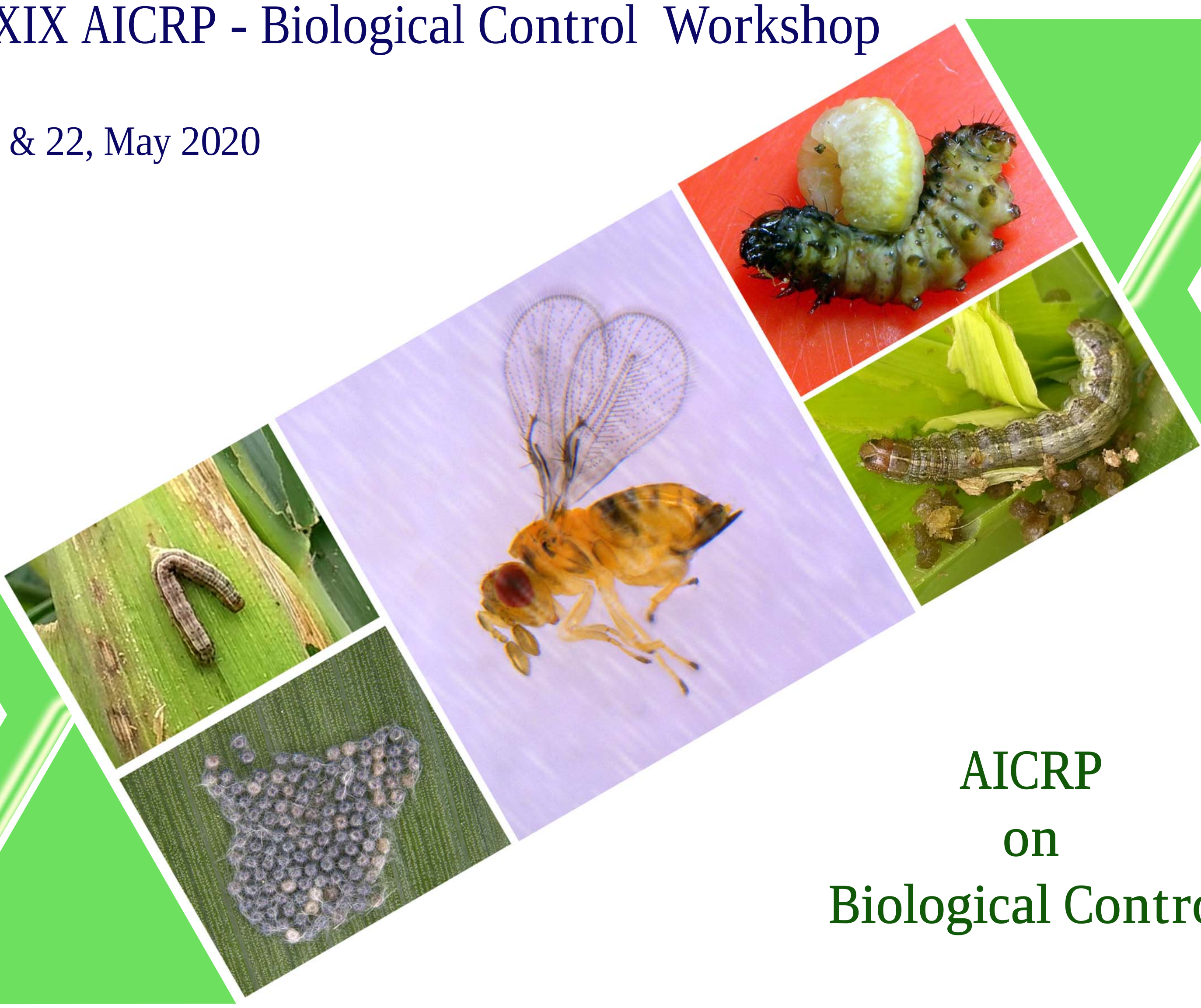
Project Coordinator's Report

XXIX AICRP - Biological Control Workshop

21 & 22, May 2020



AICRP
on
Biological Control

ICAR-National Bureau of Agricultural Insect Resources

P.B. No. 2491, H.A. Farm Post, Hebbal, Bellary Road,

Bengaluru-560024

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

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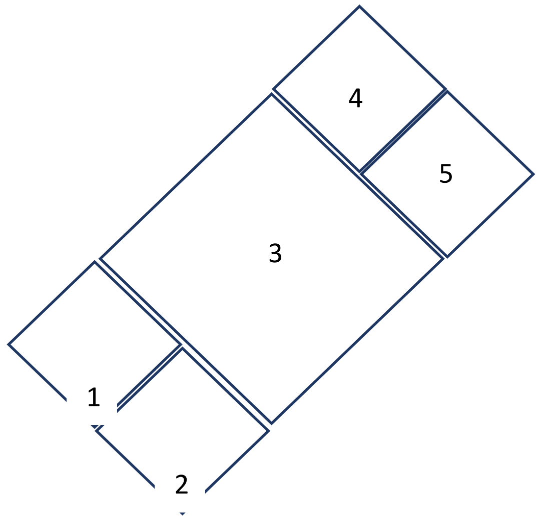
21 & 22 May, 2020

Compiled and edited by

Chandish R Ballal and Richa Varshney

ICAR- National Bureau of Agricultural Insect Resources
Bengaluru 560 024



Cover page

1. NPV infected fall armyworm larva
2. Parasitized fall armyworm eggs
3. *Trichogrammachilonis*
4. *Chelonus*sp. larva
5. Final instar larva of fall armyworm

Photo credits: Photographs 1- Dr G. Sivakumar; 2, 3 and 5 – Dr Omprakash Navik; 4 – Dr A.N. Shylesha

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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 modules.

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 pests. The recent invasive managed through AICRP-BC initatives are tomato pinworm, *Tuta absoluta*, 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 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 earlier comprised of 16 centres with funding has been strengthened through addition of 16 centres, thus currently having a strong network of 32 centres (with funding for 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 of AICRP-BC 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
20. Uttar Banga Krishi Viswavidyalaya, Pundibari, West Bengal

ICAR Institute–based centres

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

Voluntary Centres

1. Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
2. Sun Agro biotech Chennai
3. School of Agriculture Science & Rural Development, Medziphema Campus, Nagaland University
4. Sher-e-Kashmir University of Agricultural Science & Technology, Jammu
5. National Institute of Plant health Management, Hyderabad

The results from the various experiments conducted at centres across the country during the year 2019-20 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

Field surveys conducted in the maize fields infested with *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) in Karnataka, Tamil Nadu, Rajasthan and Meghalaya revealed *Cotesia ruficrus* (Haliday) (Hymenoptera: Braconidae) as the common gregarious larval parasitoid in the maize fields parasitizing *S. frugiperda*. This is the first report of *C. ruficrus* parasitizing *S. frugiperda* in India, earlier reports being from Trinidad and Tobago. *Coccygidium* (Braconidae) was also recorded as a new addition to *S. frugiperda* parasitoid complex. It is the first report of a host for *C. transcaspicum* and the first report of *C. transcaspicum* as a parasitoid of *S. frugiperda* across the globe. An egg-larval parasitoid, *Chelonus formosanus* Sonan (Hymenoptera: Braconidae) parasitizing *S. frugiperda* in India (in natural field conditions) was also recorded and this is amenable to mass production (in laboratory conditions).

4.1.2 Diversity of Trichogrammatids

A total of 876 trichogrammatids were collected from the states *viz*., Karnataka, Maharashtra, Tamil Nadu, Gujarat and Meghalaya. Eight genera of trichogrammatids, Chaetostricha, LathromeroideaMegaphragma, Oligosita, Paracentrobia, Trichogramma, Trichogrammatoidea and Tumidiclava were collected. The genera Megaphragma Timberlake was collected for the first time from Maharashtra. Parasitism of *Trichogramma chilonis* Ishii was recorded on *Spodoptera frugiperda* (J.E. Smith) for the first time on eggs of fall armyworm infesting maize. Trichogramma achaeae, T. chilonis and Trichogrammatoidea bactrae were recorded on the eggs of *T. absoluta* infesting tomato in Karnataka. Nine releases of *T. achaeae* were made to control the *Tuta absoluta* infesting tomato field in Karnataka. The field parasitism of *T. achaeae* ranged from 17.97 to 47.5% and reduced the population of larvae, pupae and number of leaf mine of *T. absoluta.*

4.1.3 Spider diversity and biocontrol potential of social spider

More than 530 spider specimens were collected from 7 states (15 locations) in different agro –ecosystems. One hundred and fifty two species identified up to the genus level and 53 species confirmed their identity at species level. Eighty one spider species from families (Salticidae, Thomisidae, Tetragnathidae, Araneidae and Gnaphosidae) were newly added into the collection. *Peucetia yogeshi* Gajbe (Oxyopidae: Araneae) the green lynx spider was redescribed. It has new distribution record to Karnataka (Gangavathi).

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

Evaluation of predatory mirid, *Dortus primarius* against *Tuta absoluta*

Dortus primarius was evaluated against *Tuta absoluta*. Both male and female were able to prey around 22–24eggs and nymph could consume 16-20 eggs per day with a continuous daily offer of 30 eggs. Among larval instars of *T. absoluta* both sexes of the predator accepted only 1st-instar larvae as preys.

Evaluation of Predatory mite, *Neoseiulus indicus* against broad mite in mulberry

Neoseiulus indicus was evaluated against broad mite, *Polyphagotarsonemus latus* (Banks) in mulberry. 88.07% reduction in mite population was observed after three releases of this predatory mite.

Evaluation of Predatory mite, *Neoseiulus indicus* and anthocorid bug, *Blaptostethus pallescens* against red spider mites in rose

Neoseiulus indicus and *Blaptostethus pallescens* were evaluated against red spider mites in roses. *Neoseiulus indicus* could reduce spider mite population by 88% followed by *B. pallescens* where 46% reduction in mite population was observed.

4.1.5 Studies on Fall Armyworm, *Spodoptera frugiperda*

Molecular Characterization of FAW:

Around **40 populations of *Spodoptera frugiperda*** were received from different parts of the country and Nepal were identified using **CO1**, **CO1B, TPI markers.** All the populations and its natural enemies were molecularly characterized & the sequences were deposited in **NCBI & ACC. Nos & DNA barcodes were obtained.**

Studies on the effect of Entomopathogenic fungi on maize fall armyworm (FAW) *Spodoptera frugiperda*

Field evaluation of *B. bassiana* (ICAR-NBAIR Bb-45) and *M. anisopliae* (ICAR-NBAIR Ma-35) against *S. frugiperda* in maize during *kharif* in NBAIR Research farm-Attur and during *rabi* in Dandeganahalli in Chikkaballapur district. Three foliar sprays @ 5g/litre ($1x10^8$ CFU/g) at 20, 30 & 40 days of the crop age were given. ICAR-NBAIR Ma-35 and ICAR-NBAIR-Bb-45 showed 62-86% of pest reduction in maize, respectively.

Evaluation of *Trichogramma pretiosum* (Th) and *Telenomus remus* against FAW eggs.

When FAW eggs were exposed to both parasitoids, *T. remus* resulted in 92.73 percent parasitism and *T. pretiosum* caused 45.51 percent parasitism. Percent adult emergence in case of *T. remus* was 95.01 percent while 68.13 percent adults were emerged from *T. pretiosum* parasitized FAW eggs. *Trichogramma pretiosum* (Th) was released (four releases @ 50,000/ha) in FAW infested field at Chikballapur, Karnataka along with other IPM interventions (pheromone traps, entomopathogenic fungi and entomopathogenic bacteria) and resulted in 76.14 percent reduction in FAW egg mass at 60 days after first release.

Evaluation of NBAIR BT-25 against FAW

Three field trails in Maize were conducted at farmer's field Chikkaballapura, NBAIR research farm and Hindupur showed 85%,88% and 76% decrease in pest incidence over control, respectively.

