# Project Coordinator's Report







XXVIII AICRP - Biocontrol Workshop
6 - 8 June, 2019

# AICRP on Biological Control

ICAR-National Bureau of Agricultural Insect Resources
Bengaluru 560 024

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

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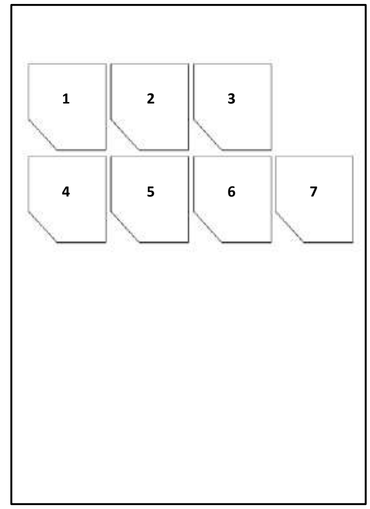


**Cover page**

1. *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae)

2. *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae)

3. *Eriosoma lanigerum* (Hausmann) (Hemiptera: Aphididae)

4. *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae)

5. *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae)

6. *Scirpophaga incertulas* (Walker) (Lepidoptera: Crambidae)

7. *Paraleyrodes bondari* Peracchi (Hemiptera: Aleyrodidae)

**Photo credits**: Photographs 1 – K. Selvaraj; 2, 3, 4 and 6 – J. Poorani; 5 – Omprakash Navik;
7 – CPCRI, Kayamkulam



**Cover design**: Sunil Joshi

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Date: 23.05.19
Bangalore

Dr. Chandish R. Ballal
Director, ICAR-NBAIR &
PC, AICRP-Biological Control

## 1. Introduction

AICRP on Biological Control was initiated during the year 1977 for minimizing the application of chemical pesticides and to develop eco-friendly biological control methods for the sustainable management of pests. As a result, several new approaches have been developed and biocontrol technologies have been standardized and field-tested for wider acceptance by the end users, the farmers. Efficient methods of mass multiplication of parasitoids, predators and pathogens against insect pests and antagonists against plant pathogens and plant parasitic nematodes have been developed. Similarly, biocontrol technologies for weed management have been developed. The field demonstrations through AICRP centers have increased the awareness of farmers regarding the usefulness of biological control based pest management.

Diversity of natural enemies, nematodes, entomopathogens and plant disease antagonists have received maximum attention. Collection and cataloguing of agriculturally important insects have been carried out covering vast geographical areas. Efficient protocols have been developed for mass multiplication of parasitoids, predators and pathogens against insect pests and antagonists, plant pathogens and plant parasitic nematodes. Cultures of biocontrol agents have been supplied to the commercial producers, state departments of Agriculture/Horticulture KVKs, researchers, students and farmers along with training on mass production and application technologies. Several agencies are now supplying biocontrol agents to the needy farmers. The field demonstrations through AICRP centers have created awareness amongst farmers regarding the usefulness of biological control in IPM modules.

The potential bioagents/biopescticides developed at ICAR-NBAIR and the other AICRP biocontrol centres are being validated under the AICRP-BC network. The success achieved in the biological control of papaya mealybug, sugar cane woolly aphid, eucalyptus gall wasp, root grubs and several others notorious indigenous and exotic pests is being successfully sustained through constant monitoring and redistribution/conservation of biocontrol agents. The AICRP BC has played a prominent role in monitoring the entry and spread of invasive. The recent invasive managed through AICRP-BC initatives are tomato pinworm, *Tuta absoluta* and the rugose spiraling whitefly, *Aleurodicus rugioperculatus* and the fall armyworm (FAW) *Spodoptera frugiperda* infesting maize. The main centre of AICRP-BC at NBAIR and its centres in Karnataka, Tamil Nadu, Telengana, Andhra Pradesh, Maharashtra, Odisha, and Gujarat were responsible for alerting not only the nation but also the neighboring countries on the entry of FAW and in recommending sustainable management advisories and providing biocontrol inputs.

During the current EFC for the period 2017-2020, the AICRP-BC which comprised of 16 centres has been strengthened through addition of 13 centres, thus currently having a strong network of 28 centres plus the PC cell.

## 1. Mandate of AICRP on Biological control of crop pests

- To evolve effective biological control strategies for important insect pests, plant pathogens and nematodes.
- To co-ordinate research on biological control aspects at national level.
- To serve as nodal agency for introduction, exchange and conservation of biological control agents at national level.
- To disseminate information and impart training on biological control

## 2. Setup

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

**State Agricultural University–based centres**

1. Acharya N.G. Ranga Agricultural University, Anakapalle
2. Anand Agricultural University, Anand
3. Assam Agricultural University, Jorhat
4. Dr. Y.S. Parmar University of Horticulture and Forestry, Solan
5. Govind Ballabh Pant University of Agriculture and Technology, Pantnagar
6. Kerala Agricultural University, Thrissur
7. Mahatma Phule Krishi Vidyapeeth, Pune
8. Pandit Jayashankar Telangana State Agricultural University, Hyderabad
9. Punjab Agricultural University, Ludhiana
10. Sher-e-Kashmir University of Agricultural Science & Technology, Srinagar
11. Tamil Nadu Agricultural University, Coimbatore
12. Central Agricultural University, Pasighat
13. Maharana Pratap University of Agriculture & Technology, Udaipur
14. Orissa University of Agriculture & Technology, Bhubaneswar
15. University of Agricultural Sciences, Raichur
16. Indira Gandhi Krishi Viswavidhyalaya, Raipur
17. KAU-Regional Agricultural Research Station, Kumarakom
18. KAU-Regional Agricultural Research Station, Vellayani
19. Dr. Y S R Horticultural University, Ambajipeta

**ICAR Institute–based centres**

1. Central Institute of Subtropical Horticulture, Lucknow
2. Central Plantation Crops Research Institute, Kayamkulam
3. Central Tobacco Research Institute, Rajahmundry
4. Indian Institute of Rice Research, Hyderabad
5. Indian Institute of Millet Research, Hyderabad
6. Indian Agricultural Research Institute, New Delhi
7. Indian Institute of Horticultural Research, Bangalore
8. Indian Institute of Vegetable Research, Varanasi
9. National Centre for Integrated Pest Management, New Delhi

**Voluntary Centres**

1. Uttar Banga Krishi Viswavidyalaya, Pundibari, West Bengal
2. Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola
3. Sun Agro biotech Chennai
4. School of Agriculture Science & Rural Development, Medziphema Campus, Nagaland University

The results from the various experiments conducted at centres across the country during the year 2018-19 are presented below.

## 4. Brief summary of research achievements

### 4.1 Basic research work at National Bureau of Agricultural Insect Resources

#### 4.1.1 Taxonomic and biodiversity studies on parasitic Ichneumonid and chalcid wasps

The natural enemy complex of *Spodoptera frugiperda* (J. E. Smith) (Insecta: Lepidoptera: Noctuidae), commonly known as fall armyworm, was reported for the first time from India. Natural parasitism by egg parasitoids *viz*., *Telenomus* sp. (Hymenoptera: Platygastridae) and *Trichogramma* sp. (Hymenoptera: Trichogrammatidae), gregarious larval parasitoid *Glyptapanteles creatonoti* (Viereck) (Hymenoptera: Braconidae), solitary larval parasitoid *Campoletis chlorideae* Uchida (Hymenoptera: Ichneumonidae), and two braconid larval parasitoids *Phanerotoma* sp. (Hymenoptera: Braconidae) and *Chelonus* sp. (Hymenoptera: Braconidae), a solitary indeterminate larval-pupal (Hymenoptera: Ichneumonidae: Ichneumoninae) parasitoid and pupal parasitoid *Trichomalopsis* (Hymenoptera: Pteromalidae) were documented. *Spodoptera frugiperda* is the first host record for *G. creatonoti* across the globe. *Glyptapanteles creatonoti*, being a well established parasitoid of various noctuids in India and Malaysia, was capable of parasitizing *S. frugiperda*. Besides these, other commonly found bioagent *viz*., *Forficula* sp. (Dermaptera: Forficulidae) was identified.

#### 4.1.2 Diversity of Trichogrammatids

Trichogrammatids were collected from the states viz., Kerala, Assam, Karnataka and Gujarat in the agricultural field, horticultural crops, grassland and from the forest areas. Total 10 genera of trichogrammatids were collected from Karnataka, Kerala, Assam & Gujarat through sweeping net, yellow pan trap and by placing sentinel cards in different ecosystems. The genera *Trichogramma*, *Trichogrammatoidea*, *Megaphragma*, *Paracentrobia*, *Chaetogramma* and *Oligosita* were collected from Gujarat, while, *Megaphragma*, *Neocentrobiella*, *Oligosita* and *Trichogrammatoidea* were collected from Assam. The genera *Megaphragma*, *Neocentrobiella***,** *Paracentrobia*, *Tumidiclava* and *Aphelinoidea* were recorded for the first time from the Assam, and the genera, *Megaphragma* and *Neocentrobiella* collected from the Gujarat. A total of 1587 host eggs belonging to different insect species were collected. In addition, about 670 eggs masses of *Spodoptera frugiperda* from maize were collected at different places in Karnataka. *Trichogramma* sp. was collected from the naturally parasitized eggs of *S. frugiperda* infesting maize. Also, *T. chilonis* and *T. achaeae* were collected from naturally parasitized eggs of *T. absoulta*.

#### 4.1.3 Spider diversity and biocontrol potential of social spider

Two hundred and fifty spider specimens have been collected from surveys undertaken in five states representing different agri-horti ecosystems like rice, red gram, maize, sunflower, Litchi. One hundred fifty specimens were identified up-to generic level. During this period 2018-19, 25 spiders including two new families were added into the existing spider repository. Rice ecosystem claims more spider diversity and has a great scope for insect pest management, due to their predatory potential. Orb-weaving spiders appear to be of higher significance because of trapping more insects than they consume. Conservation strategies are mainly adopted in case of spiders to achieve the predatory role in crop fields. *Stegodyphus* (Eresidae family), commonly called social spiders namely *S. mirandus*, *S. pacificus*, *S. sarasinorum* and *S. tibialis* have been reported from India. Out of these, *S. Sarasinorum* is the predominant one can find many numbers depending up on the web size ranging between 100 and 1000 are capable of capturing prey as large as 10 times their size are advantageous from biological control perspective.

### 4.1.4 Predator prey interaction of mirids, geocorids, anthocorids and mites

**Biology of predatory mirid, *Dortus primarius***

*Dortus primarius* Distant (Miridae: Deraeocorinae) is a predatory mirid and it was observed to feed on thrips and other soft bodied insects in the field. Biology, morphology and feeding potential of this species were studied for the first time in the laboratory (at 26±2$^{O}$ C and 65±2% RH) on UV irradiated *Corcyra cephalonica* (Stainton) eggs. A total of five instars were observed, with nymphal duration of 17.2 days. Mean fecundity was 127.6 eggs per female. Female longevity was higher than male. One nymph could consume a total of 363 *C. cephalonica* eggs in its life span. Adult male and female fed on a total of 713 and 1014.75 eggs, respectively. Cost of producing 100 *D. primarius* nymphs and adults was INR 10.34/- and INR 200/- , respectively. This species could be reared on UV irradiated *C. cephalonica* eggs and bean pieces successfully.

**Feeding efficiency of predatory mirid, *Termatophylum orientale* against *Frankliniella schultzei***

Laboratory evaluation of *Termatophylum orientale* was done against *Frankliniella schultzei* and it was observed that 4$^{th}$ and 5$^{th}$ instars consumed more number of thrips at 1:30 density while adult consumed more number of thrips at 1:40.

**Predatory efficiency of *Geocoris ochropterus* against red spider mites:**

Efficiency of *G. ochropterus* was evaluated against red spider mites on tomato plant. When *G. ochropterus* was released @ 10 nymphs /plant it could reduced infestation by 76.21 % compared to control. There was no significant difference in reduction in mite population when *G. ochropterus* nymphs were released @ 20 nymphs/plant and 30 nymphs /plant.

