

# Project Coordinator's Report 2020-21



## XXX AICRP - Biocontrol Workers Group Meeting

14 July 2021



## AICRP on Biological Control of Crop Pests



**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**



## **Project Coordinator's Report 2020-21**

### **XXX Biocontrol Workers Group Meeting**

**14 July 2021**

**Compiled and Edited**

**Richa Varshney  
G. Sivakumar  
P. Ram kumar  
N. Bakthavatsalam**



**ICAR- National Bureau of Agricultural Insect Resources  
Bengaluru - 560 024**

**Cover page:** *Trichogramma chilonis*

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*N. Bakhavatsalam*  
Dr. N. Bakhavatsalam  
Director Incharge, ICAR-NBAIR &  
Project Coordinator AICRP-Biological Control

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## 1. Introduction

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

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

The potential bioagents/biopesticides 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 other notorious indigenous and exotic pests is being successfully sustained through constant monitoring and redistribution/conservation of biocontrol agents. The AICRP BC has played a prominent role in monitoring the entry and spread of invasive. The recent invasive managed through AICRP-BC initiatives are tomato pinworm, *Tuta absoluta*, infesting tomato, the rugose spiraling whitefly, *Aleurodicus rugioperculatus* infesting coconut and oilpalm and the fall armyworm (FAW) *Spodoptera frugiperda* infesting maize. Currently emphasis is being given to import *Anagyrus lopezi*, a parasitoid of recently invaded insect pest, cassava mealybug, *Phenacoccus manihoti*. The Coordinating unit 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 comprised of 20 centres has been strengthened through addition of 16 centres, thus currently having a strong network of 36 centres along with a PC cell.

## 2. 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

### **3. Setup**

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

#### **State Agricultural University–based centres (Fully funded 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. National Rice Research Institute Cuttack
9. Sugarcane breeding Institute, Coimbatore

#### **Voluntary Centres**

1. Dr. Panjabrao Deshmukh Krishi Vidyapeeth Akola
2. School of Agriculture Science & Rural Development, Medziphema Campus, Nagaland University

3. Sher-e-Kashmir University of Agricultural Science & Technology, Jammu
4. National Institute of Plant health Management, Hyderabad
5. University of Agricultural and Horticultural Sciences, Shimogga
6. ICAR- Sugarcane Breeding Institute, Coimbatore
7. Citrus Research Station, Dr. Y.S. R. Horticultural University, Tirupati
8. ICAR- National Rice Research Institute, Cuttack

The results from the various experiments conducted at centres across the country during the year 2020-21 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 wasps**

Wasp diversity from three agro-climatic zones (Chhattisgarh Plains, Bastar Plateau and Northern Hills) including wild life sanctuaries and National Parks in Chhattisgarh state was documented. Collected 386 specimens belonging to eight families viz., Chalcididae-256 specimens (66.32%), Encyrtidae-13 (3.37%), Eulophidae-77 (19.94%), Eurytomidae-06 (1.56%), Mymaridae-02 (0.52%), Ormyridae-01 (0.26%), Pteromalidae-16 (4.14%) and Torymidae-15 (3.89%), respectively from 17 collection sites. Five predominant genera were identified as *Antrocephalus* Kirby - 48 specimens (18.75%), *Brachymeria* Westwood - 71 (27.73%), *Dirhinus* Dalman - 78 (30.47%), *Epitranus* Walker - 02 (0.78%) and *Hockeria* Walker - 57 (22.27%).

###### **4.1.2 Seasonal parasitisation of *Trichogramma chilonis* on fall armyworm in maize**

Seasonal parasitism of *Trichogramma chilonis* against fall armyworm was studied in kharif, rabi and summer seasons. The higher egg parasitism by *T. chilonis* was recorded in kharif with 38.91% followed in rabi (30.23%) and summer (9.12%). *T. chilonis* recorded as primary egg parasitoid which parasitised 90.4% egg mass in kharif, 70.8% in rabi and 70.2% in summer compared to the other egg parasitoids present in maize ecosystem. Egg parasitoid *T. chilonis* and *T. remus* together parasitised 7.9% and 21.7% fall armyworm eggs, respectively in kharif and rabi/maize. The interaction of both egg parasitoid was studied at various levels and results showed both parasitoids are complementary at equal ratio.

###### **4.1.3 Field evaluation of indigenous *Trichogramma chilonis* against fall armyworm in maize**

Field evaluation of *T. chilonis* at different rates of release was carried out against fall armyworm in maize. Results of study showed that, four releases of the parasitoid recorded 70.42% of parasitisation of egg mass over the one, two and three releases of *T. chilonis* with less vegetative damage. Based on this study, field efficacy of *T. chilonis* was compared with *T. pretiosum* by

releasing at weekly intervals. Results revealed that, four release of *T. chilonis* significantly reduced egg population of fall armyworm with average parasitism of 68.7% with comparatively higher yield than *T. pretiosum* released field.

#### **4.1.4 Geographical and host distribution of coconut rugose spiraling whitefly**

Reported and documented the new geographical and host distribution record for many whiteflies including recently invaded whitefly species viz., Meghalaya, West Bengal, Goa, Lakshadweep, Karnataka, Gujarat for rugose spiralling whitefly, *Aleurodicus rugioperculatus*; Tamil Nadu, Lakshadweep, Karnataka for woolly whitefly, *Aleurothrixus floccosus*; Lakshadweep for Bondar's nesting whitefly, *Paraleyrodes bondari* and *A. floccosus* for the first time through regular survey and monitoring. Besides, documented about 40 host plants for rugose spiralling whitefly; 21 host plants for nesting whitefly, *Paraleyrodes minei*; 9 host plants Bondars nesting whitefly, *P. bondari*; 13 host plants for solanum whitefly, *Aleurothrixus trachoides* and 3 host plants for palm infesting whitefly, *A. atratus* for the first time in India.

#### **4.1.5 Evaluation of *Isaria fumosorosea* against coconut rugose spiraling whitefly**

Efforts were made to validate the potential entomopathogenic fungus *Isaria fumosorosea* (strain ICAR-NBAIR pfu-5) for the management of *A. rugioperculatus*, *Aleurotrachelus atratus*, *Paraleyrodes bondari* and *Paraleyrodes minei* on coconut and *A. floccosus* on guava. Field validation of *I. fumosorosea* against *A. rugioperculatus* and *Aleurotrachelus atratus* in farmer's fields at several locations in Karnataka, Andhra Pradesh, Kerala and Tamil Nadu. The fungus was effective against all the developmental stages of both the species to extend of 58-80% under field conditions. Standardization of mass production and formulation technology (talc, grain and oil based) for potential strains of Pfu-5 with higher bioefficacy, persistence and longer shelf life.

#### **4.1.6 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**

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

Entomopathogens and biopesticides viz., *Pseudomonas fluorescens* strain NBAIR-PFDWD, *Bacillus albus* strain NBAIR-BATP and *Metarhizium anisopliae* strain NBAIR-MaCB, were evaluated either individually or in combination against *Thrips palmi* on watermelon under field conditions. These biopesticides were on par with the chemical control imidacloprid but the yield was at appreciable level in *B. albus*, followed by *P. fluorescens*, chemical check and *M. anisopliae*. A consortium of *B. albus* with *P. fluorescens* was found to be very effective in *T. palmi* management compared to other consortia under field conditions at Gouribidanur.

#### **4.1.7 Field evaluation of EPNs against *Spodoptera frugiperda***

Field evaluation of *Heterorhabditis indica* and *Steinernema carpocapsae* was carried out against *Spodoptera frugiperda* at Chikkaballapura in Karnataka. In the second round of spraying, the percentage reduction of larval population was found to be 37.5% at  $2.5 \times 10^8$  IJs ha<sup>-1</sup> and 73.33% at  $5 \times 10^8$  IJs ha<sup>-1</sup> for *S. carpocapsae* while for *H. indica* the percentage mortality was 54.17% at the rate  $2.5 \times 10^8$  IJs ha<sup>-1</sup> and 89% at the rate  $5 \times 10^8$  IJs ha<sup>-1</sup>. But Emamectin benzoate at recommended dose, reduced significantly greater (100%) reduction of *S. frugiperda* population. Percentage reductions increased significantly ( $P < 0.05$ ) with time after application in each treatment.

#### **4.1.8 Biocontrol based management of FAW**

IPM trial on fall armyworm management at Kadalaveni, Gouribidanur Taluk, Chikkaballapura district recorded significantly less number of FAW larvae (0.08 per plant) in biocontrol plot compared to farmer's practice plot (0.45 per plant). Similarly, average number of egg mass in treated plots was 0.01 per plant and in farmer's practice plot it was 0.08 per plant after 3<sup>rd</sup> release of parasitoid, *Trichogramma chilonis*. High percent parasitism was observed in biocontrol plot by *Trichogramma* sp & *Telenomus* sp. together with 18.75 percent parasitism while 15.62 percent parasitism was observed by *Telenomus remus* alone and *Trichogramma* sp. alone recorded 6.25 percent parasitisation in the eggs of fall armyworm.

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

Molecular characterisation based on *COI* (*Cytochrome Oxidase I*) gene was carried out for 75 agriculturally important insects like pests, parasitoids and predators and DNA barcodes were generated. The insect species were collected from different parts of the country viz. Andhra Pradesh, Bihar, Chhattisgarh, Delhi, Gujarat, Jammu and Kashmir, Karnataka, Kerala, Maharashtra, Manipur, Tamil Nadu, Telangana and West Bengal. Samples were also received from Nepal. Around 26 populations of *Spodoptera frugiperda* were received from different parts of the country, were molecularly characterised and barcoded. Invasive cassava mealybug, *Phenacoccus manihoti* was identified using *cytochrome oxidase I* gene (*CO-I*) for the first time in India and DNA barcode was generated for the same. The sequences were found to be matching 100 % with GenBank Acc. Nos. KY611349; KY611348; KY611347; KY611346 which were deposited from China and were confirmed as *P. manihoti* with Acc. No: MT895817. We had also intercepted the invasive Asian subterranean termite, *Odontotermes gestroi* (GenBank accession numbers (KC887198, KC887198, KC887197, KJ934505) in package materials shipped from the United States of America.

#### **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:** *Trichogramma chilonis* was collected from paddy and brinjal. Coccinellids were collected from okra, bitter gourd, brinjal, cabbage and cucumber.

**AAU-A:** *Trichogramma chilonis* was the major *Trichogrammatid* recorded brinjal, castor, cotton and tomato fields. *Cheilomenes sexmaculatus* Fabricius was found to be the predominant species collected from different crop ecosystems. Total 33 spider specimens were collected from paddy ecosystem. From the collected soil samples, six isolates of *Metarhizium* sp. have been isolated and identified.

**CISH:** The major 5 species of Coccinellids viz., *Coccinella septempunctata* Linn. *C. transversalis*, *Menochilus sexmaculata* Fab. *Chilocorus rubidus* Hope and *Scymnus* sp. were observed feeding on mango hoppers. The reduviid predator *Sycanus* sp., was observed preying on the larvae of mango leaf webber and mango semiloopers.

**PAU:** Three parasitoids, one egg-larval *Chelonus formosanus* (Hymenoptera: Braconidae) and two larval parasitoids (Hymenoptera: Ichneumonidae) were found to be associated with fall armyworm on maize crop. *Fulgoraecia melanoleuca* was recorded to be key parasitoid infesting *Pyrilla perpusilla* on sugarcane crop with its peak activity in September month. A total of 5 spider species from three families, Tetragnathidae, Salticidae and Araneidae were recorded from the rice fields. The key parasitoids collected from rice fields were *Trichogramma chilonis*, *T. japonicum*, *Stenobracon* sp., *Bracon* sp. and *Xanthopimpla* sp. Among predators, coccinellids (*Coccinella septempunctata*, *Cheilomenes sexmaculata*, *Brumus suturalis*, *Serangium* sp.), green lacewing (*Chrysoperla zastrowi sillemmi*), *Geocoris* sp., *Zanchius* sp. and spiders were prevalent on cotton crop. The parasitoids namely, *Encarsia* spp. and *Aenasius arizonensis* were found to be associated with whitefly and mealybug, respectively.

**TNAU:** The natural enemies viz., *Trichogramma* sp., *Cryptolaemus montrouzieri*, *Chrysoperla zastrowi sillemi*, *Mallada astur*, *Argiopes* sp and *Acerophagus papayae* were collected. In cassava, *Hyperaspis maindroni* was found to be the predominant coccinellid predator Besides *H. maindroni*, *Mallada* sp. and *Prochiloneurus aegyptiacus*, *Tetrastichus* sp. were also observed. Among the parasitoid species, *Homalotylus turkmenicus* (7320 Nos.) emerged from the coccinellid predator, *Hyperaspis maindroni* grubs. *Telenomus* sp, *Trichogramma* sp, *Cheilomenes sexmaculata*, Staphylinids and spiders were observed in maize fields. A predator *Mallada astur* was seen in coconut trees infested with RSW and BNW. *Dipha aphidivora* and *Micromus igorotus* were observed on sugarcane woolly aphid.

**KAU Thrissur:** Spiders (243 nos.) were collected from rice ecosystem in Thrissur and Palakkad districts by pit fall trap and sweep net methods and 243 specimens

**MPKV:** *Chrysoperla zastrowi sillemi* Esben. were 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. The eggs, grubs, pupal and adult stages of Coccinellids, *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. The *Cryptolaemus* adults were recovered from the custard apple and papaya orchards and ornamental hibiscus. The cadavers of NPV infected larvae of *S. frugiperda* were also collected from Maize. However, the cadavers of *SINPV* and *HaNPV* infected larvae of *S. litura* and *H. armigera* were collected on soybean, cabbage, pigeon pea, capsicum and tomato crops in farmers' fields. *H. armigera* larvae, mango hoppers and white grubs infected with *M. anisopliae* were collected and isolated from pigeon pea crops.

**YSPUF&F:** Coccinellids viz. *Coccinella septempunctata*, *Hippodamia variegata*, *Cheilomenes sexmaculata*, *Oenopea sauzetii*, *Oenopia kirbyi*, *Oenopia sexareata*, *Adalia tetraspilota*, *Propylea lutiopustulata*, *Chilocorus infernalis*, *Priscibrumus uropygialis*, *Harmonia dimidiata*, *Harmonia eucharis*, *scymnus posticalis* and *Coelophora bissellata*, were collected from different agro-climatic zones of Himachal Pradesh. *Chrysoperla zastrowi sillemi* was collected from apple, peach and cucumber infested with aphids and whiteflies. Syrphids namely *Episyrphus balteatus*, *Eupeodes frequens*, *Sphaerophoria indiana*, *Melanostoma univittatum*, *Betasyrphus serarius*, *Ischiodon scutellaris*, *Metasyrphus confrator* were collected from different flowering plants in the state. *Dinocalpus coccinellae*, a parasitoid of coccinellid beetles was also recorded parasitizing *Coccinella septempunctata*. *Diadegma semiclausum* was reared from the larvae of *Plutella xylostella* collected from Solan districts. In addition, *Cotesia glomerata* parasitizing *Pieris brassicae* in cauliflower, *Campoletis chloridae* parasitizing *Helicoverpa armigera* in tomato and *Diplazon* sp parasitizing syrphids were also collected.

**UBKV:** Twenty three numbers of spiders from three different families (Lycosidae, Oxyopidae and Sparassidae) were found during the experiment. Spiders under family Araneidae and Sparassidae were active during July to October and October to November, respectively. Whereas *Oxyopes* spider under family Oxyopidae was available throughout the cropping season in the field.

#### **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 centre during the year 2020-2021.

#### **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 spiralling whitefly (*Aleurodicus rugioperculatus*) population was found to be very low (<0.5 colonies /leaflet) during July-September 2020 and thereafter shot up to as high as 2.2 colonies by March 2021. The population of Bondar's nesting whitefly (*Paraleyrodes bondari*) was found to be higher recording as high as 4.3 colonies per leaflet in the month of July 2020 and got reduced subsequently reaching as low as 1.2 colonies on April 2021. The non-native nesting whitefly (*Paraleyrodes minei*) that co-existed with BNW and RSW during 2018 was not observed during this year and was completely displaced by the other exotic whitefly species. The palm whitefly, *Aleurotrachelus atratus* was not reported from Kerala during the period. Co-existence of exotic whiteflies viz., *A. rugioperculatus*, *P. bondari* and *P. minei* was observed on arecanut leaflets in association with the native arecanut whitefly, *Aleurocanthus arecae* for the first time in 2021.

**DRYSRHU Ambajipeta:** The mean number of spirals of rugose spiraling whitefly per leaflet ranged between 0.45 (March 2021) to 21.50 (April 2020) while the mean number of nymphs of rugose spiraling whitefly per leaflet ranged between 2.25 to 47.50. The peak population of all stages were observed in April, 2020 and slowly decreased consequently throughout the observational period. For the first time Bondars nesting whitefly was recorded on coconut in the observational blocks in July 2020.

**KAU Thrissur:** The buildup of rugose whitefly started in October, possibly due to the delayed withdrawal of the South West monsoon. The whitefly infestation was high well into March, unlike in previous years when it had declined by January under the regulatory pressure from the parasitoid *Encarsia guadeloupae*. Mean parasitism by *E. guadeloupae* during the study period ranged from 17.58 to 85.96 per cent at Thrissur and from 35.72 to 62.10 per cent at Palakkad.

**OUAT:** Survey conducted in Puri and Khurda districts revealed the incidence of rugose spiralling whitefly, *Aleurodicus rugioperculatus* during 1<sup>st</sup> week of march, 2020 and low during *Kharif* season .

**RARS Kumarakom:** Per cent infestation was noticed to be increasing from June 2020 to March 2021 in all the three localities, where Vyttila recorded the highest with 97 per cent infestation in March. Live colonies per leaflet was also found to be increasing from November onwards in all the three stations. Peak colony count of 21.85 was obtained in the month of March in Kumarakom, which was the highest among all the three stations. This might be due to the rise in temperature and relative humidity and the absence of parasitoids which might have favoured the smooth establishment of colonies.

**COA Vellayani:** RSW population was high to severe during Oct 2020 to March 2021, with a gradual increase in number of live spirals. The corresponding parasitism levels were 59.29 to 71.

26 .Unlike the previous year there was no species displacement by *P. mineyi*, though *P. bondari* was present during Jan-Feb 2021.

**PJTSAU:** Surveys in February revealed that RSW infestation was now around 5%. Surveys conducted in March also showed that the pest was in lower numbers till March 15 and thereby with increasing temperatures, populations decreased. In April 2021, RSW in Aswararaopet was below 15%.

