Theme 6: Consolidating ecologically compatible and sustainable insect pest management strategies for conventional, transgenic and organic cotton

6.1 Project Name: Investigations on bioefficacy of entomopathogens against cotton pink bollworm, *Pectinophora gossypiella* (Saunders)

Name of PI & Co-PIs: Dr. V. S. Nagrare (PI), CO-PIs - Dr. Chinna Babu Naik, Dr. S.P. Gawande, Dr. Dipak T. Nagrale, Dr. K. Velmourougane , Dr. J. Gulzar Banu

Importance of the study: In recent years, he pink bollworm (PBW), *Pectinophora gossypiella* (Saunders) has re-emerged as a serious pest of cotton in India. The chemical control for PBW is very difficult as the larvae are internal feeders live inside the green bolls. Entomologists are exploring the possibility of using entomopathogens as biological control agents, and the researchers are working towards possible expoitation of entomopathogens (bacteria, fungi, virus, EPN and protozoa) for the control of many insect pests. The project aims to explore potential of entomopathogens for management of pink bollworm in field conditions.

Salient findings

Efficacy of entomopathogens against pink bollworm under field conditions

Biopesticides *viz*., *Beauveria bassiana* (Source: Raichur, Dharwad, Rahuri), *Lecanicillium lecanii* (Source: Raichur, Rahuri), *Metarhizium anisopliae* (Source: Raichur, Dharwad, Rahuri), HaNPV (Source: Rahuri), SlNPV (Source: Rahuri), Neem oil along with chlorpyriphos 20EC as control were evaluated under field conditions.

Characterization of entomopathogens associated with larval infections of *P. gossypiella* collected from different geographic locations

- Isolations of entomopathogens were carried out from dead infected larvae of *P. gossypiella* collected from the different field locations.
- Isolated 12 bacterial and 10 fungal isolates from infected larvae.
- Bioassay studies are being carried to screen the isolates for their bioefficacy against *P. gossypiella* larvae.

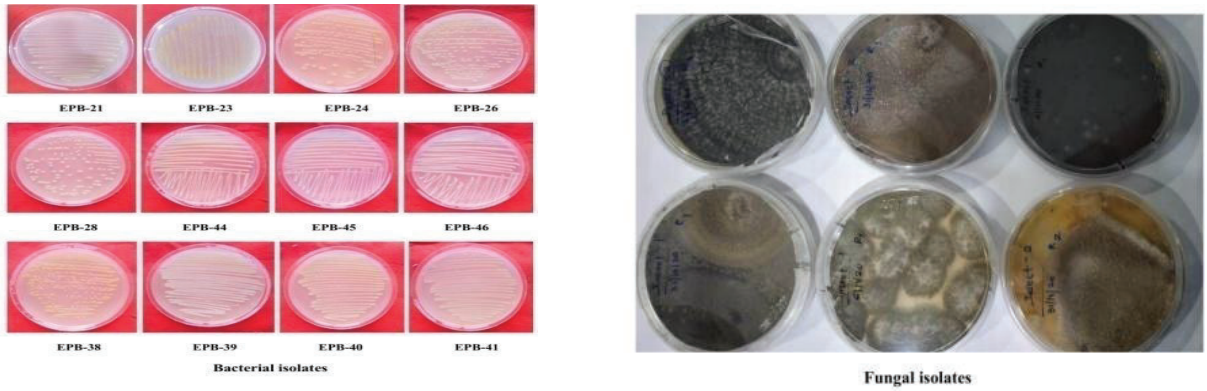


Fig. 6.1.1 Bacterial and fungal isolates obtained from dead larvae of pink bollworm

6.2 Project Name: Crop pest surveillance and advisory project (CROPSAP) in Maharashtra

Dr. V. S. Nagrare (PI)

Importance of the study: Government of Maharashtra has formulated and implemented an innovative project based on Information and Communication Technology (ICT) in the field of plant protection from 2009-10. It's an e-pest surveillance and advisory project. It has helped immensely to protect soybean, cotton, rice, tur and gram crops from pest damage. Consistent pest monitoring and adoption of appropriate pest management strategies at proper crop growth stages of the crop have been implemented. The work assigned to ICAR-CICR was i) to formulate IPM strategies for cotton, ii) to develop pest specific advisory capsules, iii) to visit hot-spots for guidance to farmers and field functionaries and iv) to get feedback for future research and developing IPM Strategies.

Salient findings

- Disseminated cotton pest management strategies through ICT tools
- Updated pest management strategies for target pests, monitored online pest situation through real time pest data uploaded on website.
- Analyzed pest situation weekly and issued advisory accordingly.
- Provided technical guidance to Agri. Department on pest management aspects as and when required.
- Since 2017-18, played proactive role in devising and dissemination of pink bollworm management strategies along with action plan to be executed by the cotton production stakeholders.
- Created mass awareness among cotton production stakeholders through print and electronic media, talks, press notes, articles in newspaper and magazines, TV, Radio, literature etc.

Other research works carried out at the institute level under CROPSAP

Population dynamics of sucking pests

Population of sucking pests *viz.*, jassid, whitefly and thrips were slightly higher in number during initial period of season however, decreased over the season and below ETL (Fig 6.2.1). Aphid population started increasing from 44 SW (6-12 Nov) and peak was recorded at 46 SW (20-26 Nov) (Fig 6.2.2).

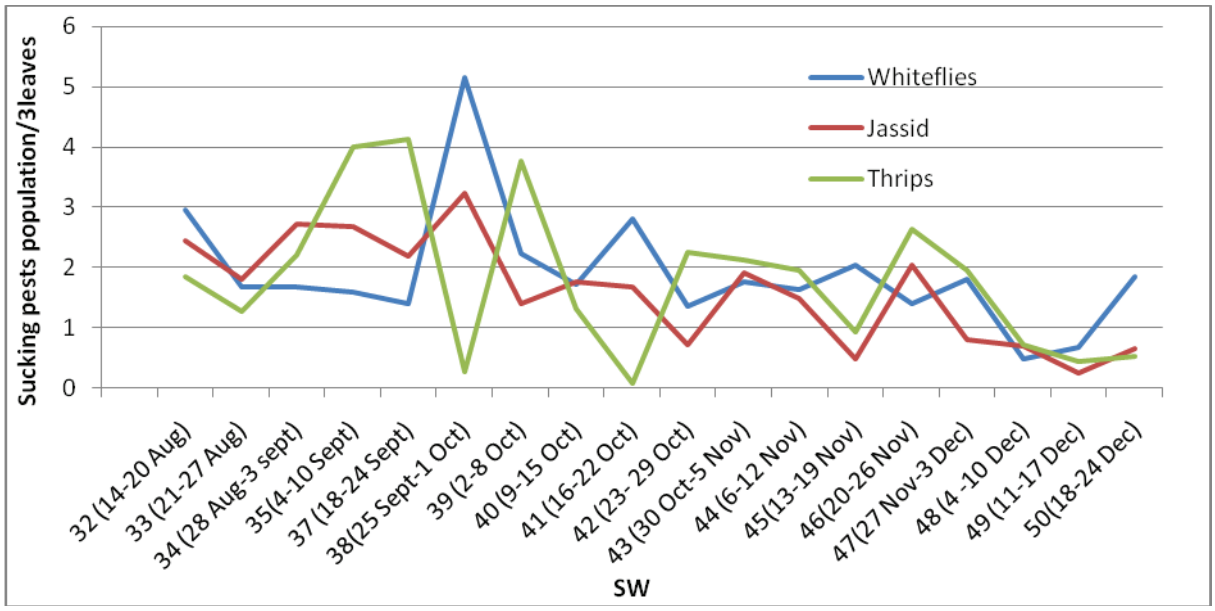


Fig.6.2.1: Population dynamics of sucking pests over the season in RCH 2 during 2020

