A. janata*) crops. As the numbers of *Trichogramma* collected was very low they were each separately multiplied in the laboratory.

In two crosses viz., TFC (male) x TCSHF (female) CA and TFC (female) x TCSHF (male) CB at 27°C the higher fecundity set was selected in F10 generation and shifted to 32°C. The culture of all the sets is maintained and is running in F10 generation at 32°C (IARI).

***Chrysoperla*:** Geographic populations of green lacewing were collected. *Chrysoperla zastrowi sillemi* was found in all the populations.

Coccinellids: Diversity of coccinellids from various crop ecosystem of the region was also studied. Twelve different coccinellids, three different morphs of *Cheilomenes sexmaculata* (Fabricius) along with one parasitoid (*Homalotylus* sp.) were found during *kharif* season.

***Cryptolaemus*:** The natural population of *C. montrouzieri* was not observed throughout the year as the incidence of host insect cotton mealybug was not noticed.

Entomopathogens: Hear NPV was the major insect pathogen present amongst field collections of dead cadavers of *Helicoverpa armigera* along with saprophytic *Bacillus* sp. & *Coccobacillus.* while no entomopathogens were recorded from *Earias Vittella.*

Spiders: Spiders belonging to 7 families and 19 genera were identified from paddy ecosystem. Highest population of spiders of family Araneidae was recorded followed by Tetragnathidae. When segregated based on family, highest population of *Neoscana* sp. was reported followed by *Tetragnatha* sp.

Insect-derived EPNs: 846 soil samples were collected from different geographic locations for isolation of EPNs. Two to three Corcyra larvae were placed at the bottom of containers of each of the above mentioned soil samples retained at the centre. The larvae were examined for mortality at 24 hours interval for 7 days. In the first set, 126 samples were checked and 21 EPN suspected samples found and were sent to NBAII. While in second set of 720 samples only 41 were found positive as EPN.

Anthocorids: Regular surveys were carried out for anthocorid predators on thrips and mite infested plants. No predators were recorded.

Parasitoids of serpentine leaf miner, *Liriomyza trifolii*: Six species of larval and one larval-pupal parasitoids were collected. Larval parasitoids were identified as *Neochrysocharis formosa, Chrysocharis* sp. *Diglyphus* sp, *Asecodes delucchii, Asecodes erxias* and *Hemiptarsenus varicornis,* whereas the larval–pupal parasitoid was identified as *Opius* sp. *N. formosa* was the dominant species (TNAU).

Parasitoids of Pea leaf miner, *Chromatomyia horticola:* Biodiversity of parasitoids of pea leaf miner, *Chromatomyia horticola* was studied on peas under mid hill conditions (1300 m AMSL). Two species of larval parasitoids, namely, *Diglyphus* sp. and *Quadrastichus* sp. and one larval-pupal parasitoid, *Opius* sp. were recorded. *Diglyphus* sp. was the dominant species (TNAU).

Surveys and collection of natural enemies of banana pseudostem weevil and banana aphid, pollu beetle and root mealybug of pepper were carried out in seven agroecological zones of Kerala. Banana Pseudostem weevil - *Odoiporus longicollis* (Oliv.): Three different species of earwigs were collected and were found feeding the eggs of pseudostem weevil. These were sent to Dr. Hedge, Zoological survey of India, Culcutta for identification. Banana aphid - *Pentalonia nigronervosa* Coq. Coccinellid predators collected as natural enemies of banana aphid were *Pseudaspidimerus trinotatus* (Thunberg), *Scymnus pyrocheilus* (Mulsant), *Jauravia soror* Weise and *Scymnus* spp. Hemerobiids (unidentified) were also found feeding on the aphids. Pepper pollu beetle – *Lanka ramakrishnai* Mots. Various predatory spiders were collected from the leaves and were identified as *Araneus bilunifer* (Araneidae), *Argiope pulchella* (Araneidae), *Bavia*

kairali (Salticidae), *Clubiona drassodes* (Clubionidae), *Oxyopes javanus* (Oxyopidae), *Charizopes bengalensis* (Araneidae), *Oxyopes birmanicus* (Oxyopidae), *Oxyopes shweta* (Oxyopidae), *Thiania bhamoensis* (Salticidae) (KAU).

Seasonal abundance of predatory spiders in rice ecosystem: Collection was made during morning hours during Kharif season. Population dynamics of the predatory spiders was worked out using quadrat method. Highest species richness was observed for *Neoscona theisi* (133) and *Leucauge sp.* (133) followed by *Cyrtophora cicatrosa (72), Argiope* sp. *(72), Tetragnatha javana (72)* and *Argiope anasuja (65), Leucauge decorata* (65).Species diversity (H') computed using Shannon-weiner index of diversity was calculated as 2.43 while Species evenness using Kreb's formula came to be 0.678435005. Totally 36 different species belonging to Araneidae, Oxyopidae, Tetragnathidae, Theridiidae, Lycosidae, Thomisidae and Salticidae were identified. Among the different species of predatory spiders, Araneidae was found to be predominant followed by Tetragnathidae and Salticidae **(**AAU-A, KAU, TNAU, AAU-J, ANGRAU, OUAT, CAU).

