Proceedings of the XXX Biocontrol Workers' Group Meeting

14 July, 2021

Virtual meeting conducted by

ICAR-National Bureau of Agricultural Insect Resources

Compiled and Edited by

Richa Varshney, G Sivakumar,

and N Bakthavatsalam

AICRP on Biological Control of Crop Pests

NATIONAL BUREAU OF AGRICULTURAL INSECT RESOURCES

P. B. No. 2491, H. A. Farm Post, Bengaluru 560024

Karnataka

XXX ANNUAL GROUP MEET OF ALL INDIA CO-ORDINATED RESEARCH PROJECT ON BIOLOGICAL CONTROL OF CROP PESTS

14 July 2021

14 July 2021 (Wednesday)

INAUGARATION		
10.00 -10.20 am	**Dr. N. Bakthavatsalam,** Project Coordinator, AICRP-BC & Director, ICAR- NBAIR, Bengaluru	Welcome & Project Coordinator's report
10.20 - 10.35am	**Dr. S. C. Dubey**, Assistant Director General (PP&BS), ICAR, New Delhi	Remarks
10.35 - 10.55am	**Dr. T. R. Sharma,** Deputy Director General (CS), ICAR, New Delhi	Remarks
10.55- 11.00 am	**Dr. G. Sivakumar,** Chairman, AICRP-BC, PC cell	Vote of thanks
PRESENTATION OF PROGRESS REPORTS		
11.00 am – 12.30pm		**SESSION I: Panel discussion for collaboration between institutes and AICRPs**
Chair Co Chair		**Dr. T. R. Sharma,** Deputy Director General (CS), ICAR, New Delhi **Dr. H.B.Singh,** Professor, Plant Pathology (Rtd), BHU, Varanasi
Rapporteurs		Dr. A. Kandan, Principal Scientist, ICAR NBAIR Dr. K. Selvaraj, ICAR-NBAIR, Bengaluru
Speakers		
Dr.A.K.Saxena ,Director, NBAIM, Mau **Dr.Pankaj Kausal**, Joint Director, NIBSM, Raipur **Dr.Y.G.Prasad**, Director, CICR, Nagpur **Dr. Meenakshisundaram**, Director, IIRR, Hyderabad **Dr.Sujay Rakshit**, Director, IIMR, Ludhiana **Dr.G.P. Dixit**, Project Coordinator (Chick pea) **Dr. I. P. Singh**, Project Coordinator (Pigeon Pea) **Dr.Rajesh Kumar**, Project Coordinator (Vegetables)		Director of respective institute and Project Coordinator AICRP

Dr.Prakash Patil Project Coordinator (Fruits) **Dr. Maheshwarappa**, Project Coordinator (Palms) **Dr. A. S. Baloda**, Network Coordinator, AINP on White grubs & Other Soil Arthropods **Dr. Balraj Singh,** Project Coordinator AICRP on Honey bees and Pollinators **Dr. Srinivasa**, Network Coordinator AINP on Agricultural Acarology, **Dr.Vipin Chaudhary**, Coordinator, AINP on Vertebrates Pest management **Dr. Uma Rao,** Project Coordinator (Nematodes)	
12.30 – 01.15 pm	**SESSION II: BASIC RESEARCH ON BIODIVERSITY AND NATURAL ENEMIES OF INSECT PESTS AT NBAIR AND BIOLOGICAL CONTROL OF PLANT DISEASES**
Chair Co -Chair	**Dr. Chandish. R. Ballal** Former Director, ICAR-NBAIR, Bengaluru **Dr.Prasanth Mohanraj** Former HOD, ICAR-NBAIR, Bengaluru
Rapporteurs	Dr. Jagadeesh Patil, ICAR-NBAIR, Bengaluru. Dr. Neelam Joshi, PAU, Ludhiana.
Speakers	
Biodiversity, Biosystematics, Molecular Characterization and Biocontrol potential of bioagents	**Dr. K.Sree Devi**, ICAR-NBAIR, Bengaluru
Biodiversity and Pest Outbreak reports	**Dr. U.Amala**, ICAR-NBAIR, Bengaluru
Biological Control of Plant diseases	**Dr. Roopali Sharma,** GBPUAT, Pantnagar
Break	
01.45 – 3.30 pm	**SESSION III: BIOLOGICAL SUPPRESSION OF PESTS OF FOOD AND FIBRE**
Chair	**Dr. Subash Chander** Director, ICAR-NCIPM, New Delhi
Co-Chair	**Dr. Sunil Joshi,** HOD, DCC, ICAR-NBAIR
Rapporteurs	Dr.M.Mohan, ICAR-NBAIR, Bengaluru Dr. B. L. Raghunandan, AAU, Anand
Speakers	
Rice	**Dr. Chitra Shanker**, ICAR-IIRR, Hyderabad
Maize & Sorghum	**Dr. Arunkumar Hosamani,** UAS, Raichur
Sugarcane	**Dr. M. Visalakshi**, ANGRAU, Anakapalle
Cotton	**Dr. Jeyarajan Nelson**, TNAU, Coimbatore
Coconut	**Dr. N. Chalapathirao**, HRS, Ambajipeta

03.30 - 04.00 pm	**SESSION IV: BIOLOGICAL SUPPRESSION OF PESTS OF OIL SEEDS AND PULSES**
Chair	**Dr. H. C. Sharma**, Former Vice Chancellor, YSPUHF, Nauni, HP & Chairman, RAC,ICAR NBAIR, Bengaluru
Co-Chair	**Dr. A.N.Shylesha,** HOD, DGCU, ICAR-NBAIR, Bengaluru
Rapporteurs	Dr. Galande, MPKV,Pune Dr. Omprakash Navik, ICAR-NBAIR, Bengaluru
Speakers	
Pulses	**Dr. B. L. Raghunandan**, AAU, Anand
Oil seeds	**Dr. G.Anitha**, PJTSAU, Hyderabad
04.00 – 04.45 pm	**SESSION V: BIOLOGICAL SUPPRESSION OF PESTS OF FRUITS, VEGETABLES AND POLYHOUSE CROPS**
Chair	**Dr.Tusar Kanti Behera**, Director, ICAR-IIVR, Varanasi
Co Chair	**Dr M. Nagesh** HOD, DGR, ICAR-NBAIR, Bengaluru
Rapporteurs	Dr. P. S. Shera, PAU, Ludhiana Dr. M. Sampath Kumar, ICAR-NBAIR, Bengaluru
Speakers	
Tropical and Temperate fruits	**Dr. B. R. Jayanthi Mala**, ICAR-IIHR, Bengaluru
Vegetables, Polyhouse crops & Flowers	**Dr. Jaydeep Halder**, ICAR-IIVR, Varanasi
04.45 – 05.45 pm	**SESSION VI: INSTITUTE AND ACADEMIA INTERACTIONS**
Chair	**Dr. S. C. Dubey**, Assistant Director General (PP&BS), ICAR, New Delhi
Co chair	**Dr. S. K. Jalali,** Former Head, ICAR NBAIR, Bengaluru
Panelists	**Dr. H. C. Sharma**, Former Vice Chancellor, YSPUHF, Nauni, HP & Chairman, RAC,ICAR NBAIR, Bengaluru **Dr. Abraham Verghese**, Former Director, ICAR- NBAIR, Bengaluru **Dr. H. B. Singh** Professor , Plant Pathology (Rtd), BHU, Varanasi **Dr. Chandish. R. Ballal** Former Director, ICAR-NBAIR, Bengaluru **Dr. S. J. Rahman**, Professor, ANGRAU, Hyderabad