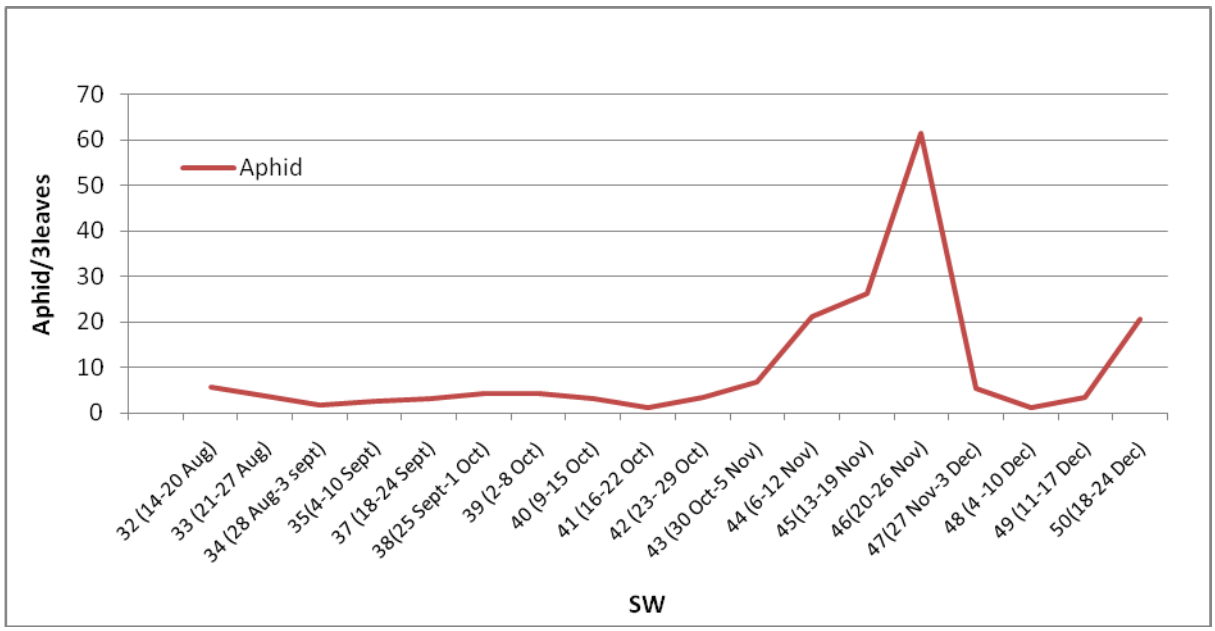


Fig.6.2.2: Population dynamics of aphid over the season in RCH 2 during 2020

Pink bollworm infestation in non-Bt and Bt cotton

In non Bt cotton (Suraj) pink bollworm infestation was recorded above ETL (>10% green boll infestation) starting from 37 SW (18-24 Sept) and subsequently remained above ETL till end of the season except during 39 SW (2-8 Oct) infestation ranged close to ETL (10% green boll infestation). While in Bt cotton (RCH 2 BGII) pink bollworm infestation started during 44 SW (6-12 Nov) and increased with the progress of season. Both Bt and non Bt cotton were found infested by pink bollworm with higher infestation recorded in non-Bt cotton. (Fig 6.2.3).

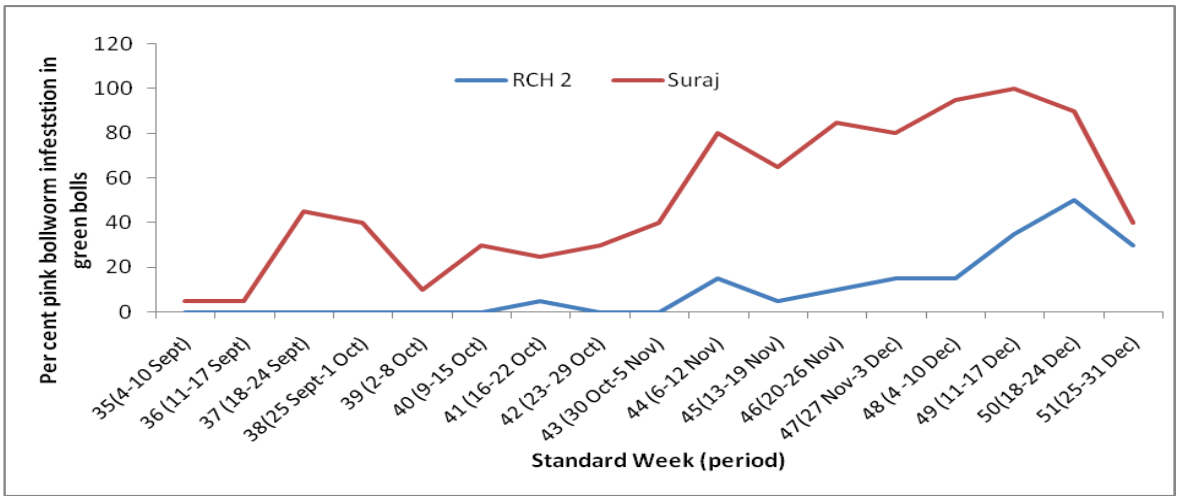


Fig 6.2.3: Pink bollworm infestation in Bt and non-Bt cotton during 2020

Pheromone trap catches

During 2020, moth catches of American bollworm and spotted bollworm were recorded to be negligible. Maximum moth catches (4 moths /trap/week) of American bollworm was recorded at 46 SW (20-26 Nov) while spotted bollworm moth catches were negligible (<1 moth /trap/week) over the season. Pink bollworm moth activity was seen starting from 38 SW (25 Sept-1 Oct) remained low till 42 SW (23- 29 Oct) and again started increasing from 43 SW (30 Oct-5 Nov), peak was recorded (45.6 moths/ trap/ week) at 48 SW (4 -10 Dec) and thereafter started decreasing. Though higher number of moth catches of tobacco caterpillar was recorded, however, infestation in the field was negligible (Fig 6.2.4).

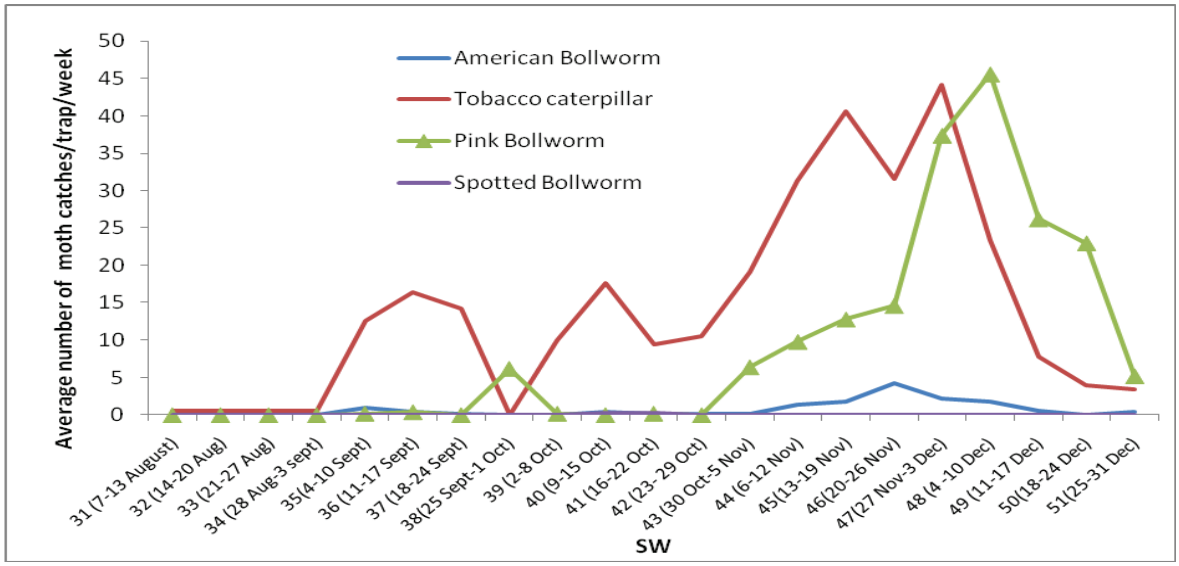


Fig 6.2.4: Pheromone trap catches during 2020 (Nagpur)

Yellow sticky trap catches

Jassid population was initially high (236 jassid/trap/week) on 35 SW (4-10 Sept), decreased with the progress of the season but again started increasing (298 Jassid/trap/week) at the end of the season 48 SW (4 -10 Dec). Populations of whitefly were fluctuated over the season, peak (219 whitefly/trap/week) was recorded at 49 SW (11-17 Dec) (Fig 6.2.5).