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Natural enemies recorded in five agro-ecological zones of western Maharashtra were *Coccinella septempunctata* Linn., *Menochilus sexmaculata (*Fab.), *Hippodamia variegata* (Goeze), *Scymnus* sp., *Chrysoperla zastrowi sillemi* (Esben-Petersen) in cotton, *Dipha aphidivora* Meyrick, *Micromus igorotus* Banks, syrphids, spiders on SWA in sugarcane, *Campoletis chlorideae* Uchida on *H. armigera* and *Cotesia* sp. on *Exelastis atomosa* larvae, *M. sexmaculata* in pigeon pea, *Nomuraea rileyi* and *Sl*NPV infection in *S. litura* on soybean, *Coccinella transversalis* F., *M. sexmaculata, Brumoides suturalis* (F.) in maize, *Scymnus coccivora* Ayyar, *Triommata coccidivora* and *B. suturalis* on mealy bug in custard apple, *Acerophagus papayae* N. and S. and *Pseudleptomastix mexicana* N. and S. on papaya mealybug and *Mallada boninensis* (Okam.) on spiraling whitefly on papaya, *Mallada* sp., spiders and anthocorid on mango hoppers and *Illeis cincta* (F.) on mulberry. *C. zastrowi sillemi* was recorded on cotton, maize, pigeon pea and *M. boninensis* on papaya, pomegranate and mango. *Cryptolaemus* grubs were collected from custard apple, papaya and guava orchards. The cadavers of *S. litura* and *H. armigera* infected with *Nomuraea rileyi, Metarhizium anisopliae, Sl*NPV, *Ha*NPV were collected from soybean, potato, pigeon pea, lucerne and isolated in laboratory (MPKV).

Survey and collection of natural enemy complex of pests of apple (Stem borer, San Jose scale, mite and other pests), apricot (borer from Ladakh and other pests), plum, pear, peach, cherry, walnut and almonds wer conducted and 20 different natural enemies including hyperparasitoids were recorded from San Jose scale, woolly apple aphid, *Eriosoma lanigerum*, unidentified apple leaf miner, and codling moth, *Cydia pomonella*.

5.2.2. Pest surveillance in Andaman Islands

Among the key pests rhinoceros beetle (*Oryctes rhinoceros*) was recorded in 1-2% of palms with negligible damage on leaves. In the coconut nursery at CARI farm,

lace bugs (*Stephanitis typica*), spiralling whitefly, (*Aleurodicus dispersus*), coconut scale (*Aspidiotus destructor*), bagworms and slug caterpillar (*Thosea* sp.?) were recorded at low level of infestation. Presence of natural enemies, *viz*., lady beetles (*Chilocorus nigrita*) and *Cybocephalus* sp. and spiders were also recorded. In the Siphighat farm, colonies of palm aphid (*Cerataphis brasiliensis*) were observed on the undersurface of coconut. In addition coconut moth, *Batrachedra arenosella* Walker (Lepidoptera: Cosmopterygidae) was found. During a general observation on the ornamental palm, *Washingtonia* sp., stellate scale, *Vinsonia stellifera* was recorded from one of the palms in Port Blair.

5.2.3. Pest surveillance in Minicoy (Lakshadweep)

Minor occurrence of inflorescence moth, *Batrachedra arenosella* was reported from coconut varieties Laccadive ordinary and LCOD. Rat (*Rattus rattus*) is the major mammalian pest of coconut in the island. All varieties including the coloured genotypes were infested by the coconut eriophyid mite (18-22%) in harvested nuts. Four different types of scale insects *viz*., coconut scale, *Aspidiotus destructor* Signoret (Diaspididae: Hemiptera), pink wax scale, *Ceroplastes rubens* Maskell (Coccidae: Hemiptera), mussel scale, *Lepidosaphes* sp. (Diaspididae: Hemiptera) and a soft scale, *Lecanium* sp. (Coccidae: Hemiptera) were recorded feeding on coconut leaflets / nuts. A mealybug belonging to the genus *Planococcus* sp. (Pseudococcidae: Hemiptera) was also found feeding on the under surface of the coconut leaflets. Two different species of lady beetles *Chilocorus subindicus* Booth (Coccinellidae: Coleoptera) and *Scymnomorphus* sp. (Coccinellidae: Coleoptera) were found predatory on coconut scale insects. In addition to that there was one more effective predator on scale insects *viz*., *Cybocephalus* sp. (Cybocephalidae/ Nitidulidae: Coleoptera). Good establishment of the parasitoid of papaya mealybug, *Acerophagus papayae* as well as the predatory caterpillar, *Spalgis epeus* was observed in the CPCRI farm in most of the mealybug infested papaya plants. The population of *Acerophagus papayae* was so high that the parasitoids were collected and released in other areas.

Mapping of EPN diversity in Punjab: Out of 200 different samples tested, the samples collected from Amritsar and Sangrur caused mortality of *Galleria* larvae and these were found infected with EPN (PAU).

5.3. Surveillance for alien invasive pests

No incidence of alien invasive pests - *Brontispa longissima, Aleurodicus dugesii, Phenacoccus manihoti* and *Phenacoccus madeirensis. Paracoccus marginatus* incidence was observed in Thrissur, Ernakulam and Palakkad districts. But the intensity was very low. The parasitoid *Acerophagus papayae* was also present in all the locations (KAU).

Surveillance for alien invasive pests and their natural enemies on *Paracoccus marginatus, Phenacoccus madeirensis* and others: Surveys conducted in different districts of the state revealed that papaya mealybug, *Paracoccus marginatus* attacked different crops including weeds like *Parthenium*, wild okra, *Cassia occidentalis*, *Cassia*

sp, *Veronica cineraria*;fruit crops like custard apple, ornamentals like *Diffenbachia*, chrysanthemum and marigold besides papaya. Monitoring biodiversity and outbreaks of invasive mealy bugs on cotton: Surveys carried out in various districts of Andhra Pradesh revealed that *Maconellicoccus hirsutus* was the most predominant species of mealybugs found on cotton. *Paracoccus marginatus* and *Phenacoccus solenopsis* were also found to some extent (ANGRAU).

Paracoccus marginatus on papaya and *Phenacoccus solenopsis* on tomato were recorded in Pune region of western Maharashtra (MPKV). Survey of apple and vegetable markets in Srinagar did not indicate the presence of invasive pests like *Aleurodicus dugesii*, *Phenacoccus manihoti*, *Paracoccus marginatus, Phenacoccus madeirensis* (SKUAST). The alien invasive pest *Brontispa longissima* was not reported on coconut from any of the areas surveyed in Kerala, Tamil Nadu, Lakshadweep, Andamans, Assam and Meghalaya (CPCRI). Regular surveys of alien invasive pests were conducted in different districts of Punjab at fortnightly intervals. No invasive pests were observed. The common mealybug species *Planococcus citri* and *Phenacoccus solenopsis* were recorded form citrus and cotton respectively (PAU).