Laboratory and field evaluation of Spfr NPV

Laboratory bioassays revealed that all the early three instar larvae were equally susceptible (LC50 2.61 to 4.21 POB/mm2) to infection by SpfrNPV. Field experiment data revealed that prophylactic spray of aqueous suspension of SpfrNPV NBAIR1@ 4ml per litre twice with the concentration of 1.5x 10^{12} POBs/ ha at 20 and 35 days after sowing was found effective in reducing FAW population by 68.96 to 82.85% during the Kharif and Rabi seasons. Laboratory protocol for the production of *Spodoptera frugiperda* nucleopolyhedrovirus (SpfrNPV) was also developed.

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.)

In glass house studies, the endophytic isolates of *B. bassiana* (ICAR-NBAIR Bb-5a & Bb-45) and *M. anisopliae* (ICAR-NBAIR-Ma-4 & Ma-35) caused 8.4-76% mortality on second instar larvae of *Plutella xylostella* when applied through different inoculation methods. Among the isolates tested, Ma-35 isolate caused highest mortality on *P. xylostella* in all the application methods.

In field experiment, among the four isolates tested, NBAIR Ma-35 isolate caused highest pest reduction 93.5% when applied through a foliar spray (1x10^8cfu/ml) after 10days of transplanting of cabbage seedlings and rest of the isolates caused 56-81% of pest reduction over untreated control.

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 Tripura, Tamilnadu, Karnataka, Maharastra, West Bengal, Telangana, Delhi, Gujarat, Kerala, Assam (10 states) and Nepal and were used for DNA barcoding studies. Molecular variation between native and exotic *Trichogrmma* species, *Glyptapanteles, Parapanteles*, whiteflies, *Microplitis maculipennis* and veterinary insect pests was determined using CO1 & ITS-2 markers.

4.1.11 **Evaluation of entomopathogens biopesticides for the management of sucking pest *Thrips palmi* in watermelon var. *Arka manik* and suppression of watermelon bud necrosis tospovirus under field conditions**

Effective use of entomopathogenic biopesticides under field conditions viz., *Metarhizium anisopliae* strain NBAIR-MaCB, *Pseudomonas entomophila* strain NBAIR-PEOWN, *Pseudomonas fluorescens* strain NBAIR-PFDWD and *Bacillus albus* strain NBAIR-BATP either individually or in consortia form could effectively manage *Thrips palmi* on watermelon compared to untreated control. These biopesticides were on par with the chemical control imidacloprid but the yield was at appreciable level in *B. albus*, followed by *P. entomophila, P. fluorescens,* chemical check and *M. anisopliae*. Consortia of *B. albus* with *P. fluorescens* is very effective in *T. palmi* management compared to other treatments.

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-J: One hundred and thirty-eight numbers (138) of spiders from 6 different families (Lycosidae, Oxyopidae, Tetragnathidae, Araneidae, Uluboridae and Salticidae) were collected from different rice fields of Jorhat district. Fifty-six (56) number of Odonate species were collected from rice ecosystem and the most dominant was dragonfly (18) and damselfly (22) species were *Brachythemis contaminata* and *Agrionemis femina* in all rice growing seasons. Eighty-two numbers of coccinellids predators were recorded from August to Nov' 2019 from rice field. In vegetable ecosystem, 183 numbers of different types of predators along with parasitoids viz., *Cotesia glomerata*, *Campoletis chlorideae*, *Trichogramma chilonis*, *Bracon* spp. parasitizing *Helicoverpa armigera*, *Diaeretiella* sp from aphid, *Encarsia* sp.from whitefly and *Phanerotoma* sp. (Larval) from brinjal fruit an shoot borer were recorded.

AAU-A: *Trichogramma chilonis* was the major *Trichogrammatid* recorded cotton, okra, maize, rice and tomato fields. *Cheilomenes sexmaculatus* Fabricius was found to be the predominant species. A total 86 spider specimens belonging to five families namely Araneidae, Oxyopidae, Salticidae, Tetragnathidae and Thomisidae were collected from paddy fields. Out of 86 specimens, 29 turned to be *Agriope* sp. and 31 were *Neoscona theisi*. Six soil samples were found positive for EPN. From the soil samples collected, four strains of *Metarhizium* sp. have been isolated and identified. During the survey of invasive pest *Spodopetra frugiperda*, NPV infected larvae were collected. NPV occlusion bodies (OBs) were isolated and pathogenicity of the virus was confirmed.

CISH: Coccinellids population recorded as high as 3.45 adults/ tree at some point in 15th SMW. Peak population of hoverflies were observed through 19th SMW, registering with 4.8/tree, and peak Chrysopid population was noticed during 17th SMW which was recorded as 1.7 adults /tree.

PAU: Sixteen species of natural enemies were recorded including 7 species of insect predators; 2 species of parasitoids and 7 species of spiders during regular surveys in cotton growing areas of Punjab. Among predators, *Chrysoperla* was the predominant species. The mean parasitization of whitefly by *Encarsia* spp. in different cotton growing areas of Punjab was 7.51 per cent (range = 0.90 to 24.1%). Out of thirty-nine soil samples collected from different crops from different zones of Punjab for the isolation of entomopathogens, two *Bacillus* bacteria were isolated.

CAU Pasighat: Five species of spiders and one species of lady bird beetle has been collected from different crops.

TNAU: The natural enemies *viz*., *Trichogramma* sp., *Cryptolaemus montrouzieri*, *Chrysoperla zastrowi sillemi* and parasitoids of papaya mealybug were collected. The egg parasitoid of maize fall army worm was identified as *Trichogramma* sp. The activity of *Chelonus* sp was observed on maize fall army worm eggs in field coditions. Staphylinids and spiders were also observed in maize fields. A predator *Mallada boninensis* was seen in coconut trees infested with rugose spiralling whitefly.

KAU Thrissur: Spiders were collected from rice ecosystem in Thrissur and Palakkad districts by pit fall trap and sweep net methods and 165 specimens were collected.

UAS Raichur: Activity of spiders and coccinellids coincided with the peak activity of the thrips and hopper populations. Similarly, syrphid predator activity coincided with the activity of aphid population.

IIMR: About 15 – 20 % parasitization by *Cotesia flavipes* was observed in *Chilo partellus* during Kharif, 2019.. In Barnyard, Proso, Little, Kodo millets, the incidence of shoot flies was recorded at seedling, panicle stages causing deadhearts and white ears, respectively. Egg parasitoid *Trichogrammatoidea simmondsi* (20 %); Larval parasitoid, *Neotrichoporoides nyemitawus* (18.0 %) and pupal parasitoid , *Spalangia endius* (10%) were found parasitizing shoot flies across species and millets.

IIRR: Survey and collection of spiders was done and the collected species were *Pardosa pseudoannulata*, *Oxyopes salticus*, *Araeneus inustus*, *Tetragnatha javana*, *Tetragnatha maxillosa*, *Tetragnatha nitens*, *Plexippus* sp., *Bianor* sp., *Argiope catalunata*, *Olios* sp., and *Thomisus* sp. The wolf spider *Pardosa* (1.25/ trap) was the most abundant in pitfall traps while *Tetragnatha* spp., (3.14) were dominant in sweep nets.

MPKV: *Chrysoperla zastrowi sillemi* Esben. was observed in aphid colonies on cotton, maize, bean, jawar, okra and brinjal crops, whereas, *Mallada boninensis* Okam. was observed in aphid, mealy bugs and hopper colonies on cotton, bean, mango, papaya and hibiscus plants from five geographic locations. *Coccinella septempunctata* L. and *Menochilus sexmaculata* F. were recorded in the aphid colonies on leaf surfaces of crops *viz.,* Cotton, sugarcane, sorghum, maize, cowpea, okra, brinjal, soybean, beans, papaya and pomegranate.

Metarhizium rileyi (Farlow) (*N. rileyi*) diseased cadavers of *S. litura* were collected and isolated from soybean and cabbage crops, while diseased cadavers of *Spodoptera frugiperda (Smith*) infected with *Metarhizium rileyi* (Farlow) (*N. rileyi*) were collected from Maize fields. The cadavers of NPV infected larvae of *S. frugiperda* were also collected from Maize.

NIPHM: A total of eight natural enemies including parasitoids and predators were recorded from maize ecosystem during *Kharif,* 2019. Recorded the predators viz., *Coccinella septempuctata* Linnaeus., *Cheilomenes sexmaculata* Fabricius., *Coccinella transversalis* Fab., *Micraspis discolour* Fab., *Scymnus nobilis* Mulsant, *Podisus maculiventris* Say., *Chrysoperla* sp. The parasitoids reported are *Bracon* sp and *Trichogramma* sp.

OUAT: During survey on the spider fauna of *kharif* paddy (Var. swarna) at Bhubaneswar, ten species of spiders belonging to six genera and four families were recorded. Among the spider species, *Tetragnatha mandibulata* was the most dominant one.

YSPUF&F: Several coccinellids, chrysopids and syrphid flies were observed in different ecosystems. Besides this *Cotesia glomerata* parasitizing *Pieris brassicae* in cauliflower and *Campoletis chloridae* parasitizing *Helicoverpa armigera* in tomato, *Diplazon* sp parasitizing syrphid flies were also collected from Nauni.

SKAUST Srinagar: Different variants of *Harmonia eucharis* (Coleoptera: Coccinellidae) were recorded on fruits. Per cent parasitism by *Aphelinus mali* (Hymenoptera: Aphelinidae) ranged 20 - 80.0 per cent in woolly apple aphid, *Eriosoma lanigerum* in different parts of Kashmir. *Chilocorus infernalis* was found actively associated with San Jose scale on apple and *Parthenolecanium corni* on plum. *Psyllaephagus* sp. was recorded first time parasitizing *P. lecanii* in Kashmir. An average of 60.0 per cent parasitism was recorded by two hymenopterous parasitoids viz. *Psyllaephagus* sp. and *Metaphycus* sp. Total larval parasitism by *Cotesia glomerata*, unidentified ichneumonid and tachinid flies was 34.34 per cent in *Pieris brassicae* whereas in *Plutella xylostella* total parasitism by *Diadegma semiclausum* and *Cotesia vestalis* was 45.75 per cent.

4.2.1.1 SURVEILLANCE FOR ALIEN INVASIVE PESTS

The alien invasive pests, *viz., Brontispa longissima, Aleurodicus dugesii, Phenacoccus madeirensis* were not recorded in any of the centres during the year 2019-2020.

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

CPCRI, Regional Station, Kayamkulam: Rugose spiraling whitefly (*Aleurodicus rugioperculatus*) was found to be very low (1.5 colonies /leaflet) during July-December 2019 and thereafter shot up as high as 4.5 colonies by February 2020. The population of Bondar's nesting whitefly (*Paraleyrodes bondari*) was found to be higher recording as high as 4.0 colonies per leaflet in the month of September 2019 got reduced subsequently reaching as low as 0.5 colonies on March 2020. The non-native nesting whitefly (*Paraleyrodes minei*) that co-existed with BNW and RSW during 2018 was not observed and was completely displaced by the other exotic whitefly species. Percentage parasitism by *Encarsia guadeloupae* on RSW colonies decreased from 48% in July 2019 to 22% in February 2020 which encouraged the buildup of RSW colonies in 2020 favoured by weather factors.

DRYSRHU Ambajipeta: The RSW population was collected from the variety East coast tall of 10 to 15 years from three different blocks of HRS., Ambajipeta farm. Nil population of parasitoid *E. guadeloupae* and low population of predator's spiders (0.25/ per four leaf lets) and predator *Dichochrysa astur* (0.50/ per four leaf lets) was recorded under natural conditions.

KAU Thrissur: Incidence of rugose whitefly on coconut was widespread in Thrissur and Palghat districts during 2019-20. The buildup of pest started in November, possibly due to the delayed withdrawal of the South West monsoon. The whitefly infestation broadly followed the pattern observed in 2018-19 though the severity of infestation was high well into March, unlike in previous years when it had declined by January. Mean parasitism by *Encarsia guadeloupae* remained throughout the study period, ranging from 28.64 to 80.18 per cent at Palakkad and from 35.72 to 62.10 per cent at Thrissur and never reached 90 per cent at either of the locations.