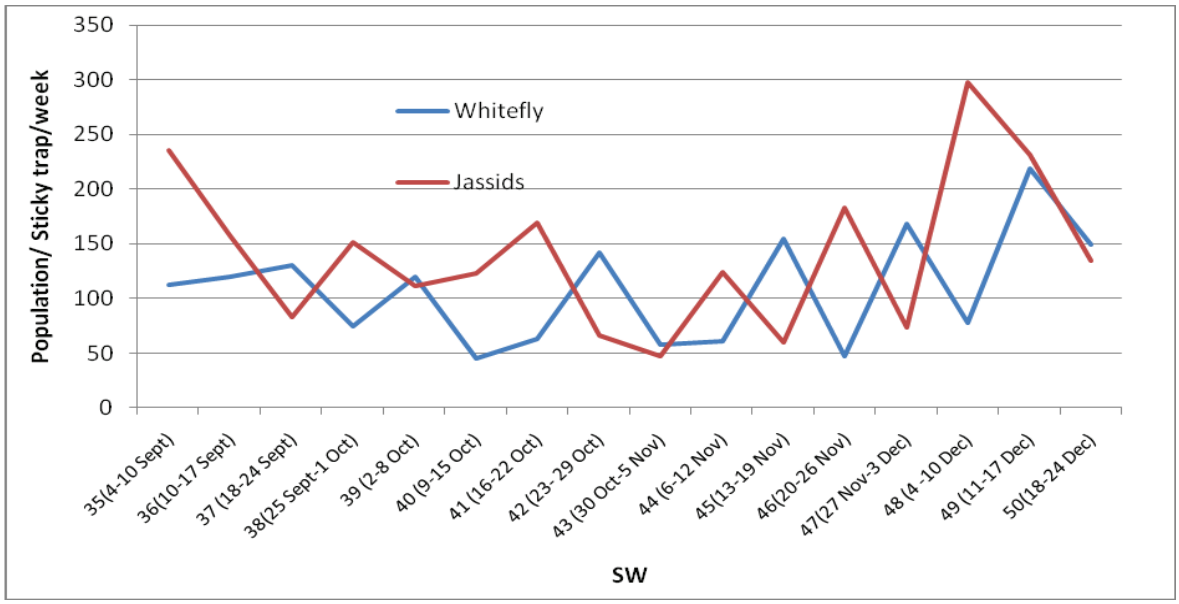


Fig 6.2.5: Sticky trap catches of Jassid and whitefly during 2020 (Nagpur)

6.3 Project Name: Insecticide resistance management: Dissemination of pink bollworm management strategies

Dr. V. S. Nagrare (PI), Co-PIs- Dr. V. Chinna Babu Naik, Dr. S.P. Gawande, Dr. S. M. Wasnik, Dr. B.B. Fand, Dr. D.T. Nagrale, Dr. S.S. Patil, Dr. K. Rameash, Dr. Rishi Kumar

Importance of the study: Pink bollworm, *Pectinophora gossypiella* (Saunders) has emerged as a serious threat to the cotton in all the three cotton growing regions of India. The project was approved during 2018-19, continued during 2019-20 and 2020-21 with the major objective of disseminating pink bollworm management strategies in Bt cotton in eight major cotton producing states (Maharashtra, Gujarat, Madhya Pradesh, Andhra Pradesh, Telangana, Karnataka, Tamil Nadu and Haryana). A project is funded by Department of Agriculture, Cooperation and Farmers' Welfare (Crops Division), Ministry of Agriculture and Farmers' Welfare, Govt. of India.

Salient findings

The project was implemented by ICAR-CICR as a nodal agency and the collaborating SAUs were: Dr PDKV, Akola; VNMKV, Parbhani; MPKV, Rahuri; NAU, Navsari; JAU, Junagadh; RVSKVV, Gwalior; UAS, Dharwad; UAS, Raichur; PITSAU, Hyderabad and ANGRAU, Guntur. It was implemented in 105 villages of 21 districts covering 1050 acres area of 8 states. IRM strategies implemented through the project comprised of management measures like cultural (timely sowing and timely termination of crop), behavioural (pheromone trap), biopesticides (Neem formulation), bio control agents (parasitoid *Trichogramma bactrae*), need based pesticides application (chemical insecticides), etc. During crop season various outreach activities carried out were field visits,

farmers' meetings, field days, farmers' field trainings, sensitization workshop for ginning mill owners/input dealers, broadcasting voice messages, TV talks, radio talks, lectures etc. Random surveys were also conducted during the crop season.

Scenario of pink bollworm infestation in cotton based on random surveys

Random surveys were conducted in IRM implemented 13 districts in the month of October. The district wise pink bollworm infestation recorded in different states was **Maharashtra** (9 districts): Akola 12-76%, Buldana 40-45%, Yavatmal 44-48%, Nanded 11-83%, Parbhani 58-75%, Jalna 3-69%, Nagpur 9-56%, Wardha 4-64%, Amravati 9-42%; **Gujarat** (1 district): Bharuch 5-40%, **Madhya Pradesh** (1 district): Khandwa 18-68%, **Karnataka** (1 district): Raichur 0-40%, **Andhra Pradesh** (1 district): Guntur 0-85%. At the time of roving survey 1-2 pickings were completed.

6.4 Project Name: Elucidating eco-toxicity and resistance development in sucking pests against newer insecticides used in cotton

Dr.V. S. Nagrare (PI), Co-PIs- Dr. V. China Babu Naik, Dr. B. B. Fand

Importance of the study: Sucking pests have assumed serious proportions in cotton especially in the era of post Bt-cotton phase. Exposure of insects to sub lethal dose of insecticides may enhance the development of resistance and reproductive fitness of insect pests. Certain insecticides exhibit stimulating effects in the plants *e.g.* acephate, monocrotophos application shows greening effect in cotton. Similarly, insecticidal enhancement of fecundity under temperature stress has been reported in few insects. Very

scanty information is available on these aspects and the same was seriously lacking for the sucking pests of cotton. Present work was conducted to understand the ecotoxicological aspects of sucking pests of cotton in the context of changing pest scenario and predicted climatic changes.

Salient findings

Phytotoxicity and growth stimulating effects on cotton crop and yield

An experiment was conducted to understand phytotoxicity and growth stimulating effect on cotton plants and crop yield with five insecticides *viz.*, clothianidin 50%WDG, spiromesifen 22.9%SC, dinotefuran 20% SG, flonicamid 50% WG, thiacloprid 21.7% SC along with control. The dosages of insecticides taken were at X, 2X and 4X. The treatments were imposed at 60, 75 and 90 DAS. No noticeable phytotoxicity and growth stimulating effects were observed with the imposed insecticidal treatments. Differences with the different dosage of insecticides on pests and natural enemies' species composition were minor. Yields did not vary significantly among the treatments.

Monitoring of resistance development in sucking pests against newer insecticide

Monitoring of resistance development in leafhopper against newer insecticides *viz.*, acetamiprid, clothianidin, dinotefuran, flonicamid, imidacloprid, spiromesifen, thiamethoxam and monocrotophos was taken up with population of Nagpur, Wardha and Yavatmal. It was observed that leafhopper populations of these districts are still susceptible to the tested insecticides.