During a survey *Paracoccus marginatus* and *Acerophagus papayae* in Sathiyamangalam**,** Tamil Nadu, a short tailed mealy bug *Pseudococcus jackbeardsleyi* Gimpel & Miller was found together with *P.marginatus* colonizing papaya in two plantations. Four species of mealybugs viz., *Phenacoccus solenapsis, Maconellicoccus hirsutus, Ferrissia virgata* and *Paracoccus marginatus* were recorded on cotton. Survey also indicated that *P. solenopsis* was the predominant species and its hosts included cotton, sunflower, vegetables (brinjal, tomato, bhendi, cucurbits), pulses, calotropis, Datura and Parthenium (TNAU).

Papaya plants in and around Bhubaneswar were found heavily infested with the mealy bug during May, 2011 and subsequently reported from various districts of Odisha. The pest was also recorded from Guava, Okra, Brinjal, Hibiscus, Teak and American silk cotton in and around Bhubaneswar. *Spalgis epius* was found to be feeding on this mealybug everywhere. Among other predators, *Cheilemenes sexmaculata, Scymnus coccivora* and green lace wing larva was found predating on this pest. Three releases of *Acerophagus papayae* (from NBAII) resulted in the reduction of the pest (OUAT).

Acerophagous papayae was mass produced on papaya mealybug grown on potato sprouts. Inoculative releases of adults of *A. papayae* on papaya mealybug infested papaya orchards in Ananthapur districts resulted in establishment of the parasitoid as observed in previous year and complete control of the mealybug in three to four months. An invasive alien mealy bug *Pseudococcus jackbeardsleyi* was reported infesting papaya from Coimbatore region. *Cryptolaemus* was found preying on this mealybug (IIHR).

5.4. Biological suppression of diseases and nematodes

Large scale demonstration was carried out at Palanpur to control whitegrub and root knot nematodes. Forty-five pomegranate growers of the Banaskantha region were

present. Scientists from NBAII explained to the farmers the incidence and factors affecting the activity and mode of action of *Pochonia chlamydosporia* as well as different EPN formulation and demonstrated the methods of application and dose (AAU).

Soil application of *Paecilomyces lilacinus* @ 20 kg formulated dust/ha + organic manure FYM at *bahar* treatment was found most effective in reducing root-knot nematode population in soil (31.7%) and number of root galls/5 g roots (25.4%), and increased fruit yield (19.1 t/ha) with 1:17.3 ICBR. However, *Pochonia chlamydosporium* @ 20 kg/ha + organic manure gave maximum yield (19.2 t/ha) of pomegranate (MPKV).

Biological management of root-knot nematodes, *Meloidogyne hapla* infesting tomato cv. Shalimar 1 in pot**:** Root dip treatment of tomato seedlings with *Paecilomyces lilacinus* @ 2.0 x 10^8 spores/ litre of water 15 minutes before transplantation significantly decreased the soil population of *Meloidogyne hapla* by 85% and increased the yield up to 84% (SKUAST).

Ninety *Pseudomonas* isolates were tested against *Fusarium udum* and 47 of them were found effective. Maximum *Pseudomonas* population was found at Undel region of Assam. Among114 Bacillus isolates tested only 30 were found effective against *F. udum* (AAU-A).

Development of oil-based formulations of selected isolates of *Trichoderma harzianum* and study of their shelf life: Among various isolates maximum CFU was observed in Th-14 (25.7x10^8 CFU/ml) at five months of storage (GBUAT).

Field evaluation of invert-emulsion formulation of *T. harzianum* for the management of foliar and soil borne disease of chick pea crop variety (PG-186) showed that maximum plant stand was observed in carbendazim (69.75 & 110.36%) over control at 45 and 90 days respectively. Least mortality between 45 to 90 DAS was recorded in IEF2 (6.80%) followed by talc (8.66%) as compared to control (32.99%). In rice among all the promising isolates evaluated under field conditions Th-14 was found best in reducing disease and increasing plant vigour and yield of rice (cv Kalanamak-3131). In Lentil (PL5) maximum plant stand was observed in Th-14 (54.08 & 78.52%). Minimum root rot incidence was observed in Th-14 (5.21%) as compared to control (18.19%). In chickpea (PG-186) maximum plant stand was observed in Th-14 (46.30 & 78.52%). Minimum root rot incidence was observed in Th-14 (7.36%) (GBUAT).

Among all fungal formulations tested for foot rot infection in Kinnow, talc formulation of *Trichoderma harzianum* (soil application) and chemical control (Ridomil gold) were on par with each other and yielded maximum number of fruits and fruit weight as compared to other treatments (PAU).

5.5. Monitoring sugarcane woolly aphid (SWA) incidence and impact assessment of natural enemies on its biosuppression

The sugarcane woolly aphid incidence and occurrence of natural enemies (*Dipha aphidivora*, *Micromus igorotus*, *Encarsia flavoscutellum*, syrphid, spider) were recorded at five agro-ecological zones of western Maharashtra. The average pest incidence and intensity were 0.44 per cent and 1.39, respectively. The natural enemies recorded in the SWA infested fields were mainly predators like *Dipha aphidivora* (0.5-2.3 larvae/leaf), *Micromus igorotus* (1.2-5.1 grubs/leaf), syrphid, *Eupeodes confrateor* (0.03-1.1 larvae/leaf) and spider (0.02-0.5 per leaf) . The parasitoid, *Encarsia flavoscutellum* was observed in Pune and Satara districts. These natural enemies were found to be distributed and established well in sugarcane fields and regulated the SWA in western Maharashtra (MPKV).