#### **4.2.1.3 Surveillance for pest outbreak and alien invasive pests including FAW and cassava mealybug**

**ANGRAU:** Moderate to severe incidence of fall army worm ( 8-22%) in maize was observed.

**KAU Thrissur:** Surveys for prevalence of cassava mealybug were carried out in more than 150 locations at Thrissur and Palakkad districts from May 2020 to March 2021. A total of 161 mealybug samples were collected and were sent to NBAIR for identification. Taxonomic identification of 128 samples showed that four mealybug species viz., *Paracoccus marginatus* (36.72%), *Ferrisia virgata* (29.69 %), *Phenacoccus manihoti* (28.90 %) and *Pseudococcus jackbeardsleyi* (4.69 %) infested the cassava plants simultaneously, forming a complex.

**UAS Raichur:** Incidence of fall armyworm was low to moderate in three districts of North Eastern Karnataka during kharif season while during rabi season very low to negligible population was noticed in both maize and rabi sorghum.

**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. The incidence of *Tuta absoluta* was observed on tomato crop in few pockets in Satana Tahasil of Nashik district and Sakur Tehsil of Latur district in Maharashtra during February and March, 2021. The Fall Armyworm (FAW) *Spodoptera frugiperda* was recorded in all maize growing areas of Maharashtra. The FAW infestation ranges between 10 to 40 per cent in maize crop. The pest extended its host range and it is also found on sorghum and Bajara crops in Pune, Solapur, Satara and Sangli districts.

**MPUAT:** The survey indicated that the incidence of fall army worm was noticed to be moderate to severe in Udaipur, Chittorgarh, Rajasamand and Pratapgarh districts of Southern Rajasthan with an average incidence range of 3-10 percent.

**YSPUH&F:** Surveys were carried out at 13 locations covering 6 districts viz. Bilaspur, Mandi, Shimla, Una, Solan and Sirmour to record the incidence of fall armyworm, *Spodoptera frugiperda* on maize. The pest incidence was recorded on all the locations and the percentage of plants infected varied from 5 to 71.

**IIMR:** The incidence was maximum at Mahboobnagar (35%) followed by Dharwad (30%). Incidence of fall armyworm was less than 5 % whorl damage at Akola, Parbhani, Rahuri, Indore,

Udaipur and Surat. During Rabi season 20 – 300 % foliar damage was observed at Hyderabad, Warangal.

**CPCRI:** Cassava (*Manihot esculenta*) cultivated as intercrop in coconut system was found infested by the exotic cassava mealybug (*Phenacoccus manihoti* Matile-Ferrero) at Kayamkulam, Kerala during April-May, 2020.

## **4.2.2 Biological suppression of plant diseases**

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

Minimum Sheath blight (*Rhizoctonia solani*) disease severity was recorded with PBAT-3 (28.04%), which did not differ significantly from Th14+Psf2 (29.24%), Th17+Psf2 (29.46%), Th17+Th14 (29.46%), Carbendazim (29.47%) and Th17+Psf173 ((30.15%). Minimum percentage of Brown spot (*Drechslera oryzae*) formerly known as *Helminthosporium oryzae* infected panicle/hill was observed with PBAT-3 (42.39%) which was statistically at par with Carbendazim (42.53%) and followed by Th17+Psf2 (43.41%).

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

Maximum percentage of seed germination was observed with PBAT-3 (85.38 %), while minimum percentage of seed germination was recorded in control (69.05 %). Maximum Plant Stand (15DAS) was recorded with PBAT-3 (213.44) followed by Th17+Psf173 (208.94), Th17+Th14 (208.83), Th14+Psf2 (208.00), Th-14 (207.90), Carbendazim (207.46), Th17+Psf2 (206.58), Th-17 (206.27) and Psf-2 (205.98) which were statistically at par with each other but significantly different from PBAT-3 and better than control (172.62).

### **4.2.2.3 Bio-efficacy of different bio-agents against the early blight of tomato**

**AAU-A:** Among the treatments where different combinations of *Trichoderma* and *Pseudomonas* evaluated as soil application, root dip and foliar spray, the treatment T<sub>6</sub>- Th+ Pf (SA + RD) + Azoxystrobin 23% SC (FS) found effective in reducing the early blight disease intensity (9.26%). This treatment was found at par with the treatment T<sub>5</sub> - Pf (SA + RD) + Azoxystrobin 23% SC (FS) (11.74 %). Among the treatments where the biopesticides were evaluated as foliar spray, the treatment T<sub>3</sub> - Th + Pf (SA + RD + FS) recorded the lowest disease intensity (16.50 %). The chemical control recorded the highest yield (31.33 t/ha) which was followed by the treatment T<sub>6</sub> . Th+Pf (SA+RD)+ Azoxystrobin 23% SC (FS) (29.67 t/ha) and T<sub>5</sub> - Pf (SA + RD) + Azoxystrobin 23% SC (FS) (28.67 t/ha). All these three treatments found statically at par with each other. The lowest fruit yield was recorded in the treatment T<sub>8</sub> – untreated control (9.67 t/ha).

#### 4.2.2.4 Bio-efficacy of different bio-agents against the early blight of potato

**AAU-A:** Among the treatments where different combinations of *Trichoderma* and *Pseudomonas* evaluated as soil application, seed treatment and foliar spray, the treatment T<sub>6</sub>-Th+ Pf (SA +ST) + Kresoxim-methyl 44.3% SC (FS) found effective in reducing the early blight disease intensity (8.52%). Among the biopesticides treatments the treatment T<sub>3</sub> - Th+ Pf (SA + ST + FS) recorded the lowest disease intensity (17.17 %). The untreated control treatment recorded the disease intensity of 40.60 %. The chemical control recorded the highest yield (21.00 t/ha) which was followed by the treatment T<sub>6</sub> - Th+ Pf (SA + ST) + Kresoxim-methyl 44.3% SC (FS) (20.33 t/ha), T<sub>5</sub> - Pf (SA + ST) + Kresoxim-methyl 44.3% SC (FS) (19.67 t/ha) and T<sub>4</sub>-Th (SA + ST) + Kresoxim-methyl 44.3% SC (FS) (19.00 t/ha). All these four treatments found statically at par with each other. The lowest tuber yield was recorded in the treatment T<sub>8</sub> – untreated control (9.33 t/ha).

#### 4.2.2.5 Ecofriendly management of stem rot, *Macrophomina phaseolina* in sesame using biocontrol agents

**ANGRAU:** kharif july sown crop, germination was high in T<sub>4</sub> - *P. fluorescens* ST + *T. asperillum* SD ( 92.88%) and was on par with other biocontrol agent compared to chemical , carbedazim ( 80.16%) and germination was low in control ( 66.27%). Stem rot disease was noticed at 60 days crop age as high in control (15.97%) and low in T<sub>4</sub> - *P. fluorescens* ST + *T. asperillum* SD (3.1 %) followed by T<sub>1</sub> - *Trichoderma asperillum* ST + SD (3.67%) and T<sub>2</sub>-*Pseudomonas fluorescens* ST + SD (3.43%). Crop was subjected to severe phyllody at maturity stage resulted in low yields.

#### 4.2.2.6 Management of Fusarium wilt/ root rot of pea through biological control agents

**YSPUH&F:** *Trichoderma asperillum* and *Pseudomonas fluorescens*, alone and in combination were evaluated in comparison to carbendazim and untreated control. All the treatments of biological control agents reduced the wilt incidence significantly as compared to control. Treatment combination comprising of seed treatment with *T. asperillum* formulation @10g/kg seed+ soil application of *T. asperillum* formulation after mixing with FYM (10g/Kg FYM @40g/m<sup>2</sup>) was the most effective in reducing the disease incidence and resulting in the highest pod yield.

#### 4.2.2.7 Management of Powdery mildew (*Uncinula necator*) of Grape by using biocontrol agents

**MPKV:** Powdery mildew, *Uncinula necator* disease of grape was effectively managed with three spraying of *Trichoderma harzianum* @ 5 g /L + *Ampelomyces quisqualis* @ 5 ml /L and recorded minimum 6.33 Per cent Disease Index (PDI) and maximum fruit yield 19.567 Mt./ha followed by *Bacillus subtilis* @ 5 g /L + *Ampelomyces quisqualis* @ 5 ml /L which recorded 8.23 PDI with fruit yield of 19.453 Mt./ha. as against in chemical check (sulphur 2g/litre of water) recording 10.00 PDI and fruit yield 19.033 Mt./ha.

#### **4.2.2.8 Evaluation of microbial antagonists for the management of foot rot of citrus (kinnow) caused by *Phytophthora* spp.**

**PAU:** Evaluation of microbial antagonist for management of foot rot in Kinnow revealed 22.70 per cent recovery in final lesion size over untreated control and recorded fruit yield of 96.5 kg per tree in *Pseudomonas fluorescens* NBAII-PWDWD (Talc based) as compared to 43.8 per cent recovery and 107.5 kg fruit yield per tree in chemical control (Curzate M8).

#### **4.2.2.9 Evaluation of microbial antagonists for the management of diseases (Powdery mildew/Ascochyta blight/Rust) in pea**

**PAU:** Evaluation of microbial antagonists for the management of Ascochyta blight in pea revealed that application of *Pseudomonas fluorescens* (NBAIR-Pf DWD) recorded with lowest disease incidence (40.48%), disease severity (33.30%) and pod yield (134 q/ha) that was at par with all other microbial antagonists treatments and significantly better than untreated control. However, chemical control recorded disease incidence (27.15%), disease severity (22.20%) and pod yield (149.6 q/ha).

#### **4.2.2.10 Efficacy of Mechanized sett treatment with antagonistic microbes, fungicide and their integration against red rot in sugarcane**

**SBI Coimbatore:** Results indicated that treating setts in the Sett Treatment Device (STD) with the combination of thiophanate methyl and *Paenibacillus alvei* was found to be significantly superior followed by combination of *P. alvei* and *T. harzianum* in protecting the setts from soil-borne inoculum and improving plant survival.

#### **4.2.2.11 Field evaluation of ICAR-NBAIR antagonistic organisms against Maize Turcicum leaf blight (*Exserohilum turcicum*)**

**SKAUST Jammu:** Among the various biopesticides assessed, NBAIR-TATP strain *T. asperellum* (Liquid formulation) (T<sub>4</sub>) - recorded lowest percent disease index (21.00%) and its talc formulation T<sub>2</sub> - (21.80%), followed by BC1 strain *Trichoderma asperellum*, talc formulation (T<sub>5</sub>) (23.10%). Percent disease index in carbendazim spray (T<sub>7</sub>) - (19.30%) was comparable to that of *P. fluorescens* (NBAIR-PFDWD strain – liquid formulation) (T<sub>1</sub>), but grain yield was significantly highest in T<sub>4</sub> (34.58 q/ha) and T<sub>2</sub> (34.31 q/ha). The grain yield was lowest in control (23.05 q/ha).

#### **4.2.2.12 Field evaluation of ICAR-NBAIR antagonistic organisms against Wheat Yellow rust (*Puccinia striiformis* f. sp. *tritici*)**

**SKAUST Jammu:** NBAIR-PFDWD strain *P. fluorescens* (Liquid formulation) (T<sub>3</sub>) - recorded lowest percent disease index (5.73%) followed by its talc formulation (T<sub>1</sub>) - (6.67%). Percent disease index in Propiconazole spray (T<sub>7</sub>) (5.53%) was comparable to that of *P. fluorescens* (NBAIR-PFDWD strain – liquid formulation) (T<sub>3</sub>), but grain yield was significantly highest in T<sub>3</sub> (28.6 q/ha). The grain yield was lowest in control (22.85 q/ha).

#### **4.2.2.13 Field evaluation of ICAR-NBAIR antagonistic organisms against Chickpea *Fusarium* wilt (*Fusarium oxysporum* f. sp. *ciceris*)**

**SKAUST Jammu:** Among the various biopesticides assessed, NBAIR-TATP strain *T. asperellum* (Liquid formulation) (T<sub>4</sub>) recorded lowest percent wilt incidence (19.11%) followed by its talc formulation (T<sub>2</sub>) (21.33%) and BC1 strain *Trichoderma asperellum* (talc formulation) (T<sub>5</sub>) (24.83%). Percent wilt incidence in carbendazim spray (T<sub>7</sub>) (22.67%) was on par with *Trichoderma asperellum* talc formulation, but grain yield was significantly highest in T<sub>4</sub> (9.58 q/ha). The grain yield was lowest in control (6.77 q/ha).

#### **4.2.2.14 Field evaluation of ICAR-NBAIR antagonistic organisms against Mustard White rust (*Albugo candida*)**

**SKAUST Jammu:** NBAIR-PFDWD strain *P. fluorescens* (Liquid formulation) (T<sub>3</sub>) recorded lowest percent disease index (23.23%) followed by its talc formulation (T<sub>1</sub>) (26.23%). Percent disease index in Ridomil spray (T<sub>7</sub>) (23.63%) was on par with *P. fluorescens* (NBAIR-PFDWD strain – liquid formulation) (T<sub>3</sub>) but seed yield was significantly highest in T<sub>3</sub> (8.61 q/ha) and T<sub>1</sub> (8.17 q/ha). The grain yield was lowest in control (6.27 q/ha) and T<sub>7</sub> – (6.48 q/ha).

#### **4.2.2.15 Field evaluation of ICAR-NBAIR antagonistic organisms against Pea Rust (*Uromyces fabae*)**

**SKAUST Jammu:** NBAIR-PFDWD strain *P. fluorescens* (Liquid formulation) (T<sub>3</sub>) recorded lowest percent disease index (6.07%) followed by its talc formulation (T<sub>1</sub>) (6.97%). Percent disease index in Mancozeb spray (T<sub>7</sub>) (5.87%) was comparable to that of *P. fluorescens* (NBAIR-PFDWD strain – liquid formulation) (T<sub>3</sub>), but seed yield was significantly highest in T<sub>3</sub> (8.16 q/ha), followed by T<sub>1</sub> (7.67 q/ha). The grain yield was lowest in control (5.76 q/ha) and T<sub>7</sub> – (6.11 q/ha).

#### **4.2.2.16 Management of major diseases of rice with *Bacillus subtilis***

**TNAU:** Bacterial leaf blight incidence ranged between 27.75 per cent (T3-Soil application of *Bacillus subtilis* -2.5kg/ha) and 28.65 per cent (T4-Foliar spray of *Bacillus subtilis*- 20g/lit) and all the treatments are on par with T6-Azoxystrobin (1ml/lit). In case of brown spot disease, all the *Bacillus subtilis* treatments were less effective when compared to Azoxystrobin (1ml/lit). Both *Bacillus subtilis* treatments and chemical treatment were statistically on par with control pertaining to the incidence of grain discoloration and sheath blight diseases

### **4.2.3 Biological suppression of sugarcane pests**

#### **4.2.3.1 Efficacy of *Aschersonia placenta* for the management of whitefly in sugarcane ecosystem**

**SBI Coimbatore:** A preliminary trial at Perani, Viluppuram district (TN) in a severely affected field with a single application of *A. placenta* against *Aleurolobus barodensis* @ $1 \times 10^{12}$ /ha was found to effectively reduce the population.

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

**MPKV:** The lowest mean clump mortality of 7.08 % by white grub was recorded in chemical treatment with Fipronil 40% + imidacloprid 40 WG @ 0.4 g /L, while it was 8.53% in case of EPN treatment *H. indica* WP. Highest white grub reduction (70.64%) was recorded in chemical treatment followed by EPN treatment *H. indica* @  $1.0 \times 10^5$ / m<sup>2</sup> (NBAIR WP formulation) with 64.63 %. The untreated control recorded clump mortality of 24.12 %.

#### **4.2.3.3 Field evaluation of ICAR-NBAIR endophytic entomopathogenic strains against shoot borers (*Chilo infuscatellus* and *Chilo sacchariphagus indicus*) in sugarcane**

**ANGRAU:** During 2020-21 kharif planted crop, Sett treatment at planting and spraying of endophytic entomopathogenic fungi three times at 14 days interval from 25 days after germination was effective in the management of shoot borers. Cumulative incidence of early shoot borer incidence upto 120 days after planting was high in untreated control(23.86% DH) and low in Cholorantraniliprole treatment (1.62 %DH) and was on par with the entomopathogenic fungal treatments i.e., Bb23 ( 2.72%DH); Bb 45 (3.36 %DH) ; Ma 4 (2.05%DH); Ma 35 (3.03 % DH). Internode borer incidence (%) and Internode borer intensity (%) was high in control ( 62.5 % and % 4.76) and low in T4- NBAIR - *Metarhizium anisopliae* Ma-35 ( 40% and 1.96%) and T2 NBAIR - *Beauveria bassiana* Bb-45 ( 50% and 2.88%) . Cane yield recorded high in Bb-45@ 5 g/lt (70.93 t /ha ) followed by Ma-35@ 5 g/lt (66.32 t/ha) and low in control ( 43.58 t/ha).

#### **4.2.4 Biological suppression of cotton pests**

##### **4.2.4.1 Biointensive management of pink bollworm on *Bt* cotton**

**PJTSAU:** Results revealed that BIPM package plots recorded higher nos. of good opened bolls per plant (0.47), least no. of bad opened bolls (1.57/plant) but was on par with farmers practices (0.39/plant), More no. of parasitized larvae/plant (6.07/plant) and boll infestation (46.23%) and yield of 3.99a/acre. Farmers practices recorded 0.23 good bolls/plant, 0.39% bad opened bolls/plant, lesser no.of parasitized larvae/plant (0.67) and least infestation by boll dissection (32.22%). Yield in farmers plot was 4.76 q/acre, while control plot recorded least yield (1.23 q/acre) and maximum boll infestation 69.09%.

##### **4.2.4.2 Evaluation of entomopathogenic fungi, *Beauveria bassiana* (ICAR- NBAIR- Bb-5a) against sucking insect pests of cotton**

**UAS Raichur:** Among the biocontrol agents, *B. bassiana* (ICAR- NBAIR-Bb-5a)  $1 \times 10^8$  @ 5gm/l recorded highest reduction of leafhopper population over control (49.15%) and it was at par with *L. leccani* (ICAR-NBAIR-VL-15)  $1 \times 10^8$  @ 5gm/l which recorded 45.38 per cent. Lowest thrips of 2.04 per plant was noticed in *B. bassiana* (ICAR- NBAIR-Bb-5a)  $1 \times 10^8$  @ 5gm/l and it was at par with *L. leccani* (ICAR-NBAIR-VL-15)  $1 \times 10^8$  @ 5gm/l and *I. fumosorosea* (ICAR-NBAIR strain)  $1 \times 10^8$  @ 5gm/l which recorded 2.84 and 2.78 thrips per plant, respectively.

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

**MPKV:** Amongst the biopesticides, *Lecanicillium lecanii* ( $1 \times 10^8$  conidia /g) @ 5 g/litre recorded lowest population of sucking pests viz., aphids (4.80), jassids (2.90), thrips (2.40) and white flies (1.72) on 3 leaves per plant compared to the untreated control. Chemical treatment recorded lowest population of all sucking pests and significantly superior over rest of the treatments. The *Lecanicillium lecanii* ( $1 \times 10^8$  conidia/g) @ 5 g/litre recorded seed cotton yield of 15.20 q/ha which is on par with Imidachloprid 17.8 % SL (17.00 q/ha). Whereas, untreated control recorded lowest seed cotton yield of 6.04q/ha.