Changes in species composition with newer insecticides

There was no distinct change in species composition with insecticides clothianidin 50%WDG, spiromesifen 22.9%SC, dinotefuran 20% SG, flonicamid 50% WG, thiacloprid 21.7% SC with three concentrations (X, 2X, 4X).

Toxicity of newer insecticides to natural enemies

Toxicity of above insecticides with three concentrations (X, 2X, 4X) on the population of natural enemies *viz*, coccinellids, chrysopa and spiders was assessed. Analyzed data indicated insignificant difference in the population of natural enemies among insecticides with chosen concentrations.

Influence of insecticides on survival and fecundity in cotton aphids under thermal stress

Development time and survival of aphids under different temperatures was assessed for insecticides flonicamid and imidacloprid at five different concentrations. Mortality enhancement with temperature increase was observed in flonicamid and imidacloprid. We could not assess the fecundity of aphids because of very low survival due to insecticide treatments.

Relative efficacy of different coloured sticky traps against whitefly

An experiment was conducted by taking 10 different coloured sticky traps to evaluate their relative performance in attracting whiteflies. It was observed that highest whitefly adults were trapped in yellow-daffodil sticky trap followed by Yellow-orange appeal sticky trap. Remaining colors were least effective in attracting whiteflies.

6.5 Project Name: Identification of oviposition deterrents for ethological management of cotton boll worm *Helicoverpa armigera* (Hübner)

Dr. Rachna Pande(PI), Co-PI- Dr. Vivek Shah

Importance of the study: Semiochemicals are the acceptable alternatives for the management of insects as they alter the behaviour of insect. In recent years, among the semiochemicals, oviposition deterrent was the most explored field. In the present study the oils containing the fatty acids as a component were evaluated both under laboratory and field conditions. Selection of oils was based on the oviposition deterrent compounds identified in previous year through GC-MS.

Salient findings

- Seven different vegetable oils *viz*., groundnut, sunflower, rice bran, soybean, safflower, sesame and palm oil were evaluated against *H. armigera* at different concentrations (1, 2, 4 and 8 %) for cotton and (0.5, 1 and 2 %) for chickpea.
- Selection of oil was based on the presence of oviposition deterrent compounds which were identified earlier *viz*., linoleic acid, palmitic acid, myristic acid and stearic acid.
- Performance of all the oils was significant in comparison to control.
- In cotton, at the concentrations of 2% and above, the population was reduced below ETL up to 15 days after spraying, whereas at lower concentrations of 1%, the population was below ETL upto 10 days only.
- In case of chickpea, oils were effective at concentrations of 1% and 2%.
- Blend of these oils was also evaluated in cotton field and it was found that all the blends were effective against *H. armigera* in comparison to control.

6.6 Project Name: Investigations into exacerbation of pest status of cotton pink bollworm *Pectinophora gossypiella* (Saunders) in the context of climate change through development of phenology model.

Dr. Babasaheb B. Fand (PI), CoPI- Dr.V.S. Nagrare, Dr.V. Chinna Babu Naik

Importance of the study: *Pectinophora gossypiella* has recently emerged as a major concern for cotton especially in central and southern parts of India, due to development of resistance in this pest against the Bt-toxins. The problem of pink bollworm damage in

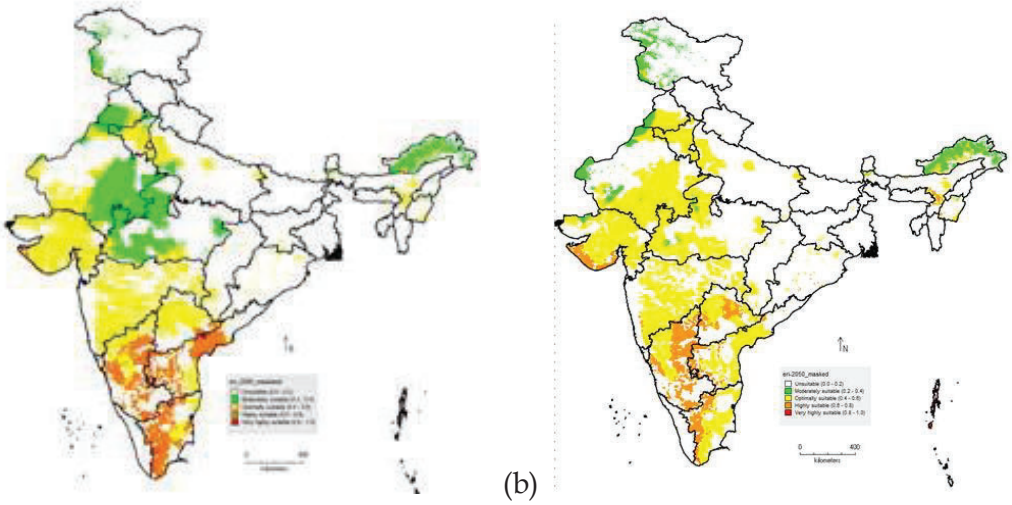
cotton is likely to worsen in future due potential climate change. Hence, the detailed knowledge on various aspects of *P. gossypiella* bio-ecology e.g. temperature – dependent population growth potential, thermo tolerance limits, initiation and peaks of infestation in a seasonal cycle, reproductive fitness and resistance to insecticides under thermal stress, etc. is of paramount importance to know how the pest will respond to predicted climatic changes.

Salient findings

Predicting the impact of climate change on abundance of pink bollworm through phenology modeling and GIS-based risk mapping

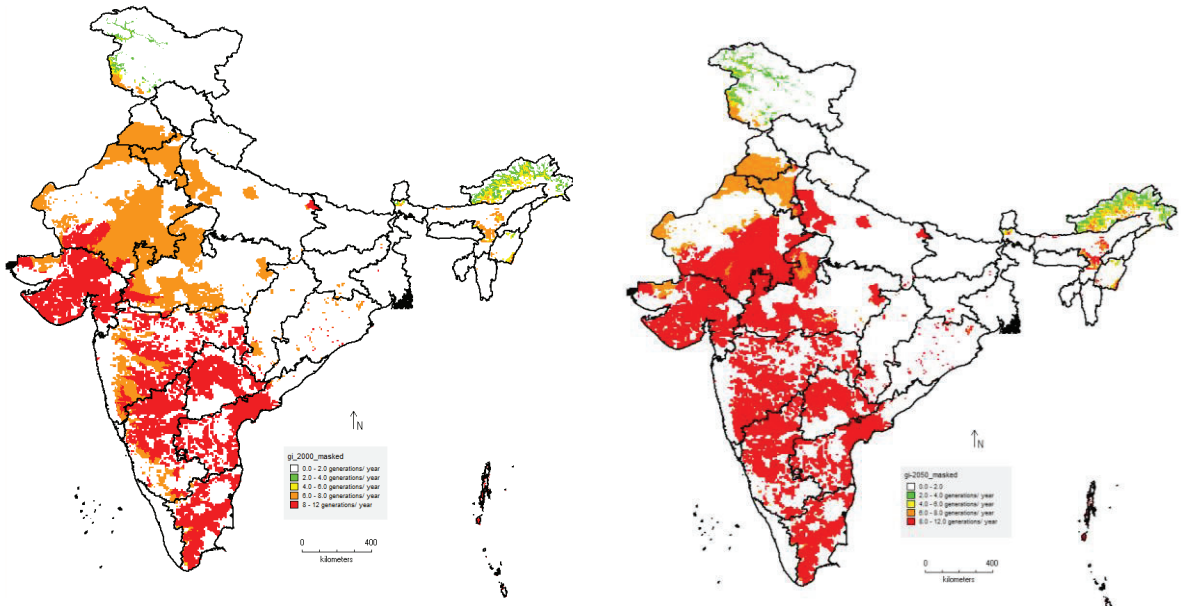
The analysis was carried out to study the hypothesis that the temperature variations due to global climate change may affect the future distribution and abundance of *P. gossypiella* and aggravate the cotton yield losses. A temperature-based phenology

model of *P. gossypiella* was coupled with a geographic information system (GIS) for mapping its population growth potentials in different cotton growing areas of India. The three risk indices *viz*., establishment risk index, generation index and activity index were computed using interpolated temperature data from Worldclim database projecting the climatic conditions for the base year 2000 and future scenario of the year 2050. Results indicated that, approximately 60% cotton growing areas of India are optimally suitable for pink bollworm establishment and survival throughout the year (Fig. 6.6.1a), which are predicted to increase upto >90% by the year 2050 (Fig. 6.6.1b). Under base temperature conditions of year 2000 pink bollworm is expected to complete > 6.0 generations per year on ~ 80% of the cotton production areas. However, economic losses are likely to occur only in areas where at least 8.0 generations can develop in a year; under current climate ~ 60 % areas fall under this category (Fig. 6.6.2a) which may rise upto 80% by the year 2050 (Fig. 6.6.2b). The increased pest activity of pink bollworm due to climate change may intensify the yield losses in cotton.