KAU Vellayani: Observations recorded for a period of 10 months revealed that the pest population is dwindling between low and severe levels. The peak was noted during Dec 19 to February 2020. Three species have been observed *A. rugioperculatus, P. mineyi and P. bondari*. When the population of *A. rugioperculatus* was more, high parasitism (75.72 %) was recorded, while less parasitism (28.74 %) was recorded when the population of nesting whiteflies is more.

RARS Kumarakom: In Kumarakom, whitefly infestation was noticed to be in a medium range from April to June 2019, followed by a slight decline in July with an average of 9.60 live colonies per leaflet. Thereafter, gradual increase was noticed in the colony count with a maximum of 24.85 colonies per leaflet recorded in February. Highest per cent intensity was noticed in March (80.32%) and the least in August (29.41%) which might be subjected to the heavy rain and flood occurred then. Per cent infestation was observed to follow an increasing trend from September 2019 onwards.

4.2.1.3 SURVEY AND SURVEILLANCE OF NATURAL ENEMIES OF PINWORM, *TUTA ABSOLUTA* ON TOMATO

AAU-A: No incidence of *Tuta absoluta* was recorded during the survey period.

TNAU: Survey was conducted to assess the occurrence of tomato pinworm, *Tuta absoluta* in tomato growing areas of Coimbatore district *viz.,* Pichanoor, Patchapalayam, Thekarai and Thudiyalur. In Thekarai, the leaf damage was 12.0 per cent where as no fruit damage was observed. In Patchapalayam, the fruit damage was 3.00 per cent. In Pichanoor, 12.00 and 4.00 per cent leaf and fruit damages were observed respectively.

MPKV: There was no infestation of *Tuta absoluta* on tomato in Pune, Satara, Sangli, Solapur and Kolhapur and Ahmednagar districts of Maharashtra state.

IIVR: Occurrence of pin worm on leaf and fruit was first recorded during the last week of November, 2019 (48th SMW). The maximum fruit damage (5.56%) was observed during the first week of January, 2020 (1st SMW) whereas lowest fruit damage (0.60%) was during third week of March, 2020 (12th SMW). Maximum 3.7 *Nesidiocoris tenuis* per apical twigs were recorded.

MPUAT: The infestation ranged from 6 to 25 per cent. Whenever no control measures were adopted, 55-65 per cent infestation was recorded in tomato crop. Survey reveals that the pest is more severe under protected conditions than in open field conditions and prefers tomato over other host plants.

PJTSAU: Marginal incidence of the pest was observed.

4.2.1.4 SURVEILLANCE FOR PEST OUTBREAK AND ALIEN INVASIVE PESTS INCLUDING FAW

TNAU: In guava orchard (11°07'N ,76°59' E) in Coimbatore, woolly whitefly (*Aleurothrixus floccosus*) (Maskell) (Hemiptera: Aleyrodidae), was observed during October 2019. Predators *viz., Cryptolaemus montrouzieri* and *Mallada desjardinsi* were found feeding on the woolly whitefly. Bondar's Nesting Whitefly *Paraleyrodes bondari* Peracchi (Hemiptera: Aleyrodidae) was observed in coconut gardens in Coimbatore, Erode and Tirupur Districts since October 2019. *Mallada boniensis* was found feeding on Bondar's Nesting Whitefly. Maize fall armyworm damage was observed in all the maize fields except in a field in Edapadi where the farmer has sprayed insecticides on 15th day after sowing.

KAU Thrissur: No report of invasive and pest outbreak.

UAS Raichur: Roving survey conducted in six districts of North Eastern Karnataka indicated that FAW incidence was negligible in rabi Jowar (M 35-1). On Maize the number of egg patches per plant and number of larvae were highest compared to rabi jowar. In Koppal district the natural epizootic of *Metarhizium rileyi* was noticed.

MPKV: Amongst the targeted invasive pests, the mealybug species, *Pseudococcus jackbeardsleyi* and *Paracoccus marginatus* were recorded on custard apple and papaya respectively, in Pune, Nadurbar, Dhule and Jalgaon districts. *Tuta absoluta* was not observed on tomato crop in Western Maharashtra. The Fall Army Worm (FAW), *Spodoptera frugiperda* (Smith) was recorded in all maize growing areas of Maharashtra. The pest extended its host range on sorghum and bajara crop in Pune, Solapur, Satara and Sangli districts. FAW is reported for the first time on Cotton crop at Susare Village of Pathardi Tahasil in Ahmednagar district.

MPUAT: Incidence of fall armyworm was noticed to be moderate to severe in Udaipur, Chittorgarh, Banswara and Dungarpur districts of Southern Rajasthan with an average incidence range of 30-40 per cent. The swarm of Locust was first spotted in month of

December, 2019 in Udaipur region, mainly Kotra block. It has damaged many hectares of mustard and wheat crops and eaten up plants in the large forest area. It has so far stationed at Dedhmariya, Phulwariya, Maldar, Mahudi and Khajuria village. Earlier, locust swarm spotted in Jaisalmer, Barmer, Jodhpur, Jalore, Sirohi, Pali, Bikaner and Ganganagar districts of Rajasthan. Among these districts, in Jalore, Barmer, Jaisalmer district, this pest caused significant damage to cumin, castor and isbagol crops.

OUAT: Mild to moderate infestation of fall armyworm was observed.

YSPUH&F: Different Vegetable and fruit ecosystems in district Solan, Sirmour, Mandi, Kullu, Bilaspur, Shimla, Kangra, Kinnaur and Lahaul & Spiti were surveyed for the collection of pests like, *Aleyrodicus digessi, Phenacoccus manihoti, Paracoccus marginatus*, *Phenacoccus madeirensis* and *Tuta absoluta* but only *T. absoluta* was recorded.

PJTSAU: Fall armyworm (FAW) incidence was noticed from low to moderate during *Kharif* 2019-20, in many maize growing districts of Telangana *viz*., Karimnanagar, Siddipet, Sangareddy & Mahbubnagar. It was found to be medium to high in Nagarkurnool and Khammam districts as compared to other districts of the state.

IIMR: Surveys for incidence of *Spodoptera frugiperda* showed 3 – 10 % foliar damage on Sorghum. During Rabi season 15 – 40 % foliar damage was observed at Hyderabad, Warangal.

4.2.2 BIOLOGICAL SUPPRESSION OF PLANT DISEASES

4.2.2.1 Evaluation of fungal and bacterial isolates for crop health management in rice

GBPUA&T: Glasshouse: In mixed formulation treatments, highest germination percentage was observed in PBAT-3 (87.00 %) followed by, Th17+Psf-173 (84.66%), Carbedazim (81.83%) as compared to control (61.00%). Maximum root length was observed with PBAT-3 (22.08 cm) followed by Th14+Psf-2 (21.83 cm), Psf-173 (21.50 cm), which did not differ significantly with each other but was significantly better than the control (15.08 cm).

Field: Minimum Sheath blight (*Rhizoctonia solani*) disease severity was recorded with PBAT-3 (30.30%) followed by Carbendazim (30.58 %), Th17+Psf-2 (31.00%) and Th17+Psf-173 (31.29%), which did not differ significantly from each other but were significantly better than control (37.30%). Minimum percentage of Brown spot (*Drechslera oryzae*) infected panicle/hill was observed with Carbendazim (42.26%) which was statistically at par with PBAT-3 (42.77%) and followed by Th17+Psf-173 (44.17%). Maximum yield was obtained with PBAT-3 (53.83 q/ha) followed by other treatments.

4.2.2.2 Evaluation of microbial antagonists for the management of foot rot of kinnow caused by *Phytophthora* spp.

PAU: The experiment to evaluate the microbial antagonists against foot rot of citrus showed highest per cent recovery in final lesion size in chemical control (45.5%) over untreated control followed by NBAII- Pf DWD *Pseudomonas fluorescence* and *Trichoderma harzianum* with 24.59 and 21.94 percent recovery, respectively. The mean number of fruits per plant was maximum (504.0) in chemical treatment (Curzate M8) followed by NBAII-PfDWD *Pseudomonas fluorescence* (482.0). However, minimum number (382.0) of fruits was recorded in untreated control. The yield per tree was 99.5 kg and 109.5 kg in *Pseudomonas fluorescence* NBAII-PfDWD and chemical control, respectively.

4.2.3 BIOLOGICAL SUPPRESSION OF SUGARCANE PESTS

4.2.3.1 Efficacy of entomopathogenic nematode and entomofungus for the management of white grub in sugarcane ecosystem UAS Raichur: Plant damage was lowest (8.50 %) in *Heterorhabditis indica* WP (ICAR- NBAIR) and it was at par with *Metarhizium anisopliae* (ICAR-NBAIR Ma 4) and Chlorantraniliprole 18.5 SC which recorded 9.25 and 6.50 per cent plant damage. Highest plant damage of 61.25 per cent was noticed in untreated control. *Heterorhabditis indica* WP (ICAR- NBAIR) recorded 121.85t/ha cane yield which was at par with *Metarhizium anisopliae* (ICAR-NBAIR Ma 4) and Chlorantraniliprole 18.5 SC which recorded 118.50 and 123.50t/ha. Untreated control recorded 95.25 t/ha cane yield.

4.2.3.2 Field efficacy of dose application of EPN against white grubs in sugarcane

MPKV: Highest white grub reduction (75.85 %) was recorded in chemical treatment with Fipronil. Amongst EPN strains, highest white grub reduction (72.78 %) was recorded in *H. indica* @ 3.0 x10^5/ m^2 (NBAIR WP formulation).

4.2.3.3 Field efficacy of EPN strains against white grubs in sugarcane.

MPKV: Amongst EPN *H. indica* @ 1.0x10^5/ m^2 (NBAIR WP formulation) treatment recorded 54.72 % and become next promising treatment after chemical treatment (Fipronil) for suppressing white grub in sugarcane

4.2.4 BIOLOGICAL SUPPRESSION OF COTTON PESTS

4.2.4.1 Biointensive management of pink bollworm on *Bt* cotton

TNAU: In the field trial, pink boll worm damage was 22.50 per cent in BIPM plots which was 28.57 per cent lesser than the damage in the control plot. There was 36.13 per cent reduction in pink boll worm damage in the insecticide sprayed plots. The yield was maximum in insecticide sprayed plots (1654Kg/ha) followed by 1562Kg/ha and 1344Kg/ha in BIPM and control plots respectively. The CB ratios were 1:2.41 and 1:2.57 for BIPM and insecticide treatments respectively.

UAS-Raichur: The number of PBW larvae in plant protection treatment (T_1) and chemical treatment (T_2) was 5.18 and 2.36 larvae per 10 bolls, respectively while in control (T_3) maximum of 8.94 larvae per 10 bolls were noticed. Rosette flower in T_1 (6.28 %) and T_2 (4.36 %) differed statistically and T_3 recorded highest rosette flower of 10.26 per cent.

Similarly, highest seed cotton yield of 31.80 q/ha was noticed in T_2 while T_1 recorded 27.35 q/ha and lowest seed cotton yield of 17.75 q/ha was recorded in $T_{3.}$

PJTSAU: Despite low incidence of PBW during *Kharif*, 2019-20, the module with pheromone traps (Funnel type) @ 10/ plot + releases of *Trichogrammatoidea bactrae* 100,000/ha/release, 6-8 releases starting from 55 days after germination + application of 5% Neem Seed Kernel Extract (NSKE) fared better in terms of percent green boll damage (19.20), percent locule damage (6.12) than insecticide treatment (24.67 % green boll and 7.13 percent locule damage).