### 4.1.5 Studies on Fall Army Worm, *Spodoptera frugiperda*

**Molecular Characterization and preliminary survey of FAW:**

Based on the surveys conducted from July to August 2018 by ICAR-NBAIR team, *S. frugiperda* was recorded from many locations in Karnataka on maize crop. Surveys were conducted in several districts of Karnataka comprising of Chikkaballapur, Hassan Shivamogga, Davanagere and Chitradurga, Raichur, Dharward to record the incidence of *S. frugiperda* where the maize crops were between the age of 15−60 days. The incidence ranged from 9.0 to 62.5% at various locations, maximum incidence was recorded in Hassan district followed by Chikkaballapur, Davanagere, Shivamogga and Chitradurga. Molecular characterization showed 100% resemblance of hasan population with the sequences submitted from Canada (GenBank: GU095403.1) and Costa Rica (GenBank JQ547900.1).

**Studies on the effect of entomopathogenic fungi on maize Fall armyworm (FAW) *Spodoptera frugiperda***

Ten entomofungal strains were evaluated against 2nd instar larvae of *S. frugiperda* in the Lab. bioassay. The strains used in the study include *Beauveria bassiana* (ICAR-NBAIR Bb5a, Bb-11 Bb-45), *Metarhizium anisopliae* (ICAR-NBAIR Ma-4, Ma-35, Ma-11, Ma-14, Ma-15) and *Nomuraea rileyi* (ICAR-NBAIR Nr-Sf1 and Nr-1). Among the ten EPF isolates tested, *M. anisopliae* NBAIR- Ma-35 caused 67.8% mortality followed by *B bassiana* NBAIR- Bb-45 with 64.3% and Bb-11 with 57.1%. Rest of the isolates showed 10.7- 28.6% mortality.

Field evaluation with *B. bassiana* (ICAR-NBAIR Bb-45) and *M. anisopliae* (ICAR-NBAIR Ma-35) were carried out against *S. frugiperda* in maize (Var. BRMH-1 hybrid) during rabi season at Yalahanka Farm, (Nov, 2018 to Feb. 2019). Three foliar sprays @ 5g/litre (rice grain formulation containing $1x10^8$ spores/g) at 15, 30 & 45 days of the crop stage were given. ICAR-NBAIR-Bb-45 and Ma-35 showed 56-80% of pest reduction.

**Studies on virus infecting FAW, *Spodoptera frugiperda***

Surveys were made at maize and sugarcane fields of Chikkapallapura, Pugalur, Coimbatore and Jolarpettai and collected diseased larvae of maize fall armyworm *Spodoptera frugiperda* which were showing characteristic viral infection symptoms. Bioassay studies revealed that larval mortality was observed at low doses of SfNPV with the $LC_{50}$ of $1 \times 10^6$ OBs/ml against second instar larvae of *Spodoptera frugiperda*. The 95% fiducial limits ranged from 1.216 to 3.457. The LC50 values observed for second instar larvae were 2.17 POBs/$mm^2$ for SfNPV. Field evaluation of *S.frugiperda* NPV is progressing

**IPM trial on management of fall armyworm in rabi maize.**

IPM trial was conducted to manage fall armyworm at Manchanahalli, Gauribidnaur, Karnataka covering 1.5 acre area. F**ollowing IPM interventions were made:**

- Pheromone traps: 20 days after transplanting @ 10 traps/acre
- Release of egg parasitoids: *Telenomus remus* (4000/acre) and *Trichogramma pretiosum* (1 trichocard/acre): total 4 releases at weekly interval from 20 days old crop onwards
- Neem oil (3 ml/litre): only 1 spray after 1 week of first release of egg parasitoids.
- *Bt* spray : only 1 spray after 15 days of first neem oil spray
- *Beauveria bassiana* (Bb-45) and *Metarhizium anisopliae* (Ma-35): only 1 spray after 10 days of *Bt*

In IPM field, per cent decrease in egg mass was 98% at 80DAT compared to 8.5% decrease in farmer's practice. Similarly larval population also decreased by 79.16% in IPM field compared to farmer's practice where 12.5% reduction was observed. Every week more than 20 adults were caught in pheromone traps. In IPM field per cent parasitism by *Trichogramma sp.* varied from 8.19-18.25%. Per cent parasitism was higher for *Trichogramma sp.* compared to *T. remus*.

**4.1.6 Studies on coconut Rugose spiraling whitefly *Aleurodicus rugioperculatus***

***In vitro* evaluation of entomopathogenic fungus, *Isaria fumosorosea* against coconut rugose spiraling whitefly**

Two isolates of *Isaria fumosorosea* (*Paecilomyces fumosoroseus*) (ICAR-NBAIR Pfu-1 and Pfu-5 were tested against rugose spiraling whitefly (RSW). Spore suspensions of these isolates at the dose of 1x$10^8$ spores/ml were used in the laboratory bioassay. Significantly higher suppression of egg hatching (64-79%), mortality of early nymphal instars (57-78%) and late nymphal instars (56-74%) was observed in both the isolates of Pfu-1 and Pfu-5 in comparison to control. The growth and sporulation of the *I. fumosorosea* was noticed on the eggs and nymphs of RSW after 3 days of treatment.

**Field evaluation of *Isaria fumosorosea* (NBAIR Pfu-5) against rugose spiraling whitefly on coconut and oil palm**

Field experiments were conducted at Nelamangala, Bengaluru rural district, Karnataka (one garden) during July –November, 2018 and in Rajahmundry, East Godavari and West Godavari districts, Andhra Pradesh (two gardens) during November-December, 2018 to evaluate the efficacy of *Isaria fumosorosea* against rugose spiraling whitefly on coconut and oil palm. The results revealed that *I. fumosorosea* Pfu-5 reduced the egg hatching (62-78%), caused mortality on early nymphal instars (52-68%) and late nymphal instars (48-63%) with overall reduction upto up to 60-79% at different location. The fungus kill the all the developmental stages of RSW under field conditions.

**4.1.7 Endophytic establishment of *Beauveria bassiana* (Bb-5a & Bb-45) and *Metarhizium anisopliae* (Ma-4 & Ma-35) in cabbage for management of diamond back moth (*Plutella xylostella* (L.)**

A glasshouse experiment was conducted to examine the endophytic ability of two isolates each of *B. bassiana* (Bb-5a & Bb-45) and *M. anisopliae* (Ma-4 & Ma-35) in cabbage root, stem and leaf tissues by seed treatment, root inoculation and foliar application. In foliar application technique, all four isolates showed colonization and persistence in stem and leaf tissues upto 15DAT. Bb-45, Ma-4 and Ma-35 isolates showed colonization and persistence upto 60DAT in leaf tissues Ma-4 isolate showed colonization only in stem and persisted upto 60DAT. SEM studies showed conidial germination and penetration of germ tube into the leaf tissues after five days of treatment with the four isolates tested. TEM studies showed the presence of conidia inside the parenchymatous and mesophyll cells of the treated leaves after 15 days.

**4.1.8 Field evaluation of *Spilosoma obliqua* nucleopolyhedrovirus (SpobNPV) in jute**

Field evaluation on *Spilosoma obliqua* nucleopolyhedrovirus (SpobNPV) in jute revealed that 68.92%, 78.59% and 93.16% reduction in larval population of jute hairy caterpillar *S. obliqua* respectively at 3, 4, 7 days after spray of SpobNPVstrain NBAIR ($1.5 \times 10^{12}$ POBs/ha @ 2ml/L).

**4.1.9. Field evaluation of *Spodoptera mauritia* NPV (SpmaNPV) against Rice armyworm**

Field evaluation of *Spodoptera mauritia*NPV (SpmaNPV) against Rice armyworm *Spodoptera mauritia* was carried at Moncompu, Kerala. All the three concentrations of NPV ($1\times 10^7$

POBs/ml, 1 × $10^6$ POBs/ml, 1× $10^5$ POBs/ml) were found effective in reducing the larval population of armyworm. The number of larvae recorded for all the concentrations ranged from 1.33 to 3.75 where as it was 0.75 in the insecticide chlorpyrifos. The concentration 1× $10^7$ POBs/ml was found most effective in reducing the larval numbers from 36.45 to 1.33 followed by concentration 1 × $10^6$ POBs/ml which reduced from 40.25 to 3.15 and the concentration 1× $10^5$ POBs/ml reduced from 38 to3.75. The insecticide chlorpyrifos reduced the larval numbers from 38 to 0.75.

#### 4.1.10 Molecular Characterization and DNA barcoding of agriculturally important parasitoids, predators and other insects

Different parasitoids, predators and other insects were collected from various crops in Karnataka, Andhra Pradesh, Maharashtra, Telangana State, Gujarat and South Andaman and were used for DNA barcoding studies. Molecular characterization and DNA barcodes were generated for 70 agriculturally important insect pests, parasitoids, predators, pollinators including invasive fall army worm *Spodoptera frugiperda* and other insects based on COI gene. Twenty four populations of *S. frugiperda* collected from Gujarat, Karnataka, Telangana State, Andaman, Andhra Pradesh, Maharashtra and were identified using COI gene and deposited in NCBI and accession numbers were obtained

## 4.2 All India Coordinated Research Project on Biological Control of Crop Pests

### 4.2.1 Biodiversity of biocontrol agents from various agro ecological zones

**AAU-A:** *Trichogramma chilonis* was the major *Trichogrammatid* recorded from cotton, groundnut, okra, maize, rice and tomato fields. Diversity of coccinellids from different crop ecosystems of the region was studied. *Cheilomenes sexmaculatus* Fabricius was found to be the predominant species. Majority of the species belonged to sub family Coccinellinae representing 40% of the total species collected, followed by Chilocorinae and Epilachinae. Total 22 spider specimens were collected from paddy ecosystem. The samples were belonging to three families namely Araneidae, Tetragnathidae and Thomisidae. Out of 22 specimens, 8 turned to be *Agriope* sp. and 8 were *Neoscona theisi.* Seventy soil samples were collected from different locations of Gujarat. Eight soil samples found positive for EPN and specimens had been sent to NBAIR, Bengaluru for identification. Out of 8 isolates, 7 turned to be *Steinernema pakistanense* (GenBank accession No. MK491792, MK491793, MK491794, MK491795, MK491796, MK491797, MK491798).

**AAU-J:** Extensive surveys were conducted in brinjal, tomato, okra, cole crops cucurbits, papaya, bhut jolokia for the presence of natural enemy. Highest number of spider population (1.0 to 3.0 spider/ $m^2$) was recorded in rice fields. 112 numbers of spiders from 7 different families (Tetragnathidae, Lycosidae, Oxyopidae, Araneidae, Salticidae, Attidae and Linyphidae) were collected from different rice fields. The predominant spider was *Lycosa pseudoannulata* (32) and *Oxopes javanus* (27).

**KAU:** Spiders were collected from rice ecosystem in Thrissur, Palghat and Ernakulam district by general collection, pit fall trap and sweep net methods.

**PAU:** Forty two samples of soil/insect cadavers collected from different crops from different zones of Punjab were processed for the isolation of entomopathogenic fungi. Three entomopathogenic fungi have been isolated from these samples and slants of these will be sent to NBAIR, Bengaluru for confirmation identification and repository deposit.

**SKAUST:** A total of thirty one natural enemies including parasitoids and predators belonging to the orders Coleoptera, Diptera, Neuroptera, Hymenoptera and Mesostigmata were collected from fruit orchards in different districts of Kashmir and Laddakh during 2018-19. Apple indicated a healthy fauna of natural enemies comprising of 20 species associated with apple pests. Out of 20 natural enemies on apple, 16 predator spp. and 4 parasitoid spp. were collected. Per cent parasitism by *Aphelinus mali* on woolly apple aphid was found highest (34.0- 80.0) per cent in unmanaged orchards. Parasitism by *Encarsia perniciosi* and *Aphytis proclia* ranged 14.0-29.0%) in similar orchards. *Chilocorus infernalis* was found actively associated with San Jose scale on apple and *Parthenolecanium corni* on plum. Among the reported natural enemies, predators constituted 81.0% with 80.0% share of coccinellids, and 19.0% parasitoids.

**YSPUHF:** Many coccinellid beetles have been recorded from different ecosystems viz. Apple, apricot, peach, plum, almond, tomato, cucumber, brinjal, okra, cole crops, maize, capsicum, carnation, rose, chrysanthemum, ground flora and wild flora of Himachal Pradesh. Besides coccinellids other natural enemies *Cotesia glomerata* parasitizing *Pieris brassicae* in cauliflower and *Campoletis chloridae* parasitizing *Helicoverpa armigera* in tomato, *Diplazon* sp parasitizing syrphid flies, *Trathla* sp parasitizing brinjal shoot and fruit borer were also collected from Nauni.