(a) (b)

Fig 6.6.1: Change in establishment and future distribution of pink bollworm in cotton production areas of India, based on establishment risk index (ERI) for current (a) and future (b) climatic conditions. Geographical regions having ERI values > 0.6 are associated with the risk of permanent establishment of pink bollworm.



(a) (b)

Fig 6.6.2: Change in number of generations per year of pink bollworm in cotton production areas of India based on generation index (GI) for current (a) and future (b) climatic conditions. Economic damage may occur in the regions with generation index values > 6.0.

6.7 Project Name: Studies on chemical cues mediating natural enemy and sucking pest interactions in cotton eco-system

Dr. Shah Vivek (PI), Co-PI- Dr. K. Shankarganesh, Dr.Rishi Kumar, Dr.K Rameash, Mr. Madhu T.N.

Importance of the study: Whitefly and jassids are the major sucking pests of cotton in India. At least 2-3 sprays are directed for their management adding to pesticide load in the ecosystem. Semiochemicals play a vital role in tritrophic interactions between crop plants, insects and their natural enemies. Present study aims at identifying volatiles emitting from the sucking pests that deploy natural enemies, so as to use them in ecofriendly pest management practices.

Salient findings

- Volatiles identified from jassids and whitefly *viz*., 9-octadecenoic acid, 9,12-octadecadienoic acid hexadecanoic acid were identified using GC-MS.
- Field evaluation of vegetable oils containing above mentioned compounds for their attractiveness to natural enemies was done.
- No significant difference was observed in population establishment as presence of natural enemies was only for brief period of 14-21 days

6.8 Project Name: Push-Pull strategy for management of pink bollworm in cotton

Dr. Shah Vivek (PI), Co-PIs- Dr. Pooja Verma, Dr. Rachna Pande

Importance of the study: Push-pull essentially employs behavior modifying stimuli from insects and its host plants to restrict the insects from damaging the host crop. Oviposition deterring pheromones (ODPs) (referred herein as 'Push component') are spacing pheromones that enable

conspecific female insects to avoid egg laying on previously exploited hosts, thereby reducing intra specific competition among the individuals of the population. Plants emit volatile compounds that attract insects (referred herein as 'Pull component') for foraging and oviposition. Insects perceive these compounds primarily by olfaction (smell). Identification of potential semiochemical compounds to repel pink bollworm from cotton and attract to the refuge of same host maintained within the same field has a potential for development of sustainable and eco-friendly management strategy.

Salient findings

- Oleic and linoleic acids from larval faecal pellets of pink bollworm exhibited oviposition deterrent properties
- Six different vegetable oils containing oleic and linoleic acid as major components identified using GC-MS profile, as a cheaper alternatives for field application were: groundnut oil, sunflower oil, rice bran oil, soybean oil, sesame oil and safflower oil.
- The compounds namely α/β pinene, carene, γ terpinene, α copaene, caryophyllene and humulene identified from four cultivated species of cotton were evaluated under choice and no-choice experiments using square extract, artificial blend and natural cotton twig to know the preference of female moth for egg laying.
- *Gossypium herbaceum* was found to be least preferred species under both choice and no-choice experiments using square extract, artificial blend and/or natural cotton twig.
- Higher proportion of γ terpinene in *G. herbaceum* might attribute to deterrent effect.
- Higher quantity of caryophyllene and α/β pinene with low levels (*G. arboreum*) or absence (*G. hirsutum* and *G. barbadense*) of γ terpinene attracts pink bollworm female for egg laying.

6.9 Project Name: Standardization and integration of strategies for sustainable nematode management

Dr. Nandini Gokte-Narkhedkar (PI)

Importance of the study: Losses due to plant parasitic nematodes have been pegged at 8-10%. Reniform nematode *Rotylenchulus reniformis* is the most prevalent and frequent nematode species in central and southern cotton growing areas. For management of nematodes no effective and environmentally sustainable management strategy is available. The project envisaged evaluation of bio-entities for their possible nematoxic effect. The project aimed at development of nematode management module by integration of all available and effective nematode management strategies.

Salient findings

Out of forty bacterial species evaluated, *Bacillus subtilis, B. cereus, Lysinibacillus sphaericus*, *Brevibacterium epidermidis, Providencia vermicola* and *Ochrobactrum pseudogrignonense* were found to induce resistance in cotton plants against reniform nematodes.

Lysinibacillus sphaericus used as seed treatment was found to reduce nematode population and induce resistance against nematodes as evidenced by split root experiment.

Field trial for evaluation of bio formulations as elicitors for induction of plant resistance against nematodes was taken up for confirmation with cotton cv. PKV081 and effect of bio formulations on nematode population in field and on final cotton yield

was evaluated. Formulation with curcumin + cow urine + neem oil spray in combination reduced nematode population and increased yield in cv PKV081(13.1 q/ha) as compared to control (11.47 q/ha). Aspirin and curcumin combination as well as neem oil with curcumin were second best giving yield of 12.77 and 12.40 q/ha respectively.

6.10 Project Name: Main Project: Exploration of beneficial microorganisms for biotic stress management in cotton

6.10.1 Sub project: Establishment of in-house short-term culture collection repository

Dr.D.T. Nagrale (PI), Co-PIs-
Dr.S.P. Gawande, Dr.N.S. Hiremani, Dr. S.K. Sain, Dr. Sampath Kumar, A.

Importance of the study: Microbial inoculants, bioinoculants can be used as biofertilizers and biopesticides. Several fungal and bacterial pathogens infect the cotton crop and lead to heavy damage in cotton, thereby reducing quality of fibre and total cotton yield. Hence, there is need to study these phytopathogens, biofertilizers and biopesticides in details with establishment of in-house microbial culture collection repository and to utilize these microbial inoculants for meeting e requirement for various experiments by the researchers in the institute and regional stations.

Salient findings

- ✓ Basic facilities of -20ºC, -80ºC and 4ºC refrigerator have been established at Division of Cop Protection, ICAR-CICR, Nagpur for deposition, preservation and maintenance of microbial cultures (Fig. 6.10.1.1)
- ✓ Glycerol stocks at -80ºC have been prepared for the preservation of characterized bacterial cultures
- ✓ Establishment of mineral oil storage facility for preservation of fungal cultures is in progress
- ✓ Polyphasic characterization of isolates are in progress

Fig. 6.10.1.1 In-house short-term culture collection repository established at Division of Cop Protection, ICAR-CICR, Nagpur

6.10.2 Sub Project: Mass multiplication of CICR-Trichocash (*Trichoderma harzianum*) and validation of its efficacy

Dr. S.P. Gawande (PI), Co-PIs- Dr. D.T. Nagrale and Dr. N.S. Hiremani

Importance of the study: *Trichoderma* spp. is the bio control agent widely used in management of diseases of crop plants. India has rich biodiversity pool of antagonists that can be explored as natural, eco-friendly and renewable resources for successful utilization as integrated management approaches of diseases. Therefore, the present proposal has been planned to utilize and validate native strains of antagonist CICR-Trichocash (*Trichoderma harzianum)* in the cotton based cropping system.