The sugarcane woolly aphid incidence and occurrence of natural enemies were recorded from seven major sugarcane growing districts covering different agro-ecological zones of Tamil Nadu. The SWA was noticed in patches and the occurrence of *Encarsia flavoscutellum*, *Dipha aphidivora* and *Micromus igorotus* was observed. A maximum of 68.2 *Encarsia*/ leaf was observed in Coimbatore during December 2012. SWA incidence was noticed in all the locations from September-October 2012 to January 2013. *Dipha* and *Micromus* populations were also observed during October 2012 to January 2013 (TNAU).

5.6. Field evaluation of *Trichogramma chilonis* produced using Eri silkworm eggs as factitious host against early shoot borer of Sugarcane

Field evaluation against sugarcane internode borer with release of *Trichogramma* reared on Eri silkworm eggs or on Corcyra eggs @ 20,000/acre was done. Preliminary laboratory studies showed that difference in parasitisation between *Trichogramma* reared on Eri silk worm eggs and that reared on *Corcyra* eggs was only five percent (ANGRAU).

There was a significant reduction in the incidence and intensity of damage due to internode borer infestation by the release of *T. chilonis* reared on Eri silkworm eggs @ 20,000 / acre and release of *T. chilonis* reared on *Corcyra* moth eggs @ 20,000/ acre than the unreleased fields. After eighth release, release of *T. chilonis* reared on Eri silkworm eggs @ 20,000/acre recorded significant reduction of INB (5.4%) as compared to release of *T. chilonis* reared on *Corcyra* eggs @ 20,000/ acre (7.2%). The untreated control recorded higher INB incidence (21.8%) (TNAU)

Evaluation was done in a farmer's field on a 45 days old ratoon crop of sugarcane. The farmer had noticed severe damage by early shoot borer with the symptoms of dead hearts in this field. *T. chilonis* releases were initiated at higher dosages of 40,000 per acre and totally fourteen releases were made. The pest incidence, intensity and infestation index were significantly lower in the treatment plots in comparison to those in the control plot. There was a build up in the pest population and the final yield was recorded as 34.7 tonnes / acre (NBAII).

5.7. Monitoring the diversity and outbreaks of sap sucking pests, mirids and their natural enemies in *Bt* cotton

The *Bt* cotton var. Ankur, Bollgard II was raised separately in the research farm of College of Agriculture, Pune. The sucking pests and natural enemies were recorded from 25 randomly selected tagged plants from the plot at fortnightly interval. Peak incidence of jassids and thrips was recorded during 1st week of November 2012 (46th MW) and whiteflies in subsequent fortnight (48th MW). The aphid population was maximum during 2nd week of January 2013 (2nd MW). Mealybugs incidence and mirids were not observed throughout the crop growth period (MPKV).

Among various sucking insect pests, leafhoppers were maximum during September-October month and moderate during August. Thrips population peaked during August and was low during December month. In general whiteflies population was low during the season. Maximum mirid bug population was recorded in December. Similarly the activity of mealy bug was noticed in first week of December and continued till January and the peak activity of parasitoid was noticed in January Second week (UAS-Raichur).

5.8. Evaluation of IPM for upland rice pests and diseases

Evaluation was done at three locations of East Siang District of Arunachal Pradesh. The incidence of stem borers in the IPM field (2.37 per cent WEH) was comparable with farmer's practice (1.41 per cent WEH). Significantly higher infestation of rice gundhi bug was recorded in untreated control than the other two treatments. The highest grain yield of 46.55q/ha was recorded in farmer's practice field and it was closely followed by IPM practice (43.65q/ha) at Sille. Similarly, at Mebo also, the grain yield of Farmer's practice (42.51q/ha) was comparable with IPM (40.66q/ha). However, at Pasighat, farmers practice (43.84q/ha) gave significantly higher yield than IPM practice (40.37q/ha) (CAU).

5.9. Biological suppression of pests of pulses and oilseeds

Evaluation of NBAII liquid formulations (PDBC-BT1 and NBAII-BTG4) and IARI *Bt* against pigeon pea pod borer (*Helicoverpa armigera*) and legume pod borer (*Maruca testulalis***)** indicated that all the treated plots registered significantly fewer *H. armigera* larvae than the untreated control. All the microbial insecticides were found equally effective in suppressing the incidence of the pest, however, relatively lesser population of *H. armigera* larvae was found in PDBC-BTG4, PDBC-BTG1, IARI *Bt* isolates, and NBAII-BT G4 sprayed at 2% concentration. Pooled results on pod damage also showed the superiority of the above treatments. All the *Bt* based microbial insecticides exhibited grain damage ranging from 7.62 to 10.77% and found on par (AAU-A, ANGRAU, MPKV, PAU, TNAU, JNKVV, UAS-Raichur).

5.10. Influence of crop habitat diversity of natural enemies in pigeonpea through FLD/OFD

Among three modules tested, pigeonpea module with sorghum as the border crop and sunflower as the intercrop recorded least population of *Helicoverpa armigera* larvae. It also recorded maximum population of coccinellids. The population of predatory stink bugs was higher in the pigeonpea module with sorghum as border crop (ANGRAU).

Field experiments were conducted to study the effect of bioagents and botanicals on the incidence of pod borers in pigeon pea. Among the bioagents and botanicals, 2 sprays of 5% CASE was more effective in reducing the mean pod damage (14.52%) followed by two sprays of *B. bassiana* (16.17%) (MPUAT).

5.11. Biological suppression of safflower aphid, *Uroleucon compositae*

Verticillium lecanii was better than *Metarhizium anisopliae* and *Beauveria bassiana* in bringing down population of aphids. *V. lecanii* was on par with neem oil and together they were on par with the insecticidal check on its lower side in recording minimum aphid population (65-123 aphids/10 plants) and maximum yield (469-509 kg/ha). Control recorded maximum aphid number (413-435 aphids/10 plants) and minimum yield (245 kg/ha) (ANGRAU).

