

Annual Report
2002-03

Project Directorate of Biological Control
Bangalore

Inauguration of the Trainees' Hostel by Dr. Mangala Rai, Secretary, DARE and Director General, ICAR, New Delhi

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Cover Page

1. The Siam Weed, *Chromolaena odorata*
2. The gall fly, *Cecidochares connexa* on the leaf
3. *Cecidochares connexa* female
4. The stem gall and window produced by the developing larva

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PREFACE

The Project Directorate of Biological Control, since its inception in 1993, has made rapid strides in basic research on different aspects of biological control forming the base for technologies in Biointensive Integrated Pest Management. It has a network of 16 crop-oriented field centres in different state agricultural universities and ICAR Institutes. The achievements made in this specialised field include introduction of potential natural enemies for managing exotic pests, development and standardisation of improved breeding and mass production techniques and low temperature storage technology for natural enemies, understanding the tritrophic relationship between host plants, pest insects and natural enemies, development of superior strains of natural enemies for different crop ecosystems, pesticide tolerance and development of biocontrol based technologies for pest management in crops like sugarcane, cotton, maize, tobacco, vegetables, fruit crops, etc. Several of these technologies have been transferred to private enterprises for commercial exploitation.

The tenth annual report of the Project Directorate embodies the endeavours of my scientist colleagues for the period from April 2002 to March 2003. I am sure that the findings presented will be of use to scientists, research workers, administrators, policy makers, farmers and others who are involved or interested in biological control of crop pests and weeds. Suggestions for improvement, collaboration, future research needs and priorities from peer groups have been given due consideration for implementation.

I am extremely grateful to Dr. Mangala Rai, Secretary, DARE & Director General, ICAR, New Delhi, for his encouragement and valuable guidance. The support extended by Dr. G.Kalloo, Deputy Director General (Crop Sciences & Horticulture), ICAR, New Delhi, is gratefully acknowledged. Dr. O.P.Dubey, Assistant Director General (Plant Protection), ICAR, New Delhi has always encouraged and inspired us to perform better. Sincere thanks are due to all project workers at Project Directorate of Biological Control and in different co-ordinating centres for completing the allotted research programmes. Thanks are also due to the Vice-Chancellors, Directors of Research of SAU based centres and Directors of ICAR-Institute-based centres for providing the facilities.

R. J. Rabindra

2. EXECUTIVE SUMMARY

2.1 Basic research

2.1.1. Introduction of natural enemies

Import permits for 12 natural enemies were obtained from Plant Protection Advisor to the Government of India. The gall fly, *Cecidochares connexa* was received from Indonesia for trails against the Siam weed, *Chromolaena odorata.*

2.1.2. Maintenance, multiplication and supply of host insects and natural enemies

Cultures of twenty-two species of host insects, twenty-five parasitoids (11 strains of *Trichogramma* and 3 strains of *Telenomus*), nineteen predators, four weed control arthropods, four insect pathogens, seven varieties of *Bt*, 326 species and strains of fungal and bacterial antagonists, four strains and species of entomopathogenic nematodes, 24 species and strains of fungi and bacteria associated with phytonematodes and one weed control pathogen are being maintained.

294 shipments (57 host insects, 65 predators, 78 parasitoids, 63 insect pathogens, 17 antagonists and 14 weed insects) were sent to different research organisations / private companies / universities / individual farmers as nucleus culture or as finished products. Forty multicelllar trays suitable for rearing *H. armigera* and 10 insect rearing cages suitable for parasitoid rearing were also supplied.

2.1.3. Biosystematic studies

2.1.3.1.Coccinellidae

A checklist has been prepared which lists 400 species (including six subspecies) under 79 genera, 22 tribes and five subfamilies. Two species, namely, *Ortalia minuta* Weise (from Bangalore, Karnataka), and *Alloneda (=Cyphocaria) duvaucelii* (Mulsant) (from Nagaland), were recorded from the Indian mainland for the first time. An identification guide for 125 species of coccinellids commonly found in the agroecosystems of the Indian subcontinent has been prepared.

2.1.3.2. Tachinidae

Specimens belonging to two subfamilies, viz., Goniinae and Tachininae are being studied. A species of *Winthemia* was found attacking the fruit-piercing moth, *Othreis materna* among several lepidopteran hosts recorded for tachinids.

2.1.4. Survey for natural enemies

A eupelmid parasitoid, *Neanastatus* sp. was recorded as a parasitoid of the pod wasp, *Tanaostigmodes cajaninae*. The maximum mean parasitization of the spiralling whitefly to the extent of 68.45% was recorded in January on papaya. The population of *A. dispersus* has been greatly reduced as compared to previous year on all hosts.

Surveys were conducted in northen districts of Karnataka and in Western Maharastra for natural enemies of the sugarcane woolly aphid, *Ceratovacuna lanigera*. *Dipha aphidivora* (Pyralidae), *Dideopsis aegrota* (Syrphidae), *Cheilomenes sexmaculata*, *Anisolemnia dilatata*, *Synonycha grandis* (Coccinellidae) were found predating on the aphid.

2.1.5. Standardization of rearing techniques and biological studies on natural enemies

Orius tantillus was continuously multiplied on UV irradiated *C. cephalonica* eggs for 12 generations in the laboratory. A rearing protocol to produce *Amblyseius longispinosus* in large numbers has been standardized.

The optimum pest parasitoid ratios of *S.litura* larvae to *C. chlorideae* adults were 1:5 with 80.57% parasitism and 1:15 with 81.95% parasitism. The ratios 1:5 or 1:15 reduced the pest population by 79.64 and 81.10 percent, respectively.

C. exiguus population on *O. arenosella* was found to be more when the pest population was in the younger stages.

Encarsia guadeloupae parasitised only first instar nymphs of *A. dispersus*.

2.1.6. Behavioural studies on natural enemies

Preliminary field trial with the stapling of kairomone treated egg cards on cotton leaves and then spray of L-tryptophan solution resulted in incrase in the number of chrysopids in treated plots at Whitefield, Bangalore. *Campoletis chlorideae* showed orientation towards the larval wash of host larvae in EAG studies.

The extent of varietal influence on parasitisation of *H. armigera* eggs by *T. chilonis* was evaluated for ten varieties/hybrids of tomato and it was found that Arka Alok and Pusa Ruby recorded highest parasitisationof 26.66 per cent.

Qualitative and quantitative variation was observed in the volatiles from the leaves and fruits of ten varieties/ hybrids of tomato, trapped, isolated and identified using standard GCMS techniques.

2.1.7. Artificial diet for host insects and natural enemies

The coconut leaf eating caterpillar, *Opisina arenopsella* could be reared successfully on an artificial diet based on toddy palm leaf powder and soy bean. The prasitoids *Goniozus nephantidis, Brachymeria nephantidis* and *B. nosatoi* could complete their development successfully on the diet-reared host. Cabbage leaf powder based diet was found good for rearing *Plutella xylostella* and the diet-reared larvae were found equally good to those reared on mustard seedlings for rearing the braconid parasitoid, *Cotesia plutellae*.

The storability of the artificial diet developed for rearing *C. carnea* was very good, the diet stored in a refrigerator at 5°C for a period of one year could be successfully used for rearing the predator.

2.1.8. Improved strains of natural enemies

2.1.8.1.Development of high temperature tolerant strains of *Trichogramma chilonis* and *Trichogramma japonicum*

In a field trial on cotton conducted in Regional Station (CICR), Coimbatore the temperature tolerant strain of *T. chilonis* gave higher parasitism (16%) and lesser (4.4%) damage of fruiting bodies as compared to no parasitism and 6.9% damage in untrated control.

A field trial conducted at RRS, Karnal to evaluate the temperature tolerant strain of *T. chilonis* against the sugarcane stalk borer, *Chilo auricilius* revealed that the heat tolerant strain released plot recorded 53.7 percent borer incidence with an intensity of 7.3% as against 68.9 percent incidence and 11.2% intensity in untreated check.

Attempts are on to develop a high temperature tolerant strain of *T. japonicum* and good parasitism has been recorded when the temperature has been raised from 32-38°C.

2.1.8.2.Selection of *Trichogramma chilonis* for tolerance to insecticides

The three strains selected as tolerant to endosulfan, monocrotophos and fenvalerate were mixed and reared under pressure of all the insecticides separately for developing a strain tolerant to these insecticides.

2.1.8.3.Evaluation of multiple insecticide tolerant strain against cotton bollworms in Gujarat, Karnataka and Tamil Nadu

Field trials were conducted in collaboration with GAU, Gujarat, Regional Station (CICR), Coimbatore, UAS, Dharwad and TNAU, Coimbatore to evaluate efficacy of multiple insecticide tolerant against cotton bollworms by releasing the tolerant parasitoids @ 150,000 / ha and comparing with the release of normal laboratory strain of parasitoids.

The trial at Coimbatore, where parasitoids were released 3 times at 15 days interval, revealed a mean per cent parasitism of 9.4% and 4.0% damage in fruiting bodies and this significantly differed with untreated control where no egg parasitism and 10.5% damage in fruiting bodies was recorded.

Low percent boll damage, higher per cent egg parasitism and higher yield were recorded in GAU, Anand in the multiple insecticide tolerant strain released fields and yields were significantly higher in tolerant strain released plots.

The trial at TNAU, Coimbatore showed that the incidence of the larvae was contained significantly more in pesticide tolerant *Trichogramma* release sequentially with insecticide application, which was followed by release of susceptible strain and insecticide application.

The evaluation of the strain against cotton bollworms at UAS, Dharwad showed that the parasitization was 25.42 per cent despite spray of different insecticides against bollworms and was significantly superior to the release of laboratory strain of *T. chilonis* (12.63%) followed by isecticide spray.

2.1.8.4.Selection of high host searching ability strain (HHSS) of various *Trichogramma* species

Selection of high host searching ability strain (HHSS) of various *Trichogramma* species indicated that the selected strain was able to retain the host searching ability even after 10 generations with a parasitising ability of 36.9 - 72.4 per cent eggs compared to 53.6 - 77.0 per cent by those reared continuously in the cages.

2.1.8.5. Storage of 'Tricho' cards for field release

The temperature of 15°C in a BOD incubator was found ideal to store 8-9 day old parasitised cards just prior to field release. Emergence occurred within 2.5 hours in the case of 8-day old parasitised cards stored for 7 days and 9-day old parsitised cards stored for 3 days.

2.1.9. Studies on entomopathogenic viruses and fungi

Nucleopolyhedro viruses of *Trichoplusia ni, Spodoptera exigua, Crocidolomia binotalis, Opisina arenosella, Chilo infuscatellus, Chrysoperla carnea* and *Cadra cautella* have been isolated and their pathogencity tested. A neogregarine protozoan pathogen, *Mattesia dispar* has been isolated from *Cadra cautella.*

Conidial spore production of *N. rileyi* was found to be maximum with 5% yeast granules as yeast source and was also found to be cheap. In trials to identify the best liquid media for conidial production of *N. rileyi* it was found that rice extract (5%) + yeast granules (5%) was best in the case of all the isolates. Conidial production was good at 25° C and 70-90% humidity for all the isolates.

Aerial conidia produced on solid medium and stationary cultures of the liquid medium were found to be infective to *S. litura* causing from 40–80% mortality after ten days. Spores of all the five isolates remained viable in sufficient numbers (10^9/g) for a period of four months at refrigerated temperature of 5-8°C.

2.1.10.UV protectants for preparing new WDP formulation of *Bacillus thuringiensis* (IARI, New Dehi)

The need to add UV protectants in the new WDP formulation of *Bacillus thruingiensis* was established as increased mortality of *H. armigera* was observed despite exposure of the formulation to UV. Amongst the protectants Congo Red was found better than Ranipal at 1% concentration.

2.1.11. Fungal and bacterial antagonists

Studies on mass production of *T. harzianum*, PDBC TH-10 and *T. viride*, PDBC TV-23 using Jaggery-soy medium (Jaggery-50.0g/L and Soyaflour-10g/L) carried out in a 10 litre cap. fermentor showed peak biomass production of both isolates after 4 days of fermentation. *In vitro* interaction studies showed that several of the strains of *T. harzianum* and *T. viride* were compatible with each other.

Suitability of the spent meals of laboratory-reared insect hosts namely *Corcyra cephalonica* and *Sitotroga cerealella* for the mass production of *Trichoderma harzianum*, *T. viride* and *T. virens* revealed that *Sitotroga* spent meal supported maximum sporulation and colony forming units in all the three species of *Trichoderma* and was on par with sorghum as a substrate.

Studies conducted at GBPUA & T, Pantnagar indicated that seed biopriming with a suspension of *Trichoderma* powder (10 g TH + 10 g FYM powder + 5 g gum arabica in 50 ml water for 1 kg seed) resulted in rapid and uniform seedling emergence and better seedling growth and protection against seed and soil borne diseases in rice, wheat, chickpea, lentil, pigeon pea, tomato, brinjal, capsicum, cabbage, cauliflower and chilli especially in *Usar* soil. Farmers' both in hills and plains of Uttaranchal were found to adopt production of *T. harzianum* in their fields by colonising the anatagonist in FYM. The technology has been demonstrated and adopted by organic producers of vegetables and other crops.

2.1.12. Entomopathogenic nematodes

A rapid and cheap mass production method using vermiculite was developed for *Steinernema carpocapsae* and *Heterorhabditis indica*. *Heterorhabditis* isolates were more effective compared to *Steinernema* sp. isolates against the white grub, *Holotrichia lepidophora*. Pathogenicity of *S. carpocapsae* and *H. indica* tested against *P. xylostella* larvae by dose-response assay showed maximum larval mortality of 96% and 98% at 72 h.

2.1.13. Biological suppression of plant parasitic nematodes

Corn meal agar (CMA) medium was better than water agar medium in inhibiting hatching of nematode eggs and also in parasitizing ability. Solid substrates like spent malt waste, cotton seed meal, wheat bran and pongamia cake supported mycelial growth for 9 days, produced significantly more chlamydospores and was comparable with CMA in terms of chlamydospores per g of substrate. Talc, sawdust and vermiculite formulations exhibited 80-60% spore viability after 10 months of storage. Talc and sawdust formulations also produced 48 and 39% reduction in root-knot nematode populations, and 42 and 34% reduction in reniform nematode populations.

Microplot experiments carried out in root-knot nematode infested farmer's field of tomato to evaluate the combinations of talc formulation of *P. lilacinus* and organic amendments revealed that egg mass parasitization and reduction in nematode population was maximum with vermicompost followed by neem cake, farm compost and pelletized organic manure.

2.1.14. Weed pathogens

Mass production of *Fusarium pallidoroseum*, a potential biocontrol agent for parthenium was undertaken in liquid media and formulated as powder, oil emulsion, alginate pellets and pesta granules. Though two sprays of the formulations was found better under green house conditions it proved ineffective under field conditions.

Alternaria alternata, a pathogen of water hyacinth was mass produced by fermentation method and formulated in powder, oil emulsion, alginate pellets and pesta granules. Under open-air conditions significant disease severity with two sprays was obtained. Maximum (8.6) disease severity was with powder formulation. *Alternaria* and *Cercospora* spp. were not pathogenic or phytotoxic to water fern, *Salvinia molesta*, water lettuce, *Pista stratiotes*, and the alligator weed, *Alternanthera philoxeroides* in specificity tests.

2.1.15. Software development

Expert system 'BIORICE' has been developed for bio-control of rice-pests. "Helico-info" – a CD has been developed to help scientists, researchers, extension workers, NGO's and farmers to get information about *H. armigera* and its natural enemies.

2.2. Biological suppression of sugarcane pests

Natural enemies of sugarcane pests monitored throughout the year at PAU, Ludhiana revealed that egg (trichogrammatids) and larval parasitoids (*Cotesia flavipes, Stenobracon nicevillei, Sturmiopsis inferens, Isotima javensis, Rhaconotus scirpophagae*) of *Chilo infuscatellus, Chilo auricilius* and *Scirpophaga excerptalis* were very active during the cropping season in Punjab. *Sturmiopsis inferens* was found active throughout the year at Coimbatore. In Haryana, *S. inferens* was common on stalk borer and Gurdaspur borer and *Isotima javensis* on top borer. Natural parasitism of *Pyrilla perpusilla* by the egg parasitoid, *Ooencyrtus papilionis* and nymphal-adult parasitoid *Epiricania melanoleuca* was recorded in Karnal, Haryana.

Field studies conducted at four locations by PAU, Ludhiana by making eight releases of *T. chilonis* at 10 days interval during April to June @50,000/ha brought about a reduction in the incidence of early shoot borer, *Chilo infuscatellus* which was comparable with Padan 5G at 25 kg/ha.

Large-scale demonstration of biocontrol was conducted at Pravaranagar, Maharashtra by releasing *T. chilonis* @ 50,000/ha at 10 days interval, which reduced the incidence of early shoot borer. At MPKV, Pune similar demonstration through eight releases of *T. chilonis* @ 50,000 adults/ha/release were found effective in enhancing parasitism and reducing dead hearts by the early shoot borer. The efficacy of *Trichogramma chilonis* against stalk borer was successfully demonstrated over 40 ha at village Karni Khera (Distt. Ferozepur).

Spraying of spore suspensions of *Beauveria bassiana* containing 10^6- 10^{10} spores/ml of water with 0.05% teepol resulted in greater number of infected larvae of the borer as also cane yield in plots receiving higher spore concentrations at CCSHAU, Karnal.

Lignite and vermicasting as carriers for *B. brongniartii* gave higher levels of mortality of third instar grubs of *H. serrata* in trials at SBI, Coimbatore. Chlorpyriphos and carbendazim were most toxic to *B. bassiana, B. brongniartii* and *M. anisopliae* as they affected the biomass and spore production completely. *Beauveria brongniartii, B. bassiana* and *M. anisopliae* were safe to *Chrysoperla carnea,* earthworm *Lampito mauritii,* common carp *Cyprinus carpio,* but the spider, *Cyrtophora cicatrosa* suffered about 16% mortality.

Sugarcane in Pune, Satara, Sangli and Kolhapur districts were surveyed for the occurrence of the woolly aphid and 5-10% damage was noticed during August-September, 2002. A coccinellid predator, *Synonycha grandis* was inoculatively released in sugarcane fields at Tilekarwadi (Dist-Pune) in the first week of November 2002 and recovered later. The predators, *viz*, *Coccinella* spp., *Cheilomenes* sp., neuropterans, *Mallada* spp. and *Dipha aphidivora* were found feeding in aphid colonies, but their population was less in Pune district. However, *C. aphidivora* was observed abundantly in Kolhapur district.

2.3. Biological suppression of cotton pests

Field trials at ANGRAU, Hyderabad, MPKV, Pune, TNAU, Coimbatore and GAU, Anand were conducted to evaluate the performance of bio-intensive integrated pest management practices in the management of cotton pests. A decrease in population of jassids and whiteflies, abundance of natural enemies like coccinellids, spiders and lacewing and higher kapas yield than in farmers' practice and untreated control was obtained. Inter cropping of maize with cotton enhanced the activity of *Cheilomenes sexmaculata* in IPM block both at Anand and at Coimbatore. Biocontrol plot also had harboured many natural enemies like *Aleiodes aligarhensis*, *T. chilonis*, *Agathis*, *Chrysoperla*, *Geocoris* and staphylinids in Anand.

In an attempt to identify other host plants harbouring natural enemies of cotton pests the activity of natural enemies was closely monitored on the crop and other host plants in the vicinity at Thondamuthur, Coimbatore district. Spiders, mantids, coccinellids, chrysopids and *Rhinocoris* spp. were observed on cotton, maize, cauliflower and tomato and also in weeds such as *Abutilon indicum*, *Solanum nigrum*, *Aristolochia*, *Hibiscus ficulensis*, *Chrozophora rottlari* and bund grasses.

The application of *N. rileyi* formulation in aqueous suspension and oil in water emulsion at $5x10^{11}$ spores/ha was as effective as endosulfan (0.07%) in reducing the incidence of *H. armigera*.

2.4. Biological suppression of tobacco pests

Biointensive IPM practices reduced the damage by *H. armigera* as a budworm and also the percentage capsules bored. Release of *Campoletis chlorideae* increased the parasitization of *S. litura* and *H. armigera* larvae from 5-10% to 7-13%.

Egg batches of *S. exiguua* exposed to *Telenomus remus* produced from 4-32% parasitization by *T. remus*. Similar exposure of *S, exiguua* larvae to *Glyptapanteles africanus* produced percent parasitization from 9-31% in different tobacco types.

2.5. Biological suppression of pulse crop pests

Results on bio-intensive pest management in pigeon pea with special reference to pod borer complex at ANGRAU, Hyderabad, showed that alternate spray of *Ha*NPV and NSKE (*Ha*NPV-NSKE-*Ha* NPV-NSKE) fared better in suppressing *H. armigera* with least cumulative larval populations and least pod damage. Damage by pod wasp and pod fly was also found to be less in BIPM plots.

Similar trials at TNAU, Coimbatore, but with *Bt-Ha*NPV alteration showed that the larval population of *H. armigera* was significantly less and damage to pods by pod wasp and other pod borers was the lowest. The treatment also yielded 1826 kg/ha as compared to just 886 kg/ha in untreated control.

Studies conducted at GAU, Anand to identify alternate host plants during off-season that harbour natural enemies showed that *Rustica* tobacco, bidi tobacco, marigold, maize, matsgandha, Cassia, starburr, parthenium, Duranta. amaranthus, *Lantana camara*, brinjal, sunnhemp and sesamum harboured *Rhinocoris*, *Bracon* sp., *Geocoris sp.*, *Trichogramma*, *Nabis*, crab spider, *C. sexmaculata*, *Xanthogramma*, anthocorid, *C. carnea* and *T. chilonis*.

Effect of entomopathogenic nematode *Heterorhabditis* sp. at 0.5, 1.0 and 2.0 billion/ ha against *Mylabris pustulata* and *Helicoverpa armigera* on pigeonpea was studied at TNAU, Coimbatore and it was found that pod damage due to *H. armigera* was less and comparable with endosulfan. However, population reduction of *M. pustulata* was not significant due to either. The efficacy of *Heterorhabditis indica* against blister beetles was evaluated similarly at IIPR, Kanpur. The treatment with EPN was found effective for 3 days with 90% mortality on the day of treatment and 72-80 percent mortality susequently.

2.6. Biological suppression of rice pests

Natural enemies of rice pests were monitored at AAU, Jorhat. The extent of parasitism of stem borer eggs by *Trichogramma japonicum* was 15-23%. The extent of parasitism of leaf folder larvae by *Aulosaphes* sp. during kharif season was 10-12%. Among the spiders *Lycosa pseudoannulata* was the most common followed by *Lycosa madani*, *Argiope catenulata* and *Neoscona* sp. Similar monitoring in PAU, Ludhiana revealed that *Telenomus dignoides*, *Trichogramma chilonis* and *T. japonicum* caused 49.19 per cent parasitization of *S. incertulas* eggs and that *T. dignoides* alone caused 40.17 per cent parasitization. *Bracon* sp. and *Cotesia* sp. and three unidentified larval parasitoids with 16.31 per cent parasitization were recorded from *C. medinalis*. The survey for natural enemies of rice pests done at KAU, Thrissur could enlist a total of 51 species of spiders belonging to 9 families and 23 genera.

Field evaluation of *Trichogramma japonicum* and *Trichogramma chilonis* releases with *Bt* spray against stem borer and leaf folder in AAU, Assam revealed that the percent infestation of leaf folder was lowest in the released plot during rabi and kharif seasons. The yield was highest (3559.20 kg/ha) in *Trichogramma* released plot. Three releases of *T. japonicum* + *T. chilonis* each @ 1,00,000 adults/ha/release were found to be the most effective at MPKV, Pune and recorded minimum dead hearts (9.92%) and white earheads (4.33%) due to stem borer and leaf folder (6.65%). The maximum yield of 48.4 q/ha was also recorded in released plot.

Integrated use of *Trichogramma chilonis* and *T. japonicum* against leaf folder, *C. medinalis* and stem borer, *S. incertulas* of rice was evaluated in farmers' fields at village Sudhar (Distt. Ludhiana) by PAU. The lowest incidence of leaf folder was recorded in parasitoid released plot (@1,00,000 per ha) (1.50%) and chemical control (1.80%) and it was significantly lower than control (5.24%) and lower dosage (50,000/ha) of parasitoids (4.80%). The mean percent dead hearts and white ears were also low in parasitoid released plot (1, 00,000 per ha) and chemical control. The highest yield (60.90q/ha) was obtained in parasitoid released plot and chemical control (60.50q/ha) and was significantly higher than control (55.30q/ha).

Biocontrol based IPM was evaluated in comparison with chemical control in a farmer's field at Borholla by AAU, Jorhat during rabi and kharif. The release of *Trichogramma* @ 50,000/ha checked the formation of dead hearts significantly (2.66% to 5.29%). Biocontrol and chemical control were on par in checking leaf folder damage. The field recovery of *T. japonicum* estimated by placing *Corcyra* egg cards revealed a recovery percentage of 20-25%. In Tamil Nadu, the per cent dead hearts and white ears were lowest in *Trichogramma* released plots in trials conducted by TNAU. The per cent damage by leaf folder was also less in release plots. The per cent parasitism of stem borer eggs was highest in *Trichogramma* release plot. The yield was 3916 kg/ha in *Trichogramma* release plot as against 2740 kg/ha in untreated check.

Large scale demonstration of IPM (seven releases of *T. chilonis*+*T. japonicum* each @ 1,00,000 per ha per week, starting 30 DAT + one application of Padan 4G@ 25kg/ ha) was conducted in farmers' fields at village Karni Khera (Distt. Ferozepur) by PAU, Ludhiana. The per cent dead hearts and white ears in IPM and chemical control were significantly lower with significantly higher yield.

2.7. Biological suppression of oilseeds crop pests

Nomuraea rileyi was evaluated against *S. litura* and *H. armigera* on groundnut at Aliyar Nagar, Pollachi by TNAU. The application of fungus formulations as aqueous suspension or oil in water formulation at $5x10^{11}$ spores/ha was better and as effective as insecticide treatment in controlling both the pests.

Verticillium lecanii was evaluated against mustard aphid, *Lipaphis erysimi* under laboratory conditions at PAU, Ludhiana. The highest mortality (40.0%) was recorded in higher dose (10^8 conidia/ml) 96 h after treatment.

2.8. Biological suppression of coconut pests

Two new formulations of the fungus *Hirsutella thompsonii* were evaluated along with the already available formulation Mycohit against the coconut mite, *Aceria guerreronis* through multilocation trials at PDBC, Bangalore, Regional Station (CPCRI), Kayangulam, ANGRAU, Hyderabad, KAU, Thrissur and UAS, Dharwad. All the treatments were applied thrice as sprays at 15-day intervals. All the three formulations significantly reduced the number of live mites/mm^2 of the nut surface. However, there was no significant reduction in nut damage in the Bangalore trials. Data on population count and damage index at maturity showed no significant difference among the treatments at one location in Kayangulam and two locations in Hyderabad. At Thrissur post-treatment count of live mites/mm^2 in the two locations was significantly lower in all the three Mycohit formulations and in wettable sulphur than in control. The trials in Dharwad indicated that all the three formulations of *H. thompsonii* were on par with wettable sulphur but significantly superior to untreated check.

Parasitization of *Opisina arenosella* was recorded throughout the year at Regional Station (CPCRI), Kayangulam. The average percentage parasitism by *Brachymeria* spp. was 34% and by *Apanteles taragamae* 41.2%. The predominant parasitoids recorded at KAU, Thrissur were *Brachymeria nosatoi* and *Apanteles* sp. as also the anthocorid predator *Cardiastethus* sp.

2.9. Biological suppression of fruit crop pests

Five releases of *Trichogramma chilotraeae* at weekly intervals @ one lakh/ ha brought about a marginal reduction in the fruit damage by *Deudorix isocrates* (29.40%) as compared to untreated control (34.62%) at IIHR, Bangalore. The principal parasitoid of pomegranate fruit borer, *D. epijarbas* at Solan was *Telenomus* sp. with 50-83.3% parasitism of eggs during July-August.

Trichogramma chilonis released five times at one lakh/ha against the ber fruit borer, *Meridarches scyrodes* at IIHR, Bangalore resulted in a mean damage in released plant 28.80% while it was 81.00% in unreleased fruit plants

A field study on the parasitoids of *A. dispersus* conducted at IIHR, Bangalore from February 2000 to February 2003 on guava showed that *E.* sp. nr. *meritoria* was the only major natural enemy encountered initially which was displaced steadily later by *E. guadeloupae*.

Natural parasitism by *Encarsia* spp. was noticed throughout the year at KAU, Thrissur and comparatively higher parasitism was observed in chilli (7.88-61.22) than in guava (1.44-41.52). A total of eight conventional pesticides and nine botanicals were screened for residual toxicity on the adults of *E. guadeloupae* at IIHR, Bangalore and monocrotophos was found to be the most persistent causing very high mortality even up to 21 days of application.

Studies on the evaluation of *Metarhizium anisopliae* against mango hopper, *Idioscopus niveosparsus* at IIHR, Bangalore showed that the fungus was effective in inflicting 68.13 to 100% mortality (concentration of 1.0 x 10^{10} spores/ml) within 48-72 hours. Biolep and Dipel @ 1 kg/lt. against pomegranate fruit borer *D. isocrates* was found effective amongst other *Bt* formulations, Halt and Delfin in Bamgalore.

Natural enemies of San Jose scale emerged normally in spite of Diesel oil emulsion (1:5); D.C Tron Plus (2%), natural tree oil (2%) and Ipol (25) treatments in trials at Solan.

2.10 Biological suppression of vegetable crop pests

Leaf mining PTM larvae were found to be parasitized by *Apanteles* spp. and *Bracon* spp. to the extent of 2.95 – 7.04% and 4.35 – 8.56%, respectively, at MPKV, Pune. In cabbage and cauliflower, *P. xylostella* was found to be parasitised by *Cotesia plutellae* (6.78–14.65%) in Pune.

NSP and *Bt* in combination with *T. bactrae* recorded lesser population of *P. xylostella* than *T. bactrae* alone and the yield was comparatively more in NSP + *T. bactrae* treatment (40t/ha) and *Bt* + *T. bactrae* (38t/ha) treatments than with *T. bactrae* releases alone (26t/ha) at IIHR, Bangalore.

Three sprays of *Bt* (Halt) @ 2 kg/ha at weekly interval starting from initiation of flowering were found to be effective against brinjal fruit borer, *Leucinodes orbanalis* recording minimum fruit infestation (4.49%) and maximum marketable fruit yield (149.9 q/ha) in Pune.

2.11. Biological suppression of potato pests

Pooled analysis of three years data revealed that releases of *C. koehleri* @ 5,000 mummies/ha in four equal doses at weekly interval in perforated plastic vials (2 x 1.5 cm size) hung 5 m apart in potato field 45 days after planting (DAP) recorded minimum PTM leaf mines (0.29 mines/m row), least tuber infestation (5.92%), maximum recovery (19.86%) and higher tuber yield (231.03 q/ha) at Pune.

Release of *C. koehleri* @ 1 mummy/4 kg tubers and *C. blackburni* @ 2 adults/kg tubers at 15 days interval was found to be the most effective method of release for parasitoids in storage devices, *Arnies*.

Application of *Sl*NPV @ 3 x 10^{12} POBs/ha was found most effective against *S. litura* in potato field at Pune.

2.12 Biological suppression of weeds

Successful control of water hyacinth has been achieved by the exotic weevils *Neochetina eichhorniae* and *N. bruchi* at Alengmara, Disangmukh and Samuguri in Assam. The weevils and mites released in four ponds in and around Hyderabad had established. The presence of larvae and adults as well as fresh damage done by the weevils was observed on water hyacinth at GAU, Anand, KAU, Thrissur and MPKV, Pune.

The adults of the weevil, *Cyrtobagous salviniae* were present in seven locations in Thrissur and one location in Ernakulam district in surveys throughout the year.

3. INTRODUCTION

3.1. Brief History

The All India Co-ordinated Research Project on Biological Control of Crop Pests and Weeds was initiated in 1977 under the aegis of Indian Council of Agricultural Research, New Delhi, with funds from Department of Science and Technology, Government of India. Within two years (1979), ICAR included the project under its research activities with full financial support. When the Commonwealth Institute of Biological Control, Indian Station, Bangalore, was closed in 1998, the Project Co-ordinator's cell was merged with that unit and taken over by the ICAR. The new headquarters called Biological Control Centre (under the administrative control of National Centre for Integrated Pest Management, Faridabad) was shifted to the premises of the erstwhile CIBC, Indian Station. Recognition of the importance of biological control came during the VIII plan with the upgradation of the centre to Project Directorate of Biological Control with headquarters at Bangalore. The Project Directorate started functioning on 19th October 1993. The AICRP started with 13 centres initially and has now increased to 16 centres, all functioning under the Project Directorate.

The Project Directorate is located on the Bangalore-Hyderabad National Highway (NH 3), about 8 km from the Bangalore City Railway Station and 17 km from the Bangalore Airport.

3.2. Past achievements

Eighty-three natural enemies (NEs) have been studied for utilisation against crop pests and weeds, out of which 61NEs could be successfully multiplied in the laboratory, 37 species have been recovered from the field, two are providing partial control, three substantial control and four are providing economic benefits worth millions of rupees and twelve are augmented the same way as indigenous natural enemies. The Encyrtid nymphal parasitoid *Leptomastix dactylopii* introduced from West Indies in 1983 has successfully established on common mealybug infesting citrus and many other crops in South India. The Coccinellid predator *Curinus coeruleus* (Origin:South America) introduced from Thailand in 1988 has colonised on subabul psyllid. The weevil *Cyrtobagous salviniae* (Origin:Argentina) introduced in 1982 colonised on exotic water fern *Salvinia molesta* in 1983. The release of weevils has resulted in annual saving of Rs. 68 lakhs on labour alone in Kuttanad district of Kerala. Weevils *Neochetina bruchi* and *N. eichhorniae* and hydrophilic mite *Orthogalumna terebrantis* (Origin: Argentina) were introduced in 1982 and colonised in 1983 on stands of water hyacinth. These weevils have now established in 15 states. Saving on labour alone is Rs. 1120 per ha of weed mat. *Cephalonomia stephanoderis* introduced in 1995-96 for the biological suppression of coffee berry borer, *Hypothenemus hampei* has established in several coffee growing areas.

Biosystematic studies on predatory coccinellids conducted and an annotated check-list of more than 400 species prepared.

A sort of classical biological control has been achieved by the redistribution of *Epiricania melanoleuca*, a parasitoid of *Pyrilla perpusilla*. Two species of *Encarsia* were found in 1999-2000 in Minicoy island of Lakshdweep and have now established in the mainland enabling suppression of the spiralling whitefly, *Aleurodicus dispersus*.

Breeding techniques for 48 host insects have been standardised including rearing on semi-synthetic diet and the cost of production has been worked out. Improved laboratory techniques have been worked out for the multiplication of 26 egg parasitoids, six egg-larval parasitoids, 39 larval/ nymphal parasitoids, 26 predators and seven species of weed insects. An acrylic multi-cellular rearing unit was devised for rearing *Helicoverpa armigera*. Semi-synthetic diets have been developed for *Chrysoperla carnea* and *Cheilomenes sexmaculata*. Mass culturing methods for aphidophagous syrphids, predatory anthocorids and several coccinellids have been developed.

Surveys for natural enemies of key crop pests have been conducted and the list of predators, parasitoids and pathogens compiled.

Tritrophic relationship between natural enemies, their hosts and host plants has been determined. Oxidized and hydrolyzed L-tryptophan elicited greater egg laying by coccinellids in cotton field. As a mass priming agent for the larvae of *C. carnea*, tricosane increased the predatory potential. *Hyposoter didymator* and *Telenomus remus* preferred to parasitise *Spodoptera litura* larvae and eggs on castor and beet root, respectively. Kairomones from scale extracts of *H. armigera* and *Corcyra cephalonica* increased the predatory potential of chrysopids. Tritrophic interaction studies between *T. chilonis*, *H. armigera* and cotton and tomato crops revealed differences among different genotypes. *Cotesia kazak* preferred host plants - tomato, cotton and okra, while *Cotesia marginiventris* preferred knol-khol, castor and cowpea and *Eucelatoria bryani* preferred cotton.

Suitable low temperatures for short-term storage of trichogrammatids, *Eucelatoria bryani*, *Carcelia illota*, *Allorhogas pyralophagus*, *Copidosoma koehleri*, *Hyposoter didymator*, *Cotesia marginiventris*, *Leptomastix dactylopii*, *Sturmiopsis inferens* and *Pareuchaetes pseudoinsulata* have been determined. Superior strains of *Trichogramma chilonis* have been determined for cotton, sugarcane and tomato crops. Endosulfan tolerant strain of *Trichogramma chilonis* was developed for the first time and the technology transferred to a private company for large-scale production. High temperature, high host searching ability and multiple insecticide tolerant strains of *T. chilonis* are being developed. Different pesticides have been screened against 37 natural enemies for identifying relatively safer ones to be used in BIPM. Primary cell culture from the embryos of *Spodoptera litura* was established to facilitate the multiplication of obligate microorganisms. *Chrysoperla carnea larvae* (one-day old) were successfully reared on artificial diet (Baculoviruses from several lepidopterous hosts were identified and cross infectivity studied. Physico-chemical characters of NPVs of *Spodoptera exigua* and *Galleria mellonella* were analysed. SMAY medium incorporated with chloramphenicol (50 ppm) and rose Bengal (100 ppm) could be used successfully for isolation of *Nomuraea rileyi* without contamination from field collected larvae of *Helicoverpa armigera* and *Spodoptera litura*. Maximum sporulation of *Beauveria bassiana*, *M.anisopliae* and *Verticillium leanii* was observed with pongamia ($3x10^9$, $2x10^9$ and $1.1x10^9$ spores/g, respectively) and castor oil cakes ($2x10^9$, $2x10^9$ and $1x10^9$ spores/g, respectively). Mass production of *V. lecanii* using soy flour-molasses medium in laboratory grade fermentor was standardized and a talc based formulation was developed using the fungal biomass.