4.2.4.2 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 all locations throughout the season in July. Mean population (average of all locations) of whitefly (adults per three leaves) was maximum in July (9.44±5.12) followed by Aug (5.23±1.39), Sep (4.55±3.29), June (3.63±1.19) and October (1.85±0.66). Among all the locations, maximum population (mean of the season) was observed in Fazilka (8.19±6.37), followed by Sirsa (5.2±2.28), Muktsar (3.81±1.91), Hanumangarh (3.79±2.17) and Sriganganagar (3.71±2.82). Mean (average of the season) parasitization (per cent) of whitefly nymphs by *Encarsia* spp or other parasitoids was recorded maximum in Muktsar (33.85, Range 25.00 – 57.14) followed by Sirsa (29.650 Range 12.50-40.90), Fazilka (29.28 range 18.11-39.42), Sriganganagar (26.57; range 12.33-38.46) and Hanumangarh (25.40 range 14.71-37.93).

4.2.4.3 Management of pink bollworm by using *Trichogrmmatoidea bactrae* on *Bt* cotton

PDKV: Significantly minimum bad open bolls were recorded in treatment T2 (insecticide treated field) (23.50 % bad open bolls) followed by treatment T1 (biocontrol practices) (26.09%), both the treatments were at par with each other and significantly superior over untreated control (36.58 %). Treatment T2 recorded significantly maximum yield of 1316.87 Kg/ha seed cotton, followed by treatment T1 recording 1221.71 Kg/ha seed cotton. Both these treatments were significantly superior over untreated control (812.76 Kg/ha seed cotton).

4.2.4.4 Biointensive Pest Management in *Bt* cotton ecosystem

UAS Raichur: Sucking pest population *viz*; thrips, leafhoppers, aphids and whiteflies population was more in biointensive practice (7.84, 11.36, 5.36 and 0.76 thrips, leafhoppers, aphids and whiteflies, respectively/leaf) compared to farmer practice (2.92, 4.84, 2.18 and 0.26 thrips, leafhoppers, aphids and whiteflies, respectively/ leaf). Biointensive practice recorded 11.32, 33.68 and 21.86 PBW larvae, GOB and BOB per plant, respectively and in farmers practice it was 7.98, 39.84 and 13.85 PBW larvae, GOB and BOB per plant, respectively. Biointensive practice recorded 27.25 q/ha seed cotton yield while in farmer practice it was 31.75 q/ha.

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

MPKV: Pooled means for two years (2017-18 and 2018-19) indicated that amongst the biopesticides, *Lecanicillum lecanii* (1 x 10^8conidia/g) @ 5 g/litre recorded lowest population of sucking pests *viz.*, aphids (5.74), jassids (2.69), thrips (2.61), and white flies (1.77) on 3 leaves per plant compared to the untreated control which recorded aphids (39.24), jassids (12.73), thrips (31.67), and white flies (10.62) on 3 leaves per plant. The *L. lecanii* treatment recorded seed cotton yield of 18.32 q/ha which is at par with dimethoate 0.05 per cent (19.02 q/ha) with B:C ratio (1.25), and 1.32, respectively.

PJTSAU: Among the biologicals evaluated, *Lecanicillium lecanii* followed by application of azadirachtin 1500 ppm @ 5ml/l at ETL hosted significantly a smaller number of sucking pests such as jassids, aphids & whiteflies as compared to control and equivalent to insecticidal check indicating *L. lecanii* as a viable alternative to insecticidal applications in cotton for the management of sucking pests.

4.2.5 BIOLOGICAL SUPPRESSION OF RICE PESTS

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

PAU: The population of plant hoppers in BIPM and control plots was 1.93 and 3.00 per hill, respectively resulting in a reduction of 35.8 per cent over control. The population of spiders was comparatively higher in BIPM plot. Basmati yield was 32.00 q/ha in BIPM as compared to 30.50 q/ha in untreated control with an increase of 4.92 per cent.

ANGRAU: Hopper population was low in BIPM plot (0.48 hoppers/hill) and farmers practice plot (0.78 hoppers/hill) compared to control plot (3.5 hoppers /hill). Reduction in hopper population after first spray was high in BIPM plot (83.6 %) and farmers practice plot (77.38%) and increase in hopper population was recorded in control plot (20.14 %). Grain yield recorded was high in BIPM practice (3.85 t/ha) compared to farmer's practice and untreated control. Percent yield increase in BIPM practice over control was 52.77% and in farmers practice was 44.05 %.

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

ANGRAU: Percent reduction in leaf folder damage over untreated control was high in Flubendiamide (81.52 %) followed by *Bacillus thuringiensis* (73.62%), *Heterorhabditis indica* (65.72%) and *Steinernema carpocapsae* (63.19 %). Percent reduction in stem borer damage over untreated control was high in flubendiamide (78.28%) and *Bacillus thuringiensis* (56.49 %). Grain yield recorded was high in chemical treatment (3.65t/ha) followed by *Bacillus thuringiensis* (NBAIR strain) (3.4 t/ha) and *Beauveria bassiana* (3.27t/ha), *Steinernema carpocapsae* (3.25 t/ha) and low in control (2.82 t/ha).

KAU Thrissur: Plots treated with *B. thuringiensis*, *H. indica,* and *B. bassiana* had significantly lower number of dead hearts (3.66, 5.00 and 8.33/ m^2 respectively) than remaining treatments 28 days after the third spray. *Metarrhizium anisopliae* and flubendiamide registered mean values of 16.00 and 21.66 dead hearts/m^2 and were on par with untreated control (17.00 dead hearts/ m^2). The lowest mean number of 1.66/m^2 rolled leaves was recorded in plots treated with flubendiamide, which was on par with both *H. indica* as well as *M anisopliae* treatments with mean values of 2.66 and 3.33 rolled leaves /m^2.

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

KAU Vellayani: Pooled analysis of data for two years 2018-19 and 2019-20 revealed that indigenous isloalate of KAU *B. bassiana* was invariably the superior treatment for the management of *C. medinalis*. Furthermore, the chitin enriched oil formulation could enhance the virulence of the pathogen as it could reduce 82.69 per cent pest population compared to its conodial suspension which showed 79.84 % reduction in larval count.

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

KAU Vellayani: Analysis of data revealed that *L. saksenae* @ 10^7 spores ml^{-1}, was the best treatment to manage *L. acuta* population, when sprayed twice at the panicle initiation and milky stage of the crop. NBAIR isolate Bb5 was found to be superior to thiamethoxam. It is notable that the bug population was nil in the *L. saksenae* treated plots after the second spraying. Data on mean count of natural enemies which included the total count of spiders, coccinellids, scarbids and mirid, analysed revealed that the population did not vary among treatments.

4.2.5.5 Testing of BIPM trial on paddy along with farmers practice and control

IGKV: Maximum percent of dead heart (8.50), white ear head (20.51) was recorded in control compared to BIPM trial (dead heart: 12.20; white ear head: 15.58). Maximum percentage leaf folds were observed in control (3.84) compared to BIPM plot (1.51). Significant maximum grain yield/plot (31.56 kg) was obtained in BIPM treatment followed by farmer’s practice (28.88kg)/plot and control (25.25 kg) per plot respectively.

4.2.6 BIOLOGICAL SUPPRESSION OF CEREAL PESTS

4.2.6.1 Evaluation of entomopathogenic fungi and *Bt* against stem borer, *Chilo partellus* (Swinhoe) in maize

PAU: Among biopesticides, lowest dead heart incidence was recorded in commercial Bt formulation (6.45%) and it did not differ significantly from NBAIR Bb-5a (8.57%) and NBAIR Bt (8.62%). The dead heart damage in NBAIR Ma-35 was 11.17 per cent and it was not significantly different from NBAIR Bt and Bb-5a. Grain yield was highest in chemical control

(49.26 q/ha). It was followed by commercial Bt formulation (46.04 q/ha), Bb-5a (44.11 q/ha), NBAIR Bt (43.44 q/ha) and Ma-35 (42.04 q/ha).

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

MPUAT: The dead heart incidence in fields with the releases of *T. chilonis* (T_1) was 9.89 per cent and in chemical control (T_2), it was 7.37 per cent. The reduction in incidence over control was 45.20 and 59.16 per cent in T_1 and T_2, respectively. The yield in *T. chilonis* (28.65q/ha) and Spinosad 45 SC(T_2) (31.45 q/ha) fields were significantly more than in untreated control (23.48 q/ha).

4.2.6.3 Bio-ecological engineering for the management of major insect pests of maize and benefit of their natural enemies

SKAUST Jammu: Percent plant damage by *C. partellus* on maize was significantly lowest in T_3 – Maize + cowpea + Sorghum. Number of *Spodoptera litura* larvae per five intercropped plants and whiteflies per five leaves of various intercrops were significantly lowest in T_3 - Maize + cowpea + sorghum. The natural enemies present in the ecosystem; Coccinellids and spiders were more active in okra and maize intercrops, where the population of whiteflies and *S. litura* larvae were more.

4.2.6.4 BIOLOGICAL SUPPRESSION OF FALL ARMYWORM *SPODOPTERA FRUGIPERDA* (J. E. SMITH) (LEPIDOPTERA: NOCTUIDAE) IN MAIZE

ANGRAU: During 2019-20, fall armyworm damage at 20 days after sowing was low in *T. pretiosum* released treatments (23.82 – 35.1 %) with egg parasitisation (5.84 - 9.01 parasitised eggs/20 plants). Upto 50 days after sowing, total damaged plants per plot recorded high in untreated control (169.33) followed by pheromones @ 15 traps/acre (155.33). Total number of dead larvae per plot was high in insecticidal check (50.38) followed by *T. pretiosum* release+ *M. anisopliae* sprays (42.9) and *T. pretiosum* release + NBAIR Bt (41.9). Cob yield recorded high in insecticidal check (40.18 q/ha) and was on par with *T. pretiosum* release + NBAIR Bt (39.97q/ha); *T. pretiosum* release + *M. anisopliae* (39.38 q/ha) and low in untreated check (22.63 q/ha).

TNAU: Among the biocontrol agents, 89.24 per cent damaged plants was observed in *Trichogramma pretiosum*+ *Beauveria bassiana* NBAIR -Bb 45 followed by *Trichogramma pretiosum*+ *Metarhizium anisopliae* Ma 35 (89.75%), *Trichogramma pretiosum*+ NBAIR Bt 2% (90.58%) and *Trichogramma pretiosum*+Spfr NPV(NBAIR1) (90.67%) on 45 days after sowing while in insecticide treated plots 59.57 per cent damage was observed. Yield was maximum (6300Kg/ha) in *Trichogramma pretiosum*+ *Beauveria bassiana* NBAIR -Bb 45 plots followed by *Trichogramma pretiosum*+ *Metarhizium anisopliae* Ma 35(6067Kg/ha) and these two treatments were on par with the yield (6513 Kg/ha) in the insecticide treated plots.

AAU-A: Among different biocontrol agents tested, significantly lowest number of *S. frugiperda* larvae/ 10 plants was recorded in treatment 1 (*Trichogramma pretiosum* @ 1 card/acre + *Bacillus thuringiensis* - NBAIR BTG1 - 1% WP) which was at par with the treatment T_2 (*T. pretiosum* @ 1 card/acre + *Metarhizium anisopliae* - NBAIR Ma35 - 1% WP) (2.19 larvae/10 plants). The treatment T_1 recorded the highest grain and fodder yield (3736.67 & 7066.67 kg/ha) which was at par with the treatment T_2 (3716.67 & 7066.67 kg/ha). No significant differences were found with regard to number of egg patches/ 10 plants and number of predators/ 10 plants among biocontrol treatments. Significant numbers of dead larvae due to entomopathogens were found in biocontrol treatments.