Three sprays of dimethoate @ 1.45 ml/lit at fortnightly interval were significantly superior over other treatments in suppressing the aphid population (4.4 aphids/5 cm apical twig) on non-spiny variety of safflower and increased the yield (11.2 q/ha). The treatments with *M. anisopliae* and NSKE 5% were statistically comparable with the superior treatment in respect of safflower yield (MPKV).

5.12. Biological control of groundnut pests

Insecticidal treatment recorded the lowest pest population in all cases with 0.7,0.4 and 0.1 larvae of *S.litura,* leafminer and hairy caterpillar respectively. In case of *S.litura,* incidence in SlNPV treatment (0.9) was on par with the insecticidal treatment (0.7). Against leafminer, Bt treatment(0.9) was again on par with the insecticidal treatment (0.4) and was followed by *Trichogramma* (2.7) and NSKE (2.9). In case of hairy caterpillars, insecticide treatment recorded the lowest pest incidence (0.1) followed by Bt (0.4) and NSKE (0.6). The yield was highest in insecticidal treatment (21.17 q/ha) followed by Bt (18.97 q/ha). Releases of *Trichogramma* was also responsible for good yield with 17.28q/ha. Control plots had the yield of 7.98 q/ha (OUAT).

5.13. Evaluation of entomopathogens and botanicals against soybean pests complex

Three sprays of *Sl*NPV @ 250 LE/ha (1.5×10^{12} POBs/ ha) was significantly superior in suppressing the larval population of *S. litura* (3.0 larvae/m row) with 78.5 per cent mortality due to virus infection and gave maximum of 21.6 q/ha yield of soybean (MPKV).

5.14. Surveillance and need-based control of coconut leaf caterpillar, *Opisina arenosella* in Kerala

Medium level of *Opisina arenosella* incidence was noticed in Puthiyavila (Trivandrum) with leaf infestation of 59.6% and population of 141/100 leaflet. Awareness campaign was conducted in the area in collaboration with Parasite Breeding Station, Trivandrum and Dept. of Agriculture, Kerala. Regular monitoring and release of stage specific parasitoids resulted in 55.7% reduction of leaf damage and 94% reduction in pest population over a period of 8 months. Outbreak of *O. arenosella* was also noticed in Kallara (Kottayam) region during August 2012 with leaf infestation of 83.4% and pest population 288/100 leaflets. Systematic monitoring and release of larval parasitoids *viz.*, *Goniozus nephantidis* and *Bracon brevicornis* could reduce leaf damage (42%) and pest population (93%) in a period of 7 months (CPCRI).

5.14.1. EPN for red palm weevil management

Four species of entomopathogenic nematodes, *viz*., *Heterorhabditis bacteriophora*, *H. indica*, *Steinernema carpocapsae* and *S. abbasi* were evaluated against red palm weevil grubs, *Rhynchophorus ferrugineus* (Olivier) on a filter-paper based bioassay. The local isolate *H. indica* was found to be more virulent inducing 92.5% mortality of red palm weevil grubs @ 1500 infective juveniles (IJ) /grub (CPCRI).

5.15. Field evaluation of *Metarhizium anisopliae* against mango hoppers

Metarhizium anisopliae @ 1 X 10^9 spores/ml reduced population of hoppers on mango effectively. *M. anisopliae* treatments recorded 2.6-2.7 hoppers/infloresence. The chemical spray however recorded the least population (0.5 hoppers/inflorescence), while the control recorded maximum population (6.3 hoppers/inflorescence) (ANGRAU).

Spraying of *M. anisopliae* @ 1 x 10^9 spores/ml during off season in the month of December followed by four sprays of the pathogen mixed with adjuvant (sunflower oil 1 ml/lit + Triton- X 100 @ 0.1 ml/lit) at weekly interval during flowering was significantly superior over other treatments in suppressing the hopper population and increased fruit setting. The mean surviving population was recorded as 10.4 hoppers and 12.1 fruit set per inflorescence in this treatment as against 52.1 hoppers and 6.0 fruits set of mango per inflorescence in untreated control block (MPKV).

5.16. Biological suppression of mealybugs, *Maconellicoccus hirsutus* and *Ferrisia virgata* with *Scymnus coccivora* on custard apple

Two releases of *Scymnus coccivora* @ 10 grubs per infested tree at monthly interval during July-August 2012 were found to be significantly superior in suppressing the population of *M. hirsutus* (9.8 mealy bugs/fruit) and *F. virgata* (3.3 mealy bugs/fruit) in custard apple orchards and increased yield of marketable fruits (34.1 kg/tree). It was, however, on par with similar releases of *Cryptolaemus montrouzieri* @ 5 grubs per infested tree. The pest intensity rating was recorded low (1.0-1.1) in orchards with these treatments (MPKV).

5.17. Economic analysis of impact of release of *Acerophagus papayae* on papaya production, seed production, papaine industry, mulberry and tapioca

Economic analysis of biological control of papaya mealybug with the release of parasitoid *Acerophagus papayae* in farmer's fields in papaya, tapioca and mulberry resulted in a saving of Rs 714.55 crores during 2012-13. The savings from papaya, tapioca and mulberry are 59.95, 514.5 and 140 crores, respectively (TNAU).

5.18. Bioefficacy of EPNs against citrus trunk borer, *Anoplophora versteegi*

Stem injection of EPN resulted in significant reduction of *A. versteegi* infestation. Lowest infestation of 1.13 trunk borer/ plant was recorded in CAUH-1 during July and 0.87trunk borer/plant in NBAII-01 and CAU-1 in August. No significant difference was observed in trunk borer infestation between the different EPN collections during August. Similarly at Ringing, significantly lower infestation of trunk borer was observed in all the EPN collections than the untreated control during July and August except NBAII-01 (1.47 trunk borer/ plant) during July and CAU-2 (1.13 trunk borer/ plant) during August (CAU).