A wheat bran powder based formulation of *Trichoderma harzianum* (PDBCTH 10) was found very effective in controlling chickpea root rot and wilt (*Rhizoctonia solani*). A new cost-effective medium (molasses-soy) was identified which resulted in maximum production of chlamydospores of *T. harzianum*. *Pseudomonas putida* (PDBCAB19) and *P. fluorescens* (PDBCAB2,PDBCAB29 and PDBCAB 30) were identified as potential antagonists of *Botrytis cinerea*, *Macrophomina phaseolina*, *Sclerotium rolfsii*, *Rhizoctonia solani* and *Fusarium oxysporum* f. sp. *ciceri*.

Efficient strains of entomophilic nematodes were isolated and tested from soil samples through out the country. *In vitro* mass production technique for entomophilic nematodes, *Steinernema* spp. and *Heterorhabidtis* spp. was developed utilising Wout's medium. *Verticillium chlamydosporium*, *Pseudomonas flourescens* and *Pasteuria penetrans* were found effective in suppressing plant parasitic nematodes.

Egg parasitoids *T. chilonis* and *Telenomus dignoides*, larval parasitoids *Cotesia flavipes*, *Glyptomorpha nicevillei* and *Isotima javensis* were found important for the control of sugarcane borers. *Beauveria bassiana*, *B. brongniartii* and *Metarhizium anisopliae* were mass cultured and utilized effectively against sugarcane white grubs. *T. chilonis* has proved to be effective against maize stem borer, *Chilo partellus*. BIPM modules developed for cotton pest control were found effective in Coimbatore and Anand. The module could increase yield, conserve naturally occurring biotic agents and increase the benefits compared to insecticidal sprays. Integration of *Telenomus remus*, *Chrysoperla carnea*, *Bt*, *Sl*NPV and neem seed kernel suspension was successful in the management of *S. litura* on tobacco.

Bt and *Sl*NPV formed important components of BIPM in tobacco. *Bt* and *Ha*NPV were important components of BIPM of pod borer complex in pigeonpea and pod borer of chickpea.

Biocontrol based IPM modules involving trichogrammatid releases for the control of stem borer and leaf folder of rice was found better than routine insecticide schedules. The cost-benefit ratio for BIPM was 1:2.74 whereas for chemical control it was 1:1.52.

Apanteles taragamae, *Bracon hebetor*, *Goniozus nephantidis*, and *Brachymeria nosatoi* are the key biocontrol agents on *Opisina arenosella*. Their inundative release coinciding the first release with the first appearance of the pest has proved effective. *Oryctes* baculovirus has been highly successful in reducing the *Oryctes rhinoceros* population in Kerala, at Minicoy, Androth (Lakshadweep) and Andaman Islands.

Release of *Cryptolaemus montrouzieri* was found to reduce the population of mealybugs, *Planococcus lilacinus* and *Maconellicoccus hirsutus*. Eggs of pomegranate fruit borer, *Deudorix isocrates* were heavily parasitised by three species of egg parasitoids. *Aphelinus mali* and several coccinellid predators were found effective against apple woolly aphid. San Jose scale natural enemies, *Encarsia perniciosi* and *Aphytis* sp., were well established in Jammu & Kashmir and Himachal Pradesh.

Trichogrammatoidea bactrae and *Bt* were found effective against *Plutella xylostella*. Management of tomato fruit borer, *H. armigera* through release of *T. pretiosum* and *Ha*NPV spray was found effective. *Copidosoma koehleri* and *Bt* were found effective against potato tuber moth in country stores.

Significant impact of *Neochetina eichhorniae*, *N. bruchi* and *Orthogalumna terebrantis* against water hyacinth was seen in Assam, Maharashtra, Gujarat, Kerala and Punjab. *Fusarium pallidoroseum* was found suitable as a candidate for parthenium control. Training programmes on mass production and demonstration of the impact of *Trichogramma, Cryptolaemus, Chrysoperla*, *Ha* NPV and *Sl* NPV have been conducted in many states.

Software on biological control namely, PDBC INFOBASE, giving information about bioagent producers, BIOCOT, giving information about biocontrol measures for cotton pests and "Helico-info", a software on *Helicoverpa armigera* developed in Ms-Access 97, giving details on the taxonomy of the pest, its host plants, distribution, natural enemies and detailed biocontrol measures to be undertaken have been developed.

3.3. Mandate

* To evolve effective schedules for biological suppression of important crop pests, diseases, nematodes and weeds.
* To quantify the natural enemy biodiversity and its role in regulation of pest population and serve as a national repository of natural enemies.
* To serve as a nodal agency for introduction, exchange and conservation of biological suppression agents at the national level.

* To co-ordinate research on biological suppression aspects at the national level and to serve as a linkage with international agencies.

* To develop state-of-the-art national information system on biological suppression (NISBS), disseminate information and impart training on latest technologies in biological control.

3.4. Organisational set-up

With a view to fulfil the mandate effectively and efficiently, the Project Directorate is functioning with Biosystematics, Introduction and Quarantine Laboratory, Mass Production Laboratory, Pathology Laboratory, Entomophagous Insect Behaviour Laboratory, Biotechnology Laboratory and a Co-ordination, Documentation and Training Cell (Fig. 1)..

3.5. Financial statement

Head	Plan*	Non-plan	Total
Pay & allowances	00.00	103.42	103.42
TA	02.60	02.20	04.80
Other charges including equipment	26.40	18.80	45.20
Works/petty works	02.00	01.00	03.00
Total	31.00	125.42	156.42

* Excluding co-ordinating centres

Centre-wise budget (ICAR share)

Name of the centre	Amount sanctioned (Rs. in lakhs)	Total expenditure (Rs. in lakhs)
CPCRI, Kayangulam	*	NA
CTRI, Rajahmundry	*	NA
IARI, New Delhi	*	NA
IIHR, Bangalore	*	NA
IISR, Lucknow	*	NA
SBI, Coimbatore	*	NA
AAU, Jorhat	08.58	10.33
ANGRAU, Hyderabad	09.30	**
GAU, Anand	17.07	20.45
KAU, Thrissur	12.18	11.73
MPKV, Pune	05.87	08.25
PAU, Ludhiana	10.94	11.12
SKUAS&T, Srinagar	06.52	**
TNAU, Coimbatore	05.25	05.02
YSPUH&F, Nauni, Solan	07.45	**
GBPUA&T, Pantnagar	02.92	**

* Since the Project has been merged with Non-Plan, ICAR Institute-based centres did not maintain separate budget account

** Expenditure details not furnished

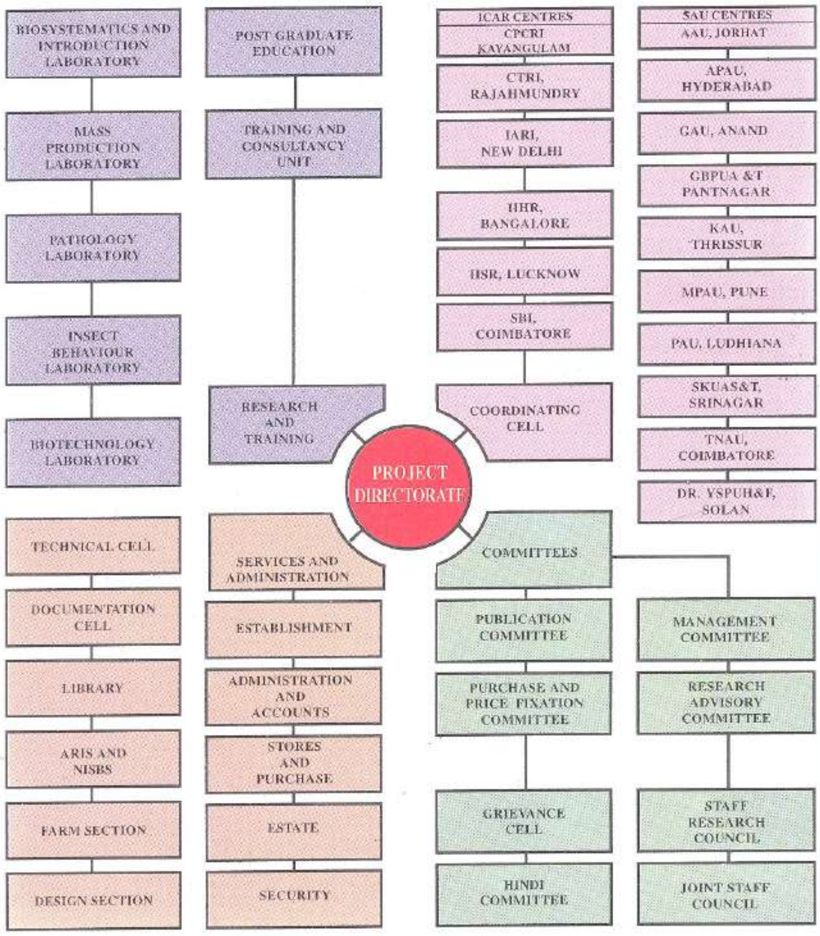
3.6 Staff position

Category	Posts sanctioned up to 31-03-2003 *	Posts filled up to 31-03-2003	Vacant positions
PDBC, Bangalore			
Research Management	01	01	-
Scientific	25	22	3
Technical	18	17	1
Administrative	07	07	-
Hindi cell	01	-	1
Supporting	06	6	-
Sub total (a)	58	53	5
SAU-based Centres			
Scientific	21	17	4
Technical	31	31	-
Administrative	1	1	-
Sub total (b)	53	49	4
ICAR Institute-based Centres			
Scientific	12	10	2
Technical	38	38	-
Sub total (c)	50	48	2
Grand total (a+b+c)	161	150	11

· Including IX Plan sanctioned posts

PROJECT DIRECTORATE OF BIOLOGICAL CONTROL BANGALORE

Organisational Chart



4. RESEARCH ACHIEVEMENTS

4.1 Importation of natural enemies

Import permits for *Smicronyx lutulentus, Cecidochares connexa, Nephaspis bicolor, Ganaspidium utilis, Chrysocharis parksi, Delphastus pusillus, Telenomus triptus, Telenomus ullyetti, Glabromicroplitis croceipes, Meteorus pulchricornis* and *Trichogramma mwanzai* have been obtained from the Plant Protection Advisor to Govt. of India.

4.1.1 Quarantine screening of *Chromolaena odorata* stem gall fly, *Cecidochares connexa*

Chromolaena odorata potted plants were got ready for receiving the consignment of stem gallfly. A consignment of *Cecidochares connexa* was received from Indonesia on November 27th 2002. A total of 52 females and 54 males emerged from the consignment. After mating the adults were enclosed in a nylon cage with four potted plants of *C. odorata* for oviposition. The plants were taken out on 8th or 9th day and watered regularly. The galls started forming in leaf axils and bases of buds two weeks after oviposition. The larval, pre-pupal & pupal and adult stages lasted 55-60, 22-28 and 7-9 days, respectively. Mature galls are green but woody, 2 to 3 cm long and 0.8 to 1.5 cm wide. All the plants containing galls were enclosed in nylon cages (1 m^3). The larvae generally cut an emergence tunnel to the gall surface, leaving the entrance closed by a "window" of epidermal tissue, to enable easy emergence by the adults.

The culture was established by carefully using only the emerged adults, which were allowed to oviposit on potted plants. Parasitoids belonging to the families Pteromalidae, Ormyridae and Eupelmidae emerged from the gall fly puparia received fron Indonesia, but were carefully eliminated from the culture by using only emerged gall fly adults for oviposition.

4.2. Taxonomic studies

4.2.1 Annotated checklist of Coccinellidae of the Indian subcontinent

An annotated checklist of the Coccinellidae (excluding Epilachninae) of the Indian Subcontinent was completed and published during the year. Nomenclatural changes and new faunal and distribution records were added to update the checklist. The checklist lists 400 species (including six subspecies) under 79 genera, 22 tribes and five subfamilies. It was also loaded on Platypus, the software produced by CSIRO, Australia, for taxonomic information management.

4.2.1.1 Taxonomic studies on Coccinellidae of the Indian region

Taxonomic studies on coccinellids of the Indian subcontinent were continued and fifteen species were studied. An apparently new species belonging to the genus *Microserangium* Miyatake was recorded on jasmine whitefly from Bangalore. Two species, namely, *Ortalia minuta* Weise (from Bangalore, Karnataka), and *Alloneda (=Cyphocaria) duvaucelii* (Mulsant) (from Nagaland), were recorded from the Indian mainland for the first time.

Based on the studies carried out, combination of *Pullus nymphaeae* Kapur & Munshi with *Scymnus (Neopullus)* Sasaji has been proposed. *Sticholotis rufolimbata* Canepari, so far known only from Nepal, was recorded from India from the states of Tamil Nadu, Karnataka, and Meghalaya. Examination of male genitalia and other generic characters indicated that it belongs in *Synonychimorpha* Miyatake. *Stethorus guangxiensis* Pang & Mao was found to be a junior synonym of *Stethorus indira* Kapur.

4.2.1.2 Identification guide for common coccinellids of the Indian region

An identification guide for 125 species of coccinellids commonly found in the agroecosystems of the Indian subcontinent has been prepared. The guide provides information on the current nomenclature, synonyms, a brief diagnostic description, geographic distribution, prey/associated habitat, seasonal activity, and important references pertaining to taxonomy and biology/economic importance, for all the species included. Colour photographs or illustrations of the habitus have been provided for all the species, along with illustrations of other diagnostic characters and genitalia. Colour photographs of the common morphs of polymorphic species, and immature stages of various groups of coccinellids have been given. A brief account of the morphology, taxonomy, and bioecology of Coccinellidae has been given. Keys have been provided to the subfamilies, tribes, genera, and species covered in the guide.

4.2.2 Tachinidae of the Indian subcontinent

Biosystematic studies on Indian Tachinidae have been continued. Specimens belonging to two subfamilies, viz., Goniinae and Tachininae are being studied. Specimens from lepidopterous hosts belonging to the genera *Carcelia, Palexorista, Sturmiopsis, Goniophthalmus* and *Winthemia* have beeen encountered and are being examined. The subfamily Goniinae is being studied at first.

4.2.2.1 Preparation of a checklist of Indian Tachinidae

A checklist is under preparation for the Indian Tachinidae including all taxa under the family. The checklist prepared so far has 124 species under 23 genera, 17 tribes and three subfamilies. Literature search and collection of bibliographic information about the hosts, collection, distribution, synonyms, etc. from different sources is being done for the preparation of the checklist. The information will be put into a taxonomic information management software, PLATYPUS (CSIRO, Australia).

4.2.2.2 Lepidopteran hosts and associated tachinids

Tachinids reared from *Helicoverpa armigera* feeding on cotton collected from Jalgaon, Barwah, Khandwa, Bangalore were found to belong to *Carcelia* and *Palexorista*. A species of *Winthemia* was found attacking the fruit piercing moth, *Othreis materna*. Other hosts from which tachinids have been collected are *Chilo infuscatellus, Bombyx mori, Spilosoma* spp., *Amsacta albistriga, Trichoplusia* spp.

Some important lepidopterous host insects and the associated tachinids are given below:

Amsacta albistriga	-	*Exorista xanthaspis*
Spilosoma obliqua	-	*Blepharipa zebina, Carcelia* sp.
Bombyx mori	-	*Exorista sorbillans*
Pelopidas mathias	-	*Theocarcelia oculata, Palexorista* sp.
Trabala vishnou	-	*Blepharipa zebina*
Achaea janata	-	*Compsilura concinnata*
Anomis flava	-	*Exorista sorbillans*
Earias vittella	-	*Peribea* sp.
Helicoverpa armigera	-	*Carcelia illota, Goniophthalmus halli, Palexorista laxa, Peribaea orbata, Exorista* sp.
Sesamia inferens	-	*Sturmiopsis inferens*
Spodoptera litura	-	*Peribaea orbata, Blepharella* sp.
Papilio demoleus	-	*Blepharipa zebina, Sturmia sp.*
Chilo infuscatellus	-	*Sturmiopsis inferens*
Chilo partellus	-	*Sturmiopsis inferens*
Crocidolomia pavonana	-	*Palexorista* sp.
Hypsipyla robusta	-	*Palexorista solennis, Compsilura concinnata*
Acherontia styx	-	*Zygobothria* sp.

4.2.3 Development of an interactive identification key for important families of insect parasitoids and predators

An interactive identification key for 31 families of parasitic Hymenoptera has been prepared. The families included in the key are Ichneumonidae, Braconidae, Evaniidae, Trichogrammatidae, Mymaridae, Eulophidae, Elasmidae, Encyrtidae, Eupelmidae, Aphelinidae, Tanaostigmatidae, Ormyridae, Torymidae, Eurytomidae, Pteromalidae, Perilampidae, Eucharitidae, Tetracampidae, Signiphoridae, Chalcididae, Leucospidae, Ceraphronidae, Proctotrupidae, Scelionidae, Platygastridae, Cynipidae, Eucoilidae, Figitidae, Diapriidae, Bethylidae and Dryinidae. The families, taxonomic characters used in their identification and various character states were loaded on LucID and scoring was done for their presence or absence. Notes on the taxonomy, biology, and economic importance of the families included have been added to the software. Line drawings and photographs of various characters and character states were prepared, scanned and loaded in the software. The key is being tested and validated.

4.3. Survey for natural enemies

4.3.1 Field survey for parasitoids and predators

Ichneumonids were obtained from *H. armigera* larvae infesting rose and marigold in August, tomato in September and Dolichos and sunflower in December. Maximum ichneumonid parasitism was obtained from Dolichos and sunflower during December. *Orius maxidentex* was collected from maize, aster, bhendi, cotton and sunflower field and *O. tantillus* from sunflower and maize fields. A eupelmid parasitoid, *Neanastatus* sp. was recorded as a parasitoid of the pod wasp, *Tanaostigmodes cajaninae.*

Amblyseius longispinosus (Phytoseiidae), *Triommata coccidivora* (Cecidomyiidae), *Synonycha grandis, Anisolemnia dilatata, Scymnus* sp.,(Coccinellidae), *Dipha aphidivora* (Pyralidae), ?*Micromus* sp. (Hemerobiidae), *Stethorus pauperculus* (Coccinellidae) and *Oligota* sp.(Staphylinidae) were collected from host crop fields and naturally vegetated areas for studies and evaluation on their predatory capacities on various homopteran hosts.

4.3.2 Monitoring the population of *Aleurodicus dispersus* and its parasitoids

The population of *A. dispersus* and its parasitoids were monitored on papaya, guava, *Michaelia champaka, Cassia siamea* and *Bauhinia* sp. at weekly interval. The month and week-wise percent parasitisation is presented in Table 1.

Table 1. Parasitisation of *Aleurodicus dispersus* during different months

Month (2002)	Per cent parasitisation				
	Papaya	Guava	*Michaelia champaka*	*Cassia siamea*	*Bauhinia* sp.
April	0.0	0.0	0.65	0.0	6.30
May	0.0	0.0	1.23	0.0	18.10
June	0.0	4.13	21.00	26.50	21.13
July	0.0	0.0	0.0	0.0	12.20
August	4.38	4.25	12.78	7.20	9.95
September	14.13	11.15	24.45	11.20	37.20
October	19.48	19.95	37.43	13.48	43.43
November	25.00	9.98	24.43	15.80	35.68
December	28.48	11.35	20.48	28.15	28.65
January	68.45	42.20	38.00	32.23	27.80
February	11.58	0.0	8.00	10.48	11.23
March	5.20	1.93	1.75	4.30	16.93

It was observed that parasitisation by *Encarsia gaudeloupae* was present throughout the year in *M. champaka* and *Bauhinia* sp. In papaya parasitization was seen only from August–March and the maximum mean parasitization of 68.45% was recorded in January. In guava also the highest mean parasitization of 42.20% was seen in January. The population of *A. dispersus* has come down compared to previous year on all hosts. All the emerged parasitoids were *E. gaudeloupae* confirming that it is a dominant parasitoid.

4.3.3 Survey for predators of the sugarcane woolly aphid

Surveys were conducted in the northen districts of Karnataka and in Western Maharastra to collect the predators of the sugarcane woolly aphid, *Ceratovacuna lanigera*. The predators observed and collected from the field were: *Dipha aphidivora* (Pyralidae), *Dideopsis aegrota* (Syrphidae), *Cheilomenes sexmaculata*, *Anisolemnia dilatata*, *Synonycha grandis* (Coccinellidae). They were also collected on the bamboo aphid, *Pseudoregma bambusicola*. A species of *Scymnus* (Coccinellidae) and ?*Micromus* (Hemerodiidae) were also collected during surveys.

4.4 Culturing techniques for host insects and natural enemies

4.4.1. Monitoring of *H. armigera* cultures

H. armigera culture was monitored regularly for 3 years and the per cent pupation recorded to understand the trend of production during different months in the laboratory.

The trend of production was varying from year to year. During 2000, the percent pupation ranged from 28.5 in May to 90.05 in October. During 2001, percent pupation varied between 11.6 in October to 80.2 in February. During 2002, less than 50% pupation was recorded only in February. From the month of April, a modified diet was used which improved the production and less than 50% pupation was recorded only in the month of July. The pupation varied between 55 to 73% during different months (Fig. 2).

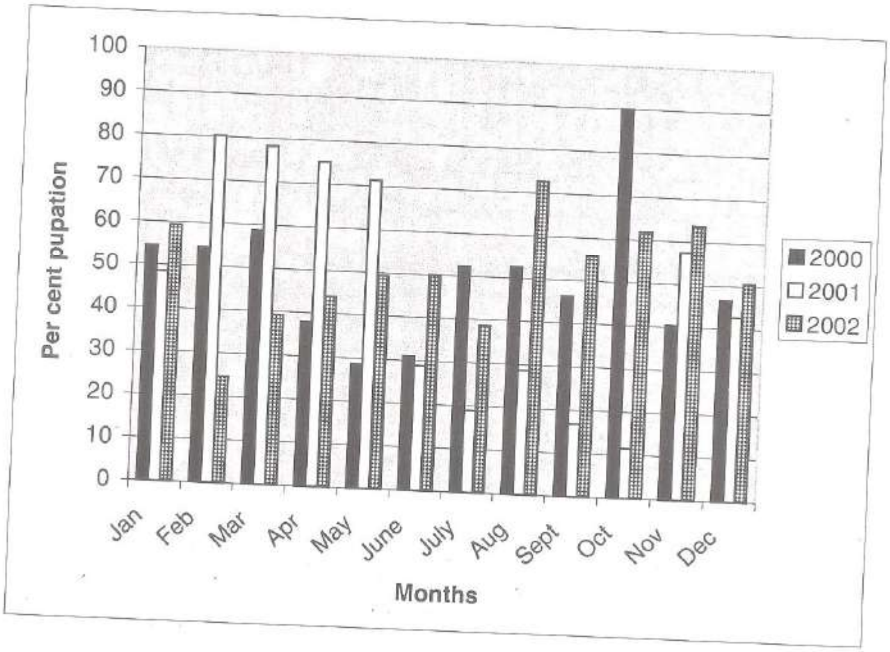


Fig. 2. Per cent pupation in *H. armigera* culture

4.4.2. Feasibility of rearing anthocorid predator *Orius* sp. in the laboratory

An attempt was made to continuously multiply *Orius tantillus* on UV irradiated *C. cephalonica* eggs. The adults were originally from the maize ecosystem. In the laboratory generations, the progeny production was low, 0.5 to 8.6 per female and a mean of 80.23% of the nymphs could form into adults. The sex ratio varied from 1:0.5 to 1:2. *O. tantillus* could be continuously multiplied for 12 generations in the laboratory on alternate laboratory host, but the progeny production was found to be low.

4.4.3 Culturing selected predators of *Ceratovacuna lanigera*

The life cycles of some of the predators were studied in the laboratory. They were provided with *Pseudoregma bambusicola* as food because *C. lanigera* does not occur in Bangalore and it was thought inadvisable to multiply them here, as it could pose a threat to the sugarcane being grown in Mandya, where the pest has not yet made an appearance. The life cycles of these species are detailed below (Table 2-7). The cultures of these predators however, could not be maintained beyond mid-March as the population of *P. bambusicola* reduced drastically. This resulted in a severe shortage of food as these predators don't appear to accept alternative food.

Table 2. Life cycle (days) of *Anisolemnia dilatata* on *Pseudoregma bambusicola*

	Egg	I	II	III	IV	Pupa	Total
N	12	23	22	22	22	21	12
Range	3-4	2-3	1-2	2-3	4-6	5-6	18-22
Mean ±SD	3.1±0.3	2.8± 0.5	1.5 ±0.5	2.5± 0.5	4.3± 0.6	5.1 ±0.4	19.3±1.2

Table 3. Life cycle (days) of *Synonycha grandis* on *Pseudoregma bambusicola*

	Egg	I	II	III	IV	Pupa	Total
N	14	14	12	11	9	13	6
Range	4	2-4	2-3	2-3	4-6	5-8	20-23
Mean ±SD	4±0	2.3± 0.7	2.5 ±095	2.3± 0.5	4.8± 0.8	5.5 ±0.9	21.3 ±1.3

Table 4. Life cycle (days) of *Synonycha grandis* on *Aphis craccivora*

	I	II	III	IV	Pupa	Total
N	7	7	4	4	4	4*
Range	2-3	2-3	2-3	5-7	4-5	21-22
Mean ±SD	2.14± 0.4	2.7 ±0.5	2.75± 0.5	5.75± 0.9	4.5 ±0.6	21.3 ±0.5

* 3 adults deformed and 1 normal

Table 5. Life cycle (days) of *Dipha aphidivora* on *P. bambusicola*

	Egg	Larva	Pupa	Total	Adult longevity
N	20	16	15	14	5
Range	3-4	13-20	5-10	24-31	3-7
Mean ±SD	3.7±0.5	14.6 ±2.73	7.3±1.4	25.9± 2.48	5.4 ±1.7

Table 6. Life cycle (days) of *Scymnus* sp. on *P. bambusicola*

	Egg	Larva	Pupa	Total
N	15	7	7	7
Range	3-4	10-13	5-8	16-22
Mean ±SD	3.6±0.4	11.0±0.6	5.1±1.3	19.3±1.5

Table 7. Life cycle (days) of ?*Micromus* sp. on *P. bambusicola*

	Egg	Larva	Pupa	Total
N	24	24	18	24
Range	3-4	5-10	6-8	16-20
Mean ±SD	3.6±0.5	7.6±1.4	6.9±0.8	17.5±1.2

4.4.4 Development of a rearing protocol for *Amblyseius longispinosus* and *Triommata coccidivora*

A rearing protocol to produce *A. longispinosus* in large numbers is being standardised. The technique being developed involves the following steps. The spider mites are multiplied on cowpea seedlings. Starting with a mean initial population of 2 spider mites per leaf a population of 50-55 spider mites/leaf can be built up in one week. Using 6 such leaves a population of 100-110 spider mites/leaf can be built up in another week. *A. longispinosus* could be released on this prey population density @ 2 mites per leaf. Within twelve days 400 to 500 adults of the phytoseiid can be produced.

Cecidomyiids, including the mealy bug feeding *Triommata coccidivora* occurred in very low numbers in the field. Only small numbers could be collected during the months from September to January.

4.5 Bioecological studies on laboratory hosts and natural enemies

4.5.1. Biology of *Cybocephalus* sp.

Cybocephalus sp. (Nitidulidae: Coleoptera) is a dominant predator of spiralling whitefly, *Aleurodicus dispersus*. The biology of this species was studied on *A. dispersus*. The eggs and freshly hatched larvae were reared individually. The measurements like length of the body and breadth of the head capsule of the larva were taken every day.

Freshly laid eggs were transparent, elongate, cylindrical with both ends rounded. Eggs were generally laid close to veins where eggs of the whitefly were present. The contents of egg was clear at the beginning and slight granulation developed on third day. The duration of different life stages is given in Table 8.

Table 8. Duration of different life stages of *Cybocephalus* sp.

Stage	Duration (days)		
	Minimum	Maximum	Average
Egg	4	4	4
Larva – I	2	7	3.95
– II	2	3	2.22
– III	2	4	3.80
Pre-pupa	3	4	3.50
Pupa	10	10	10
Total average			27.47

The first instar had white body and pink bodies (one or two) were seen inside 6, 7 or 8 abdominal segments of second instar. The third instar feeds voraciously. The third instar stops feeding and searches a place for pupation one or two days before becoming pre-pupa (C shaped). The pupa is naked. The total period from egg to adult was 27.27 days.

4.5.2. Stage of *Aleurodicus dispersus* accepted by *Encarsia guadeloupae* for parasitisation

Encarsia guadeloupae is one of the dominant parasitoids of *Aleurodicus dispersus* in India. A study was made to know the correct stage of *A. dispersus* accepted for parasitisation by *E. guadeloupae*. Immediately after the eggs hatched, everyday nymphs were exposed to adults of *E. guadeloupae* for a day. This procedure was followed for all stage nymphs till just before pupation. From the parasitised nymphs, the percent parasitisation was worked out. It was found that the percent parasitisation was highest (15.0%), when four-day old first instar nymphs were exposed indicating their suitability. The percent parasitisation on one, two, three and five days old nymphs was 10, 8, 7 and 5. The second instar nymphs were not parasitised.

4.5.3. Use of size index of egg patch for assessing the number of eggs of *Spodoptera litura*

Spodoptera litura egg masses were individually observed under microscope for greatest length (l) and breadth (b) in millimeters and number of layers of eggs (L) and number of eggs in each mass. An attempt was made to arrive at a size index based on the three measured parameters *viz.*, l, b and L. Five size indices were chosen, *viz.*, *L* x *l* x *b*, *l* x *b*, *L* x *l* and *L* x *b*. Regression analysis was done to find out if significant relationship existed between each size index and the number of eggs in each patch.

Regression analysis between size index and number of eggs in each mass revealed that among the various indices calculated the size index *L* x *l* x *b* was best able to explain the number of eggs in each mass with an R^2 of 0.512 (Y=1.8345x+74.427). Based on this size index three major groups were defined, *viz.*, 15-50, 60-150 and 160 - >200 and number of eggs per egg mass in each group was estimated as 100, 200 and > 300, respectively.

4.5.4 Evaluation of *Campoletis chlorideae* at different dosages on *Spodoptera litura* infesting castor

Studies were carried out to determine the optimum pest parasitoid ratio required for exposure of *S.litura* larvae to *C. chlorideae* adults in order to obtain maximum parasitism. Maximum parasitism was obtained at parasitoid: host ratio of 1:5 (80.57) and 1:15 (81.95%), but both were on par with each other and significantly superior to the treatment where parasitoid host density was 1:25 (62.29%) (Table 9). The percent larval survival was least in

Table 9. Effect of different parasitoid host ratios on parasitisation by *Campoletis chlorideae*

Parasitoid: Host density	Mean per cent parasitism (Based on cocoon formation)	Mean per cent larval survival (Based on pupal formation)	Per cent reduction in *S. litura* population
1 : 5	80.57 (64.07) a	19.43 (25.90) a	79.64
1 : 15	81.95 (65.80) a	18.04 (24.20) a	81.10
1 : 25	62.29 (52.30) b	37.71 (37.70) b	60.48
Control	00.00 (00.57) c	95.43 (80.52) c	–
CD (P=0.05)	06.53	08.12	

Figures in parentheses are arcsine values

Values followed by the same letter are not statistically different the ratios 1:5 (19.43) and 1:15 (18.04), in comparison to the ratio 1:25, where larval survival was 37.71%. In the control a larval survival of 95.43% was recorded. Thus, if *C. chlorideae* is released at parasitoid host ratio of 1:5 or 1:15, the pest population reduced by 79.64 and 81.10 percent, respectively.

4.5.5. Field evaluation of *Cardiasiethus exiguus* on *Opisina arenosella*

At Channapatna, a field trial was conducted to evaluate the performance of *C. exiguus* on *O. arenosella*. The experiment was initiated during end July 2002 and monthly observations were recorded on pest population per leaflet and *Cardiastethus* population per leaflet. Six field releases were made during this period, the first three at weekly intervals when young larvae were observed in the samples. Last three releases were made at monthly intervals.

The larval population per leaflet was 0.55 in the pre-treatment observation and during observation V it was 0.08. The count of anthocorid/leaflet was 0.22 in the pre-treatment count, while during the second observation it was 0.68/leaflet (Table 10). During the last two observations, *O. arenosella* larvae were in late instar and the anthocorid count was also less. The anthocorid population was found to be more when the pest population was in the younger stages.

Table 10. Population of *Opisina arenosella* and *Cardiastethus exiguus* in plots where *C. exiguus* releases were made

Observation No.	*Opisina* larvae/ leaflet	*Opisina* pupae/ leaflet	Number of *Cardiastethus*/ leaflet
Pre-treatment	0.55	0.10	0.22
Observation I	0.42	0.30	0.14
Observation II	0.12	0.00	0.68
Observation III	0.12	0.04	0.20
Observation IV	0.06	0.24	0.18
Observation V	0.08	0.06	0.04

4.5.6 Biology of predatory mites

The life cycles of two predators of spider mites were studied in the laboratory. *Stethorus pauperculus* completed its life cycle and laid fertile eggs when fed on laboratory reared *T. neocaledonicus*. *Oligota* sp. had a total developmental period of 14 days from egg to adult, but in most cases, failed to complete its life cycle on the spider mite. Pupal development was affected resulting in a very low adult emergence rate (Table 11). The few adults that emerged in the laboratory failed to lay eggs. All the eggs obtained during the study were obtained from gravid females collected from the field. *S. pauperculus* is the more efficient of the two predators.

Table 11. Life cycle (days) of *Stethorus pauperculus* on *T. neocaledonicus*

Parameter	Egg	I	II	III	IV	Pupa	Adult longevity
N	23	24	20	11	15	13	5
Range	3-5	1-2	1-2	2-3	3-5	3-4	14-20
Mean ±SD	3.6 ± 0.7	1.7 ± 0.5	1.6 ± 0.5	2.2 ± 0.4	4.1 ± 0.3	3.5 ± 0.5	17.8 ± 2.3

Fecundity: 162 eggs; Egg laying period: 14 days

4.6 Studies on behavioural response of natural enemies and tritrophic interaction

4.6.1 Testing kairomone compounds for adult chrysopids

Linallol and B-caryophyllene are important compounds responsible for the attraction of the chrysopids in different crops. Commercially available linallol was tested after diluting to different concentrations with n-hexane. Fifteen females of *C. carnea* in the age group of 7-15 days were released in the test chamber of a wind tunnel. On the other chamber (bait chamber) the test compound was kept. After 1 hour the number of adults reaching the bait chamber was counted. The experiment was replicated five times.

The results indicated that 0.10, 0.15 and 0.20 ml of linallol in 10 ml of hexane elicited positive response from 4.8-6.0 adults and the response was on par.

4.6.1.1 Improvement of kairomone formulations for chrysopids

Instead of hydrochloric acid, weak acids like acetic acid and citric acid were used for hydrolysis of L-trypophan to avoid the highly corrosive hydrochloric acid. L-tryptophan at 3.33 g with citric acid or acetic acid at different concentrations starting from 3 g to 8 g was added and kept for complete hydrolysis.

The compounds were tested under wind tunnel studies. The percent adults that responded was recorded. Less number of adults were responsive to both the citric acid and acetic acid hydrolysed L-tryptophan. However, the response was higher in higher doses of citric or acetic acid (Table.12).

Table 12.Response of female *C. carnea* to hydrolysed L-tryptophan after 3 days of hydrolysis

Treatments	Percent adults responsive
3.33 g L.Tryptophan + 3 g citric acid in 100ml water	0.00
3.33 g L.Tryptophan + 4 g citric acid in 100ml water	1.33
3.33 g L.Tryptophan + 5 g citric acid in 100ml water	6.66
3.33 g L.Tryptophan + 6 g citric acid in 100ml water	8.00
3.33 g L.Tryptophan + 7 g citric acid in 100ml water	12.00
3.33 g L.Tryptophan + 8 g citric acid in 100ml water	8.00
3.33 g L.Tryptophan + 3 ml acetic acid in 100ml water	0.0
3.33 g L.Tryptophan + 4 ml acetic acid in 100ml water	0.0
3.33 g L.Tryptophan + 5 ml acetic acid in 100ml water	0.0
3.33 g L.Tryptophan + 6 ml acetic acid in 100ml water	9.33
3.33 g L.Tryptophan + 7 ml acetic acid in 100ml water	8.00
3.33 g L.Tryptophan + 8 ml acetic acid in 100ml water	10.66

4.6.1.2 Field trial using kairomones for the adults and larvae of chrysopids

Field trials were conducted at Whitefield and at UAS, Dharwad. Three patches of cotton plants, each patch containing at least 1000 cotton plants and separated by at least 50 m from each other were selected and the following treatments imposed.