**PJTSAU:** Three sprays of Neem oil 1500 ppm @ 1litre/acre and *Lecanicillium lecanii* @ 1 litre/acre have shown their supremacy in managing sucking pests in cotton and have proved to be on par with chemical treatments in reducing hopper population and in recording higher yield also.

#### **4.2.5 Biological suppression of rice pests**

##### **4.2.5.1 Management of rice stem borer and leaf folder using Entomopathogenic microorganisms**

**KAU Thrissur:** There was no significant difference among the different treatments either in terms of mean number of dead hearts/white earheads. The leaf folder infestation in trial plots also remained at low levels till later stages of the crop with no significant variation among the treatments in terms of mean number of leaf folds. A sudden increase in leaf folder infestation was observed in all treatments nine weeks after treatment.

##### **4.2.5.2 Comparative efficacy of entomopathogenic fungi against sucking pests of rice, *Leptocoris acuta***

**IIRR:** Among all biopesticides, three days after spray the lowest population per hill of 2.33 was observed in *Metarhizium anisopliae* @  $10^7$  spores ml<sup>-1</sup> and Thiamethoxam 2.40. But only the efficacy of Thiamethoxam lasted beyond a week. After the second spray the cumulative per cent

control ranged from 31.92 – 85.33 per cent among the entomopathogens while the highest of 97.18 per cent was recorded in Thiamethoxam. However, all treatment were significantly higher than untreated control

#### **4.2.5.3 BIPM trial on paddy along with farmers practice and control**

**IGKV:** The results indicated that maximum dead heart (DH) (4.03) and white ear head (WEH) (7.42) were recorded from control as compared to BIPM treated varieties. Maximum grain 16.62 q/acre was obtained in BIPM treated plots as compared to control (12.80 q/acre).

**COA Vellayani:** Analysis of data on leaf rollers revealed that the population was less in farmers practice during the crop period, compared to BIPM plots, until 14 DAP the population of both the plots attained a non-significant variation. The mean population was 0.28/plot in BIPM while it was nil in Farmers practice. The population of rice bug was statistically on par in both the fields after 7 days of spray I and spray II. Thereafter at 14<sup>th</sup> day the bug population was significantly high in chemical treatment (farmers practice).

#### **4.2.5.4 Evaluation of identified bacterial and fungal isolates against stem borer (*Scirpophaga incertulas*) and BPH (*Nilaparvata lugens*) in ICAR-NRRI, Cuttack in collaboration with ICAR-NBAIR, Bengaluru**

**NRRI:** An increased BPH nymphal mortality (13.33-23.33%) was observed in all the NBAIR isolates compared to untreated control where less mortality of BPH was observed (3.58%). It was also observed that the plants sprayed with NBAIR isolates took more days to dry/wilt compared to untreated control plants which dried very quickly due to BPH feeding.

#### **4.2.6 Biological suppression of cereal pests**

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

**MPUAT:** The large plot demonstrations on the releases of *Trichogramma chilonis* were conducted at farmer's fields in an area covering 10 hectares in Udaipur district of Rajasthan. The dead heart incidence in fields with the releases of *T. chilonis* was 11.67 per cent and in chemical control, it was 8.94 per cent. The reduction in incidence over control was 42.93 and 56.28 per cent in T1 and T2, respectively. The yield in *T. chilonis* (T1) (30.22 q/ha) and Spinosad 45 SC (T2) (34.60 q/ha) fields were significantly more than in untreated control (24.10 q/ha).

##### **4.2.6.2 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 (4.44%) and number of whiteflies per five leaves of various intercrops (16.30 whiteflies) was significantly lowest in–Maize + cowpea + napier as compared to sole maize plots. The natural enemies present in the ecosystem; Coccinellid sps. and Spiders were more active in okra intercrops (8.33 and 2.00 No. of lady bird beetle/m<sup>2</sup> area and spider/m<sup>2</sup> area on maize and intercrops, respectively), where the population of whiteflies and *S. litura* larvae were more. Significantly highest maize equivalent yield was obtained in Maize + cowpea + napier (46.39 q/ha) and the B: C ratio was also highest in this treatment (2.553).

#### **4.2.6.3 Biological suppression of fall armyworm *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) in maize**

**CAU:** Among different biocontrol agents tested, significantly lowest number of *S. frugiperda* larvae/ 10 plants was recorded in the treatment *T. chilonis* @ 1 card/acre + NBAIR Bt @2% (1.85 larvae/10 plants) which was at par with the treatment *T. chilonis* @ 1 card/acre + *Pseudomonas fluorescens* NBAIR PfdWD @2% (1.96 larvae/10 plants), *T. chilonis* @ 1 card/acre + *Metarhizium anisopliae* NBAIR-Ma 35 @0.5% (2.05 larvae/10 plants) and *T. chilonis* @ 1 card/acre + SpfrNPV-NBAIR1 @2ml/litre water (2.11 larvae/10 plants).

**PJTSAU:** In the trial against FAW in Maize, use of Trichocards + foliar sprays of NBAIR *Bt* 2%, Trichocards + Pheromone traps @15/acre recorded lesser damage by FAW and higher yield among all the biocontrol treatments and were on par with the chemical check. Significantly least no.of damaged plants/plot were seen in *Bt* treated plots (37.89%) and pheromone treated plots (36.74%) apart from chemical treated plots (33.62 %) and highest were seen in pseudomonas (89.93%) and control plots (88.83%) (73.66). Significantly, highest yield was seen in Trichocards + *Bt* treated plots (29.27q/a) and pheromone treated plots (28.90 q/a) apart from chemical treated plots (29.33 q/a) and least was seen in control plots (11.71 q/a) (15.45 q/a).

**TNAU:** Among the biocontrol agents, 43.62 per cent damaged plants was observed in *Trichogramma pretiosum*+ NBAIR *Bt* 2% followed by *Trichogramma pretiosum*+ *Metarhizium anisopliae* Ma (48.31%), *Trichogramma pretiosum*+ *Beauveria bassiana* NBAIR -Bb 45 35 (50.78%), and *Trichogramma pretiosum*+EPN *H. indica* NBAIR H38 (52.71%) and *Trichogramma pretiosum*+Spfr NPV(NBAIR1) (53.96%) on 10th day after first spraying of entomopathogens and insecticide, while in insecticide treated plots 41.42 per cent damage was observed.

**AAU-A:** Among the different control agents evaluated against fall armyworm in maize, the treatment T<sub>1</sub>- *Trichogramma pretiosum* @ 1 card/acre + *Bacillus thuringiensis* - NBAIR BtG4 - 1% WP found effective in reducing the larval population (1.96 larvae/10 plants). This treatment was found statistically at par with the treatment T<sub>5</sub> - *T. pretiosum* @ 1 card/acre + *Pseudomonas*

*fluorescens* NBAIR PfDWD - 1% WP (2.39 larvae/ 10 plants). Similarly the treatment T<sub>1</sub>- *Trichogramma pretiosum* @ 1 card/acre + *Bacillus thuringiensis* - NBAIR BtG4 - 1% WP recorded the significantly lowest plant damage (9.27%) as compared to other biocontrol treatments. The treatment T<sub>1</sub> recorded the highest grain and fodder yield (3817 and 4778 kg/ha) which was at par with the treatment T<sub>5</sub> (3783, 4600 kg/ha) and T<sub>2</sub> (3770, 4570 kg/ha).

**IIMR (WN):** Among the treatments, minimum per cent plant infestation and minimum number of egg masses were observed in *Trichogramma pretiosum* 1 Card/ acre+ *Beauveria bassiana* NBAIR -Bb 45 ( 30.68), *T. pretiosum* 1 Card/ acre+ *Metarhizium anisopliae* NBAIR -Ma 35 (31.21).

**MPKV Pune:** The treatment with Farmers' practice (application of Emamectin benzoate 5 SG @ 0.4 g/L at 10, 20, 30, 40 and 50 DAS ) recorded minimum egg patches (0.16), larval population (0.01) per 10 plants/plot and plant damage (0.83%) of FAW, *S. frugiperda* in maize crop as against BIPM practices and untreated control which recorded egg patches (0.26) and ( 0.58 ), larval population (0.35) and (0.88) per 10 plants/plot and plant damage (34.55%) and (80.00 % ), respectively.

**PAU:** Among different biocontrol agents, lowest plant infestation due to fall armyworm, was recorded in Tc + NBAIR-Bt 25 (8.83 %) followed by Tc + NBAIR-Ma 35 (10.69 %) and Tc + NBAIR-Bb 45 (11.27 %) as compared to untreated control (17.28 %). Likewise, larval population was also significantly lower in Tc + NBAIR-Bt 25 (3.50/ 10 plants), Tc + NBAIR-Ma 35 (4.17/ 10 plants) % and Tc + NBAIR-Bb 45 (4.33/ 10 plants) as against untreated control (6.83/ 10 plants). However, chemical control was significantly better in reducing the plant infestation and larval population as compared to all treatments and also recorded highest grain yield.

#### **4.2.6.4 Laboratory bioassay of *Metarhizium (Nomuraea) rileyi* (Anakapalle strain AKP-Nr-1) against maize fall armyworm , *Spodoptera frugiperda***

**ANGRAU:** Fall army worm larval mortality recorded high in T6- *M. rileyi* (AKP-Nr-1)  $1 \times 10^9$  spores / ml ( 93.3 %) followed by T-5 *M. rileyi* (AKP-Nr-1)  $1 \times 10^8$  spores / ml (86.67%) and T4- *M. rileyi* (AKP-Nr-1)  $1 \times 10^6$  spores / ml (80%) and low in T3- *M. rileyi* (AKP-Nr-1)  $1 \times 10^5$  spores / ml (73.33%) ; T2- *M. rileyi* (AKP-Nr-1)  $1 \times 10^4$  spores / ml (70%) and T1: T6- *M. rileyi* (AKP-Nr-1)  $1 \times 10^6$  spores / ml (66.66%). T6- *M. rileyi* (AKP-Nr-1)  $1 \times 10^6$  spores / ml (73.33%).

#### **4.2.6.5 Bioassay of *Metarhizium rileyi* collected from North Eastern Karnataka against fall armyworm, *S. frugiperda* in laboratory during 2020-21**

**UAS Raichur:** The desired  $LC_{50}$  value for UASRBC-Nr7 isolate was found to be  $1.92 \times 10^6$  and  $6.75 \times 10^7$  conidia/ml with fiducial limit ranging from  $1.45 \times 10^6$  to  $1.70 \times 10^{10}$  and  $1.97 \times 10^3$  to  $1.08 \times 10^9$  conidia/ml, respectively.

#### **4.2.6.6 Field efficacy of *Metarhizium (Nomuraea) rileyi* isolate (Anakapalle strain AKP-Nr-1; UAS,Raichur) against fall armyworm, *Spodoptera frugiperda* in maize**

**ANGRAU:** Percent reduction in fall army worm incidence after two sprays of *M. rileyi* was high in T2- *M. rileyi* (Anakapalle strain AKP-Nr-1)  $1 \times 10^{10}$  spores / ml (84.01 %) and was on par with other treatments. Cob yield recorded high in T2 - *M. rileyi* (Anakapalle strain AKP-Nr-1)  $1 \times 10^{10}$  spores/ml (56.53 q/ha) and T4-*Metarhizium rileyi* (UAS,Raichur)  $1 \times 10^8$  spores / ml ( 53.81 q/ha) and low in control ( 29.43 q/ha).

#### **4.2.6.7 Field efficacy of *Metarhizium rileyi* (Anakapalle strain AKP-Nr-1 and *Metarhizium rileyi* (UASR strain KK-Nr-1).**

**UAS Raichur:** Ten days after first spray lowest larval population of 0.38 larva per plant was noticed in the highest dosage of *Metarhizium rileyi* (KK-Nr-1) @  $1 \times 10^{12}$  spores/ml (5g/L) and it was at par with *Metarhizium rileyi* (AKP-Nr-1) @  $1 \times 10^{12}$  spores/ml (5g/L) which recorded 0.44 larva per plant and these treatments were also at par with *Metarhizium rileyi* (KK-Nr-1) @  $1 \times 10^{10}$  spores/ml (5g/L) and *Metarhizium rileyi* (AKP-Nr-1) @  $1 \times 10^{10}$  spores/ml (5g/L) which recorded 0.58 and 0.46 larva per plant, respectively and similar trend was noticed at second and third spray.

#### **4.2.6.8 Evaluation of entomopathogenic fungi formulations against millet borers in Finger millet, Kharif, 2020**

**IIMR, Hyderabad:** There was 67.5 and 59.7 % reduction in dead hearts over the control in T4 (Ma-35 @ 10 ml /lt) and T3 (Bb-45 @ 10 ml /lt), respectively while treatment with Fironil 3G @ 17.5 kg /ha resulted in 68.0% reduction in deadhearts over the untreated control. There was 47.6 % and 42.3% increase in grain yield over the control in T4 and T3. Soil application of application of Fipronil 3G @ 17.5 kg /ha) at sowing + whorl application of Fipronil 3G @ 7.5 kg at 30 DAE resulted in 49.2% increase in yield over the untreated control.

### **4.2.7 Biological suppression of pests of pulses**

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

**MPKV:** *Bacillus thuriangiensis* @ 1 Kg/ha (2g/L of water) effectively suppressed the gram pod borer, *Helicoverpa armigera* infestation in chickpea and recorded the larval population of 0.37 larvae / Sq. m., pod damage of 5.33 % and grain yield of 15.97 q/ha as against in chemical check

spinosad 45 SC @ 150ml/ha (0.3 ml/L of water) with 0.37 larvae / Sq. m., pod damage of 4.27 % and grain yield of 16.28 q/ha. Whereas, untreated control plots recorded 2.35 larvae / Sq. m., pod damage of 12.75 % and grain yield of 9.52 q/ha.

#### **4.2.7.2 Evaluation of oil formulation of *Lecanicillium* spp against sucking pests of cowpea**

**COA Vellayani:** After the first spraying, three days after treatment, chitin enriched oil formulation 10 ml/L of *L. saksenae* and its spore suspension  $10^7$  spores mL<sup>-1</sup> were equally effective in managing pod bugs with a mean population of 0.5 bugs per plot.

#### **4.2.7.3 BIPM module for management of *Helicoverpa armigera* on chickpea**

**TNAU:** BIPM modules and insecticide treatment were found to be statistically similar in their effect on 14 DAFS. The population of larvae after second spraying also showed the same trend as that of population of larvae after first spraying. Pod damage was less in insecticide treatment (8.38%) when compared to the BIPM module 1 (bird perches+ *HaNPV* strain + pheromone traps) (13.41%) and BIPM module 2 (bird perches+ *Bt* + pheromone traps) (14.17%). There was 43.82 per cent increase in the yield in insecticide treatment followed by BIPM module 1 (21.91%) and BIPM module 2 (25.00%).

**PAU:** BIPM modules evaluated for the management of *Helicoverpa armigera* on chickpea revealed that all the treatments were significantly better than untreated control in reducing the pod damage. Minimum percent pod damage (1.03%) was recorded in chemical control followed by BIPM 2 module (2.90%). The yield was also significantly better in all treatments as compared to control. Maximum yield (18.83 q/ha) was recorded in chemical control and it was not significantly different from BIPM 2 (18.02 q/ha).

#### **4.2.7.4 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 (1.9 larvae per plant) and the minimum reduction was observed in *Bt*. @ 1 Kg/ha (2.9 larvae per plant) at ten days after spray; whereas, the untreated control recorded least reduction in larval population (5.8 larvae per plant) at ten days after spray. Minimum per cent pod damage was recorded in treatment of quinalphos 25 EC @ 250g a.i/ha (9.37%) and maximum was in *Bt*. @ 1 Kg/ha (14.67%).

#### **4.2.7.5 Integration of botanicals, microbials and insecticide spray schedule for the management of pod borer complex in Greengram**

**ANGRAU:** Leaf webs per plant was negligible in all the treatments except in untreated control (2.46 %). Pod damage was low in T9- Spinosad two sprays ( 1.73%) and T8 – spinosad + *Bt* (

2.65%) and T1 – Bt + Azadiractin ( 4.82 and T 2 - Bt two sprays ( 5.84%) and high in control ( 52.14%). Grain yield recorded low in control (3.05 q/ha); high in T3 – Bt+ spinosad (5.51 q/ha); followed by T4 – Azadiractin + Bt (5.38 q/ha) and T2 -Bt two sprays ( 5.33 q/ha)

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

##### **4.2.8.1 Field evaluation of microbial biocontrol agents for the management of mango thrips**

**CISH:** Among the bio-pesticides, low incidence of thrips was observed in *B. bassiana* (CISH formulation) which registered 7.00 thrips/ panicle at 7 days after spraying. Efficacy of *B. bassiana* (NBAIR formulation) and *M. anisopliae* (NBAIR formulation) was in parity with each other.

**DRYSRHU Ambajipeta:** The results revealed that after second and third spray, Fipronil and Azadiractin 10000 ppm treated trees had nil thrips population. The biopesticide treatments *Metarhizium anisopliae* and *Beauveria bassiana* also recorded low thrips population *i.e.*, 0.20, 0.06 and 0.40, 0.16 thrips per tree, respectively after second and third sprays. Among the bio-pesticide treatments, *Lecanicillium lecanii* had a high thrips population of 0.80 thrips/tree. In untreated control block a high population of mango thrips ranging from 4.26 to 15.25.14 was recorded.

##### **4.2.8.2 Bioefficacy of entomopathogenic fungi formulations in suppression of mango tortricid borers**

**CISH:** Entomopathogenic fungi *Beauveria bassiana* (CISH and NBAIR strain) and *Metarhizium anisopliae* (NBAIR Strain) were able to reduce the incidence of fruit borer incidence significantly. While considering the bioefficacy of *B. bassiana* both the strains did not differ significantly and exhibited in parity with *M. anisopliae* on account of fruit borer infestation at 7 and 14 days intervals. Interestingly the effectiveness of native bioagents of *B. bassiana* (CISH formulation) after 21 days of treatment reflected better to that of NBAIR formulation.

##### **4.2.8.3 Biological control of guava mealy bug and scales using entomopathogens**

**SKAUST Jammu:** Significantly highest percent reduction in mealy bug population was recorded in *M. anisopliae* spray (49.51% reduction) that was at par with that of *B. bassiana* spray (47.19%) at 7 DAS. At 3 DAS also mealy bug population was significantly lowest in *M. anisopliae* spray (16.9 mealy bug nymphs or adults per leaf). Significantly highest mealy bug and scales population was recorded in untreated control.