5.18.1. Field evaluation of mass released *Trichogramma embryophagum* against codling moth, *Cydia pomonella* on apple

Two sequential releases of *Trichogramma* spp. @ 2500- 3000 adult wasps/ tree and twice use of pheromone traps @ 4 traps/ orchard were made during the year 2012. Average apple fruit damage (on tree + dropped) in treated orchards ranged between 56.8 and 70.2 per cent, as compared to 79.5 per cent in untreated control. Average catch of codling moth per trap during June and July ranged 119.8 and 41.6 respectively. In terms of per cent reduction in damage over control, treatment T_3 (use of *Trichogramma* + pheromone) was found superior to both T_2 (traps only) and T_1 (use of *Trichogramma* only) (SKUAST).

Evaluation of entomopathogenic fungi and EPNs for the suppression of Apple root borer, *Dorysthenes hugelii* under field conditions revealed that chlorpyriphos (0.06%) gave highest grub mortality (86.4%) followed by (74.4%) by *Metarhizium anisopliae* (10^6 conidia/cm^2). Other biopesticides like *Beauveria bassiana* (10^6 conidia/cm^2), *Heterorhabditis indica* and *Steinernema carpocapsae* (80 IJ/cm^2 each) were moderately effective against apple root borer resulting in 34.0, 45.9 and 34.9 per cent mortality of the grubs, respectively, as against 8.5 per cent in untreated control (YSPUHF).

Testing of predatory mite, *Neoseiulus longispinosus* along with HMO, NeemBaan and fenazaquin against phytophagous mites of apple was conducted on 2-3 year old trees. Three sprays of fenazaquin (0.0025%) at three weeks interval was the most effective showing an average mite population of 2.4 mites/leaf. Three releases of *N. longispinosus* at three weeks interval and HMO (1.0%) + 2 releases of *N. longispinosus* were statistically on par with fenazaquin (0.0025%) (YSPUHF)

5.19. Developing bio intensive IPM package for the pests of Cole crops

A biocontrol based IPM package was evaluated in farmers' field located at Allengmora, Jorhat against cabbage aphid *Brevicoryne brassicae* and other lepidopteran pests of cabbage during *rabi* 2012-13. In the BIPM package the population of *Pieris brassicae* and DBM significantly reduced from 2.45 to 1.34 and 4.85 to 1.94 whereas in farmers practice they were 2.6 to 1.4 and 4.65 to 1.97, respectively after 55 DAT (third spray). Maximum yield (169.9q /ha) was registered in IPM package which was significantly superior to farmers' practice (163.7 q /ha) AAU-J).

Spray of Dipel (4.9 larvae/ plant) was better in reducing the number of larvae of *P. brassicae* on cauliflower and it was significantly on par with quinalphos (5.8 larvae/ plant). Both Dipel and quinalphos were significantly better than mechanical collection (11.6 larvae/ plant) (PAU).

Comparison of *T. chilonis* and *T. brassicae* in terms of reduction of DBM larvae after each release indicated significant difference between the two species used. Overall per cent decline in larval density caused by *T. chilonis* and *T. brassicae* was 33.7 and 20.1, respectively which indicated the supremacy of *T. chilonis* over *T. brassicae* against DBM on Knol khol (SKUAST).

5.19.1. Evaluation of microbial pesticides against diamond back moth (DBM) (CAU)

Onet round of spray of profenophos recorded lowest the mean population of DBM (0.02 larvae/leaf) followed by EPN (CAUH-I), Bt (NBAII) and EPN (CAU-I). Among the entomopathogenic microbes, Bt (NBAII) recorded the lowest population (0.22 larvae/leaf). *M. anisopliae* was found as least effective (CAU).

5.19.2. Field evaluation of thelytokous and arrhenotokous strains of *Trichogramma pretiosum* against *H. armigera* on tomato

Six releases of *T. pretiosum* thelytokous strain @ 1 lakh parasitoid/ha at weekly interval was significantly superior in suppressing *H. armigera* (1.9 larvae/10 plants) and increasing marketable fruit yield of tomato (223.5 t/ha) compared to arrhenotokous strain of the parasitoid. The parasitism was higher in thelytokous (56.2%) than arrhenotokous (46.5%) strain of the parasitoid (MPKV).

5.19.3. Evaluation of different BIPM modules against shoot and fruit borer, *Leucinodes orbonalis* in brinjal

Three sprays of profenophos (0.05%) at fortnightly interval were found significantly superior in reducing the shoot (9.0%) and fruit (9.6%) infestation and gave maximum marketable yield (228.7 q/ha). However, the BIPM module consisting release of *T. chilonis f*ollowed by spraying of NSKE 5% and *Bt* @ 1 lit./ha twice at weekly

interval was the next best treatment showing 9.9% shoot and 15.3% fruit infestation with 42.5% parasitism (MPKV).

Least incidence of the shoot borer was recorded in the insecticidal treatment. The incidence of shoot borer ranged from 8.8 to 11.6 % in rynaxypyr at various locations. However, BIPM treatment was on par with rynaxypyr in all locations recording 11.4 to 12.8% shoot borer incidence as against 29.3 to 29.9 % in untreated control. The control plots recorded 36.0 to 39.7% fruit damage (OUAT).

5.19.4. Biological suppression of onion thrips, *Thrips tabaci* with predatory anthocorid and microbial agents

Three sprays of profenophos at fortnightly interval were found significantly superior to other treatments in suppressing thrips (av. 3.1 thrips/plant) with 1 rating of intensity of white patches. However, 3 sprays of *M. anisopliae* @ 10^8 cfu/ml which showed av. 7.5 thrips/plant and 1.5 rating of white patches on leaves was the next best treatment in this respect (MPKV).