Speakers	**Dr. A. Kandan**, Principal Scientist, ICAR- NBAIR, Bengaluru Representatives from Private industries (5 minutes each) **Dr.Sithanantham**, Sun Agro Biotech, Chennai **Dr. Dinesh Shetty**, Ponalab, Bengaluru **Dr. A. John Peter**, Varsha Bioscience Tech Pvt Ltd **Dr. Natraj**, Multiplex Biotech Pvt ltd Bengaluru **Mr. Ramji Mangukia, Managing Director,** Agriland biotech
Rapporteurs	**Dr. Jaydeep Halder**, ICAR- IIVR, Varanasi **Dr. Richa Varshney**, ICAR- NBAIR, Bengaluru
05.45 - 06.45 pm	**SESSION VII: Valedictory and Plenary:**
Chair Co chair	**Dr. T. R. Sharma,** Deputy Director General (CS), ICAR, New Delhi **Dr. N. Bakthavatsalam,** PC, AICRP-BC & Director, NBAIR, Bengaluru
Presentation of Recommendations by Rapporteurs	Dr. Jagadeesh Patil, ICAR- NBAIR, Bengaluru Dr. M. Sampath Kumar, ICAR-NBAIR, Bengaluru Dr. K. Selvaraj, ICAR-NBAIR, Bengaluru Dr. Amala Udayakumar, ICAR- NBAIR, Bengaluru Dr. Richa Varshney, ICAR- NBAIR, Bengaluru
Remarks by	**Dr. S. K. Jalali,** Former HOD, ICAR, NBAIR, Bengaluru **Dr. H. B. Singh,** Former Professor, BHU, Varanasi **Dr. H. C. Sharma**, Former Vice Chancellor, YSPUHF, Nauni, HP and Chairman, RAC, ICAR- NBAIR, Bengaluru **Dr. S. C. Dubey**, Assistant Director General (PP&BS), ICAR, New Delhi **Dr. T. R. Sharma,** Deputy Director General (CS), ICAR, New Delhi
Vote of Thanks	**Dr. G. Sivakumar,** Chairman, AICRP- BC, PC cell

INAUGURAL SESSION

The ICAR-National Bureau of Agricultural Insect Resources, Bengaluru organized the Virtual XXX Annual Review Meet of All India Coordinated Research Project on Biological Control of Crop Pests on 14 July 2021.

Dr (Ms) N,Bakthavatsalam, Director, ICAR-NBAIR, Bengaluru & Project Coordinator, AICRP on Biological control welcomed the dignitaries and participants. He briefly presented the highlights of the project for the period 2020-21, which included the development, validation of promising bioagents by the project and area covered through the adoption of biocontrol modules. He also presented the monitoring and management of the recent invasive pests and preparedness to tackle the invasive attacks.

Dr. Tilak Raj Sharma, Deputy Director General (Crop science), inaugurated the Annual meet and appreciated the progress made in the project. He appreciated the seventeen minutes video developed by NBAIR and insisted to develop more three minutes video on various aspects of biological control. The validated microbes should be registered at ICAR- NBAIM with the bio efficacy and biosafety data. The presentations of the progress of various projects should be under various objectives. He requested to release the package of practicesof recommendations and validated biocontrol technologies along with the technical bulletin in the next annual review meeting. He urged the centres to evaluate the validates technologies for management of plant diseases. He advised the AICRP BC to collaborate with NIBSM and NCIPM.

Dr.S.C. Dubey,Assistant Director General (PP&Biosafety) emphasized to prepare distribution maps to assess the spread and establishment of various natural enemies of pests and plant pathogens. The severity of rugose spiralling whitefly of coconut has to be indicated. Data on multilocational trails of the organisms should be used for final registration. The details of the technical programme should be clearly mentioned and all the centres should follow the technical programme with out any deviation.

Experts nominated by ICAR: Dr H C Sharma, former Vice Chancellor, DrYSPUHF, Solan, Dr H B Singh, Former Professor (Plant Pathology), BHU,Varanasi and Dr S K Jalali, former Head, ICAR NBAIR, Bengaluru. Former directors of NBAIR; Dr Abraham Verghese and Dr ChandishR.Ballal participated the annual meet. Around 109 scientists and five company representatives from different parts of the country participated in the XXX Virtual AICRP BC Workshop.

Valedictory and Plenary session

Dr. N,Bakthavatsalam, Director, ICAR-NBAIR, Bengaluru & Project Coordinator, AICRP on Biological control welcomed the dignitaries and participants.

Dr. Tilak Raj Sharma, Deputy Director General (Crop science)stressed again in conducting meeting involving the NBAIR, NBAIM, NCIPM and NIBSM for future collaborations and exchange of materials. He highlighted the branding of the biocontrol products for further promotion. Finger print data have to be generated of for all new strains. Locations of large scale demonstrations of proven technologies have to be informed to DDG (CS) to make visit to those fields.

Dr. S.C. Dubey, Assistant Director General (PP&Biosafety) mentioned that the efficient strains of microbes of NBAIR and NBAIM should be used. Quality control aspects of all microbial products have to be checked before using them. Crops and pests / diseases have to be prioritised to have the intervention of microbial biocontrol agents. He spoke about the draft for revised guidelines for registration of biocontrol products and the exemption of toxicological data for registration of safer biocontrol products. GPS based survey has to be done to assess and quantify the pests as well as their natural enemies. Microbes with multiple traits have to be focussed and validated in the future programmes. More importance should be given to the experiments which will be carried out under protected cultivation.