Whitefield trial

Treated plot: Two thousand larvae of *C. carnea* were released and kairomone treated egg cards were stapled on leaves from the next day. After 20 -25 days of release L-tryptophan solution was sprayed on the cotton plants and egg laying was observed. On the 29-30th day again kairomone treated cards were stapled (without release of chrysopids). On the 50th day of release L-Tryptophan was sprayed again.

Treated control: Two thousand larvae of *C.carnea* @ 2 larvae per plant were released. Again 2000 larvae of *C. carnea* were released @ 2 larvae per plant 30 days after first release.

Untreated control: The number of chrysopid eggs, larvae and adults were counted before treatment and after treatment 1 and 2. In the pretreatment observations, the eggs of *Apertochrysa* sp., mostly hatched eggs were observed. After each treatment, the number of

C. carnea was considerably more in the treated plot, lesser in the treated control and nil in control plants (Table 13), The results suggests that the number of chrysopids in the treated plot has increased significantly.

Table 13. Activity of chrysopids in kairomone treated cotton in Whitefield

Observations	Treated plot	Treated control	Untreated plot
Pretreatment	27	5	17
Post treatment I	5	3	0
Post treatment II	8	4	0

Dharwad trial

Among the treatments release of chrysopid larvae @ 2 per plant recorded comparatively higher population of chrysopids (15, 23 and 15 eggs, grubs and adults per 50 plants, respectively) after 22 days of release, compared to other two treatments. The population of *Chrysoperla* eggs, larvae and adult was 14, 19 and 12 per 50 plants, respectively, after a day of tryptophan applications. The population in T_1 and T_2 did not vary much. After second spray of tryptophan (50 days of release) the population was higher in T_1 than T_2. The observation at this stage indicated 29 eggs, 32 grubs and 26 adults of *C. carnea* per 50 plants in T_1 compared to 24 eggs, 27 grubs and 23 adults in T_2. In the block where there was no release of *C. carnea* or kairomonal application the population seemed to be dwindling down over time.The kairomonal exploitation (T_1) resulted in building up of very high population of *C.carnea* eggs (37), grubs (41) and adults (24). In T_2 only grub population was found to increase compared to the previous observation and that of eggs and adults remained almost same. There was slight increase in population in untreated block also (Table 14).

Due to kairomonal exploitation and release of *C. carnea* grubs in T_1 and release of *C. carnea* two times in T_2 the pest incidence was comparatively less in these treatments (Table 15 & 16). There was a slight increase in the yield of seed cotton in T_1 compared to T_2 and T_3. The yield in untreated check was lowest among the treatments.

Table 14. Effect of kairomones on chrysopid population in cotton

Treatments	Before treatment *No. of* C. carnea/ *50 plants*			After first spray No. of *C. carnea/* 50 plants			After second spray No. of *C. carneal* 50 plants			Pre harvest count No. of *C. carneal* 50 plants		
	Eggs	Grubs	Adults	Eggs	Grubs	Adults	Eggs	Grubs	Adults	Eggs	Grubs	Adults
Release of *Chrysoperla carnea* grubs + kairomone treated eggs + tryptophan sprays (T_1)	9.00	8.00	5.00	14.00	19.00	12.00	29.00	32.00	26.00	37.00	41.00	24.00
Release of *Chrysoperla carnea* grubs (two releases) (T_2)	11.00	7.00	4.00	15.00	23.00	15.00	24.00	27.00	23.00	23.00	33.00	21.00
Untreated Control (T_3)	10.00	9.00	4.00	6.00	9.00	6.00	4.00	5.00	5.00	7.00	11.00	8.00

Table 15. Impact of natural enemies on sucking pest incidence in cotton

Treatments	Aphids population /50 plants				Jassids / 50 plants			
	Before treatment	After first spray	After second spray	Pre harvest count	Before treatment	After first spray	After second spray	Pre harvest count
Release of *Chrysoperla carnea* grubs + kairomone treated eggs + tryptophan sprays (T_1)	473	407	191	77	78	63	39	27
Release of *Chrysoperla carnea* grubs (two releases) (T_2)	481	317	297	197	69	52	47	41
Untreated Control (T_3)	469	510	573	912	73	76	81	87

Table 16. Impact of natural enemies on bollworm incidence in cotton

Treatments	*Helicoverpa* eggs / 50 plants				*Helicoverpa* larvae / 50 plants				Yield q/ha
	Before treatment	After first spray	After second spray	Pre harvest count	Before treatment	After first spray	After second spray	Pre harvest count	
Release of *Chrysoperla carnea* grubs + kairomone treated eggs + tryptophan sprays (T_1)	57	49	31	26	42	39	27	17	11.25
Release of *Chrysoperla carnea* grubs (two releases) (T_2)	63	42	33	31	44	34	31	21	11.15
Untreated Control (T_3)	56	61	47	40	47	39	27	23	10.25

4.6.2 Kairomone formulations for *Trichogramma chilonis*

Formulation prepared with *Corcyra* scale fortified with 0.5% of tricosane, pentacosane or nonacosane was tested in multiple choice and no choice experiments with *T. chilonis*.

4.6.2.1 Multiple choice test

The formulations were prepared in petroleum ether as well as hexane. In an eight-arm olfactometer all the treatments were maintained on the *Corcyra* eggs sprayed with the kairomones and kept in individual tubes. Fifty adults of *T. chilonis* were released in the centre and kept for 30 minutes. The eggs were collected later and observed for parasitisation. The parasitization varied from 21.2 to 27.2, but no significant differences were seen between treatments with all the three kairomones in ether as well as hexane.

4.6.2.2 No choice experiment

This experiment was conducted to study the influence of kairomone (tricosane and pentacosane) to enable parasitization at a longer distance. The kairomone treated *Corcyra* egg cards were kept in the bait chamber of the wind tunnel along with a small white card (3 X 3 cm) glued with gum and twenty adult *T. chilonis* were released. After 30 minutes, the card was collected and the number of adults counted. The egg card was collected and kept for observing the parasitization. There was no significant difference in the different treatments both in terms of percent response and percent parasitization for all the kairomone treatments (scale extract kairomone).

4.6.2.3 Dual choice experiment

A kairomone formulation was developed by mixing tricosane, pentacosane, docosane, dodecane, eicosane, nonocosane and hexacosane at 1.0 mg/10 ml. The *Corcyra* egg cards containing 50 number of eggs were sprayed with the kairomone and kept in one arm of a 'Y' tube and in the other arm the eggs treated with hexane were kept. Twenty number of *T. chilonis* adults were released at the stem portion and the number of adults reaching the kairomone arm were counted. After 30 minutes the *Corcyra* eggs were collected and observed for parasitization. The parasitization in the kairomone treated cards was 24.4% while the hexane treated cards had 13.6% parasitization and the difference was significant.

4.6.3 Influence of diets on the kairomonal production

EAG studies were conducted to identify the kairomones for *Campoletis chlorideae*. Petroleum ether was used for extracting the kairomones. The kairomone extract from the larvae or frass from *S. litura* or *H. armigera* was used as stimulus and the response of *C. chlorideae* females was recorded .

The EAG response was poor for the frass of *S. litura* and *H. armigera* compared to their larval wash.

The extracts were tested in the wind tunnel with 5 females each time. The number of adults entering the bait chamber was noted and the experiment was repeated five times. *C. chlorideae* showed orientation towards the larval wash more than the frass. Among the concentrations tested 30 mg larval wash of *H. armigera* and *S. litura* recorded greater response from females (Table 17).

Table 17. Behavioural response of *C. chlorideae* to kairomones from the frass and larvae of *H. armigera* and *S. litura*

Treatments (mg per 10 ml)	Percent responsive
30 mg larval wash of *S. litura*	60.00
40 mg larval wash of *S. litura*	28.00
50 mg larval wash of *S. litura*	40.00
60 mg larval wash of *S. litura*	32.00
70 mg larval wash of *S. litura*	56.00
30 mg frass wash of *S. litura*	32.00
40 mg frass wash of *S. litura*	32.00
50 mg frass wash of *S. litura*	32.00
60 mg frass wash of *S. litura*	52.00
70 mg frass wash of *S. litura*	60.00
30 mg larval wash of *H. armigera*	20.00
40 mg larval wash of *H. armigera*	20.00
50 mg larval wash of *H. armigera*	32.00
60 mg larval wash of *H. armigera*	36.00
70 mg larval wash of *H. armigera*	36.00
30 mg frass wash of *H. armigera*	4.00
40 mg frass wash of *H. armigera*	20.00
50 mg frass wash of *H. armigera*	32.00
60 mg frass wash of *H. armigera*	40.00
70 mg frass wash of *H. armigera*	52.00
CD (P=0.05)	8.02

4.6.4 Influence of tomato genotypes, on the parasitization efficiency of the egg parasitoid, *Trichogramma chilonis* on the eggs of fruit borer *Helicoverpa armigera*

Ten varieties/ hybrids of tomato namely, Varalakshmi, Arka Meghali, Arka Ashish, Arka Abha, Arka Alok, Arka Ahuti, Arka Vikas, Arka Saurabh, Ramya and Pusa Ruby were evaluated under polyhouse condition to know their influence on parasitization efficiency of *Trichogramma chilonis* on *Helicoverpa armigera* eggs. The trials were repeated three times with three replications each time. The results of the pooled data on percent parasitization of eggs revealed the influence of genotypes on the parasitization efficiency. Highest parasitization was observed on Arka Alok (26.66%) followed by Pusa Ruby (26.66%). Lowest parasitization (13.33%) was observed on variety Arka Abha (Table 18).

Table 18. Influence of tomato genotypes on the parasitization efficiency of *T. chilonis* on *H. armigera* eggs

Variety/Hybrid	Mean percent egg parasitization		
	1st trial	2nd trial	3rd trial
Varalakshmi	13.33 (17.71)	13.33 (17.71)	26.66 (30.79)
Arka Meghali	13.33 (17.71)	20.00 (26.57)	13.33 (17.71)
Arka Ashish	13.33 (17.71)	13.33 (17.71)	26.66 (30.79)
Arka Abha	13.33 (17.71)	13.33 (17.71)	13.33 (17.71)
Arka Alok	26.66 (30.79)	26.66 (30.79)	26.66 (30.79)
Arka Ahuti	20.00 (26.57)	26.66 (30.79)	26.66 (30.79)
Arka Vikas	20.00 (26.57)	26.66 (30.79)	26.66 (30.79)
Ramya	13.33 (17.71)	20.00 (26.57)	13.33 (17.71)
Pusa Ruby	26.66 (30.79)	26.66 (30.79)	26.66 (30.79)
Arka Saurabh	20.00 (26.57)	20.00 (26.57)	26.66 (30.79)
CD (P=0.05)	(7.61)	NS	NS

4.6.4.1 Olfactometric responses of *T. chilonis* to green volatiles released by leaves and fruits of different genotypes of tomato

Responses of *Trichogramma chilonis* to the green volatiles of leaves and fruits of ten varieties/ hybrids of tomato, viz., Varalakshmi, Arka, Meghali, Arka Ashish, Arka Abha, Arka Alok, Arka Ahuti, Arka Vikas, Arka Saurabh, Ramya and Pusa Ruby were evaluated using a "Y- Shaped Olfactometer" in the laboratory. Among the tested genotypes, there was no significant difference in net response to the green volatiles from the leaves as well as fruits of any of the varieties.

4.6.5 Electrophysiological responses

4.6.5.1 *Helicoverpa armigera* (females) to the volatiles of leaves of different varieties/ hybrids of tomato

Responses of *H. armigera* (females) to the leaves of ten varieties/ hybrids of tomato were evaluated using EAG. Each trial was repeated thrice. Maximum mean absolute net EAG response was given to Arka Vikas (-1.234 mv) followed by Arka Alok (-1.166mv) and Arka Saurabh (-0.960mv). Minimum response was given to Arka Ashish (-0.500mv) (Table 19).

Table 19. EAG response of *H. armigera* to tomato leaf volatiles of different varieties / hybrids

Sl. No.	Variety/hybrid	Mean absolute net EAG response (-mv)
1	Varalakshmi	0.569
2	Arka Meghali	0.728
3	Arka Ashish	0.500
4	Arka Abha	0.796
5	Arka Alok	1.166
6	Arka Ahuti	0.798
7	Arka Vikas	1.234
8	Ramya	0.690
9	Pusa Ruby	0.932
10	Arka Saurabh	0.960
11	Standard (Honey)	1.429

4.6.5.2 *Campoletis chlorideae* to the volatiles of leaves of different varieties / hybrids of tomato

Responses of *Campoletis chlorideae* (females) to the leaves of ten varieties/ hybrids of tomato were evaluated using EAG. Each treatment was replicated ten times. Honey was used as standard to compare the responses. Maximum mean absolute net EAG response was given to Arka Alok (-0.442 mv) followed by Ramya (-0.368mv) and Arka Ahuti (-0.362mv). Minimum response was given to Arka Meghali (-0.288mv) (Table 20).

Table 20. Electrophysiological responses of *C. chlorideae* to the volatiles of tomato leaves

Sl. No.	Variety/hybrid	Mean absolute net EAG response (-mv)
1	Varalakshmi	0.323
2	Arka Meghali	0.288
3	Arka Ashish	0.356
4	Arka Abha	0.345
5	Arka Alok	0.442
6	Arka Ahuti	0.362
7	Arka Vikas	0.319
8	Ramya	0.368
9	Pusa Ruby	0.332
10	Arka Saurabh	0.319
11	Standard (Honey)	1.492

4.6.5.3 *Campoletis chlorideae* to the leaves of coriander and methi

EAG responses of *Campoletis chlorideae* females to the volatiles of coriander and methi leaves were studied using Electroantennogram. The responses were compared with honey as standard cue. The Absolute Net EAG response for coriander volatiles was higher (-0.979mv) than the response for methi leaf volatiles (-0.672mv). However, the responses were lower to the standard cue-honey (-1.109mv).

4.6.6 Trapping and identification of volatiles

4.6.6.1 Leaves and fruits of different varieties and hybrids of tomato

Volatiles from the leaves and fruits of ten varieties/ hybrids of tomato namely, Varalakshmi, Arka Meghali, Arka Ashish, Arka Abha, Arka Alok, Arka Ahuti, Arka Vikas, Arka Saurabh, Ramya and Pusa Ruby were trapped, isolated and identified using standard GCMS techniques. Qualitative as well as quantitative variation was observed in the components. The most common fractions were: tetradecane, pentadecane, heptadecane, octodecane, nonadecane, eicosane, alpha pinene, linalool, 1,2-benzenedicarboxylic, cembrene and phenol, 2,4-bis. There were clear-cut differences in the fractions profile between leaves and fruits.

4.6.6.2 Tomato fruits before and after infestation by *H. armigera*

Volatiles from healthy and damaged fruits of tomato hybrids (Varalakshmi, Arka Meghali, Suraksha and Uttsav) were trapped, isolated and identified using standard GCMS techniques. Mostly qualitative changes in the fractions of synomones released by infested and healthy fruits were observed. (Table 21).

Table 21. Profile of volatiles released by healthy and damaged tomato fruits by *H. armigera*

Volatiles	Varalakshmi		Arka Meghali		Suraksha		Uttsav	
	H	D	H	D	H	D	H	D
1,2-Benzenedi -carboxylic acid	+	-	-	+	+	-	+	-
Beta-bisabolene	-	-	-	-	-	-	+	-
Beta-Farnesene	-	-	-	-	+	-	-	-
Cembrene	+	-	+	-	+	+	-	-
Eicosane	-	-	-	-	+	+	-	-
Cyclohepta siloxane	-	+	-	-	-	-	-	-
Heptadecane	+	+	+	+	+	-	+	+
Linalool	-	-	+	+	+	+	+	+
Linalool oxide	-	-	-	-	-	+	-	-
Nonadecane	+	+	+	-	+	+	-	-
Octodecane	+	+	-	+	-	+	+	+
Pentadecane	+	+	+	-	+	-	-	+
Phenole, 2,4-bis	+	-	-	-	-	-	-	-
Tetradecamethyl	-	+	+	-	-	-	-	-
Tetradecane	+	+	+	-	+	-	-	-
(E,E)-7,11,15-Trimethyl-3-methylene	-	-	-	+	-	-	-	-

4.6.7.3 Healthy and damaged bolls of different genotypes of cotton

Green volatiles released by healthy and damaged bolls of cotton genotypes namely G-Cot-10, Abadhita and Sahana were trapped, extracted, concentrated and identified using GC-MS. The most common compound in the bolls of different genotypes were: alpha-terpinene, terpinolene, limonene, phenol, 2-4-bis, cembrene, pentadecane, heptadecane, octadecane, eicosane and 1,8-cineole (Table 22).

Table 22. Profile of volatiles released by healthy and damaged bolls of different cotton varieties

Compound	G-Cot-10		Abadhita		Sahana	
	Healthy	Damaged	Healthy	Damaged	Healthy	Damaged
Alpha-terpinene	-	+	+	+	-	-
1, 2-Benzenedi-carboxylic acid	-	-	-	-	+	-
(R) – (-)-Cembrene	-	-	+	+	+	-
1,8-Cineole	-	+	+	+	+	-
Eicosane	+	-	-	-	-	+
Heptadecane	+	+	+	+	+	+
Limonene	-	-	+	+	-	-
Linalool – L	+	+	-	+	-	-
m-Menthadien-6 - Trans-ol	+	-	-	-	-	+
p-Mentha 1,5,8 Trione	-	-	-	-	-	+
Nonadecane	-	-	-	-	+	-
Octodecane	+	-	+	+	+	+
Para-cymene	-	-	+	+	-	-
Pentadecane	-	+	+	+	+	-
1-Phellandrene	-	-	+	-	-	-
Sabinene	-	-	+	-	-	-
Terpinolene	+	-	-	+	-	+
1-4, Terpineol	-	-	-	-	-	+

4.7. Studies on artificial diets for host insects

4.7.1 *Opisina arenosella*

Our earlier studies indicated that diet comprising of toddy palm leaf powder in combination with deffated soya and kabuligram was found suitable for the development of the pest. This diet was further refined and evaluated for rearing *O. arenosella* and the diet-reared host was tested for its suitability to development of the parasitoids. The diet described by Jayanth & SudhaNagarkatti (1981) was used for comparison.

Toddypalm leaf powder + soya based diet was found superior to the one prescribed by earlier workers. The percentage larval survival (91.62%), pupation (86.4%) and female emergence (48.4%) on the diet was comparable with that reared on natural diet (coconut leaves) (Table 23). The duration of developmental periods of various life stages of the pest was prolonged on artificial diets. Significant differences were observed in all the biological attributes between the natural and artificial diets. Nevertheless, artificial diets sustained the development of the insect pest. Replacement of some of the ingredients and refining the diets is in progress.

4.7.1.1 Suitability of diet reared *Opisina arenosella* for rearing parasitoids

The artificial diet reared host was tested for its suitability for the development of late larval parasitoid *Goniozus nephantidis* and pupal parasitoids, *Brachymeria nephantidis/B. nosatoi*. The development of the parasitoid on diet reared host was compared with that reared on natural diet, to observe the differences in the biological attributes.

Goniozus nephantidis

The development of late larval parasitoid *Goniozus nephantidis* on diet reared larvae was prolonged (16.64 days), while the adult longevity (51.6 days) and the number of female progeny (15.4) was reduced, as compared to the parasitoid developed on host reared from natural diet. The differences were significant with respect to the total development period, adult longevity and number of larvae parasitised during their lifetime, while they were on par with respect to the number of parasitoids emerged per larva and female progeny on both the diets (Table 24).

Brachymeria nephantidis and *B. nosatoi*

Both the pupal parasitoids completed their development on the diet-reared host. The developmental period of both the parasitoids on host reared on artificial diet was comparable to those reared on natural diet (on coconut leaves) (Table 25). However, differences existed with respect to the adult longevity and the number of female progeny, which were low as compared to those, reared on the natural diet. The average longevity of *B. nosatoi* and *B. nephantidis* was 49.4 days and 47.8 days, respectively on diet reared host as compared to 62.0 days and 63.0 days, respectively on host reared on natural diet. The sex ratio of the parasitoids was female biased on both the hosts, irrespective of the diet.

Table 23. Development of *Opisina arenosella* on artificial and natural diets

Treatments	Biological attributes							
	Larval survival (%)	Larval period (days)	Pupal period (days)	Pupation (%)	Adult emergence (%)	Female emergence (%)	Adult Longevity (days)	Fecundity
Toddy palm leaf (Nd)	100.0^{a}	35.32^{a}	8.64^{a}	94.0a	93.2^{a}	57.80^{a}	7.65^{a}	122.60^{a}
Coconut leaf (Nd)	100.0^{a}	38.62^{ab}	9.82^{b}	92.6^{b}	88.30^{a}	53.6^{a}	6.15^{b}	96.22^{b}
TP + Ds + Kbg	91.62^{b}	43.20^{b}	11.47^{c}	86.40^{c}	74.07^{b}	48.4^{b}	6.82^{b}	76.20^{c}
Cn + Kbg *	82.84^{c}	46.42^{bc}	11.62^{c}	63.60^{d}	57.50^{c}	19.8^{c}	4.22^{c}	45.60^{d}
CD (P=0.05%)	2.87	7.03	1.02	4.12	7.15	5.03	1.21	5.62

Means followed by the same letter are not significantly different

TP + Ds + Kbg = Toddy palm leaf powder + defatted soya + Kabuligram

CN + Kbg = Coconut leaf powder + Kabuligram (*diet prescribed by Jayanth & SudhaNagarkatti, 1981), Nd - Natural host

Table 24. Development of *Goniozus nephantidis* reared on artificial and natural diets

Biological attributes	*Goniozus nephantidis*		
	On diet reared larvae	Host plant reared larvae	Student's "t" test(P<0.05)
Total developmental period (days)	16.4 ± 1.464 [a]	12.6 ± 0.4714 [b]	2.42 **
Number of parasitoids emerged/larvae	6.4 ± 0.1957 [a]	8.6 ± 0.5082 [a]	NS
Adult longevity (days)	51.6 ± 2.122 [a]	62.2 ± 1.785 [b]	3.57 **
Sex ratio (female: male)	15.4:1 ± 0.8860 [a]	19.2:1 ± 302 [a]	NS
Number of larvae parasitised during life time	11.2 ± 0.1471 [a]	15.1 ± 0.130 [b]	2.71**

Means followed by the same letter are not significant at (P<0.05)

Table 25. Development of pupal parasitoids on artificial diet reared and natural diet reared host

Biological attributes	*B. nephantidis*		*B. nosatoi*	
	Diet reared host	Leaf reared host	Diet reared host	Leaf reared host
Total developmental period (days)	16.6	15.0	16.4	16.0
Adult longevity (days)	47.74	63.0	49.42	62.0
Sex ratio (female:male)	2.5:1	4:1	2.66:1	3:1
Percent parasitisation	86.24	95.20	82.63	92.42

Mean of four generations

4.7.2 *Plutella xylostella*

Semi synthetic diets reported elsewhere were modified and evaluated for mass rearing of *Plutella xylostella*. Cabbage leaf powder in combination with deffated soya enriched with others (cholesterol, Wesson's salt mixture, casein etc.,) was found suitable for development of *P. xylostella*. The host culture was obtained from different locations (Doddabasanna, Hessaraghatta, Malur, Rajankunte and Tumkur) in and around Bangalore. The semi synthetic diet was evaluated against these strains. Among the strains, the strain from Malur could complete the development successfully on the artificial diet.

The developmental periods of various life stages were prolonged when the host was reared on artificial diets. Significant differences between the host reared on artificial and natural diet was observed with respect to the various biological parameters. Among the artificial diets, soya based diet gave higher percent larval survival (63.62%), adult emergence (72.24%) and fecundity (67.7) compared to others (Table 26).

4.7.2.1 Development of *Cotesia plutellae* on *P. xylostella* reared on artificial and natural diets

The soya-based diet was found to be more suitable than others for the development. Hence the larvae reared on this diet were tested for their suitability for development of the parasitoid *Cotesia plutellae* in comparison with that of the host reared on mustard seedlings.

Diet reared larvae were accepted for parasitisation. No significant difference was observed in the developmental period from egg to larvae and cocoon to adult emergence, in those reared on artificial and natural diet. However, marked differences were noticed in the adult longevity (8.27 and 13.62 days) and percent parasitisation (78.62 and 92.33 %), respectively on the artificial and natural diet reared host (Table 27).

Table 27. Development of *Cotesia plutellae* on host reared on artificial and natural diets

Biological attributes	*Cotesia plutellae*		
	On host reared on soya based artificial diet	On host reared on mustard seedlings	Student's "t" test (P<0.05)
Developmental period (Egg + larvae (days)	10.30 ± 0.325^{a}	7.26 ± 0.311^{a}	NS
Cocoon to adult emergence (days)	5.62 ± 0.453^{a}	4.32 ± 0.485^{a}	NS
Adult longevity (days)	8.27 ± 0.316^{a}	13.62 ± 0.983^{b}	2.28^{**}
Sex ratio (female: male)	$2.5:1 \pm 0.136^{a}$	$4:1 + 0.152^{a}$	NS
Percent parasitisation	78.62 ± 3.090^{a}	92.33 ± 0.690^{b}	9.38^{**}

Means followed by the same letter are not significant at (P<0.05)

Table 26. Development of *Plutella xylostella* on artificial diets and natural host

Mean Larvae /Plant	Biological attributes							
	Egg period (Days)	Larval period (days)	% Larval survival	Pupal period (days)	% pupation	% adult emergence	Adult longevity (days)	Fecundity
Soya based diet*	4.25 ^{a}	13.25 ^{b}	63.62 ^{c}	7.22 ^{b}	63.44 ^{b}	72.24 ^{bc}	12.25 ^{ab}	67.7 ^{b}
Modified Shelton's diet	4.82 ^{b}	16.2 ^{c}	55.42 ^{ab}	9.8 ^{d}	56.62 ^{a}	67.50 ^{ab}	10.32 ^{a}	61.5 ^{ab}
Modified Biever's diet	5.3 ^{c}	14.2 ^{b}	50.32 ^{a}	8.25 ^{c}	76.32 ^{c}	62.66 ^{a}	12.62 ^{b}	56.2 ^{a}
Control (Mustard seedlings)	4.25 ^{a}	9.2 ^{a}	95.6 ^{d}	4.5 ^{a}	88.68 ^{d}	79.9 ^{c}	18.25 ^{c}	89.6 ^{c}
CD (P=0.05%)	0.471	1.38	7.74	1.14	5.61	7.99	2.37	7.42

* Cabbage leaf powder + deffated soya based diet. Means followed by the same letter are not significant
Mean of four generations

4.8. Studies on artificial diets for natural enemies

4.8.1 *Cheilomenes sexmaculata*

Two and three days old larvae of *Cheilomenes sexmaculata* were reared individually on artificial diet and their biology was compared with those reared on natural diet (*Aphis craccivora*). Larva developed fast (5.7 days) on natural diet and was significantly different from the artificial diet reared larvae. Pupal period was least (3 days) when reared on natural diet. Pupation percentages were not significantly different among diets but natural diet reared insects showed higher adult emergence (68.11%) than the artificial diet reared ones (Table 28).

Table 28. Comparative biology of *Cheilomenes sexmaculata* reared on artificial diet and natural diet

Growth parameters	2 days old larvae on AD	3 D days old larvae on AD	*Aphis craccivora* (control)	CD (P=0.05)
Larval period (days)	7.69 b @	7.87 b	5.66 a	0.7570
Pupal period (days)	4.50 b	3.50 a	3.0 a	0.6857
Pupation (%)	64.8 (53.65) *	67.1 (55.07)	68.5 (55.91)	NS
Adult Emergence (%)	60.44 b (51.04)	62.97 b (52.60)	68.11 a (54.95)	2.6819

* Figure within parentheses are arcsine values; NS: Non-Significant

@ Means followed by same letter are not significantly different

Newly emerged adults were released in a plastic container and allowed for mating for 4-5 days. Artificial diet reared beetles were not found to lay eggs on artificial diet as the females require aphids for egg laying. Hence, the diet-reared beetles were provided with *Aphis craccivora* to find out their fecundity. Predatory efficiency of *C. sexmaculata* larva was studied by providing known number of mature aphids (*Aphis craccivora*). There was no significant difference in larval and pupal periods between artificial and natural diet reared *C. sexmaculata*. Pupation and adult emergence were significantly less in artificial diet reared beetles. The artificial diet and natural diet reared *C. sexmaculata* consumed 238 and 245 aphids, respectively. Fecundity was not significantly different on artificial diet (fecundity-222.6) and natural diet (fecundity 248.8) reared *C. sexmaculata* (Table 29).

Table 29. Biology and predatory efficiency of *Cheilomenes sexmaculata* reared on artificial diet and *Aphis craccivora*

Growth parameters	Artificial diet reared *C. sexmaculata*	Aphid (*Aphis craccivora*) reared *C. sexmaculata*	Student's t test (P<0.05 %)
Larval period (days)	5.84 ± 0.688	5.69 ± 0.751	NS
Pupal period (days)	2.84 ± 0.376	3.0 ±0	NS
Pupation (%)	63.8 ± 2.746 b@	68.8 ± 2.651 a	3.42 **
Adult emergence (%)	60.4 ± 3.750 b	68.2 ± 1.996 a	4.90 **
No. of aphids consumed/larva	238.0 ± 17.483	245.0 ± 17.713	NS
Fecundity (nos/female)	222.6 ± 37.831 (on aphids)	248.8 ± 26.779	NS

NS —Non-Significant
** —Significant
@ Means followed by same letter are not significantly different

4.8.2 *Cryptolaemus montrouzieri*

C. montrouzieri larvae (2-3 days old) were reared on artificial diet and were compared with natural diet (*M. hirsutus*). The larval period of *C. montrouzieri* on artificial diet was 11.6 days and there was no significant difference between artificial diet and natural diet reared predators. Pupation and adult emergence of *C. montrouzieri* on artificial diet were 75.9 and 69.4 %, which was significantly less when compared to natural diet (90% and 89.02%). As *C. montrouzieri* adults require mealy bugs and its ovisacs for egg laying the beetles were provided with ovisacs of the host insect, *M. hirsutus*. The beetles prefer to lay eggs inside the ovisac of the mealy bug, so the number of larvae produced per female was counted. Maximum number of *C. montrouzieri* larvae was obtained in natural diet reared *C. montrouzieri* (253.7 larvae/female), which was significantly more than the artificial diet reared (238.25) (Table 30).

4.8.3 *Cardistethus exiguus*

Cardiastethus exiguus was reared on artificial diet and the biology of the predator was compared with natural diet (15.7 days) reared (*Corcyra* and *Opisina arenosella* eggs). The treatments were T1-Nymphal & adult stages reared on artificial diet (AD); T2-Nymphal & adult stages on AD and *Corcyra* eggs, respectively; T3-Nymphal & adult stages on

Table 30. Biology of *Cryptolaemus montrouzieri* on artificial diet and *Maconellicoccus hirsutus*

Growth parameters	Artificial diet reared *C. montrouzieri*	Aphid (*Aphis craccivora*) reared *C. montrouzieri*	Student's t test (P<0.05 %)
Larval period (days)	11.60 ± 0.786	12.13 ± 0.694	NS
Pupal period (days)	7.73 ±1.109	8.15 ± 0.545	NS
Pupation (%)	75.91 ± 2.72 [b]	90.0 ± 1.69 [a]	12.44**
Adult emergence (%)	69.375 ± 8.52 [b]	89.62 ± 1.68 [a]	6.60**
No. of larvae produced/adult female	238.25 ± 15.508 [b]	253.7 ± 7.573 [a]	2.54*

@ Means followed by same letter are not significantly different

NS Non-Significant;

** Significant

Corcyra eggs & AD respectively; T4-Nymphal & adult stages on *Corcyra* eggs; T5-Nymphal & adult stages on *Opisina arenosella* eggs.

The nymphal period on artificial diet (18.4 days) was higher than the natural diet. Adult formation was highest in *Corcyra* eggs (91%) and significantly more than *O. arenosella* (87.0) and artificial diet reared (80.4). Artificial diet reared predators did not lay eggs when artificial diet was provided during the adult stage. A group of artificial diet predators were provided with *Corcyra* eggs during adult stage and the fecundity was 64 eggs/female. Again *Corcyra* egg reared predators provided with artificial diet during adult stage resulted in a fecundity of 6 eggs/female. Maximum fecundity (74 eggs/female) was observed when the predator was reared on its natural host (*O. arenosella*) and *Corcyra* eggs, which was significantly higher than the artificial diet reared (Table 31). Maximum longevity of the predator was observed in their natural host insects compared to artificial diet reared.

Eggs produced by *C. exiguus* reared on different diets were highly fertile. Oviposition pattern of *C. exiguus* was studied when reared on *Corcyra* and *O. arenosella* eggs and on artificial diet (nymphal stage- artificial diet; adult –*Corcyra* eggs). Maximum fecundity was during first and second week of the oviposition period and again one more peak was observed during fourth week. Entire oviposition period lasted 7 weeks.

Table 31. Development of *C. exiguus* reared on artificial diet and host insects

Treatments	Nymphal period (days)	Adult formation (%)	Pre-ovipositional period (days)	Fecundity (Nos./ female)	Viability of eggs (%)	Longevity (days)
Artificial diet	18.4	80.43 (63.62) [c]	8.0	---	---	20.0 [d]
Artificial diet + Corcyra eggs	---	---	---	64.0 [c] (71.57) [b]	90.0	40.0 [b]
Corcyra eggs + Artificial diet	---	---	---	6.0 [d]	88.0 (69.82) [b]	31.0 [c]
Corcyra eggs	15.7	91.0 (72.65) [a]	8.0	71.0 [b]	92.0 (73.83) [a]	45.0 [a]
O. arenosella Eggs	15.74	87.0 (68.92) [b]	8.0	74.0 [a]	93.0 (74.94) [a]	47.0 [a]
CD (P=0.05)		1.9384	NS	3.4102	2.4620	4.3955

Figures within parentheses are angular transformed values

NS Non Significant

@ Means followed by same letter are not significantly different

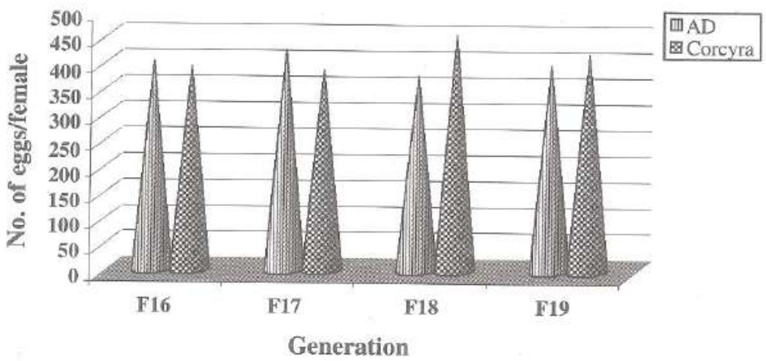
4.8.4 *Orius tantillus*

Orius tantillus was collected from maize and chrysanthemum and was maintained on *Corcyra* eggs and thrips (Chrysanthemum flowers). The predator culture maintained on these host insects was used for artificial diet studies. Two-day-old nymphs were released individually and provided with artificial diets and beans pieces. Mean developmental time on artificial diet was 11.6 days and the mean adult formation was 71.3 %.

4.8.5 *Chrysoperla carnea* on artificial diet

Chrysoperla carnea larvae (one day old) were continuously reared on artificial diet from F16 to F21 generations. The mean pupation, adult emergence and fecundity of *C. carnea* on artificial diet were 88.9 %, 87.1 % and 399.2 eggs/female. The above parameters of the predator on *Corcyra* were 87.7 %, and 84.3 % and 412 eggs/female, respectively (Fig. 3). Per cent female emergence on artificial diet and *Corcyra* egg was 46.5% and 45 % and longevity was 49.0 days and 53.7 days, respectively. Newly hatched larva were also

Fig.3 Comparative fecundity of *C. carnea* (one day old) reared on artificial diet and *Corcyra* eggs



reared continuously on artificial diet for 19 generations and the mean adult emergence and fecundity was found to be 86.9 % and 383.6 eggs/female, which was on par with *Corcyra* reared.

4.8.5.1 Group rearing of *C. carnea* on artificial diet and *Corcyra* eggs

Group rearing of *C. carnea* was compared through rearing in groups of 20, 25, 30 and 50 on artificial diet and *Corcyra* eggs. The experiment was replicated three times. *Corcyra* eggs were provided separately on the corrugated paper strips in a plastic container. One-day-old larvae were released and the mean survival of *C. carnea* was 42.0, 41.3, 50.3 and 26.5 in 20, 25, 30 and 50 larval groups, respectively. Mean survival in *Corcyra* was 22.8 when 50 larvae were released in a group.