5.19.5. Identification of major aphid parasitoids and their extent of parasitism in mustard and cabbage

The extent of parasitism increased with the rise in temperature and maximum parasitization was recorded in the third week of March which was as high as 88.6% in mustard and 92.6 % in cabbage. Validation of BIPM of major insect pests in tomato in farmer's field revealed that field parasitism gradually increased to a maximum in *T. pretiosum* (thelytokous) and showed less mean fruit damage (15.2%), over rest of treatments (MPUAT).

5.19.6. Evaluation of anthocorid predator *Blaptostethus pallescens* against mite, *Tetranychus urticae* on brinjal and okra

In brinjal release of *B. pallescens* @ 10 per plant recorded 110.40 mites/10 plants which was far superior as the untreated plots recorded 765.80 mites/10 plants. Maximum webbings/10 plants were observed in control plots (29.75) followed by predator released plots at 30, 20 and 10 *B. pallescens*/10 plants, respectively. In okra release of *B. pallescens* @ 10/plant recorded 151.30 mites/10 plants which was far superior compared to untreated plots (326.8 mites/10 plants). Maximum webbing/10 plants was observed in control plots (21.4) followed by *B. pallescens* released plots at 30, 20 and 10 /10 plants, respectively (OUAT).

All the doses of *B. pallescens* i.e. @ 10, 20 and 30 nymphs/ plant were on par with one another and better than untreated control in minimizing the population of mites on brinjal. With an initial population of 63.5-69.0/plant, the mite population reduced to 14.1-31.3/ plant. However, Omite @ 300ml/ plant was found better than *B. pallescens* releases/plant and untreated control. In Omite treated, the population reduced to 1.0- 1.6 mites/plant. *B. pallescens* along with Omite/ac can be included in the IPM of *T. urticae* on brinjal in polyhouse. In okra release of *B. pallescens* @ 30 nymphs/ plant was found

best (11.40 mites/ plant) and it was significantly on par with *B. pallescens* @ 20 nymphs/plant (17.80 mites/plant) in reducing the mites. Both of these bioagent release doses were also significantly on par with omite (9.53 mites/ plant). Hence *B. pallescens* @ 20 nymphs and 30 nymphs/plant along with Omite 300 ml/ac can be included in the IPM *T. urticae* on okra in nethouse (PAU).

5.19.7. Studies on effectiveness of bioagents and botanicals against aphid, *Lipaphis erysimi* infesting mustard

Among the different bioagents and botanicals evaluated, the mean per cent reduction in aphid population was more in 2 sprays of NSKE 5% (54.82), which was statistically at par with 2 sprays of *Veticilium* sp. (52.58) However, 2 sprays of imidacloprid was most effective in mean per cent reduction (79.74) of *L. erysimi* population at 7 days after 2nd spray and yielded 9.52, 9.44, 10.85 q/ha, respectively over control 6.20 q/ha **(**MPUAT**).**

5.20. Population dynamics of tea mosquito bugs in tea and its natural enemies

Except *Oxyopes* sp. no other was observed to predate on the host provided. The predation rate of *Oxyopes* sp. was 7.80. The incidence of *Helopeltis theivora* in April 2012 was initially low with a population of 4.67 / 3 shoots. .Peak population of the pest was recorded in September 2012 (25.00 /3 shoots). The second highest population (18.67/3shoots) was observed during October 2012. The nymphal population of *H. theivora* decline abruptly from November 2012. The abrupt decline was mainly due to the fact that the crops by then were approaching pruning and there was lack of fresh new shoots to sustain the pest. The pest completely disappeared from the field from January and February 2013 and reappeared from March 2013 with a population of 3.30/3 shoots (AAU-J).

5.21. Biological Suppression of Polyhouse crop pests

5.21.1. Evaluation of Biological Control Agents against Mites in Carnation under protected condition

Among biocontrol agents, release of coccinellid beetle, *Stethorus pauperculus* and predatory mite, *Amblyseius* sp @ 10 and 5 mites/ plant were effective in reducing two spotted spider mite, *Tetranychus urticae* which were on par, followed by *Beauveria bassiana* 10^8 CFU/ ml spray. However, two sprays of the standard acaricide, abamectin 1.9 EC @ 0.3 ml/ litre reduced the mite population (1.3 / 10 plants) significantly over all other treatments evaluated. The untreated check recorded the highest mite population of 78 / 10 plants 7 days after second treatment. The highest yield of 2465 numbers of flush/ plot were recorded in abamectin treated plot followed by *Stethorus*, *Amblyseius* sp, *Beauveria bassiana* biocontrol plots. Untreated check recorded the lowest yield of 1540 kg (TNAU).

5.21.2. Evaluation of predatory mite, *Neoseiulus longispinosus* against phytophagus mite in carnation under polyhouse condition

Results indicated that profenophos (0.05%) was the most effective treatment resulting in 87.5 per cent reduction of mite population over control, which was, however, statistically on par with three releases of *N. longispinosus* at 1:10 predator: prey ratio where the corresponding reduction was 73.8 per cent. Other biocontrol agents like, Neem Baan (3ml/L), and *N. longispinosus* at predator: prey ratio of 1:20 and 1:30 resulted in 62.3, 69 and 62 per cent reduction of mite polulation over control, respectively. All these treatments were statistically on par with each other and also with *N. longispinosus* at 1:10 predator: prey ratio (YSPUHF).

5.21.4. Biological suppression of thrips on capsicum in polyhouse

The effectiveness of biological control agents Entomopathogens and predator *B. pallescens*, botanicals, and chemicals were carried out against *S. dorsalis* on capsicum F1 hybrid, Indra. Results indicated no increase in the rating of thrips in all treatments while in control it recorded 2.6 (ranged from 1.0 to 5.0 rating) (IIHR).