**MPKV:** The natural enemies inclusive of coccinellids like *Coccinella septempunctata* L. *Menochilus sexmaculata* F., *Scymnus* sp., *Dipha aphidivora* Meyrick, *Micromus igorotus* Bank. and syrphid, *Eupeodes confrater* and the parasitoid *Encarsia flavoscuttellum* were recorded on SWA in sugarcane, *Coccinella transversalis* F., *M. sexmaculata, Brumoides suturalis* F., *Scymnus coccivora, Triomata coccidivora* Ayyar and *B. suturalis* in mealybug colonies on custard apple, *Acerophagus papayae* N. & S., *Mallada boninensis* Okam. and *Spalgis epius* Westwood on papaya mealybug. Parasitism by *Trichogramma* sp. was observed in the crops like cotton, maize, soybean, pigeon pea, sugarcane, tomato and brinjal in Pune region. The chrysopid, *Chrysoperla zastrowi sillemi* Esben. was observed in cotton, maize, bean, sorghum, okra and brinjal, while, *Mallada boninensis* Okam. on cotton, beans, mango, papaya and ornamental plants. The *Cryptolaemus* adults were recovered from the custard apple and papaya orchards, cotton and ornamental hibiscus. The entomopathogens particularly the cadavers of *S. litura* and *H. armigera* infected with *Nomuraea rileyi*, *Metarhizium anisopliae*, *Sl*NPV, *Ha*NPV were collected from soybean, cabbage, pigeon pea and tomato crops in farmers fields

**TNAU:** The natural enemies *viz*., *Trichogramma* sp., *Cryptolaemus montrouzieri*, *Chrysoperla zastrowi sillemi* and parasitoids of papaya mealybug, scales were collected. The parasitoid of rugose whitefly in coconut was identified as *Encarsia guadeloupe*. The activity of egg parasitoid, *Trichogramma* sp. parasitizing fruit borer of tomato, bhendi and shoot and fruit borer of brinjal, bud borer of jasmine and DBM in cabbage was observed. The predators *viz., C. montrouzieri*, *Chrysoperla zastrowi sillemi and Mallada sp* was seen on mealybug, scales, whiteflies, psyllids infesting the crops namely tapioca, papaya, brinjal, bhendi, curry leaf and coconut while *Dipha aphidivora* and *Micromus igorotus* were observed on sugarcane woolly aphid. Staphylinids and spiders were observed in maize fields. Spiders *viz., Telamonia dimidiata, Peucetia viridana* were collected from brinjal field.

**CISH:** Predator and parasitoids population in relation to pest infestation was recorded in mango ecosystem during the flowering and fruiting period. Coccinellids viz., *Coccinella septempunctata, Cheilomenes sexmaculata,, Chilocorus rubidus, Scymnus* sp. were observed feeding on mango hoppers, most abundant was *Coccinella septempunctata.* Peak population of Hoverflies and Chrysopids was recorded during $18^{th}$ and $16^{th}$ SMW with 4.2 and 1.3 adults /tree respectively. It was observed that presence of natural enemies in mango ecosystem regulated the pest population.

**IIMR:** About 25% parasitization by *Cotesia flavipes* was observed in *Chilo partellus.* Egg parasitoid *Trichogrammatoidea simmonds*i (18%); Larval parasitoid, *Neotrichoporoides nyemitawus* (21%) and pupal parasitoid , *Spalangia endius* (13%) were found parasitizing shoot flies across species and millets.

**IIRR:** Spiders were collected from rice ecosystem. The most abundant group were the Tetragnathids, followed by the Lycosid and *Pardosa*.

**UBKV:** *Chrysoperla*, *Rhynocoris*, *Mantis*, *Coccinella*, Dragon fly, *Forficula* (Earwig) and *Calosoma* (Ground beetle) were collected from tea. *Trichogramma, Tetrastichus, Chelonus, Bracon and Ichneumon* parasitisation was also observed.

#### 4.2.1.1 Surveillance for alien invasive pests

The alien invasive pests, *viz*., *Brontispa longissima, Aleurodicus dugesii, Phenacoccus manihoti, Phenacoccus madeirensis* were not recorded in any of the centre during the year 2018-2019. However, *Tuta absoluta* was observed in TamilNadu, Himachal Pradesh and Varanasi. In Maharashtra, the mealybug species *Pseudococcus jackbeardsleyi* and *Paracoccus marginatus* were recorded on custard apple and papaya respectively in Pune region. Papaya mealybug incidence was observed in Tamil Nadu, Gujarat, Assam, and Maharashtra. New alien pest, Fall Army Worm (FAW), *Spodoptera frugiperda* (Smith) was reported from Gujarat, Rajasthan, Maharashtra, Bengal, Karnataka, Kerala, Telangana, Andhra Pradesh, Tamil Nadu. Surveys for incidence of *Spodoptera frugiperda* was carried out during Kharif season in Mahboobnagar (Telangana), Parbhani, Rahuri, Akola (Maharastra) where incidence of pest was observed at low levels (< 5.0%) on Sorghum. Incidence was not observed at Hisar, Udaipur, Ludhiana, Indore and Surat. During Rabi (Sept - Dec) at medium to severe damage (10.0 - 60.0%) was observed across the millets. On an average 1-2 larvae were found in each whorl of Sorghum, Pearl millet.

#### 4.2.1.2 Surveillance of rugose whitefly & other whiteflies in coconut and assessing the population of natural biocontrol agents

**NBAIR:** About 3 trips were made to Dakshina Kannada, Udupi and Uttar Kannada districts and 3 trips in Ramanagara, Mandya, Mysuru districts 4 trips to Bangalore rural district in Karnataka for survey on incidence and infestation of rugose spiraling whitefly *Aleurodicus rugioperculatus* Martin on coconut and other host plants during 2018-19. The pest population continues to spread newer areas along coastal tracts in Karnataka and incidence was even more serious in Goa. As per the natural parasitism is concern, the predominant natural enemies were *Encarsia guadeloupae* which parasitism was recorded to extent of 24-62%. Besides, RSW infestation of three invasive whiteflies such as Bondar's nesting whitefly, *Paraleyrodes bondari* and *P. minei* to the extent of 15-28% on coconut was noticed. The intensity and severity of this whitefly on coconut and areca palm is about 10-80% of leaflets per frond per palm and observed in few isolated garden across the two districts. Four predators such as *Dichochrysa astour (*Neuroptera: Chrysopidae), *Cybochephalus* spp. (Coleoptera: Nitidulidae), *Chilocorus nigrita* and *Jauravia pallidula* (Coleoptera: Coccinellidae) observed feeding on this whitefly in the field, however no natural parasitism could be seen till date.

**OUAT:** Rugose whitefly, *Aleurodicus rugioperculatus* was not noticed during the survey.

**CPCRI:** A new distribution record of rugose spiraling whitefly (RSW), *Aleurodicus rugioperculatus* was confirmed from Nalbari and Kamrup districts of Assam infesting on coconut, arecanut, ornamental yellow palm, banana and crotons during August 2018. Observations revealed 82.1% natural parasitism by *Encarsia guadeloupae* in RSW samples collected from Nalbari and Kamrup districts of Assam. The neuropteran predator green lacewing, *Pseudomallada astur* was observed in Madhapur, Nalbari district where the pest population is significantly reducing. RSW population was reduced immediately after monsoon in Andhra Pradesh and Tamil Nadu but increased greater in certain coconut gardens during winter months. Two species of new invasive nesting whiteflies were reported infesting coconut leaves. The neotropical invasive Bondar's nesting whitefly, *Paraleyrodes bondari* Peracchi and the exotic nesting whitefly, *Paraleyrodes minei* Iaccarino on coconut palms from Kerala.

**ANGRAU:** Rugose whitefly in coconut in Srikakulam, Vizianagaram, Visakhapatnam districts of Andhra Pradesh during February, 2019.

### 4.2.2 Biological suppression of plant diseases

**Evaluation of bio-agent consortium in glasshouse (pot experiments) and in field for crop health management in chickpea**

**GBPUA&T:** Mixed formulation (Th 14+Psf173) shown better performance over individual isolates with respect to its effect on seed germination and plant growth. Minimum Number of mature plant wilt (3.7) at 120 DAS was observed with consortium Th17+Psf 173 (3.0), while maximum in control (5.7) after 120 days of sowing.

**Isolation and evaluation of temperature tolerant *Trichoderma* isolates for crop health management during coldest/hottest climate**

**GBPUA&T:** The extensive collection of samples led to the generation of 20 isolates of *Trichoderma*, coded as Ta-1 to Ta-20. A temperature of 30$^{o}$C was significantly best for the growth of all the isolates of *Trichoderma.* Isolate Ta 18 recorded maximum colony diameter at 10$^{o}$C and isolate Ta15 showed maximum colony diameter at 40$^{o}$C.

**Field evaluation of promising *Trichoderma/ Pseudomonas* isolates for crop health management**

**GBPUA&T:** Among all the isolates, Psf-173, PBAT-3, Th14, TCMS 36 and NBAIR-2 were comparatively better than other bioagents in reducing diseases and in increasing yield in rice. In c**hickpea** among all the isolates PBAT-3, BARC-Th and NBAIR1-Th were better in reducing plant wilt and in increasing plant growth.

### 4.2.3 Biological suppression of sugarcane pests

#### 4.2.3.1 Efficacy of entomopathogenic nematodes and entomopathogenicfungus for the management of white grub in sugarcane ecosystem

**ANGRAU:** Entomopathogenic nematode, *Heterorhabditis indica* and *Metarhizium anisopliae* (NBAIR Ma-4) were found effective in reducing white grub damage compared to chemical . Per cent reduction in plant damage due to white grub recorded high in *Heterorhabditis indica* (81.17%), *Metarhizium anisopliae* (78.83%) compared to chlorantraniliprole 18.5SC (54.17%) and untreated control

**UAS-R:** In the post treatment observations the plant damage due to white grub was lowest in (7.50 %) in *Metarhizium anisopliae* (ICAR-NBAIR Ma 4) treated plots which was statistically superior over rest of the treatments, phorate 10G and Neem cake recorded 20.50 and 30.50%, respectively. Similarly, the number of white grubs at six months after treatment imposition the lowest number of grubs were noticed in *M. anisopliae* (ICAR-NBAIR Ma 4) which recorded 2.82 grubs per 10 m row length which was significantly superior over phorate 10G (6.10/10mrl) and Neem cake (7.80/10 mrl). The highest cane yield of 164.75 t/ha was recorded in *M. anisopliae* (ICAR-NBAIR Ma 4) treatment which was significantly higher than Phorate 10 G (141.75 t/ha) and Neem cake (132.85t/ha).

### 4.2.4 Biological suppression of cotton pests

#### 4.2.4.1 Management of Pink bollworm by using *Trichogrammatoidea bactrae* in *Bt* cotton

**UAS-R:** The results indicated that the number of PBW larvae in biocontrol field (T1) and chemical treated field (T2) was 11.62 and 8.32 larvae per 10 bolls, respectively. Rosette flower in $T_1$ (4.36 %) and $T_2$ (2.28 %) differed statistically. Similarly, highest seed cotton yield of 32.56 q/ha was noticed in $T_2$ while $T_1$ recorded 28.62 q/ha.

**PDKV Akola:** Significantly minimum rosette flowers of 0.03 per 5 plants per plot was recorded in biocontrol field (T1) followed by the insecticidal treatment (T2), both being at par with each other and significantly superior over untreated control. Lowest mean green boll damage of 1.88 % per plot was observed in T1 and was at par with treatment T2 with 2.50 % green boll damage per plot. Insecticide treated field recorded significantly maximum yield of 934.93 Kg seed cotton, followed by biocontrol field recording 812.76 Kg seed cotton.

#### 4.2.4.2 Evaluation of entomofungal agents and botanicals for the management of sucking pests in cotton

**MPKV:** Amongst the biopesticides with *Lecanicillum lecanii* (1 x $10^8$conidia /g) @ 5 g/litre recorded lowest population of sucking pests *viz.,* aphids (4.80) , jassids ( 2.90), thrips ( 2.40), and white flies (1.72) on 3 leaves per plant compared to the untreated control which recorded aphids (38.10) , jassids ( 13.26), thrips ( 30.66), and white flies (10.57) on 3 leaves per plant. The *Lecanicillum lecanii* (1 x $10^8$conidia /g) @ 5 g/litre recorded seed cotton yield 17.85 q/ha which is at par with dimethoate 0.05% (18.56 q/ha).