SALIENT ACHIEVEMENTS OF AICRP-BIOCONTROL DURING 2019-20

N. Bakthavatsalam
Project Coordinator, AICRP-Biological Control

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 initatives 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 Co ordingator 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 2020-21are 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%).

4.1.3 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 rabimaize. The interaction of both egg parasitoid was studied at various levels and results showed both parasitoids are complementary at equal ratio.

4.1.4 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.

4.1.5 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 validat 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 valiadation of *I. fumosorosea* agaisnt *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 2.5×10^8 IJs ha^{-1} and 73.33% at 5×10^8 IJs ha^{-1} for *S. carpocapsae* while for *H. indica* the percentage mortality was 54.17% at the rate 2.5×10^8 IJs ha^{-1} and 89% at the rate 5×10^8 IJs ha^{-1}. 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 3rd 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 *CO1* (*Cytochrome Oxidase 1*) 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-1*) 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 predating on the larvae of mango leaf webber and mango semiloopers.

PAU: Three parasitoids, one egg-larval *Chelonus formosanus* (Hymenopetra: 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 septempuntata*, *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 *Sl*NPV and *Ha*NPV 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 varigieta, 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 univitatum, 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 sp*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 1st 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 T6- 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_5 - Pf (SA + RD) + Azoxystrobin 23% SC (FS) (11.74 %). Among the treatments where the biopesticides were evaluated as foliar spray, the treatment T_3 - 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_6 - Th+ Pf (SA + RD) + Azoxystrobin 23% SC (FS) (29.67 t/ha) and T_5 - 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_8 – 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 T6- 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_3 - 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_6 - Th+ Pf (SA + ST) + Kresoxim-methyl 44.3% SC (FS) (20.33 t/ha), T_5 - Pf (SA + ST) + Kresoxim-methyl 44.3% SC (FS) (19.67 t/ha) and T_4–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_8 – 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 T4 - *P. fluorescens* ST + *T. asperillum* SD (92.88%) and was on par with other biocontrol agenst 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 T4 - *P. fluorescens* ST + *T.asperillum* SD (3.1 %) followed by T1 - *Trichoderma asperillum* ST + SD (3.67%) and T2- *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 asperellum* 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.* **asperellum** formulation @10g/kg seed+ soil application of *T.a***sperellum** formulation after mixing with FYM (10g/Kg FYM) @40g/m^2) 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_4) - recorded lowest percent disease index (21.00%) and its talc formulation T_2 - (21.80%), followed by BC1 strain *Trichoderma asperellum*, talc formulation (T_5) (23.10%). Percent disease index in carbendazim spray (T_7) - (19.30%) was comparable to that of *P. fluorescens* (NBAIR-PFDWD strain – liquid formulation) (T1), but grain yield was significantly highest in T_4 (34.58 q/ha) and T_2 (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_3) - recorded lowest percent disease index (5.73%) followed by its talc formulation (T_1) - (6.67%). Percent disease index in Propiconazole spray (T_7) (5.53%) was comparable to that of *P. fluorescens* (NBAIR-PFDWD strain – liquid formulation) (T_3), but grain yield was significantly highest in T_3 (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_4) recorded lowest percent wilt incidence (19.11%) followed by its talc formulation (T_2) (21.33%) and BC1 strain *Trichoderma asperellum* (talc formulation) (T_5) (24.83%). Percent wilt incidence in carbendazim spray (T_7) (22.67%) was on par with *Trichoderma asperellum* talc formulation, but grain yield was significantly highest in T_4 (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_3) recorded lowest percent disease index (23.23%) followed by its talc formulation (T_1) (26.23%). Percent disease index in Ridomil spray (T_7) (23.63%) was on par with *P. fluorescens* (NBAIR-PFDWD strain – liquid formulation) (T_3) but seed yield was significantly highest in T3 (8.61 q/ha) and T_1 (8.17 q/ha). The grain yield was lowest in control (6.27 q/ha) and T_7 – (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_3) recorded lowest percent disease index (6.07%) followed by its talc formulation (T_1) (6.97%). Percent disease index in Mancozeb spray (T_7) (5.87%) was comparable to that of *P. fluorescens* (NBAIR-PFDWD strain – liquid formulation) (T_3), but seed yield was significantly highest in T3 (8.16 q/ha), followed by T_1 (7.67 q/ha). The grain yield was lowest in control (5.76 q/ha) and T_7 – (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* @$1x10^{12}$/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* @ $1.0x10^5$/ m2 (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) 1×10^8 @ 5gm/l recorded highest reduction of leafhopper population over control (49.15%) and it was at par with *L. leccani* (ICAR-NBAIR-VL-15) 1×10^8 @ 5gm/l which recorded 45.38 per cent. Lowest thrips of 2.04 per plant was noticed in *B. bassiana* (ICAR- NBAIR-Bb-5a) 1×10^8 @ 5gm/l and it was at par with *L. leccani* (ICAR-NBAIR-VL-15) 1×10^8 @ 5gm/l and *I. fumosorosea* (ICAR-NBAIR strain) 1×10^8 @ 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 x 10^8conidia /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 x 10^8conidia/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, *Leptocorisa 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 $^{-1}$ 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 oar in both the fields after 7 days of spray I and spray II. Thereafter at 14th 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^2 area and spider/m^2 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 + *Spfr*NPV-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 entomopahogens 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_1- *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_5 - *T. pretiosum* @ 1 card/acre + *Pseudomonas fluorescens* NBAIR P*f*DWD - 1% WP (2.39 larvae/ 10 plants). Similarly the treatment T_1- *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_1 recorded the highest grain and fodder yield (3817 and 4778 kg/ha) which was at par with the treatment T_5 (3783, 4600 kg/ha) and T_2 (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) $1x10^9$ spores / ml (93.3 %) followed by T-5 *M. rileyi* (AKP-Nr-1) $1x10^8$ spores / ml (86.67%) and T4- *M. rileyi* (AKP-Nr-1) $1x10^8$ spores / ml (80%) and low in T3- *M. rileyi* (AKP-Nr-1)