**UAS Raichur:** Highest per cent reduction in mealy bug population over control was noticed in *B. bassiana* (ICAR- NBAIR-Bb-5a) @  $1 \times 10^8$  @ 5 gm/l (80.94%) and it was at par with *I. fumosorosea* (ICAR-NBAIR strain) @  $1 \times 10^8$  @ 5.0 g/l which recorded 79.79 per cent. Among the biocontrol agents, *B. bassiana* (ICAR- NBAIR-Bb-5a) @  $1 \times 10^8$  @ 5 gm/l recorded highest fruit yield of 18.56 t/ha and it was at par with *I. fumosorosea* (ICAR-NBAIR strain) @  $1 \times 10^8$  @ 5.0 g/l which recorded 18.13 t/ha.

#### **4.2.8.4 Biological control of root knot nematode in guava**

**UAHS Shimogga:** There was a significant reduction in the plant parasitic nematodes (PPN) after the application of bioagents. The maximum reduction of PPN was observed in the treatment with consortia of *P. lilacinum* + *P. fluorescens* + *T. harzianum* @  $1 \times 10^8$  Cfug - 10g each/plant multiplied in 3kg of FYM it was on par with the treatment with Carbofuran 10 G @ 25g per plant the minimum population of PPN was recorded in untreated control.

#### **4.2.8.5 Biological control of anola mealy bug and scales using entomopathogens**

**SKAUST Jammu:** Significantly highest percent reduction in mealybug population was recorded in *M. anisopliae* and Azadirachtin spray (36.62 and 36.53% reduction) followed by *B. bassiana* spray (35.29% reduction) at 7 DAS. At 3 DAS mealybug population was significantly lowest in Azadirachtin spray (5.53 mealy bug / 10 cm twig). Significantly highest mealy bug population was recorded in untreated control (8.53 mealy bugs / 10 cm twig).

#### **4.2.8.6 Bio-efficacy of entomopathogens against Banana fruit and leaf scarring beetles, *Nodostoma subcostatum***

**AAU-J:** Amongst the different treatments, bunch covering with perforated plastic bags was the most promising in reducing the beetle (9.72/plant) with 31.55 per cent reduction over control followed by *Beauveria bassiana* (AAU Culture) as leaf axil filling, where the beetle population was 10.73/plant. However, the chemical insecticide Chloropyriphos 20 EC at its recommended dose @ 2.5ml /lit was the best in suppressing the beetle population (8.63/plant) with 39.23 PROC.

#### **4.2.8.7 Evaluation of different isolates of entomopathogenic fungi against citrus thrips**

**CRS Tirupati:** The preliminary results showed that *Beauveria bassiana* @5g/L was found effective with least infestation by thrips on fruits (11.68%) followed by *Lecanicilium lecanii* @5g/L (13.10%) and *Metarhizium anisopliae* @ 5g/L (16.82%) as compared to local check, acephate 75SP with 17.34% infestation and maximum infestation was recorded in control with 24.14% fruits infested.

#### **4.2.8.8 Evaluation of different isolates of entomopathogenic fungi against citrus Rust and Green mites**

**CRS Tirupati:** The preliminary results showed that *Lecanicillium lecanii* @5g/L was found very effective with least infestation by rust mites on fruits (3.32%) followed by *Beauveria bassiana* @ 5g/L (4.15%) as compared to local check, propargite with 4.59% infestation and maximum infestation was recorded in control with 16.52 % fruits infested.

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

##### **4.2.9.1 Field evaluation of some bio pesticides against green apple aphid, *Aphis pomi* and mites infesting apple in Kashmir**

**SKAUST Srinagar:** Average population of aphid<sup>-terminal shoot</sup> after 3 sprays of azadirachtin and *L. lecanii* was found minimum (6.77<sup>-shoot</sup>) in case of T5 which received sprays of Azadirachtin 1500 ppm @ 5.0 ml<sup>-1</sup> followed by *Lecanicillium lecanii* (1x10<sup>8</sup> CFU/ml) @ 5.0 ml<sup>-1</sup> and was statistically superior to all the bio pesticides used. One treatment of Fenazaquin 10 EC @ 0.4ml<sup>-1</sup> recorded lowest cumulative population of two spotted spider mite (4.4 1) whereas three sprays of Nimbecidine 300 ppm @ 5.0 ml<sup>-1</sup> showed an average of 10.94 mites.

##### **4.2.9.2 Organic management of woolly apple aphid, *Eriosoma lanigerum* infesting apple in high density and traditional orchards**

**SKAUST Srinagar:** Bio efficacy of *M. anisopliae* was found statistically on par with Chlorpyrifos 50 %+ Cypermethrin 5% EC. *L. lecanii* @ 10.0 ml<sup>-1</sup> also caused 67.30 per cent reduction. However, at recommended dose (5.0 ml<sup>-1</sup> of water) per cent reduction in aphid density was 58.83 and 53.82 for *L. lecanii* and *M. anisopliae* respectively.

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

**YSPUH&F:** The results reveal that chlorpyrifos (0.04%) was the most effective resulting in 100 per cent mortality of the pest. Among different biocontrol agents evaluated, *Heterorhabditis bacteriophora* (5000IJs/gallery) was the most effective resulting in 80 per cent mortality followed by *Steinernema feltiae* (5000IJs/gallery) and azadirachtin (2ml/L of 1500ppm; 10ml/gallery) (66.7% each). Other treatments were not very effective and resulted in 33.3 to 50 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:** Under good nutrition management, it was found that palms treated with neem oil (5%), water spray and conservation biological control could reduce the RSW population significantly ranging from 0.18-0.73. Palms sprayed with *Isaria fumosorosea* registered highest RSW population (0.95) after one-month of treatment. However, after two months all treatments were found on par indicating the importance of pesticide holiday approach and conservation biological control in the biological pest suppression of RSW with higher parasitism (58.8%) by *E. guadeloupeae*. The least reduction was observed on palms exposed to *Isaria fumosorosea* (36.7%), whereas, neem oil treated palms registered highest pest reduction of 82.4%.

**ANGRAU:** Per cent reduction in whitefly intensity was observed high in T1- *Isaria* sprays + *Encarsia* release (70.6%) after two sprays than one spray ( 31.67%) due to parasitization by *Encarsia* released after first spraying of *Isaria* fungus and in T2 – *Isaria* sprays + *Dichocrysa* release ( 70.6%) after two sprays than one spray ( 31.67%) due to *Dichocrysa* redation released after first spraying of *Isaria* fungus. Reduction in white fly intensity was low in T3 - Neem formulation 10000 ppm sprays (21.37%) after two sprays than one spray (16.82%).

**DRYSRHU Ambajipeta:** 15 days after treatments imposition lowest number of egg spirals were recorded in neem oil spray and *I. fumosorosea* treatment (1.54 and 2.69 egg spirals respectively). Significantly the lowest number of RSW infested leaflets /leaf was recorded in *I. fumosorosea* sprayed treatment (38.98 %). A high number of egg spirals were observed in natural conservation of *E. guadeloupeae* treatment. A number of parasitized nymphs (live & blackened) & nymphs with parasitoid emergence holes/leaflet (3.62) was recorded in natural conservation of *E. guadeloupeae* treatment while comparatively high number of aborted nymph/pupae was recorded in neem oil and water spray.

**KAU Thrissur:** Forty five days after second spray untreated trees as well as trees sprayed with *I. fumosorosea* had significantly higher mean number of parasitized colonies at 14.53 and 14.39 respectively, as compared to water spray with an average of 6.25 number of colonies.

**UAHS Shimogga:** Percent Reduction in intensity and live colonies of RSW population was recorded, after first spray maximum percent reduction in intensity and number of live colonies was recorded in the treatment with *Encarsia guadeloupeae* 49.02 (44.4) and 52.80 (46.60) respectively. Similarly, after second spray percent reduction in intensity and number of live colonies also recorded in the same treatment 60.92 (64.09) and 89.66 (71.24), the minimum percent reduction in intensity and live colonies were recorded in the untreated check.

#### **4.2.10.2 Biological suppression of Bondar’s nesting whitefly in coconut**

**KAU Kumarakom:** Both the treatments with *I. fumosorosea* (pfu-5) and neem oil spray could significantly reduce healthy nymphs per leaflet at 20 DAS. Though both treatments were found to be statistically on par, neem oil spray could cause 49.19 % reduction over control, where *I. fumosorosea* (pfu-5) could only result in 25.31 % reduction. However, at 60 DAS, treatment with ‘*I. fumosorosea* (pfu-5)’ brought 61.54 % reduction in healthy nymph count over control, which was statistically superior to all other treatments.

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

**DRYSRHU Ambajipeta:** Soil application of 50 g of *Trichoderma reesei* along with 5kg neem cake led to 64.24 per cent reduction in pod rot over control.

#### **4.2.10.4 Area-wide demonstration of biological suppression of black headed caterpillar (BHC) using *Goniozus nephantidis* and *Bracon brevicornis***

**CPCRI:** Moderate incidence of BHC was observed in coconut gardens at Mogral Puttur, Kasaragod district during October 2019 with 30.6% pest incidence. To combat the pest incidence, pruning and destruction of infested fronds at lower whorls as well as timely augmentative release of *Goniozus nephantidis* and *Bracon brevicornis* @ 20 parasitoid/palm was undertaken during November 2019. During the post-release phase, the pest incidence was reduced significantly to 11.4%, 3.0% and 1.1% in March 2020, August 2020 and March 2021, respectively. Laboratory maintenance of parasitoids viz., *Goniozus nephantidis* and *Bracon brevicornis* was continued and these parasitoids were supplied to State Parasite Breeding Stations and farmers as per demand. During 2020, a microlepidopteran Gelechiid, *Coconympha iriarcha* was found associated with the incidence of *O. arenosella* at Kasaragod, Kerala.

#### **4.2.10.5 Converging biological suppression approaches for area-wide management of coconut rhinoceros beetle.**

**CPCRI:** As part of “Convergence of bio-control technologies for area-wide management of coconut rhinoceros beetle”, more than 50 kg of *Metarhizium majus* mass multiplied in semi-cooked rice was distributed to dairy farmers in Vallikunnam panchayat since September 2020. The application procedure of the entomopathogenic fungus on the breeding sites was demonstrated by ICAR-CPCRI Crop Protection Scientists at the hamlet with few progressive dairy farmers under the co-ordination of the Agricultural Officer. The farmers were empowered on the technical know-how as well as sustainable impact of the technology moulding Vallikunnam as a bio-village model. A group of women farmers were also trained on the mass

production of green muscardine fungus at farm level and inoculation in the breeding zones of the bio-village during February 2021.

#### **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**

**YSPUH&F:** the fruit infestation in the two plots (BIPM and Chemical) remained almost same throughout the season and varied from 2.33 to 3.67 per cent in BIPM plots and 1.67 to 4.0 per cent in chemical plots (Table 6). The yield recorded in BIPM plots (31.3t/ha) was also statistically on par with that recorded in chemical treated plots (29.4t/ha). The incidence of *Helicoverpa armigera* remained very low throughout the cropping season and varied from 0.33 to 1.0 per cent in different plots.

**PJTSAU:** Fruit damage by *H. armigera* was lesser (4.25-5.5%) in BIPM package and farmers package compare to control (10%). Aphids and mirids were also lesser in BIPM compared to Farmers practice (1.54/leaf aphids each and 1.9-2.5 mirids/plant compared to control (3.93/plant). Parasitoids were more in the BIPM package plots and control plots (2.40-3.03/plant). Yield (kg/plot) was 280, 290 and 103 respectively in BIPM package, farmers' package and in control plots. B: C ratios were 4.44 in BIPM package and 3.71 in farmers' practices.

##### **4.2.11.2 Bio-intensive insect management in brinjal**

**AAU-A:** Among the three modules evaluated for the management of shoot and fruit borer in Brinjal, lowest shoot damage was recorded in in chemical module (2.85%) followed by BIPM module (3.65 %), whereas the untreated control module recorded the highest shoot damage (8.47%). Similarly, the chemical module witnessed lowest fruit damage (3.11 % on number basis, 3.61 % on weight basis) than the BIPM module (4.32% on number basis, 5.47% on weight basis). The fruit yield of both the modules *viz.*, chemical module (515.72 q/ha) and BIPM module (499.13 q/ha) found statistically at par with each other.

**KAU Thrissur:** Plots treated with insecticides were significantly superior to other treatments with the lowest mean fruit damage of 31.51 per cent. The BIPM plots recorded a mean of 40.05 per cent fruit damage, which however was significantly superior to the mean damage of 58.51 per cent in control plots. The BIPM and chemical treated plots recorded economic yields of 21.24 and 14.98q/ha respectively, which were on par with each other. Significantly lower yield of 6.54 q/ha was recorded in untreated plots

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

**IIHR:** The mean number of ash weevils per plant were significantly lower in treatments *Heterorhabditis indica* @ 2.5 10<sup>9</sup> IJs ha<sup>-1</sup> and *M. anisopliae* NBAIR followed by *B. bassiana* NBAIR and *B. bassiana* AAU strains. Similarly, the leaf damage scoring by ash weevil in different treatments were recorded. The *B. bassiana* NBAIR and *M. anisopliae* AAU strains were showing significantly lower leaf damage scoring compared to other treatments.

#### **4.2.11.4 Evaluation of biointensive IPM module against key pests of okra.**

**AAU-J:** The results indicated a significant difference between BIPM package and chemical control plot with regard to the parameters viz., mean number of sucking pests /leaf, number of larvae/5 plants and per cent fruit damage after treatment. In chemical control plot, six numbers of alternate spray of insecticides at fortnightly intervals contributed maximum protection from infestation of larvae per five plant and per cent fruit damage of 1.62 and 7.27 %, respectively as against 1.98 and 8.06 % in BIPM plot. However, highest marketable fruit yield of 75.75 q/ha was recorded in BIPM plot, whereas in chemical control plot, the yield was 68.75 q/ha. The per cent parasitisation on *Corcyra* sentinel cards by *Trichogrammatids* species in BIPM plot was 7.4 per cent as against 2.8% in chemical control plot.

#### **4.2.11.5 Efficacy biocontrol agents for management of fruit borer, *Earias vittella* on bhendi**

**IIVR:** Amongst the tested biopesticides, spraying of *Bacillus thuringiensis* @ 1 kg/ha was found most promising against okra fruit borer with maximum (62.93) per cent reduction over control (PROC). For okra jassids spraying of *Metarhizium anisopliae* (NBAIR) 1×10<sup>8</sup> spores/ g @ 5 g/lit and Azadirachtin 1500 ppm @ 2 ml/lit were found superior with 50.63 and 47.28 PROC, respectively, over other biopesticides and untreated control. However, in case of whitefly (*Bemisia tabaci*), Azadirachtin 1500 ppm @ 2 ml/lit was found most effective followed by *Metarhizium anisopliae* (NBAIR) 1×10<sup>8</sup> spores/ g @ 5 g/lit.

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

**IIVR:** Among the biopesticides tested, *Metarhizium anisopliae* (Ma-4 strain) was most promising with 56.08 per cent reduction over control (PROC) against diamond back moth followed by *Lecanicillium lecanii* (VI-8 strain). In case of aphid maximum reduction (49.45 PROC) was recorded with *Lecanicillium lecanii* (VI-8 strain) which is statistically superior over the other biopesticides followed by *Beauveria bassiana* (Bb-45 strain) with 46.92 PROC.

**AAU-J:** The result showed that, among the different biopesticides *L. lecanii* (VI-8 isolate) @ 5 ml/litre was the best treatment in reducing the mean population of aphid, *B. brassicae* (3.20/plant) and *P. xylostella* ( 4.15/plant), with 66.14 and 57.65 per cent reduction over control followed by the next best treatment of ICAR- NBAIR strains of *B. bassiana* (Bb-45 isolate)

with 64.02 and 51.02 per cent reduction over control of aphid (3.40/plant) and DBM (4.80/plant), respectively. In case of yield, maximum of 214.50 q/ha was obtained in *L. lecanii* (VI-8 isolate) treated plot.

**CAU Pasighat:** Among the different biopesticides evaluated, T4-VI-8 isolate of *Lecanicillium lecanii* was found promising in getting higher cabbage yield (22.19 t/ha), followed by T2 – Bb-45 isolate of *Beauveria bassiana* (20.30 t/ha). The highest (24.68 t/ha) and lowest (15.09 t/ha) cabbage head yield was respectively recorded in recommended Insecticide application and untreated control.

**MPKV:** The next best treatment after four sprays of Cyntraniliprole 10.26% OD @ 1.50 ml per litre was Bb-5a isolate of *Beauveria bassiana* @ 5.00gm per liter of water which recorded population of aphids (74.92 aphids /plant) and that of DBM (1.04 larvae /plant) with cabbage yield of 108.60 q/ha. It was followed by the treatment with Ma-4 isolate of *Metarhizium anisopliae* @ 5.00 gm per litre of water with aphids population of 72.04 aphids /plant and 1.45 DBM larvae /plant and recorded yield of 106.80 q/ha.

#### **4.2.11.7 Management of hoppers, aphids and Whitefly on Okra by oil based formulation of *Metarhizium anisopliae* (IIHR Strain)**

**IIHR:** The results reveal that there was no significant reduction in the population of leafhoppers among the different doses of *M. anisopliae* after 3 sprays.

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

**KAU Kumaralom:** After third spraying, Ma – 4 isolate of *M. anisopliae* and VI – 8 isolate of *L. lecanii* were able to produce significant reduction in mite attack on both 5th and 9th days after spray, where both these treatments were found on par. These two bioagents were found to be the best after the chemical check, which was noticed with the highest per cent reduction in pest attack after each of the spray.

#### **4.2.11.9 Evaluation of BIPM against fruit flies *Deccaus bactrocera* sp. in cucumber**

**AAU-J:** It was observed that the BIPM package revealed minimum per cent damaged fruits (16.36%) which was significantly different from chemical control where the per cent damaged fruit was 28.37% after 65 Days after treatment (DAT). The marketable fruit yield was also significantly different in case of BIPM package with that of conventional practices where 86.89 q/ha yield was recorded in BIPM package as against 59.00 q/ha in conventional package. The

maximum damaged fruits (35.46 %) caused by *Deccaus bactrocera* was recorded in untreated control plot with minimum yield of 44.82 q/ha.

#### **4.2.11.10 Management of *Fusarium* wilt in vegetable cowpea using microbial agents**

**COA Vellayani:** The results revealed that the incidence was least in plots treated with *Pseudomonas fluorescence* foliar + *Trichoderma* basal application. Incidence was also found to be reduced in plots treated with *Peudomonas* alone.

#### **4.2.11.11 Efficacy of different biocontrol agents against onion thrips, *Thrips tabaci* L.**

**AAU-A:** Among the different biopesticides evaluated, T<sub>3</sub> – *Metarhizium anisopliae* AAU strain Ma1 (3.70 thrips/plant) was the first effective treatment with lowest number of thrips/plant followed by T<sub>6</sub> – Azadirachtin10000 ppm (4.98 thrips/ plant). The untreated control treatment recorded the highest thrips population of 15.02 thrips/ plant. The efficacy of biopesticide treatments in reducing the thrips population was depicted in bulb yield of onion. Among the different biopesticides evaluated, T<sub>3</sub> – *Metarhizium anisopliae* AAU strain Ma1 was found promising in getting higher bulb yield (113.67 q/ha), followed by T<sub>6</sub> – Azadirachtin10000 ppm(108.33 q/ha) which were at par with each other.