#### 4.2.4.3 Biointensive Pest Management in *Bt* cotton ecosystem

**AAU-A: S**ignificant difference was observed between BIPM package and farmers practice with regard to number of good open bolls and bad open bolls and it was observed that the incidence levels of PBW was less as compared to previous year incidence. In case of sucking pests, there was an incidence of thrips and aphid only. No whitefly and jassid infestation noticed. Farmers practice module recorded 23.13 q/ha cotton seed yield which was significantly higher than the yield recorded in BIPM package (20.70 q/ha).

**UAS-R:** Biointensive practice recorded 10.64, 30.56 and 20.02 PBW larvae, GOB and BOB per plant, respectively and in farmers practice it was 8.32, 38.46 and 12.52 PBW larvae, GOB and BOB per plant, respectively. Maximum locule damage of 28.50% was noticed in biointensive practice, while in farmer practice it was 15.75%. In biointensive practice the seed cotton yield was 30.50 q/ha while in farmer practice it was 33.75 q/ha.

#### 4.2.4.4 Monitoring of whitefly, its natural enemies in cotton

**PAU:** Regular surveys were conducted in cotton growing areas of Punjab (Fazilka, Bathinda, Mansa and Muktsar districts) to monitor whitefly population on cotton crop during *kharif* 2018. No major outbreak was recorded. The population of whitefly remained low to moderate except at few locations in Khuiyan sarvar block of Fazilka. **The PAU recommended strategy was successfully implemented in cotton growing areas through the joint efforts of PAU and Department of Agriculture (Punjab).** *Encarsia lutea* (Masi) and *Encarsia sophia* (Girault & Dodd) were the two parasitoids that emerged from whitefly nymphs. The mean parasitization of whitefly by *Encarsia* spp. in different cotton growing areas of Punjab was 5.01% (range = 2.04 to 18.62%).

#### 4.2.4.5 Population dynamics of whitefly, *Bemisia tabaci* (Gen) and its natural enemies in cotton: A study in farmers' field in North Zone

**NCIPM:** Whitefly population (adults/ 3 leaves) remained below ETL in June and crossed ETL at few locations during July-August and thereafter remained below ETL in all locations. In the month of October population of whitefly and other pests was negligible. Among natural enemies predators Chrysopid and spiders were the dominant and presence of *Geocoris* bug was also noticed. Population of Coccinelid beetles was not found in most of the fields. Mean (average of the season) the per cent parasitization of whitefly nymphs by *Encarsia* spp or other parasitoids was recorded maximum in Fazilka (45.87, Range 28.74-60.90) followed by Muktsar (45.10 Range 23.08-55.94), Sirsa (43.66 range 26.00-54.25), Hanumangarah (34.10 range 22.27-45.49) and Sriganganagar (30.31; range 19.62-51.95). Parasitization was maximum in July and August which coincide with the population of whitefly nymphs thereafter it declined due to decline whitefly population and spray of insecticides.

### 4.2.5 Biological suppression of rice pests

#### 4.2.5.1 Management of rice stem borer and leaf folder using Entomopathogenic nematodes and entomopathogenic fungi

**ANGRAU, Anakalle:** Per cent reduction in leaf folder damage over untreated control was high in *Steinernema carpocapsae* (73.62%) followed by and *Bacillus thuringiensis* (68.0%) and flubendiamide (63.19%). Per cent reduction in stem borer damage over untreated control was high in flubendiamide (56.25%) and *Bacillus thuringiensis* (53.12%). Grain yield recorded high in chemical treatment followed by *Bacillus thuringiensis* (NBAIR strain) (3.27 t/ha) and *Metarhizium anisopliae* (NBAIR- Ma 4) (3.13 t/ha) and low in control (2.73 t/ha).

**KAU Thrissur:** All the plots treated with entomopathogenic microbes were significantly superior to the untreated control and on par with each other 21 days after second spray. Both *Bacillus thuringiensis* and flubendiamide recorded the lowest mean values of 4.33 dead hearts/$m^2$ each. A similar trend was discernable seven days after the third spray as well. Plots treated with *Bt* had the lowest mean number of 4.00 dead hearts/$m^2$, followed by plots treated with flubendiamide.

#### 4.2.5.2 Management of plant hoppers through BIPM approach in organic *basmati* rice

**ANGRAU:** Reduction in hopper population was high in BIPM plot (99.4 %) and farmers practice plot (98.03 %). Grain yield was high in BIPM practice (3.56 t/ha) compared to farmer’s practice

**PDKV Akola:** The population of green leaf hopper and WBPH was significantly minimum in BIPM field followed by Farmers’ practice, both being at par with each other and significantly superior over control. BIPM was significantly most effective in reducing BPH population recording 2.73 and 2.81 BPH per hill at 92 and 107 DAT, respectively. Maximum yield of 22.52 Q/ha was recorded in treatment Farmers’ practice followed by BIPM field recording 21.78 q/ha, both being at par with each other and significantly superior over untreated control.

PAU: The population of plant hoppers in BIPM and control plots was 2.88 and 4.21 per hill resulting in a reduction of 31.7% over control. The population of spider was comparatively higher in BIPM plot. Basmati yield was 31.25 q/ha in BIPM as compared to 29.75 q/ha in untreated control with an increase of 5.04%.

#### 4.2.5.3 Improved formulation of *B. bassiana* against Rice leaf roller *Cnaphalocrocis medinalis*

**KAU Vellayani:** Chitin rich formulation of *Beauveria bassiana* against Rice leaf roller *Cnaphalocrocis medinalis* revealed that the mean population per plot ranged from 34.75 to 45.50 per 10hills/plot prior to treatment, while it was reduced to 0 to 8.5 after treatment.

#### 4.2.5.4 Comparative efficacy of entomopathogenic fungi against sucking pests of rice, *Leptocorisa acuta*

**KAU Vellayani:** Plots treated with *Lecanicillium saksenae* @ $10^{7}$ spores /mL was the superior treatment, closely followed by NBAIR isolate Bb5 @$10^{8}$ spores/mL, where the mean population per sweep is 5 and 6.75 respectively. Among the four biocontrol agents *L. saksenae* was most effective for rice bug with mean population per sweep 1.75 no., followed by *B.bassiana* (2.75).

### 4.2.6 Biological suppression of cereal pests

#### 4.2.6.1 Evaluation of NBAIR entomopathogenic strains (endophytic EPF) and *Bt* against maize stem borer *Chilo partellus* (Swinhoe) in fodder maize

**PAU:** Chemical control was significantly better than other treatments in reducing the leaf injury (1.33%) and dead hearts (0.56%) by maize borer. Among the four isolates, Ma-35 isolate of *Metarhizium anisoplae* and Bb-5a isolate of *Beauveria bassiana* were significantly effective in reducing the incidence of leaf injury (4.24 and 4.66%) and dead hearts (2.64 and 2.78%).

#### 4.2.6.2 Biological control of maize stem borer, *Chilo partellus* using *Trichogramma chilonis*

**ANGRAU, Anakapalle:** Release of *Trichogramma chilonis* @ 100,000/ha/release at 15, 22 and 29 days after seedling emergence at 7-10 day interval resulted in 100% reduction in *Chilo partellus* damage; 35.47% reduction in *Sesamia inferens* damage and 49.2% reduction in *Spodoptera frugiperda* damage.

**MPUAT:** The dead heart incidence in fields with the releases of *T. chilonis* was 8.67% and in chemical control, it was 6.47%. The reduction in incidence over control was 49.28 and 62.09% in biocontrol field and chemical treated field, respectively. The yield in *T. chilonis* ($T_1$) (31.10 q/ha) and spinosad 45SC ($T_2$) (33.67 q/ha) fields were significantly more than in untreated control (25.83 q/ha).

**PAU:** The reduction in stem borer incidence over control was 56.05 and 77.55% in biocontrol and chemical control, respectively. Similarly, yield in biocontrol (44.04 q/ha) and chemical control (46.51 q/ha) fields were significantly more than in untreated control (39.50 q/ha). The yield increase over control was 12.33% in biocontrol as compared to 18.81% in chemical control. The net returns over control in biocontrol package were Rs. 7218/- as compared to Rs.10742/- in chemical control

#### 4.2.6.3 Adhoc field trial against Fall Armyworm in Rabi maize

**ANGRAU, Anakapalle:** Fall army worm dead larvae per plot recorded at 30 days after sowing was significantly high in chemical control (48.33) followed by T2 *Trichogramma pretiosum* + *Metarhizium anisopliae* NBAIR -Ma 35 ) (23.0) and T1 (*Trichogramma pretiosum* + NBAIR *Bt* 2% ) (22.0). At 40 days after sowing, fall armyworm damaged plants per plot were low in T1 (51.66) and T2 (55.67).

**OUAT:** The number of egg patches & larvae per 10 plants, plant damage due to fall army worm (FAW) and number of predators/10 plants were highest in untreated check and lowest in chemical control as compared to different bio-products. On the other hand, green cob yield was highest (17.54t/ha) in chemical check and lowest (8.14t/ha) in untreated control. Among the tested bio-modules, trichocard releases+ *Bt* sprays expressed highest yield (16.05t/ha and lowest pest damage which is comparable to emamectin benzoate and closely followed by trichocard releases+ *Pseudomona*s sprays .

### 4.2.6.4 Adhoc field trial against Fall Armyworm in Rabi sorghum

**IIMR:** It was found that there was significant reduction in the larval population in T7 (Emamectin benzoate sprayed field) (0.0 nos/10 plants) after application of second round of treatment and it was on par with T2 (*Trichogramma pretiosum* 1 card/acre + spray of *Metarhizium anisopliae* Ma 35 0.5% at 20, 30 DAE) (1.00 larvae/ 10 plants) and T1 (*Trichogramma pretiosum* 1 card/acre + spray of NBAIR *Bt* 2% twice at 20, 30 DAE) (1.33). Significantly highest yield was recorded in treatment T7 (4.790 kg) which was on par with T2 (7.015 kg) and T1 (6.979 kg). Among the biocontrol agents I treatment T2 there was 46.45 % increase in yield over the control. Overall among the biocontrol agents the treatment T2 (*Trichogrammapretiosum* 1 card/acre (2 releases, first release one week of planting & second one after one week of release + spray of *Metarhizium anisopliae* (Ma 35) 0.5 % at 20, 30 DAE) was the best in terms of reduction in no of egg patches, larval population, plant damage and increased yield over the control. However, the treatment T7 (Emamectin benzoate 0.4 gm/lt at 20, 30 DAE) was significantly the best and it was on par with T2.

**UAS-R:** Minimum of 74 larvae per plot was noticed in $T_3$ *Trichogramma pretiosum* (1 card per acre followed by application of EPN *H. indica*) which was followed by sole release of *Trichogramma pretiosum.* Highest per cent parasitisation was noticed in continuous release of *Trichogramma pretiosum* which recorded 30.25%. The highest grain yield of 6.85 /ha was noticed in $T_3$ *Trichogramma pretiosum* (1 card per acre followed by application of EPN *H. indica*) which was at par with all the treatments including untreated control.

### 4.2.6.5 Evaluation of entomopathogenic fungi formulations against millet borers in Finger millet

**IIMR:** The DH caused in Finger millet were least in chemical control (1.84%DH) and it was on par with T3 (Bb-45 @ 10 ml /lt) (2.55% DH). There was 86.9 and 81.8% reduction in DH over the control where in 14.0 % DH was recorded. Similar trend was observed in White ear heads. Highest grain yield was o*bt*ained in chemical control (3.75 kg/plot) which was on par with other biocontrol treated plot. Overall based upon the reduction in damage to Finger millet by Pink borer and yield the treatment T5 (Application of carbofuran 3G granules @ 20 kg/ha) was the best and it was on par with T3 (Bb-45 @ 10 ml /lt).