$1x10^6$ spores / ml(73.33%) ; T2- *M. rileyi* (AKP-Nr-1) $1x10^5$ spores / ml (70%) and T1: T6- *M. rileyi* (AKP-Nr-1) $1x10^4$ spores / ml(66.66%). T6- *M. rileyi (*AKP-Nr-1) $1x10^6$ 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 1.92×10^6 and 6.75×10^7 conidia/ml with fiducial limit ranging from 1.45×10^6 to 1.70×10^{10} and 1.97×10^3 to 1.08×10^9 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) $1x10^{10}$ spores / ml (84.01 %) and was on par with other treatments. Cob yield recorded high in T2 - *M. rileyi* (Anakapalle strain AKP-Nr-1)$1x10^{10}$ spores/ml (56.53 q/ha) and T4-*Metarhizium rileyi* (UAS,Raichur) $1x10^8$ 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) @ 1×1012 spores/ml (5g/L) and it was at par with *Metarhizium rileyi* (AKP-Nr-1) @ 1×10^{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) @ 1×1010 spores/ml (5g/L) and *Metarhizium rileyi* (AKP-Nr-1) @ 1×10^{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 thuriengiensis* @ 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 of15.97 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^{-1}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+ *Ha*NPV 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 – Azadirachtin + 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 Azadirachtin 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) @ 1×108 @ 5 gm/l (80.94%) and it was at par with *I. fumosorosea* (ICAR-NBAIR strain) @ 1×108 @ 5.0 g/l which recorded 79.79 per cent. Among the biocontrol agents, *B. bassiana* (ICAR- NBAIR-Bb-5a) @ 1×108 @ 5 gm/l recorded highest fruit yield of 18.56 t/ha and it was at par with *I. fumosorosea* (ICAR-NBAIR strain) @ 1×10^8 @ 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 x 10^8 Cfu/ g - 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 *Lecanicilium 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$^{-terminal\ shoot}$ after 3 sprays of azadirachtin and *L. lecanii* was found minimum (6.77^{-shoot}) in case of T5 which received sprays of Azadirachtin 1500 ppm @ 5.0 ml^{-l} followed by *Lecanicillium lecanii* (1x10^8 CFU/ml) @ 5.0 ml^{-l} and was statistically superior to all the bio pesticides used. One treatment of Fenazaquin 10 EC @ 0.4ml^{-l} recorded lowest cumulative population of two spotted spider mite (4.4 1) whereas three sprays of Nimbecidine 300 ppm @ 5.0 ml^{-l} 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 Chlorpyriphos 50 %+ Cypermethrin 5% EC. *L. lecanii* @ 10.0 ml^{-l} also caused 67.30 per cent reduction. However, at recommended dose (5.0 ml^{-l} 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 chlorpyriphos (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 *Steinernemma 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. guadeloupae*. 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. guadeloupae* treatment. A number of parasitized nymphs (live & blackened) & nymphs with parasitoid emergence holes/leaflet (3.62) was recorded in natural conservation of *E. guadeloupae* 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 colinies was recorded in the treatment with *Encarsia guadeloupae* 49.02 (44.4) and 52.80 (46.60) respectively. Similarly, after second spray prcent 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 Vallikunnan 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 *Myllocerous subfasciatus* on brinjal

IIHR: The mean number of ash weevils per plant were significantly lower in treatments *Heterorhabditis indica* @ 2.5 10^9 IJs ha^{-1} 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. anispoliae* 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) 1×10^8 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) 1×10^8 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* (Vl-8 strain). In case of aphid maximum reduction (49.45 PROC) was recorded with *Lecanicillium lecanii* (Vl-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* (V1-8 isolate) @ 5 ml/litre was the best treatment in reducing the mean population of aphid, *B. brassicae* (3.20/plant) and *P. xyllostella* (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* (V1-8 isolate) treated plot.

CAU Pasighat: Among the different biopesticides evaluated, T4-Vl-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 Cynantraniliprole 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 flourescence* 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_3 – *Metarhizium anisopliae* AAU strain Ma1 (3.70 thrips/plant) was the first effective treatment with lowest number of thrips/plant followed by T_6 – 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_3 – *Metarhizium anisopliae* AAU strain Ma1was found promising in getting higher bulb yield (113.67 q/ha), followed by T_6 – 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 pallescens* under polyhouse condition

KAU Thrissur: The mite population in plots where *B. pallescens* 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. pallescens @ 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 *Lecanicilium lecanii* (NBAIR Vl8) @ 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* (1x108 CFU/ml) @ 5.0 m-l + Nimbecidine 0.03% @5 ml-l > *L. lecanii* (1x108 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$^{\text{-flower bud}}$ (11.1) was observed in case of treatment with Propargite 57 % EC @ 2.0 ml^{-1} which was followed by *L .lecanii* ($1x10^8$ CFU/ml) @ 5.0 ml^{-1} + Nimbecidine 0.03% @ 5.0 ml^{-1} > *L. lecanii* ($1x10^8$ CFU/ml) @ 5.0 ml^{-1} > Nimbecidine 0.03% @ 5.0 ml^{-1} > 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.

IIRR: 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 famers' 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 *Ha*NPV (1.06 larvae/plant). Farmers practice recorded lowest pod damage (6.38%) followed by *Ha*NPV (12.46 %). Highest grain yield of 14.18q/ha was recorded in FP followed by *Ha*NPV (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, *Dorysthenes 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 chlorpyriphos (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*)1×10^8 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)*1×10^8 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*)1×10^8 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, Vijayrmpura 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), Dediyapada, Navsari Agricultural University, khedutshibir and training programmes were organized in the month of September 2020and 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 awreness 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
Total	**121**	**121**	**70**	**312**

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

Crop/Insect	**Experiments**	**Large Scale Demonstrations**
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	-
Total	**87**	**27**

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

Item of Expenditure	**Sanctioned and allotted grants (Rs. in lakh)**	**Grants released during 2020-21 from ICAR (Rs. in lakh)**	**Total expenditure (Rs.)**
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
TOTAL	**574.81**	**574.81**	**574.81**

PROCEEDINGS OF THE TECHNCIAL SESSIONS

The Significant achievements and recommendations of the various sessions are as follows.

PROCEEDINGS OF THE TECHNCIAL SESSIONS OF THE XXX ANNUAL GROUP MEETING OF AICRP-BC (14JULY 2021)

The ICAR-National Bureau of Agricultural Insect Resources, Bengaluru organized the Virtual XXX Annual Review Meet of All India Coordinated Research Project on Biological Control of Crop Pests on 14 July 2021.
Dr. N. Bakthavatsalam, Director, ICAR-NBAIR, Bengaluru & Project Coordinator, AICRP on Biological control welcomed the dignitaries and participants. He briefly presented the highlights of the project for the period 2020-21, which included the development, validation of promising bioagents under the project and area covered through the adoption of biocontrol modules. He also presented the progress in monitoring and management of the recent invasive pests and preparedness to tackle the invasive attacks.