4.8.5.2 Shelf life of artificial diet of *Chrysoperla carnea*

Artificial diet was prepared and stored in refrigerator (5°C) for different periods and the diet used for rearing *C. carnea*. The mean pupation and adult emergence on diet stored for 250-260 and 360-370 were 80.3% and 75%, respectively. Mean per cent female emergence and fecundity was 40.5 % and 340.5 eggs/female. The study revealed that the quality of *C. carnea* did not deteriorate much when the predator was reared on artificial diet, which was stored for more than one year.

4.9. Evaluation of improved and selected species/strains of natural enemies

4.9.1 Development of high temperature tolerant strains of *Trichogramma chilonis* and *Trichogramma japonicum*

4.9.1.1 *Trichogramma chilonis*

The experiment was initiated by exposing host eggs to *T. chilonis* by shifting parasitoids from 36°C in BOD incubator to variable temperature from 32° - 38°C and RH 60% in growth chamber. The aim was to achieve adult survival for > 5 days and parasitism > 90 per cent. In each generation about 3500 eggs were exposed to female parasitoids for 24 hours. Percent parasitism and longevity of parasitoids was recorded. The exposure was carried out in insect rearing cages (30cm^3) by releasing adults in bottom and hanging the egg card on the top of the cage. The results indicated that parasitoids show adaptability of tolerating high temperature up to 38°C.

The results indicated that high temperature tolerant strain gave significantly higher parasitism 16.0% (range 8.0 - 28.0 per cent) compared to untreated control where no parasitism was recorded (CD at 5% = 7.3). The mean per cent damage of fruiting bodies recorded in released plots was 4.4% and it differed significantly from untreated control with 6.9 per cent damage (CD at 5% = 0.62).

A field trial was conducted at RRS, Karnal to evaluate and compare the efficiency in controlling the stalk borer, *Chilo auricilius* in sugarcane crop of temperature tolerant strain (PDBC) with the local laboratory raised strain of *Trichogramma chilonis*. Eight liberations of the parasitoid @ 1 lakh parasitised eggs per hectare were made from first fortnight of August to end October 2002 at about 10 days interval. The pre-treatment borer incidence ranged from 28.4 to 39.6 percent. The field receiving PDBC heat tolerant strain recorded 53.7 percent borer incidence 20 days after the last release (mid-Nov.) as against 68.9 percent recorded in check. The field receiving the local strain acclimatized to a temperature range of 16 - 33°C was almost on a par (55.7 percent) with the PDBC strain (Table 32). The recovery of the parasitoid checked initially a week after the fourth release and then at the same interval after the last release was also almost on a par in the two strains. The intensity of the borer was 7.3 percent (PDBC strain) and 8.1 percent (local laboratory strain) as compared to 11.2 percent in check plot.

4.9.1.2 *Trichogramma japonicum*

The experiment was initiated during the year by exposing *T. japonicum* at 32°C and gradually shifting them to higher temperatures. At each temperature parasitoids were reared till adult survival was > 5 days and parasitism > 90 per cent. In each exposure about 2000

Table 32. A comparison of the PDBC temperature tolerant strain and local laboratory strain of *T. chilonis* in controlling *C. auricilius* infestation in sugarcane crop

Observations	PDBC strain	Local laboratory strain	Untreated
Pre-treatment incidence %	33.4	39.6	28.4
Post-treatment incidence %	53.7 (-34.7)	55.7 (-19.0)	68.9
Intensity %	7.3 (-34.7)	8.1 (-27.7)	11.2
Recovery % (Mean of two checks)	4.7	5.1	-

Figures in parentheses are percent increase (+) or decrease (-) compared to untreated

eggs were used and exposure was done for 24 hours. The observations recorded were percent parasitism and survival.

The results indicated that high temperature tolerant strain of *T. japonicum* was capable of parasitising 90.0% eggs after successive exposure of high temperature and longevity increased to 6 days from initial < 2 days at variable temperature of 32° - 38°C (Table 33).

Table 33. Development of high temperature tolerant strain of *T. japonicum*

Temperature (°C)	Per cent parasitism		Longevity (in days)	
	1st	last	1st	last
32	2.0	88.0	< 2	8
34	15.0	90.0	< 2	7
36	10.0	85.0	< 1	7
32 - 38	20.0	90.0	< 2	6

The experiment to test parasitising efficiency of heat tolerant strain in comparison to laboratory strain was carried out by releasing 1 to 5 females / 100 eggs in temperatures from 30°, 35° to 32 - 38°C in BOD incubators and growth chambers and results are presented in Table 34.

Table 34. Laboratory evaluation of temperature tolerant strain of *T. japonicum*

Number of females / cage	Temperature (°C)					
	30		35		40	
	Per cent parasitism by		Per cent parasitism by		Per cent parasitism by	
	LS	HTTS	LS	HTTS	LS	HTTS
1	13.3	42.7	2.7	12.7	14.7	32.0
2	26.0	88.2	14.0	32.0	24.7	29.3
3	36.0	92.7	10.0	40.7	32.7	43.3
4	50.0	95.3	6.7	56.7	26.0	56.0
5	64.0	78.7	26.7	62.0	18.0	65.3

LS = Laboratory strain, HTTS = High temperature tolerant strain

The parasitism at 30°C varied from 42.7 - 95.3% in high temperature tolerant strain compared to 13.3 - 64.0% in laboratory strain. At 35°C, parasitism was 12.7 - 62.0% in tolerant strain compared to 2.7 - 26.7% in the laboratory strain and at variable temperature of 32°C - 38°C parasitism varied from 32.0 - 65.3% in tolerant strain compared to 14.7 - 32.7% in laboratory strain. The results indicated that tolerant strain was more promising at higher temperature conditions.

4.9.2 Selection of *Trichogramma chilonis* for tolerance to insecticides

4.9.2.1 Multiple tolerant-strain

The three strains tolerant to endosulfan, monocrotophos and fenvalerate were mixed. Open ended glass tubes were sprayed with insecticide solution. Adults from the mixed population were released in each tube after they were dry. An egg card each containing about 8000 *Corcyra* eggs (½ cc) was introduced in each tube to obtain further generations.

Parasitism in all insecticides was 90 – 95 per cent and survival 15 – 40 per cent after 6 hours of constant exposure.

4.9.2.2 Multiple insecticide and high temperature tolerant strain

The mixed strain described above was used to develop a tolerant strain for high temperature. The parasitoids were exposed to variable high temperature of 32° - 38°C.

The results revealed that after 20 generations parasitism increased from 20.0 to 70.0% and survival from 0.0 to 5.0% after constant exposure of 6 hours in endosulfan. In monocrotophos, after 6 generations of exposure parasitism increased to 20.0% but no parasitoids survived after 6 hours of exposure. In fenvalerate, parasitism increased to 50.0% from initial 15.0% and survival to 10.0%. Results indicated that longer acclimatisation is necessary to get the strain, which could be tolerant to multiple insecticides and high temperatures.

4.9.3 Evaluation of multiple insecticide tolerant strain against cotton bollworms in Gujarat, Karnataka and Tamil Nadu

The field trial was carried out in collaboration with GAU, Gujarat, Regional Station (CICR), Coimbatore, UAS, Dharwad and TNAU, Coimbatore to evaluate efficacy of multiple insecticide tolerant against cotton bollworms. The parasitoids were released @ 150,000 / ha at weekly interval 6 - 8 times.

Regional Station (CICR), Coimbatore

The field trial at Coimbatore, where parasitoids were released 3 times at 15 days interval revealed mean per cent parasitism of 9.4% (range 4.0 - 12.0%) and it varied significantly with untreated control where no egg parasitism was recorded (Table 35). Per cent fruiting bodies damaged were also significantly low (4.0%) compared to 10.5% in untreated control. Results indicated that multiple insecticide tolerant strain was effective against bollworms.

Table 35. Field trial with multiple insecticides tolerant strain of *T. chilonis* against cotton bollworms at CICR, Coimbatore

Treatments	Mean % parasitism	Mean % damage of fruiting bodies
T. chilonis released plots	9.40	4.00
In control plots	0.00	10.50
CD at 5%	3.35	0.42

GAU, Anand

The percent egg parasitism was significantly higher in tolerant strain released plots compared to other treatments. Percent square damage was significantly lower in university practices plots and it differed significantly with all treatments. Percent boll damage was lowest in university practices and multiple insecticide tolerant strain released plots and damage in these plots differed significantly from other treatments. The yield recorded was highest (18.94 q/ha) in multiple tolerant strain released plots but was on par with laboratory strain of *T. chilonis* (Table 36). The results indicated that multiple insecticide tolerant strain of *T. chilonis* gave highest percent egg parasitism and yield of cotton.

Table 36. Field trial with multiple insecticides tolerant strain of *T. chilonis* against cotton bollworms at GAU, Anand

Treatments	% egg Parasitism	% square damage	% boll damage	Yield (q / ha)
Multiple tolerant strain	32.19	8.17	15.98	18.94
Laboratory strain	28.25	8.23	16.32	18.05
GAU University practices	8.71	6.65	15.32	17.36
Control	15.70	15.67	26.67	12.50
SEM	0.89	0.26	0.19	0.28
CD at 5%	3.10	0.90	0.65	1.00

TNAU, Coimbatore

Field evaluation of multiple insecticide tolerant *Trichogramma* strain was carried out on cotton Var. LRA 5166 in farmer's field at Puthur village, Thondamuthur, Coimbatore. The treatments evaluated were multiple insecticide tolerant *Trichogramma*, laboratory strain of *Trichogramma* @ 1.5 lakh/ha, insecticide check and control. The parasitoids were released eight times in the evening hours after few adults emerged commencing from 62 days after sowing. Bits of Trichocards containing ca. 750 eggs were stapled per 50 m^2 beneath the leaves. Totally seven rounds of insecticides were applied. The releases of *Trichogramma* were preceded by insecticide application.

The incidence of the larvae was contained significantly more in pesticide tolerant *Trichogramma* release sequentially with insecticide application, which was followed by release of susceptible strain and insecticide application. The field parasitism remained low and it was significantly higher in control and multiple pesticide tolerant *Trichogramma* + insecticides treated plot. The extent of parasitism was significantly lower in susceptible strain of *Trichogramma* + insecticides or insecticide-treated plot (Table 37). The damage to squares and bolls was significantly lowest in *Trichogramma* released sequentially with insecticides which was on par with susceptible strain of *Trichogramma* + insecticides (Table 38). Similar trend was observed with boll retention. Maximum yield was obtained in plots receiving *Trichogramma*. Pesticides-tolerant strain gave higher yield compared to the susceptible strain

Table 37. Field evaluation of multiple pesticide tolerant *Trichogramma chilonis* in the control of *H. armigera* population on cotton (var. LRA5166)

Treatment	Pre-treatment	Insecticide application days after sowing (DAS)							
		Spray 1 (62)	Spray 2 (70)	Spray 3 (77)	Spray 4 (87)	Spray 5 (100)	Spray 6 (114)	Spray 7 (122)	
		Trichogramma release after insecticide application (DAS)							
		Release 1(66)	Release 2 (73)	Release 3 (80)	Release 4 (90)	Release 5 (97)	Release 6 (109)	Release 7 (117)	Release 8 (125)
		Population of *H. armigera*/10 plants after spray application and *Trichogramma* release**							
		8 DAT	7DAT	10 DAT	9DAT	10 DAT	8DAT	8DAT	15DAT
Trichogramma chilonis (pesticide tolerant strain)+ insecticide application *sequential	7.8	5.4a	2.8a	4.2a	3.0a	2.2a	0.8a	1.0a	1.2a
Trichogramma chilonis (pesticide susceptible strain)+ insecticide application *sequential	3.6	4.8a	2.0a	6.4ab	3.8ab	3.2a	0.8a	1.6a	1.6a
Insecticide alone*	6.0	6.2a	2.8a	8.2b	4.6ab	3.4a	2.4a	1.2a	0.8a
Control	5.4	13.2b	11.8b	15.4c	12.8c	11.8b	9.4b	4.2b	4.8b

* endosulfan spray 1and 4; phosalone spray 2; quinalphos spray 3 and 5; chlorpyriphos spray 6; monocrotophos spray 7

** Observations recorded days after each spray application

In vertical columns, means followed by similar letters are not different statistically (P = 0.05) by DMRT

Table 38. Parasitism of *H. armigera* eggs by *Trichogramma* under field conditions on cotton: parasitization of *H. armigera* eggs

Treatment	Parasitization (%) of *H. armigera* eggs (after release)				
	Pre-treatment	1	3	5	7
Trichogramma chilonis (pesticide tolerant strain)+ insecticide application* sequential	3.13	9.42a	10.78a	8.97a	4.47b
Trichogramma chilonis (pesticide susceptible strain)+ insecticide application *sequential	3.49	2.15b	8.19a	4.69b	3.72b
Insecticide alone*	4.00	1.04b	1.29c	3.21b	1.24c
Control	4.11	7.22a	9.28a	10.76a	7.16a

Mean of five replication

* endosulfan spray 1and 4; phosalone spray 2; quinalphos spray 3and 5; chlorpyriphos spray 6; monocrotophos spray 7

In vertical columns, means followed by similar letters are not different statistically (P = 0.05) by DMRT

and both were on par. The combination of *Trichogramma* with insecticides was found to be significantly superior to insecticides alone. Untreated check recorded the lowest yield (Table 39).

UAS, Dharwad

The efficacy of multiple-insecticide tolerant strain of *T. chilonis* (Source: PDBC) against cotton bollworms was evaluated. The trial was conducted on var. DHH-11 under rainfed conditions, with the following four treatments replicated five times.

T_1 Release of PDBC strain of *T. chilonis* along with insecticide schedule

T_2 Release of laboratory strain of *T. chilonis* along with insecticide schedule (@ 1.0 lakh/acre/release)

T_3 Only insecticide (RPP)

T_4 Untreated control

Insecticide schedule:

Oxydemeton methyl 25 EC (Metasystox) @ 1.5l/ha (July 2nd week)
Dimethoate 35 EC (Rogar) @ 2.0 l/ha (July last week)
Quinalphos 25 EC (Eukalyx) @ 2.5 l/ha (August 3rd week)

Table 39. Efficacy of pesticide tolerant *Trichogramma* under field conditions on cotton: damage to fruiting parts and yield

Treatment	Square damage (%)		Boll damage (%)*	Bolls retained/ 5plants	Yield (kg/ha)
	Pre-treatment	After treatment*			
Trichogramma chilonis (pesticide tolerant strain) + insecticide application * sequential	14.96	14.40a	9.94a	112.92a	2168.6a
Trichogramma chilonis (pesticide susceptible strain) + insecticide application *sequential	14.40	13.30ab	10.94a	113.72ab	2076.0ab
Insecticide alone*	13.14	15.22b	11.76a	111.5b	1931.8b
Control	15.14	35.64c	24.42b	80.94c	1404.4c
CD (P=0.05)	NS				

* endosulfan spray 1and 4; phosalone spray 2; quinalphos spray 3and 5; chlorpyriphos spray 6; monocrotophos spray 7

** Observations recorded days after each spray application

In vertical columns, means followed by similar letters are not different statistically (P = 0.05) by DMRT

Monocrotophos 35 EC (Nuvacron) @ 1.5 l/ha (10-9-2002)
Endosulfan 35 EC (Endocel) @ 3.0 l/ha (17-10-2002)
Chlorpyriphos 20 EC (Dursban) @ 2.5 l/ha (26-10-2002)
Endosulfan 35 EC (Endocel) @ 3.0 l/ha (05-11-2002)
Cypermethrin 10 EC (Cyperkill) @ 0.75 l/ha (12-11-2002)

Date of parasitoids release: 09-10-2002, 19-10-2002, 23-10-2002, 28-10-2002, 06-11-2002, 09-11-2002 and 13-11-2002

The parasitization by multiple insecticide tolerant strain of *T. chilonis* was 25.42 per cent despite the spray of different insecticides against bollworms, which was significantly superior to the release of laboratory strain of *T. chilonis* (12.63%). Parasitization was also seen in insecticide-free plot (4.24%). It was negligible (1.64%) in the plot were insecticides only were used. The damage caused to the fruiting bodies was significantly less in T_1 (4.0%), compared to T_2 and T_3, which were statistically on par.

The yield levels were low during the current season and no significant differences among treatments except with control was observed. However, the yield was highest (11.83 q/ha) in RPP, followed by the treatment where multiple insecticide tolerant *T. chilonis* was used (Table 40).

Table 40. Efficacy of multiple insecticide tolerant strain of *T. chilonis* against bollworms in cotton

Treatments	Parasitization (%)	Damage to fruiting bodies (%)	Yield (q/ha)
PDBC strain of *T. chilonis*	25.42 (30.23)	4.00 (11.45)	11.80
Laboratory strain of *T. chilonis*	12.63 (20.76)	6.02 (14.14)	11.64
Only insecticide (RPP)	1.64 (7.19)	6.11 (14.13)	11.83
Untreated control	4.24 (11.80)	10.15 (18.53)	6.10
CD (P=0.05)	1.30	1.05	0.79

Number of eggs collected per replication for parasitization studies – 10/treatment (each time)
Figures in parentheses are arc-sine values

4.9.4 Selection of high host searching ability strain (HHSS) of various *Trichogramma* species

4.9.4.1 Parasitizing ability and retention of trait

The experiment was conducted by exposing *Trichogramma chilonis* in insect rearing cage (30 cm^3). The parasitoids were released @ 30 adults per cage. The regular maintenance was done in the cage itself. After 30 generations of rearing in the cage, uniform parasitism of > 95% was obtained. To know low long such searching ability of the parasitoids are retained in the laboratory, parasitoids after 30^{th} generation were reared in glass vials for 10 generations and experiment was conducted by exposing parasitoid 1, 2, 3, 4, 5 and 10 pairs per cage in parasitoid: egg ratio of 1E: 50 eggs. The parasitised egg card was collected back after 3 days and observed for per cent parasitism. The comparison of HHSS was done with parasitoids continuously reared in the cage.

The results presented in Table 41 indicated that HHSS parasitoids were able to retain their host searching ability even after 10 generations. HHSS could parasitise 36.9 - 72.4 per cent eggs compared to 53.6 - 77.0 per cent by those reared continuously in the cages. The sex ratio obtained for HHSS was 67.5% females compared to 50.0% females in laboratory strain. The result indicated that once this trait is acquired, HHSS can be mass produced in traditional way of breeding parasitoids for field release.

Table 41. Parasitizing ability of high host searching ability strain

Release rate	Per cent parasitism by (parasitoid: egg ratio 1F: 50 eggs)		
	HHSS parasitoid	Check species	HHSS after 10 generations
1 pair	53.6	4.0	36.9
2 pairs	50.6	34.0	60.8
3 pairs	60.0	30.4	67.0
4 pairs	73.8	24.4	60.2
5 pairs	77.0	11.2	72.4
10 pairs	55.0	23.0	61.0
.Mean	61.7	21.2	59.7

4.9.4.2 Dosage and host density response

Attempts were made to work out dosages in the laboratory by releasing 1 to 5 pairs of HHSS parasitoids in the cage compared with the check species, *T. pretiosum*. A bouquet of tomato plant was kept in the cage and *Helicoverpa armigera* eggs were inoculated @ 2, 4, 8 and 16 eggs / cage and 1 - 5 pairs were released in the cage. After 3 days eggs were collected and observed for per cent parasitism, hatching and super parasitism, if any.

The results indicated that HHSS of *T. chilonis* parasitised 0.0 - 50.0% compared to 0.0 - 20.0% *H. armigera* eggs by *T. pretiosum* where 1 pair of parasitoids were released in each cage (Table 42). Similarly parasitism in 2 pairs to 5 pairs cage ranged from 10.0 - 63.7%

Table 42. Host and parasitoid density response of HHSS

Dose	HHSS (*T. chilonis*)				Check species (*T. pretiosum*)			
	2 eggs	4 eggs	8 eggs	16 eggs	2 eggs	4 eggs	8 eggs	16 eggs
1 pair	10.0	40.0	10.0	25.0	0.0	0.0	17.5	0.0
2 pairs	0.0	30.0	24.0	33.7	20.0	20.0	2.5	10.0
3 pairs	50.0	35.0	47.5	63.7	10.0	50.0	15.0	1.0
4 pairs	50.0*	10.0*	10.5*	39.9*	0.0	35.0	0.0	64.9
5 pairs	0.0*	25.0*	12.5*	26.3*	0.0	15.0	22.5	17.5
Mean	22.0	28.0	20.9	37.7	6.0	24.0	11.5	18.7
* Super parasitism ranging from 30.0 - 60.0%								

for HHSS compared to 0.0 - 64.9% by *T. pretiosum*. In HHSS cages where 4 and 5 pairs of parasitoids were released super parasitism ranging from 30.0 - 60.0% was also recorded. The mean parasitism irrespective of host density or parasitoids density in HHSS was 27.2% compared to 15.1% by *T. pretiosum*. The results indicated that HHSS of *T. chilonis* performed better against *H. armigera* on tomato.

4.9.4.3 Evaluation of high host searching ability strain of trichogrammatid in the cage and net house against *Helicoverpa armigera* on tomato

The net house and field study was carried out on potted plants. The pots were arranged in the net house @ 4 potted plants per row and 4 rows in one net house with the spacing of 2.5 feet between row and between plants. *Helicoverpa armigera* eggs were inoculated at flower initiation stage @ 2, 4, 8 and 16 eggs / plant @ 2 egg / leaf from top most leaf. Parasitoids were released @ 0.50, 2.50. 5.00 and 10.0 lakhs / ha. The eggs were collected back after 24 hours and observed for parasitism. Each treatment was replicated 3 times.

Similar method was followed for open field study. Except that *H. armigera* eggs were inoculated every alternate day for a period of 21 days and parasitoids were released once in 3 days. Eggs were inoculated 10 times and parasitoids were released 6 times @ 2.50 lakhs / ha. The eggs inoculated were not removed from the plants. The three treatments imposed were pots treated with HHSS of *T. chilonis*, pots where insecticide (2 rounds of endosulfan and two rounds of monocrotophos) was sprayed and untreated control. The four egg densities were 2, 4, 8 and 16 eggs/plant and 4 pots used for each density. Each treatment was replicated three times. The data on total number of fruits, number damaged and yield was recorded.

When HHSS of *T. chilonis* was released in net house mean per cent parasitism was uniform in parasitoid release rate ranging from 2.5 lakhs to 10.0 lakhs. The parasitism ranged from 16.3 - 19.7%. The parasitoids also exhibited density response. The mean parasitism obtained was 9.4, 13.0, 22.7 and 17.2% in egg density of 2, 4, 8, and 16 eggs / plant. The results indicated that parasitoids can be released @ 2.50 lakhs / ha to achieve higher parasitism and better results (Table 43).

Table 43. Parasitising efficiency of HHSS against *H. armigera* on tomato in net house

Release rate (lakhs / ha)	Per cent parasitism				
	2 eggs	4 eggs	8 eggs	16 eggs	Mean
0.5	0.0	2.1	15.6	14.1	7.9
2.5	12.5	29.2	16.7	15.1	18.4
5.0	16.7	10.4	32.3	19.3	19.7
10.0	8.3	10.4	26.1	20.3	16.3
Mean	9.4	13.0	22.7	17.2	

The percent damage of fruits increased significantly with increase in egg density from 2 eggs / plant to 16 eggs / plant and subsequently the larval population. The per cent fruit damage in HHSS of *T. chilonis* released pots ranged from 14.2 - 37.7% compared to 5.7 - 21.7% in insecticide sprayed pots and damage was highest in untreated control (Table 44). The larval population per plant also increased with increase in load of eggs, however, larval population was significantly less in insecticide treated plants and in HHSS it was significantly less than untreated control. The yield recorded was highest in HHSS pots (10.1 kg) compared to 9.9 and 7.2 kg in insecticide and untreated control, respectively.

Table 44. Effect of field release of HHSS of *T. chilonis* on damage by *H. armigera* and tomato yield

Egg density	HHSS treated pots			Insecticide treated pots			Untreated pots		
	Percent fruits damaged	Mean larvae / plant	Yield (kg)	Percent fruits damaged	Mean larvae / plant	Yield (kg)	Percent fruits damaged	Mean larvae / plant	Yield (kg)
2	17.7	0.75	3.4	5.7	0.25	1.9	37.5	1.25	2.6
4	14.2	0.25	1.9	3.2	0.25	2.8	65.2	1.50	1.2
8	24.3	1.0	2.3	7.4	0.25	3.8	40.7	1.50	1.5
16	37.7	2.25	2.4	21.7	0.50	1.3	65.6	3.75	1.8
Mean	23.4	1.06	10.1	7.7	0.31	9.9	50.0	2.0	7.2

4.9.5 Storage of 'Tricho' cards for field release

There is a need to overcome the problem of predation of parasitised eggs in the field where emergence continues for about 2 days. Cards were stored at 5°, 10° and 15°C in BOD incubators. The temperature of 15°C was found to be most ideal to store cards for utilization in the field immediately. The experiment was carried out by storing 'Tricho cards' at 15°C at various developmental stages. The cards that were 8 and 9 days old were found to be most suitable for storage for utilization for field purpose. The cards were stored for 3, 5 and 7 days at 15°C in total darkness. Observations on first and total emergence after removal to laboratory was recorded (Table 45).

Table 45. Storage studies with *Trichogramma chilonis*

Age of parasitised eggs (in days)	No. of days in storage	Time taken for emergence to start (day / hour minutes)	Time taken for total emergence (day / hour minutes)
8	3	1 day	5 hours
8	5	12 hours	4 hours
8	7	30 minutes	2 hours
9	3	about 5% emergence in storage	1 hour
9	5	- do -	1 hour
9	7	- do -	30 min

The results presented in Table 45 indicate that 8 days old parasitised card can be stored in BOD incubator for 7 days and entire emergence will be completed within 2.50 hours of its removal from BOD. Nine days old parasitised cards can be kept for 3 days before making field release. This will enable all the parasitoids to emerge from cards in the field within a short time and will avoid field predation of parasitised eggs in the field.

4.9.6 Developing low temperature tolerance in *Chrysoperla carnea* by selection techniques

The experiment was initiated to develop strain of *C. carnea* adapted to lower temperatures. The growth chamber was set at 22° - 24°C and 65% RH for rearing *C. carnea*. Before initiating the experiment, laboratory data on developmental period, fecundity and longevity was obtained and this served as baseline data for comparison. The predator was shifted to 20° - 24°C and 18° - 24°C. In each generation 50 larvae were reared and 5 pairs of adults were utilised for fecundity study. The rearing was done on *C. cephalonica* eggs (Table 46).

Table 46. Biology of *Chrysoperla carnea* at lower temperatures

Parameters	Laboratory temperature	22° - 24°C* 65% RH	20° - 24°C* 65% RH
Egg period (days)	3	4.6	6
Larval period (days)	7	10 – 12	11 - 12
Pupal period (days)	7 - 8	8 – 11	10 - 12
Pre-oviposition period (days)	4	6.5	5
Oviposition period (days)	10 - 78	26 – 87	in progress
Adult longevity (days)	14 - 82	32 - 90	in progress
Mean fecundity (numbers)	453.8	618.8	in progress
Mean feeding potential (numbers)	351.8	650.3	in progress

* mean of 3 generations

The results indicated that it is possible to develop an adapted strain by acclimatising these predators to lower temperatures. *Chrysoperla carnea* after adaptation performs better at lower temperature though for first few generations about 30 - 60% larval mortality was obtained.

4.10. Studies on insect pathogens

4.10.1 Survey for viruses of insect pests

Nucleopolyhedro viruses of *Trichoplusia ni, Spodoptera exigua* and *Crocidolomia binotalis* have been isolated from the cruciferous crop eco-system. NPV's have also been isolated from *Opisina arenosella, Chilo infuscatellus, Chrysoperla carnea* and *Cadra cautella*. A neogregarine protozoan pathogen, *Mattesia dispar* has been isolated from *Cadra cautella*.

4.10.1.1 Host-pathogen relationship

NPV's isolated from *T. ni, S. exigua* have been test verified for their pathogenicity through leaf surface contamination technique. The pathogenicity of NPV of cabbage leaf webber, *Crocidolomia binotalis*, was verified by purifying the virus by differential centrifugation. The neonate larvae were inoculated @ $1x10^6$ POB's/ml through leaf surface contamination technique and it produced cent percent mortality within 4-5 days showing typical symptom of skin breaking.

4.10.1.2 Cross- infectivity

Studies conducted on the cross infectivity of NPV of *Cadra cautella* to 11 hosts revealed the susceptibility of *Galleria mellonella* (100% mortality). Mortalities of 20, 25 and 30 percent were recorded in *S. litura, H. armigera* and *T. ni* with this NPV (Table 47). The cross infectivity to the extent of causing cent percent mortality of *S. exigua* GV to *Spodoptera litura* and *Adisura atkinsoni* GV to *Helicoverpa armigera* has also been noticed while testing eight lepidopteran hosts. *Chilo infuscatellus* NPV was found to cross infect *Chilo partellus* when tested along with nine other hosts.

Table 47. Cross infectivity of *C. cautella* NPV

Insects tested	Stages treated (larval instar)	No. Tested period (days)	% Mortality	Incubation
Helicoverpa armigera	II and III	20+20	25	4-5
Spodoptera litura	II	30	20	3-4
Chilo partellus	II and III	15+15	–	–
Trichoplusia ni	III and IV	10+10	30	3-5
Achaea janata	II	30	–	–
Opisina arenosella	II and III	10+10	–	–
Agrotis segetum	II	20	–	–
Pericallia ricini	11	20	–	–
Amsacta albistriga	11	30	–	–
Spilarctia obliqua	11	30	–	–
Galleria mellonella	11 and 111	20+20	100	8-10

4.10.1.3 Safety tests

Opisina arenosella and *Corcyra cephalonica* NPV's were found safe to the mulberry silkworm, *Bombyx mori*.

4.10.1.4 Development of improved formulations of NPV for management of *Helicoverpa armigera* and *Spodoptera litura* in tomato

Bioassay studies were conducted to study the influence of tomato varieties on susceptibility of *Helicoverpa armigera* to *Ha*NPV and *Spodoptera litura* to *Sl*NPV. The varieties of tomato selected were Arka Alok, Arka Vikas, Arka Ahuti and Arka Megali. Bioassay was done through leaf disc method using 3.3 cm cut tomato leaf discs and 10 ml of viral suspension on each disc at different concentrations. Ten neonate larvae of *H. armigera* were released on each leaf disc and allowed to feed for 24 hours. They were then transferred to the semisynthetic diet. Mortality of larvae was recorded daily for 10 days. An untreated control was maintained. The treatments were replicated thrice. Corrected mortality percentage was calculated (Table 48). Similar bioassay was conducted with *S. litura* (Table 49).

Table 48. Mortality data for neonate *Helicoverpa armigera* as on 10th day

Concentration of virus administered (POBs/ml)	No. of larvae used	Corrected percentage mortality of *H.armigera* larvae			
		Arka Vikas	Arka Meghali	Arka Alok	Arka Ahuthi
$5x10^4$	30	72.4	96.55	71.4	86.2
$1x10^4$	30	68.9	65.55	57.1	82.7
$2x10^3$	30	72.4	58.6	25.0	62.1
$4x10^2$	30	72.4	37.9	46.4	72.4
$0.8x10^2$	30	58.6	27.5	25.0	51.7
$0.16x10^2$	30	41.37	27.5	22.1	27.5

Table 49. Mortality data for neonate *Spodoptera litura* as on 10th day

Concentration of virus administered (POBs/ml)	No. of larvae used	Percentage mortality of *Spodoptera litura* larvae			
		Arka Vikas	Arka Meghali	Arka Alok	Arka Ahuthi
$5x10^7$	30	100	100	100	100
$5x10^6$	30	100	100	100	100
$5x10^5$	30	91.17	93.33	100	73.00
$5x10^4$	30	96.77	84.37	58.00	84.00
$5x10^3$	30	87.55	76.92	80.00	91.00
$5x10^2$	30	81.55	72.97	95.00	94.00

4.10.2 Production of *Nomuraea rileyi*

4.10.2.1 Source of yeast and solid media

Three yeast sources, *viz.*, yeast extract (Rs.1,500/kg.), yeast tablets (Rs.500/kg) and yeast granules (Rs.150/ kg) were tested at concentrations of 1 and 5% solutions in the basal medium of rice to find out their effect on the spore production of five isolates of *N. rileyi* (Nr-3, Nr-12, Nr-26, Nr-7 and Nr-17). Conidial production of *N. rileyi* was estimated after 20 days of incubation at 25° C and 80% RH. In case of all five isolates 5% yeast granules gave good sporulation and has been found to be cheaper than the other two yeast sources. Addition of 25 ml of 5% yeast granule solution to the basal medium of rice gave good sporulation of *N. rileyi*. For Nr-3 isolate, yeast extract (1 & 5%) and yeast tablets (5%) and for Nr-7 isolate yeast tablets (5%) gave good sporulation (Table 50).

Table 50. Conidial production of *N. rileyi* on rice + yeast sources

Substrate	Conidial production (x 10^9/g) after 20 days				
	Nr-3	Nr-12	Nr-26	Nr-7	Nr-17
Rice + Yeast extract (1.0%)	3.8	2.7	2.1	1.1	0.9
Rice + Yeast extract (5.0%)	3.9	2.7	2.3	1.5	1.4
Rice + Yeast granules (1.0%)	2.4	1.8	1.0	1.6	1.3
Rice + Yeast granules (5.0%)	3.9	3.0	2.2	2.5	2.0
Rice + Yeast tablets (1.0%)	2.5	1.3	0.9	2.0	0.7
Rice + Yeast tablets (5.0%)	3.6	2.5	1.8	2.6	1.3
CD (P=0.05)	0.4	0.3	0.3	0.5	0.6

4.10.2.2 Mass production of *N. rileyi* in liquid media

Rice extract (RE) (5%) was tested along with yeast extract (YE), yeast granules (YG) and yeast tablets (YT) at 1 and 5% concentrations in conical flasks in stationary cultures at 25° C and 80% RH. Sabouraud maltose broth with yeast extract (SMY) was used as control. Conidial production of the five isolates of *N. rileyi* was estimated after 20 days of incubation. Among the different liquid media tested for mass production of five isolates of *N. rileyi,* rice extract (5%) + yeast granules (5%) showed maximum sporulation of all isolates (Table 51)

Table 51. Conidial production of *N. rileyi* on rice extract + yeast sources in liquid media after 20 days of incubation

Substrate	Conidial production/gram after 20 days)				
	Nr-3	Nr-12	Nr-26	Nr-7	Nr-17
5% R.E+1%YE	2.2×10^5	1.0×10^5	0.9×10^5	2.3×10^3	1.3×10^3
5%R.E+5%YE	5.9×10^7	4.2×10^7	3.7×10^7	2.6×10^5	1.3×10^5
5%R.E+1%YG	2.4×10^8	3.5×10^7	3.7×10^6	4.2×10^5	2.7×10^5
5%R.E+5%YG	4.3×10^9	2.4×10^9	1.5×10^9	0.4×10^9	0.3×10^9
5%R.E+1%YT	9.3×10^5	1.3×10^5	1.1×10^4	1.0×10^4	2.1×10^3
5%R.E+5%YT	1.1×10^6	3.2×10^5	1.5×10^4	1.3×10^4	2.5×10^3
SMY (Control)	1.7×10^7	0.7×10^7	0.7×10^6	0.5×10^5	0.3×10^5

4.10.2.3 Effect of temperature on the sporulation of *N. rileyi*

Conidial production of five isolates of *N. rileyi* on rice + 5% yeast granules were studied at 20, 25, 30, 35 and 40^0 C temperatures and 80% RH. Maximum conidial production from 2×10^9 to 3.7×10^9 was observed at 25^{0}C for all the isolates. No growth and sporulation was observed at 40^0 C

4.10.2.4 Effect of humidity on the sporulation of *N. rileyi*

Conidial production of five isolates of *N. rileyi* on rice + 5% yeast granules were studied at 50, 60,70, 80 and 90% RH at a constant temperature of 25^{0}C. Maximum conidial production was observed at 70, 80 and 90% RH for all the isolates (Table 52).

Table 52. Conidial production of *N. rileyi* on rice + 5% yeast granules at different humidities

Humidity (% RH)	Conidial production/gram after 20 days)				
	Nr-3	Nr-12	Nr-26	Nr-7	Nr-17
50	4.3×10^7	2.9×10^7	1.9×10^5	0.8×10^5	0.3×10^5
60	3.1×10^9	2.0×10^9	1.2×10^7	5.8×10^6	2.0×10^6
70	3.7×10^9	2.9×10^9	1.8×10^9	2.0×10^9	1.8×10^9
80	3.7×10^9	3.0×10^9	2.2×10^9	2.2×10^9	2.0×10^9
90	3.9×10^9	2.9×10^9	2.0×10^9	2.3×10^9	2.2×10^9
CD (P=0.05)	0.3	0.7	0.9	0.5	0.7

4.10.2.5 Virulence of different isolates of *N. rileyi* grown on rice + 5% yeast granules at different conditions

Five isolates of *N. rileyi* (Nr-3, Nr-12, Nr-26, Nr-7 and Nr-17) were grown on rice + 5% yeast granules (solid medium), rice extract (5%) + yeast granules (5%) (liquid medium stationary culture), rice extract (5%) + 5% yeast granules (liquid medium shake culture) and rice extract (5%) + 5% yeast granules (liquid medium - fermentor). These isolates were then tested on *Spodoptera litura* (2nd instar larva) by bioassay method at 1x 10^9 cfu/ml on castor leaves at 25°C and 80% RH. Production of aerial conidia was observed on solid medium and liquid medium stationary cultures condition only. Blastospores/thin walled submerged conidial production was observed under shake culture condition/fermentor. Only aerial conidia produced on solid medium and stationary cultures of the liquid medium were found to be infective to *S. litura* causing from 40–80% mortality after ten days, while blastospores/thin walled submerged conidia from shake cultures/fermentors were not at all infective to *S. litura* (Table 53).