IIMR: number of egg mass laid were minimum in *Trichogramma pretiosum* 1 Card/ acre +NBAIR *Bb 45* (1.66) and *Trichogramma pretiosum* 1 Card/ acre + NBAIR *H* 38 (2.00) and *Trichogramma pretiosum* 1 Card/ acre + *Pf* DWD 2% (2.67) and were significantly different compared to control (14.67). The treatments *Trichogramma pretiosum* 1 Card/ acre+ NBAIR *MA* 35- 0.5% and NBAIR *Bb* 45- 0.5% recorded maximum number of dead larvae of 5.67 and 4.33, respectively. Maximum grain yield was recorded in *Trichogramma pretiosum* 1 Card/ acre+ NBAIR *H* 38 0.5% (4436.66 kg/ha), *Trichogramma pretiosum* 1 Card/ acre+ NBAIR *Bb*-45 0.5% (4275.55 kg/ha) and *Trichogramma pretiosum* 1 Card/ acre+ Spfr NPV (NBAIR 1) (4048.89 kg/ha). However, standard check emamectin benzoate (4555.56) gave highest yield when compared to all the treatments.

OUAT: Although, the insecticidal check excelled best among all other treatments, but among the bio-modules, trichocard releases (2)+Bt sprays (2) expressed highest green cob yield (/14.12t/ha) and lowest pest damage which is comparable to chemical check and closely followed by trichocard releases (2) + *Metarhizium* sprays (2).

UAS-Raichur: Three days after spray treatment $T_{3.}$ (*Trichogramma pretiosum* (1 card per acre to be installed after one week of planting) + EPN *H. indica* NBAIR H38 whorl application @ 4kg/acre) recorded lowest of 0.48 larva per plant which was at par with chemical treatment, Emamectin benzoate 5 SG @ 0.4 g/lit which recorded 0.36 larva per plant. Per cent plant damage was also low in T_3 (14.25 per cent) and it was at par with chemical treatment (12.75 per cent) while, untreated control recorded 41.25 per cent plant damage. Yield q/ha was on par between T_3 and chemical treatment.

MPKV Pune: Three sprays of (Emamectin benzoate 0.4g/l) recorded lowest plant damage of FAW (4.44 %) and it was significantly superior over rest of the treatments. Among the biocontrol agents, *T. pretiosum* 1 card (2 Rel.) + EPN *H. indica* NBAIR H38 @ 4kg/acre and *T. pretiosum* 1 card (2 Rel.) + *M. anisopliae* Ma 35, 0.5% @ 2.0 g/l) were the next best treatments in suppressing the FAW in maize with plant damage of 28.89 %.

4.2.6.5 EFFICACY OF BIOCONTROL AGENTS AGAINST FALL ARMYWORM IN RABI SORGHUM DURING 2019-20

UAS-R: Number of egg patches of FAW ranged from 1.58 to 1.84 per plant which was statistically non significant. Minimum of 0.64 larva per plant 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 28.75 per cent. The highest grain yield of 13.10 q/ha was noticed in T_3 which was at par with all the treatments including untreated control.

4.2.6.6 Evaluation of entomopathogenic fungi formulations against millet borers in Finger millet, Kharif, 2019

IIMR: The Dead heart caused in Finger millet due to Pink borer were significantly least in Bb-45 @ 10 ml /lt treatment (3.08%) and it was on par with T_4 (Ma-35 @10 ml /lt) (3.31%) and statistically better than Carbofuran soil application (4.13%). White earhead were least in T5 (Carbofuran 3G granules @ 20 kg/ha) soil application) (2.50 %) and it was statistically on par with T_4 (2.68%) and T3 (2.78%). Highest grain yield was obtained in T5 (3.78 kg/plot) which was on par with T4 (3.62 kg/plot) and T3 (3.48 kg/plot).

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

PDKV: The data on pod borer damage at harvest revealed significant differences among the treatments, recording significantly minimum damage of 13.13 % in Bt treatment (T1) followed by treatment T2 with insecticidal sprays recording 14.13 % pod damage and both the treatments were significantly superior to untreated control (24.25 % damage). Maximum yield (16.59 q/ha) was observed in T2 followed by T1 (15.74 q/ha) and both treatments were at par with each other and significantly superior over untreated control.

UAS Raichur: The per cent pod damage in NBAIR *Bt* G 4 was 10.16 per cent while in farmers practice it was 7.38 per cent. In NBAIR *Bt* G 4 the grain yield was 10.68q/ha in farmers practice 13.04 q/ha.

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

MPUAT: The maximum reduction was recorded in quinalphos 25 EC @ 250g a.i/ha treatment (1.7 larvae per plant) and the minimum reduction was observed in *Bt.* @ 1 Kg/ha (2.2 larvae per plant) at ten days after spray; whereas, the untreated control recorded least reduction in larval population (5.0 larvae per plant). Minimum per cent pod damage was recorded in chemical treated field (8.68%) followed by *B. bassiana* (12.18 %) and Bt (13.56%) and maximum was recorded in control (18.59).

4.2.7.3 Evaluation of entomopathogenic fungi against pod bug *Riptortus pedestris* on cowpea, *Vigna unguiculate*

KAU- Thrissur: *Beauveria bassiana* (NBAIR Strain) and malathion were significantly superior to the untreated control with mean pod damage of 34.05 per cent. The treatments did not differ significantly at either 10 or 12 days after second spray. There was no significant difference among the treatments in terms of yield, though plots treated with *B. bassiana* recorded the highest yield of 822.91 g/plot.

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

GBPUA&T: Glasshouse: In mixed formulation treatments maximum germination percentage, root length was observed by PBAT-3 followed by other treatments. Maximum shoot length was observed with Th17+Psf2 (42.90 cm) which was statistically at par with PBAT-3. Maximum fresh weight was observed with Th17+Psf173 (0.28 gm) which was statistically at par with PBAT-3.

Field: Maximum plant stand, 60 DAS and 120 DAS respectively was recorded with consortium Th17+Psf173 followed by PBAT-3 and other treatments. Minimum number of mature plant wilt at 120 DAS was observed with consortium Th17+Psf173 (3.24), while maximum in control (6.10) after 120 days of sowing.

4.2.7.5 BIPM module for management of *Helicoverpa armigera* on chickpea

TNAU: Larval population in both the BIPM modules (BIPM 1: Erection of bird perches Spray of HaNPV strain twice during the early pod formation stage at 15 days interval, Use of pheromone traps @ 1 trap per plot; BIPM module -2: Erection of bird perches Spray of *Bacillus thuriengiensis* at 7 day interval, 2 sprays twice during the early pod formation stage at 15 days intervals, Use of pheromone traps @ 1 trap per plot) were statistically similar with 3.17 and 3.00 larvae/ 10 plants respectively on seventh day after spraying (DAS). The same trend was observed on 14DAS also. Pod damage was significantly less (7.29%) in chemical treatment when compared to BIPM modules. However, there was 35.93 to 37.53 per cent reduction in the pod damage in BIPM modules. The yield was maximum in chemical treatment (644Kg/acre) followed by BIPM module-2 (578Kg/acre) and BIPM module-1 (567Kg/acre).

4.2.8 BIOLOGICAL SUPPRESSION OF PESTS OF TROPICAL FRUIT CROPS

4.2.8.1 Effect of bio pesticides for management of Mango hoppers *Idioscopus* spp in field condition

CISH Lucknow: Entomopathogenic fungi *viz.*, *Beauveria bassiana* and *Metarhizium anisopliae* formulations were tested for their bio-efficacy against mango hoppers. Significant difference was found between the treatments at 3, 7 and 14 days after the spray. Among the bio pesticides, low incidence of hopper was recorded in *B. bassiana* (NBAIR formulation) which registered 6.23 hoppers/ panicle at 7 days after spraying. Efficacy of *B. bassiana* (CISH formulation) and *M. anisopliae* (NBAIR formulation) was in parity with each other.

DRYSRHU Ambajipeta: After second spray of imidacloprid and azadirachtin 10000 ppm recorded nil population of hoppers. Among the bio-pesticide treatments, *Metarhizium anisopliae* and *Beauveria bassiana* recorded a low hopper population of 0.25 and 0.75 hoppers / tree after second spray. In untreated control block also a low population of mango hoppers ranging from 3.50 to 4.75 was recorded during the experimental period**.**

4.2.8.2 Bioefficacy of entomopathogenic fungi formulations in suppression of mango leaf webber

CISH: Significant difference was found between *Beauveria bassiana* and *Metarhizium anisopliae* at 7, 15 and 21 days after the spray. All the entomopathogenic fungi reduced the incidence of leaf webber significantly.

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

DRYSRHU Ambajipeta: After second spray, fipronil treated trees had nil thrips population followed by *Metarhizium anisopliae* (NBAIR strain), azadirachtin 10000 ppm and *Beauveria bassiana* (NBAIR strain) with 0.75, 0.25 and 1.00 thrips per tree, respectively. In untreated control block a high population of mango thrips ranging from 7.50 to 11.25 was recorded consistently.

4.2.8.4 Biological control of guava mealy bug and scales using entomopathogens

SKAUST Jammu: Entomopathogenic fungi *B. bassiana*, *M. anisopliae* and *L. lecanii* formulations (NBAIR isolates), along with azadirachtin 10000 ppm were assessed against guava mealy bug and scale. Significantly highest percent reduction in mealy bug as well as scale population was recorded in *B. bassiana* (NBAIR isolates) spray (45.88 and 44.56% reduction in mealy bug and scale population respectively) that was at par with that of azadirachtin spray (44.86 and 41.83% reduction in mealy bug and scale population respectively) at 7 DAS**.**

4.2.8.5 Biological control of anola mealy bug and scales using entomopathogens

SKAUST Jammu: Entomopathogenic fungi *B. bassiana*, *M. anisopliae* and *L. lecanii* formulations (NBAIR isolates), along with azadirachtin 10000 ppm were assessed against aonla mealy bug. Significantly highest percent reduction in scale population was recorded in azadirachtin spray (46.01% reduction) followed by *B. bassiana* spray (34.43% reduction) at 7 DAS.

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 Srinagar: Overall fruit damage in treated orchards during 2019 varied from 22.59 to 60.47 per cent as compared to untreated control (83.7). Per cent reduction in damage over control was found highest in T_2 (Light trap + Pheromone trapping + four releases of *T. cacoeciae*+ trunk banding + use of *H. pakistanensis+* field sanitation) (61.28) followed by T_1 (Two sprays of Chlorpyriphos 20 EC @ 1.0 ml./ lit. of water + Pheromone + Trunk banding+ field sanitation) (44.61) and (Farmer's practice) (33.68) which was statistically different for treatments. Maximum profit of 300830.0/ 10 tree was earned out of treatment T2 followed by T1.

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 Srinagar: Two releases of *B. pallescens* @ 400 /plant caused 34.11 and 68.51 per cent reduction in population of ERM and TSSM, respectively over control as compared to *B. pallescens* @ 200/plant which caused 25.25 and 43.71 per cent reduction. Application of Fenazaquin 10EC @ 0.4 ml/ litre of water caused 90.06 and 89.85 per cent reduction in population of ERM and TSSM respectively. Anthocorid bugs showed more preference to two spotted spider mites than European red mite.

4.2.9.3 Management of apple root borer using *Metarhizium anisopliae*

YSPUH&F: A large scale demonstration on the management of apple root borer covering an area of 5h was conducted. *Metarhizium anisopliae* (10^8conidia/g) was applied @ 30g/ tree basin mixed in well rotten farm yard manure (FYM) during July- August i.e. at the time of egg hatching and emergence of new/young grubs. Chemical treatment comprising of chlorpyriphos (0.06%) was also applied. *Metarhizium anisopliae* treatment resulted in 62.1 to 73.4 per cent mortality of the apple root borer grubs in different orchards, while in chlorpyriphos (0.06%) treated plants the grub mortality was 77.3 to 84.5%.