5.21.5. Biological management of root knot nematode infesting tomato, gerbera, carnation in poly houses

In a pot trial conducted to evaluate the fungal biocontrol agent *Paecilomyces lilacinus* and chemical, abamectin against root-knot nematode *Meloidogyne hapla* infesting tomato cv. Shalimar 1, a significant reduction in soil population of nematodes was observed in treated seedlings as compared to untreated. Highest reduction in soil population of nematodes was 85% in *P. lilacinus* (2.0×10^8 spores/ lit of water) followed by Abamectin (1.0 ml/ lit of water) where it was 78.0% (SKUAST).

5.22. Storage Pests - Evaluation of anthocorid predators against storage pests in rice

Inoculative release of *Xylocoris flavipes* @ 30 nymphs per kg of stored rice (18.00 moths/ container) was significantly superior to all other treatments in reducing the emergence of *Corcyra* moths. However, *B pallescens*,@ 30 nymphs/container and *X. flavipes* @ 10 nymphs / container were on par with each other where 32.5 and 36.0 moths emerged respectively from these treatments **(**AAU-J)

6. Director's visit to AICRP centers

S. N	Dates	Place of visit	Highlights of visit
1.	3.4.12 to 6.4.12	AAU-Jorhat and CAU-Pasighat	Reviewed the progress of work of AICRP on BC centres at College of Horticulture and Forestry, Pasighat on 4th April, 2012 Reviewed the progress of work of AICRP on BC centres at Assam Agricultural University, Jorhat on 5th and 6th April, 2012
2.	16.4.12 to 19.4.12	PAU, Ludhiana	Organized QRT meeting of the NBAII at PAU, Ludhiana from 16th to 19th April, 2012. . The chairman and members of QRT, NBAII were present
3.	21.5.12 to 22.5.12	ANGRAU Hyderabad,	Organised the workers group meeting of AICRP on BC at ANGRAU, Hyderabad from 21st to 22nd May, 2012
4.	30.5.12	OUAT, Bhubaneshwar	Due to outbreak of papaya mealybug a serious problem on horticultural and other crops in Bhubaneshwar and the concerned authorities at Bhubaneshwar have requested this bureau to release the parasitoids. Accordingly I carried the culture of the parasitoids to Bhubaneshwar released on 30th May, 2012.
5.	5.11.12 to 6.11.12	AAU, Anand	Reviewed the progress of work of AICRP on BC centre at Anand Agricultural University, Anand on 5th November, 2012. Participated in the Farmers Meet on 6th November, 2012 Umiyanagar in Palanpur wherein large scale demonstration took place in order to create awareness and to educate them about the technologies available for the control of root knot nematodes in pomegranate crop amongst the farmers.
6.	5.12.12 to 7.12.12	New Delhi	Participated in the meeting of Project Coordinators of AICRPs and Network Project Coordinators under the chairmanship of Hon'ble DG, ICAR held on 5th and 6th December, 2012 at NBPGR auditorium, New Delhi.
7.	11.2.13 to 14.2.13	IARI, New Delhi	Reviewed the progress of work of AICRP centre at IARI, Pusa Centre on 11th February, 2013.
8.	18.3.13 to	ICAR	Had discussions on XII plan fund allocation with

	22.3.13	New Delhi	AICRP on BC at IARI, New Delhi centre on 21st March, 2013.

7. Publications

During the year 2012-13, a total of 217 research papers, scientific/symposium papers/review/Technical Bulletins, etc., were published by the different centers (based on information provided by centers). The details on number of publications from each

Center	Research papers published in scientific journals	Papers presented in symposia / seminars etc.	Book chapters/Tech. Bulletin/ popular articles etc.	Total
NBAII, Bangalore	40	45	7	**92**
ANGRAU, Hyderabad	-	-	-	**-**
AAU, Anand	2	19	2	**23**
AAU, Jorhat	1	-	6	**7**
GBPUAT, Pantnagar	8	13	-	**21**
KAU, Thrissur	1	1	-	**2**
MPKV, Pune	3	2	4	**9**
PAU, Ludhiana	8	6	6	**20**
SKUAST, Srinagar	-	-	-	**-**
TNAU, Coimbatore	9	3	-	**12**
YSPUHF, Solan	1	3	3	**7**
CAU Pasighat	-	-	-	**-**
JNKVV, Jabalpur	-	-	-	**-**
MPUAT, Udaipur	-	-	-	**-**
OUAT, Bhubaneswar	3	-	-	**3**
CPCRI, Kayangulam	4	4	2	**10**
CTRI, Rajamundry	-	2	1	**3**
IIHR, Bangalore	4	4	-	**8**
IARI, New Delhi	-	-	-	**-**
IISR, Lucknow	-	-	-	**-**
Total	**84**	**102**	**31**	**217**

***8. Profile of experiments and demonstrations carried out during 2012-13**

Crop/Insect	Experiments	Large scale Demonstrations*
Rice	3	3
Maize	1	1
Sugarcane	3	5
Cotton	2	0
Tobacco	2	0
Pulses	2	0
Oil seeds	3	0
Vegetables	9	0
Tropical fruits	7	0
Temperate fruits	5	0
Coconut	3	1
Tea mosquito bug	2	0
Mealybugs	3	0
Storage pests	2	0
Weeds	2	0
PPNs & Antagonists	8	1
Polyhouse crops	6	0
Total	**63**	**11**

9. Enabling large scale adoption of proven biocontrol technologies

Following large scale demonstration trials were taken up at different AICRP centres during 2012-13.

1. Rice- AAU-J (Adat model), KAU (Adat model), OUAT (Large scale adoption of proven bio control technologies)

2. Sugarcane

i. Large scale demonstration of biocontrol for suppression of plassey borer, *Chilo tumidicostalis* using *Trichogramma chilonis* (ANGRAU)

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

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

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

v. Large-scale Demonstration on the use of *T.chilonis* against early shoot borer and internode borer of Sugarcane in Farmers' field (OUAT, ANGRAU)

3. Maize

i. Demonstration of Biological control of maize stem borer, *Chilo partellus* using *Trichogramma chilonis* and *Cotesia flavipes*

4. Coconut

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