### 4.2.7 Biological suppression of pests of pulses

#### 4.2.7.1 Evaluation of NBAIR *Bt* formulation on pigeon pea against pod borer complex

**ANGRAU:** Chemical control plot gave 50.52 % reduction and NBAIR *Bt* spraying gave 33.82 % reduction in *Maruca* webber damage over untreated control. Pod damage recorded low in *Bt* plot (34.5%) compared to chemical control plot (35.29 %) and high in untreated control (39.69 %)

**MPKV:** Three sprays of chlorantraniliprole 18.5%SC at fortnightly interval was significantly superior over other treatments in suppressing the larval population of *M. testulalis* (av. 4.51 larvae/plant), *E. atomosa* (av. 2.45 larvae/plant) and *H. armigera* (av. 1.07 larvae/plant) and recorded minimum pod (6.60%) and seed (5.32%) damage with maximum 16.60 q/ha yield. It was however, at par with the NBAII-*Bt* G4 @ 2% in respect of pod damage ( 8.90% ), grain damage ( 6.03%) and yield (15.12 q/ha) on pigeon pea.

**TNAU:** Both the NBAII-*BT*G4 formulation and the chemical sprays gave higher grain yield of 625 and 590 Kg/ha respectively than control (415 Kg/ha). The CB ratio was maximum (2.13) in NBAII *Bt*G4 treatment.

**UASR:** NBAIR *Bt* G 4 recorded 9.74% pod damage with a grain yield of 6.25q/ha while in farmers practice the per cent pod damage was 6.98 with a grain yield of 7.10 q/ha.

**PDKV Akola:** The mean observation of 2 sprays on pod damage revealed that significantly minimum damage was recorded in insecticidal treatment with 0.67% pod damage due to lepidopteran pod borers followed by *Bt* treatment with 4.37% pod damage and both the treatments were significantly superior to untreated control (12.40 %).

#### 4.2.7.2 Integration of botanical/microbials and insecticide spray schedule for the management of pod borer complex in mungbean

**PAU:** Chemical treatment was at par with treatment first spray of commercial *Bt* formulation @ 1.25 litre/ha and second of spinosad 45 SC @ 150 ml/ha each. (7.38 %) and treatment (T2) both sprays of *Bt* formulation @ 1.25 litre/ha (7.75%). Maximum yield was 11.07 q/ha in chemical treatment and it was followed by T3 (10.89 q/ha) (1$^{st}$ spray of *Bt* formulation @ 1.25litre/ha & 2$^{nd}$ of spinosad 45SC @ 150 ml/ha), T2 (10.87q/ha) (both spray of *Bt* formulation @ 1.25 litre/ha) and T6 (10.81%) (1$^{st}$ spray of azadirachtin 1% and 2$^{nd}$ of spinosad 45SC @ 150 ml/ha).

#### 4.2.7.3 Management of *Helicoverpa armigera* by HearNPV in chickpea ecosystem (NBAIR) in collaboration with UAS-R)

**UAS-R:** HearNPV NBAIR @ 2 ml/l recorded 7.78% pod damage which was at par with HearNPV UASR @ 2 ml/l which recorded 8.16% pod damage. Farmers practice block recorded 5.32% pod damage which was statistically superior over HearNPV treatments.

#### 4.2.7.4 Biological suppression of pod borer, *Helicoverpa armigera* (Hubner) infesting chickpea

**MPUAT:** Minimum per cent pod damage was recorded in treatment of quinalphos 25EC @ 250g a.i/ha (8.20%) and maximum was in *Bt.* @ 1 Kg/ha (13.00%). Maximum grain yield was recorded in quinalphos 25EC @ 250g a.i/ha (17.40 q/ ha) while minimum was in *Bt.* @ 1 Kg/ha (13.80 q/ha); however, untreated control had the lowest grain yield (11.30q/ha).

### 4.2.8 Biological suppression of pests of tropical fruit crops

#### 4.2.8.1 Bioefficacy of entomopathogens against Banana fruit and leaf scarring beetles, *Nodostoma subcostatum*

**AAU Jorhat:** In case of entomopathogenic fungi, the treatments of filling of leaf axil with *B. bassiana* (AAU culture) @ 5ml/lit, spray of *B. bassiana* (AAU culture) @ 5ml/lit and Neem product (azadirachtin 1500 ppm) @ 5 ml/lit showed no significant differences amongst them in reducing the population of fruit and leaf scarring beetle (10.50 10.88, 11.75 beetles/plant). Highest number of beetles (17.19 per plant) was registered in untreated control plot.

#### 4.2.8.2 Effect of bio pesticides for management of Mango hoppers, pests *Idioscopus* spp in field condition

**DRYSRUH, Ambajipeta:** After third spray of bio pesticides, *Metarhizium anisopliae* (AAU) and *Metarhizium anisopliae* (Ma-Shiv) were effective in suppressing mango hoppers to 0.63 hoppers per tree followed by *Beauveria bassiana* (AAU) (0.75 hoppers per tree). However, conventional insecticide, Imidacloprid and botanical insecticide azadirachtin 10000 ppm were effective than the microbial insecticides with zero hopper population and 0.34 hopper/tree, respectively. Among the bio-pesticide treatments, *Lecanicillium lecanii* (VI-22) had a high hopper population of 0.63 insects/ tree after third spray.

#### 4.2.8.3 Bioefficacy of entomopathogenic fungi formulations in suppression of mango leaf webber

**CISH Lucknow:** Among the biocontrol agents low incidence of leaf webber was recorded in *B. bassiana* (CISH formulation) and it was on par with the of *M. anisopliae* (NBAIR-Ma-4) with 5.65 and 5.90 live webs/tree respectively. At 21 DAS *B. bassiana* (CISH formulation) and *B. bassiana* (NBAIR-Bb-5a) were found effective in reducing the leaf webber incidence significantly.

#### 4.2.8.4 Management studies for inflorescence thrips on mango with bio-pesticides in field conditions

**DRYSRUH, Ambajipeta** : After third spray, Fipronil treated trees had a low mean thrips population of 2.13 followed by bio pesticide *Metarhizium anisopliae* (Ma-IIHR), Azadirachtin 10000 ppm, *Metarhizium anisopliae* (AAU) and *Beauveria bassiana* (AAU) with 2.75, 3.25, 6.06 and 6.25 thrips per tree, respectively. Among the bio-pesticide treatments, *Lecanicillium lecanii* (VI-22) had a high thrips population of 7.75 thrips/tree after third spray. In untreated control block a high population of mango thrips ranging from 16.25 to 31.25 was recorded consistently.

#### 4.2.8.5 Field evaluation of bio-management inputs against root-knot nematode in guava

**CISH Lucknow:** Neem cake @ 50g/ 2 kg soil and CISH-Biopesticide @ 50g/ 2 kg soil were the best treatments which significantly reduced root-knot index and increased plant growth as compared to controls. Carbofuran applied @ 50 mg/ 2 kg soil was probably much lower dose and was found ineffective.

### 4.2.9 Biological suppression of pests of temperate fruit crops

#### 4.2.9.1 Integrated Pest Management of apple Codling moth, *Cydia pomonella*

**SKAUST:** T1 (2.0 spray of *H. pakistanense*) showed as good result as T3 (one spray of chlorpyrifos 20EC @ 1.0 ml/ lit. of water) in terms of overall fruit damage and also per cent reduction in damage over control. Per cent larval mortality caused by $1^{st}$ and $2^{nd}$ spray of *H. pakistanense* during May and July' 18 was 13.2 and 53.24, respectively. However, Release of *T. cacoeciae* @2.5 lakh/ha. (4 releases/ season) + Trunk banding + disposal of infested fruits + Pheromone traps+ spray of *Heterorhabditis pakistanense* (NBAIR) was found best as it caused 52.31% reduction in fruit damage over control

#### 4.2.9.2 Evaluation of predatory bug, *Blaptostethus pallescens* against European Red mite *Panonychus ulmi* and two spotted spider mite *Tetranychus urticae* on apple

**SKAUST:** Per cent reduction in European mites population$^{-leaf}$ over control for treatments T1 (@200 bugs), T2(@400 bugs) and T3 (acaricide) was worked out as 29.88, 43.67 and 83.44 respectively. Per cent reduction in red spider mites population$^{-leaf}$ over control for treatments T1, T2 and T3 was 48.83, 59.99 and 88.45, respectively.

#### 4.2.9.3 Evaluation of *Trichogramma* spp against apple fruit moth, *Argyresthia conjugella* under laboratory conditions

**YSPHUF:** Among all the *Trichogramma* spp., maximum parasitisation obtained was only 26.6% which was resulted by *T. embryophagum*. The parasitism resulted by *T. achaeae*, *T. pretiosum* and *T. chilonis* was 11.1, 12.2 and 17.7%, respectively. *Trichogramma pieridis*, however, failed to parasitize the eggs of apple fruit moth. Adult emergence from the parasitized host eggs was 90.9, 72.7, 87.5 and 85% for *T. achaeae, T. pretiosum, T. chilonis* and *T. embryophagum*, respectively, of which 50, 100, 56.3 and 65% were the females.

#### 4.2.9.4 Management of apple root borer using *Metarhizium anisopliae*

**YSPHUF:** *Metarhizium anisopliae* treatment resulted in 67.8 to 78.4% mortality of the apple root borer grubs in different orchards, while in chlorpyrifos (0.06%) treated plants the grub mortality was 76.4 to 88.6%. It can therefore be concluded that *Metarhizium anisopliae* can be used as a substitute for chlorpyrifos for the control of apple root borer, *Dorysthenes hugelii* in apple

### 4.2.10 Biological suppression of pests in plantation crops

#### 4.2.10.1 Surveillance of rugose whitefly in coconut and assessing the population of natural biocontrol agents

**CPCRI:** RSW population ranged from 58-60/leaflet during June and July 2018 with percentage parasitism ranging from 63-68%. Parasitism by *Encarsia guadeloupae* steadily increased from 42-50% during October–November along with increase in pest population. During December 2018, incidence of nesting whiteflies, *Paraleyrodes bondari* and *Paraleyrodes minei* were observed co-existing along with RSW.

**DRYSRHU:** Mean number of spirals per 4 leaflets was ranged between 11.13 to 54.24. During April, the mean number of spirals were 28.53 and 40.73 and the corresponding mean number of adult whiteflies were 71.36 and 38.58 in East Godavari and West Godavari districts, respectively. The whitefly population was observed to increase from October with 22.16 and 24.02 spirals per 4 leaflets and the corresponding adult insect population was 21.22 and 21.38 per 4 leaflets at East Godavari and West Godavari districts, respectively. This increasing trend of population was continued till December.

**KAU Kumarakom:** High infestation ranging from 53 -73 % was observed at Kumarakom. The highest infestation was during the month of September (73.54%) which later decreased up to 53.60% in December and further increased up to 61.91% during March. At Kumarakom, infestation was seen on the nuts and base of the fronds. The per cent parasitism by *Encarsia guadalopae* was found to be high in the month of March (42.1%). At Moncompu (Alapuzha district), low to medium infestation ranging from 37 to 51% was observed with percentage of parasitism ranging from 12-58%.

**KAU Thrissur:** Incidence of rugose whitefly on coconut was more widespread in Thrissur and Palghat districts during 2018-19 compared to previous year. The severity of infestation was high during the early stages but gradually declined towards the end of the study period. Mean parasitism by *Encarsia guadeloupae*, however, remained relatively low till January 2019 when it crossed 80% in both the locations. Mean parasitism was highest in March 2019.

#### 4.2.10.2 Management of Coconut black headed caterpillar using *Goniozus nephantidis* and *Bracon brevicornis* in endemic areas of Kerala

**CPCRI:** Regular monitoring on the incidence of black headed caterpillar, *Opisina arenosella* was undertaken in Kannur and Kasaragod districts, Kerala as well as Dakshina Kannada and

Udupi districts, Karnataka. Larval population ranged from 1.1 to 7.8 per leaflet during the survey. Various natural enemies recorded from field are pupal parasitoids, *Brachymeria* sp., larval parasitoid, *Bracon* sp. and predator *Cybocephalus* sp. Timely augmentative release of *Goniozus nephantidis* and *Bracon brevicornis* @20 parasitoid/palm significantly subdued the pest population. A fresh incidence of *O. arenosella* was reported from Kumarakom, Kerala during April 2019. Release of larval parasitoids will be undertaken after assessing pest population.

### 4.2.10.3 Screening of coleopteran specific *Bt* formulation (NBAIR strains) against red palm weevil (*Rhynchophorus ferrugineus*)

**CPCRI:** BTAN4 @ 4% formulation (1 Litre per palm) was tested in the field on red palm weevil infested palms for curative treatment. Out of 6 palms tested in field, 3 palms with early infestation completely recovered with fresh spear leaf emergence and one palm died.