4.2.9.4 Evaluation of some biocontrol agents against leopard moth, *Zeuzera multistrigata* in apple

YSPUH&F: Results showed that chlorpyriphos (0.04%) was the most effective treatment resulting in 100 per cent mortality of the pest. Among different biocontrol agents evaluated, *Heterorhabditis bacteriophora* (5000IJs/gallery) (local culture) was the most effective resulting in 77.8 per cent mortality followed by *Steinernemma feltiae* (5000IJs/gallery)(local culture) and azadirachtin (2ml/L of 1500ppm; 10ml/gallery) (66.7% each). Other treatments were not very effective and resulted in 33.3 to 44.4 per cent pest mortality; in control no pest mortality was recorded.

4.2.10 BIOLOGICAL SUPPRESSION OF PESTS IN PLANTATION CROPS

4.2.10.1 Efficacy of biorationals on the bio-suppression of rugose spiraling whitefly

CPCRI, regional station, Kayamkulam: Results exhibited that palms treated with neem oil (5%) and water spray could reduce the RSW population significantly and closely followed by *Isaria fumosorosea*-treated palms (56.7%). The least reduction was observed on palms exposed to conservation biological control. Under natural suppression about 36.3% reduction could be obtained in a period of two months.

ANGRAU: Per cent reduction in whitefly intensity was observed high (71.01 % & 75.51%) after two sprays of *Isaria fumosorosea (*NBAIR- Pfu 5) than one spray (36.74% & 58.22 %).

DRYSRHU Ambajipeta: 15 days after second spray lowest number of egg spirals were recorded in neem oil and *I. fumosorosea* treated palm (8.63 and 9.65 egg spirals/leaflet). A high number of egg spirals were observed in natural conservation of *E. guadeloupae* and water spray treatment. However, the nymphal and adult population was observed to be low in Neem oil treatment as compared to other treatments. The numbers of parasitized nymphs (live & blackened) & nymphs with parasitoid emergence holes/leaflet and aborted nymph/pupae were found to be very low in all treatments including natural conservation of *E. guadeloupae* treatment without any significant difference.

TNAU: In a field trial, on 60th day after 2nd spraying, RSW nymphal population was drastically reduced in *Encarsia guadeloupae* (natural conservation) (20.0Nos.) when compared with foliar application of *Isaria fumosorosea* (pfu-5) @ 1x10^{8} cfu/ml (36.0Nos), foliar water spray (39.0Nos.) and foliar application of neem oil 0.5% (44.0 Nos.). Parasitised nymphs in *E.guadeloupae* (natural conservation) and foliar application of neem oil were same (14.00 Nos.) and higher than in *I. fumosorosea* (10.0 Nos.) and foliar water spray (13.0Nos.).

KAU Thrissur: There was no significant difference among the treatments at different intervals even after two rounds of sprays, except in case of nesting whitefly, where 15 days after second spray, the sprayed palms had significantly lower number of parasitized nesting whiteflies than in unsprayed trees.

KAU Vellayani: After 60 days of treatment, percentage reduction in number of RSW spirals was maximum in water spray (37.01%) followed by natural conservation (27.18%). Palms treated with *Isaria fumosorosea* (pfu-5) had 27.18 % reduction in live spirals. Neem oil 0.5 % was least effective (20%). *Isaria fumosorosea* (pfu-5) treatment was effective in reducing the number of pupae (42.18%) followed by neem 0.5% (34.21 %). However, parasitisation was found to be greatly reduced when treated with *I. fumosorosea* treatment (68.8 %). Water spray and neem oil 0.5% did not affect the parasitisation efficacy of *Encarsia*.

4.2.10.2 Biological suppression of Bondar's nesting whitefly in coconut

KAU Kumarakom: Per cent reduction of 17.73 and 8.38 over control were noted in the intensity of whitefly attack in treatments with *Isaria fumosorosea* (Pfu-5) and neem oil respectively at 20 days after spraying. However, significant reduction in per cent intensity could not be obtained at 60 days after spraying in any of the treatments.

4.2.10.3 *In vivo* evaluation of effective bio control agents against *Phytophthora* Pod rot management in cocoa

DRYSRHU Ambajipeta:

Pod rot: Soil application of 50 g of *Trichoderma reesei* along with 5kg Neem cake (once before onset of monsoon) resulted in reduction in pod rot from 45.5 to 53.3 per cent followed by spraying of *T. reesei* spore suspension (2×10^{6} cfu/ml) @ 2 sprays at 15 days interval which led to reduction in pod rot from 32.5 percent to 81.8 %, whereas in control, pod rot percent increased from 30.8% to 35.2%.

Stem canker: Chiselling of canker area on the stem and application of *T. reesei* coir pith cake led to reduction in lesion size by 40.6 cm followed by chiselling of canker area on the stem and application of *T. reesei* paste formulation (2×10^{6} cfu/ml) on the chiselled area with 32.4 cm reduction.

4.2.10.4 Field evaluation of bio-pesticides against tea red spider mite, *Oligonychus coffeae*.

UBKV: Among the tested fungal bio-pesticides, *Lecanicilium lecani* (NBAIR strain) reduced the mite population better which is statistically at par with azadirachtin 10000 ppm and *Beauveria bassiana* (NBAIR strain). However, best red mite management was noticed in the plots treated with Spiromesifen 240 SC in all spraying. Significantly highest yield of tea leaves was obtained in chemical treatment (6.56 qt/ha) followed by azadirachtin 10000 ppm (4.49 qt/ha), *Lecanicilium lecani* (4.25 qt/ha) and *Beauveria bassiana* (3.84 qt/ha).

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

PAU: The pooled per cent fruit damage in BIPM (13.24%) was significantly lower than untreated control (17.93%). However, chemical control recorded minimum per cent fruit damage (10.86%). The per cent reduction in fruit damage over control was 49.47 and 26.15 per cent in chemical control and BIPM plot, respectively. The fruit yield in BIPM (27.16 q/ha) was at par with chemical control (30.94 q/ha).

AAU-A: No significant difference was observed between BIPM package and chemical control with regard to number of *H. armigera* larvae/plant and fruit damage. Chemical control module recorded the highest yield (16.87 t/ha) which was at par with the yield recorded in BIPM package (16.05 t/ha). However, lowest yield was recorded in untreated control (10.64 t/ha). It can be concluded that BIPM package is promising in minimizing the pest damage with higher yield.

YSPUH&F: Both the BIPM module and the chemical insecticides were statistically equally effective in managing the pest. The average fruit infestation was statistically same in all the plots and varied from 0.47 per cent in chemical control to 0.51 per cent in BIPM plots. Both the BIPM and chemical insecticides were statistically equally effective in reducing the fruit infestation by *T. absoluta* in tomato. The yield was maximum (26.1t/ha) in BIPM plots, but, statistically on par (24.9t/ha) with that recorded in chemical treated plots.

MPKV: Pooled means for two years (2017-18 and 2018-19) indicated that BIPM treatment recorded minimum larval population of *H. armigera* (1.43 larvae/10 plants) which was at par with chemical treatment. In BIPM treatment, fruit damage on number basis (15.75%) and on weight basis (14.05 %) was at par with chemical treatment (20.58 %) and (17.15 %), respectively. Regarding sucking pest population, the BIPM treatment recorded minimum number of thrips (3.42 thrips/plant) and whiteflies (2.04 flies/plant). The highest marketable fruit yield (21.72 t/ha) was recorded in BIPM treated plots with B:C ratio (1.60) as against yield in chemical treatment (20.24 t/ha) with B:C ratio (1.53).

4.2.11.2 Bio-intensive insect management in brinjal

TNAU: The fruit damage in brinjal due to *Leucinodes orbonalis* was significantly low (17.82%) in plots sprayed with pesticides followed by 21.80 per cent fruit damage in BIPM plots (Azadirachtin 1500 ppm @2ml/lit (one round of spray) + *Lecanium lecanii* (one round of spray) + *Trichogramma pretiosum* (8 releases) + Pheromone traps @20/ha + Cowpea as bund crop). In the control plot fruit damage was 32.55 per cent. The marketable fruit yield was 12140Kg/ha in BIPM plots while in control plots the yield was 8495Kg/ha. The cost benefit ratio realized in BIPM was 1:3.90 as against 1:4.83 in insecticides treated plots.

AAU-J: BIPM module (Spray of Azadirachtin 1500 ppm @ 2ml/lt, Spray of *Lecanicillium lecanii* (NBAIR strain) 1x 10^8 spores/ml @ 5g/lt, Ten releases of *Trichogramma chilonis* multiple insecticide tolerant strain @100,000/ha, at weekly interval from initiation of flowering, Use of pheromone traps @ 20 nos/ha, Mechanical collection and destruction of infested shoot and fruits) was the next best treatment with 10.94 % shoot and 12.11% fruit infestation and contributed next higher yield of 205 q/ha after chemical treatment (six sprays).

4.2.11.3 Bio-efficacy of microbial agents against *Myllocerous subfasciatus* on brinjal

IIHR: The mean number of ash weevils per plant were significantly lower in *Heterorhabditis indica* @ 2.5 10^9 IJs ha^{-1} (4.22/plant) and *M. anisopliae* NBAIR (4.44/plant) followed by *B. bassiana* NBAIR (5.33/plant) and *B. bassiana* AAU strains (5.44/plant). The *B. bassiana* NBAIR and *M. anispoliae* AAU strains were showing significantly lower leaf damage scoring compared to other treatments.

4.2.11.4 Bio-intensive pest management (including RKN) in brinjal

CAU Pasighat: The BIPM module (*P. lilacinus* @ 20 g/m^2 (Root Knot Nematode management), Azadirachtin 1500ppm @2ml/L, *Lecanicillium lecanii* (NBAIR Strain) $1x10^8$ spores/ml @ 5g/L (For Sucking Pests) and Mass trapping, Release of *Trichogramma chilonis* @ 100,000/ha. 8-10 release at weekly interval from initiation of flowering, *Bacillus thuringiensis* NBAIR BtG4 2% Spray (Brinjal Fruit and Shoot Borer)) was the next best treatment showing 14.33% shoot and 12.22% fruit infestation and gave 210.83 q/ha yield after chemical treatment (yield: 235.65 q/ha).

MPKV: The treatments with chlorpyriphos 0.04 per cent and BIPM were found at par with each other by recording shoot infestation (7.14 % and 8.64%), fruit damage on number basis (7.45% and 8.93 %) and on weight basis (4.33% and 5.14 %), respectively. The highest marketable fruit yield (228.45 q/ha) with B:C ratio 5.89 was recorded in chlorpyriphos 0.04 per cent treated plots which was at par with BIPM treated plot (212.93 q/ha) with B:C ratio 4.93.

4.2.11.5 To evaluate the efficacy of different biocontrol agents on fruit borer *Earias vittella* infesting okra

AAU-A: Application of *Bacillus thuringiensis* (1% WP - $2x10^8$ cfu/g) (NBAIR strain) @ 50g/10 liter water at fortnightly interval for three times or six releases of *Trichogramma chilonis* @ 50000/ha at weekly interval found effective for the management of fruit borer (*Earias vittella*) on okra. Highest fruit yield (111.02 q/ha) was recorded in *Bacillus thuringiensis* @ 5 g/ litre which was at par with *Trichogramma chilonis* @ 50,000 parasitoids/ ha (105.10 q/ha) and NSKE 5% (104.64 q/ha).

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

IIVR: Among the NBAIR biopesticide isolates tested, *Metarhizium anisopliae* (Ma-4 strain) was most promising with 57.13 per cent reduction over control against diamond back moth (*Plutella xylostella*) followed by *Lecanicillium lecanii* (Vl-8 strain). In case of aphid (*Myzus persicae*), maximum reduction (36.99) was recorded with *Lecanicillium lecanii* (Vl-8 strain) which is statistically superior over the other biopesticides followed by *Beauveria bassiana* (Bb-45 strain) with 24.43 percent reduction. However, amongst the all treatments, indoxacarb 14.5 SC @ 0.75ml/lit was the best both in reducing DBM and Aphids in cabbage.