Table 53. Mortality of *Spodoptera litura* with different isolates of *N. rileyi* grown on rice + yeast granules

Substrate used for growing *N. rileyi*	% mortality of *S litura* after 10 days of treatment				
	Nr-3	Nr-12	Nr-26	Nr-7	Nr-17
Rice + 5% yeast granules (Solid medium) *	56.0	52.0	70.2	72.0	86.0
5% Rice extract + 5% yeast granules (Liquid medium-Stationery culture)*	40.0	42.0	58.0	70.0	74.0
5% Rice extract + 5% yeast granules (Liquid medium - Shake culture)**	0.0	0.0	0.0	0.0	0.0
5% Rice extract + 5% yeast granules (Liquid medium in Fermentor)**	0.0	0.0	0.0	0.0	0.0

* Contains aerial conidia @ 1x 10^9 /ml

** Contains blastospores/submerged conidia @ 1x 10^9 /ml

4.10.2.6 Shelf life and virulence of *N. rileyi* in rice flour formulation

Shelf life of the spores of five isolates of *N. rileyi* (Nr-3, Nr-12, Nr-26, Nr-7 and Nr-17) in rice flour at room temperature (17 to 32°C) and in refrigerator at 5-8°C were studied for a period of 6 months (Table 54). Five isolates of *N. rileyi* were grown on rice + 5% yeast granules for 20 days, powdered, dried (12%moisture) and stored in sterile

Table 54. Shelf life of *N. rileyi* spores in rice flour for six months

Isolate	cfu /g after days						
	0 (Sep-02)	60 (Nov-02)		120 (Jan-03)		180 (Mar-03)	
		RT	R	RT	R	RT	R
Nr-3	3.0×10^9	2.0×10^9	2.8×10^9	7.2×10^8	1.8×10^9	3.2×10^6	6.4×10^7
Nr-12	3.0×10^9	2.0×10^9	2.8×10^9	5.3×10^8	1.2×10^9	1.6×10^6	2.8×10^7
Nr-26	2.0×10^9	1.2×10^9	1.7×10^9	3.6×10^8	0.8×10^9	3.6×10^5	5.4×10^6
Nr-7	2.0×10^9	1.3×10^9	1.5×10^9	2.7×10^8	0.4×10^9	2.7×10^5	3.8×10^6
Nr-17	2.0×10^9	1.2×10^9	1.3×10^9	2.2×10^8	0.2×10^9	2.2×10^5	3.2×10^6

RT - Room Temperature; R – Refrigerated temperature (5-8 °C)

polypropylene bags. Samples were drawn at monthly intervals and cfu count, contamination and virulence on *S. litura* by bioassay method were studied.

Spores of all the five isolates remained viable in sufficient numbers (10^9/g) for a period of four months at refrigerated temperature of 5-8°C. After six months of storage, the spore count reduced drastically for all isolates both at room temperature (10^5-10^6/g) and at refrigerated temperature (10^6-10^7/g) (Table 55).

Table 55. Virulence of the spores of *N. rileyi* stored in rice flour on *S. litura*

Storage period (days)	Storage Condition	% mortality of *S litura*				
		Nr-3	Nr-12	Nr-26	Nr-7	Nr-17
0 (Fresh)	–	58.4	50.6	76.8	72.4	89.4
60	Room temp.	50.0	50.0	68.8	68.0	82.8
60	Refrigerator	52.8	52.0	70.4	69.6	84.2
120	Room temp.	48.8	46.4	60.4	64.8	72.6
120	Refrigerator	50.0	50.4	68.2	68.2	80.0
180	Room temp.	25.4	22.6	24.2	32.2	36.4
180	Refrigerator	30.2	26.8	28.6	38.4	42.8
CD (P=0.05)		8.6	10.4	9.2	12.8	13.9

There was no significant reduction in the infectivity of *N. rileyi* spores till 120 days of storage for all the isolates. However, drastic reduction in the mortality of *S. litura* was observed for all the isolates, which were stored for a period of 180 days. Mortality of *S. litura* with the spores of *N. rileyi* stored at room temperature and refrigerated temperature did not vary significantly.

4.10.2.7 Field trials with *N. rileyi* on cotton and groundnut

Field trials with *N. rileyi* on cotton and groundnut were conducted at ANGRAU, Hyderabad and TNAU, Coimbatore. The trial had four treatments, *viz*., *N. rileyi* aqueous suspension along with Tween 80 (0.02%), *N. rileyi* in oil in water emulsion, recommended schedule of chemical insecticide and untreated check. *N. rileyi* was grown on rice + yeast granules (5%) and spores were harvested. Two spore preparations were made viz., Direct spore dust (10^{13} spore/ha in water) and spore in oil emulsion (Sunflower oil +Triton-X, 9:1, 10^{13} spore/ha in water). The samples were sent to ANGRAU and TNAU. The results are presented under 4.18.5 and 4.2.2.2.

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4.10.3 UV protectants for preparing new WDP formulation of *Bacillus thuringiensis*

4.10.3.1 Concentration of UV protectants

Studies were carried out to determine the amount of UV protectant (Ranipal and Congo Red) that can be used in WDP formulation. Different concentrations of UV protectants (0.25, 0.5, 1 and 2% w/w) were mixed with the formulation. Different concentrations of WDP formulation were then prepared in distilled water and mixed in diet. The diet in container was exposed to UV light (30W) for 60 minutes and at 50 cm distance. Bioassay was done using neonate larvae of *H. armigera* and mortality recorded 72 h after treatment. WDP formulation without UV protectant and unexposed served as control. Duncan's multiple range test (DMRT) was used to compare the mortality.

Results on concentration of Ranipal indicated that as the concentration increased mortality of larvae increased up to 1% (Table 56). Results on concentration of Congo red indicated significant differences in mortality of *H. armigera*. As the concentration of UV protectant increased mortality of larvae increased up to 1% and above this there was no increase in mortality. It can be concluded that both the UV protectants up to 1% w/w might be used in the formulation (Table 57).

Table 56. Effect of Ranipal on the bioactivity of WDP formulation at 60 minutes UV exposure

Concentration of WDP	% mortality at different concentrations of					
Ranipal	0.025	0.05	0.1	0.15	0.2	0.25
WDP exposed + No Ranipal	16.10 (39.23)[e]	25.00 (42.13)[e]	33.33 (20.99)[e]	36.66 (30.00)[e]	40.00 (35.27)[e]	44.99 (37.27)[e]
WDP + 0.25%	23.88 (42.13)[d]	30.00 (46.90)[d]	35.55 (29.26)[d]	41.66 (33.21)[d]	45.00 (36.60)[d]	53.33 (40.19)[d]
WDP + 0.5%	27.40 (48.19)[c]	33.33 (50.57)[c]	41.10 (31.56)[c]	45.55 (35.27)[c]	55.00 (39.87)[c]	60.00 (42.45)[c]
WDP + 1.0%	29.55 (51.41)[b]	36.10 (52.39)[b]	46.10 (32.93)[b]	54.44 (36.94)[b]	61.10 (42.77)[b]	62.77 (47.55)[b]
WDP + 2.0 %	29.55 (51.09)[b]	35.55 (52.39)[b]	46.10 (32.51)[b]	54.44 (36.60)[b]	61.10 (43.10)[b]	62.77 (47.55)[b]
WDP unexposed (control)	56.66 (65.25)[a]	66.66 (81.50)[a]	74.07 (48.83)[a]	78.99 (54.74)[a]	86.66 (59.40)[a]	97.77 (62.60)[a]

Figures in parentheses are arc sine transformed values
In a column, means followed by same letter are not significantly different by DMRT (P=0.05)

Table 57. Effect of Congo Red on the bioactivity of WDP formulation at 60 minutes UV exposure

Concentration of	% mortality at different concentrations of WDP					
Congo Red	0.025	0.05	0.1	0.15	0.2	0.25
WDP exposed + No Congo Red	26.10 (30.72)[e]	32.21 (34.85)[e]	37.77 (37.89)[e]	42.22 (40.52)[e]	45.88 (42.64)[e]	51.06 (46.96)[e]
WDP + 0.25%	33.88 (35.60)[d]	41.66 (40.19)[d]	43.88 (41.49)[d]	45.00 (42.13)[d]	50.00 (45.00)[d]	56.10 (48.50)[d]
WDP + 0.5%	38.33 (38.24)[c]	46.66 (43.08)[c]	57.21 (49.14)[c]	60.55 (51.09)[c]	65.00 (53.70)[c]	67.44 (55.20)[c]
WDP + 1.0%	43.88 (41.50)[b]	50.55 (45.31)[b]	65.55 (54.05)[b]	68.33 (55.75)[b]	73.33 (58.90)[b]	76.66 (60.73)[b]
WDP + 2.0 %	43.22 (41.11)[b]	50.00 (45.00)[b]	65.00 (53.70)[b]	68.33 (55.76)[b]	73.33 (58.90)[b]	76.66 (60.73)[b]
WDP unexposed (control)	57.21 (49.07)[a]	71.10 (57.49)[b]	75.00 (60.00)[a]	80.22 (63.84)[a]	87.22 (69.08)[a]	98.33 (82.55)[a]

Figures in parentheses are arc sine transformed values
In a column, means followed by same letter are not significantly different by DMRT (P=0.05)

4.10.3.2 Comparison of Ranipal and Congo Red as UV protectants

Studies were also undertaken to select the best UV protectant among Ranipal and Congo Red. UV portectants at 1% were added to the formulation. Different concentrations of WDP formulation were prepared in distilled water and mixed in diet. The diets in containers were exposed to UV for different durations (30, 60, 90 and 120 min.). WDP formulation unexposed to UV light served as control. A bioassay was carried out using *H. armigera* neonate larvae. Duncan's multiple range test (DMRT) was used to compare the mortality.

Results on exposure time indicated that there was significant difference in mortality of *H. armigera*. As the time of exposure increased mortality of larvae decreased indicating that UV light has influence on the activity of *Bt* WDP formulation (Table 58). When 1% Congo Red was added in WDP formulation and it was not exposed to UV the mortality was high and the mortality decreased as the exposure time increased. (Table 59).

Table 58. Effect of UV light on the bioactivity of WDP formulation containing 1% Ranipal

Exposure time to UV (minutes)	% mortality at different concentrations of WDP					
	0.025	0.05	0.1	0.15	0.2	0.25
Unexposed	56.44 (48.81)[a]	66.66 (54.73)[a]	73.88 (59.27)[a]	78.99 (62.73)[a]	86.66 (68.58)[a]	97.77 (81.48)[a]
30	41.10 (39.88)[b]	51.66 (45.95)[b]	61.10 (51.42)[b]	65.55 (54.05)[b]	72.21 (58.19)[b]	77.21 (61.49)[b]
60	28.88 (32.51)[c]	36.10 (36.94)[c]	46.10 (42.76)[c]	54.44 (47.85)[c]	61.10 (51.40)[c]	62.77 (52.39)[c]
90	15.55 (23.22)[d]	21.66 (27.72)[d]	26.66 (31.08)[d]	32.77 (34.91)[d]	39.99 (34.91)[d]	43.88 (39.22)[d]
120	6.66 (14.88)[e]	13.88 (21.87)[d]	13.88 (28.11)[e]	13.88 (32.51)[e]	13.88 (36.67)[e]	13.88 (39.23)[d]

Figures in parentheses are arc sine transformed values

In a column, means followed by same letters are not significantly different by DMRT (P=0.05)

Table 59. Effect of UV light on the bioactivity of WDP formulation containing 1% Congo Red

Exposure time to UV (minutes)	% mortality at different concentrations of WDP					
	0.025	0.05	0.1	0.15	0.2	0.25
Unexposed	57.21 (49.18)[a]	71.10 (57.49)[a]	75.00 (60.00)[a]	80.55 (63.84)[a]	87.22 (69.05)[a]	98.33 (82.50)[a]
30	51.10 (45.63)[b]	55.55 (48.19)[b]	71.10 (57.49)[b]	75.00 (60.00)[b]	80.77 (64.00)[b]	85.00 (67.21)[b]
60	43.88 (41.49)[c]	50.10 (45.32)[c]	65.55 (54.05)[c]	68.33 (55.33)[c]	73.33 (58.90)[c]	76.66 (61.41)[c]
90	34.66 (35.93)[d]	36.44 (36.03)[d]	46.10 (42.76)[d]	56.10 (48.50)[d]	60.55 (57.10)[d]	65.55 (54.05)[d]
120	26.10 (30.63)[d]	32.21 (34.58)[d]	33.88 (35.60)[e]	37.22 (37.59)[e]	40.55 (39.54)[d]	49.44 (44.68)[e]

Figures in parentheses are arc sine transformed values
In a column, means followed by same letters are not significantly different by DMRT (P=0.05)

Results indicated that UV light had adverse effect on the bioactivity of WDP formulation compared to unexposed. With an increase in exposure time there was significant decrease in bioactivity fo WDP formulation at each time interval indicating that the formulation was inactivated by UV light. Addition of UV protectants to WDP formulation was useful to enhance the survival and activity of *Bt*. Amongst the two UV protectants Congo Red was better than Ranipal.

4.11. Fungal and bacterial antagonists

4.11.1. Development of fermentor based mass production and formulation for promising isolates of *Trichoderma*

Studies on mass production of *T. harzianum*, PDBC TH-10 and *T. viride*, PDBC TV-23 using Jaggery-soy medium (Jaggery-50.0g/L and Soyaflour-10g/L) were carried out in a fermentor (10 litre cap.). Ten litres of the Jaggery-soy medium was taken and sterilized and inoculated with 300 ml of 7-day old *T.harzianum/T. viride* broth (PDB). The fermentor was run for five days at 25°C and 500 rpm speed. 100 ml of samples were drawn at 24 h intervals and analysed for biomass production (fresh weight and dry weight/100ml) and viable propagules (cfu/ml).

Peak biomass production of both isolates occurred after 4 days of fermentation. Between the two fungi tested, *T. viride* produced maximum biomass (dry weight, 2.112g/100ml) and viable propagules (2.0 X 10^7cfu/ml) compared to *T. harzianum* (dry weight 1.777g/100ml and 1.0 X 10^7cfu/ml) (Table 60).

Table 60. Biomass production of *Trichoderma* spp. in jaggery-soya medium in fermentor

Fermentation duration (h)	Biomass dry weight (g/100ml)		Viable propagules (cfu X 10^7/ml)	
	T. harzianum PDBC TH-10	*T. viride* PDBC TV-23	*T. harzianum* PDBC TH-10	*T. viride* PDBC TV-23
24	0.187	0.226	0.009	0.001
48	1.02	0.648	0.014	0.002
72	1.775	1.726	0.500	0.400
96	1.833	2.112	1.000	2.000
120	1.777	2.050	0.85	1.500

4.11.1.1 Shelf-life studies of talc-based formulations

Talc-based formulations of *T. harzianum* and *T. viride* were prepared by mixing 4-day old wet fermentor biomass with sterilized talc powder @ 1:2 v/w. the moisture level of the mixture was brought down from 26% to 10% by drying the mixture in an oven at 40°C temp. The samples were packed in sterilized polythene bags and sealed. One set of samples were placed in room temperature (14-35° C) and another set was maintained in a refrigerator (5-8°C).

The count of viable propagules (cfu/g) in the formulation was estimated at 0, 30, 60, 90,120, 150 and 180 days of preparation of formulations by serial dilution technique on TSM. The results are presented in Table 61. Contamination of the formulation during storage by bacteria/other fungi was also recorded if any.

The initial population of *T. harzianum* and *T. viride* in the freshly prepared talc-based formulations was 4.72 and 7.36 X 10^6/g respectively. A gradual decline of the *Trichoderma* populations in the formulation was observed at room and refrigerator temperatures during the 180 days storage. However, population of *T. harzianum* and *T. viride* remained above 10^6/g formulation even after 180 days of storage at refrigerator.

Table 61. Shelf life of *T.harzianum and T.viride* spp.in the talc-based formulations prepared from Jaggery-Soya medium

Antagonist	Viable propagules (cfu X 10^6/g after days)													
	0		30		60		90		120		150		180	
	Ro	Re.	Ro	Re.	Ro	Re	Ro	Re.	Ro	Re	Ro	Re	Ro	Re
T.harzianum PDBC TH-10	4.72	4.72	4.50	4.64	4.42	4.54	3.00	3.56	2.50	3.42	1.18	2.38	0.68	1.84
T.viride PDBC TV-23	7.36	7.36	2.00	2.25	1.66	2.08	1.33	2.0	1.00	1.76	0.84	1.48	0.48	1.26

Ro = At room temperature (14-35° C)
Re =At refrigerator temperature (5-8°C)

4.11.1.2 Compatibility of different isolates of *Trichoderma* spp.

In vitro interaction studies were done to find out mutual inhibitory interactions occurring among the selected antagonistic fungi *T. harzianum*, *T. viride*, and *T. virens* (PDBCTH-10, PDBCTH-15, PDBCTV-23, PDBCTV-32e and PDBCTVs-12 isolates) to identify the compatible antagonistic fungi. Dual culture method was used for studying the interactions among the selected antagonistic fungi. Direct opposition method using simultaneous inoculation of test fungi was adopted. Six mm discs of test fungi cut from 3-day old cultures were placed on PDA plates (90 mm diameter) in such a manner that they lie opposite to each at two corners of the plate. Plates inoculated with either fungus individually in a similar position served as control. Observation on the growth patterns, microscopic observations on hyphal abnormalities and viability tests from different areas of interactions from the dual culture plates were recorded for a period of 10 days

The results showed that PDBC TH-10 is compatible with PDBC TV-23. Similarly PDBC TV-23 is compatible with PDBC TV-32, PDBC TVS-12 and PDBC TH-15 with PDBC TV-32. All other combinations were found not compatible.

4.11.1.3 Mass production of *Trichoderma* spp. on spent meals of parasitoid hosts reared in laboratory

Suitability of the spent meals of laboratory-reared insect hosts namely *Corcyra cephalonica* and *Sitotroga cerealella* for the mass production of *Trichoderma harzianum*, *T. viride* and *T. virens* was studied. Assessment of optimum moisture level required in *Corcyra* spent meal for mass production of *Trichoderma* spp. revealed that 45 per cent moisture yielded maximum *Trichoderma* growth (Table 62). *Sitotroga* spent meal supported maximum sporulation and colony forming units in all the three species of *Trichoderma* and was on par with sorghum as a substrate. *Corcyra* spent meal yielded lowest growth and sporulation due to caking of the substrate (Table 63).

Table 62: Effect of moisture levels in Corcyra spent meal substrate on the growth of *Trichoderma* spp.

Moisture (%)	X 10^6 cfu g^{-1} substrate after 10 days		
	T. harzianum	*T. viride*	*T. virens*
40	0.87^{bc}	0.93^{b}	0.93^{b}
45	1.53^{a}	1.67^{a}	1.63^{a}
50	1.00^{b}	1.07^{b}	0.93^{b}
55	0.60^{c}	0.63^{c}	0.53^{c}
60	0.20^{d}	0.27^{d}	0.17^{d}
CD (P=0.05)	0.30	0.27	0.30

Table 63. Effect of substrates on the growth and sporulation of *Trichoderma* spp.

Substrate	*Trichoderma* population-x 10^6 cfu g^{-1} (after 21 days)		
	T. harzianum	*T. viride*	*T. virens*
Corcyra spent meal	8.60[d]	22.00[c]	20.00[b]
Sitotroga spent meal	16.63[a]	39.00[a]	39.33[a]
Barley	12.73[c]	29.00[b]	26.67[b]
Sorghum	15.17[b]	38.33[a]	37.00[a]
CD (P= 0.05)	1.43	6.27	7.74

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4.11.2 Improved method for seed biopriming with *Trichoderma harzianum* and *Pseudomonas fluorescens*

Seed biopriming involves pre-sowing hydration treatment to improve seedling establishment. The seeds were coated with a suspension of *Trichoderma* powder (10 g TH + 10 g FYM powder + 5 g gum arabia in 50 ml water for 1 kg seed) and then placed on a plastic sheet as a heap and covered with moist sacks. Incubation was done under warm (27 to 32 °C) and moist conditions until just prior to radical emergence (24 to 48 h after treatment) to help PsF and TH colonize the seed surface. This results in rapid and uniform seedling emergence and better seedling growth and protection against seed and soil borne diseases. Seed biopriming was tested in rice, wheat, chickpea, lentil, pigeon pea, tomato, brinjal, capsicum, cabbage, cauliflower and chilli and proved very useful especially in *Usar* soil.

4.11.3 Mechanism of antagonism between *Trichoderma harzianum* and *Meloidogyne*

Mechanism of antagonism between TH and *Meloidogyne* was investigated. Culture filtrate of TH inhibited hatching of egg masses. Direct parasitism against *Meloidogyne* was observed as hyphae of TH trap second stage larvae of *Meloidogyne* by forming loops. TH hyphae coil around nematode body, penetrate, colonize and kill second stage larvae of *Meloidogyne*.

4.11.4 Production of *Trichoderma harzianum* at farmer's level and popularisation of the technology

A method was developed for the mass multiplication of TH through Farm Yard Manure (FYM) and/or compost. Approximately 100 kg of FYM/compost was mixed thoroughly with 100 g of TH formulation or colonized jhangora seed waste and spread as a layer (6" thick) under shade. It was then covered with rice straw or sugarcane leaf and water sprayed on the top to make the FYM moist. It was incubated (approx. 25 to 32°C) for 15 days and the FYM air-dried to get FYM with TH

A similar method can be used by the farmers in compost (FYM) pits. 100 g TH colonized Jhangora seed waste after grinding (to remove spores) and sieving or 100 g formulation of TH may be mixed with compost. After making it moist, it was covered with rice straw or sugarcane leaves and sprayed with water. 100 g of TH (as a Jhangora seed waste or formulated product) or 2 kg TH colonized FYM was added at monthly interval to compost pits. There was faster decomposition of compost and quality of the TH colonized FYM was found superior to non-colonized FYM. It is suitable for farmers to multiply TH in their FYM pits during the months of March to May & July to November in plains and April to July in hills. Population of TH in FYM collected from farmers varied from 10^5 to 10^{11} cfu/g of air-dried FYM.

This technology is finding wide acceptability at farmers' level. It has been adopted by a large number of farmers' both in hills and plains. State government departments, both in Uttaranchal and U.P., are popularizing this technology. Use of TH colonized FYM is now an integral component of IPM modules

In hills (Ranichauri, Tehri, Uttaranchal) as a means to add value to the conventionally prepared FYM, cow-dung was impregnated with TH during the process of decomposition. This facilitates addition of greater amount of bioagents to depleted soils through application of FYM than what usually goes through seed treatment. This practice was demonstrated through 15 farm families in 4 villages by treating 131 q of dung employing 25 kg TH and jhangora waste.

4.11.5 Demonstrations

Demonstrations of bioagents as a component of IPM were conducted during kharif 2002. The demonstrations have been conducted in the fields of 43 farmers growing rice, soybean, capsicum, tomato and ginger covering an area of 798 acres in the districts of Udham Singh Nagar (plains). Similar demonstrations have also been done in Tehri disrict (hills) in 23 villages covering 291 farmers in rice, ragi, tomato, chillies, brinjal, capsicum, cole crops and ginger. Impact of IPM in these areas is monitored independently by the Department of Agriculture Economics of the University.

Disease and pest management in different organically grown crops using biocontrol agents particularly application of TH colonized FYM and seed treatment and/or root dip in suspension of mixed formulation of TH + PsF in 400 acres cultivated by members of Tarai Organic Farmers' Association is also being monitored.

4.12 Mass production, formulation and field-testing of entomopathogenic nematodes against important lepidopteran pests

4.12.1 Survey

Soil samples from IARI, Delhi yielded *Steinernema* sp. and *Heterorhabditis* sp.

4.12.1.1 Mass production

A rapid and cheap mass production method using an environmentally compatible porous material, vermiculite was developed for *Steinernema carpocapsae*, and *Heterorhabditis indica*. The multiplication was fast as very high yield of 63 lakhs / 250ml flask was obtained in one week with raw egg in vermiculite compared to 42 lakhs / 250ml flask from Wouts medium in 25 days for *S. carpocapsae*. This will eliminate formulation in a different carrier material enabling using the same directly in the field.

4.12.1.2. Bioefficacy of indigenous isolates of EPN against white grubs and diamond back moth, *Plutella xylostella* and their progeny production

White grub: Bioefficacy of EPN isolates was tested against white grub, *Holotrichia lepidophora* in the lab by sand barrier assay to document the suitable strain. *H. indica* isolates, *H. bacteriophora*, *Steinernema* spp. were tested for their pathogenicity to white grubs @ 1500Ijs/larva. In general *Heterorhabditis* isolates were more effective compared to *Steinernema* sp. isolates. *H. indica* 13.3 and *H. bacteriophora* were found most effective with 70% mortality 6 days after exposure and complete mortality in 11days. Among steinernematids, *S. abbasi* 3.1, *S. carpocapsae* and *S. glaseri* were found effective against white grubs (Table 64)

Table 64. Pathogenicity of EPN isolates against white grub *Holotrichia lepidophora*

Nematode isolates isolates	% mortality of white grub due to EPN (days after incubation)				
	3	6	9	11	14
S. abbasi	0.00 (1.3)	33.33 (30.5)	66.66 (60)	66.66 (60)	66.66(60)
S. feltiae	0.00 (1.3)	0.00 (1.3)	33.33 (35.3)	33.33 (35.3)	33.33(35.3)
S. carpocapsae (11)	0.00 (1.3)	0.00 (1.3)	66.66 (6)	66.66 (60)	66.66(60)
Steinernema sp.11.1	0.00 (1.3)	0.00 (1.3)	0.00 (1.3)	33.3 (35.3)	33.3(35.3)
S. tami 2.1	0.00 (1.3)	0.00 (1.3)	0.00 (1.3)	33.3 (30.5)	66.7(60)
S. carpocapsae 6.61	0.00 (1.3)	0.00 1.3)	0.00 (1.3)	66.7 (60)	66.7(60)
S. carpocapsae 1.4	0.00 (1.3)	0.00 (1.3)	0.00 (1.3)	66.7 (60)	66.7(60)
S. glaseri	0.00 (1.3)	0.00 (1.3)	66.67 (60)	66.7 (60)	66.7 (60)
H. indica 13.3	0.00 (1.3)	66.66 (60)	66.66 (60)	100 (90)	100 (90)
H. bacteriophora	0.00 (1.3)	33.33 (30.5)	33.33 (41.8)	66.66 (60)	100 (90)
H. indica 14.2	0.00 (1.3)	0.00 (1.3)	0.00 (1.3)	33.33 (30.5)	33.33 (30.5)
*H. indica*14.3	0.00 (1.3)	0.00 (1.3)	33.3(30.51)	66.7 (60)	66.7 (90)*
CD (P 0.05)	27.99				

* Figures in parentheses are transformed values

Plutella xylostella: Pathogenicity of *S. carpocapsae* and *H. indica* was tested against *P. xylostella* larvae by dose-response assay. Maximum larval mortality of 96% and 98% was recorded at 72 h due to *S. carpocapsae* and *H. indica*, respectively. Percent mortality of DBM larvae ranged from 71-86% at 48h exposure by *S. carpocapsae* and 58-85% by *H. indica* but lower dosage (25 Ijs/larva) of *H. indica* caused higher mortality (45%) than *S. carpocapsae*. In the dose-response assay, larval mortality increased over time at all dosages in respect of both species of nematodes. The LC_{50} for *S. carpocapsae* and *H. indica* was calculated 48h post exposure and was estimated as 34 Ijs / larva and 31 Ijs/larva, respectively. LT_{50} was 45 h for *Steinernema* and 38 h for *H. indica*.

4.12.1.3 Progeny production of *S. carpocapsae* and *H. indica* in *P. xylostella*

Among the two species tested the highest yield was obtained for *H. indica* in final instar larvae of *P. xylostella*. Yield of nematodes varied depending on initial inoculum level used in the experiment with higher yield for higher dosage used. Amongst *Heterorhabditis* and *Steinernema* species, the higher yield for *H. indica* indicated that the recycling ability of *H. indica* was better than *S. carpocapsae* in *P. xylostella* larvae (Table 65).

Table 65. Yield of infective juveniles of EPN isolates in *P. xylostella* final instar larvae

Dosage (Ijs/larva)	Yield of Ijs /larva	
	S. carpocapsae	*H. indica*
25	210	250
50	240	300
75	285	370
100	465	1290

4.12.1.4 Survival of EPN in aqueous solutions of different antidesiccants

Effect of antidesiccants (Starch, Triton X 100, Glycerol and Liquid Paraffin 0.5%, 1.0% and 1.5%) on *S. carpocapsae* (PDBC EN 11) and *H. indica* (PDBC EN 13.3) was evaluated in the lab. No deleterious effect on the survival of Ijs was observed. Maximum survival percent was obtained in Triton X followed by liquid paraffin, glycerin and starch. A decrease in survival percent was observed only in the third week compared to control. In general *S. carpocapsae* survived for longer periods than *H.indica* in all treatments (Table 66 & 67)

Table 66. Survival of *S.carpocapsae* in aqueous solution of antidesiccants

Antidesiccants	conc %	% survival after weeks		
		1	2	3
Liquid Paraffin	1.5	100 (90.0)	97 (80.04)	87 (69.34)
	1.0	100 (90.0)	98 (83.78)	85 (67.36)
	0.5	100 (90.0)	100 (90.00)	89 (71.19)
Triton X 100	1.5	100 (90.0)	96 (78.26)	90 (72.19)
	1.0	100 (90.0)	98 (83.78)	92 (73.76)
	0.5	100(90.0)	97(81.95)	91 (72.79)
Glycerin	1.5	100(90.0)	99(87.29)	78 (62.05)
	1.0	99.6 (88.1)	97(80.46)	87 (69.21)
	0.5	99(87.29)	98(82.05)	88 (69.50)
Starch	1.5	98(82.67)	94(75.49)	83 (65.43)
	1.0	99(88.09)	88(70.05)	87(69.21)
	0.5	99(88.09)	95(77.12)	82(64.66)
Control		100(90.0)	100(90.00)	98(82.05)*

CD (P=0.05) - 5.3;

*Figures in parentheses are transformed values

Table 67. Survival of *Heterorhabditis indica* in aqueous solution of antidesiccants

Antidesiccants	conc %	% survival after weeks		
		1	2	3
Liquid Paraffin	1.5	90 (71.56)	84 (66.45)	83 (65.66)
	1.0	91 (72.56)	84 (67.01)	82 (64.92)
	0.5	90 (71.56)	84 (67.01)	87(68.87)
Triton X 100	1.5	95(77.12)	71(57.42)	64(53.13)
	1.0	94(75.95)	72(58.06)	70(56.79)
	0.5	95(77.12)	85(67.28)	74(59.35)
Glycerine	1.5	94(75.85)	87(68.87)	82(64.93)
	1.0	93(74.76)	85(67.33)	82(64.92)
	0.5	96(79.13)	87(68.87)	84 (66.43)
Starch	1.5	87(68.93)	87(68.93)	81(64.16)
	1.0	84 (66.53)	81(64.16)	78 (62.04)
	0.5	87 (69.11)	80(63.43)	77(61.35)
Control		95 (77.12)	89(71.19)	84 (66.53)*

CD (P=0.05) - 3.8;

*Figures in parentheses are transformed values

4.12.1.5 Effect of antidesiccants on survival and infectivity of *S. carpocapsae* and *H. indica* by leaf disc assay

Protective effect of these chemicals as antidesiccants for EPN was tested on cauliflower leaf discs. The survival of nematode population was higher when sprayed with antidesiccants than in control. Glycerin exhibited more protective ability with higher percent survival (76% & 20% survival in 60min. for *S. carpocapsae* & *H. indica*) followed by liquid paraffin (58% & 16% survival in 60min. for *S. carpocapsae* & *H. indica*), triton X (48% & 16% survival in 60 min. for *S. carpocapsae* & *H. indica*) and starch (40% & 8% survival in 60 min. for *S. carpocapsae* & *H. indica*). Twenty minutes of exposure resulted in complete dehydration and absolute mortality in control whereas moisture was retained for a longer period in other treatments. In general survival of *Steinernema* was superior to *Heterorhabditis* (Table 68).

Mortality of DBM larvae due to the EPN isolates was relatively constant for 10 and 30 min exposure. Exposure of Ijs for 1h caused a reduction in pathogenicity and lower mortality of DBM larvae (20-60% & 40-80% for *S. carpocapsae* and *H. indica*). Percent mortality of DBM larvae was higher (100-60% and 100-80%) when Ijs were applied along

Table 68. Survival of *S. carpocapsae* and *H. indica* in different antidesiccants on cauliflower leaf disc exposed to sunlight for varying periods

Antidesiccants	% survival of Ijs exposed to sunlight in different antidesiccants					
	S. carpocapsae			*H. indica*		
Period (min.)	10	30	60	10	30	60
Liq. paraffin	80 (66.2)	60 (50.9)	58 (49.9)	28 (32)	24 (29.2)	16 (23.6)
TritonX100	89 (75.1)	72 (58.2)	48 (43.9)	20 (26.6)	20 (26.5)	16 (23.5)
Glycerin	84 (66.7)	80 (66.2)	76 (61)	64 (53.2)	48 (43.9)	20 (26.9)
Starch	64 (53.2)	52 (46.2)	40 (39.3)	32 (34.4)	24 (29.3)	8 (16.4)
Control	36 (36.4)	30 (33.2)	20 (26.6)	10 (18.3)	8 (16.9)	4 (11.4)*

CD (P=0.05)= 6.9 * Figs in parentheses are transformed values

with liq. paraffin, Triton X 100 and glycerin. Percent survival of Ijs of both the species of nematodes in starch as well as the mortality of DBM larvae due to above Ijs was less when compared to Ijs in other antidesiccants. In different antidesiccants and time exposures, *H. indica* was found more virulent and effective than *S. carpocapsae* against *P. xylostella* (Table 69).

Table 69. Pathogenicity of *S. carpocapsae* and *H. indica* exposed on leaf disc in different antidesiccants against *P. xylostella* larvae

Antidesiccants	% mortality of larvae due to EPN exposed to sunlight on leaf disc					
	S. carpocapsae			*H. indica*		
Period (min.)	10	30	60	10	30	60
Liq. Paraffin	90(75.70)	80(69.00)	60(51.00)	100(90.0)	90(75.7)	70(57.70)
TritonX100	90(76.00)	70(59.80)	40(38.99)	100(90.0)	80(66.5)	70(57.70)
Glycerin	90(78.00)	80(66.5.00)	60(51.55)	100(90.0)	100(90.0)	80(71.55)
Starch	60(51.00)	40(38.99)	20(26.01)	80(66.5)	40(43.7)	20(23.50)
Control	60(51.55)	20(23.7)0	0(1.28)	80(69.0)	20(25.9)	0 (1.28)

		CD (P=0.05)		
Antidesiccant	(A)	6.73	A x B	NS
Nematode	(B)	4.26	AxC	11.663
Time	(C)	5.216	BC	NS
			AxBxC	NS

Glycerin, liquid paraffin and triton X 100 were evaluated for their property as evaporetardants for EPN (*S. carpocapsae* and *H. indica*) in liquid suspension. The results indicated that all of them allowed the nematode fungi to survive for 72 h at concentration of 0.5, 1.0 and 1.5%.

4.12.2. Field surveys for antagonistic agents against plant parasitic nematodes

Surveys in grape vineyards in and around Bangalore, Doddaballapura and Devanahalli resulted in isolation of several antagonistic species.

4.12.2.1 Method for rapid screening of antagonists against eggs, egg masses, juveniles and adults of nematodes

A serial dilution technique with water agar/CMA on specific selective media for isolating egg-mass/egg infective fungi from soil/root homogenate and for evaluating the antagonism against the nematode eggs is being standardized. The fungal spores and nematode eggs were incubated together at 27°C for different duration and the eggs were pipetted on to media and observed for infection. The results (Table 70) show that CMA medium was better than water Agar medium in inhibting hatching of eggs and also in parasitizing ability.