Dr. Tilak Raj Sharma, Deputy Director General (Crop science), in his inaugural address appreciated the progress made in the project. He complemented ICAR-NBAIR forthe seventeen minutes documentary video produced by NBAIR and suggested to develop a short video of 3-4 minutes duration for presentation to dignitaries and VIPs on various aspects of biological control. He mentioned that validated microbes should be registered at ICAR- NBAIM with the bio efficacy and biosafety data. Presentations of the progress of various projects should be under various objectives, release of developed strains/ species of biocontrol agents, package of practicesof recommendations and validated biocontrol technologies along with the technical bulletin in the next annual review meetingand evaluation of the validated technologies for the management of plant diseases are some of the suggestions made by Dr Sharma. He also advised the AICRP BC to collaborate with other Plant Protection Institutes specially with ICAR-NIBSM and ICAR- NCIPM.

Dr.S.C. Dubey, Assistant Director General (PP& Biosafety) emphasized to prepare distribution maps to assess the spread and establishment of various natural enemies of pests and plant pathogens. The severity of rugose spiralling whitefly of coconut has to be indicated. Data on multilocational trials of the organisms should be used for final registration. The details of the technical programme should be clearly mentioned and all the centres should follow the technical programme without any deviation.

Experts nominated by ICAR: Dr H C Sharma, former Vice Chancellor, Dr YSPUHF, Solan, Dr H B Singh, Former Professor (Plant Pathology), BHU,Varanasi and Dr S K Jalali, former Head, ICAR NBAIR, Bengaluru. Former directors of NBAIR Dr. Abraham Verghese and Dr Chandish R. Ballal participated the annual meet. Around 109 scientists and five company representatives from different parts of the country participated in the XXX Virtual AICRP BC Workshop.

Plenary session of the meeting was held on 15th July at 3:00 PM under the Chairmanship of Dr. Tilak Raj Sharma, Deputy Director General (Crop science) and Dr S. C. Dubey, ADG (PP&BS) as Co-chairman. Dr Sharma stressed again in conducting meeting involving the NBAIR, NBAIM, NCIPM and NIBSM for future collaborations and exchange of materials. He highlighted the branding of the biocontrol products for further promotion. Finger print data have to be generated for all new strains. Locations of largescale demonstrations of proven technologies have to be informed to DDG (CS) to make visit to those fields.

Dr. S.C. Dubey, Assistant Director General (PP & Biosafety) mentioned that the efficient strains of microbes of NBAIR and NBAIM should be used. Stringent quality control measures of all microbial products, prioritization of Crops and pests / diseases for the intervention of microbial biocontrol agents, GPS based survey to assess and quantify the pests as well as their natural enemies, focussing on microbes with multiple traits and more experiments on the biological control of pests and diseases under protected cultivation are some of the points made by Dr Dubey. He reiterated that the draft revised guidelines for registration of biocontrol products exempt toxicological data for registration of safer biocontrol products. Microbes with multiple traits have to be focussed and validated in the future programmes.

Recommendation and Conclusions

SESSION I: Panel discussion for collaboration between institutes and AICRPs

Chairman : Dr. T.R. Sharma, DDG (CS)
Co-Chairman: Dr.H.B.Singh, Professor, BHU

Rapporteurs : Dr. A. Kandan, Deepa Bhagat
K. Selvaraj, ICAR-NBAIR

The session was intended to have inter-institutional collaboration on promising biocontrol and bio-control compatible technologies for management of insect pests and diseases. Dr. G. Sivakumar Chairman, AICRP on BC cell, ICAR-NBAIR, Bengaluru presented AICRP on BC technologies (crop-wise) available for large scale demonstration and validation

Speakers:

Dr. A K Saxena, Director, ICAR-NBAIM, Mau

- All the centres of AICRPs to be made as voluntary centres to evaluate biological control technologies against pests and diseases.
- Authenticated cultures of NBAIR/NBAIM may be provided to other crop based AICRPs for evaluation.
- Collaboration needed to further evaluate the technologies in large scale.
- Meeting should be conducted in time bound manner.
- It was suggested that 10 minutes presentation on biocontrol technologies by NBAIR/NBAIM to be made on all the crop based AICRP Annual meetings.

Dr Y.G Prasad, Director, ICAR-CICR, Nagpur

- Major problem in cotton is root knot nematode, root rot and pink bollworm. Biocontrol technologies should be evolved for the management of above pests through fruitful collaboration.
- The Biocontrol based IPM evolved for pink bollworm may be tested in Maharastra and Gujarat centres of AICRP-Cotton.
- More studies on the mass rearing field release techniques of *Braconhebetor* and *Braconlefroyi*which are recorded as important parasitoids on cotton pests.

Dr. R.Meenakshi Sundaram, Director, ICAR-IIRR, Hyderabad

- ICAR-IIRR ready to evaluate the ICAR-NBAIR *Trichoderma* spp. and *Pseudomonas fluorescens* strain for the management of seed and soil borne rice diseases in large scale.
- A meeting to be conducted between IIRR, NBAIR and NBAIM for the biocontrol technologies for the management of rice pests and diseases by IIRR.

Dr. Sujay Rakshit, ICAR-IIMR

- ICAR-IIMR is evaluating many technologies for the management of FAW in collaboration with ICAR-NBAIR.
- Availability of quality biocontrol agents especially parasitoids and predators is a major constraint for the uptake of biocontrol technologies
- Industry meet may be conducted by IIMR inviting the directors of NBAIM, NBAIR and NCIPM for detailing the biocontrol technologies available for commercialization.
- Officials of Department Agriculture, cooperation and farmers welfare may be informed about the mass rearing technologies of bioagents.

Dr. G.P. Dixit, Project Co-ordinator (Chick pea)

- ICAR-NBAIR technologies on *Bacillus thuringiensis*, *Metarhizium* and *NPV* strains to be evaluated in large scale on chick pea for the suppression of *Helicoverpa armigera*.
- Fusarium wilt and root rot diseases are another problem in chick pea. We are ready to collaborate with ICAR-NBAIR for the management of this diseases with the available technologies.
- Looking for collaboration with ICAR-NBAIR for Nanogel slow-release pheromone formulations for management of *Helicoverpa armigera* and *Spodoptera litura*
- Comatability of botanicals with biocontrol agents need to be studied.