Salient findings

- ✓ Established mass multiplication unit at Bio control laboratory of ICAR-CICR, Nagpur.
- ✓ Evaluation of field efficacy of CICR-Trichocash (*T. harzianum*) in comparison with commercial seed dressers is being carried out.
- ✓ Mass multiplication of talc-based formulation of *T. harzianum* has been initiated (Fig.6.10.2.1) and 200 packets (500gms each) distributed as a critical input to farmers under MGMG and SCSP (Fig.6.10.2.2).

Fig. 6.10.2.1. Mass multiplication of *Trichoderma* on PDA

Fig. 6.10.2.2. Distribution of CICR-Trichocash packets to the farmers under MGMG and SCSP

6.11 Project Name: Development of wireless smart trap for automated monitoring of lepidopterous pests in cotton

Dr K. Rameash (PI), Co-PI- Dr K. Shankarganesh

Importance of the study: The study is aimed at developing an automated trap with image sensors for providing real time surveillance for multi species lepidopterous pests in cotton for efficient pest monitoring. By integrating the traditional trapping method with modern information communication technology (ICT), the trap system would provide a real-time information on the field conditions and the dynamics of the pest population at different monitoring sites.

Salient findings

The pheromone compounds 7,11-Hexadecadienyl acetate, (*Pectinophora gossypiella*); (Z,E)-9,11-Tetradecadienyl acetate, (*Spodoptera litura*); (Z)-9-Hexadecenal,

(*Helicoverpa armigera*); (E,E)-10,12-Hexadecadienyl, (*Earias vittella*) were evaluated as single septa (@ 2 mg pheromone loaded per septa) in individual pheromone traps as well as combined traps (1+2+3+4 as separate traps together in a treatment); combined lures (1+2+3+4 as four individual septa in single trap); mixed lure (1+2+3+4 as blend in a single septa - single trap) (Fig. 6.11.1). The study was conducted in a randomized block design (RBD) with eight treatments and three replications at two locations. The traps were placed with a distance of 15 m from each other and at 30 cm height above the crop canopy. Observations on trap catches of adult males of four lepidopteran pests were recorded at weekly intervals.

The trap catches of *P. gossypiella* and *S. litura* were found to be identical in individual traps, combined traps and combined lures. However, in mixed lure trap a significant reduction in trap catches was noticed. Trap catches of *H. armigera* and *E. vittella* were recorded at a lower rate throughout the season. The information on compatibility and field efficacy of multi lure pheromone system against major lepidopteran pests of cotton was explored in the present study. The field experiments provided insight on how different pheromone compounds would perform in combination in attracting more than one lepidopteran pests in cotton to cater the needs of pest monitoring and management. Based on the results of the two field studies, the combined lure setup would be carried forward as an integral part in fabrication of wireless trap (Fig. 6.11.2 and 6.11.3).

Combined traps (a) | **Combined lures: external view (b)** | **Combined lures: internal lure arrangement (c)**

Fig. 6.11.1. Arrangement of different traps and lures

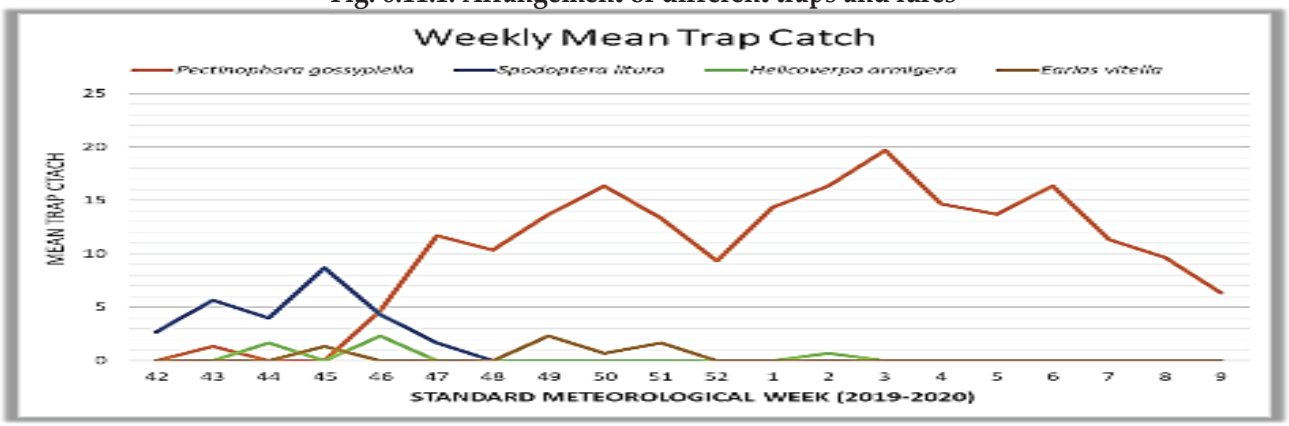
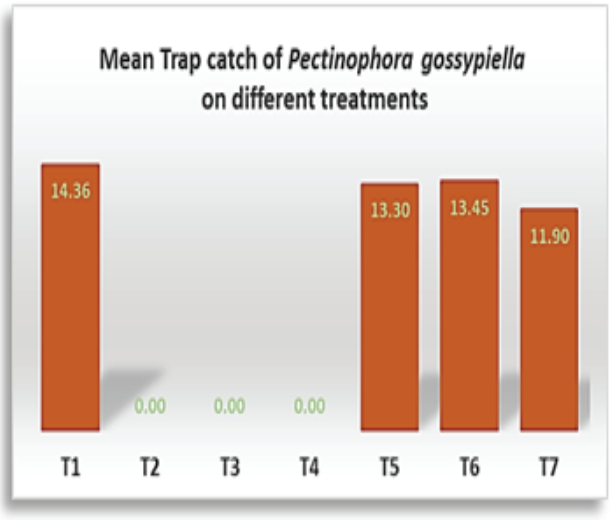
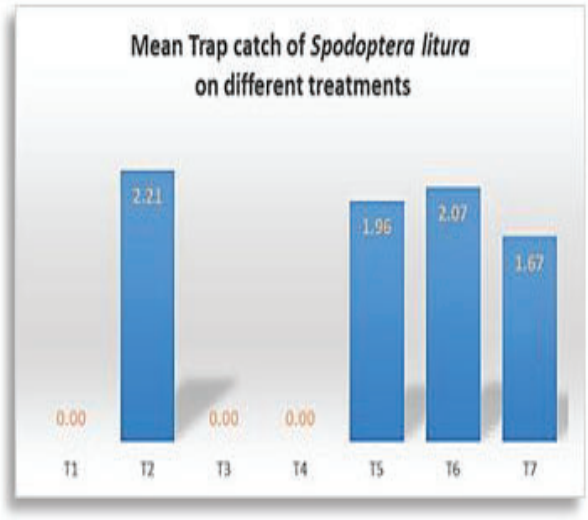


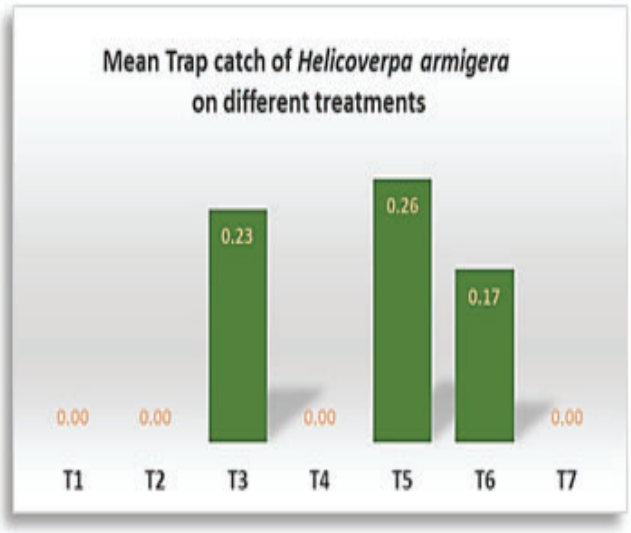
Fig. 6.11.2: Weekly mean male moth trap catches of lepidopteran pests of cotton