Table 70. Hatching of *M. incognita* eggs and their infection by *Pochonia chlamydosporium* by water-agar/CMA dilution technique

Duration		Water Agar medium		CMA medium	
Hours	Treat-ment	Percent eggs hatched	Percent eggs parasitized	Percent eggs hatched	Percent eggs parasitized
1	Check	22.0 ± 4.2	0	22.0 ± 4.2	0
	PC	14.0 ± 2.2	0	9.0 ± 2.2	0
2	Check	39.0 ± 4.6	0	39.0 ± 4.6	0
	PC	23.0 ± 3.8	8.0 ± 2.0	38.0 ± 4.8	12.0 ± 2.0
4	Check	56.0 ± 6.2	0	56.0 ± 6.2	0
	PC	29.0 ± 3.6	21.0 ± 4.8	24.0 ± 2.2	36.0 ± 3.3
6	Check	89.0 ± 6.6	0	89.0 ± 6.6	0
	PC	36.0 ± 4.4	39.0 ± 5.2	26.0 ± 2.8	51.0 ± 8.6

PC: *Pochonia chlamydosporium;* Each value is a mean of 10 replicates

4.12.2.2 Influence of solid substrates on chlamydospore production of *Pochonia chlamydosporium*

The common solid substrates, viz., malt waste, cotton seed meal, pongamia and neem oil cakes, rice and wheat bran and sorghum grain were used to study the chlamydospore production of *P. chlamydosporium* at 28°C with CMA as check. Spent malt waste, cotton seed meal, wheat bran and pongamia cake supported the mycelial growth in 9 days and produced significantly more chlamydospores than neem cake, rice bran and sorghum grain. Malt waste, wheat bran and sorghum grain produced highest yield of chlamydospores comparable with CMA in terms of chlamydospores per g of substrate. Caking and clumping were seen in oil cakes, rice bran and seed meal (Table 71).

Table 71. Effect of solid substrates on chlamydospore production of *Pochonia chlamydosporium* (Mean of 10 replicates)

Substrate	Complete mycelial cover (DAI)	Chlamydospore yield (number/ g substrate)	Apparent completion of sporulation (DAI)	Caking and clumping (%)
Spent malt waste	8	6.1×10^5	14	<5
Cotton seed meal	10	1.4×10^4	18	20-25
Pongamia cake	9	5.8×10^3	16	20-30
Neem oil cake	16	2.2×10^2	23	40-45
Rice bran	14	3.8×10^3	20	70-80
Wheat bran	9	1.8×10^5	16	35-45
Sorghum grain	15	1.1×10^5	21	45-60
CMA	7	8.4×10^5	10	–
CD (P=0.05)	–	48.94	–	–

4.12.2.3. Influence of liquid substrates on conidia /chlamydospore production of *Pochonia chlamydosporium* under submerged conditions

Corn meal extract, malt waste, barley salt broth, cotton seed meal extract, tapioca broth and PD broth at 5 and 10 per cent concentration were evaluated for chlamydospore production of *P. chlamydosporium* per cycle (after 30 days of incubation) as batch cultures in Erlynemeyer flasks. The duration of cycles and chlamydospore number differed in different media and their concentrations. Chlamydospore production was highest in corn meal extract, barley salt broth and cotton seed meal extract compared to malt waste, tapioca broth and PD broth at both the concentrations. The chlamydospore production ranged between $1.6x10^2$ to $2.1x10^7$ per ml of the substrate (Table 72).

Table 72. Effect of liquid substrates on chlamydospore production of *Pochonia chlamydosporium* (Mean of 10 replicates)

Medium	Chlamydospores/ml	
	5%	10%
Corn meal extract	$4.4x10^5 \pm 12.4$	$2.1x10^7 \pm 14.8$
Malt waste	$2.6x10^2 \pm 4.6$	$4.8x10^4 \pm 12.8$
Barley salt broth	$6.8x10^4 \pm 23.5$	$3.2x10^6 \pm 96.4$
Cotton seed meal extract	$4.6x10^4 \pm 18.8$	$2.4x10^6 \pm 88.0$
Tapioca broth	$1.6x10^2 \pm 8.2$	$3.3x10^4 \pm 26.2$
PD broth	$3.4x10^3 \pm 32.4$	$8.2x10^4 \pm 44.2$

4.12.2.4. Influence of selective carriers of *P. lilacinus* on spore viability and efficacy against reniform and root-knot nematodes under glass house conditions

The fungal propagules of *P. lilacinus* were formulated on different carrier material, *viz.*, talc, vermiculite powder, coir pith and sawdust with a moisture level of 8% each. These formulations were stored at ambient temperature. Samples were drawn from each of them at monthly interval for 10 months and the spore viability recorded on water-agar medium. Six month-old formulations were evaluated for efficacy against root-knot nematode on tomato and reniform nematode on cowpea under glasshouse conditions. Conidiospores on talc, sawdust and vermiculite exhibited 80-60% spore viability after 10 months of storage, while on coir powder the spore viability declined to 38% (Fig. 4). The efficacy of talc and sawdust formulations was the best with a 48 and 39% reduction in root-knot nematode populations respectively, and 42 and 34% reduction in reniform nematode populations (Table 73).

4.12.2.5. Influence of laboratory culturing of *P. lilacinus* and *P. chlamydosporium* on the spore viability and infectivity against root-knot nematode

Two isolates each of *P. lilacinus* and *P. chlamydosporium* were repeated by sub-culturing on PDA and sorghum grain every 21 days with an intervening storage period (resting period) of 7 days, and evaluated for their spore viability and infectivity against the eggs of *M. incognita* on water-agar medium. There was no significant reduction in spore viability and infectivity in all the four isolates for 8 generations of sub-culturing on PDA and

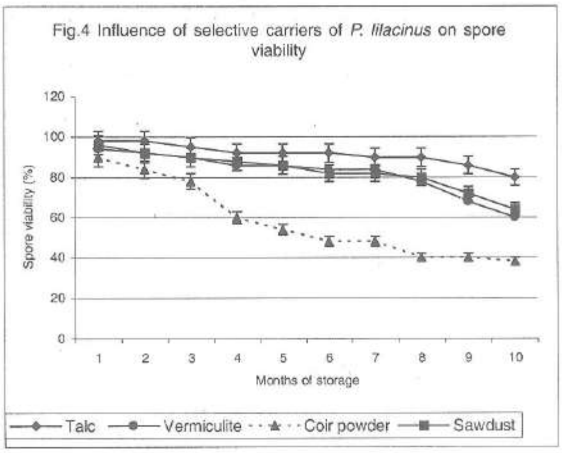


Table 73. Influence of selective carriers of *P. lilacinus* after six months of storage on efficacy against reniform and root-knot nematodes

Treatment	*M. incognita*			*R. reniformis*		
	RKI (0-5 scale)	Egg mass parasiti zation (%)	Healthy root (%)	Parasitised females (%)	Egg mass parasiti zation (%)	Healthy root (%)
PL	3.70	24.00	34.00	16.00	20.00	39.00
Plain talc	4.30	–	24.00	-	-	45.00
Vermiculite	4.40	–	24.00	-	-	46.00
Coir powder	4.50	–	29.00	-	-	40.00
Sawdust	4.50	–	30.00	-	-	48.00
PL in talc	2.60	70.00	62.00	28.00	58.00	76.00
PL in vermiculite	3.00	48.00	52.00	20.00	34.00	56.00
PL in coir powder	3.20	39.00	46.00	20.00	31.00	50.00
PL in sawdust	2.90	52.00	54.00	22.00	46.00	68.00
Untreated check	4.60	–	28.00	-	-	36.00
CD (P=0.05%)	0.82	12.44	6.11	11.24	11.48	4.44

sorghum grain. There was a 5-36 per cent reduction in spore viability on PDA and sorghum grain in 10th generation in both the fungi. Infectivity also declined by 24-49 per cent from 10th generation.

4.12.2.6 Studies on pH and temperature optima of PDBC isolates of *P. lilacinus* and *P. chlamydosporium*

Laboratory studies were carried out to identify the pH and temperature optima for the PDBC isolates of *P. lilacinus* and *P. chlamydosporium*. pH of PDA was adjusted between 4.0 and 9.0 for examining the mycelial growth of *P. lilacinus,* while the pH of CMA was adjusted between 5.5 and 9.0. pH optima recorded was 5.5-8.5 and 6.0-9.0 for *P. lilacinus* and *P. chlamydosporium* isolates, respectively. The temperature optima for spore germination for *P. lilacinus* was 28-40°C while *P. chlamydosporium* recorded a temperature optima between 24 and 33°C.

4.12.2.7 Field efficacy of *Paecilomyces lilacinus* and neem cake against *Meloidogyne incognita* on gherkins

A field study was carried out to evaluate comparative performance of *P. lilacinus* (20 kg/acre) and neem cake (300 kg/acre) against root-knot nematode in gherkin (cv. Calipso) with phorate (1.5 kg a.i./acre) and phenamiphos (1.5 kg a.i./acre) as checks. There was a significant reduction in root-knot index and number of egg masses per g root in all the treatments. There was initial reduction of root infection for 30 days in nematicide-treated plants, which later exhibited high root infection and galling. The plants treated with PL + neem cake exhibited root galling 15 days after plant emergence, which did not spread to the roots that emerged later, thus reducing the infection till 75 days of plant growth.

4.12.2.8 Field evaluation of talc formulation of *P. lilacinus* in combination with commercial and local organic amendments against root-knot nematode in tomato

Microplot experiments were carried out in root-knot nematode infested farmer's field to evaluate the combinations of talc formulation of *P. lilacinus* and organic amendments, *viz.*, farm compost, pelletized organic manure, vermicompost and neem cake with suitable respective checks against root-knot nematode in tomato (cv. Avinash). The rate of application was maintained uniform in all treatments. Organic amendments in general were beneficial to the plant and for the establishment, proliferation and infectivity of *P. lilacinus*. Egg mass parasitization and reduction in nematode population was maximum in PL combination with vermicompost followed by PL with neem cake, farm compost and pelletized organic manure (Table 74).

Table 74. Effect of talc formulation of *P. lilacinus* in combination with organic amendments against root-knot nematode in tomato

Treatment	Plant		Root-knot nematode	
	RKI (0-5 scale)	Healthy root (%)	Egg mass parasitized (%)	Increase/ reduction in nematode populations (%)
PL in talc	3.80	41.00	8.00	(-) 7
Farm compost	3.90	42.00	6.00	(-) 6
Pelletised organic manure	4.00	39.00	3.00	(+) 12
Neem cake	3.70	47.00	3.00	(-) 18
Vermicompost	3.80	46.00	8.00	(-) 8
PL+ Farm compost	3.20	59.00	36.00	(-) 35
PL + Pelletised organic manure	3.40	48.00	26.00	(-) 29
PL + Neem cake	2.80	70.00	28.00	(-) 40
PL+Vermicompost	2.80	82.00	52.00	(-) 68
Untreated check	4.10	39.00	3.00	(+) 94
CD (P=0.05)	0.98	3.88	9.21	11.14

4.13 Survey, identification and utilization of plant pathogens for the biological control of weeds with particular reference to parthenium and water hyacinth

4.13.1 Mass production of *Fusarium pallidoroseum*

Mass production of *F. pallidoroseum*, a potential biocontrol agent for parthenium (*Parthenium hysterophorus*) was undertaken in liquid media. The fungal characteristics on solid media were also studied.

4.13.1.1 Solid culturing

The radial growth of *F. pallidoroseum* was studied on potato dextrose agar (PDA); up to 21 days. The radial growth (diameter including the inoculum disc) of the fungus was measured everyday up to 21 days. The diameter of the colony was 64 mm after 7 days and at 10 days it was 90 mm. The periphery of the colony was wavy. The fungus was light to dark rose light orange coloured. The growth was cottony and the reverse showed pigmentation.

The spore count was taken at the end of 21 days. Five discs of 6-mm diameter were cut from the colony in such a manner that all the parts from the centre (except the original inoculum) to the border were covered. The discs were put in a vial containing 5 mL of water plus Tween 20 (0.05%), vortexed at high speed for about 2 minutes and the spore count was recorded using a haemocytometer. The average spore count was 7.32 x 10^6/disc. Both macro- and micro-conidia were produced. The same suspension was used for counting the colony forming units (CFU) (only condia). When 1 mL of the suspension was plated, an average of 3.10 x 10^5 CFU/disc was realized. Spore measurements were also recorded (N = 100). The maximum length of spore was 40.0ì and the minimum was 10.0ì. The maximum width was 5.0ì and the minimum was 2.5ì (Table 75).

4.13.1.2 Shake culturing

Exactly 100 mL of potato dextrose broth (PDB; HiMedia) was prepared in 250-mL Erlenmeyer flasks and sterilized in the autoclave. Spore suspension from a fresh culture was prepared and 1 mL was used to inoculate each flask. The flasks were placed on an orbital shaker set at 150 rpm for 7 days under ambient conditions. The spore count, CFU, wet weight and dry weight were recorded. Spore measurements (N = 100) were also made (Table 75).

Robust macroconidia were formed by the fungus. A conidial yield of 2.2 x 10^7/mL was recorded at the end of shaking. The biomass gave an average CFU of 1.0 x 10^7/mL. The

Table 75. Parameters of *F. pallidoroseum* grown in liquid and solid cultures

Parameter			Liquid culture (PDB)		Solid culture (PDA)
			Shake culture (At the end of 6 days; 150 rpm)	Fermentation (At the end of 6 days; 500 rpm)	(At the end of 21 days)
Wet weight			7350 mg/ 100 mL	8880 mg/ 100 mL	–
Dry weight			344 mg/ 100 mL	476 mg/ 100 mL	–
Conidia production			2.2 x 10^7/mL	5.9 x 10^7/mL	7.32 x 10^6/6-mm disc
CFU			1.0 x 10^7/mL	6.0 x 10^7/mL	3.10 x 10^5/6-mm disc (only conidia)
Radial growth			–	–	90 mm Ø (At the end of 10 days)
Spore size (Macro-conidia)	Length	Maximum	25.0 µ	25.0 µ	40.0 µ
		Minimum	5.0 µ	7.5 µ	5.0 µ
	Width	Maximum	10.0 µ	7.5 µ	10.0 µ
		Minimum	2.5 µ	2.5 µ	2.5 µ

average wet and dry weights of the biomass were 7350 mg and 344 mg/100mL, respectively. The maximum length of the spore was 25.0 ì and the minimum was 10.0 ì. The maximum width was 5.0 ì and the minimum was 2.5 ì.

4.13.1.3 Fermentation

A bench-top fermentor of 3-litre capacity was used in the study. Two litres of PDB with 0.05% of an antifoaming agent (Silicone) was sterilized and the pH adjusted to 6.5. After sterilization, 200 mL of fresh inoculum obtained through shake culture (5-day-old in PDB) was added to the contents aseptically. The fermentor was set at 500 rpm (agitation), 0.5 lpm (air) and 25 °C and run continuously for 6 days. At the end of the run, the wet weight, dry weight, CFU and spore count were recorded. Spores, especially robust macro-conidia, were also formed. Spore measurements were also recorded (N = 100).

The wet and dry weights recovered were 8880 mg and 476 mg/100 mL, respectively. A count of 6.0 x 10^7 CFU/ mL was obtained at the end of fermentation. A spore count of 5.9 x 10^7 / mL was obtained. The maximum length of the spore was 25.0μ and minimum was 7.5ì. The maximum width was 7.5ì and the minimum was 2.5μ

4.13.1.4 Development of formulations of *F. pallidoroseum*

Biomass of *F. pallidoroseum* obtained through fermentation was formulated into four different products (bioherbicides), viz. powder, oil emulsion, alginate pellets and pesta granules. A minimum CFU of 1 x 10^9 per g or mL was maintained in the formulations.

Powder formulation in talc (mycelia and conidia)

Oil emulsion formulation in sunflower oil

Alginate granule formulation

Pesta granule formulation (wheat flour, mycelial / conidial homogenate and kaolin)

4.13.1.5 Effect of *F. pallidoroseum* formulations against *P. hysterophorus*

All the four formulations (bioherbicides) were evaluated under greenhouse as well as field conditions.

4.13.1.6 Greenhouse evaluation

Parthenium seedlings were raised separately for the experiment. Healthy seedlings in the 5-6 leaf stage were selected and planted in mud pots [25 (top Ø) x 15 (bottom Ø) x 25 (height) cm] at the rate of one plant per pot. All the pots were transferred to the greenhouse benches and plants were allowed to grow further to reach 7-8 leaf stage before the application of treatments. The maximum temperature and relative humidity at noon were 37 °C and 75 %.

Each formulation was evaluated in the form of one and two sprays. Each treatment consisted of 10 plants. Spray suspensions were prepared at 1% concentration in tap water with Tween 80 (0.05%) and sprayed onto the plants in such a manner that there was runoff of the spray solution. Each plant was sprayed with approximately 25 mL of the suspension. Plain water with the wetting agent served as control. One set of all the treated plants were sprayed once again after 10 days by the same method with the respective formulations.

Observations were made at the end of 25 days from the first spray. The leaves of each plant sprayed were counted and visually rated individually for disease symptoms using a 0 – 6 scale (0 = no disease; 1 = 0 –5%; 2 = 6–25%; 3 = 26–75%; 4 = 76–95%; 5 > 95% of leaf surface with necrosis; 6 = leaf dead). The total necrotic leaf area was calculated as a percentage using the formula $(2.5 \times n_1 + 15 \times n_2 + 50 \times n_3 + 85 \times n_4 + 97.5 \times n_5 + 100 \times n_6)/N$, where n_x is the number of leaves with rating x and N is the total number of leaves treated.

Significant differences were observed between treatments and all the treatments were effective in causing disease (Table 76). It was found that two sprays were better than a single spray with regard to all the formulations tested. Within the one-spray treatments, the highest (34.68 %) necrotic leaf area was with alginate granule formulation followed by the powder formulation (26.46 %) and the oil emulsion formulation (22.36 %). The least effective

Table 76. Effect of *F. pallidoroseum* formulations against *P. hysterophorus* in the greenhouse

Treatment	Necrotic leaf area (%)
Powder formulation (one spray)	26.46 (28.84)
Powder formulation (two sprays)	31.87 (35.15)
Oil emulsion formulation (one spray)	22.36 (25.98)
Oil emulsion formulation (two sprays)	65.54 (59.77)
Alginate granule formulation (one spray)	34.68 (36.06)
Alginate granule formulation (two sprays)	53.12 (48.43)
Pesta granule formulation (one spray)	16.54 (21.11)
Pesta granule formulation (two sprays)	64.05 (60.58)
Control (Water) (one spray)	0.00 (0.00)
Control (Water) (two sprays)	0.00 (0.00)
CD (P=0.05)	17.29

Note: Figures in parentheses are arc-sin transformed values.

was the pesta granule formulation (16.54 %). When sprayed twice the incidence of disease was the maximum (65.54 %) through the oil emulsion followed by pesta granule formulation (64.05 %).

4.13.1.7 Field evaluation

A field experiment was conducted in Singapura near Jalahalli in Bangalore Urban district. Plots of 2 x 2.5 m were prepared to fine tilth and were irrigated to field capacity. A spacing of 0.3 m was maintained between the plots on all sides. CRD was followed to prepare the layout. Healthy parthenium seedlings at 5-6 leaf stage were transplanted the next day at the rate of 40 plants per plot. All the treatments had three replicates each.

Each formulation at 1% concentration was sprayed onto the plants at the rate of 500 mL per plot (1.5 l/treatment). Tween 80 at 0.05 % was used as a sticker. The same concentration of formulations was once again applied on the plants in the respective plots 10 days after the first spray. The control plots were sprayed only with water containing the sticker. Sprayings were undertaken in the evening using a hand-held sprayer. Disease assessment was made after 25 days from the first spray employing the same methods as in the case of greenhouse evaluation.

None of the formulations of *F. pallidoroseum* were effective in the field with regard to their effect on parthenium with just 14.72-9.66 per cent necrotic leaf area recorded and the difference was not significant (P=0.05).

4.13.2 Mass production of *Alternaria alternata*

Alternaria alternata, an important and regular pathogen of water hyacinth (*Eichhornia crassipes*) was taken up for mass production studies by fermentation method. Its macro- and micro-morphological features were compared in liquid and solid media.

4.13.2.1 Solid culturing

Radial growth of *A. alternata* was studied to compare the characters of the fungus grown in different methods.

The growth characteristics were studied on PDA up to 21 days in a BOD incubator at 25 °C. The fungus could reach the maximum diameter of 90 mm at the end of 10 days. The growth was circular and dark brown coloured and the reverse showed dark brown pigmentation.

The spore count from colony was taken after 21 days growth. Five 6-mm plugs from the centre (except the inoculum) to border of the plates were taken in 5 mL of deionized water containing Tween 20 (0.05 %) and put on a vortex mixer at high speed for about 2 minutes. Spore count was made with the help of haemocytometer. The average conidia production was 2.0 x 10^4/6-mm disc. The same suspension was used for CFU counts by plating 1 mL of the suspension. The average recorded was 6.8 x 10^2 CFU/6-mm disc. The spore dimensions were measured (N = 100) and the number of septa in each spore was also counted. The maximum length of the spore was 37.5 ì and the minimum was 20.0 ì. The maximum width was 12.5 ì and the minimum was 7.5 ì. The number of transverse septa varied from 1 to 4 and the number of longitudinal septa varied from 0 to 2 (Table 77).

Table 77. Parameters of *A. alternata* grown in liquid and solid cultures

Parameter			Liquid culture (PDB)		Solid culture (PDA)
			Shake culture (At the end of 6 days; 150 rpm)	Fermentation (At the end of 6 days; 500 rpm)	(At the end of 21 days)
Wet weight			20952.5 mg/ 100 mL	4972 mg/ 100 mL	–
Dry weight			911.5 mg/ 100 mL	163.5 mg/ 100 mL	–
Conidia production			1.4 x 10^5/mL (after incubation 13 days)	3.0 x 10^5/mL (after incubation 13 days)	2.0 x 10^4/6-mm disc
CFU			1.3 x 10^4/mL	7.8 x 10^4/mL	6.8 x 10^2/6-mm disc (only conidia)
Radial growth			–	–	90 mm Ø (At the end of 10 days)
Spore size (Macro-conidia)	Length	Maximum	50.0 μ	45.0 μ	37.0 μ
		Minimum	17.5 μ	12.5 μ	20.0 μ
	Width	Maximum	10.0 μ	15.5 μ	12.5 μ
		Minimum	2.5 μ	5.0 μ	7.5 μ
	Number of septa	Transverse	1-4	1-5	1-4
		Longitudinal	0-2	0-2	0-2

4.13.2.2 Shake culturing

Exactly 100 mL of PDB was prepared in 250 mL Erlenmeyer flasks and sterilized in the autoclave. Spore suspension from a fresh culture of *A. alternata* was prepared and 1 mL was used to inoculate each flask. The flasks were placed on the orbital shaker set at 150 rpm for 7 days under ambient conditions. The CFU, wet weight and dry weight were recorded. Since sporulation did not occur, the flasks were incubated further for 13 days in the BOD incubator to get the biomass sporulate. Spore measurements were also made (N = 100).

The average wet and dry weights obtained were 20952.5 mg and 911.5 mg/100mL, respectively. The average CFU recorded was 1.3 x 10^4/ mL. The average spore count recorded (after 13 days of incubation for sporulation) was 1.4 x 10^5/ mL. The maximum length of the spore was 50.0 ì and the minimum was 17.5 ì. The maximum width was 10.0 ì and the minimum was 2.5 ì. The number of transverse septa varied from 1 to 4 and the number of longitudinal septa varied from 0 to 2 (Table 77).

4.13.2.3 Fermentation

A bench-top fermentor of 3-litre capacity was used in the study. Two litres of PDB with 0.05% of an antifoaming agent (Silicone) was sterilized and the pH adjusted to 6.5. After sterilization, 200 mL of fresh inoculum obtained through shake culture (5-day-old in PDB) was added to the contents aseptically. The fermentor was set at 500 rpm (agitation), 0.5 lpm (air) and 25 °C and run continuously for 6 days. At the end of the run, the wet weight, dry weight and CFU were recorded. Since sporulation did not occur in the fermentor, the biomass was transferred to roux bottles and was incubated in the BOD incubator for 13 days to get sporulation.

The average wet weight recorded was 4972.0 mg/ 100 mL and the average dry weight obtained was 163.5 mg/100mL. The average CFU recorded was 7.8 x 10^4/ mL. The average spore count recorded (after 13 days of incubation for sporulation) was 3.0 x 10^5/ mL. The spore measurements were also made (N = 100). The maximum length of the spore was 45.0 ì and the minimum was 12.5 ì. The maximum width was 15.0ì and the minimum was 5.0 ì. The number of transverse septa varied from 1 to 5 and the number of longitudinal septa varied from 0 to 2 (Table 77).

4.13.2.4 Development of formulations of *A. alternata*

The biomass (only mycelia) of *A. alternata* obtained through fermentation was formulated into four different products (bioherbicides), viz. powder, oil emulsion, alginate pellets and pesta granules. A minimum CFU of 1 x 10^8 per g or mL was maintained in the formulations.

Powder formulation in talc (mycelia)
Oil emulsion formulation in sunflower oil
Alginate granule formulation (mycelial homogenate)
Pesta granule formulation (wheat flour, mycelial homogenate and kaolin)

4.13.2.5. Limited open-air trials with the *A. alternata* formulations

Open-air trials were conducted with all the four formulations (bioherbicides) at 1 % concentration in translucent plastic buckets (15-L capacity). The treatments consisted of single and double spray of the formulations along with the respective controls, which contained only water with the wetting agent. Tween 80 (0.05%) was used as the wetting agent. Each treatment consisted of 10 individual water hyacinth plants and each plant served as a replicate. The efficacy of different treatments was determined from the level of disease severity (area of foliage damaged by the disease) with the pictorial scale of 0 to 9 at the end of 4 weeks.

All the treatments were effective in terms of bringing about significant disease severity in water hyacinth (Table 78). The formulations fared better when sprayed two times than when sprayed only once. Among the single spray treatments, the maximum disease severity (7.8) was recorded with the powder formulation and the minimum (4.2) was obtained with pesta granule formulation. Among the two-spray treatments, the maximum (8.6) disease severity was given by the powder formulation followed by the oil emulsion formulation, which produced a disease severity of 7.0.

Table 78. Effect of *A. alternata* formulations against *E. crassipes*

Treatment	Disease severity
Powder formulation (one spray)	7.8
Powder formulation (two sprays)	8.6
Oil emulsion formulation (one spray)	6.2
Oil emulsion formulation (two sprays)	7.0
Alginate granule formulation (one spray)	4.6
Alginate granule formulation (two sprays)	5.6
Pesta granule formulation (one spray)	4.2
Pesta granule formulation (two sprays)	5.6
Control (Water) (one spray)	0.0
Control (Water) (two sprays)	0.0
CD (P=0.05)	0.97

4.13.3 Extended host range studies for selected water hyacinth pathogens

Investigations were done to see if other aquatic weeds growing along with water hyacinth were also susceptible to *Alternaria* and *Cercospora* spp. Both pathogenicity of the fungi and phytotoxicity of their metabolites were tested as part of the host range testing. Two methods of screening viz., the detached leaf technique (*in vitro*) and the *in vivo* method consisting of intact plants were employed for studying pathogenicity as well as phytotoxicity.

4.13.3.1 Pathogenicity

In the first method, 15-cm petri plates, containing a layer of moist absorbent cotton covered with a disc of aluminium foil in the lower dish, were used as moist chambers to maintain 100% RH. Each detached leaf of the test plants was placed, one per plate, in the plates by inserting the petiole through a hole made in the foil, so as to allow it to be in contact with the moist cotton. A concentration of 1×10^8 conidia/mL of the pathogens was used. The suspension was evenly brushed on both surfaces of the leaves. All the plant species tested had 10 replicates of inoculated leaves. Control leaves, also with 10 replicates, were applied only with sterile water containing the surfactant (Tween 20). Observations were taken every day for any visible signs of infection up to a week. In the second method, intact healthy plants were sprayed with the conidial suspension. Treated plants and control plants were replicated 10 times.

4.13.3.2 Phytotoxicity

The same methods described above were followed for phytotoxicity assessment as well. However, only metabolites from culture filtrates were used. The cultures were grown in PDB for 15 days and the culture filtrates obtained through filtration was used without dilution. Observations were taken every day for any visible signs of phytotoxicity up to a week.

Alternaria and *Cercospora* spp. were neither pathogenic nor phytotoxic to the water fern (*Salvinia molesta*), the water lettuce (*Pistia stratiotes*), and the alligator weed (*Alternanthera philoxeroides*).

4.14 Cultures of host insects/ parasitoids/ predators/ nematodes/ antagonists/ pathogens

4.14.1. Host cultures

Cultures of *Corcyra cephalonica, Chilo partellus, Phthorimaea operculella, Plutella xylostella, Helicoverpa armigera, Spodoptera litura, S. exigua, Aphis craccivora, Ferrisia virgata, Planococcus citri, Hemiberlesia lataniae, Tetranychus neocaledonicus, Pseudoregma bambusicola, Opisina arenosella, Galleria mellonella, Trichoplusia ni,* *Crocidolomia binotalis, Hellula undalis, C. saccariphagus indicus* and *Adisura atkinsoni* are being maintained on natural food or artificial diet.

4.14.2. Parasitoids

Campoletis chlorideae, Eriborus argenteopilosus, Telenomus remus, Telenomus three species, *Encarsia gaudeloupae, Cotesia flavipes, Cotesia plutellae, Goniozus nephantidis, Brachymeria nephantidis, B. nosatoi, Adelencyrtus mayurai, Coccidoxenoides peregrinus* and eleven species of *Trichogramma* and eleven of its strains were maintained.

4.14.3. Predators

Cheilomenes sexmaculata, Coccinella septempunctata, Ischiodon scutellaris, Cryptolaemus montrouzieri, Scymnus coccivora, Pharoscymnus horni, Chilocorus nigrita, Chrysoperla carnea, Mallada boninensis, M. astur, Apertochrysa sp., *Cardiastethus exiguus, Orius tantillus, Blaptostethus pallescens, Brumoides suturalis, Sticholotis cribellata, S. quadrisignata, Paragus serratus* and *Curinus coeruleus* were maintained.

4.14.4. Insect pathogens

Nuclear polyhedrosis viruses of *H. armigera* and *S. litura* and granulosis virus of *P. xylostella* are being maintained on their host insects. A culture of *Nomuraea rileyi*, a fungal pathogen is maintained. Seven varieties of *B. thuringiensis* (*aizawai, entomocidus, gallerie, israelensis, kurstaki, sotto* and *thuringiensis*) are maintained on Nutrient Agar and Poly medium Repository in the Division of Entomology at IARI, New Delhi. *Nosema* sp. has been added to repository in Division of Entomology at IARI, New Delhi.

Antagonistic fungi maintained (with number of isolates in parentheses) are *Trichoderma harzianum* (52), *T. viride* (35), *T. hamatum* (6), *G. virens* (22), *T. koningi* (14), *T. pseudokoningi* (2), *T. piluliferum* (8), *T. citrinoviride* (3), *T. longibrachiatum* (2), *T. polysporum* (4), *Gliocladium deliquescens* (4), *G. roseum* (2), *G. catenulatum* (1) and *Chaetomium globosum* (1).

Bacterial antagonists (number of isolates in parentheses) maintained are fluorescent pseudomonads (96), *Pseudomonas fluorescens* (24), *Pseudomonas* spp. (4), *Alcaligenes odorans* (1), *Bacillus subtilis* (4), *Bacillus thuringiensis* (6) and endophytic bacteria (35).

Entomopathogenic nematodes maintained are *Steinernema glaseri, S. carpocapsae* (2 strains), *S. bicornutum* (1 strain), *Heterorhabditis indica* (1 strain).

The nematophagous fungi/bacteria maintained are *Arthobotrys oligospora, Fusarium oxysporum* (4 isolates), *F. sporotrichoides, Paecilomyces lilacinus* (5 isolates), *Phoma* *glomerata, Trichoderma harzianum* (7), *T. viride, Pochonia chlamydosporium,* Bacteria *Pasteuria penetrans* (5 isolates) and *Pseudomonas flourescens* (3 isolates).

An isolate of parthenium leaf spot disease WF (Ph) 30 of *Fusarium pallidoroseum* (Cooke) Sac. (=*F. semitectum* Auct.) is maintained.

4.15 Shipments

294 shipments (comprised of 57 host insect cultures, 65 predatory cultures, 78 parasitoid cultures, 63 insect pathogens, 17 antagonists and 14 weed insects) were sent to different research organisations / private companies / universities / individual farmers

4.16 Software development for identifying and suggesting biological control measures for different crop pests using a PC

Expert system 'BIORICE' is developed for bio-control of rice-pests. The software can work as an expert, in the absence of a scientist. Based on the pictures of the pest or the pictures of symptoms, the pest can be identified and bio-control measures are suggested for the pest. Information about the morphology, geographic distribution, natural enemy complex, host range, IPM and scope for further research are also included in the software. Picture gallery is also provided for the natural enemies.

4.16.1 Development of National Information system on Biological Suppression of crop-pest

To improve the information system 'PDBC-INFOBASE' hundreds of pictures have been collected, scanned and edited and included in the software.

4.16.2 Knowledge Base System of *Helicoverpa armigera* and its natural enemies

"Helico-info" – a CD has been developed to help scientists, researchers, extension workers, NGO's and farmers to get information about *H. armigera* and its natural enemies for successful biocontrol. The CD gives details about the taxonomy, bionomics, distribution, biocontrol and natural enemies recorded on the pest. The species of *Helicoverpa/Heliothis* and population dynamics of *H. armigera* in relation to abiotic factors are also added. Video clips have been recorded for the biology of *H. armigera*.

4.16.3 Decision support system for identification of potential natural enemies and safer pesticides to natural enemies

Software has been developed in Visual Basic 6.0, which gives information about the pest on different crops, its natural enemies and pesticides that are safer to these natural enemies.

4.17 Biological suppression of sugarcane pests

4.17.1 Seasonal fluctuation of natural enemies of sugarcane borers (PAU, Ludhiana)

The seasonal fluctuations of natural enemies of sugarcane borers were studied at village Behram (Distt. Nawanshahr). The survey was carried out at 15 days interval during April 2002-March 2003. Egg clusters, larvae and pupae of sugarcane borers were collected and reared in the laboratory for emergence of natural enemies or next stage of the pest.

Chilo infuscatellus: Two egg parasitoids, namely *Trichogramma chilonis* and *T. chilotraeae* were recorded during second fortnight of June and first fortnight of July, causing 9.9 to 10.0 per cent and 9.9 per cent parasitism, respectively. Four larval parasitoids, namely, *Bracon* sp., *Cotesia flavipes*, *Stenobracon nicevillei* and *Sturmiopsis inferens* caused 4.50-9.52, 4.50-8.33, 4.00-4.16 and 4.16 per cent parasitism, respectively. One unidentified parasitoid was also recorded causing 3.70 per cent parasitism. *Bracon* sp. and *C. flavipes* were most common larval parasitoids. Only *Tetrastichus* sp. (5.0%) emerged from pupae.

Chilo auricilius: *Trichogramma chilonis* was the only egg parasitoid recorded during July-September (16.66 to 18.18%). Four larval parasitoids, *viz. C. flavipes, S. inferens, S. nicevillei* and an unidentified species caused 2.85-11.11, 3.57-10.52, 8.57- 10.71 and 3.57-10.0 per cent parasitism, respectively. *C. flavipes* and *S. inferens* were recorded throughout the year, while *S. nicevillei* was observed during July-August and an unidentified species during May. During January-March only *S. inferens* was recorded. Only 6.66 per cent pupal parasitism was observed during the first fortnight of March 2003.

Scirpophaga excerptalis: *Trichogramma chilonis* was recorded during May, causing 5.55 per cent parasitization. *T. japonicum* was observed during April-July (2.77 to 12.00%). However, *Telenomus dignoides* was most common and observed during April-September causing 6.66 to 30.76 per cent parasitization. Four larval parasitoids, *viz. Isotima javensis, Rhaconotus scirpophagae, S. nicevillei* and an unidentified species were recorded during May-December 2002 causing 2.38-15.38, 5.00-12.50, 2.50-11.53 and 2.85 to 4.16 per cent parasitism, respectively.

4.17.2. Field studies on shoot borer and natural enemies (SBI, Coimbatore)

Shoot borer was active at Coimbatore during March 2002 - February 2003. The fortnightly incidence of the borer varied from 0.9 to 16.5% with slightly higher levels during April - July 2002. Barring the highest peak in the first fortnight of July (16.5%), the incidence of the borer was uniform during the observation period. *Sturmiopsis inferens* was also active throughout the year, with a parasitism range of 0.0 - 4.0%. The parasitoid was not active during April II fortnight - June I fortnight.

The parasitoid was field evaluated against shoot borer in six field trials (Table 79). Augmentative releases of the parasitoid were made at the rate of 10-26 mated females/ac in at least 2000 m^2 plots. The flies were released over a one-week period at two spots in the plot. Another 2000 m^2 crop with an isolation distance of more than 100m served as control. Pre-release and post-release counts of deadhearts in release and control plots indicated a general decrease in shoot borer incidence between the observations with no clearcut trend. Parasitism rates of shoot borer in three trials were considerably higher in released plots than in control. In two other trials, parasitism rates in release plots were marginally higher.