### 4.2.10.4 Screening of coleopteran specific *Bt* formulation (NBAIR/CPCRI strains) against rhinoceros beetle (*Oryctes rhinoceros*)

**DRYSRHU:** Promising two isolates from ICAR-CPCRI, Kayamkulam were subjected to bioassay. Isolate 1 (*Bacillus* sp.) induced 80% mortality of 3$^{rd}$ instar grubs within 15 days after treatment. Isolate 2 (*Proteus* sp.) showed conspecific symptoms as that of field collected grubs and induced 70% mortality of grubs in 15DAT. The *Bt* formulation of ICAR-NBAIR, BTAN4, was tested on third instar grubs of rhinoceros beetle (average weight of grubs 7 grams) at concentrations 2% and 4% along with control with 10 grubs per treatment. No mortality was observed on 3$^{rd}$ instar grubs.

### 4.2.10.5 Management of Coconut Rugose spiraling whitefly using entomopathogenic fungus, *Isaria fumosorosea* (NBAIR Pfu-5)

**ANGRAU:** Reduction in whitefly population at 15 days after first spraying with mummifield nymphs and malformed adullts noticed in February, 2019 due to favourable weather (temparature below 28°C and humidity above 90%). Whitefly damage as new egg spirals was not noticed at 15 days after first spraying in february, 2019**.**

**KAU Kumarakom:** Percentage reduction live colonies ranged from 6.49 to 78.79% (3$^{rd}$ DATreatment) when compared with initial count. At 7$^{th}$ day it ranged from 8.78 to 75%. Up to a maximum of 75% reduction was observed in the number of live colonies when compared with pre-treatment count.

### 4.2.10.6 Field evaluation of bio-pesticides against tea red spider mite, *Oligonychus coffeae*

**UBKV:** Best management was recorded in the plots treated with spiromesifen 240SC. Among the tested biopesticides, *Beauveria bassiana* (NBAIR strain) reduced the mite population better which is statistically at par with azadirachtin 10000 ppm. Significantly highest yield of tea leaves was also recorded in the treatment spiromesifen 240SC (6.57qt/ha) followed by *Beauveria bassiana* (NBAIR strain) and azadirachtin 10000 ppm.

### 4.2.11 Biological suppression of pests in vegetables

#### 4.2.11.1 Bio-intensive pest management of *Helicoverpa armigera*, *Tuta absoluta* and sucking pests of tomato

**AAU-A:** BIPM package found equally effective as chemical control against *H. armigera*. Chemical control module recorded the highest yield (16.43 t/ha) which was at par with the yield recorded in BIPM package (16.25 t/ha). However, low yield was recorded in untreated control (10.89 t/ha). It can be concluded that BIPM package is promising in minimizing the pest damage with higher yield.

**PAU:** The pooled per cent fruit damage in BIPM (12.86%) was significantly lower than untreated control (18.79%). However, chemical control recorded minimum per cent fruit damage (10.80%). The per cent reduction in fruit damage over control was 47.63 and 31.55% in chemical control and BIPM plot, respectively. The fruit yield in BIPM (28.32q/ha) was at par with chemical control (32.83q/ha), However, both the treatments were significantly better than untreated control (20.62/ha).

**TNAU:** The results indicated that in the BIPM field, on 60 Days after Transplanting (DAT), the leaf damage caused by *T. absoluta* (6.70%) was significantly lesser than farmers practice and control plot. At 105 DAT, the fruit damage caused by *T. aboluta* (10.90 %) was significantly lesser in BIPM plots when compared to chemical treatment (13.20%) and control (18.90%). Moreover, the fruit damage caused by *H. armigera* (11.30%) was significantly lesser in BIPM when compared to chemical treatment (16.10%) and control (25.30%). The fruit yield (24t/ha) was significantly higher in BIPM plot as compared to insecticide treated plot (21.5t/ha) and control plot (18.25/ha).

**IIVR:** BIPM had lowest whitefly (0.27), aphid (0.20), jassid (0.23) and leaf miner (0.97) populations per leaf were recorded in the BIPM module followed by chemical module. However, lowest fruit damage by its borer complex was recorded in chemical control module (1.57%) followed by BIPM module (3.33%).

**YSPUHF:** The average fruit infestation was statistically same in all the plots and varied from 0.57% in BIPM plot to 0.62% in untreated control. With the passage of time the incidence increased in all the plots and was 1.34, 1.26 and 3.49% in BIPM, chemical and untreated plots, respectively. Both the BIPM and chemical insecticides were statistically equally effective in reducing the fruit infestation by *T. absoluta* in tomato. The yield was maximum (22t/ha) in BIPM plots, but, statistically on par (21.3t/ha) with that recorded in chemical treated plots.

#### 4.2.11.2 Role of habitat manipulation for insect pests, nematodes and natural enemies in brinjal

**AAU-J:** The population of sucking pest (aphids and leaf hopper/ leaf) and *Leucinodes orbonalis* in different treatments indicated that brinjal intercropped with Carrot and Cowpea as border crop recorded the least population of aphid (2.65/leaf), leaf hopper (2.32/leaf) and per cent shoot (11.37) and fruit (10.08) infestation with a maximum yield of 210.67 q/ha. The next higher yield of 202.10 q/ha was recorded in Treatment-1, where brinjal intercropped with Coriander and Carrot as border crop followed by Treatment -3 (brinjal intercropped with Cowpea and Coriander as border crop) with 184.40 q/ha.

**4.2.11.3 Bio-intensive insect management in brinjal**

**AAU-J:** The incidence of shoot and fruit infestation in BIPM plot was 11.43 and 13.24%, as against 18.67 and 23.88% in untreated control plots, respectively. The yield of BIPM package was 236.61q/ha, as against 135.25q/ha in untreated control plot.

The per cent parasitisation on *Corcyra* sentinel cards by trichogrammatids species in BIPM plots was 6.8 as against 2.4% in chemical control plots.

**MPKV:** Treatments with chlorpyrifos 0.04% and BIPM were found at par with each other by recording shoot infestation (6.56% and 8.12%), fruit damage on number basis (5.58% and 10.04%) and on weight basis (4.74% and 5.68%), respectively. The highest marketable fruit yield (226.34 q/ha) was recorded in chlorpyrifos 0.04% treated plots which was at par with BIPM treated plot (208.40 q/ha).

**KAU Thrissur:** Both BIPM and insecticide treated plots had significantly fewer fruits damaged (34.07% and 26.15%, respectively) as compared to untreated control, five days after first spray following fruiting ($3^{rd}$ overall). Both BIPM and insecticide treated plots recorded yields of 8.61 and 9.76 Kg per plot, respectively, which were significantly superior to untreated plots with mean yield of 5.42 Kg/plot.

**TNAU:** The fruit damage in brinjal was significantly low (10.45%) in plots sprayed with pesticides followed by 14.65% fruit damage in BIPM plots. In the control plot fruit damage was 31.28%. The fruit damage in BIPM and insecticides treated plots was significantly lower than the fruit damage in the control plot. The cost benefit ratio realized in BIPM was 1:3.58 as against 1:4.57 in insecticides treated plots.

**CAU:** Sprays of dimethoate 0.05% was effective by causing lowest shoot (6.90%) and fruit (8.40%) damage and gave maximum yield (224.40 q/ha). However, the BIPM module was the next best treatment showing 10.3% shoot and 12.40% fruit infestation and gave 213.60 q/ha yield. The per cent reduction over the control was max chemical control (53.33%) compared to the BIPM module (31.11%).

**OUAT:** Highest yield (9.5 t/ha) and C:B ratio (1:1.54) were noted in BIPM plots followed by chemical control. Lowest yield (6.9 t/ha) was recorded in untreated control.

**NBAIR:** Per cent fruit and shoot damage was less compared to the farmer practice. The per cent fruit damage was recorded significantly lower in the biocontrol agent applied field in comparison to farmer practices ($F$= 105.65; df =1,119, $P$<0.0001). Similarly the per cent shoot damage was also significantly lower in the biocontrol agent applied field in comparison to farmer practices ($F$= 98.73; df= 1,119, $P$<0.0001).

**4.2.11.4 Efficacy biocontrol agents for management of fruit borer *Earias vittella* on okra**

**TNAU:** Among the biocontrol treatments, maximum reduction in fruit damage (83.43%) was registered in *Trichogramma chilonis* @50,000 parasitoids/ha, 6 releases at weekly interval followed by *Bacillus thuringiensis* @ 1 kg/ha (70.82%). The fruit yield was also significantly high (9978 Kg/ha) in *Trichogramma chilonis* @50,000 parasitoids/ha, while in control, the fruit yield was 8266Kg/ha.

**AAU-A:** Among different biocontrol agents tested, significantly lowest number of *E. vittella* larvae/plant was recorded in the treatment T5 (*B. thuringiensis* @ 5 g/litre) (0.99) which was followed by treatments T4 (*T. chilonis* @50,000 parasitoids/ha) (1.06), T6 (NSKE 5% suspension) (1.09) and T3 (*B. bassiana* @ 5 g/litre) (1.10). Similar trend was observed with regard to yield parameter and the efficacy of bioagents *B. thuringiensis* was nearly equal to that of chemical insecticide used.

**4.2.11.5 Evaluation of *Steinernema carpocapsae, Heterorhabditis indica* (NBAIR strain) and *H. pakistanense* against lepidopteran pest complex on Cabbage**

**SKAUST:** Average mortality of larvae of *Pieris brassicae* after 96 hours of treatment was 54.4, 44.0 and 17.6% by *H. pakistanense, H. indica* and *S. carpocapsae*. During similar period of observation, mortality caused to larvae of DBM was 58.4, 41.6 and 21.6% by aforementioned EPN species, respectively.

**4.2.11.6 Biointensive pest management in cabbage**

**TNAU:** The results revealed that the efficacy of BIPM practices was significantly superior in reducing the population of DBM by recording 0.46 larvae/plant after three rounds of spray while it was 1.62 and 7.66 larvae /plant in chemical treatment and control plot, respectively. A highest yield of 44.25 t/ha was recorded in BIPM plot which was on a par with chemical treatment (43.2 t/ha). Yield from control plot was 38.7 t/ha. The CB ratio was 3.53 in BIPM plot while it was 2.84 in chemical treatment.

**4.2.11.7 Field evaluation of ICAR-NBAIR entomopathogenic strains against cabbage aphid (*Myzus persicae*) and *Plutella xylostella* (DBM)**

IIVR: Among the biopesticides tested, *Metarhizium anisopliae* (Ma-4 strain) most promising with 33.77% reduction over control (PROC) against DBM followed by *Lecanicillium lecanii* (Vl-8 strain). In case of aphid (*Myzus persicae*), maximum reduction (51.01 PROC) was recorded with *Lecanicillium lecanii* (Vl-8) followed by *Beauveria bassiana* (Bb-45 strain) with 50.34 PROC and these are statistically at par with each other. However, amongst the all treatments, Indoxacarb 14.5 SC was the best both in reducing DBM and Aphids.

**4.2.11.8 Evaluation of Fungal pathogens against chilli yellow mite, *Polyphagotarsonemus latus***

**UBKV:** The treatment with spiromesifen 240SC ranked best in controlling the mite in both the spray. Among the tested fungal biopesticides, *Metarhizium anisopliae* (NBAIR strain) significantly reduced the mite population as compared to the other two cultures. Significantly highest yield of green chilli was registered in the treatment spiromesifen 240SC (168 qt/ha) followed by *Metarhizium anisopliae* (NBAIR strain).

**4.2.11.9 Bio-efficacy of some bio-pesticides against white fly (*Bemisiatabaci*) and jassids (*Empoasca flavescens*) in cucumber**

**UBKV:** Among the tested fungal biopesticides, *Lecanicillium lecani* (NBAIR strain) significantly reduced the white fly population as compared to the other culture. The treatment *Lecanicillium lecani* (NBAIR strain) was almost at par with the effect of azadirachtin 10000 ppm. Significantly highest yield of cucumber was obtained in the treatment buprofezin 25SC (241.25qt/ha) followed by *Lecanicillium lecani* (NBAIR strain).