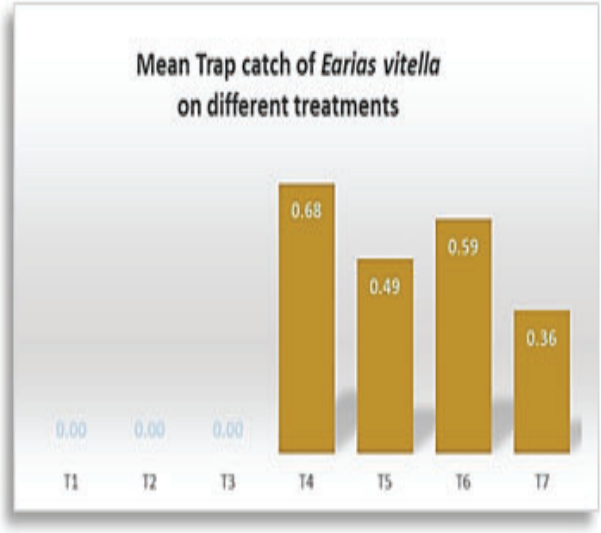
a



b



c



d

Fig. 6.11.3. Mean male moth trap catches of lepidopteran pests of cotton in different combinations of treatments

6.12 Project Name: Identification of semiochemicals associated with host plant cotton and insect pest stem weevil *Pempheres affinis*

Dr. K. Shankarganesh (PI),Co-PI- Dr. J. Annie Sheeba, Dr. A. Manivannan

Importance of the study: The project aims at screening for source of tolerance against stem weevil in cotton under field condition.

Salient findings

Screening for tolerance of cotton varieties / hybrids against stem weevil

- Out of the nine genotypes, Mallika Bt hybrid and MCU5VT were found to be more susceptible to stem weevil.
- The infestation varied from 10 to 43%. The maximum incidence was observed in Mallika Bt and MCU 5 VT and it was

comparatively less in Surabhi, LRA 5166, MCU 3, RCHB 625 BGII.

Morphology of stem galls:

- Cells in affected stems underwent hypertrophy and hyperplasia, resulting in extensive stem swelling. The diameters of stems with galls ranged from 1.6 to 3.4 mm.
- In affected stems, the periderm was split and pushed away from the stem by galls.
- The phloem ring was disrupted, and it appeared that phloem cells might have differentiated into cells of gall tissue.
- Most of the samples showed phenolic deposition in the pith region (Fig. 6.12.1).

Fig. 6.12.1. Cross section of stem weevil infested plants with stem gall: a microscopic view (a) and general view (b)

Biochemical difference in susceptible and tolerance varieties

- Plant phytochemicals contributing to host plant resistance/susceptibility to stem weevil such as phenols, sugars and terpenoids were estimated from leaves and collar regions of different varieties of cotton plants chosen for the study.
- Among the varieties, MCU3 and Bahubali showed field level tolerance to stem weevil.
- MCU3 recorded higher phenolic content from 16th to 19th day old seedlings in the collar region which may be one of the reasons of tolerance of these varieties.
- Soluble sugars were high in leaves of Mallika followed by Bahubali.
- Higher terpenoid content is recorded in the collar region of MCU 3 on 15th, 16th, 21-23rd days and on 25th day.
- Bahubali too recorded higher terpenoid values on 15th and 16th in the collar region

6.13 Project Name: Development of biocontrol consortia with multifaceted fungi for the management of important pests and nematodes of cotton

Dr. J. Gulsar Banu(PI); Co-PI- Dr. M. Amutha

Importance of the study: Fungal biopesticides and nematicides are used for the eco-friendly management of pests and nematodes, respectively. Field application is hampered as some of them lack virulence under field condition. Each biopesticide is having different mode of action and target pests. Identification of fungi with different mode of action and unique capacity which are compatible with each other will be required in future. Hence there is a need to develop biocontrol consortia with multifaceted fungi for the management of

important insect pests and nematodes of cotton

Salient findings

- Bioefficacy of four entomopathogenic fungi *viz., Lecanicillium lecanii, Metarhizium anisopliae, Beauveria bassiana* (BB and MB) and *Cladosporium cladosporioides* alone and in combination were tested against jassids, aphids and mealybug, *Phenococcus solenopsis* under *in vitro* condition. Entomopathogenic fungal consortia could cause significant mortality of target pests than fungus alone.
- Twenty isolates of endophytic fungi from the cotton roots were isolated.
- Two bacterial symbionts of entomopathogenic nematode, *Xenorhabdus nematophilus* and *X. stockiae* (primary and secondary forms) were tested against jassids under *in vitro* condition. Among two bacteria, *X. nematophilus* primary form could cause significantly higher mortality than *X. stockiae*.
- Mode of action of these two bacteria against 16 fungi (11 plant parasitic and 5 entomopathogenic fungi) was tested by dual culture assay. Six isolates of entomopathogenic fungi were isolated from *S. litura.*
- Standardised a methodology for the virulent isolates of entomopathogenic nematode and fungi by modified soil baiting method. By this method most virulent isolate against target pests alone will be isolated there by reducing time in collection and screening of several isolates against target pests.
- One entomopathogenic fungus and nematode was isolated from *S. frugiperda* larvae. This entomopathogenic nematode, *Steinernema* sp could cause 100% mortality of larvae and pupae within 24 hours after inoculation at an initial inoculum of 10 IJ/ larva or pupa.
- Maximum production of infective juveniles of *Steinernema* sp was recorded at an initial inoculum of 10 IJ/ larva.

6.14 Project Name: Exploration of beneficial microorganisms for biotic stress management in cotton

Sub project 1: Collection, characterization and evaluation of beneficial fungal microorganisms from North, Central and South cotton growing zones

Dr.S.K. Sain (PI); Co-PIs- Dr. S.P. Gawande , Dr.Amarpreet Singh, Dr.P. Valarmathi, Dr. Nandini Gokte Narkhedkar

Importance of the study: Soil microorganisms play a key role in the agricultural ecosystem for plant growth and health. They act as phyto stimulators, produce phytohormones, promote plant development through altering root architecture and induce biotic stress tolerance in plants. Until now, studies on isolation and characterization of the rhizosphere fungi from cultivated cotton in India arelacking. The identified beneficial fungal strains can further be used for developing bioformulation or consortia for improving the plant health, and ultimately the productivity of the cotton cropping system.

Salient findings

- Survey and collection of rhizosphere soil samples from different cotton cropping systems in North, Central and South Zones of India was undertaken and more than 80 cotton rhizosphere soil samples were collected (Table 6.14.1).
- Fungal colony in the sample ranged from 1-16 with an average of 5.5 c.f.u. $x10^{-4}$.
- About 100 fungal isolates including the genus *Aspergillus, Trichoderma, Sclerotome, Mortierella, Metarhizium, Macrophomina, Rhizopus, Penicillium, Curvularia, Bipolaris, Colletotrichum, Paecilomyces, Fusarium, Nigrospora, Acremonium* and some

unidentified fungi were purified and are being further characterized (Fig. 6.14.1).