- A meeting to be arranged with Directors of NBAIR and NBAIM on the biocontrol technologies for the management of pests and diseases of chickpea.

Dr. Pankaj Kaushal, Joint Director (Research), ICAR-NIBSM, Raipur

- ICAR-NIBSM is ready to collaborate with ICAR-NBAIR on the basic research and strategies for the management of pests and diseases.
- It was suggested to Dr Dubey to arrange a meeting between Directors of NBISM, NBAIR and NCIPM to study strategies to avoid overlapping in the programs between these institutions.
- ICAR-NBAISM was requested to invite all the Plant Protection institutions in its RAC meeting.

Dr. IP Singh, Project Co-ordinator (AICRP-Pigeonpea)

- In pigeonpea, pod borer and pod fly are the major problem and technologies for the production of *Bacillus thuringiensis* formulations may be passed to AICRP-Pigeonpea for the management of pigeon pod borer.
- Biocontrol technologies need to be developed for the management of pod fly.

Dr. Rajesh Kumar, Project Co-ordinator (AICRP-Vegetables)

- Fusarium wilt, Sclerotium rot in vegetables are major challenging diseases along with diamond backmoth in cabbage and root knot nematode in tomato as serious pests and diseases.
- Syrphid flies are very important insects as pollinators and biocontrol agents under protected cultivation .and technologies if any for their use need to be disseminated to the AICRP on vegetable.
- Effective collaboration was suggested between AICRP-Vegetables, NBAIR and NBAIM on evaluation of biocontrol technologies against insect pests and diseases of vegetables

Dr. Prakash Patil, ICAR-IIHR, Project Co-ordinator (AICRP-Fruits)

- Evaluation fruit fly parapheromone in large scale for the management of mango fruit fly is being done.
- Further Mango fruit borer and stem borer in guava and citrus is major problem.
- Biocontrol technologies using *Acerophagus papayae* for the management of papaya mealy bugs by ICAR-NBAIR may be demonstrated at relevant centres of AICRP_Fruits.
- Large scale demonstration of ICAR-NBAIR *Metarhizium ansiopliae* strain against mango leaf hopper along with IIHR *Metarhizium ansiopliae* strain will be undertaken.
- Efficient biocontrol technologies for management of whitefly, hoppers, fruit sucking moths and thrips are very much needed.

Dr.Maheshwarappa, Project Co-ordinator (AICRP-Palms)

- Rugose spiralling whitefly is a serious insect pest in coconut and oil palmbesides, tea mosquito bug is another serious pest on cocoa and cashew
- Technologies on mass production protocol for *Encarsia guadeloupae* for management of rugose spiralling whitefly may be shared with AICRP-Palms

- Pheromone technology developed for red palm weevil may be demonstrated at AICRP-Palm centres

Dr. Balraj Singh, Project Co-ordinator (Pollinators)

- NBAIR can share its expertise on biosystematics for the taxonomic identification of honey bees and pollinators.
- ICAR-NBAIR technologies on Stingless bees and syrphid mass production protocols if any may be passed on to AINP-Pollination
- Study on diseases of honey bee and their management through biological control method may be studied as a collaborative study
- Project coordinator may write a letter to director NBAIR regarding the technologies needed and also inviting him for the meeting propose on 9th October under intimation to ADG (PP&BS)

Dr. Srinivasa, Project Coordinator (AICRP on Acarology)

- Yellow mite in mulberry is a serious pest and any biocontrol technologies for the management of yellow mite can be evaluated by AICRP-acarology
- Also expecting the protocols for long term storage of potential predatory mites
- Project co-ordinator was requested to develop a meeting to work out collaboration between NBAIR and AICRP-on Acarology

Dr. Uma Rao, Project Coordinator (AICRP-Nematodes) & Head, Division of Nematology, IARI

- In polyhouse root knot nematodes management is a challenging problem.
- Compatibility of biocontrol agents for the management of nematodes is urgently needed.
- A meeting with all stakeholders including NBAIR, NBAIM, NCIPM and PC, AICRP-fruits should be arranged in 15 days time.

Session II: Basic Research on Biodiversity and natural enemies of insect pest at NBAIR and Biological control of plant diseases

Chairperson: Dr. Chandish. R. Ballal, Former Director, ICAR-NBAIR, Bengaluru

Speakers : Dr. K. Sree Devi, ICAR-NBAIR, Bengaluru,
Biodiversity, Biosystematics,Molecular Characterization and Biocontrol Potential of Bioagents (NBAIR)
Dr. U. Amala, ICAR-NBAIR, Bengaluru, Biodiversity and Pest Outbreak reports
Dr.Roopali Sharma, GBPUAT, Pantnagar, Biological control of Plant diseases using antagonists

Rapporteurs: Dr. Jagadeesh Patil, ICAR-NBAIR, Bengaluru
Dr. Neelam Joshi, PAU, Ludhiana

Achievements

- 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.
- 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.
- *Isaria fumosorosea* (strain ICAR-NBAIR pfu-5) was effective against all the developmental stages of *A. rugioperculatus* and *Aleurotrachelus atratus* to extend of 58-80% under field conditions.
- The percentage reduction of FAW larval population was found to be 37.5% at 2.5×10^8 IJs ha^{-1} and 73.33% at 5×10^8 IJs ha^{-1} for *S. carpocapsae* while for *H. indica* the percentage mortality was 54.17% at the rate 2.5×10^8 IJs ha^{-1} and 89% at the rate 5×10^8 IJs ha^{-1}
- Around 26 populations of *Spodoptera frugiperda* were received from different parts of the country, were molecularly characterized and barcoded. Invasive cassava mealybug, *Phenacoccus manihoti* was identified using *cytochrome oxidase* I gene (*CO-1*) for the first time in India and DNA barcode was generated for the same.
- The alien invasive pests, *viz*., *Brontispa longissima*, *Aleurodicus dugesii*, *Phenacoccus madeirensis* were not recorded in any of the centre during the year 2020-2021.
- Minimum Sheath blight (*Rhizoctonia solani*) disease severity and minimum percentage of Brown spot (*Drechslera oryzae*) was recorded with PBAT-3 (Pant Biocontrol agent) in Rice.
- Among the treatments where different combinations of *Trichoderma* and *Pseudomonas* evaluated as soil application, root dip and foliar spray, the treatment T6- Th+ Pf (SA + RD) + Azoxystrobin 23% SC (FS) found effective in reducing the early blight disease intensity (9.26%) in tomato.
- Treatment combination comprising of seed treatment with *Trichoderma asperellum* formulation @10g/kg seed+ soil application of *T. **a**sperellum* formulation after mixing with FYM (10g/Kg FYM) @40g/m^2) was the most effective in reducing the Fusarium wilt/ root rot of pea incidence and resulting in the highest pod yield.