#### **4.2.12 Biological suppression of oilseed crop pests**

##### **4.2.12.1 Field evaluation of bio-pesticides against mustard aphid**

**UBKV:** Among the tested fungal bio-pesticides, *Beauveria bassiana* (NBAIR strain Bb-5a) reduced the aphid population better. However, best mustard aphid management was noticed in the plots treated with Imidacloprid 17.8 SL in all spraying.

#### **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 palleescens* under polyhouse condition**

**KAU Thrissur:** The mite population in plots where *B. palleescens* were released at 20/m row was also significantly lower than that of control plots, indicating the potential of the predator to be a safer alternative to synthetic acaricides in managing spider mites in cucumber under polyhouse conditions. Acaricide treated plots recorded a mean yield of 22.01 kg/plot, which was on par with plots that of *B. palleescens* @ 20 m/row. (17.6 kg/plot). The yield results confirm the potential of anthocorid predator in polyhouse conditions.

#### 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 *Lecanicillium lecanii* (NBAIR V18) @ 5g/L was significant efficacy against aphids on capsicum under polyhouse conditions.

#### 4.2.13.3 Field efficacy of some bio pesticides against two spotted spider mite, *Tetranychus urticae* in carnation

**SKAUST Srinagar:** Cumulative mean population of mites on leaves was found to be minimum (3.85-leaf) when treated with two sprays of Propargite 57 % EC @ 2.0 ml-l followed by *Lecanicillium lecanii* (1x10<sup>8</sup> CFU/ml) @ 5.0 ml-l + Nimbecidine 0.03% @ 5 ml-l > *L. lecanii* (1x10<sup>8</sup> CFU/ml) @ 5.0 ml-l > Nimbecidine 0.03% @ 5.0 ml-l > untreated check. All the treatments were found superior over untreated check and statistically significant. At the end of experiment, lowest number of cumulative mean population of mites<sup>-flower bud</sup> (11.1) was observed in case of treatment with Propargite 57 % EC @ 2.0 ml<sup>-1</sup> which was followed by *L. lecanii* (1x10<sup>8</sup> CFU/ml) @ 5.0 ml<sup>-1</sup> + Nimbecidine 0.03% @ 5.0 ml<sup>-1</sup> > *L. lecanii* (1x10<sup>8</sup> CFU/ml) @ 5.0 ml<sup>-1</sup> > Nimbecidine 0.03% @ 5.0 ml<sup>-1</sup> > untreated check.

#### 4.2.13.4 Management of phytophagous mites on cucumber using *Blaptostethus pallescens* and *Neoseiulus longispinosus* under polyhouse condition

**YSPUH&F:** The mite population in treated plots decreased gradually and was 1.7, 1.4, 1.6, 1.1 and 0.6 mites in plants treated with *B. pallescens* (10nymphs/m row), *B. pallescens* (20nymphs/m row), *N. longispinosus* (1:30), *N. longispinosus* (1:20) and spiromesifen (100g a.i./ha), respectively after 14 days of the second treatment. The highest yield (6.3kg/plant) was recorded in plants treated with spiromesifen (100g a.i./ha) followed by *N. longispinosus* (1:20), *N. longispinosus* (1:30), *B. pallescens* (20nymphs/m row) and *B. pallescens* (10nymphs/m row).

#### 4.2.14 Large scale adoption of proven biocontrol technologies

##### 4.2.14.1 Rice

**GBPUAT:** Large scale field demonstrations of bio-control technologies were conducted at the end of 40 farmers of 10 villages of Haldwani block, District Nainital, covering an area of 100 ha (250 acre). An average yield of 71.0 q/ha was recorded by the farmers adopting bio-control technologies along with need based organic practices as compared to an yield of 58.0 q/ha by the farmers adopting conventional practices. Through the adoption of biocontrol practices, the cost benefit ratio was 1:2.25 as compared to 1:1.36 where farmers used conventional practices.

**AAU-J:** Large scale field demonstrations of bio-control technologies were conducted over 50 ha area at Chowdungpothar, Golaghat district and Rajabahar, Jorhat district. Mean per cent dead heart of 2 locations was 2.92 and 2.82 in respect of BIPM and farmers practice, respectively at 65 DAT. The mean per cent damaged leaves observed 9.51 in BIPM plot whereas it was 3.30 in farmers practice plot at 65 DAT. The mean yield of 4851.05 kg/ha in BIPM plots was significantly superior to farmers practice plot with 4667.45 kg/ha. The net return over chemical control in BIPM package was Rs. 96,319.3 as compared to 88,158.3 in farmers practice plot with a cost: benefit ratio of 1: 3.85 and 1: 3.09, respectively.

**IIR:** Demonstration was carried out over 4 ha area. The leaf folder incidence was lowest in the BIPM module with *Trichoderma* seed treatment (9.61 %) while the highest incidence was observed in untreated control (23.15 %). The number of spiders observed per five hills was highest in untreated control (9.00). Due to heavy rainfall natural zoonosis of leaf folder larvae was observed this year with highest number of diseases larvae being observed in untreated control (15.25/ 5 hills). The yield was highest in *Pseudomonas* and *Bacillus* treatments (8275 and 8475 kg/ha respectively) indicating the economic feasibility of these modules.

**KAU Thrissur:** Large scale validation of BIPM in rice was carried out over an area of 200 ha in Alathur Grama Panchayat of Palakkad district from November 2020 to March 2021. The dead heart as well as white ear head symptoms in BIPM plots were approximately 85 per cent lower than in non BIPM plots. Similarly, leaf folder damage was approximately 25 per cent lower than in 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, at 6939 kg/ha was approximately 22 per cent more than that obtained from non BIPM plots (5400 kg/ha). The cost of cultivation also was nearly three per cent lower in the former. The increased yield as well as reduced cost resulted in an increase in profit by Rs 44,951/ha. The cost benefit ratio, at 1.70 for BIPM fields compared quite favorably with 1.05 for non BIPM fields.

**OUAT:** Large scale demonstration was carried over 5 ha area. The silver shoot(SS), dead heart (DH), white ear head (WEH) and leaf folder (LF), incidence in BIPM demonstrated plots were 2.40, 4.32, 3.20 and 4.18%, respectively as compared to 3.12, 3.90, 2.56 and 3.90% infestation in farmers practice (FP) with the use of chemical pesticides. Significantly higher SS (4.84%), DH (9.76%), WEH (10.76%) and LF (10.84%) infestation was noticed in untreated control. The yield (39.48 q/ha) in BIPM package was at par with FP. The benefit cost ratio in BIPM treated plots was found (1.38) as against 1.40 and 1.09 in FP and untreated control, respectively.

**PAU:** Large scale demonstrations of biocontrol based IPM (5-6 releases of *T. chilonis* and *T. japonicum* each @ 1,00,000/ha) conducted at farmers' fields in organic *basmati* rice over an area of 310 acres rendered lower incidence of dead hearts in biocontrol fields (1.91%) as against untreated control (4.10%) resulting in a reduction of 53.3 per cent. Similarly, leaf folder damage in release field was significantly lower in biocontrol fields (1.69%) as compared to untreated control (4.15%) with a mean reduction of 58.55 per cent. The mean incidence of white ears was significantly lower in biocontrol field (2.41%) as against untreated control (4.86%) resulting in a reduction of 50.4 per cent. The additional benefit in biocontrol practices was Rs 7070/- per ha over untreated control.

#### 4.2.14.2 Chickpea

**UAS Raichur:** One day before spray, larval population ranged from 3.32 to 3.48 per plant among treatments. Seven days after treatment imposition lowest of 0.58 larva per plant was noticed in FP followed by *HaNPV* (1.06 larvae/plant). Farmers practice recorded lowest pod damage (6.38%) followed by *HaNPV* (12.46 %). Highest grain yield of 14.18q/ha was recorded in FP followed by *HaNPV* (12.44 q/ha) while untreated control recorded 10.24 q/ha

#### 4.2.14.3 Pigeon pea

**AAU-A:** The efficacy of *Trichoderma harzianum* as promising biopesticide in minimizing the disease incidence with higher yield in pigeon pea crop has been demonstrated. The BIPM module recorded the significant lowest wilt incidence (6.05 %) in comparison to farmers' practice (7.45 %). Similar trend was observed in yield of the crop. The significant highest yield was recorded in BIPM module (13.70 q/ha). The untreated control treatment witnessed the highest disease incidence (16.81 %) with lowest yield (7.40 q/ha).

#### 4.2.14.4 Okra

**AAU-A:** Between the two modules demonstrated for bio-intensive pest management in okra, the lowest larval population was recorded in chemical module (*H. armigera* - 0.86/ plant, *E. vittella* - 2.88/plant) and it was found at par with the population documented in BIPM module (*H. armigera* – 1.21 larvae/plant, *E. vittella* – 3.82/plant). Whereas, the fruit damage was significantly lower in BIPM module (3.08 % - number basis, 3.51 %– weight basis) as compared to chemical module (4.94% - number basis, 4.88 %– weight basis). The BIPM module recorded the significantly higher yield (136.36 q/ha) as compared to chemical module (111.21 q/ha).

#### 4.2.14.5 Tomato (hybrid)

**GBPUAT:** Field demonstrations were laid at 30 farmers field at village Devela Malla, Haldwani, District Nainital covering an area of about 22 ha. The interventions were as i) Soil solarization of nursery beds, ii) Soil application with FYM/vermicompost colonized with Pant bioagent-3 (PBAT-3), iii) Seed bio-priming by PBAT-3 @10 g/kg seed, iv) Seedling dip treatment @10g/lit. water followed by three foliar sprays of PBAT-3 (10g/lit. water) after 15 days interval. Occurrence of fungal and bacterial diseases was very low.

**CAU:** Field demonstrations was conducted covering 2 ha area at Jampani village, East Siang district, Arunachal Pradesh. The BIPM module recorded the significantly lowest pest population of *H. armigera* (1.54 larvae/plant) and sucking pests (whiteflies and leaf hoppers) (7.70/plant) than that of chemical module (*H. armigera*–0.98 larvae/plant, Sucking pests–4.61/plant). Whereas, the fruit damage was significantly lower in BIPM module (7.43 %) as compared to chemical module (9.47 %). The BIPM module recorded the significantly higher yield (22.80 t/ha) as compared to chemical module (20.43 q/ha).

**MPUAT:** Demonstration was carried out over 2 ha area. No significant difference was observed between BIPM package and chemical control with regard to the parameters *viz.*, number of *H. armigera* larvae/plant and fruit damage. BIPM package was equally effective as chemical control against *H. armigera*. Chemical control module recorded the highest yield (14.35 t/ha) which was at par with the yield recorded in BIPM package (12.80 t/ha). Significantly, low yield

was recorded in untreated control (8.20 t/ha). It could be concluded that BIPM package had promising results in minimizing the pest damage with higher yield.

#### 4.2.14.6 Cabbage

**AAU-A:** Between the two modules demonstrated for bio-intensive pest management in cabbage, the chemical module documented the lowest population of DBM (2.83/ plant) and aphid (18.92/ plant), it was found statistically at par with the pest population recorded in BIPM module (DBM – 3.08/plant, aphid – 21.94/ plant). Further, BIPM module recorded the significantly higher fruit damage (4.25 %) as compared to chemical module (3.00 %). Due to significant low fruit damage in chemical module, it recorded the highest yield (28 t/ha) which was significantly higher than the yield of BIPM module (25.01 t/ha). With respect to the population of natural enemies, BIPM module witnessed highest natural enemies (3.41/ plant) which were significantly higher than the population observed in chemical module (0.82/plant).

#### 4.2.14.7 Mustard

**CAU:** Large scale demonstration trial covering 4 ha area at Yagrung Todeng village, East Siang district, Arunachal Pradesh revealed the efficacy of BIPM module in reducing the pest population in comparison to farmers practice is presented. The farmers' module documented the highest population of aphid (41.92/plant), it was found statistically significant with the pest population recorded in BIPM module (25.12 aphids/plant). Although, the farmers practice recorded the higher number of natural enemies (coccinellid beetles and syrphid flies) *i.e.* 5.47 per plant, it was found statistically at par with those recorded in BIPM module (4.11/plant). Due to higher pest incidence in farmers practice and no externally added agro inputs, it was recorded with the lowest yield (6.44 q/ha) significantly lower than that of BIPM module (9.36 q/ha).

#### 4.2.14.8 Maize

**CAU:** large scale demonstration was conducted over 4 ha area. The BIPM module (3.40/plant) documented the significantly higher natural enemies (coccinellids, lacewing flies and spiders) than chemical module (0.98/plant). In spite of higher FAW incidence, the BIPM module recorded the grain yield of 36.15 q per ha which was statistically at par with farmers practice (35.45 q/ha).

**PAU:** Large-scale demonstrations using *T. chilonis* against maize stem borer, *Chilo partellus* were carried out at farmer's fields on an area of 60 acres in Hoshiarpur, Jalandhar, SBS Nagar and Gurdaspur districts of Punjab in collaboration with Krishi Vigyan Kendras and Farm Advisory Service Centres. Two releases of *T. chilonis* @ 1,00,000/ ha at 10 and 17 days old crop resulted in 55.1 per cent reduction in dead hearts incidence over control as compared to 84.1 in chemical control. The additional benefit over untreated control in biocontrol package was Rs 6160/- per ha as compared to Rs 11368/- per ha in chemical control.

#### 4.2.14.9 Apple

**DYSPUHF:** A large scale demonstration on the management of apple root borer, *Dorystenes hugelii* by using *Metarhizium anisopliae* was laid in apple (cv Royal Delicious) in 13 orchards in Shimla, Sirmaur and Kinnaur districts covering an area of 5ha. *Metarhizium anisopliae*

treatment resulted in 68.6 to 83.1 per cent mortality of the apple root borer grubs in different orchards, while in chlorpyrifos (0.06%) treated plants the grub mortality was 79.4 to 87.3 per cent.

#### 4.2.14.10 Sugarcane

**OUAT:** Demonstration was carried over 5 ha area. Maximum infestation due to early shoot borer (ESB), and top shoot borer (TSB) in BIPM package were 10.4% and 1.94% as against 10.7% and 2.18% in FP indicating comparable level of infestation. But, much higher levels of infestation due to ESB (11.5%) and TSB (3.46%) were recorded in untreated control. Highest cane yield (75.04 t/ha) and B: C ratio (1.72) were recorded in BIPM package which is comparable to FP (72.60/ha). Lowest yield (60.47 t/ha) and B: C ratio (1.38) were noted in untreated control.

**PAU:** Large-scale demonstrations on the effectiveness of *Trichogramma* @ 50,000 per ha at 10 days interval (10-12 releases) over an area of 5010 acres conducted at farmers' fields in collaboration with Krishi Vigyan Kendras (KVKs), Regional Station (Gurdaspur) and four sugar mills of the state reduced the incidence of stalk borer, *Chilo auricilius* by 56.9 per cent over untreated control with higher additional returns of Rs. 16730/- per ha.

**UAS Raichur:** Demonstration was carried over 10 ha area. Before treatment imposition dead hearts ranged from 17.50 to 18.75 per cent. Two months after treatment imposition minimum of 1.25 per cent dead hearts were noticed in farmers practice which was followed by release of *T. chilonis* (TTS) recorded 1.85 per cent while untreated control recorded 6.50 per cent dead hearts. The highest cane yield of 138.25 t/ha was recorded in farmers practice and it was followed by *T. chilonis* (TTS) release plot 138.25 t/ha while untreated control recorded 123.14 t/ha.

#### **Soybean:**

**UAS Raichur:** Demonstration was carried over 50 ha area. A day before treatment imposition the defoliator larval population ranged from 5.06 to 5.18 per meter row length. On seven days after spray, *M. rileyi* (KK-Nr-1)  $1 \times 10^8$  spores/g @ 5.0 g/l recorded 2.36 larvae per mrl and it was significant over untreated control (5.18 larvae/mrl). Similar trend was noticed at ten days after spray. *M. rileyi* (KK-Nr-1)  $1 \times 10^8$  spores/g @ 5.0 g/l recorded 11.34 per cent foliage damage while untreated control recorded 28.36 per cent. *M. rileyi* (KK-Nr-1)  $1 \times 10^8$  spores/g @ 5.0 g/l recorded 15.82 q/ha grain yield which was superior over untreated control which recorded 11.94 q/ha grain yield.

#### 4.2.14.11 Pea (var. Pant sabji matar 3)

**GBPUAT:** Large scale field demonstrations of bio-control technologies on pea were conducted at 35 different farmers of Haldwani block of district Nainital covering an area of 25 acre during Rabi season. Seed treatment with bio-agents resulted in considerably higher germination upto 10.0 per cent more than the conventional practices. There was no disease incidence in the crop. An average green pod yield of 70.0 q/ha was recorded with bio-control technologies as compared to 55.0 q/ha with conventional farmers practices.

#### **4.2.15 Tribal Sub plan programme (TSP)**

**GBPUAT:** Demonstrations on bio-control technologies were conducted amongst tribes in district Udham Singh Nagar in Uttarakhand State at Bajpur block in two villages namely, Vijaympura and Sheetpuri covering 200 farmers (with average land holding 0.5-20 acre). Seeds of coriander, spinach, pea, Fenugreek were distributed among 1000 farmers. Trainings on organic cultivation were given to 1325 farmers.

**AAU-A:** In the year 2020-21, 125 tribal farmers were selected from Dediapada, Nanded and Garudeshwartalukas of Narmada district. In association with KrishiVigyan Kendra (KVK), Dediapada, Navsari Agricultural University, khedutshibir and training programmes were organized in the month of September 2020 and March 2021 to train the farmers on use of biocontrol inputs and strategies to tackle key pests and diseases to achieve sustainable crop production. Biocontrol inputs were distributed to the farmers. Significant reduction (25-30%) in use of chemical pesticides was documented with the use of bio-inputs provided.

**AAU-J:** A total of 200 farmers from four villages (Sekuria, Neulgaon, Dangdhora and Solguri ) of Jorhat district have been selected under the programme.

**ANGRAU:** During 2020-21, Conducted awareness programme on organic farming in vegetables at Kothapalli, Chinthpalli mandal on 10.12.2020; at Kollaput, Dumbriguda mandal ,araku valley on 17.12.2020. Conducted Training programme on Bee keeping at Kollaput on 17.12.2020 at Kollaput, Dumbriguda and established established Ecovibes Apiary unit for empowering Arakuvalley tribal women with apiary units-10 No. and issued to a group of 8 women farmers. ICAR-Tribal sub plan programme created awareness on Biological control in organic cultivation by 52 tribal farmers of 4 hamlet villages in Araku valley and chinthapalli.