AAU-J: Among the different EPF, V1-8 isolate of *L. Lecanii* @ 5 ml/litre was the best treatment in reducing the mean population of aphid (3.15/plant) and DBM (5.09/plant), with a higher yield of 196.0q/ha after chemical treatment. The rest of the EPF strains (Bb-5a, Bb-45, Ma-4) in reducing the cabbage aphids and DBM was equally effective, and found to be statistically different only from untreated control plots.

CAU Pasighat: Biocontrol based IPM significantly reduced the aphid population 3.5, 2.14, 1.8 colony/ per plant after 1st, 2nd, 3rd spray respectively. Farmers sprayed dimethoate 0.05%, and recorded the aphid population of 4.5, 2.85, 2.5 colony per plant after 1st, 2nd, 3rd spray respectively. Highest yield was recorded in biocontrol based IPM compared to chemical control. In case of DBM biocontrol based IPM recorded significantly lower incidence 1.6,0.9,0.4,0.22 DBM larvae/ leaf at 45, 60, 75 and 90 DAT, respectively. Highest yield 42370kg/ha was recorded in biocontrol based IPM.

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

UBKV: Among the tested fungal biopesticides, *Lecanicilium lecani* (NBAIR strain) significantly reduced the mite population as compared to the other two biopesticides. Significantly highest yield of green chilli was registered in chemical treatment (Spiromesifen 240 SC) (138 qt/ha) followed by *Lecanicilium lecani* (90.75 qt/ha), *Beauveria bassiana* (78.25 qt/ha) and *Metarhizium anisopliae* (72.50 qt/ha).

4.2.11.8 Screening of promising isolates of entomopathogenic fungi for management of mites in chilli

KAU Kumaralom: None of the bioagents could cause significant reduction in mite population after first and third sprays. However, Vl-8 isolate of *L. lecanii* showed significant reduction in mite infestation at 1st, 3rd, 5th and 9th days after fourth spray, where it was on par with the chemical check at 5thday after spray. *Lecanicillium lecanii* produced notable reduction of 79.91 per cent over control at 3rd day after fourth spray, which was followed by Bb-5a and Ma – 6.

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

UBKV: Among the tested fungal biopesticides, *Lecanicillium lecani* (NBAIR strain) significantly reduced the whitefly population as compared to the other biopesticides. However, the chemical treatment (buprofezin 25SC) was superior in controlling the whitefly followed by azadirachtin 10000 ppm and *Lecanicillium lecani* (NBAIR strain). Significantly highest yield was obtained in chemical treatment (194.75 qt/ha) followed by azadirachtin 10000 ppm (106.75 qt/ha) and *Lecanicillium lecani* (103 qt/ha).

4.2.11.10 Evaluation of *Steinernema carpocapsae, Heterorhabditis indica* (NBAIR strain) and *H. pakistanensis* against lepidopteran pest complex

SKAUST Srinagar: *H. pakistanensis* treatment exhibited maximum larval mortality, both of *P. brassicae* (60.8) and *Plutella xylostella* (64.0) as compared to *H. indica* (42.4 and 53.6) and *S. carpocapsae* (24.8 and 36.8). *Heterorhabditis pakistanensis* was found superior over *H. indica* and *S. carpocapsae* in terms of larval mortality of *Plutella xylostella*. Active Juvenile stage (IJS/ plant) after 24 hrs. on kale was found maximum in case of *H. pakistanensis* (7900.00) followed by *H. indica* (5100.00) and *S. carpocapsae* (3800.00).

4.2.11.11 Efficacy of fungal and bacterial isolates on anthracnose disease of yard long bean

KAU Kumarakom: The fungal isolate *Trichoderma harzianum* (Th-3), *T. viride* (KAU strain) and *Pseudomonas fluorescens* (KAU strain) were effective in controlling yardlong bean anthracnose to about 67 per cent. The next effective treatment was *Hanseniaspora uvarum* (Y-73). Higher yields were obtained in biocontrol agent treated plots but were not significant when compared to control.

4.2.12 BIOLOGICAL SUPPRESSION OF OILSEED CROP PESTS

4.2.12.1 Bio-efficacy of entomopathogenic fungus against mustard aphid

AAU-J: Three rounds of sprays of dimethoate 30 EC @ 2ml/lit at 10 days interval significantly reduced the mean population of aphids (5.91 per 10 cm apical twig) in comparison to other treatments with highest yield of 7.60q/ha. However, it was at par with *Lecanicillium lecanii* (NBAIR strain) @ 5g/litre and *Beauveria bassiana* (AAU-J culture) in reducing the mustard aphids (10.0 and 11.19 /10 cm twig) with next higher yield of 7.35 q/ha and 7.10 q/ha, respectively.

4.2.13. BIOLOGICAL SUPPRESSION OF POLYHOUSE AND FLOWER CROP PESTS

4.2.13.1 Management of spider mite in cucumber using anthocorid predator, *Blaptostethus pallescens* under polyhouse condition

KAU Thrissur: Among all the treatments, spiromesifen at the rate of 100 g a.i ha^{-1} was the most effective treatment, with reduction in mean mite population from 3.89/ cm^2 to 0.08/cm^2. The mite population in plots where *B. pallescens* were released at 20/m row was comparable to that of acaricide treated plots. While 93.6 per cent of plants survived infestation in plots treated with spiromesifen, the corresponding figures were 66.4 per cent and 31.8 per cent for release rates of 20 and 10 bugs/m row respectively. None of the plants survived mite infestation beyond 20 days after release of mites in control plots.

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

IIHR: Among all the treatment *Beauveria bassiana* (NBAIR Bb5a) @ 5g/L followed by *Lecanicilium lecanii* (NBAIR Vl8) @ 5g/L was significantly effective against aphids on capsicum under polyhouse conditions. Thrips infestation was negligible during this period.

YSPUH&F: Among biocontrol agents, *Chrysoperla zastrowi sillemi* (4 larvae / plant) resulted in the highest (80.6%) reduction in the aphid population which was on par with imidacloprid (0.5ml/L) (90.3%) at 10 days of second spray. *Lecanicillium lecanii* (5g/l of 10^8 conidia/ g) (73%) and azadirachtin (2ml/L of 1500ppm) (68%) were also on par with *Chrysoperla zastrowi sillemi* (4 larvae / plant), but could not match with imidacloprid (0.5ml/L) treatment in their efficacy against the pest. Other biocontrol agents namely *Metarhizium anisopliae and Beauveria bassiana* (5g/L of 10^8 conidia/ g each) resulted in 54.3 to 58 per cent reduction in the aphid population over control 10 days after the second spray/ release.

4.2.14 LARGE SCALE ADOPTION OF PROVEN BIOCONTROL TECHNOLOGIES

4.2.14.1 Rice

PAU: Large scale demonstrations of biocontrol based IPM (5 releases of *T. chilonis* and *T. japonicum* each @ 1,00,000/ha) over an area of 248 acres rendered lower incidence of dead hearts in biocontrol field (1.60%) as against untreated control (3.60%) resulting in a reduction of 55.2 per cent. Similarly, leaf folder damage in release field was significantly lower in biocontrol fields (1.90%) as compared to untreated control (4.40%) with a mean reduction of 56.8 per cent. The mean incidence of white ears was significantly lower in biocontrol field (2.24%) as against untreated control (4.47%) resulting in a reduction of 49.9 per cent. The additional benefit in biocontrol practices was Rs 7760/- per ha over untreated control.

ANGRAU: Demonstration conducted in 14 acres area. Paddy stem borer damage was low in BIPM package (1.78 % dead heart) compared to farmers practice (6.25 % dead heart). Leaf folder was low (1.44%) in BIPM plot compared to farmers practice (7.48%). Grain yield recorded high in BIPM plot (5.38 t/ha) compared to farmers practice plot (4.9 t/ha). Adoption of BIPM package in three locations resulted in 9.65 % increased yields with high incremental ratio of 12.04 compared to farmers practice with low incremental ratio of 4.62.

AAU-A: Demonstration was carried out in 2 ha area. In BIPM package the number of damaged leaves/10 hill was 7.62, 9.37 and 12.12 at 30, 45 and 60 DAT, respectively. Whereas in farmers practice the number of damaged leaves/10 hill was 7.37, 11.75 and 14.50 at 30, 45 and 60 DAT, respectively. Significantly lower damaged leaves were recorded at 45 and 60 DAT in BIPM package as compared to farmers' practice. With regard to the yield, the two treatments found at par with each other. It can be concluded that use of BIPM strategies resulted in lower incidence of rice leaf folder and higher grain yield.

KAU Thrissur: Large scale validation of BIPM in rice was carried out over an area of 150 ha. The dead heart as well as white ear head symptoms in BIPM plots was approximately 75 per cent lower than in non BIPM plots. Similarly, leaf folder damage was only 30 per cent of what was reported from conventionally managed plots, while the rice bug population was less than 50 per cent of that in farmer's field. The yield obtained from BIPM plots was approximately 58 per cent more than that obtained from non BIPM plots. The increased yield as well as reduced cost resulted in an increase in profit by Rs 82,910/ha. The cost benefit ratio, at 2.90 for BIPM fields compared quite favorably with 1.66 for non BIPM fields.

GBPUA&T: Large scale demonstration was carried out on 12 ha area. An average yield of 65.0 q/ha was recorded by the farmers adopting bio-control technologies along with need-based organic practices as compared to an average yield of 50.0 q/ha by the farmers adopting conventional practices for the management of insect pests and diseases.

IIRR: Research Farm: Results indicated that organic cultivation with *Trichoderma* or *Pseudomonas* and without application of fertilizers and insecticides significantly reduced incidence of stem borer damage at both dead heart and white ear stage. The white ear damage was significantly higher in farmers practice with insecticidal treatment. However, the yield in organic practices with seed treatments (5980 and 5900 kg/ ha respectively) was also on par with farmers' practice (6340 kg/ha). The reduction in white ears in organic cultivation could be attributed to higher parasitisation of egg masses of stem borer observed (75.26 and 64.68%) as compared to 35.46 per cent in plots with insecticide application.

IIRR: Telangana (2 ha): The leaffolder incidence was lowest in the BIPMmodule with *Bacillus subtilis* seed treatment (4.37 %). The number of spiders observed per five hills were significantly higher in BIPM treatments with the highest number being recorded in the *Bacillus subtilis* based module.

IIRR: Odisha (1.6ha): Stemborer incidence was under ETL in the IPM fields (5.88 and 10.2% respectively) as compared to the significantly high incidence of 17.37 and 22.35 % in non IPM fields. There was an outbreak of brown planthopper in these districts and reached high numbers due to intermittent rains. But the population in IPM fields was significantly lower than that of non IPM fields.

4.2.14.2 Groundnut

AAU-A: Large scale demonstration covering 200 ha area exhibited significantly lower incidence of whitegrub in IPM module (0.39 larva/meter length row) as compared to farmers' practice (1.42 larva/meter length row). Higher yield was also recorded in IPM module.

4.2.14.3 Sugarcane

PAU: Large-scale demonstrations on the effectiveness of *Trichogramma chilonis* @ 50,000 per ha at 10 days interval over an area of **8208 acres** showed 57.14 percent incidence reduction of stalk borer, *Chilo auricilius* over untreated control. Similarly, *T. chilonis* @ 50,000 per ha at 10 days interval (eight releases) over an area of 2688 resulted in 53.9 and 80.4 per cent reduction over control in release fields and chemical control (chlorantraniliprole 18.5 SC @ 375 ml/ ha), respectively. However, the cost: benefit ratio (1: 18.16) was higher in biocontrol as compared to chemical control (1: 10.03). Release of *T. japonicum* against top borer, *Scirpophaga excerptalis* over an area of **510 acres** reduced its incidence over control by 53.4 and 79.7 per cent in release fields and chemical control (chlorantraniliprole 0.4 GR @ 25 kg/ha), respectively. The cost benefit ratio was higher in biocontrol (1: 17.60) as against chemical control (1: 11.08).