**4.2.11.10 Field evaluation of ICAR-NBAIR entomopathogenic strains against cowpea aphid (*Aphis craccivora*)**

**KAU Thrissur:** Plots treated with imidacloprid and *Lecanicilium lecanii* NBAIR Vl-8 isolate recorded the lowest mean aphid population of 22.72 and 56.18 per plant respectively five days after the second spray,. Both were on par with each other and were significantly superior to both *B. bassiana* (NBAIR Bb-59) and *M. anisopliae*, (NBAIR Ma-4)with 87.12 and 98.64 mean numbers of aphids per plant. The latter treatments were also superior to untreated control. No significant differences were recorded in terms of yield.

**4.2.11.11 Screening of promising fungal and bacterial isolates for management of anthracnose disease in cowpea**

**KAU Kumarakom:** It is found that the fungal isolate *Hanseniaspora uvarum* (Y-73) gave 59 per cent control of the disease and was on par with chemical check. The efficacy of *Trichoderma harzianum* (Th-3), *Trichoderma viride* (KAU strain) and *Pseudomonas fluorescens* (KAU strain) were the next best effective treatments

**4.2.12 Biological suppression of oilseed crop pests**

**4.2.12.1 Bio-efficacy of entomopathogenic fungus against mustard aphid**

**AAU-J:** Dimethoate 30 EC @ 2ml/lit at 10 days interval was the best in suppressing the aphid population (7.07 per 10 cm apical twig) in comparison to other treatments with highest yield of 7.60q/ha. However, amongst the entomopathogenic fungus, *Lecanicillium lecanii* (NBAIR culture) @ 5g/lit was the next best treatment (10.22 per 10 cm apical twig) with next higher yield of 7.50 q/ha and it was, found to be at par with *Lecanicillium lecanii* (AAU-J Culture) and *Beauveria bassiana* (AAU-J Culture) @ 5g/lit in their efficacy in respect of mean population of aphid (11.15 and 11.73 per 10 cm of apical twig) and with yield (7.19 and 7.23 q/ha).

**4.2.13. Biological suppression of polyhouse and flower crop pests**

**4.2.13.1 Evaluation of biocontrol agents for the control of sucking pests in capsicum under polyhouse**

**PAU:** Chemical control (malathion 50EC @ 4 ml/litre) was found most effective in reducing the aphid population after three sprays (89.15% reduction over control). It was followed by releases of *C. zastrowi sillemi* @ 4 larvae/ plant (88.17% reduction). Among the biopesticides, significant reduction of aphid population was observed in *L. lecanii* (76.39% reduction; 12.06 aphids per plant) followed by *M. anisopliae* (68.45 % reduction; 31.75 aphids per plant), *B. bassiana* (56.34% reduction; 22.73 aphids per plant), and azadirachtin 1500 ppm @ 2 ml/litre (17.49% reduction; 41.75 aphids per plant).

**YSPUHF, Solan: I**midacloprid (0.5ml/L) was the best treatment resulting in 98.8 to 100% reduction in the aphid population. Among biocontrol agents, *Chrysoperla zastrowi sillemi* (4 larvae/ plant) resulted in the maximum reduction (55.8%) in aphid population over control which was, however, on par with that resulted by *Lecanicillium lecanii* (50.3%) and azadirachtin (49.8%). Other bioagents resulted in 33.1 to 39.2% pest reduction over control.

### 4.2.13.2 Management of bud worm and blossom midge on jasmine

**TNAU:** After third round of spray, among all the treatments, application of *Beauveria bassiana* (NBAIR formulation) at 5g/ litre of water along with 6 releases of *Trichogramma chilonis* and *Chrysoperla* at 7 days interval from bud initiation stage was superior in checking the bud borer with minimum bud damage of 21.70% followed by azadirachtin @ 1500 ppm @ 2ml/L (25.42%). The data on blossom midge damage in treatment plots revealed that there was no significant difference between the treatments. The flower yield ranged between 1650 and 1945 Kg/ha in the treatments while it was 1450Kg/ha in control.

### 4.2.14 Large scale adoption of proven biocontrol technologies

### 4.2.14.1 Rice

**AAU-A: At** 45 and 60 DAT there was significant lower leaf damage in BIPM package as compared to farmers practice block. Similar trend was recorded with regard to grain yield. Significant grain yield (39.10 q/ha) was recorded in BIPM package as compared to farmers practice (36.43 q/ha). It can be concluded that use of BIPM strategies resulted in lower incidence of rice leaf folder and higher grain yield

**ANGRAU:** Paddy stem borer damage and leaf folder damage was low in BIPM package (0.97 % dead heart and 1.51% leaf damaged) compared to farmers practice (3.21% dead heart and 5.55%white ear and 5.55% leaf damaged). Grain yield recorded was 5.64 t/ha in BIPM plot compared to farmers practice plot (4.63 t/ha). Adoption of BIPM package in three locations resulted in 20.32 % increased yields (5.64 t/ha) with high incremental ratio (12.84) over farmers practice (4.63 t/ha with incremental ratio of 4.56).

**KAU Thrissur: T**he dead heart as well as white ear head symptoms recorded 40 and 66% reduction in BIPM plots as compared to non BIPM plots. Similarly, leaf folder damage as well as rice bug populations were nearly 20% of what was reported from conventionally managed plots.

The yield obtained from BIPM plots, at 8000 kg/ha was approximately 14.5% more than that obtained from non BIPM plots (7000 kg/ha). The cost of cultivation also was nearly 8% lower in the former. The increased yield as well as reduced cost resulted in an increase in profit by Rs 46,210/ha. The cost benefit ratio, at 2.24 for BIPM fields compared quite favorably with 1.90 for non BIPM fields.

**OUAT:** The silver shoot (SS), dead heart (DH), white ear head (WEH) and leaf folder (LF), incidence in BIPM demonstrated plots were 2.80,4.71,3.55 and 4.61%, respectively as compared to 3.70, 4.09, 2.90 and 4.50% infestation in their respective farmers practice (FP) with the use of chemical pesticides. Highest yield (18.68q/ha) was recorded in FP. But the yield (79.46 q/ha) in BIPM package was at par with FP. The benefit cost ratio in BIPM treated plots was found highest (1.63) as against 1.35 and 1.28 in FP and untreated control, respectively

**IIRR:** The brown plant hoppers was lowest in the BIPM plots (25/ 10 hills) with a single application of insecticide while in farmers practice the numbers increased to 150/ 10 hills in spite of spraying four times. The incidence of stem borers, leaf folder and false smut were significantly lower in the BIPM fields. An awareness workshop was conducted at Narla block, Kalahandi, and the farmers shared their experiences with other farmers. They highlighted the lower incidence of false smut and stem borer in BIPM fields. The yield however was lower in this region in general due to the traditional practices followed and has great scope for improvement.

**GBPUAT, Pantnagar:** Large scale field demonstrations of bio-control technologies has been conducted at certified organic growers of Basmati rice at three different blocks viz. Kotabagh, Ramnagar (village Patkot and some area of Okhaldunga) and Batalghat (Mallisathi and some area of Okhaldunga) in district Nainital, Uttarakhand covering 764 farmers (average land holding 0.25 -1.0 acre) with a total acreage of 532.0 acres (221.7 ha) in association with Nature Bio-Foods Ltd. A total of 9.0 quintal of PBAT-3 (Th-14+Psf-173) was distributed to the farmers to conduct field trials.The performance of PBAT-3 along with farmer's practices was found highly satisfactory in managing sheath blight, bacterial blight and blast as compared to farmer's practices

**AAU-J:** The per cent dead heart and damaged leaf were 3.42 and 3.60 in BIPM package as against 2.85 and 2.85 in farmer's practice after 60 DAT, respectively. In case of WEH, the per cent incidence was 2.83 in BIPM plots which was superior to farmer's practice plots (3.65) at 100 DAT without any significant difference in between the treatments. Maximum yield of 4965.3 Kg/ha was registered in BIPM plots which was significantly higher compared to farmer's practice plot with 4639.0 Kg/ha. Minimum yield of 3373.5 Kg/ha was recorded in Untreated control plot.

**PAU:** The mean reduction of dead heart incidence in BIPM fields was 53.89% over control. Similarly, leaf folder damage was 2.15 and 2.48% at 45 and 60 DAT, respectively as compared to 4.74 and 6.12% in untreated control with a mean reduction of 57.06%. The mean incidence of white ears was significantly lower in biocontrol field (2.66%) as against untreated control (5.45%) resulting in a reduction of 51.20%. Grain yield in biocontrol field (26.6 q/ha) was significantly better as compared to 23.52 q/ha in untreated control, respectively. The yield increase in release fields was 13.10% more than untreated control. It can be concluded that 5-6 releases of *T. chilonis* and *T. japonicum* each @ 1, 00,000/ha resulted in lower incidence of rice insect pests and higher grain yield in organic *basmati* rice with an additional benefit of Rs. 7626/- per hectare

**NBAIR:** Based on the mean of all locations, mean dead heart incidence in BIPM fields was 6.27 and 5.69% at 45 and 60 DAT, respectively. The corresponding figures in Farmer's practice were 5.9 and 3.28%. Similarly, leaf folder damage in BIPM field was 5.92 and 2.8% at 45 and 60 DAT, respectively as compared to 5.75 and 3.23% in Farmer's practice field. Per cent white earhead (2.74) was significantly low ($F$=3.73, $P$=0.05) in BIPM field compared to farmer's practice (3.78). Grain yield in BIPM field (49.98 q/ha) ($F$=104.66, $P$<0.0001) was significantly better as compared to 45.18 q/ha in farmer's practice, respectively.

### 4.2.14.2 Groundnut

**AAU-A:** Significant difference was observed between IPM module and farmers' practices. Lower incidence of white grub was noticed in IPM module compared to farmers' practice block and similarly the higher yield in IPM module. It can be concluded that adoption of bioagents based IPM module will be useful for the effective management of white grub menace in groundnut crop.

### 4.2.14.3 Sugarcane

**ANGRAU:** Early shoot borer incidence upto 120 days recorded low in temperature tolerant strain *T. chilonis* release (8+4 times) plot at RARS, Anakapalle (7.25% DH) with significantly low internode borer incidence ( 51.2%) and internode borer intensity (3.79%) resulted in higher cane yield (75.81 t/ha), sucrose (19.9%) with high incremental cost benefit ratio (73.85) compared to farmer's practice of chlorpyrifos sprays four times (7.33% DH ; 64.17 % INB incidence; 70.6 t/ha; 18.4% sucrose and 12.95 incremental benefit cost ratio).

**MPKV:** Eight releases of *T. chilonis* TTS @ 50,000 parasitoids/ha at weekly interval starting from 40 days after emergence of shoots found significantly superior to untreated control in reducing the ESB infestation (from 22.35 to 6.38% dead hearts) and increased number of tillers (9.55 tillers/clump) as well as cane yield (138.70 MT/ha). It was, however, statistically comparable with chemical control.

**OUAT:** Maximum infestation due to ESB, IB and TSB in BIPM package were 8.17%.3.51% and 1.67%, respectively as against 7.23%. 4.03% and 2.12% in FP indicating comparable level of infestation. Highest cane yield (75.755 t/ha) and B:C ratio (1.09) were recorded in BIPM package which is comparable to FP. Lowest yield (70.074 t/ha) and B:C ratio (1.04) were noted in untreated control.

**PJTSAU:** The module with releases of *T. chilonis* @ 50,000/ha at weekly intervals 6 releases fared better than farmers' practice in terms of infestation levels (8.43 compared to 9.41 in FP) as well as net gains (72.87 t compared to 67.76 t/ha in FP).

**PAU:** In large-scale demonstrations, 12 releases of *T. chilonis* @ 50,000 per ha at 10 days internal during July to October reduced the incidence of stalk borer by 58.2%. Eight releases of *T. chilonis* @ 50,000 per ha at 10 days interval during mid-April to end-June reduced the incidence of early shoot borer by 54.3%. The cost: benefit ratio (1: 16.21) was high in biocontrol as compared to chemical control (1: 9.07). Eight releases of *T. japonicum* at 10 days interval during mid-April to mid-June @ 50,000 per ha proved as effective as chemical control for the control of top borer. The cost benefit ratio was high in biocontrol (1: 17.85) as against chemical control (1: 10.73).