**CAU:** Materials (Talc based formulations of *Metarhizium anisopliae*, *Beauveria bassiana*) were distributed among 180 farmers.

**YSPUH&F:** Demonstrated the use of *Metarhizium anisopliae*, *Beauveria bassiana*, *Trichoderma* and azadirachtin for the management of insect pests and diseases in apple and vegetable crops to 40 farmers.

**IGKV:** Three tribal centres were chosen for conducting trainings five trainings to 100 farmers. These centres were, Kondagaon, Ambagarh Chowki and Jagdalpur (Bastar).

**KAU Thrissur:** Vegetable seeds (cowpea, brinjal, amaranth, chilli, bitter gourd and bhindi) and bioagents were provided to 41 farmers (121 family members) in the Kallichithra colony of Thrissur district. Training programme was also conducted for the farmers on proper use of biocontrol agents in organic vegetable cultivation.

**UBKV:** Training programme on proper cultivation techniques of mustard was given and all essential inputs for cultivation were distributed among 155 tribal farmers. The seed yield ranged from 50-70kg/bigha. Harvested mustard seeds were used by the tribal community mainly for oil extraction and also for domestic consumption. 30% increase in yield was observed.

**SKAUST Srinagar:** Inputs in kinds were given to seventy five farmers belonging to 28 villages of subdivision Kargil. They were sensitized on integrated management of apple fruit borers.

**5. Publications:** During the year 2020-21, a total of 312 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	27	40	17	84
AAU, Anand	6	34	6	46
AAU, Jorhat	9	12	13	34
ANGRAU	2	5	-	7
KAU, Thrissur	-	6	-	6
KAU, Vellayani	3	-	3	6
MPKV, Pune	1	-	-	1
MPUAT, Udaipur	1	-	2	3
PAU, Ludhiana	7	2	8	17
UAS Raichur	3	-	2	5
TNAU, Coimbatore	9	-	-	9
SKUAST, Srinagar	6	2	1	9
SKAUST Jammu	6	2	-	8
DRYSRUH	5	-	-	5
YSPUHF, Solan	10	6	2	18
IGKV	10	5	3	18
CPCRI	5	2	6	13
UBKV	1	3	-	4
PJTSAU	5	-	1	6
CPCRI	5	2	6	13
<b>Total</b>	<b>121</b>	<b>121</b>	<b>70</b>	<b>312</b>

## 6. Profile of experiments and demonstrations carried out during 2020-21

<b>Crop/Insect</b>	<b>Experiments</b>	<b>Large Scale Demonstrations</b>
Biodiversity of biocontrol agents	4	-
Antagonists of crop disease management	16	-
Sugarcane	3	4
Cotton	3	-
Rice	5	7
Cereals	8	2
Plantation crops	3	2
Pulses	5	2
Oilseeds	2	2
Tropical and temperate fruits	11	2
Vegetables	11	6
Polyhouse crops	4	-
TSP	12	-
<b>Total</b>	<b>87</b>	<b>27</b>

## 7. Budget of AICRP on Bio control for 2020-21

<b>Item of Expenditure</b>	<b>Sanctioned and allotted grants (Rs. in lakh)</b>	<b>Grants released during 2020-21 from ICAR (Rs. in lakh)</b>	<b>Total expenditure (Rs.)</b>
Pay and allowances	205.81	205.81	205.81
Rec. Contingencies	318.35	318.35	318.35
T.A	50.65	50.65	50.65
<b>TOTAL</b>	<b>574.81</b>	<b>574.81</b>	<b>574.81</b>

## 8. Experiments conducted by centres

<b>Experiment allotted</b>	<b>Centres identified</b>	<b>Centres conducted the experiment</b>
Biodiversity of biocontrol agents from various agro-ecological zones	All Centres	All Centres
Surveillance for pest outbreak and alien invasive pests	All Centres	All Centres
Evaluation of fungal and bacterial isolates for crop health management in rice	GBPUA&T	GBPUA&T
The bio-control efficacy of identified biocontrol agents towards rice sheath blight ( <i>Rhizoctonia</i>	ICAR-NRRI, Cuttack	ICAR-NRRI, Cuttack

<i>solani</i> ) disease under potted plants		
Management of major diseases of rice with <i>Bacillus subtilis</i>	TNAU, Coimbatore	TNAU, Coimbatore
Field evaluation of ICAR-NBAIR antagonistic organisms against wheat yellow rust ( <i>Puccinia striiformis</i> f. sp. <i>tritici</i> )	SKUAST, Jammu	SKUAST, Jammu
Field evaluation of ICAR-NBAIR antagonistic organisms against Maize Turcicum leaf blight ( <i>Exserohilum turcicum</i> )	SKUAST, Jammu	SKUAST, Jammu
Demonstration of <i>Trichoderma</i> sp. for the management of <i>Fusarium</i> wilt in pigeon pea	AAU, Anand	AAU, Anand
Title : Management of Fusarium wilt in vegetable cowpea using microbial agents	KAU, vellayani	KAU, vellayani
Evaluation of bio-agent consortium in glasshouse (pot experiments) and in field for crop health management in chickpea	GBPUAT, Pantnagar	GBPUAT, Pantnagar
Field evaluation of ICAR-NBAIR antagonistic organisms against Chickpea Fusarium wilt ( <i>Fusarium oxysporum</i> f. sp. <i>ciceris</i> )	SKUAST, Jammu	SKUAST, Jammu
Field evaluation of ICAR-NBAIR antagonistic organisms against Mustard White rust ( <i>Albugo candida</i> )	SKUAST, Jammu	SKUAST, Jammu
Ecofriendly management of stem rot, <i>Macrophomina phaseolina</i> in sesame using biocontrol agents	ANGRAU at RARS, Anakapalle	ANGRAU at RARS, Anakapalle
Evaluation of bio-agents against root-knot nematode and Fusarium wilt complex in guava under controlled conditions	CISH, Lucknow	CISH, Lucknow
Evaluation of microbial antagonists for the management of foot rot of citrus (kinnow) caused by Phytophthora spp.	PAU, LUDHIANA	PAU, LUDHIANA
Management of Powdery mildew ( <i>Uncinula necator</i> ) of Grape by using biocontrol agents	MPKV, Pune	MPKV, Pune
Bio-efficacy of different bio-agents against the	AAU, Anand	AAU, Anand

early blight of tomato		
Screening of promising isolates antagonistic fungi and bacteria against bacterial wilt of Tomato ( <i>Ralstonia solanacearum</i> )	RARS, kumarakom	RARS, kumarakom
Bio-efficacy of different bio-agents against the early blight of potato	AAU, Anand	AAU, Anand
Field evaluation of ICAR-NBAIR antagonistic organisms against Pea Rust ( <i>Uromyces fabae</i> )	SKUAST, Jammu	SKUAST, Jammu
Management of Fusarium wilt/ root rot of pea through biological control agents	Dr YS PUHF, Solan	Dr YS PUHF, Solan
Efficacy of Mechanized sett treatment with antagonistic microbes, fungicide and their integration against red rot in sugarcane	SBI, Coimbatore	SBI, Coimbatore
In vivo evaluation of effective bio control agents against Phytophthora Pod rot management in cocoa	DRYSRHU, AMBAJIPETA, A.P	DRYSRHU, AMBAJIPETA, A.P
Management of <i>Phytophthora</i> disease in black pepper nursery using biocontrol agents	KAU, Thrissur	KAU, Thrissur
Field evaluation of ICAR-NBAIR entomopathogenic strains against Rice stem borer ( <i>Scirpophaga incertulas</i> ), leaf folder ( <i>Cnaphalocrocis medinalis</i> ), Brown planthopper ( <i>Nilaparvata lugens</i> )	ICAR-NRRI, Cuttack	ICAR-NRRI, Cuttack
Management of rice stem borer and leaf-folder using entomopathogenic nematodes and entomopathogenic fungi	KAU, Thrissur	KAU, Thrissur
Large scale bio-intensive pest management on rice	PAU, KAU-Vellayani, KAU-Thrissur, AAU-J, OUAT, IGKV	PAU, KAU-Vellayani, KAU-Thrissur, AAU-J, OUAT, IGKV
Large scale demonstrations on bio-intensive pest management in organic <i>basmati</i> rice	PAU, Ludhiana	PAU, Ludhiana
Management of rice stem borer and leaf-folder using entomopathogenic microorganisms	KAU, Thrissur	KAU, Thrissur

Enabling large scale adoption of proven bio control technologies	AAU, Jorhat	AAU, Jorhat
Large scale bio-intensive pest management in rice	OUAT, Bhubaneswar	OUAT, Bhubaneswar
Large scale bio-intensive pest management on rice	ICAR-IIRR, Hyderabad	ICAR-IIRR, Hyderabad
Biointensive pest management in rice	KAU-Vellayani	KAU-Vellayani
Validation of BIPM practices against pest complex of organic Black rice	AAU-Jorhat	AAU-Jorhat
Comparative efficacy of entomopathogenic fungi against sucking pests of rice, <i>Leptocorisa acuta</i>	ICAR-IIRR, Hyderabad	ICAR-IIRR, Hyderabad
Laboratory bioassay of <i>Metarhizium rileyi</i> (Anakapalle strain AKP-Nr-1) against Fall armyworm, <i>Spodoptera frugiperda</i>	ANGRAU-Anakapalle	ANGRAU-Anakapalle
Field efficacy of <i>Metarhizium rileyi</i> (Anakapalle strain AKP-Nr-1) against fall armyworm, <i>Spodoptera frugiperda</i> in maize	ANGRAU, Anakapalle; UAS, Raichur	ANGRAU, Anakapalle; UAS, Raichur
Evaluation of entomopathogenic fungi and <i>Bt</i> against maize stem borer	PAU, Ludhiana	PAU, Ludhiana
Biological control of maize stem borer, <i>Chilo partellus</i> using <i>Trichogramma chilonis</i>	PAU, Ludhiana; MPUAT, Udaipur	PAU, Ludhiana; MPUAT Udaipur
Biological Control of Maize Stem Borer, <i>Chilo partellus</i> using <i>Trichogramma chilonis</i> .	MPUAT, Udaipur	MPUAT, Udaipur
Bio-ecological engineering for the management of major insect pests of maize and benefit of their natural enemies	SKSUAT-Jammu	SKSUAT-Jammu
Demonstration of BIPM module against fall army worm, <i>Spodoptera frugiperda</i> on rabi maize	AAU, Jorhat	AAU, Jorhat
Field trial against Fall armyworm in maize at AICRP-BC centres	IIMR, Maize Hyderabad, PAU, PJTSAU, AAU-Anand, OUAT, MPKV, CAU and TNAU	IIMR, Maize Hyderabad, PAU, PJTSAU, AAU-Anand, OUAT, MPKV, CAU and TNAU

Large scale demonstration of proven biocontrol technologies against maize stem borer, <i>Chilo partellus</i> using <i>Trichogramma chilonis</i>	PAU, Ludhiana	PAU, Ludhiana
Field trial against fall armyworm in maize	PJTSAU, Hyderabad	PJTSAU, Hyderabad
Field trial against Fall Armyworm in <i>Rabi</i> maize	OUAT, Bhubaneswar	OUAT, Bhubaneswar
Field trial against Fall Armyworm in maize	CAU, Imphal	CAU, Imphal
Biological suppression of fall armyworm, <i>Spodoptera frugiperda</i> (J. E. Smith) (Lepidoptera: Noctuidae) in maize	AAU-Anand	AAU-Anand
Trial on maize fall army worm	TNAU, Coimbatore	TNAU, Coimbatore
Evaluation of BIPM module for fall armyworm, <i>Spodoptera frugiperda</i> in maize ecosystem	UAS, Raichur	UAS, Raichur
Large scale demonstration of management of fall armyworm using biological control agents and biopesticides	ANGRAU, Anakapalle	ANGRAU, Anakapalle
Evaluation of BIPM module for fall armyworm, <i>Spodoptera frugiperda</i> in maize ecosystem	MPKV, Pune	MPKV, Pune
Evaluation of NIPHM white media for production of <i>Nomuraea rileyi</i> ( <i>Metarhizium rileyi</i> ) NIPHM MRF-1 strain for management of maize fall armyworm ( <i>Spodoptera frugiperda</i> )	NIPHM, Hyderabad	NIPHM, Hyderabad
Evaluation of entomopathogenic fungi formulations against millet borers in finger millet, kharif2020	IIMR, Hyderabad	IIMR, Hyderabad
Integration of botanicals, microbials and insecticide spray schedule for the management of pod borer complex in Greengram	ANGRAU, Anakapalle	ANGRAU, Anakapalle
Evaluation of entomopathogenic biopesticide against <i>Aphis craccivora</i> in cowpea ( <i>Vigna unguiculata</i> ).	AAU, Jorhat	AAU, Jorhat
Evaluation of oil formulation of <i>Lecanicillium</i> spp against sucking pests of cowpea	KAU, Vellayani	KAU, Vellayani

Biological suppression of pod borer, <i>Helicoverpa armigera</i> (Hubner) infesting chickpea	MPKV, Pune	MPKV, Pune
BIPM module for management of <i>Helicoverpa armigera</i> on chickpea	PAU, Ludhiana	PAU, Ludhiana
Two BIPM modules were evaluated for the management of <i>Helicoverpa armigera</i>	TNAU, Coimbatore	TNAU, Coimbatore
Large Scale Demonstration of Ha NPV Kalaburgi strain against chickpea pod borer during 2020-21	UAS, Raichur	UAS, Raichur
Habitat manipulation / Bio-ecological engineering for the management of <i>Helicoverpa armigera</i> in chickpea	SKUAST, Jammu	SKUAST, Jammu
Evaluation of Biointensive Integrated Pest Management against pod borer in chickpea In Bundelkhand region	ICAR, NCIPM	ICAR, NCIPM
“Evaluation of NBAIR Bt formulation on pigeon pea against pod borer complex	PDKV, Akola	PDKV, Akola
Evaluation of microbial antagonists for the management of diseases (Powdery mildew/Ascochyta blight/Rust) in pea	PAU, Ludhiana	PAU, Ludhiana
Evaluation of entomofungal agents and botanicals for the management of sucking pests in cotton	MPKV, Pune, PJTSAU, Rajendranagar, UAS, Raichur	MPKV, Pune, PJTSAU, Rajendranagar, UAS, Raichur
Evaluation of entomofungal agents and botanicals for the management of sucking pests in cotton	PJTSAU	PJTSAU
Evaluation of entomopathogenic fungi, Beauveria bassiana (ICAR- NBAIR- Bb-5a) against sucking insect pests of cotton	UAS, Raichur	UAS, Raichur
Biointensive management of pink bollworm in Bt cotton	PJTSAU Hyderabad, TNAU, Coimbatore	PJTSAU, Hyderabad, TNAU, Coimbatore
Field efficacy of EPN strains against white grubs in sugarcane	MPKV Pune	MPKV, Pune
Large scale demonstration of <i>Trichogramma</i>	MPKV Pune, OUAT	MPKV, Pune, OUAT,

species against sugarcane borer	Bhuvaneswar	Bhuvaneswar
Large Scale Demonstration of <i>Trichogramma chilonis</i> (TTS) against sugarcane early shoot borer	UAS, Raichur	UAS, Raichur
Large scale demonstrations of proven biocontrol technologies against sugarcane stalk borer, <i>Chilo auricilius</i>	PAU, Ludhiana	PAU, Ludhiana
Efficacy of <i>Aschersonia placenta</i> for the management of whitefly in sugarcane ecosystem	ICAR, SBI	ICAR, SBI
Efficacy of entomopathogenic fungi for the management of white grub in sugarcane ecosystem	ICAR, SBI	ICAR, SBI
Evaluation of locally isolated potential entomopathogenic fungi, <i>Metarhizium rileyi</i> (KK-Nr-1) against groundnut leaf miner and tobacco caterpillar in ground nut ecosystem	UAS, Raichur	UAS, Raichur
Frontline demonstration on biological control of insect pests of mustard	CAU, Pasighat	CAU, Pasighat
Field evaluation of bio-pesticides against mustard aphid	UBKV, Pundibari	UBKV, Pundibari
Bio-efficacy of entomopathogens against Banana fruit and leaf scarring beetles, <i>Nodostoma subcostatum</i>	AAU, Jorhat	AAU, Jorhat
Monitoring and record of the incidence of papaya mealybug and its natural enemies on papaya and other alternate hosts	AAU, Anand	AAU, Anand
Large scale demonstration on bio-intensive management of mango hopper	AAU, Anand	AAU, Anand
Management studies for inflorescence thrips on mango with bio-pesticides in field conditions.	DRYSRHU, Ambajipeta	DRYSRHU, Ambajipeta
Habitat manipulation for conservation of bio-agents for management of mango insect pests	CISH, Lucknow	CISH, Lucknow
Biological control of guava mealybug using entomopathogens	SKUAST, Jammu	SKUAST, Jammu
Development of biocontrol based IPM module for	CISH, Lucknow	CISH, Lucknow

the management of guava fruit borer.		
Biological control of root-knot nematode in guava	UAHS, Shimogga	UAHS, Shivamogga
Evaluation of entomopathogenic fungi, <i>Beauveria bassiana</i> (ICAR-NBAIR-Bb-5a) against mealy bug in guava ecosystem	UAS, Raichur	UAS, Raichur
Management of apple root borer using <i>Metarhizium anisopliae</i>	Dr YSPUHF, Solan	Dr YSPUHF, Solan
Field evaluation of some bio pesticides against green apple aphid, <i>Aphis pomi</i> and mites infesting apple in Kashmir.	SKUAST, Srinagar	SKUAST, Srinagar
Evaluation of different isolates of entomopathogenic fungi against citrus thrips	Dr. Y.S.R. Horticultural University	Dr. Y.S.R. Horticultural University
Biological control of anola mealy bug using entomopathogens	SKUAST, Jammu	SKUAST, Jammu
Bio-intensive management of litchi fruit borer, <i>Conopomorpha sinensis</i> (Bradley) in litchi	PAU, Ludhiana	PAU, Ludhiana
Surveillance of rugose spiralling whitefly in coconut and population of natural biocontrol agents	ICAR-NBAIR, Bengaluru	ICAR-NBAIR, Bengaluru
Surveillance of Rugose white fly in coconut and population of natural biocontrol agents	KAU, Vellayani	KAU, Vellayani
Surveillance of rugose whitefly <i>Aleurodicus rugioperculatus</i> in coconut and assessing the population of natural bio control agents	DRYSRHU, Ambajipeta	DRYSRHU, Ambajipeta
Surveillance of rugose whitefly in coconut and assessing the population of natural biocontrol agents	KAU, Thrissur	KAU, Thrissur
Surveillance of rugose whitefly in coconut and assessing the population of natural biocontrol agents	RARS, Kumarakum	RARS, Kumarakum
Biological suppression of rugose spiralling whitefly in coconut	RARS, Anakapalle	RARS, Anakapalle
Biological control of rugose spiralling whitefly in	CPCRI,	CPCRI,