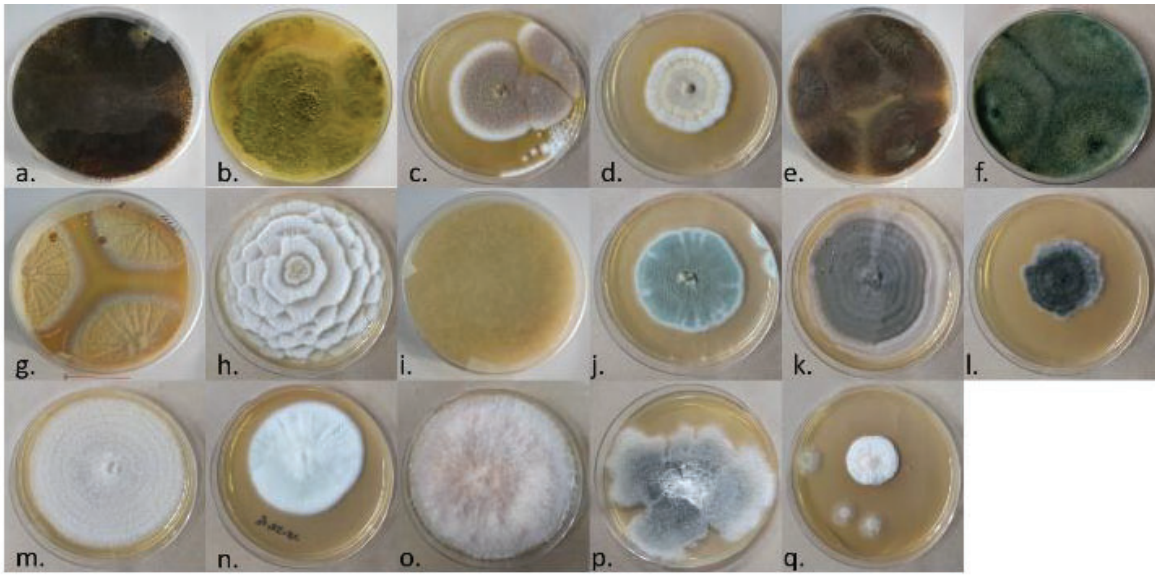


Fig. 6.14.1 Fungal genera recorded in different soil samples: a. *Aspergillus niger,* **b.** *Aspergillus flavus*, **c.** *Aspergillus terreus,* **d.** *Aspergillus fumigatus* **e.** *Aspergillus foetidus,* **f.** *Trichoderma* spp., **g.** *Sclerotium rolfsii,* **h.** *Mortierella* spp., **i.** *Rhizopus stolonifer,* **j.** *Penicillium* spp., **k.** *Curvularia* spp., **l.** *Bipolaris* spp., **m.** *Colletotrichum* spp., **n.** *Paecilomyces* spp., **o.** *Fusarium spp.,* **p.** *Nigrospora* spp., **q.** *Acremonium* spp.

Table 6.14.1: Number of different fungal genus isolated and purified from North, Central and South cotton growing zones

Zone	Soil samples	Fungal colonies (purified)	Fungal genera recorded
North	63	**345 (61)**	*Aspergillus (88), Fusarium (35), Bipolaris (1), Curvularia (2), Rhizopus (6), Sclerotomerolfsii (2), Trichoderma (7), Mortierella (20), Nigrospora (2),Penicillium (32), Acremonium, Colletotrichum, Paecilomyces,*and non-sporulation
Central	10	25 (15)	*Aspergillus, Macrophomina, Fusarium, Rhizopus, Trichoderma, Penicillium, Metarhizium.*
South	21	65 (25)	*Aspergillus (40), Penicillium (2), Fusarium (14), Bipolaris (4)* and *Rhizopus (5)*

6.15 Project Name: Studies to identify the most virulent strains of entomopthogenic fungi for whitefly control (2016-2020)

Dr.S. K. Sain (PI); Co-PIs- Dr. D. Monga, Dr.S. Kranthi, Dr.Rishi Kumar, Mr. Prabhulinga T., Dr.Dipak Nagrale, Dr. Neelakanth Hiremani

Importance of the study: Entomopathogenic fungi (EPF) are ecofriendly alternative to chemical insecticides for the management of whitefly. The scanty availability of effective bioinsecticide is making farmers dependent

on chemicals, resulting in insecticide resistance and environmental pollution. The top most virulent EPF strains found compatible with chemical insecticides under polyhouse conditions and laboratory were evaluated under field conditions

Salient findings

- Three liquid bioinsecticide formulations developed using the most virulent EPF strains compatible with insecticides (CICRRS *Cordyceps javanica*-102, CICRRS *Metarhizium anisopliae*-1299 and CICRRS *Beauveria bassiana*-4511).
- These three bioinsecticides @ 0.5%, commercial formulations of *Lecanicillium lecanii* @ 0.5%, spiromesifen @ 0.1% along with control treatment were evaluated in large plot field trial at ICAR- CICR Regional Station Sirsa.
- The results of three consecutive sprays of individual treatments indicated that the highest area under nymph mortality progress curve (AUMPC) was observed with spiromesifen, followed by CICRRS Cj-102, CICRRS Ma-1299 and CICRRS Bb-4511.
- Compared to other treatments, lower CLCuD PDI (%) was observed in spiromesifen, Cj-102, Ma-1299, Bb-4511 and the higher seed cotton yield (q/ha) was recorded in Bb-4511, Cj-102, Ma-1299 and spiromes ifen (Fig 6.15.1)

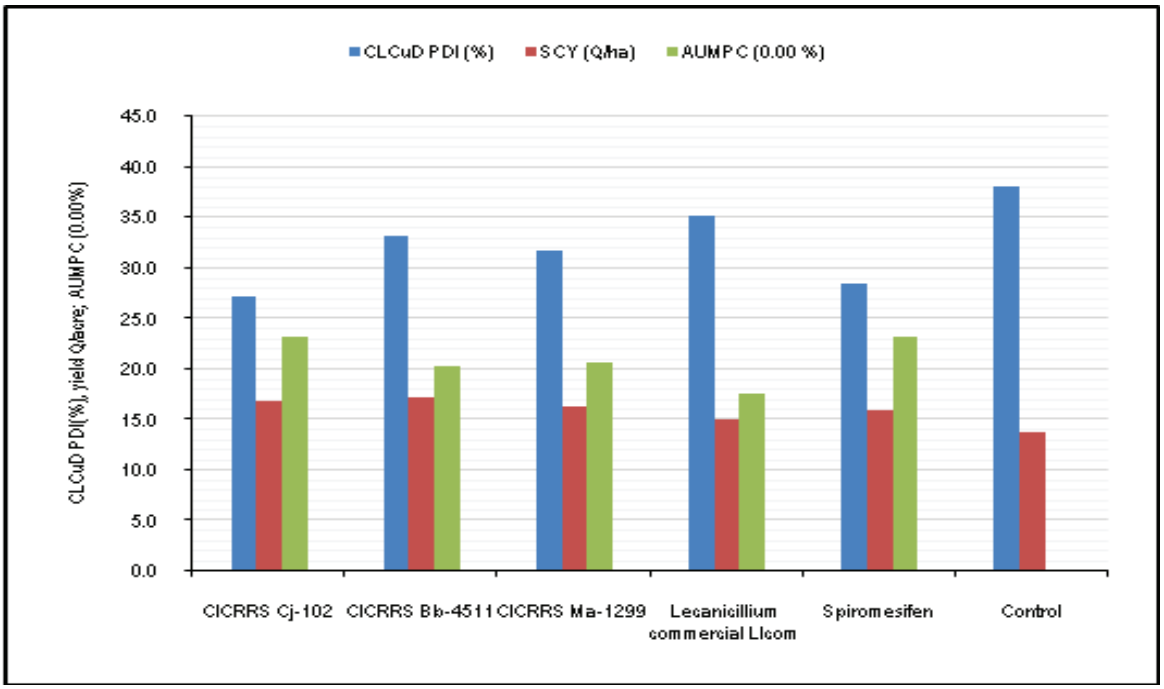


Fig 6.15.1: Comparative effect of bioinsecticide formulations, chemical insecticide on whitefly nymph mortality, CLCuD, and seed cotton yield