Session III. **Biological suppression of pests of Food and Fibre**

Chairman : Dr. S. K. Jalali, Former Head, ICAR NBAIR, Bengaluru
Co-Chairman: Dr. Sunil Joshi, ICAR NBAIR, Bengaluru

Speakers: **Dr. Chitra Shanker**, ICAR-IIRR, Hyderabad, Rice
Dr. ArunkumarHosamani, UAS, Raichur, Maize & Sorghum
Dr. M. Visalakshi, ANGRAU, Anakapalle, Sugarcane
Dr. Jeyarajan Nelson, TNAU, Coimbatore, Cotton
Dr. N. Chalapathirao, HRS, Ambajipeta, Coconut

Rapporteurs : Dr. M.Mohan, ICAR-NBAIR, Bengaluru
Dr. B. L. Raghunandan, AAU, Anand

Achievements:

- 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 in sugarcane.
- BIPM package in cotton 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 farmer's practices (0.39/plant), more no. of parasitized larvae/plant (6.07/plant) and boll infestation (46.23%) and yield of 3.99a/acre.
- 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 paddy, 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).
- In maize, 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).
- In finger millet, there was 67.5 and 59.7 % reduction in dead hearts over the control in treatment with Ma-35 @10 ml /lt and treatment with 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.
- Per cent reduction in whitefly intensity was observed high in Treatment- *Isaria* sprays + *Encarsia* release (70.6%) after two sprays than one spray (31.67%) and in Treatment – *Isaria* sprays + *Dichocrysa* release (70.6%) after two sprays than one spray (31.67%)

Session IV: Biological suppression of pest of Oil seeds and Pulses

Chairman : **Dr.H. C. Sharma**, Former Vice –Chancellor, Dr. YSPUHF, Nauni, HP &Chairman, RAC, ICAR-NBAIR, Bengaluru
Co-chairman : **Dr.A. N. Shylesha**,HOD, DGCU, ICAR- NBAIR, Bengaluru

Speakers : **Dr B. L. Raghunandan**, AAU, Anand, Pulses

Dr G. Anitha, PJTSAU, Hyderabad, Oil seeds

Rapporteurs : **Dr. Galande**, MPKV,Pune
Dr. Omprakash Navik, ICAR-NBAIR, Bengaluru

Achievements:

- 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.
- *Bacillus thuriengiensis* @ 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 of15.97 q/ha and on par with chemical check.
- 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%). Maximum yield (18.83 q/ha) was recorded in chemical control and it was not significantly different from BIPM 2 (18.02 q/ha).

- Leaf webs per green gram 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 – Azadirachtin + Bt (5.38 q/ha) and T2 -Bt two sprays (5.33 q/ha)

Session V: Biological Suppression of Pests of fruits, Vegetables and Polyhouse crops

Chairman : **Dr.TusarKanti Behera**, Director, ICAR-IIVR, Varanasi
Co-chairman: **Dr M. Nagesh**, HOD, DGR, ICAR-NBAIR, Bengaluru
Speakers : **Dr. B. R. Jayanthi Mala**, ICAR-IIHR, Bengaluru, Tropical and Temperate fruits
Dr.Jaydeep Halder, ICAR-IIVR, Varanasi, Vegetables, Polyhousecrops & Flowers
Rapporteurs : **Dr. P. S. Shera**, PAU, Ludhiana
Dr. M. Sampath Kumar, ICAR-NBAIR, Bengaluru

Achievements

- In Mango, among the bio-pesticides, low incidence of mango thrips was observed in *B. bassiana* (CISH formulation) which registered 7.00 thrips/ panicle at 7 days after spraying.
- In Guava, significantly highest percent reduction in mealybug 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.
- There was a significant reduction in the plant parasitic nematodes (PPN) in guava 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 x 10^8 Cfu/ g - 10g each/ plant multiplied in 3kg of FYM it was on par with the treatment with Carbofuran 10 G @ 25g per plant.
- Among different biocontrol agents evaluated, *Heterorhabditis bacteriophora* (5000IJs/gallery) was the most effective resulting in 80 per cent mortality of leopard moth, *Zeuzera multistrigata* in apple followed by *Steinernemma feltiae* (5000IJs/gallery) and azadirachtin (2ml/L of 1500ppm; 10ml/gallery) (66.7% each).
- Fruit damage by *H. armigera* was lesser (4.25-5.5%) in BIPM package and farmers package compare to control (10%).
- The mean number of ash weevils per brinjal plant were significantly lower in treatments *Heterorhabditis indica* @ 2.5 10^9 IJs ha^{-1} and *M. anisopliae* NBAIR followed by *B. bassiana* NBAIR and *B. bassiana* AAU strains.
- 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).

- In Cabbage, among the different biopesticides *L. lecanii* (V1-8 isolate) @ 5 ml/litre was the best treatment in reducing the mean population of aphid, *B. brassicae* (3.20/plant) and *P. xyllostella* (4.15/plant), with 66.14 and 57.65 per cent reduction over control.
- In Onion, among the different biopesticides evaluated, *Metarhizium anisopliae* AAU strain Ma1 (3.70 onion thrips/plant) was the first effective treatment with lowest number of thrips/plant followed by Azadirachtin10000 ppm (4.98 thrips/ plant).
- The mite population in plots where *B. pallescens* 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.
- The mite population in treated cucumber plots under polyhouse condition 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.