Table 79. Field evaluation of *Sturmiopsis inferens* against shoot borer

Month (2002-03)	No. of females /4000m^2	Shoot borer incidence				Post-release % parasitism	
		Pre-release		Post-release			
		Treat	Cont	Treat	Cont	Treat	Cont
July	18	6.4	4.2	–	–	12.5	0.0
September	24	6.5	6.9	2.9	3.5	11.8	2.2
December	10	4.5	5.3	3.4	3.3	10.0	8.3
January	26	4.8	2.2	3.7	2.7	13.3	0.0
February	24	3.0	4.8	1.7	1.6	2.8	0.0
March	10	10.2	5.9	4.0	–	1.3	–

4.17.3. Natural enemies of sugarcane insect pests (CCSHAU, Karnal)

In Karnal region, natural parasitism of *Pyrilla perpusilla* by egg parasitoid, *Ooencyrtus papilionis* and nymphal-adult parasitoid *Epiricania melanoleuca* was 39.4 and 74.70 per cent, respectively. *Cotesia flavipes* was recorded parasitizing the larvae of stalk borer and top borer to the extent of 9.0 and 2.2 percent, respectively. A rover beetle, an earwig, two species of black ants and three species of predatory spiders were found predating on the black bug, *Cavelerius sweeti* eggs and nymphs. *Chrysoperla carnea* and a species of ladybird beetle predated on the sugarcane white fly, *Neomaskellia bergii. Sturmiopsis inferens* was recorded as the common parasitoid of stalk borer (10.33) and Gurdaspur borer (5.67%). *Isotima javensis* (15.33 %) was mainly parasitic on the top borer.

4.17.4. Field studies on *Trichogramma chilonis* against early shoot borer *Chilo infuscatellus* (PAU, Ludhiana)

The field studies on the efficacy of *Trichogramma chilonis* against early shoot borer, *Chilo infuscatellus* were carried out in farmers' fields at four locations, namely Bhattian (Distt. Jalandhar), Khothran and Mehli (Distt. Nawanshahr) and Khera (Distt. Kapurthala). The plot size was 0.2 ha for each treatment. Eight releases of *T. chilonis* were made at 10 days interval during mid April to end June @50,000 per ha. In chemical control, granular insecticide Padan 4G (Cartap hydrochloride) was applied @ 25kg/ha, 45 days after germination as per PAU recommendation.

In all the villages, the incidence of early shoot borer was significantly lower in treated plots as compared to control (Table 80). The mean incidence was lowest (4.95%) in chemical

Table 80. Field evaluation of *Trichogramma chilonis* against *Chilo infuscatellus*

Treatment	Period of release / insecticide application	*Post treatment incidence of *C. infuscatellus* at different locations (%)				Mean
		Bhattian	Khothron	Mehli	Khera	
Biological control (release of *T. chilonis*	Mid April to end June	5.60 (13.62)	6.00 (14.15)	2.60 (9.23)	5.60 (13.62)	5.25 (13.23)
Chemical control (Padan 4 G 25 kg/ha)	45 DAP	6.20 (14.38)	6.60 (14.82)	3.00 (9.91)	5.20 (13.14)	4.95 (12.84)
Control	–	17.80 (24.94)	9.20 (17.63)	4.20 (11.77)	16.40 (23.84)	11.90 (20.16)
CD (P=0.05)	–	(0.96)	(1.77)	(1.57)	(2.07)	(0.70)

Note: Pre-releases incidence was below one per cent at all the locations
* Based on 100 shoots in each sub-plot
Figures in parentheses are arc sin transformations

control and was at par (5.25%) with releases of *T. chilonis* and both were significantly better than control (11.90%). At all the four locations, the egg parasitism was very high (60.00-63.63%) as compared to chemical control (4.16-8.30%) and control plots (4.16-12.00%). The mean parasitism was 61.81 per cent in parasitoid released fields as compared to 5.34 per cent in chemical control and 6.63 per cent in control (Table 81).

Table 81. Field recovery of *Trichogramma chilonis* from *Chilo infuscatellus* eggs at different locations

Treatment	*Parasitism (%) at different locations during June-July				Mean
	Bhattian	Khothron	Mehli	Khera	
Biological control	60.00	63.63	62.50	61.11	61.81
Chemical control	4.16	4.54	8.30	4.34	5.34
Control	5.26	5.10	12.00	4.16	6.63

* Pre-release egg parasitism was nil during March-April, 2002

4.17.5. Large-scale demonstration of *Trichogramma chilonis* against early shoot borer IISR, Lucknow

Efficacy of T. *chilonis* releases against early shoot borer was demonstrated at Pravaranagar, Maharashtra.

The release of parasitoid was started from 5th November 2002 @ 50,000/ha at 10 days interval. The mean incidence of borer varied from 0.32 to 4.42 from November-January in parasitoid released field, whereas in the control plot it varied from 0.90 to 11.43 during the same period. In both the plots, there was no incidence of the pest at the start of the experiment.

MPKV, Pune

Eight releases of *T. chilonis* @ 50,000 adults/ha/release were found effective in enhancing parasitism (28.67%) and reducing dead hearts by 51.6% over control. The yield of sugarcane also increased by 33.4% over control (Table 82).

Table 82. Evaluation of *Trichogramma chilonis* against early shoot borer on sugarcane

Treatment	% parasitism		% dead hearts		Yield kg/15 clumps
	Pre-release	Post-release	Pre-release	Post-release	
T. chilonis @ 50,000/ha at 10 days interval (8 releases)	4.87	38.67	3.42	5.16 (51.6)*	280.8 (33.4)**
Untreated control	4.50	6.73	2.95	10.66	210.5

* Pre cent reduction in dead hearts over control

** Per cent increase in yield over control

PAU, Ludhiana

The efficacy of *Trichogramma chilonis* against stalk borer was demonstrated over 1.0 ha at village Hadiabad (Distt. Kapurthala) and 40 ha at village Karni Khera (Distt. Ferozepur). The parasitoid was released @ 50,000/ha at 10 days interval during July-October. The post-release incidence of the stalk borer was recorded in the month of November. The cane yield was also recorded.

In both villages, the incidence of stalk borer was significantly lower than control (Table 83 & 84). The parasitization and yield in released fields were significantly higher than control.

Table 83. Large-scale demonstration of effectiveness of *Trichogramma chilonis* against *Chilo auricilius* at Hadiabad (Distt.Kapurthala)

Treatment/ plot size	Period of release	*Post release incidence of *C. auricilius* (%)	Recovery of *T. chilonis* (%)	Yield (q/ha)
T. chilonis (1.0 ha)	July – October	10.60 (18.96)	42.85	635
Control (1.0 ha)	–	27.80 (31.79)	5.26	507
CD (P=0.05)		(2.84)	-	58

Releases made@ 50,000/ha at 10 days interval

* Incidence based on 100 canes from ten sub-plots each. Pre-release incidence was below one per cent at all locations

Figures in parentheses are arc sin transformations

Table 84. Large-scale demonstration of effectiveness of *Trichogramma chilonis* for the control of *Chilo auricilius* at Karni-Khera (Distt. Ferozepur)

Treatment/ plot size	Period of release	*Post release incidence of *C. auricilius* (%)	Recovery of *T. chilonis* (%)	Yield (q/ha)
T. chilonis (40 ha)	July – October	3.5	73.6	650
Control (1.0 ha)	-	13.7	8.7	510

Releases made at 10 days interval from July to October

*Incidence based on 2000 plants in released fields and 500 plants in control

Large scale demonstration of effectiveness of *T. chilonis* over an area of 3500 acres was also carried out in collaboration with Morinda Co-op Sugar Mills Ltd., Morinda and Doaba Co-op Sugar Mills Ltd. Nawanshahr. The egg parasitoid *T. chilonis* was released from July-October in both the mill areas at 10 days interval @50,000 per ha. The incidence of *C. auricilius* at Nawanshahr and Morinda in parasitoid released fields was 3.10 and 2.19, respectively. The corresponding figures in the control fields were 7.30 and 6.85. The reduction in damage over control in both the mills was 62.77 per cent.

4.17.6. Laboratory studies on *S. inferens*

In the laboratory, adult emergence of the parasitoid was slightly male biased in different months. Mating rates of freshly emerged females, when individually caged with one to two-day old males, were very high (81.3-100.0%) with an occasional low value (58.3%). Parasitisation rates on shoot borer varied considerably when exposed to larvae at 2 parasitoid maggots: 1 host larva ratio. A preliminary attempt was made to rear the parasitoid *in vitro* in a media comprising whole body extract of *Galleria mellonella* larvae, wheat bran, dry yeast, soy flour, sucrose, etc.

4.17.7. Field studies on *Trichogramma japonicum* for the control of top borer, *Scirpophaga excerptalis* (PAU, Ludhiana)

Field evaluation of *Trichogramma japonicum* for the control of top borer *S. excerptalis* was carried out in farmers' fields in the locations mentioned under 4.18.2. It was compared with chemical control (Thimet 10G@ 30kg/ha) and untreated control. The egg parasitoid, *T. japonicum* was released 5 times during May-July @ 50,000 per ha coinciding with the availability of eggs in the fields.

The incidence of the top borer in the released fields was on par with chemical control at all the locations and significantly low than control (Table 85). The mean incidence was lowest in chemical control (8.15%) and it was on par with released fields (9.15%) and was significantly lower than control (17.00%). The egg parasitism was very high (24.00-25.64%) in parasitoid released fields as compared to chemical control (0.00-3.12%) and control (2.56-5.88%). The mean egg parasitization was highest in released fields (24.97%) as compared to 1.49 per cent in chemical control and 3.52 per cent in control (Table 86).

4.17.8. Field efficacy of *Beauveria bassiana* against stalk borer, *Chilo auricilius* in sugarcane (CCSHAU, Karnal)

Spore suspensions containing 10^6- 10^{10} spores/ml of water with 0.05% teepol were individually sprayed on sugarcane stalks of cultivar CoH 119 coinciding with the third and

Table 85. Field evaluation of *Trichogramma japonicum* against *Scirpophaga excerptalis*

Treatment/ Plot size	Releases/ insecticide application dates	*Incidence of *S. excerptalis* at different locations (%)				Mean
		Bhattian	Khothron	Mehli	Khera	
T. japonicum (0.4 ha)	03-05-02 21-05-02 26-06-02 04-07-02 09-07-02	9.60 (18.01)	9.20 (17.61)	9.00 (17.40)	8.80 (17.20)	9.15
Chemical control (0.2 ha) (Thimet 10G)	Last week of June- First week of July	8.80 (17.20)	7.80 (16.19)	8.20 (16.59)	7.80 (16.15)	8.15
Control (0.4 ha)	–	17.60 (24.77)	18.60 (25.35)	15.40 (23.07)	16.40 (23.84)	17.00
CD (P=0.05)	–	(2.01)	(1.62)	(1.85)	(2.01)	-

Releases coincided with availability of egg cluster; *Based on 100 shoots/cane per sub-plot; Figures in parentheses are arc sin transformations

Table 86. Field recovery of *Trichogramma japonicum* from *Scirpophaga excerptalis* eggs

Treatment	*Egg parasitism (%) at different locations during June-July				Mean
	Bhattian	Khothron	Mehli	Khera	
T. japonicum	25.22	25.00	24.00	25.64	24.97
Chemical control	3.12	2.85	0.00	0.00	1.49
Control	5.88	2.77	2.85	2.56	3.52

T. japonicum not recovered during pre-treatment observations at any location in May

fourth broods. Pre-treatment incidence was 13 to 27 per cent. The incidence of third and fourth broods was lowered by a maximum of 39 and 23 percent in plots treated with a spore concentration of 10^{10}, but the fifth brood incidence did not differ much between treated plots and untreated check. The number of infected larvae of the borer as also the cane yield was highest in plots receiving the highest spore concentration. The intensity of attack was found to gradually decline with increase in spore concentration (Table 87).

Table 87. Effect of *B. bassiana* concentrations on *C. auricilius* infestation and cane yield

Concentration (spores/ml)	Stalk borer		Larval infectivity	Cane yield (MT/ha)
	Incidence (%)	Intensity (%)		
$1x10^6$	58.3	20.3	3.4	83.7
$1x10^7$	63.4	18.4	7.8	84.7
$1x10^8$	49.4	18.7	5.9	84.7
$1x10^9$	52.1	14.9	21.6	86.3
$1x10^{10}$	41.1	12.8	37.9	86.8
Check	60.7	20.9	-	84.2
CD (P= 0.05)	5.7	3.8	11.13	0.83

4.17.8.1 Efficacy of *Beauveria* sp nr. *bassiana* against early shoot borer, *Chilo infuscatellus* under field conditions (CCSHAU, Karnal)

In a preliminary field testing, the efficacy of *Beauveria* sp. nr. *bassiana* was compared with chemical insecticide fipronil 0.03 GR applied at first irrigation (45 days after planting). Two foliar applications of the fungus @ $1x10^7$ spore/ml given coinciding with the first and second broods of the early shoot borer resulted in about 23 percent reduction in incidence of first brood and 21 percent incidence of the second brood as against 35.7 percent and 34.3 percent reduction recorded with fipronil 0.03 GR @ 20 kg per hectare. The fungus treated plot contained 15.6 percent infected larvae of first brood and 9.3 percent of the second brood. Fipronil treated plot contained stout canes with greater height and thickness and more number of internodes than fungus treated plot and control (Table 88).

Table 88. A comparison of the effects of *B.* sp. nr. *bassiana* and insecticide fipronil on incidence of the early shoot borer, *C. infuscatellus* and cane yield

Observations	*B.* sp. nr. *bassiana*	Fipronil 0.03GR	Untreated
Pre-treatment incidence %	2.6	3.9	2.1
Incidence % 20 DAT	7.9	6.5	10.4
Incidence % 20 DAT	15.1	12.2	20.1
Cane yield (MT) at harvest	86.7	92.4	85.9

4.17.9. Studies on the fungus *Beauveria brongniartii* against white grub (SBI, Coimbatore)

4.17.9.1 Persistence of the fungus in treated fields

The persistence of *B. brongniartii* applied in farmers' fields in M/s Bannari Amman Sugar Mills, Satyamangalam, Tamil Nadu, is being monitored by collecting grubs of *Holotrichia serrata* from treated fields and examining them in the laboratory for disease incidence. Grubs collected during 1997-98 to 2001-02 from fields that received a single application of the fungus, mostly as press-mud formulation, showed a range of infection (1.9 - 17.1%). Some fields did not show infection in collected grubs. The infection levels appeared to have decreased from the previous year. Besides *B. brongniartii*, natural occurrence of *Metarhizium anisopliae* (1.7-15.1%) and *Bacillus popilliae* (1.7-19.0%) was also observed in these plots.

4.17.9.2 Bioassay of formulations

Three formulations, containing press mud, lignite and vermicasting as carrier, were bioassayed in the lab against third instar grubs of *H. serrata* at two dosage equivalents of 10^{12} and 10^{14} spores/ha (Table 89). Lignite and vermicasting gave higher levels of mortality than press mud formulation at the higher dosage.

Table 89. Bioassay of three formulations of *Beauveria brongniartii* against third instar grubs of *Holotrichia serrata*

Formulation	Dosage (≈ spores/acre)	Per cent infection	Incubation period (d)
Press mud	10^{12}	8.0	21-88
	10^{14}	0.0	
Lignite	10^{12}	8.0	21-78
	10^{14}	16.0	
Vermicasting	10^{12}	8.0	15-78
	10^{14}	26.0	

* n = Five replications of five grubs each

In a preliminary study, the effect of two adjuvants *viz.* Teepol and Tween on the efficacy of *B. brongniartii*, *B. bassiana* and *Metarhizium anisopliae* was evaluated (Table 90). The adjuvants, primarily added for extraction of spores from cultures, seemed to have affected spore germination of *B. brongniartii* as indicated by the lower levels of mortality of white grub eggs.

Table 90. Effect of adjuvant on pathogenicity of entomogenous fungi against *Holotrichia serrata* eggs

Fungus	Isolate	Per cent mortality *		
		Teepol	Tween.	No adjuvant
Beauveria brongniartii	White grub	10.0	35.0	40.0
Beauveria brongniartii	White grub (Kovvur, A.P.)	7.5	10.0	17.5
Beauveria bassiana	Root borer	12.5	12.5	15.0
Metarhizium anisopliae	White grub	20.0	25.0	20.0

* Four replications of 10 eggs each

4.17.9.3 Compatibility with pesticides

Compatibility of common insecticides, fungicides and weedicides with *B. bassiana*, *B. brongniartii* and *M. anisopliae* was studied. Among the five insecticides tested, chlorpyriphos was the most toxic to all three species of the fungi (Table 91) as it affected the biomass and spore production completely, although some radial growth was observed on agar media. Lindane was selectively toxic to *B. bassiana*. Endosulfan and malathion affected spore production of the three fungi to different levels. The fungicide carbendazim was completely toxic to all three species though it supported some radial growth of *B. bassiana* on agar media. Mancozeb followed close behind with some radial growth, but zero or much reduced biomass and spore production in all three fungi. 2,4-D completely suppressed radial growth and biomass but supported normal spore production in *B. brongniartii*. It was similarly toxic to *B. bassiana* but less toxic to *M. anisopliae* at normal dosage. Glyphosate was less toxic to *B. bassiana* than to the other two fungi.

4.17.9.4 Safety to non-target organisms

Beauveria brongniartii, *B. bassiana* and *M. anisopliae*, were evaluated for safety to non-target organisms. The fungi were tested against second instar grubs of the predator *Chrysoperla carnea* at two doses (10^6 and 10^8 spores/ml) as single exposure. Development of the grubs following treatment up to adult emergence showed no mortality of the predator at both concentrations. *M. anisopliae* was tested at 10^8 spores/ml against *Cyrtophora cicatrosa*, a common spider found in sugarcane crop system, by exposure to residual spray in

Table 91. Effect of pesticides on three entomogenous fungi

Insecticide	*Beauveria brongniartii*			*Beauveria bassiana*			*Metarhizium anisopliae*		
	Radial growth (cm)	Biomass (g)	Spore count ($x10^{10}$)	Radial growth (cm)	Biomass (g)	Spore count ($x10^{10}$)	Radial growth (cm)	Biomass (g)	Spore count ($x10^{10}$)
Chlorpyriphos	2.13	0.00	0.00	2.63	0.00	0.00	2.00	0.00	0.00
Lindane	2.00	0.66	3.00	2.33	0.00	0.00	2.07	0.82	2.66
Monocrotophos	3.00	0.55	2.32	4.20	0.51	3.37	2.23	0.84	2.08
Malathion	1.93	0.66	2.32	2.23	0.58	1.20	2.33	0.00	0.38
Endosulfan	2.03	0.74	1.77	3.47	0.36	1.63	2.37	0.76	1.62
Control	4.00	0.82	4.07	6.73	0.81	3.89	4.70	0.98	3.21
Carbendazim	0.00	0.00	0.00	3.90	0.00	0.00	0.00	0.00	0.00
Mancozeb	1.77	0.14	0.58	2.03	0.00	0.00	3.37	0.23	0.98
Control	4.00	0.59	4.07	5.83	0.44	3.89	4.87	0.42	3.21
Glyphosate (Normal)	3.60	0.38	0.44	3.90	0.51	3.27	3.43	0.42	1.37
Glyphosate (Higher)	3.97	0.35	0.27	4.57	0.56	2.45	3.83	0.33	0.33
Atrazine (Normal)	3.03	0.29	2.20	5.00	0.42	2.39	4.63	0.76	1.58
Atrazine (Higher)	2.87	0.26	3.14	4.40	0.46	1.54	4.67	0.66	0.82
2,4-D (Normal)	0	0.07	2.00	1.53	0.07	1.98	2.97	0.40	2.70
2,4-D (Higher)	0	0.03	1.32	1.23	0.03	0.58	1.90	0.31	0.34
Control	4.30	0.47	3.70	5.30	0.61	5.39	5.13	0.86	3.28

test tubes. At the end of the 20-day exposure period, the spiders suffered about 16% mortality.

The three fungi were tested against the earthworm *Lampito mauritii* by two methods. In one method, the fungi at 10^6 spores/ml were directly sprayed on the worms, which were later released in soil. In the second method, the fungi at 10^9 spores/ml were applied to soil containing worms. Observations after two months showed no mortality of the worms in both methods. The fungi were also tested against the common carp *Cyprinus carpio* at 10^7 spores/ml and 10^9 spores/ml by adding 10 ml of fungal suspension to 10 litres of water and releasing 10 fish per replication. At the end of one month the fish suffered no mortality.

4.17.10 Seasonal activity of woolly aphid and its natural enemies on sugarcane (MPKV, Pune)

Sugarcane in Pune, Satara, Sangli and Kolhapur districts were surveyed for the occurrence of the woolly aphid and 5-10% damage was noticed during August-September, 2002 (Table 92). The natural enemies of this pest were recorded during October 2002 – February 2003. Different stages of predators feeding on woolly aphids were collected and identified. The coccinellid predators, *Synonycha grandis* was inoculatively released in sugarcane fields at Tilekarwadi (Dist-Pune) in the first week of November 2002 and recovered later.

The woolly aphid infestation was observed in isolated pockets in sugarcane fields during October 2002 on CO 86032 and CO 671 varieties and natural enemies were not observed initially. Aphid incidence was at its peak in December-January at maturity stage of crop. The leaves were found covered with woolly growth of aphids, sugary secretion and black sooty mould. Pre-seasonal sugarcane planting also was found infested with woolly aphids during January 2003 (Table 92).

The predators, *viz, Coccinella* spp., *Cheilomenes* sp., neuropterans, *Mallada* spp. and *Dipha aphidivora* were found feeding in aphid colonies, but their population was meagre in Pune district. However, *C. aphidivora* was observed abundantly in Kolhapur district. Higher population of ladybird beetles was observed in aphid infested sugarcane field intercropped with maize. *S. grandis* was released as eggs, grubs and adults with the help of PDBC, Bangalore, but were not recovered until harvest (Table 93).

Table 92. Incidence of woolly aphid on sugarcane in Western Maharashtra during August-September 2002

District	Total area under sugarcane (ha)	Infested area by woolly aphids (ha)	Varieties grown & found infested by woolly aphids	Incidence of woolly aphid		Per cent damaged canes	Common insecticides used by farmers
				Number of aphids/leaf	NEs recorded		
Pune	49,000	587	CO 86032, CO 671	9.5 to 17.7	Nil	5-10	Endosulfan 35 EC, Endosulfan + Methyl demeton, Methyl parathion 2% dust and Dimethoate 30 EC
Satara	49,500	1337	-do-	–	–	5	
Sangli	59,800	4129	CO 86032, 671, 8011, 8014, 7219, 7527	–	–	2.5	
Kolhapur	97,400	253	CO 86032, 671, 7527, 8011, 8014, 92020, 8369	–	–	10	
Ahmednagar	74,200	1000	CO 8632, CO 671	–	–	5-10	
Solapur	9,000	85	-do-	–	–	2.5	

Table 93. Seasonal activity of woolly aphids and its natural enemies in sugarcane

Date of observation	Aphid population (6.25 cm^2/leaf)	Natural enemy	Remarks
I. Location: Dist-Pune			
26-10-2002	62/75 (32-80)	–	–
08-11-2002	70.25 (38-105)	–	Released eggs, grubs & adults of *Synonycha grandis* in sugarcane fields
27-11-2002	105.15 (59.137)	*Cheilomenes* sp. *Coccinella* sp. Chrysopids	*S. grandis* not recovered
11-12-2002	110.50 (70-142)	–do–	–do–
27-12-2002	142.80 (105-210)	–do–	–do–
09-01-2003	138.60 (95-180)	–do–	–do–
Winged adults 4-5/leaf noticed			
22-01-2003	125.50 (79-172)	–do–	W/A 7-10/leaf
06-02-2003	110.25 (55-140)	–do–	W/A 12-15/leaf
25-02-2003	95.40 (40-125)	–do–	W/A 15-20/leaf
II. Location: Dist-Satara (Atit, Wahagaon, Khodasi, Karad villages)			
06-01-2003	135.0 (97-180)	Lady bird beetles	2 grubs/plants 2-3 beetles/plant
III. Location: Dist-Sangli (Islampur, Sangli, Jaisingpur			
06-01-2003	140.5 (102-190)	–do–	–do–
IV. Location: Dist-Kolhapur (Shiroli, College Farm, Shenda Park)			
07-01-2003	148.0 (110-188)	Coccinellids, chrysopids, *Dipha aphidivora*	2-3 larvae/plant

4.17.11 Preliminary evaluation of insecticides and *Verticillium lecanii* against woolly aphids on sugarcane (MPKV, Pune)

Two separate trials were conducted in farmers' fields at village Dingrajwadi, Dist-Pune and Agronomy Farm, AC, Pune (Variety CO-86032). Pre-treatment aphid population was recorded just before application of treatments, and post treatment count was recorded after 72 hrs. Nymphs and adults were counted with the help of a graticule (1" sq.) on infested leaves from 10 plants. Granular application was given by broadcasting in furrows. For irrigation treatments, first 75% irrigation water was given and then insecticide was added in irrigation water with the help of dropping bottles.

Table 94a. Preliminary testing of some insecticides and *Verticillium lecanii* against woolly aphid, *Ceratovacuna lanigera* on sugarcane

Treatment	Method of application	Dose	Precount, Av. No. of aphids/ 6.25 cm^2/leaf)	Mean mortality of aphids (%)*
Fipronil (Bilgran 0.3%)	Granules in furrows	40kg/ha	103	8.7 (16.4)
Imidacloprid (Confidor 200 SL)	Irrigation water	350 ml/ha	98	3.0 (9.5)
Imidacloprid (Confidor 200SL)	Irrigation water	700 ml/ha	99	6.0 (12.6)
Imidacloprid (Confidor 200SL)	Irrigation water	1000 ml/ha	101	17.7 (24.8)
Thiomethaxam (Actara 25%)	Irrigation water	200 g/ha	100	11.7 (19.9)
Imidacloprid (Confidor 200SL)	Spray	0.5 ml/lit	100	59.7 (50.6)
Imidacloprid (Confidor 200SL)	Spray	0.3 ml/lit	103	46.7 (43.1)
Verticillium lecanii	Spray		101	91.0 (72.6)
Methyl parathion 2% D	Dust	20 kg/ha	97	91.0 (72.6)
Control	–	—	98	0.0 (0.0)
CD (P=0.05)		NS	7.5	

* Figures in parentheses are arc sin transformed values

Foliar application of methyl demeton 20EC and methyl parathion 2% D was found most effective in recording above 90% mortality of woolly aphids, followed by Beta cyfluthrin (Bulldock 2.45 SC), Imidacloprid (Confidor 2000 SL) and Nirma detergent powder. However, Imidacloprid (Confidor 200 SL) and Thiomethaxam (Actara 25% EG) applied through irrigation water were not found effective against woolly aphids. *V. lecanii* recorded 6.7 to 36.7% aphid mortality for up to 72 hrs (Table 94a and 94b).

Table 94b. Preliminary testing of some insecticides and *Verticillium lecanii* against *Ceratovacuna lanigera* on sugarcane

Treatment	Method of application	Dose	Precount, Av. No. of aphids/ 6.25 cm^2/leaf)	Mean mortality of aphids (%)*
Imidacloprid (Confidor 200 SL) + sticker	Spray	0.5 ml/lit water	140	69.3 (61.6)
Imidacloprid (Confidor 200 SL) + sticker	Spray	0.3 ml/lit water	141	64.0 (54.3)
Beta cyfluthrin (Bulldock 2.45 SC)	Spray	0.5 ml/ lit water	145	77.0 (66.3)
Nirma detergent	Spray	2 g/lit water	143	65.7 (59.4)
Imidacloprid (Confidor 200 SL)	Drenching	1.5 ml/lit water	144	6.3 (14.4)
Thiomethaxam (Actara 25% WG)	Drenching	1.0 g/ 10 lit water	140	9.3 (17.5)
Fipronil (Bilgran 0.3% GR)	Granules	40 kg/ha	143	48.7 (44.2)
Methyl demeton (Metasystox 20 EC)	Spray	1 ml/lit water	137	93.0 (80.9)
Verticillium lecanii	Spray		145	36.7 (37.1)
Control	—	—	141	3.0 (8.1)
CD (P=0.05)			NS	23.5

*Figures in parentheses are arc sin transformed values

4.18 Biological suppression of cotton pests

4.18.1. Bio-intensive integrated pest management

ANGRAU, Hyderabad

The experiment was laid out at Agricultural Research Station, Warangal with the following treatments (var. NA1588).

T1 : BIPM module

- Hand picking of pest stages and putting them in wire screen cage
- Sowing of maize as intercrop 10 days after main crop
- One release *Chrysoperla carnea* @ 14,000 larvae/ha synchronizing with the occurrence of bollworms
- Eight releases of *T. chilonis* each @ 1,50,000/ha/week synchronizing with the appearance of eggs of bollworm.
- Need based application of HaNPV @ 3 x 10^{12} POB/ha (500LE/ha) and systemic insecticides against sucking pests.

T2 : Insecticidal control (recommended insecticides)

Need based application of insecticides such as monocrotophos, chlorpyriphos, endosulfan, quinalphos, triazophos, acephate as per farmers' practice.

T3 : Untreated control

The jassid and whitefly populations were less in BIPM and Farmers' practice modules than in control (Table 95), while aphid populations were more in farmers' practice. No clear differences were observed between treatments regarding egg/larval population and extent of *H. armigera* damage. Regarding the abundance of natural enemy populations in different modules, higher number of coccinellids, spiders and lacewing were recorded in BIPM module and in control. Farmers practice recorded least number of natural enemies. The kapas yield in BIPM and farmers practice modules was much higher than that from control. In terms of monetary returns BIPM module was superior to insecticidal control.

Table 95. Effect of BIPM on insect pests, natural enemies and yield of cotton

Particulars	BIPM	Insecticidal Control	Control
I. Sucking Pests			
a. Jassids (No./plants)	2.27	2.01	5.44
b. Whiteflies (No./plant)	2.37	11.78	7.64
c. Aphids (No./plant)	2.12	11.13	1.88
II. Bollworms			
a. Eggs of *H.armigera*/plant	0.54	0.66	0.41
b. Larvae of *H.armigera*/plant	0.34	0.36	0.20
III. Damage (%)			
a. Squares	17.48	11.99	7.93
b. Bolls	19.54	10.88	12.50
IV. Natural Enemies			
a. Coccinellids (per plant)	0.01	0.01	0.01
b. Spiders (per plant)	0.36	0.12	0.21
c. Eggs of lacewings (per plant)	0.05	0.04	0.05
V. Yield			
Kapas (kg/ha)	550	549	289
Income from Intercrop (maize)	3312	–	–
VI. Total Returns (Rs.)	10922	9027	6647
VII. Cost-Benefit Ratio	1:1.64	1:1.35	–

GAU, Anand

In a field trial IPM module was evaluated against cotton pest complex and compared with insecticidal control and untreated control.

T_1: IPM Module

i. Hand picking of pest stages and putting them in wire screen cage twice during peak incidence.

ii. Inter planting of maize

iii. One release of *Chrysoperla carnea* @ 14,000 larvae (2-3 days old) /ha/week synchronizing with the appearance of the pests.

iv. Releases of *Trichogramma chilonis* @ 1,50,000 as per pest incidence.

v. Application of 1 Kg/ha *Bt* when any one of the bollworms is seen. If *Helicoverpa* is seen apply *Ha*NPV @ 3 X 10^{12} POB/ha. Apply systemic insecticide spray if necessary for sucking pests. (PDBC supplied *Bt* and *Ha*NPV).

T_2: Insecticidal control (recommended insecticide)

T_3: Untreated control

The bud and boll damage was significantly lower in IPM module than that in control and insecticidal treatments (Table 96). The bollworm damage to the locules was significantly lower in IPM block. The damage due to *E. vittella* in the IPM, insecticides and control plot was found to be 7.33,11.41 and 26.18 per cent, respectively. Similarly the damage due to *P. gossypiella* in above treatments was 20.38, 28.31 and 40.57per cent, respectively. The population of sucking pests was also significantly lower in IPM module as compared to control. The release of *Chrysoperla* gave significantly better protection against aphid, jassid, and whitefly.

Table 96. Effect of Biointesive IPM on Cotton Pests

Treatment	Sucking pests / 15 leaves			% damage by boll worms				Yield (kg/ha)
	Aphid*	Jassid*	White fly*	Buds**	Bolls**	Locules		
						*Ev***	Pg**	
IPM	7.93 (61.88)	1.93 (2.72)	1.85 (2.42)	12.64 (4.79)	17.20 (8.74)	15.71 (7.33)	26.83 (20.38)	2917
Insecticides	8.61 (43.13)	2.19 (3.80)	2.03 (3.12)	14.94 (6.65)	22.04 (15.32)	17.74 (11.41)	32.14 (28.31)	2135
Control	14.51 (181.25)	3.51 (11.46)	3.16 (9.11)	23.32 (15.20)	31.09 (29.12)	30.78 (24.55)	39.57 (39.89)	1250
SEm	0.181	0.07	0.03	0.20	0.49	0.61	1.09	96.56
CD (P=0.05)	0.59	0.24	0.09	0.66	1.60	1.97	3.57	314.89

* $\sqrt{X+1}$ transformation ** Arc sine per cent transformations

Figures in parentheses are retransformed values

Since IPM plots received less spray of chemical insecticides, many of the bio-agents were conserved (Tables 97 and 98). The noteworthy amongst them were bollworm parasites *Aleiodes aligarhensis*, *T. chilonis* and *Agathis* sp. The population of these natural enemies was greatly hampered due to application of chemical insecticide.

Table 97. Effect of Biointesive IPM on mean % parasitism by *T. chilonis* in eggs and *A. aligarhensis* and *Agathis* spp. in larvae of *E. vittella*

Parasitoid	IPM	Insecticide	Control
Egg parasitism by *T. chilonis*	32.17	8.71	15.70
Larval parasitism by *A. aligarhensis*	39.70	13.19	32.13
Larval - pupal parasitism by *Agathis*	26.72	8.97	19.29

The yield in IPM module (2917 kg/ha) was significantly superior to control (1250 kg/ha).

Inter cropping of maize with cotton enhanced the activity of *Cheilomenes sexmaculata* (4.23 /plant) in cotton crop in IPM block whereas it was 1.33 /plant in control. Mechanical control of *E. vittella* on cotton was achieved by hand picking of infested material. From this material natural enemies like *Aleiodes, Agathis, Apanteles,* etc. were reared.

MPKV, Pune

The field trial was laid out on Research Farm of Cotton Improvement Project, MPKV, Rahuri using variety NHH-44 (Nanded – 44) with three treatments replicated 10 times. The treatment details are as follows:

T1: IPM module

- i) Hand picking of pest stages and putting them in wire screen cages twice at peak incidence
- ii) Interplanting of maize
- iii) One release of *Chrysoperla carnea* @ 14,000 larvae/ha at the appearance of the pests
- iv) Release of *Trichogramma chilonis* @ 1,50,000 adults/ha/week as per pest incidence
- v) Application of *Bt* @ 1 kg/ha at the appearance of *Earias* spp.
- vi) Spraying of *Ha*NPV @ $3x10^{12}$ POBs/ha against *H. armigera*

Table 98. Effect of biointesive IPM on population of biocontrol agents

Month		*Chrysoperla*			*C. sexmaculata*				*Geocoris*			Staphylinidae	
Control		IPM	Insecticides	Control	IPM	Insecticides	Control	IPM	Insecticides	Control	IPM	Insecticides	Control
Aug -	I	35	20	24	50	25	48	15	07	10	00	00	00
	II	47	25	30	75	20	55	20	08	15	03	01	02
Sep -	I	85	40	45	96	25	61	30	07	15	02	02	02
	II	130	30	60	48	16	36	17	08	14	11	05	07
Oct -	I	90	12	28	20	07	20	12	06	08	15	06	10
	II	35	10	20	17	05	15	14	05	06	10	03	08
Mean		70.33	22.83	34.5	51	16.33	39.17	18.0	6.83	11.33	06.83	02.83	04.83

T2: Insecticidal control as per state recommendation

T3: Untreated control

IPM module and chemical control were found equally effective in the suppression of aphids, jassids and bollworms and were significantly superior to untreated control. The bollworm damage was minimum (23.70%) in BIPM module as against that in untreated control (32.81%) plots (Table 99).

Table 99. Efficacy of BIPM module against sucking pests and bollworms in cotton

Treatment	Sucking pests/15 leaves*				% Boll damage due to bollworms **
	Aphids	Jassids	Thrips	Whiteflies	
IPM Module	36.10 (5.94)	9.30 (3.09)	5.70 (2.45)	5.70 (2.42)	23.70 (29.00)
Chemical control	25.40 (4.99)	7.40 (2.75)	2.40 (1.63)	9.40 (3.12)	23.98 (29.16)
Control	73.90 (8.51)	23.98 (5.36)	10.60 (3.31)	22.00 (4.69)	32.81 (34.84)
CD (P=0.05)	(1.20)	(0.63)	(0.46)	(0.66)	(4.16)

Figures in parentheses are * $\sqrt{x+0.5}$ and ** angular transformations

PAU, Ludhiana

The experiment for the management of cotton bollworms was carried out in farmers' field at village Khuban (Distt. Ferozepur). There were three treatments, *viz.* biocontrol, farmers' practice and control. In the biocontrol plot, 13 releases of *Trichogramma chilonis* were made @ 1,50,000 per ha at weekly interval during July-September. It was compared with farmers' practice (15 sprays of insecticides) and control. In another experiment 13 releases of *T. chilonis* + 8 insecticidal sprays were compared with only insecticidal sprays (8) and control. The parasitoid was released 3 days after each spray.