coconut	Kayamkulam	Kayamkulam
Surveillance of rugose whitefly <i>Aleurodicus rugioperculatus</i> in coconut and assessing the population of natural bio control agents	DRYSRHU, Ambajipeta	DRYSRHU, Ambajipeta
Surveillance of rugose whitefly in coconut and assessing the population of natural biocontrol agents	KAU, Thrissur	KAU, Thrissur
Biological suppression of rugose spiralling whitefly in coconut	TNAU, Coimbatore	TNAU, Coimbatore
Field evaluation of bioagents against rugose spiralling whitefly on coconut	UAHS, Shivamogga	UAHS, Shivamogga
Converging biological suppression approaches for area-wide management of coconut rhinoceros beetle	CPCRI, Kayamkulam	CPCRI, Kayamkulam
In vivo evaluation of effective biocontrol agents against Phytophthora pod rot management in cocoa	DRYSRHU, Ambajipeta	DRYSRHU, Ambajipeta
Survey and surveillance of natural enemies of pinworm, <i>Tuta absoluta</i> on tomato	AAU, Anand	AAU, Anand
Role of Habitat manipulation for pest management in Tomato	CAU (Imphal)	CAU (Imphal)
Demonstration on bio-intensive management of insect pests of tomato	Dr YS PUHF, Solan	Dr YS PUHF, Solan
Bio-intensive pest management of <i>Helicoverpa armigera</i> , <i>Tuta absoluta</i> and sucking pests of tomato	IIHR, Bengaluru	IIHR, Bengaluru
Large Scale Field Trials for the Management of <i>Helicoverpa armigera</i> (Hubner) on Tomato	MPUAT, Udaipur	MPUAT, Udaipur
Management of sucking pests in tomato under polyhouse condition	PAU, Ludhiana	PAU, Ludhiana
Survey and surveillance of natural enemies of pin worm, <i>Tuta absoluta</i> on tomato	PJTSAU, Hyderabad	PJTSAU, Hyderabad
Development of bio-intensive pest management (BIPM) module for the management of shoot and fruit borer, <i>Leucinodes orbonalis</i> (Guenee) in	AAU, Anand	AAU, Anand

brinjal		
2Bio-efficacy of microbial agents against <i>Myllocerous subfasciatus</i> on brinjal	IIHR	IIHR
Bio-intensive insect pest management in brinjal	KAU, Thrissur	KAU, Thrissur
Evaluation of biointensive IPM module against key pests of okra	AAU, Jorhat	AAU, Jorhat
Large scale demonstration on bio-intensive pest management in okra	AAU, Anand	AAU, Anand
Management of hoppers, aphids and Whitefly on Okra by oil based formulation of <i>Metarhizium anisopliae</i> (IIHR Strain)	IIHR	IIHR
Efficacy biocontrol agents for management of fruit borer, <i>Earias vittella</i> on bhendi	IIVR, Varanasi	IIVR, Varanasi
Evaluation of <i>Neoseiulus indicus</i> for the management of spider mites on okra	KAU, Thrissur	KAU, Thrissur
Field evaluation of ICAR-NBAIR entomopathogenic strains against cabbage aphid ( <i>Brevicoryne/Myzus</i> ) and <i>Plutella xylostella</i> (DBM)	CAU, Imphal	CAU, Imphal
Field evaluation of ICAR-NBAIR entomopathogenic strains against cabbage aphid ( <i>Myzus persicae</i> ) and <i>Plutella xylostella</i> (DBM)	IIVR, Varanasi	IIVR, Varanasi
Field evaluation of ICAR-NBAIR entomopathogenic strains against cabbage aphid, <i>Brevicoryne brassicae</i> (L.) and <i>Plutella xylostella</i> (L.).	MPKV, Pune	MPKV, Pune
Field evaluation of ICAR-NBAIR entomopathogenic strains against cabbage aphid, <i>Brevicoryne brassicae</i> and dimond back moth, <i>Plutella xylostella</i>	AAU, Jorhat	AAU, Jorhat
Influence of habitat manipulation on incidence and severity of pest damage in cabbage	AAU, Anand	AAU, Anand
Management of thrips, aphids and whitefly on chilli by oil based formulation of <i>Metarhizium</i>	IIHR	IIHR

<i>anisopliae</i> (IHR Strain)		
Screening of promising isolates of entomopathogenic fungi for management of mites in chilli	RARS, Kumarakom	RARS, Kumarakom
Survey for incidence of <i>Phenacoccus manihoti</i> - the recent invasive mealybug on cassava. Host range of <i>P. manihoti</i> across agricultural and horticultural crops	TNAU, Coimbatore	TNAU, Coimbatore
Evaluation of BIPM against fruit flies <i>Deccaus bactrocera</i> sp. against cucumber	AAU, Jorhat	AAU, Jorhat
Management of phytophagous mites on cucumber using <i>Blaptostethus pallescens</i> and <i>Neoseiulus longispinosus</i> under polyhouse	Dr YS PUHF, Solan	Dr YS PUHF, Solan
Management of spider mite in cucumber using anthocorid predator, <i>Blaptostethus pallescens</i> under polyhouse condition	KAU, Thrissur	KAU, Thrissur
Evaluation of entomopathogenic fungi, <i>Beauveria bassiana</i> (NBAIR-Bb-5a) and <i>Lecanicillium leccani</i> (NBAIR-VL 15) against sucking insect pests of capsicum in open field condition	UAS, Raichur	UAS, Raichur
Efficacy of capsule formulations of <i>Beauveria bassiana</i> for the management of amaranthus leaf webber, <i>Hymenia recurvalis</i>	KAU, vellayani	KAU, vellayani
Large scale demonstration of entomopathogenic fungi, <i>Metarhizium rileyi</i> (KK-Nr-1) against soybean defoliators in Bidar district.	UAS, Raichur	UAS, Raichur
Survey for incidence of <i>Phenacoccus manihoti</i> - the recent invasive mealybug on cassava. Host range of <i>P. manihoti</i> across agricultural and horticultural crops	TNAU, Coimbatore	TNAU, Coimbatore
Efficacy of different biocontrol agents against onion thrips, <i>Thrips tabaci</i> L.	AAU, Anand	AAU, Anand
Management of spider mite in cucumber using anthocorid predator, <i>Blaptostethus pallescens</i> under polyhouse condition	KAU, Thrissur	KAU, Thrissur

Management of sucking pests in tomato under polyhouse condition	PAU, Ludhiana	PAU, Ludhiana
Evaluation of biocontrol agents for the control of sucking pests in capsicum under polyhouse	IIHR, Bengaluru	IIHR, Bengaluru
Management of phytophagous mites on cucumber using <i>Blaptostethus pallescens</i> and <i>Neoseiulus longispinosus</i> under polyhouse	YSPUHF, Solan	YSPUHF, Solan
TRIBAL SUB PLAN	All Centres	All Centres

### 9. Experiments not conducted

Name of the experiment	Centre
Validation and large scale field demonstration of IPM Technology of Codling moth, <i>Cydia pomonella</i> infesting apple in Ladakh	SKUAST, Srinagar
Evaluation of predatory bug, <i>Blaptostethus pallescens</i> against European Red mite <i>Panonychus ulmi</i> and two spotted spider mite, <i>Tetranychus urticae</i> on apple	SKUAST, Srinagar
Field evaluation of anthocorid bug, <i>Blaptostethus pallescens</i> against spider mite, <i>Tetranychus urticae</i> infesting carnation in Kashmir (Poly house)	SKUAST, Srinagar
Evaluation of microbial antagonist for the management of ginger rot Disease	AAU, Jorhat
Demonstration of <i>Heterorhabditis indica</i> (NBAIR culture) WP and <i>Metarhizium anisopliae</i> formulation for management of arecanut root grubs in malnad and coastal regions of Karnataka	UAHS, Shimogga
Evaluation of entomopathogenic fungi against cowpea pod bug	KAU Thrissur
Evaluation of ICAR NBAIR entomopathogenic strains against cowpea aphid	KAU, Thrissur, MPKV, Pune

### 10. Experiments concluded (only experiments with two or more years)

Experiment allotted	No of years	Remarks based on the results from various centres	Status of the experiment

Trial on maize fall army worm	2	<p>Among the biocontrol agents, 43.62 per cent damaged plants was observed in <i>Trichogramma pretiosum</i>+ NBAIR Bt 2% followed by <i>Trichogramma pretiosum</i>+ <i>Metarhizium anisopliae</i> Ma (48.31%) on 10<sup>th</sup> day after first spraying of entomophagous and insecticide, while in insecticide treated plots 41.42 per cent damage was observed.</p> <p>After second spraying, 8.99 per cent damaged plants was observed in <i>Trichogramma pretiosum</i>+ NBAIR Bt 2% followed by <i>Trichogramma pretiosum</i> <i>Beauveria bassiana</i> NBAIR -Bb 45 (10.94%) and <i>Trichogramma pretiosum</i>+ <i>Metarhizium anisopliae</i> Ma (13.21%), while in insecticide treated plots 41.42 per cent damage was observed.</p> <p>The yield was maximum 5561Kg/ha in insecticide treated plot followed by <i>Trichogramma pretiosum</i> (2releases)+ NBAIR Bt 2% (2Sprayings) (5310Kg/ha).</p>	Brought as a recommendation
BIPM module for management of <i>Helicoverpa armigera</i> on chickpea	2	<p>Pod damage was less in insecticide treatment (8.38%) when compared to the BIPM module 1 (13.41%) and BIPM module 2 (14.17%).</p> <p>There was 43.82 per cent increase in the yield in insecticide treatment followed by BIPM module 1 (21.91%) and BIPM module 2 (25.00%)</p>	Recommended for MLT
Biointensive management of pink bollworm on <i>Bt</i> cotton	2	<p>In BIPM module, there was 14.61 per cent reduction in the bad open bolls while 40.00 per cent reduction in bad open bolls was observed in insecticides treated plots.</p> <p>The yield was maximum in insecticide sprayed plots (1976Kg/ha) followed by 1684Kg/ha and 1416Kg/ha in BIPM and control plots respectively.</p>	Recommended for large scale demonstrations
Biological suppression of rugose spiralling whitefly in coconut	2	<p>Population of RSW nymphs was minimum (12.40Nos.) in the coconut trees sprayed with neem oil 0.5% followed by 12.80 numbers of nymphs in foliar application of <i>Isaria fumosorosea</i> (pfu-5) @ 1x10<sup>8</sup> cfu/ml, Foliar water spray (15.50Nos.) and <i>Encarsia</i></p>	Recommended for large scale demonstrations

		<i>guadeloupae</i> (natural conservation) (21.6Nos.) on 15 <sup>th</sup> day after 2 <sup>nd</sup> spraying.	
Management of Coconut Rugose spiralling whitefly using entomopathogenic fungi, <i>Isaria fumosorosea</i>	2	Per cent reduction in rugose spiralling whitefly intensity recorded high after two sprays of <i>Isaria fungus and one release of Encarsia</i> parasite/ <i>Dichocrysa</i> predator.	Recommended for large scale demonstrations
Biointensive pest management in brinjal	2	The pooled analysis of two years' results showed comparable results among BIPM and chemical plots, in terms of economic yield. The BIPM and chemical treated plots recorded economic yields of 21.24 and 14.98 q/ha respectively, which were on par with each other. Significantly lower yield of 6.54 q/ha was recorded in untreated plots. On the basis of the above, the BIPM package could be a viable alternative to chemical methods.	Recommended for MLT
Biological control of guava mealy bug using entomopathogens	2	Significantly highest percent reduction in mealy bug population was recorded in <i>M. anisopliae</i> spray (49.51% reduction) that was at par with that of <i>B. Bassiana</i> spray (47.19%) at 7 DAS. At 3 DAS also mealy bug population was significantly lowest in <i>M. anisopliae</i> spray (16.9 mealy bug nymphs or adults per leaf). Significantly highest mealy bug and scales population was recorded in untreated control.	Recommended for large scale demonstrations
Biological control of anola mealy bug using entomopathogens	2	Significantly highest percent reduction in mealybug population was recorded in <i>M. anisopliae</i> and Azadirachtin spray (36.62 and 36.53% reduction) followed by <i>B. bassiana</i> spray (35.29% reduction) at 7 DAS. At 3 DAS mealy bug population was significantly lowest in Azadirachtin spray (5.53 mealy bug / 10 cm twig). Significantly highest mealy bug population was recorded in untreated control (8.53 mealy bugs / 10 cm twig).	Will be continued
Evaluation of bio-agents against root-knot	2	Treatments were found effective but not to satisfactory extent. Need modification in experiment and further work	Recommended for large scale demonstrations

nematode and Fusarium wilt complex in guava under controlled conditions (CISH Lucknow)			
Area-wide demonstration of biological suppression of black headed caterpillar using <i>Goniozus nephantidis</i> and <i>Bracon brevicornis</i>	4	Pruning and destruction of infested fronds at lower whorls as well as timely augmentative release of stage specific parasitoids viz., <i>Goniozus nephantidis</i> and <i>Bracon brevicornis</i> @ 20 parasitoid/palm could subdue the incidence of black headed from 87% in November 2018 to 1.1% in March 2021 with pest reduction of 98.7% in coconut plantation at Mogral Puttur, Kasaragod.	Gone as a recommendation
Management studies for inflorescence thrips on mango with bio-pesticides in field conditions.	3	Among the various bio pesticides evaluated the treatment <i>Metarhizium anisopliae</i> (NBAIR Strain Ma4) recorded low thrips population	Recommended for MLT
Evaluation of bio-agents consortia in glasshouse and in field for crop health management in rice.	2	Of all the 5 consortium of fungal and bacterial isolates evaluated in glasshouse and field, the consortium of <i>Trichoderma harzianum</i> (Th14) and <i>Psuedomonas fluorescens</i> (Psf 173) named as Pant Bioagent-3 (PBAT-3) was comparatively better than other bioagents in reducing Sheath blight and Brown spot diseases of rice and increase in plant growth and yield of rice.	Recommended for large scale demonstrations
Evaluation of bio-agent consortium in glasshouse (pot experiments) and in field for crop health management in	2	In field the performance of consortium of PBAT-3 (Th14 + Psf 173) and Th17+Psf173 showed maximum yield, with better plant stand and reduced number of wilted plants.  Experiments under glasshouse and field conditions resulted that consortium of bioagents showed better performance over single isolates.	Recommended for large scale demonstrations

chickpea			
Testing of BIPM trial on paddy along with farmers practice and control	2	Significant maximum grain yield/plot (31.56 kg) and per acre (1303.22) was obtained in BIPM treatment followed by farmer's practice (28.88kg)/plot and (1284.63Kg) and control (25.25 kg) and (1122.87kg) per plot and per acre respectively.	Recommended for large scale demonstrations
Management of apple root borer using <i>Metarhizium anisopliae</i>	3	Management of apple root borer by using <i>Metarhizium anisopliae</i> was successfully demonstrated to the farmers of Shimla, and Kinnaur districts by covering an area of 5h and 13 orchards. <i>Metarhizium anisopliae</i> (10 <sup>8</sup> conidia/g) @ 30g/ tree basin was as effective as chlorpyrifos (0.06%). The pest mortality ranged from 68.6 to 83.1 in <i>M. anisopliae</i> treated orchards and 79.4 to 87.3 per cent in chlorpyrifos treated orchards	Will be continued
Evaluation of some biocontrol agents against leopard moth, <i>Zeuzera multistrigata</i> in apple	2	Among different biocontrol agents evaluated against <i>Zeuzera multistrigata</i> in apple (cv Royal Delicious), <i>Heterorhabditis bacteriophora</i> (5000IJs/gallery) was the most effective resulting in 80 per cent mortality followed by <i>Steinernemma feltiae</i> (5000IJs/gallery) and azadirachtin (2ml/L of 1500ppm; 10ml/gallery) (66.7% each). as compared to chlorpyrifos (0.04%) resulted in 100 per cent mortality of the pest.	Will be continued
Evaluation of entomopathogenic biopesticide against <i>Aphis craccivora</i> in cowpea ( <i>Vigna unguiculata</i> ).	2	<i>Verticillium lecanii</i> 1×10 <sup>8</sup> cfu/ml@5gm/lit followed by spinosad 45 SC @0.3 ml/lit (11.78/terminal shoot) with a yield of 38.68 and 36.48 q/ha, respectively.	Recommended for large scale demonstrations
Field evaluation of ICAR-NBAIR entomopathogenic strains against cabbage aphid, <i>Brevicoryne</i>	2	Among the different biopesticides <i>V. lecanii</i> (V1-8 isolate) @ 5 ml/litre was the best treatment in reducing the mean population of aphid, <i>B. brassicae</i> (3.20/plant) and <i>P. xylostella</i> ( 4.15/plant), with 66.14 and 57.65 per cent reduction over control followed by the next best treatment of ICAR- NBAIR strains of <i>B. bassiana</i> (Bb-45 isolate) with 64.02 and 51.02	Recommended for large scale demonstrations

<i>brassicae</i> and diamond back moth, <i>Plutella xylostella</i>		per cent reduction over control of aphid (3.40/plant) and DBM (4.80/plant), respectively.	
Evaluation of BIPM against fruit flies <i>Deccaus bactrocera</i> sp. against cucumber	2	BIPM package revealed minimum per cent damaged fruits (16.36%) which was significantly different from chemical control where the per cent damaged fruit was 28.37% at 65 Days after treatment (DAT). The marketable fruit yield was also significantly different in case of BIPM package with that of conventional practices where 86.89 q/ha yield was recorded in BIPM package as against 59.00 q/ha in conventional package.	Recommended for large scale demonstrations
Validation of BIPM practices against pest complex of organic Black rice	2	the incidence of dead heart and White ear head (WEH) and damage leaf due to leaf folder were much lower (<3.0%) in both BIPM and farmers practice field. However, the mean dead heart and WEH incidence in BIPM fields were 2.82 and 2.60% at 65 Days after transplanting, respectively. The corresponding figures in farmers practice were 2.78 and 2.99 %. Similarly leaf folder damage in BIPM field was 2.64 % as compared to 2.95 % in farmers practice. As regards to grain yield, maximum yield of 3124.8 kg/ha was significantly superior as compared to 2882.6 kg/ ha in farmers practice plots	Concluded
Evaluation of entomopathogenic fungi and <i>Bt</i> against stem borer, <i>Chilo partellus</i> (Swinhoe) in maize	2	Among bio-formulations, lowest dead heart incidence was recorded in commercial Bt formulation (5.54%) followed by NBAIR Bt (6.97%), Bb-5a (7.08%), and Ma-35 (9.13%) as compared to 12.84% in untreated control. However, chemical control was significantly superior (2.23% dead hearts) and also recorded highest yield	
Evaluation of microbial antagonists for the management of foot rot of Kinnow caused by <i>Phytophthora</i>	2	Among bioformulations <i>Pseudomonas fluorescence</i> (NBAIR-PfDWD) recorded (22.90%) recovery of final lesion size over control. However, Per cent recovery of final lesion size over control was maximum (43.8%) in chemical control (Curzate M-8) and was significantly better than all other bio-formulations for the management of foot root	Continuing

spp.		disease in Kinnow and also recorded highest yield.	
BIPM module for management of <i>Helicoverpa armigera</i> on chickpea	2	BIPM module 2 (Two Sprays of <i>Bacillus thuringiensis</i> @ 2 kg/ha at 15 days interval, seed bio-priming <i>T. harzianum</i> @ 10g/kg , bird perches @ 8/acre, raising marigold as trap crop and use of pheromone traps @ 1 trap per plot.) recorded minimum percent pod damage (2.86%). However, chemical control (chlorantraniliprole 18.5 SC) recorded significantly lowest pod damage (1.03%). The yield was also significantly better in all treatments as compared to control	Continuing as a large scale demonstrations
Evaluation of entomopathogenic fungi formulations against millet borers in Finger millet, Kharif, 2020, (IIMR, Hyderabad	2 years	Application of Ma 35 oil based formulation @ 10 ml/lit at 20 & 40 DAE) and treatment comprising application of Bb-45 oil based formulation @ 10 ml/lit at 20 & 40 DAE) were equally effective and were on par with application of Fipronil 3G @ 17.5 kg /ha) at sowing + whorl application of Fipronil3G @ 7.5 kg at 30 DAE.	Continued for large scale demonstrations