VI. Academia –Industry interactions

Chairman :**Dr. N Bakthavatsalam**, director ICAR-NBAIR
Co-chairman :**Dr. S. K. Jalali,** Former Head, ICAR NBAIR, Bengaluru

Speakers :**Dr. A. Kandan**, Principal Scientist, ICAR- NBAIR, Bengaluru
Dr.Sithanantham, Sun Agro Biotech, Chennai
Dr. Dinesh Shetty, Ponalab, Bengaluru
Dr. A. John Peter, Varsha Bioscience Tech Pvt Ltd
Dr. Natraj, Multiplex Biotech Pvt ltd, Bengaluru
Mr. Ramji Mangukia, Managing Director,Agriland biotech
Rapporteurs :**Dr. Jaydeep Halder**, ICAR- IIVR, Varanasi
Dr. Richa Varshney, ICAR- NBAIR, Bengaluru

Specific recommendations

- Uniformity in treatments, number of treatments and replications should be followed for each experimental trial across the locations for better statistical analysis and interpretation of data (All centres)
- While recording pest incidence, instead of mentioning as low, moderate and severe incidence,quantified data has to be presented (All centres)
- For the survey programme, the PC cell has to fix the standard methodology, which has to be followed by centres.
- Future surveys should cover unexplored areas in collaboration with the centres of AICRP-BC or other crop AICRP centres which are located in that region (All centres).
- Formulation of microbials can be used instead of using pure culture in the experiments (All centres).
- The accession number of microbial agents, based on cataloguing at the institute level, to be mentioned in the experiments; and the same isolates must be

submitted to ICAR-NBAIM, Mau, to get the national accession number. Both the local accession numbers to be mentioned (All centres)

- Centres can try to develop mass production protocols for the promising natural enemies recorded on specific crops and pests (All centres)
- The data on whitefly species distribution should include information on the natural enemy in those regions. (CPCRI Kayankulam, HRSAmbajipetta)
- *Isaria fumosorosea* can be tested against RSW infesting banana (HRS, Ambajipetta)
- Information should be presented on the cultures maintained and supplied by the centres (All centres).
- In the experiments where BIPM module is compared with farmers practice, recommended package of practice by respective university has to be included instead of farmers practice as a check (All centres)
- In case of coconut rugose spiralling whitefly (RSW) experiments, neem oil is proved to be very effective, therefore, it may be included as one of the components in large scale demonstration trial (Coconut centres). Since *Isaria fumosorosea* has been observed to be compatible with parasitoid, *Encarsia*, further observation of emergence holes of the parasitoid can be examined for confirmation of any mitigation effect of fungus (Coconut centres)

General recommendations

- GB Pant University should supply their promising isolates / formulations to be tested in other centres facing disease problems (GBPANT)
- The source of microbials has to be mentioned in all reports and presentations (All centres).
- If a centre is presenting information on occurrence of the invasive papaya mealybug, it should accompany information on parasitism by *Acerophagus papayae.*
- Centres should aim to cover larger areas in their biocontrol trials (All centres).
- While reporting *Fusarium* species as pathogenic to insect pests, proper care has to be taken to study pathogenic effect of crops as majority of *Fusarium* species are plant pathogenic in nature (All centres)
- Adequate pest/disease incidence to be ensured before imposing treatments for optimal results (All centers)
- The production protocol for production of *Metarhizium rileyi* be shared with the other AICRP Centers for the production of the inoculum (Action: UAS, Raichur)
- Biological control interventions should be compatible with the recommended insecticides for the management of chickpea pests, or they should be alternated with insecticide application in case of severe outbreaks (Action: All AICRP Centres)
- Selection of companion crops in ecological engineering should be based on the philosophy of source (of the natural enemies) or as a sink for the pest (as a trap crop), and practicable by the farmers and fit into the cultivation practices in a region (Action: SKUAST, Jammu).

- Evaluation of biopesticides for pest management under poly-house conditions should be intensified with more experiments and generate adequate data (YSPUHF, Solan).
- A standard isolate (s) should be included as standard check in evaluation trials with any new/local isolate (s) for comparative performance.
- Relook data again before concluding the experiment on Bio-intensive insect pest management in brinjal as damage percentage is quite high in treatments (KAU Thrissur)
- Research works should be concentrated on development of more robust strains of biocontrol agents with additional attributes
- Consortia of microbials with longer shelf life have to be developed and validated for combating complex crop pests and diseases.
- All the institutes and AICRPs/AINPs should contact NBAIR/NBAIM/NCIPM for the biocontrol technologies/cultures and other technologies with the prior intimation to ADG PP within 15 days.
- Provision for admitting emergency registration of microbials without toxicological data to deal with invasive insect pests
- Partnership research involving private firms to be promoted to scale up the validated biocontrol agents.
- Funding from private organizations has to be explored to carry out more research to develop smart biocontrol agents with longer shelf life
- All the directors of plant protection institute should be invited to participate the NBAIR industry meet and directors of the institutes should have frequent physical meeting and formal collaboration on biocontrol.

LIST OF PARTICIPANTS

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Experts & Special External Invitees

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ACRONYMS

AICRP-BC	All India Coordinated Research Project of Biological Control of Crop Pests, Bengaluru
NBAIR	National Bureau of Agricultural Insect Resources, Bengaluru
AAU-A	Anand Agricultural University, Anand
AAU-J	Assam Agricultural University, Jorhat
ANGRAU	Acharya N.G.Ranga Agricultural University, Anakapalle
GBPUAT	Gobind Ballabh Pant University of Agriculture and Technology, Pantnagar
KAU	Kerala Agricultural University, Thrissur
MPKV	Mahatma Phule Krishi Vidyapeeth, Pune
PAU	Punjab Agricultural University, Ludhiana
PJTSAU	Pandit Jayashankar Telangana State Agricultural University, Hyderabad
SKUAST	Sher-e-Kashmir University of Agricultural Science & Technology, Srinagar
TNAU	Tamil Nadu Agricultural University, Coimbatore
YSPUHF	Y.S. Parmar University of Horticultural and Forestry, Solan
CAU	Central Agricultural University, Pasighat
MPUAT	Maharana Pratap University of Agriculture & Technology, Udaipur
OUAT	Orissa University of Agriculture & Technology, Bhubaneswar
UAS-R	University of Agricultural Sciences, Raichur
IGKV	Indira Gandhi Krishi Viswavidhyalaya, Raipur
KAU RARS	KAU-Regional Agricultural Research Station, Kumarakom
KAU RARS	KAU-Regional Agricultural Research Station, Vellayani
YSRUH	Dr. Y S R Horticultural University, Ambajipeta
UBKV	Uttar Banga Krishi Vishwavidyalaya, Pundibari, West Bengal
CISH	Central Institute of Subtropical Horticulture, Lucknow
CPCRI	Central Plantation Crops Research Institute, Kayamkulam
CTRI	Central Tobacco Research Institute, Rajahmundry
IIHR	Indian Institute of Horticultural Research, Bengaluru
IIRR	Indian Institute of Rice Research, Hyderabad
IIMR	Indian Institute of Millet Research, Hyderabad
IIVR	Indian Institute of Vegetable Research, Varanasi
NCIPM	National Centre for Integrated Pest Management, New Delhi

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