ANGRAU: Large scale demonstration using temperature tolerant strain *T. chilonis* was conducted in **13 acres** area against early shoot borer and internode borer. Cane yield and incremental benefit cost ratio recorded was high in temperature tolerant strain of *T. chilonis* released plot (63.93 t/ha and IBCR: 50.19) compared to farmers practice (53.54 t/ ha and IBCR: 6.74). Early shoot borer incidence upto 120 days was low in temperature tolerant strain *T. chilonis* release field with significantly low internode borer incidence (23.6%) and resulted in higher cane yield (83.82 t/ha) with high incremental benefit cost ratio (81.6) compared to farmer's practice.

UAS Raichur: (area: 10 ha) The per cent dead hearts was low in *T. chilonis* (temperature tolerant strain) release plot (1.25 per cent dead hearts per 10 mrl) which was significantly superior over farmers practice and untreated control which recorded 2.85 and 5.25 per cent dead hearts per 10 mrl, respectively. The highest cane yield of 123.50 t/ha was recorded in *T. chilonis* (temperature tolerant strain) release plot which was superior over the farmers practice and untreated control which recorded as 118.50 t/ha and 108.25 t/ha respectively.

MPKV: The pooled means of three years trial conducted during 2017-18, 2028-19 and 2019-20 revealed that eight releases of *T. chilonis* temperature tolerant strain @ 50,000 parasitoids/ha at weekly interval starting from 40 days after emergence of shoots was significantly superior to untreated control in reducing the ESB infestation (from 22.16 to 6.41 % dead hearts) and recorded maximum cane yield (139.64 Mt/ha) with B:C ratio 2.31.

PJTSAU: The module with six releases of *T. chilonis* @ 50,000/ha at weekly intervals fared better than farmers' practice in terms of infestation levels (9.23 percent incidence of early shoot borer compared to 10.57 percent in farmer's practice) as well as cane yield (79.89 t/ha in BIPM module and 71.45 t/ha in farmer's practice).

4.2.14.4 Pigeon pea

PAU: Large scale evaluation of NBAIR Bt formulation against pod borer complex in pigeonpea at farmer's field revealed that per cent pod damage and grain yield in NBAIR Bt G4 @ 2% (9.84%; 11.15q/ha) and chlorantraniliprole18.5 SC @ 150 ml/ha (5.97%; 12.05 q/ha) treatments were significantly superior to untreated control (20.59%; 9.75 q/ha).

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

MPUAT: Demonstration experiment was conducted covering 2 ha area. BIPM package was equally effective as chemical control against *H. armigera*. Chemical control module recorded the highest yield (15.10 t/ha) which was at par with the yield recorded in BIPM package (14.35 t/ha). Significantly, low yield was recorded in untreated control (9.05 t/ha).

4.2.14.6 Maize

PAU: Large-scale demonstrations using *T. chilonis* against maize stem borer, *Chilo partellus* on an area of 448 acres showed that two releases of *T. chilonis* @ 1,00,000/ ha at 10 and 17 days old crop resulted in 53.2 per cent reduction in dead heart incidence over control as compared to 82.9 in chemical control. The additional benefit over untreated control in biocontrol package was Rs 5483/- per ha as compared to Rs 9764/- per ha in chemical control.

ANGRAU: Demonstration conducted in 15 acres during rabi, 2019-20. Damage by maize stem borer, *Chilo partellus* was nil in *Trichogramma chilonis* and *T. pretiosum* release plots and low in chemical sprayed plot (2.67% DH) and *Sesamia inferens* damage as shot holes was low in *T. pretiosum* release plot (6.39 %) followed by *Trichogramma chilonis* release plot (6.7 %) and high in chemical sprayed plot (11.84 %) .
Fall army worm, *Spodoptera frugiperda* damage recorded low in *Trichogramma pretiosum* release plot (15.72 %) followed by *Trichogramma chilonis* release plot (21.2 %) and high in chemical sprayed plot(41.45%).

4.2.14.7 Soybean

MPKV: The pooled result of trials conducted during 2017 and 2018 *Kharif* seasons indicated that two sprays of *Metarhizium rileyi* (Farlow) (N. rileyi*)* 2.0 x 10^8 cfu/g were significantly superior in suppressing the larval population of *S. litura* (2.46 larvae/m row) due to fungal infection with maximum soybean yield of 16.43 q/ha with BC ratio 1.62:1.

4.2.14.8 Pea

GBPUA&T: Large scale field demonstrations of bio-control technologies on pea were conducted covering an area of 25 ha during rabi season. Seed treatment with bio-agents resulted in considerably higher germination upto 30 per cent more than the conventional practices. There was no disease incidence in the crop. An average green pod yield of 80 q/ha was recorded with bio-control technologies as compared to 62 q/ha with conventional farmers practices.

4.2.15 Tribal Sub plan programme (TSP)

ANGRAU: Front line Demonstrations and trainings were conducted on organic farming of paddy, ginger, turmeric and vegetables at eleven villages in 165 acres benefitting 280 tribal farmers of Arakuvalley and Chinthapalli divisions,Visakhapatnam district, Andhra Pradesh. TSP farmers benefited with organic farming technology in obtaining good yields in rice, ginger and turmeric and expressed willingness to adopt organic farming for achieving higher yields.

KAU Thrissur: A total of 184 farmers in Kottathara, Padinjarethara, Kuppadithara and Vengappalli Panchayats in Mananathavadi Taluk and Edavaka and Nallurnad Panchayats in Vythiri Taluk were provided with biopesticides. The major agriculture crops include black pepper, ginger, rice, turmeric, banana, coconut, arecanut, vegetables, cardamom, coffee and tea. The bioinputs distributed included trichocards, *Trichoderma viride*, *Pseudomonas flourescens*, *Lecanicillium lecanii*, *Paecilomyces lilacinus* and arbuscular mycorhizal fungi (AMF).

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

Tribal farmers (100 No.) from Dediyapada, Sagbara and Tilakwada tehsils of Narmada district covering ~1 acre area/farmer. Biopesticides and pheromone traps were distributed among farmers. Field visits were conducted to record the use of bio-inputs by the farmers and bio-efficacy of inputs. Significant reduction (35-40%) in use of chemical pesticides was recorded.

UBKV Pundibari: 195 farmers were trained and inputs were supplied to them for management of insect pests of vegetables, rice, and pulses.

AAU-J: A total of 200 farmers were selected from Baksa district dominated by tribal community. Four villages (Amarabati, Barama, Tamulpur and Baganpara) were selected under the programme. Biopesticides and neem pesticides were supplied to the farmers.

IGKV: About 150 farmers were selected all belonging to ST category. Three trainings were organised. Application method of Trichocards was demonstrated on a model plant. Low cost candle based light traps were also displayed. These were also distributed to the tribal farmers.

SKAUST: Under Tribal Sub Plan, inputs were given to seventy seven farmers, in a total of forty villages of subdivision Kargil and Leh. Interacted with the farmers and provided know-hows in each village for the use of distributed inputs. Beneficiaries from different villages of Kargil reported 20- 90.0 per cent increase in marketable yield.

YSPHU&F Solan: To manage the insect-pests and diseases of important cash crops through eco-friendly methods to minimize the use of chemical pesticides on these crops: Two hundred farmers of Powari, Kangosh, Rangrik and Hurling villages of districts Kinnaur and Lauhal and Spiti of Himachal Pradesh covering 35 ha area of apple, almond, apricot, cabbage and pea were benefited from the trainings/demonstrations. These farmers were exposed to the use of bio-pesticides for pest management for the first time. In pea, 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.

5. Project Coordinator's and monitoring team visits to AICRP-BC centers during 2019-20

Sl. No.	Dates	Visit of Director/ NBAIR Scientist	Place of visit	Highlights of visit
1	06.-6.2019 to 07.06.019	Dr Chandish R. Ballal Director and Project Coordinator, NBAIR, Bengaluru	AAU Anand	To organize the 28th AICRP-BC workshop and monitor the progress of the centre.
2	22.08.2019	Dr Chandish R. Ballal Director and Project Coordinator, NBAIR, Bengaluru	AAU Anand	Reviewed the progress of the committed AICRP-BC programme
3	13.05.2019	Dr N. Bakthavatsalam Principal Scientist & HOD	IGKV, Raipur	Reviewed the progress of the committed AICRP-BC programme
4	29.05.19 09.11.19 27.01.20	Dr.G.Sivakumar, Principal Scientist, NBAIR, Bengaluru	TNAU, Coimbatore	Reviewed the progress of the committed AICRP-BC programme
5	13.09.19	Dr.N.Bakthavatsalam, Principal Scientist, & HOD NBAIR, Bengaluru	TNAU, Coimbatore	Reviewed the progress of the committed AICRP-BC programme
6	26.09.19	Dr.R.Chandish Ballal, Director and Project Coordinator, NBAIR, Bengaluru	TNAU, Coimbatore	Reviewed the progress of the committed AICRP-BC programme
7	13.12.2019	Dr. Sreeramkumar, Principal Scientist and Dr. Sampath, Scientist, NBAIR, Bengaluru	KAU Thrissur	Reviewed the progress of the committed AICRP-BC programme
8	23.12.2019	Dr Chandish R. Ballal Director and Project Coordinator, NBAIR, Bengaluru	NCIPM, New Delhi	Reviewed the progress of the committed AICRP-BC programme
9	02.02.2020	Dr Chandish R. Ballal Director and Project Coordinator, NBAIR, Bengaluru	MPKV Pune	Reviewed the progress of the committed AICRP-BC programme
10	05.02.2020	Dr Chandish R. Ballal Director and Project Coordinator, NBAIR, Bengaluru	IIHR, Bengaluru	Reviewed the progress of the committed AICRP-BC programme
11	14.02.2020	Dr Chandish R. Ballal Director and Project Coordinator, NBAIR, Bengaluru	UAS Raichur	Reviewed the progress of the committed AICRP-BC programme
12	25.02.2020	Dr Chandish R. Ballal Director and Project Coordinator, NBAIR, Bengaluru	CAU Imphal	Reviewed the progress of the committed AICRP-BC programme

6. Publications: During the year 2019-20, a total of 431 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	66	58	93	217
AAU, Anand	3	2	5	10
AAU, Jorhat	8	-	13	21
ANGRAU	4	2	2	8
GBPUAT,Pantnagar	5	4	12	21
KAU, Thrissur	-	-	-	-
KAU, Vellayani	2	4	-	6
MPKV, Pune	4	-	2	6
MPUAT, Udaipur	1	3	3	7
PAU, Ludhiana	6	6	7	19
UAS Raichur	5	19	1	25
TNAU, Coimbatore	13	-	2	15
SKUAST, Srinagar	6	1	-	7
SKAUST Jammu	4	3	7	14
DRYSRUH	-	-	-	-
YSPUHF, Solan	10	3	-	13
IGKV	4	-	7	11
UBKV	5	8	1	14
CISH	-	-	-	-
CPCRI	2	7	6	15
IIVR	1	1	-	2
Total	**149**	**121**	**161**	**431**

7. Profile of experiments and demonstrations carried out during 2019-20

Crop/Insect	Experiments	Large Scale Demonstrations
Biodiversity of biocontrol agents	5	-
Antagonists of crop disease management	2	-
Sugarcane	3	5
Cotton	5	-
Rice	5	7
Cereals	6	2
Plantation crops	3	-
Pulses	5	1
Oilseeds	1	2
Tropical and temperate fruits	9	1
Vegetables	11	2
Polyhouse crops	3	-
Tea	1	-
TSP	8	-
Total	**67**	**20**

8. Budget of AICRP on Bio control for 2019-20

Item of Expenditure	Sanctioned and allotted grants (Rs. in lakh)	Grants released during 2019-20 from ICAR (Rs. in lakh)	Total expenditure (Rs.)
Pay and allowances	225.38	225.38	225.38
Rec. Contingencies	387.40	387.40	387.40
T.A	66.40	66.40	66.40
TOTAL	**679.18**	**679.18**	**679.18**