## 11. Technologies identified for large plot multilocational trials

Details of technologies	Centres which the conducted trials	Proposed centres to take up the trial
Large scale demonstration of Management of fall armyworm using biological control agents and Biopesticides	ANGRAU, Anakapalle	UAS, Raichur
Large scale bio-intensive pest management in rice	KAU, Thrissur,	OAUT, Bhubaneswar
Biological control of rugose spiralling whitefly in coconut	CPCRI, Kayankulam	DRYSRUH, Ambajipetta
Converging biological suppression approaches for	CPCRI,	DRYSRUH,

area-wide management of coconut rhinoceros beetle.	Kayankulam	Ambajipetta
large scale demonstrations of natural enemies for the management of coconut rugose spiraling whitefly	DRYSRHU, Ambajipetta	CPCRI, Kayankulam
Large scale field demonstrations of bio-control technologies for the management of rice diseases	GBPUAT, Pantnagar	KAU, Thrissur,
Large scale field demonstrations of bio-control technologies for the management of chick pea wilt	GBPUAT, Pantnagar	UAS, Raichur
Bio-intensive management of insect pests of tomato	DYSPUHF, Solan	IIVR, Varanasi
Management of apple root borer using <i>Metarhizium anisopliae</i>	DYSPUHF, Solan	SKUAST, Srinagar
Demonstration of <i>Trichoderma</i> sp. for the management of Fusarium wilt in pigeon pea	AAU, Anand	UAS, Raichur
Large scale demonstration on bio-intensive pest management in okra	AAU, Anand	IIHR, Hesaraghata
Large scale demonstration on bio-intensive pest management in cabbage	AAU, Anand	IIHR, Hesaraghata
Large scale demonstration on bio-intensive management of mango hopper	AAU, Anand	CISH, Lucknow, IIHR Hesaraghata
Large scale demonstrations of proven biocontrol technologies against sugarcane stalk borer, <i>Chilo auricilius</i>	PAU, Ludhiana	ANGRAU, Anakapalle
Large scale demonstrations on bio-intensive pest management in organic <i>basmati</i> rice  Mechanical control for leaf folder by passing the 20-30 m long coir/jute rope before flowering, forwards and then backwards, both ways while touching the crop canopy  Biocontrol (5 releases of <i>T. chilonis</i> and <i>T. japonicum</i> @ 1 lakh/ha each at weekly interval starting from 30 days after transplanting) for stem borer and leaf folder	PAU, Ludhiana	AAU, Jorhat
Large scale demonstration of proven biocontrol technologies against maize stem borer, <i>Chilo partellus</i> using <i>Trichogramma chilonis</i>	PAU, Ludhiana	ANGRAU, Anakapalle

## 12. Technologies identified for commercialization/POP practices

Details of technologies	Centres which conducted the trials	Proposed universities where the technologies will be included in the POP/commercialized
IPM module (Bio-inoculant ( <i>Azospirillum</i> ) + Intercropping (with mungbean 3:2) + mechanical control + yellow sticky trap) is recommended for achieving higher sesame yield over the recommended practice to reduce the insect pests and Phyllody incidence in sesame	SKUAST, Jammu	SKUAST, Jammu
Management of rice bug using a local isolate <i>Beauveria bassiana</i>	KAU, Thrissur	KAU, Thrissur
<i>Lecanicillium lecanii</i> (NBAIR IV-8) @ 5gm/litre can be recommended for management of tea red spider mite and white fly in cucumber	UBKV, Pundibari	UBKV, Pundibari
Augmentative release of stage specific parasitoids viz., <i>Goniozus nephantidis</i> and <i>Bracon brevicornis</i> @ 20 parasitoid/palm in the bio-suppression of black headed caterpillar, <i>Opisina arenosella</i> in sporadic outbreak situation.	CPCRI, K ayankulam	CPCRI, K ayankulam KAU, Thrissur
Conservation biological control using the aphelinid parasitoid, <i>Encarsia guadeloupae</i> and sooty mould scavenger beetle, <i>Leiochrinus nilgirianus</i> was found effective in the bio-suppression of rugose spiralling whitefly ( <i>Aleurodicus rugioperculatus</i> ) under Kayamkulam condition	CPCRI, Kayankulam	CPCRI, Kayankulam
Biopesticide <i>Metarhizium anisopliae</i> (NBAIR Strain Ma4) @ 5 ml/litre was effective in reducing mango inflorescence thrips population under field conditions as observed during experimentation from 2019-21	DRYSRHU, Ambajipetta	DRYSRHU, Andhra pradesh
Foliar application of entomopathogenic fungi <i>Isaria fumosorosea</i> @ $1 \times 10^8$ spores/ml ( 5 gm /litre along with sticker 2 ml/litre ) was found effective against Rugose spiralling whitefly in coconut and oil palm	DRYSRHU, Ambajipetta	DRYSRHU, Andhra pradesh
Mass production technology of predator	DRYSRHU,	DRYSRHU,

<i>Pseudomallada astur</i> against rugose spiralling whitefly	Ambajipetta	Ambajipetta
Seed treatment with <i>T. harzianum</i> @15g/Kg, Seedling dip with <i>Pseudomonas fluorescens</i> 2% solution Spray of <i>P. fluorescens</i> @ 1.5 Kg/ha against foliar diseases	IGKV,Raipur	IGKV,Raipur
Release of <i>Trichogramma japonicum</i> @ 1,00,000/ha (6 releases at 10 days interval starting from 25 DAT) to manage the pests of crops	IGKV, Raipur	IGKV, Raipur
6 releases of <i>Trichogramma japonicum</i> @ 50,000/ha/week starting from 25-30 days after transplanting gives significantly good control (30-60% parasitism ) of rice stem borer and leaf folder .	AAU, Jorhat	AAU, Jorhat
6 releases of <i>Trichogramma chilonis</i> or <i>T . preteosum</i> @ 50,000 /ha at 10 days interval starting from fruit formation stage was the best to management of tomato fruit borer, <i>Helicoverpa armigera</i>	AAU, Jorhat	AAU, Jorhat
<i>Bacillus thuringiensis kurstaki</i> (DOR Bt 1) @ 800 g/ acre for the management of gram caterpillar in gram	PAU, Ludhiana	PAU, Ludhiana
Integrated management of early shoot borer, <i>Chilo infuscatellus</i> with pheromone traps and <i>Trichogramma chilonis</i> in sugarcane	PAU, Ludhiana	PAU, Ludhiana

### 13. Action taken report on recommendations of XXIX AICRP BC Annual review meeting

<b>General Recommendation</b>	
<b>Recommendations</b>	<b>Action Taken</b>
In case of large scale demonstration trials, centres may increase the area under coverage so as to stimulate the supply chain of biocontrol agents for eco-friendly management of insect pests. <b>(All AICRP-BC Centres)</b>	Extensive area will be taken while conducting large scale demonstration trials
Centres must ensure the inclusion of biocontrol agents (at least predators and parasitoids) which does not require CIB registration in university package of practice after the successful evaluation of biocontrol agent against particular pest in a particular crop. <b>(All AICRP-BC Centres)</b>	<i>Trichogrammatoidea bactrae</i> has been included in the trials
Strain name and source of entomopathogens should be mentioned in the experimental results <b>(All AICRP-BC Centres)</b>	The source and strain of the entomopathogens used are mentioned in the experimental results.
Extensive studies on invasive whiteflies undertaken in coconut may be taken up in other crops <b>(All AICRP-BC Centres)</b>	Critical and explorative studies on exotic pests have been undertaken in other crops. The host range of invasive white flies is also being documented
Pest incidence level above threshold level should be reported in pest outbreak report <b>(All AICRP-BC Centres)</b>	Pest incidence levels above threshold levels were added in crop pest outbreak reports and will be presented
<b>Rice</b>	
<i>Lecanicillium saksenae</i> may be evaluated for efficacy against all the important sucking pests of rice in multilocation trials at a few centres. Cultures/ Formulation of the fungus should be sent to NBAIR for further action <b>(KAU, Vellayani, NBAIR)</b>	<i>L. saksenae</i> formulations were tested at RARS Warangal and TNRRI Aduthurai, TNAU through the rice coordination programme (IIRR)
Release of <i>Trichogramma</i> for the management of stem borer and leaf folder should be made based on occurrence of eggs scouted by monitoring. <b>(All centres)</b> .	Followed as per recommendation

<p>The proven model of IPM demonstrated in the entire Adat and nearby panchayats may be compared with any new models that are evaluated and the cost benefit ratio compared (<b>KAU, Thrissur</b>).</p>	<p>The present large scale validation involves the core elements of the Adat package</p>
<p>Data on dead hearts, white ears and leaf folder damage may be recorded as a percentage in addition to number per m<sup>2</sup> (<b>All Centres</b>).</p>	<p>Followed as per recommendations</p>
<p>Potential bioagents (macrobiols &amp; microbials) may also be supplied to All India Coordinated Rice Improvement Project for evaluation under biopesticide/IPM trials in rice from different Network centres across India (<b>NBAIR, AICRP- RICE</b>).</p>	<p>IIRR received <i>L. saksanae</i> from KAU Thrissur through NBAIR and other microbials for testing against ear head bug. It was carried out in two centres Warangal and Aduthurai</p>
<p><b>Maize and Sorghum</b></p>	
<p>Keeping in view of the natural parasitisation by <i>T.chilonis</i> on FAW, it is suggested to have a midterm change in the technical programme to include the parasitoids, <i>T. chilonis</i> and <i>Telenomus remus</i> as treatments to compare with <i>T. pretiosum</i>.</p> <p><b>(IIMR, Maize Hyderabad, PAU, PJTSAU, AAU-Anand, OUAT, MPKV, CAU and TNAU)</b></p>	<p>All the centres included the <i>T. chilonis</i> and <i>Telenomus remus</i> as treatments to compare with <i>T. pretiosum</i> against FAW</p>
<p>It was quite evident from the Adhoc trials undertaken by various centres that bioagents both macrobiols and microbials including EPN are effective in suppressing the Fall armyworm and increased yield on par with the chemical control. Centres should ensure that a supply chain for biocontrol agents is established in model of the State Biocontrol laboratory, Mannuthi, Thrissur Kerala (<b>All centers</b>)</p>	<p>All the centres initiated the production of microbials to supply the farmers on demonstration basis</p>
<p><b>Sugarcane</b></p>	
<p>Large scale demonstration trials centres may increase the area under coverage (<b>PAU, ANGRU, UAS(R), MPKV</b>)</p>	<p>Increase the area of large scale demonstration trials for ecofriendly management of insect pests</p>

Biocontrol agents inclusion in university package of practices after successful evaluation (ANGRAU)	Centre included the Temperature tolerant <i>Trichogramma chilonis</i> @ 50,000/ha /release 8+4 times against shoot borers in sugarcane in package of practices
While recording C:B ratio of increase in yield due to biocontrol technologies, the yield advantage in terms of monetary benefits to be worked of all experiments (PAU, ANGRU, UAS(R), MPKV)	Calculated monetary benefits along with yield increase and C:B ratio
Centre may explore taking up demonstration trials with EPF/EPN against sugarcane white grub in other parts of andhra pradesh when pest is reported (ANGRAU)	ANGRAU centre conducted demonstration trials with EPF against sugarcane white grub in krishna district
<b>Coconut</b>	
Concept of ecological engineering in coconut is to be popularised. (TNAU, KAU, DRYSRH)	Ecological engineering in coconut is well popularized through publications, demonstrations and production of a short video film
Detailed study on competitive regulation and co-existence of invasive whiteflies in coconut is envisaged (CPCRI)	The outcome of the detailed study of co-occurrence of exotic whiteflies will be presented in the workshop
Impact of <i>Isaria fumosorosea</i> on natural parasitism of <i>Encarsia guadeloupae</i> need to be studied for synergistic utilization. (TNAU, KAU, DRYSRH, CPCRI)	The data on impact of <i>Isaria fumosorosea</i> sprayings on <i>Encarsia guadeloupae</i> under natural field conditions was generated and will be presented in workshop
<b>Pulses</b>	
The management options should be addressed for the pod borer complex of pigeon pea such as <i>Maruca vitrata</i> , pod wasp, pod fly along with <i>Helicoverpa armigera</i> under field conditions. (PDKV, Akola)	The new technical programme addressing the management of pod borer complex in pigeon pea will be taken up in the year 2021-22
Formulation of <i>B. thuringiensis</i> strain BtG4 should be used as component of IPM in pigeon pea and two sprays may be taken in pigeon pea (PDKV, Akola)	Implemented
BIPM adopted for pod borer management in pigeon pea should follow uniform observation viz., No. of larvae,	Implemented

per cent pod damage, grain yield and also record the occurrence of natural enemies on the pod borer complex by all the centres ( <b>PDKV, Akola</b> )	
<b>Oil seeds</b>	
Cost benefit ratio may be worked for the area-wide demonstration of biosuppression of white grub in groundnut. (Action: <b>AAU, Anand</b> ).	CB ratio has been worked out in the experimental results
The components of BIPM package may be discussed with AINP on soil arthropods to avoid conflict in recommendations (Action: <b>AAU, Anand</b> ).	Implemented (Large scale demonstration trial on white grub in groundnut)
Conservation technologies for parasitoids of mustard aphid may be worked out (Action: <b>AAU, Jorhat</b> ).	Planted tolerant varieties like TS- 36, TS- 44, TS- 46 and TS- 67 etc. Removed aphid infested plant part at initial stage. Installation of yellow sticky trap to monitor aphid population. Conserved the natural enemies (Ladybird beetles viz., <i>Coccinella septempunctata</i> , <i>Menochilus sexmaculata</i> , <i>Hippodamia variegata</i> and <i>Cheilomones vicina</i> thatare ; syrphid fly i.e., <i>Sphaerophoria spp.</i> , <i>Eristallis spp.</i> , <i>Metasyrphis spp.</i> , <i>Xanthogramma spp</i> and <i>Syrphus spp.</i> ; braconid parasitoid <i>Diaretiella rapae</i> ) by growing of attractant plants viz., Wild mustard ( <i>Sinapis arvensis</i> ), white mustard ( <i>Sinapis alba</i> ) and avoided application of chemical pesticide
<i>Metarhizium anisopliae</i> (Ma4) was found as a promising bio-control agent and therefore all centres may procure the technology from ICAR-NBAIR for localized production and distribution to farmers ( <b>AAU, Anand</b> )	The mass production and distribution of ICAR-NBAIR strain Ma-4 for demonstration purposes is under progress
<b>Tropical and Temperature Fruits</b>	
Biological control agents are a component of IPM and needs integration in BIPM module. Thus in all experiments approved insecticides and their compatibility with biocontrol agents may be studied for	Recommended insecticides have been included in experiments along with biocontrol agents.

microbial agents to the extent possible. (YSP UHF, Solan)	
A treatment comprising of combination of entomofungal bioagent and insecticide application can be used in the trials on mango webber and apple borer management. (YSPUHF, Solan)	For apple root borer management, a treatment of chlorpyrifos has been included along with <i>Metarhizium anisopliae</i> .
<b>Vegetables, polyhouse crops and Flowers</b>	
For protected cultivation, mass production in commercial scale for sucking pests need perfection and generation in regular norms. In greenhouses, mites, aphids, jassids, thrips, whiteflies etc. are common pests. Mass production protocols for predatory mites/wasps like <i>Amblyseius</i> , <i>Phytoseiulus</i> , <i>Neoseiulus</i> , <i>Eretmocerus</i> , <i>Encarsia</i> for whiteflies, <i>Diglyphus</i> and <i>Orius</i> for leafminers etc., needs to be standardized and developed in commercial scale ((YSPUHF, Solan)	Mass production of predatory mite, <i>Neoseiulus longispinosus</i> has been standardised. Similarly, Predatory bug, <i>Blaptostethus pallescens</i> has also been multiplied using production protocol given by NBAIR.
<b>Biological control of Plant diseases</b>	
While reporting local strain to be potent its genotyping characterization must be done to know how it is different from other strains (GBPUA&T, Pantnagar).	Genotyping characterization of 18 isolates of potent <i>Trichoderma</i> has been done and submitted in NAIMCC and NCMR with their accession numbers.
Economics of experiment should be projected for farmers to take up the technology. (GBPUA&T Pantnagar).	This is under progress.
More concentration on biological control of plant diseases should be given and centres for this may be identified. In future data on percent disease and yield should be provided instead of agronomical data (All AICRP-BC Centres)	15 new centres have been identified for biological control of plant diseases. It is taken care to provide data on percent disease and yield instead of agronomical data.
More concentration on biological control of plant diseases should be given and centres for this may be identified. In future data on percent disease and yield should be provided instead of agronomical data. (YSP UHF Solan)	An experiment on management of <i>Fusarium</i> wilt/root rot of pea through biological control agents has been taken up and data on per cent disease and yield has been given.

<p>More concentration on biological control of plant diseases should be given and centers for this may be identified. In future, data on per cent disease and yield should be provided instead of agronomical data. <b>(All AICRP-BC Centres)</b></p>	<p>Two trials on plant diseases were conducted during 2020-21. Data on Percent disease and yield was recorded.</p>
<p>Biological control of plant diseases in Brinjal has to be taken up. <b>(UBKV)</b></p>	<p>As per the recommendation the trial for biological control of plant diseases in brinjal has been initiated.</p>