**Sun Agro:** The differences among the treatments were found to be significant for both cane basis and internode basis incidence of INB, besides for sugarcane yield. 70.3% in control block to 48.3% in *Trichogramma* release block, while the block with *Trichogramma* and pheromone trapping together showed the least incidence (19.8%).The respective reduction in borer damage on cane basis due to *Trichogramma* alone was 31%, while when combined with pheromone trapping the reduction in INB was72%. The benefit for *Trichogramma* release was Rs.10, 400 (5.2 ton x Rs.2000), while when combined with pheromone trapping it was Rs.23, 000 (11.5 ton x Rs 2000).The respective cost-benefit ratios were1:3.5 and 1:3.8.The benefit for pheromone tapping alone was estimated as Rs.12, 600 (6.3tonxRs2000), the cost benefit ratio working out to 1:4.2.

**UAS-R:** Per cent dead hearts was low in *T. chilonis* (temperature tolerant strain) release plots. The highest cane yield of 162.75 t/ha and 181.62 t/ha was recorded in *T. chilonis* (temperature tolerant strain) release plots of Hampasagar and Mudhol, respectively and it was followed by farmers practice plot which recorded 158.50 t/ha and 176.75 t/ha in both Hampasagar and Mudhol, respectively. Untreated control recorded 151.75 t/ha and 171.50 t/ha in both Hampasagar and Mudhol.

### 4.2.14.4 Demonstration on biological suppression of *Spodoptera litura* with *Nomuraea rileyi* in soybean

**MPKV:** The results indicated from it is revealed that two sprays of *N. rileyi* ($2.0 \times 10^8$ cfu/ g) was significantly superior in suppressing the larval population of *S. litura* (2.13 larvae/m row) due to fungal infection with 16.21 q/ha yield.

### 4.2.14.5 Large scale field trials for the management *Helicoverpa armigera* (Hubner) on tomato

**MPUAT:** Chemical control module recorded the highest yield (15.90 t/ha) which was at par with the yield recorded in BIPM package (15.10 t/ha). Significantly, low yield was recorded in untreated control (9.75 t/ha). It could be concluded that BIPM package had promising results in minimizing the pest damage with higher yield.

### 4.2.14.6 Large scale demonstration on biological suppression of maize stem borer

**PAU:** Large scale demonstrations using *T. chilonis* against maize stem borer, C*hilo partellus* was carried out at farmer's fields on an area of 163.49 hectare. Two releases of *T. chilonis* @ 100,000/ ha at 10 and 17 days old crop resulted in 57.4% reduction in dead hearts incidence over control as compared to 74.8 in chemical control. The net returns over control in biocontrol package were Rs. 6240.25/- as compared to Rs.8817.25/- in chemical control .

### 4.2.15 Tribal Sub plan programme (TSP)

**AAU-A: Biological interventions to enhance the crop production and productivity of tribal farmers of Narmada district in Gujarat**

Two hundred tribal farmers were selected from Dediyapada, Sagbara and Tilakwada talukas of Narmada district. Area covered was ~1 acre/farmer. Training and demonstration programmes were organized.

**AAU-J: Bio-input distribution under Tribal Sub plan project**

Two hundred tribal farmers were selected from four districts and distributed bio-inputs. Trainings were provided on management of insect pest of rice and vegetables. The eco-freindly way of management of insect pests were emphasized along with the proper use of Biopesticides with knapsac Sprayer.

**ANGRAU: Organic farming in paddy, turmeric, ginger, vegetables and *Trichogramma chilonis* production in Tribal areas**

Demonstrations, awareness cum training Programmes, Rythusadassu were organized in 11 villages in Araku valley and Chinthapalli areas of Visakhapatnam district covering 143 acres of paddy, rajmah, ginger crops in Araku valley and Chinthapalli areas in Visakhapatnam district. Total 330 farmers got benefitted. Imparted training on importance of bicontrol agents (*Trichogramma*) , botanicals (neem oil, neem cake), biopesticides (Trichoderma, Pseudomonas, Metarhizium) and Biofertilizers (*Azospirillum*, Phosphobacterium, potash solubilizing bacteria, VAM) benefiting 142 tribal farmers.

**GBPUAT, Pantnagar : Inputs were distributed amongst farmers**

**TNAU, Coimbatore:** Trainings on production of biocontrol agents and biointesive pest mamagement were conducted to benefit the 100 tribal farmers from Coimbatore, Erode and Tirupur Districts.

**YSPUHF:** One hundred farmers of Khani and Holi villages of Chamba district of Himachal Pradesh were benefited from the trainings/demonstrations. These farmers were exposed to the use of bio-pesticides for pest management for the first time. In peas, beans, cauliflower and cabbage there was a reduction of 2 sprays of chemical pesticides. In case of apple, farmers saved about Rs 15000/- per hectare by avoiding chemical treatment for the control of apple root borer.

**CAU Pasighat:** Inputs were supplied among farmers. Three days Training programme **"*Integrated Pest Management in Horticultural Crops*"** from 23-25 March, 2019 under TSP.

**IGKV, Raipur:** The area selected under TSP was Jagdalpur. (Bastar) belonging to the Bastar plateau zone of Chhattisgarh. About 150 ST farmers in six villages (Lamker, Pallichakwa, Badechakwa, Nadisagar, Tahkapal & Tandpal) were selected and their adhaar card numbers and Bank account numbers were recorded. The TSP was launched along with a training on 12/01/2019, in which men & women farmers and school students from Village –Badechakwa (Jagdalpur) attended the training and also saw the live bioagents displayed. The second training was held on 31/01/2019 in the village- Badechakwa. Training and demonstration programme was organized on preparation and release of Trichocards in the field.

**UBKV, Pundibari:** 160 farmers were selected from Alipurdwar, Cooch Behar and Dakshin Dinajpur districts of West Bengal. The awareness cum training programme on use of biocontrol agent for management of pest and diseases of different crops was provided first time to all the tribal farmers. Microbial biocontrol agents were given to the trained tribal farmers for field demonstration against diseases of crops. Pheromone traps were distributed among trained tribal farmers for management of cucurbit fruit fly. Training and inputs for bee-keeping were given to the tribal farmers for upliftment of their livelihood.

## 5. Project Coordinator's and monitoring team visits to AICRP-BC centers during 2018-19

| Sl. No. | Dates | Visit of Director/ NBAIR Scientist | Place of visit | Highlights of visit |
|---|---|---|---|---|
| 1 | 11.04.2018 | Dr Chandish R. Ballal<br><br>Dr. K.S. Murthy | AAU Anand | Reviewed the progress of the committed AICRP-BC programme |
| 2 | 17.05.2018 | Dr Chandish R. Ballal | KAU, Thrissur | Reviewed the progress of the committed AICRP-BC programme |
| 3 | 22.06.2018 | Dr Chandish R Ballal, Dr J Patil | YSPUHF, Solan | Reviewed the progress of the committed AICRP-BC programme |
| 4 | 04.07.2018 | Dr Chandish R. Ballal | CTRI Rajahmundry | Reviewed the progress of the committed AICRP-BC programme |
| 5 | 05.07.2018 | Dr Chandish R. Ballal | YSRH University Ambajipeta | Reviewed the progress of field experiments of the centre |
| 6 | 06.07.2018 and 07.07.2018 | Dr Chandish R. Ballal | ANGRAU Anakapalle | Reviewed the TSP work of the centre in Aruku Valley |
| 7 | 10.07.2018 | Dr Chandish R. Ballal | IIMR & IIRR Hyderabad | Reviewed the progress of the committed AICRP-BC programme |
| 8 | 18.07.2018-19.07.2018 | Dr Chandish R. Ballal | PJTSAU, Hyderabad | Reviewed the field trials of the centre in Adilabad |
| 9 | 21.08.2018 | Dr S K Jalali, Dr J Patil | AAU- Jorhat | Reviewed the progress of the committed AICRP-BC programme |
| 10 | 23.08.2018 | Dr. O.P. Naveek | AAU- Jorhat | Reviewed the progress of the committed AICRP-BC programme |

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|---|---|---|---|---|
| 11 | 26.10.2018 | Dr Chandish R. Ballal | OUAT Bhubaneswar | Reviewed the progress of the committed AICRP-BC programme |
| 12 | 27.11.2018 | Dr Chandish R. Ballal | CISH Lucknow | Reviewed the progress of the committed AICRP-BC programme |
| 13 | 28.11.2018 | Dr Kolla Sreedevi | PAU, Ludhiana | Reviewed the progress of the committed AICRP-BC programme |
| 14 | 30.11.2018 | Dr Chandish R. Ballal | PAU, Ludhiana | Reviewed the progress of the committed AICRP-BC programme |
| 15 | 21.12.2018 | Dr. Kolla Sreedevi | MPKV, Pune | Reviewed the progress of the committed AICRP-BC programme |
| 16 | 03.01.19 | Dr. B. Ramanujam | ANGRAU, Anakapalle | Reviewed the progress of the committed AICRP-BC programme |
| 17 | 18.01.2019 | Dr Chandish R. Ballal | IGKV Raipur | Reviewed the progress of the committed AICRP-BC programme |
| 18 | 21.1.2019 | Dr. M. Nagesh, | MPKV, Pune | Reviewed the progress of the committed AICRP-BC programme |
| 19 | 26.02.2019-27.02.2019 | Dr. Chandish R. Ballal | KAU, Thrissur | Reviewed the progress of the committed AICRP-BC programme |
| 20 | 21/03/2019 | Dr. Kolla Sreedevi | CAU, Pasighat | Reviewed the progress of the committed AICRP-BC programme |
| 21 | | Dr. Amala Udayakumar | MPUAT, Udaipur | Reviewed the progress of the committed AICRP-BC programme |

**6. Publications:** During the year 2018-19, a total of 171 Research papers/symposium papers/reviews/technical bulletins, etc. were published by the different centers.

| **Centre** | **Research papers in journals** | **Papers in Symposia/Seminars** | **Books/ Book Chapters /Tech. Bulletins/ Popular articles/ Newsletters/Proceedings articles** | **Total** |
|---|---|---|---|---|
| NBAIR,Bangalore | 26 | - | - | 26 |
| AAU, Anand | 3 | - | 4 | 7 |
| AAU, Jorhat | 6 | - | 24 | 30 |
| ANGRAU | - | - | 1 | 1 |
| GBPUAT,Pantnagar | 10 | 7 | 7 | 24 |
| KAU, Thrissur | 1 | - | - | 1 |
| MPKV, Pune | 2 | - | 3 | 5 |
| PAU, Ludhiana | 8 | 7 | 7 | 22 |
| TNAU, Coimbatore | 1 | 2 | - | 3 |
| SKUAST, Srinagar | 5 | - | 1 | 6 |
| **DRYSRUH** | 4 | - | 1 | 5 |
| YSPUHF, Solan | 8 | - | 1 | 9 |
| IGKV | 1 | 3 | 12 | 16 |
| UBKV | 3 | - | - | 3 |
| CISH | 1 | - | - | 1 |
| CPCRI | 4 | - | 8 | 12 |
| **Total** | **83** | **19** | **69** | **171** |

## 7. Profile of experiments and demonstrations carried out during 2018-19

| Crop/Insect | Experiments | Large Scale Demonstrations |
|---|---|---|
| Biodiversity of biocontrol agents | 2 | - |
| Antagonists of crop disease management | 3 | - |
| Sugarcane | 2 | 7 |
| Cotton | 5 | 0 |
| Tobacco | 2 | 0 |
| Rice | 4 | 9 |
| Cereals | 5 | 1 |
| Plantation crops | 6 | 1 |
| Pulses | 4 | 2 |
| Oilseeds | 1 | 2 |
| Tropical and temperate fruits | 9 | 0 |
| Vegetables | 11 | 1 |
| Polyhouse crops | 2 | 0 |
| Flowers | 1 | 0 |
| TSP | 9 | 0 |
| **Total** | **66** | **23** |

## 8. Budget of AICRP on Bio control for 2018-19

| Item of Expenditure | Sanctioned and allotted grants (Rs. in lakh) | Grants released during 2018-19 from ICAR (Rs. in lakh) | Total expenditure (Rs.) |
|---|---|---|---|
| Pay and allowances | 215.55 | 215.55 | 215.55 |
| Rec. Contingencies | 396.85 | 396.85 | 396.85 |
| T.A | 70.90 | 70.90 | 70.90 |
| TOTAL | **683.30** | **683.30** | **683.30** |