The incidence of bollworms among the intact fruiting bodies was lowest (3.7%) in farmers' practice, which was significantly lower than biocontrol (22.0%), which in turn was significantly lower than control (56.8%). Similarly, the bollworm incidence among the green bolls was lowest (3.8%) in farmers' practice, which was significantly lower than biocontrol (27.8%), which in turn was significantly lower than control (35.2%). Highest yield (9.67q/ha) was obtained in farmers' practice, which was significantly higher than biocontrol (3.82q/ha), which in turn was significantly higher than control (1.12q/ha). The recovery test showed mean parasitization of *H. armigera* eggs was higher in biocontrol (6.8%) plot than control (0.4%). However, no parasitization was observed in farmer's practice (Table 100).

Table 100. Biocontrol based management of cotton bollworms at village Khuban (Distt. Ferozepur)

Treatment/Plot size	Incidence of bollworms (%)		Yield (q/ha)
	Fruiting bodies	Green bolls	
Biocontrol (0.4 ha)*	22.0 (27.96)	27.8 (31.80)	3.82
Farmers' practice (0.4 ha)**	3.7 (11.08)	3.8 (11.23)	9.67
Control (0.2 ha)	56.8 (48.90)	35.2 (36.37)	1.12
CD (P=0.05)	(1.66)	(1.88)	0.38

* Thirteen releases of *Trichogramma chilonis* @1,50,000/ha/week during July-September

** Fifteen insecticidal sprays given against cotton bollworms

Note: 1. Figures in parentheses are arc sin transformations

2. Bollworm incidence based on 10 and 4 observations for fruiting bodies and green bolls, respectively

When *T. chilonis* was integrated with insecticides, it proved effective for the control of bollworms as it showed significantly lower bollworm incidence in intact fruiting bodies (5.5%) and green bolls (4.8%) than insecticidal sprays (15.6 and 9.2%, respectively) and control (56.8 and 35.2%, respectively). Highest seed cotton yield (13.07q/ha) was obtained when *T. chilonis* was integrated with insecticides. It was significantly higher than insecticides alone (11.80q/ha) and control (1.12 q/ha). The mean parasitization of *H. armigera* eggs was 6.5 per cent in the fields where *T. chilonis* was integrated with insecticides as compared to 0.4 per cent in control (Table 101). However, no parasitization was observed in insecticides alone.

Table 101. Integration of *Trichogramma chilonis* with insecticides for the management of cotton bollworms at village Khuban (Distt. Ferozepur)

Treatment/Plot size	Incidence of bollworms (%)		Yield (q/ha)
	Fruiting bodies	Green bolls	
T. chilonis + Insecticides (1.0 ha)	5.5 (13.55)	4.8 (12.65)	13.07
Insecticides (1.0 ha)	15.6 (23.24)	9.2 (17.64)	11.80
Control (0.2 ha)	56.8 (48.90)	35.2 (36.37)	1.12
CD (P=0.05)	(2.90)	(1.26)	0.65

Note: 1. Eight insecticidal sprays given in T_1 and T_2 for the control of bollworms

2. Thirteen releases of *T. chilonis* made @1, 50,000/ha/week during July-September in T_1. The release made 3 days after spray

3. The incidence of bollworm based on 10 and 4 observations for fruiting bodies and green bolls, respectively

TNAU, Coimbatore

BIPM of cotton pests was evaluated in a field trial in Thondamuthur village, Coimbatore district on variety LRA 5166 under irrigated condition in black cotton soil. The following were the treatments:

T_1 – IPM module

i. The pest stages were hand picked and put in wire screen cage (3' x 3' x 3') thrice during peak incidence

ii. Maize was interplanted. Besides this, cowpea was planted as border crop

iii. One release of *Chrysoperla carnea* @ 14,000 larvae/ha on the 75th day

iv. Six releases of *Trichogramma chilonis* @ 1,50,00o/ha/week on the 60th day and subsequent releases at 15 days interval

v. Application of *Bt* (Delfin) @ 1.0 kg/ha on 80th day, *Ha*NPV @ 3×10^{12} POB/ha on 90th, 105th and 120th days and systemic insecticide against aphids on 45 and 60 DAS

T_2 – Insecticidal control

Nine rounds of recommended insecticides

T_3 – Untreated check (Control)

At 60 DAS there was no significant difference in the number of aphids among the plots (Table 102). At 90 DAS the lowest number of aphids were seen in IPM module (11.6/5

Table 102. Incidence of different bollworm species in cotton under different IPM modules

Treatments	Bollworm	Mean number / 5 plants					
		75 DAS	90 DAS	105 DAS	120 DAS	135 DAS	150 DAS
IPM module	*Earias vittella*	8.2[b]	4.1[a]	5.9[a]	18.5[b]	–	–
	Pectinophora gossypiella	–	–	–	1.8	3.6[x]	8.2
Insecticidal control	*Earias vittella*	4.0[a]	6.8[a]	42.5[c]	11.1[a]	–	–
	Pectinophora gossypiella	–	–	–	2.0	4.3[x]	5.1
Untreated control	*Earias vittella*	8.2[b]	12.6[b]	22.3[b]	31.4[c]	–	–
	Pectinophora gossypiella	–	–	–	14.3[y]	10.1	NS

a-d : Comparisons for *E. vittella*
x-z : Comparisons for *P. gossypiella*
Data are means of 10 values. Means followed by similar letters in a column are not statistically different DMRT, P = 0.05.

plants), compared to untreated check (128/5 plants). The lowest number of whiteflies on 105 DAS was seen in IPM plot (7.2/5 plants). Jassids and thrips occurred as minor pests. Whitefly incidence continued up to 105 days.

Helicoverpa armigera was the major pest damaging squares and bolls from 90 and 135 DAS. The lowest numbers were observed in IPM module and the highest in untreated check on 120 DAS. *Earias vittella* occurred from 75 to 120 DAS. *Pectinophora gossypiella* occurred from 120 to 150 DAS.

There was no significant difference in the per cent boll damage on 75 DAS. The boll damage was the lowest in IPM plot from 90 DAS to 135 DAS. Insecticidal control was the second best on 105 DAS and 135 DAS (Table 103).

The highest kapas yield (2348 kg/ha) was obtained from IPM plot followed by 1687 kg/ha in insecticidal control plot (Table 104). The untreated check yielded 937 kg/ha.

Parasitism

The highest per cent egg parasitism was noted in IPM module plot. The lowest larval parasitism of all bollworms was noted in insecticidal control plot (Table 105). The population

Table 103. Incidence of sucking pests of cotton in the different IPM modules (numbers / 5 plants)

Treatments	Population after days of sowing											
	Aphids			Whiteflies			Jassids			Thrips		
	60	75	90	75	90	105	30	45	60	60	75	90
IPM module	80.2 a	42.1 b	11.6 a	11.2 a	11.3 a	7.2 a	-	8.1 a	-	3.0	5.8	
Insecticidal control	78.1 a	32.1 a	46.1 b	18.1 a	6.1 a	7.8 a	-	21.3 b	-	6.1	11.2	
Untreated control	96.3 a	33.1 a	128.3 c	29.1 b	18.1 b	26.1 b	-	38.1 c	-	11.8	8.1	-
CD (P=0.05)										NS	NS	

Data are means of 10 values
Observations taken on 5 plants per replication 10 plots / treatment
Means followed by similar letters in a column are not statistically different (P = 0.05)

Table 104. Bollworm incidence in different IPM modules

Treatments	Mean no. of larvae on 5 plants					Mean per cent damage of bolls					Kapas yield (kg/ha)
	75 DAS	90 DAS	105 DAS	120 DAS	135 DAS	75 DAS	90 DAS	105 DAS	120 DAS	135 DAS	
IPM module	25.2	22.1^{b}	11.8^{a}	10.6^{a}	19.6^{a}	32.8	29.1^{a}	11.2^{a}	9.6^{a}	11.8^{a}	2348^{a}
Insecticidal control	26.4	13.6^{a}	9.3^{a}	19.2^{b}	31.4^{b}	29.2	42.1^{b}	24.1^{b}	14.1^{a}	31.8^{b}	1687^{b}
Untreated control	31.8	48.3^{c}	45.1^{b}	56.3^{c}	54.5^{c}	34.1	28.5^{a}	31.2^{c}	42.1^{b}	39.5^{c}	937^{c}
CD (P=0.05)	NS					N.S.					

Data are means of ten values taken on plants / replicate plot.
Means followed by similar letters in a column are not statistically different DMRT P = 0.05

Table 105. Occurrence of natural enemies and parasitism of bollworms in different IPM modules

Treatments	Per cent egg parasitism			Larval parasitism % (50 larvae)			Predators No. / 50 plants		
	H.a.	*E.v.*	*P.g.*	*H.a.*	*E.v.*	*P.g.*	*H.a.*	*E.v.*	*P.g.*
IPM module	19.9	23,1	21.2	16.21	19.32	31.10	42	21	18
Insecticidal control	3.1	0.2	12.0	2.10	0.80	0.90	3	1	-
Untreated check	5.8	2.1	4.3	2.8	3.1	2.8	35	29	27

Data are means of ten values

H.a. – *Helicoverpa armigera* ; *E.v.* – *Earias vittella* ; *P.g.* – *Pectinophora gossypiella*

Means followed by similar letters in a column are not statistically different (P = 0.05) of *Trichogramma chilonis*, chrysopids and other predators was higher on intercropped maize than untreated control.

4.18.2. Field evaluation of inundative release of *T. chilonis* in combination with *Chrysoperla carnea* against cotton pest complex (GAU, Anand)

The efficacy of inundative releases of *T. chilonis* in combination with *Chrysoperla carnea* was evaluated against cotton pest complex at GAU, Anand.

Treatments

T_1 *T. chilonis* @1,50,000/ha/week synchronized with the appearance of bollworms and *C. carnea* @ 14,000/ha twice a week

T_2 Insecticidal treatment (recommended chemical)

T_3 Control (no treatment)

The bud and boll damage was significantly lower in release plot over control as well as insecticidal treatments (Table 106).

The population of sucking pests was also significantly lower in biocontrol plot as compared to control.

Table 106. Effect of inundative release of *T. chilonis* in combination with *C. carnea* on cotton pests

Treat.	Sucking pests/15 leaves			% Damage by boll worms				Yield
	Aphid	Jassid	W. Fly	Bud	Boll	Locules		(kg/ha)
						Ev	*Pg*	
T.c.+ C.c.	8.18 (65.91)	2.01 (3.04)	1.93 (2.72)	13.27 (5.27)	18.05 (9.60)	18.54 (10.11)	28.13 (22.23)	2639
Insecticide	8.61 (73.13)	2.19 (3.80)	2.09 (3.12)	14.94 (6.65)	23.04 (15.32)	19.74 (11.41)	33.48 (30.43)	2135
Cont	14.51 (209.54)	3.51 (11.32)	3.16 (8.99)	23.32 (15.67)	31.09 (26.67)	30.78 (26.18)	39.57 (40.57)	1250
CD (P=0.05)	0.53	0.25	0.10	0.67	0.36	1.30	1.0	214.85

*$\sqrt{X+1}$ transformations ** Arc sine transformations

Figures in parentheses are retransformed values.

Since biocontrol plot received no spray of chemical insecticides, many bio- agents such as bollworm parasitoids *Aleiodes aligarhensis*, *T. chilonis* and *Agathis* were conserved. The count of predators such as *Chrysoperla*, *Cheilomenes*, *Geocoris* and staphylinids was also higher in biocontrol plot (Table 107).

The yield in release plot (2639 kg/ha) was significantly superior over control (1250 kg/ha).

Table 107. Effect of inundative release of *T. chilonis* in combination with *C. carnea* on mean % parasitism by *T. chilonis* in eggs and *A. aligarhensis* and *Agathis* spp. in larvae of *E. vittella*

Parasite	*Cc + Tc*	Insecticide	Control
Eggs parasitism by *T. chilonis*	31.15	8.71	15.70
Larval parasitism by *A. aligarhensis*	31.08	13.19	32.13
Larval pupal parasitism by *Agathis*	29.03	08.97	12.29

4.18.3. Impact of inundative release of *Chrysoperla carnea* against cotton pest complex (GAU, Anand)

The efficacy of inundative releases of *Chrysoperla carnea* against cotton pest complex was evaluated at GAU, Anand.

The predator was released @ 14000/ha in both treatments

The bud and boll damage was significantly lower in released plots than control (Table 108). The population of sucking pests was also significantly lower in chrysopid released plots as compared to control.

Table108. Impact of inundative release of *C. carnea* against cotton pests

Treat.	Sucking pests/15 leaves			% Damage by boll worms				Yield
	Aphid	Jassid	W. Fly	Bud*	Boll*	Locules		(q./ha)
						*Ev***	*Pg***	
*C.c.*1 release	9.87 (96.42)	2.96 (7.76)	2.71 (6.35)	18.01 (9.56)	27.23 (20.94)	22.82 (15.04)	35.71 (34.07)	1583
C.c.2 release	8.99 (79.82)	2.21 (3.88)	2.08 (3.33)	15.44 (7.09)	23.49 (15.89)	21.39 (13.31)	33.70 (30.79)	2194
Cont.	14.51 (209.54)	3.51 (11.32)	3.16 (8.99)	23.32 (15.67)	31.09 (26.67)	30.78 (26.18)	39.57 (40.57)	1250
CD (P=0.05)	0.88	0.25	0.14	0.74	0.67	2.08	1.71	318.13

*$\sqrt{X+1}$ transformations ** Arc sine per cent transformations

Figures in parentheses are retransformed values.

Since release plots did not receive any chemical insecticide spray, bio-agents such as bollworm parasitoids *Aleiodes aligarhensis*, *T. chilonis* and *Agathis* (Table 109) and predators *Chrysoperla*, *Cheilomenes*, *Geocoris* and staphylinids were conserved (Table 110).

Table 109. Impact of inundative release of *C. carnea* on bollworm parasitoids

Parasitoid	*C. carnea* 1 release (T1)	*C. carnea* 2 releases (T2)	Control
Eggs parasitism by *T. chilonis*	17.56	16.51	15.70
Larval parasitism by *A. aligarhensis*	30.56	33.92	32.13
Larval pupal parasitism by *Agathis*	19.94	20.69	19.29

The yield in predator released plots was 1583 and 2194 kg/ha, respectively, which was significantly superior to control (1250/ha)

Table 110. Impact of inundative release of *C. carnea* on population of biocontrol agents

Months	*Chrysoperla*			*C. sexmaculata*			*Geocoris*			Staphylinids		
	C. carnea 1 release	*C. carnea* 2 releases	Control	*C. carnea* 1 release	*C. carnea* 2 releases	Control	*C. arnea* 1 release	*C. carnea* 2 releases	Control	*C. carnea* 1 release	*C. carnea* 2 releases	Control
Aug - I	25	30	24	50	52	48	08	12	10	00	00	00
II	38	40	30	65	70	55	15	17	15	02	01	02
Sep - I	65	70	45	80	82	61	13	19	15	03	02	02
II	85	100	60	40	43	36	14	16	14	08	10	07
Oct - I	55	60	28	20	18	20	08	09	0	811	12	10
II	22	25	20	15	13	15	08	09	06	05	08	08
Mean	48.33	54.17	34.5	45.0	46.33	39.17	11.00	12.17	11.33	4.83	5.50	4.83

4.18.4. Identification of host plants harbouring arthropod natural enemies (TNAU, Coimbatore)

In a cotton plot (5 cents) at Thondamuthur, Coimbatore district, activity of natural enemies was recorded throughout the cropping period at fortnightly interval. No chemicals were sprayed. Natural enemies such as spiders, mantids, coccinellids, chrysopids and *Rhinocoris* spp. were observed on cotton, maize, cauliflower and tomato in neighboring fields and also weeds such as *Abutilon indicum, Solanum nigrum, Aristolochia, Hibiscus ficulensis, Chrozophora rottlari* and bund grasses.

On 45 and 60 DAS of cotton, coccinellids were observed in large numbers on all weeds and plants as these coincided with the outbreak of aphids in cotton. The population of coccinellids was less on 105 DAS as also the preying mantid population.

4.18.5. Evaluation of *Nomuraea rileyi* against *Helicoverpa armigera* on cotton (TNAU, Coimbatore)

The effect of formulations of the entomopathogenic fungus, *Nomuraea rileyi* against *H. armigera* was studied under field conditions in Puthur Village, Thondamuthur, Coimbatore on cotton var. LRA5166. Five applications of the fungus formulations in aqueous suspension and oil in water emulsion ($5x10^{11}$ spores/ha) were given commencing from 71 days after sowing using low volume applicator. Insecticide check (endosulfan 35 EC 0.07%) and control were included for comparison.

The application of *N. rileyi* formulations was as effective as endosulfan (Table 111) in reducing the incidence of the larvae. Observations recorded on the other pests indicated stray incidence of *Spodoptera litura*. The number of mycosed cadavers ranged from 0.00 to 2.2/10 plants during different periods of crop growth. The pooled analysis of data on damage to fruiting parts showed that it ranged from 13.11 to 31.83% in different treatments. Application of oil in water emulsion was on par with endosulfan and significantly superior to the other formulation in reducing the square damage. Boll damage showed similar trend. Highest bolls were retained in insecticide application (111.28/5plants), which was on par with oil in water formulation (109.69/5 plants). The seed cotton yield was significantly higher in insecticide application (2012.2kg/ha). The fungus formulation treatments were on par and recorded 1777.20 -1838.6 kg/ha (Table 112).

Table 111. Field efficacy of formulations of *Nomuraea rileyi* (5 x 10^{11} spores/ha) against *H. armigera* on cotton

Treatment	Population of *H. armigera*/10 plants (days after spray)*										
	Crop age in days after sowing										
	71	78	88	94	101	111	113	121	123	136	138
	Pre-treatment	I Spray		II Spray		III Spray		IV Spray		V Spray	
		7	10	7	9	8	10	8	10	7	9
N. rileyi aqueous suspension	8.8	6.0b	5.6b	3.4ab	2.4a	4.0a	6.6b	4.0a	1.8a	2.2a	2.2a
N. rileyi oil in water emulsion	8.4	5.6b	5.2b	4.6b	1.8a	4.2a	6.4b	5.6a	2.6a	1.2a	1.2a
Endosulfan (0.07%)	9.0	2.8a	3.6a	1.8a	1.4a	2.6a	2.6a	5.4a	1.6a	1.4a	0.8a
Control	9.6	10.6c	6.2b	9.4c	11.2b	13.4b	10.2c	17.6b	11.0b	8.6b	6.6b

* Mean of five replications

In vertical columns, means followed by similar letters are not different statistically (P = 0.05) by DMRT

Table 112. Field efficacy of formulations of *Nomuraea rileyi* (5 x 10^{11} spores/ha) against *H. armigera* on cotton (var. LRA5166)

Treatment	Square damage (%)		Boll damage (%)*	Bolls retained/5 plants	Yield (kg/ha)
	Pre-treatment	After treatment*			
N. rileyi aqueous suspension	15.94	19.30b	17.22b	106.83b	1777.2b
N. rileyi oil in water emulsion	16.66	15.60ab	16.10ab	109.69ab	1838.6b
Endosulfan (0.07%)	21.63	13.11a	13.07a	111.28a	2012.2a
Control	20.85	31.83c	26.41c	86.97c	1483.4c

* Mean of seven counts

Mean of five replications

In vertical columns, means followed by similar letters are not different statistically (P = 0.05) by DMRT

4.19. Biological suppression of tobacco pests (CTRI, Rajahmundry)

4.19.1. BIPM of *Helicoverpa armigera* in irrigated NLS tobacco

The BIPM practices were imposed in an area of 2000 m^2 in CTRI farm Jeelugumilli and observations recorded. The following modules were tested.

a. BIPM practices

i. Planting one row of castor (outer row) and one row of tagetes (inner row) around tobacco crop
ii. Application of *Ha*NPV, 4.5 X10^{12} PIBs/ha at 40-50 DAT
iii. Release of *Campoletis chlorideae* coinciding with the appearance of early instar larvae @ 100 parasitoids /0.5 ha 3 releases at 30,40,50 DAT
iv. Sex pheromone traps baited with *Nomuraea rileyi* @ 10/ha.
v. Entomophathogenic nematode (*Steinernema carpocapsae)* 4.0 x 10^6 IJ/2000 m^2, 30 DAT, 40 DAT and 50 DAT along with irrigation
vi. Hand picking of grown up larvae on trap/main crop
vii. Bird perches, 20/ha from 50 DAT

b. Chemical control practices

i. Chlorpyriphos 2.5 ml/lit at 30 DAT

ii. Acephate 2g/lit at 60 DAT

c. Farmer's method

i. Chlorpyriphos 2.5 ml/lit two times at 30 and 40 DAT

ii. Acephate 2g/lit at 60 DAT

Egg and larval counts were taken on the main crop and trap crop at 15 days interval. 100 larvae were collected and percentage parasitization recorded 5 days after release of *Campoletis*. Larvae were also observed for incidence of fungal pathogens and nematode infection. Number of damaged plants, leaves, capsules and yield was also recorded.

Damage by *Helicoverpa* as a budworm: At 30 DAT percentage plants damaged were 4.51 in BIPM, 5.41 in chemical control and 10.62 in farmer's method. At 40 DAT percentage plants damaged in BIPM were 5.02 in BIPM, 642 in chemical control and 14.40 in farmer's method. At 50 DAT the plants damaged by *Helicoverpa* were 5.48 in BIPM, 8.17 in chemical control and 16.68 in farmer's method. The progressive increase in the percentage of plants damaged from 30 DAT to 50 DAT was low in BIPM whereas in chemical control and farmer's field the increase was comparatively higher (Table113).

Percentage capsules damaged per plant: BIPM (5.09%) was at par with chemical plant protection (11.06%) in case of mean percentage capsules damaged/plant.

Larvae on tobacco & Trap crops: Number of larvae were observed in the main plot (tobacco)/3500 plants. The total larval population was lower in BIPM plots than in chemical control and farmers' fields on 30 DAT, 40 DAT and 50 DAT. On panicles average number of larvae observed were 2.75 at 60 DAT, 2.0 at 70 DAT and 1.75 at 80 DAT in BIPM. On panicles average number of larvae were 3.0 at 60 DAT, 1.5 at 70 DAT and nil at 80 DAT in chemical control plot.

On Tagetes, from 30 DAT to 80 DAT (at 10 days interval) average number of larvae observed was 3.25, 2.50, 2.50, 1.50, 1.10 and 0.50. At 50 DAS and 60 DAS average number of larvae observed were 1 and 0.5 on flower heads and seed capsules.

4.19.2. Observations on bioagents used and their impact (Field trial)

a) *Steinernema carpocapsae*: Talc based formulation was applied to soil @ 4.0 x 10^6 IJ/ $2000m^2$, along with irrigation water in six equal doses. The nematode was successfully recovered from soil in the intervening period between two irrigations (10 days interval approximately). From field collections of larvae EPN was not recovered. When EPN

Table 113. Activity of *H. armigera* in irrigated tobacco and Tagetes

Module	Time of observation	Total number of ,plants observation	Number of plants damaged	Number of larvae observed
BIPM	30 DAT	3500	158 (4.51)	107 [65]
	40 DAT	3500	176 (5.02)	58 [50]
	50 DAT	3500	192 (5.48)	63 [50]
	60 DAT	On tagetes		30
	70 DAT	On tagetes		22
	80 DAT	On tagetes		10
Chemical Control	30 DAT	3500	180 (5.14)	138
	40 DAT	3500	225 (6.42)	124
	50 DAT	3500	286 (8.17)	106
Farmers' Field	30 DAT	3500	372 (10.62)	235
	40 DAT	3500	504 (14.40)	223
	50 DAT	3500	584 (16.68)	190

Figures in ( ) are percent plants damaged
Figures in [ ] are larvae on Tagetes
Number of larvae observed on trap crops

was applied to terminal leaf buds of infested tobacco plants, there was no inhibition of damage 5 days after application. There was no phytotoxicity to leaf primordial due to application of EPN in talc.

b) *Nomuraea rileyi*: Contaminated male moths of *Spodoptera litura* and *Helicoverpa armigera* were released from baited pheromone traps to spread infection. However its impact was not realized in terms of disease incidence in the larval populations of the pest.

c) *Campoletis chlorideae*: Natural parasitization by *Campoletis chlorideae* on *S. litura* and *H. armigera* NLS tobacco was 5-10 percent and attempts were made to augment this. 100 female parasitoids were released each time at 10 days interval from 40^{th} to 60^{th} day after transplanting tobacco. Due to the releases there was slight increase in percent parasitism by 2-3%.

d) *Ha*NPV: *Ha*NPV was used @ 450 LE/ ha. Larval populations collected from field were affected by *Ha*NPV.

4.19.3. Natural biocontrol

On tobacco crop in BIPM plots, the activity of natural enemies was high compared to chemical control and farmer's field. Coccinellids and spiders were also abundant. On tagetes, besides parasitization of eggs by *Trichogramma* (16-22%) coccinellids were predominant (Table 114).

Table 114. Natural biological control of *H. armigera* in BIPM, chemical control and farmer's fields (per 20 plants) (number of predators per 20 plants)

Crop	BIPM plot	Chemical control plot	Farmers' field*
Tobacco			
Harpactor costalis	2-5	Nil.	Nil
Oxyopes sp.	12-20	2-3	2-3
Coccinella tranversalis	15-30	5-10	2-5
Campoletis chlorideae	10-12%	2-3%	2-5
Carcelia illota	5-10%	3-5%	1-2%
Apanteles sp.	2-10%	Nil	Nil
Tagetes			
Peribaea orbata	5-10%	–	–
Oxyopes sp.	2-5	–	–
Cheilomenes sp.	15-20	–	–
Trichogramma sp.	16-22%	–	–

4.19.4. Laboratory evaluation of EPN against *H. armigera*

Thirty-third instar larvae of *H. armigera* were offered leaf discs coated with 1-4 gm of talc based formulation containing 100-400 IJ of EPN and kept on moist filter paper in ventilated plastic containers with 5 replications. EPN was highly effective at 400 IJ/larva with 83.33% mortality. However, it was not as effective as acephate (97.99% mortality). Among EPN treatments 200 IJ and 300 IJ/larva were on par with 70.66 and 74.13 percent mortality. Least mortality occurred in 100 IJ/larva (53.99%). In control the mortality was only 8.33% due to unknown causes (Table 115).

Table 115. Effect of EPN (*S.carpocapsae*) at different doses on *Helicoverpa armigera* (III instar larvae) on tobacco under laboratory conditions

Treatments (IJ/larva)	Mean percent mortality after 72 hours.
100 IJ	53.99
200 IJ	70.66
300 IJ	74.13
400 IJ	83.33
Acephate 2g/l	97.99
Control	8.33
CD (P=0.05)	8.34

Yield data: The yield of green leaf, cured leaf and grade index of tobacco in BIPM was 13,236, 1851 and 1368 kg, respectively, as against 11,301, 1564 and 11074 kg, respectively, in chemical control.

4.19.5. Identification and utilization of biocontrol agents of *Spodoptera exigua*, an emerging pest of solanaceous crops

Egg batches and larvae of *S. exigua* were exposed to *Telenomus remus* and *Glyptapanteles africanus*, respectively; and later were reared on tobacco and control plants. Observations were recorded on percent parasitization.

Mean percent parasitization of *S. exigua* egg clusters by *T. remus* was highest on groundnut (32.66), followed by Lanka tobacco (30.38) which were on par. Parasitization on FCV 16.67 and Burley 11.60 were on par but significantly lower than that on Lanka tobacco. On Turkish tobacco least parasitization occurred (4.37).

Mean percent parasitization of *S. exigua* larvae by *Glyaptanteles africanus* was highest on Lanka tobacco 31.32 and significantly superior to the rest of the tobacco types and groundnut (control). On FCV and Burley, the percent parasitizations were 17.86 and 16.34, respectively and on par. Least parasitization was observed on Turkish tobacco (9.09%). Parasitization on groundnut was significantly superior (23.42) to that on tobacco types except on Lanka tobacco (Table 116).

Table 116. Mean percent parasitization of *S. exigua* egg clusters by *T. remus* and larvae by *G. africanus* on different tobacco types (seedlings)

Tobacco type	Mean egg parasitization by *T. remus*	Mean larval parasitization by *G. africanus*
FCV	16.67	17.86
Lanka	30.38	31.32
Burley	11.60	16.34
Turkish	4.37	9.09
Groundnut	32.66	23.42
CD (P=0.05)	5.60	4.12

4.20. Biological suppression of pulse crop pests

4.20.1. Bio-Intensive pest management in pigeon pea with special reference to pod borer complex

ANGRAU, Hyderabad

Different bio control based operations were evaluated for the management of pod borer complex at the Agricultural Research Station, Warangal. The treatment details are as follows.

T1: *Ha*NPV-NSKE-*Ha*NPV-NSKE
T2: Bt-NSKE-Bt-NSKE } at 10 days interval
T3: NSKE-NSKE-NSKE-NSKE
T4: Endosulfan 3 sprays at 15 days interval
T5: Untreated Control

Alternate spray of *Ha* NPV and NSKE (*Ha* NPV-NSKE-*Ha* NPV-NSKE) fared better in suppressing *H. armigera* with least cumulative *H. armigera* larval populations (2.00) as compared to untreated control 15.5 (Table 117). *Ha* NPV and NSKE alteration recorded least pod damage (9.75 per cent) among all biocontrol based operations. Similar trend was noticed in terms of damage by pod wasp with 4.25 percent damage recorded in *Ha* NPV-NSKE alteration while least damage (3.75 per cent) was recorded in endosulfan sprays. More or less similar trends were noticed in case of pod fly damage and yield returns. Overall, *Ha* NPV-NSKE-*Ha* NPV-NSKE sequence proved the best biocontrol option in suppressing the pod borer complex with good returns.

Table 117. Effect of BIPM treatments on the incidence of pod borer complex and yield of pigeon pea

Treatment	Pre treatment *H. armigera* populations	Cumulative Pod damage (%) larval population*	Ha	Pw	Pf	Yield (Kg/ha)
*Ha*NPV-NSKE-*Ha*NPV-NSKE	20.25 (4.55)	2.00 (1.56)	9.75 (17.63)	4.25 (11.76)	11.75 (19.86)	1148
Bt-NSKE-Bt-NSKE	20.00 (4.52)	7.75 (2.87)	12.75 (20.49)	8.00 (15.00)	15.25 (22.95)	1000
NSKE-NSKE-NSKE-NSKE	20.00 (4.52)	9.25 (3.11)	14.75 (22.46)	4.75 (12.44)	11.50 (19.63)	921
Endo-Endo-Endo	19.50 (4.46)	3.00 (1.86)	8.50 (16.58)	3.75 (10.84)	14.50 (22.22)	1259
Control	19.2 (54.44)	15.50 (3.99)	12.50 (20.59)	8.50 (16.88)	16.00 (23.43)	870
CD (P=0.05)	NS	0.42		NS	NS	NS

* Pooled data recorded 7 days after each spray

Ha : H.armigera; Pw : Pod wasp; Pf : Pod fly; Figures in parentheses are transformed values

TNAU, Coimbatore

This trial was conducted at Puthur village, Coimbatore district on Co-5 red gram variety under irrigated condition. The treatments were

T_1 - *Ha*NPV + 10% crude sugar + 10% CSKE + 0.1% egg yolk + 0.1% Ranipal
T_2 - *Ha*NPV + 0.5% Teepol
T_3 - *Ha*NPV – NSKE alternation
T_4 - *Ha*NPV – Endosulfan alternation
T_5 - Endosulfan
T_6 - Control

Dosages

*Ha*NPV : 1.5×10^{12} POB/ha
Endosulfan : 350 g/ha
NSKE : 5%

Seed treatment	:	*Trichoderma* @ 4.0 g/kg seed
Spray equipment	:	Controlled droplet application
Spray fluid	:	12.5 l/ha
Plot size	:	100 m^2
Design	:	RBD
Replication	:	4

A cloth screen was used all around the plots to prevent spray drift. The treatments were applied in the evening hours. The first spray was taken up on 56 DAS when flower initiation had occurred and then at 15 days intervals. *Helicoverpa* larval population was above ETL on 56 DAS. The larval populations were counted on 7 DAT. *Helicoverpa* larval population 7 days post treatment was significantly less in T_1 (Table 118). The larval population in endosulfan treated plots (29.32) was significantly less than untreated check.

Table 118. Effect of treatments on the *H. armigera* larval populations on pigeonpea

Treatments	Mean no. of larvae / 10 plants		
	67 DAS	82 DAS	97 DAS
	I Spray	II Spray	III Spray
HaNPV + 10% crude sugar + 10% CSKE + 0.1% egg yolk.	12.12^{a}	12.32^{a}	15.12^{c}
HaNPV + 0.5% teepol	17.02^{bc}	16.98^{a}	11.01^{b}
HaNPV – NSKE alternation	19.58^{c}	19.41^{ab}	8.12^{a}
HaNPV – endosulfan alternation	14.92^{b}	14.12^{a}	9.36^{a}
Endosulfan	29.32^{d}	23.26^{c}	10.12^{b}
Control	36.16^{e}	41.32^{d}	33.28^{d}

Data are means of 4 values.
Means followed by similar letters in a column are not statistically different, P =0.05

The pod borer damage was the lowest in *Ha*NPV – endosulfan alternation. The per cent pod damage was lowest (9.26) in *Ha*NPV – NSKE alternation treatment (Table 119). The highest grain yield (1442 kg/ha) was obtained from *Ha*NPV – endosulfan alternation followed by *Ha*NPV – NSKE alternation (1380 kg/ha). Treatments one and two yielded 1310 and 1328 kg/ha respectively and were on a par. 610 kg/ha yield was obtained from untreated check, which was the lowest.

Table 119. Effect of NPV based management on pod borer damage and pigeonpea yield

Treatments	Per cent pod borer damage pre-treatment	Per cent pod borer damage 7 DAT			Pod damage	Yield (kg/ha) (%)
		I Spray	II Spray	III Spray		
*Ha*NPV + 10% crude sugar + 10% CSKE + 0.1% egg yolk	48.21	26.12^{b}	17.3^{e}	14.21^{c}	14.12^{b}	1310^{c}
*Ha*NPV + 0.5% teepol	58.48	28.32^{c}	11.2^{a}	10.12^{b}	13.21^{b}	1328^{c}
*Ha*NPV – NSKE alternation	54.23	21.11^{b}	10.1^{a}	8.32^{a}	9.26^{a}	1380^{b}
*Ha*NPV – endosulfan alternation	49.10	14.32^{a}	13.8^{ba}	11.21^{b}	10.8^{a}	1442^{a}
Endosulfan	57.10	24.12^{b}	12.1^{a}	26.10^{d}	15.2^{b}	980^{d}
Untreated check	56.20 NS	48.11^{d}	43.10^{d}	55.2^{e}	49.2^{d}	610^{e}

Data are means of 4 values.
Means followed by the similar letters in a column are not statistically different (P=0.05)

4.20.2. Demonstration of *Bt-Ha*NPV-*Bt-Ha*NPV in pigeonpea for management of pod borer complex (TNAU, Coimbatore)

The trial was laid out at Puthur village under irrigated condition on var. CO5 with the following treatments.

I. *Bt* – *Ha*NPV – *Bt* – *Ha*NPV
(Biolep @ 1.0 kg/ha; *Ha*NPV @ 1.5×10^{12}POB/ha

II. Control

Four rounds of application were given with backpack sprayer (high volume) with hollow cone nozzle in the evening hours. Larval counts of all pod borers (*H.armigera*, *Maruca testulalis* and *Lampides boeticus*) were made on 10 randomly selected plants per plot and on three branches of the selected plant.

The maximum yield (1828 kg/ha) was obtained from *Bt–Ha*NPV–*Bt–Ha*NPV alternation. The yield from untreated check plot was 886 kg/ha. The standard yield of this variety is 1500 kg/ha (Table 120).

Table 120. Effect of IPM treatments on *Helicoverpa armigera* larval population and total pod borer damage in pigeonpea (CO-5)

Treatments	Pre-treatment No./10 plants *H. armigera*		*H. armigera* larval population				Peak pod borer damage%	% pod borer damage at harvest / 10 plants	Grain yield Kg/ha
	Eggs	Larvae	85	100	115	130			
Bt. –*Ha*NPV – *Bt.* – *Ha*NPV	38	26.2	8.2[a]	13.8[a]	14.26[a]	3.8[a]	11.38	6.31	1828[a]
Control	42	38.2	33.2[b]	41.8[b]	38.2[b]	41.32[b]	21.22[d]	16.41[c]	886[b]
	NS	NS							

Damage caused by all pod borer species on 10 plants

Data are means of 4 values

Table 121. Occurrence of various pod borers in pigeonpea BIPM plots

Treatments	7 DAT (85 DAS)				Nos./10 plants at maturation (135 DAS)				Harvest time			
	No. / 10 plants*				No. / 10 plants*				No. / 10 plants*			
	Ha	Pf	Pw	Pm	*Ha*	Pf	Pw	Pm	*Ha*	Pf	Pw	Pm
Bt– *Ha*NPV – *Bt* – *Ha*NPV	14.6^{a}	21.3^{a}	1.8^{a}	3.8^{a}	0.2^{a}	1.66^{a}	0.09^{a}	2.12^{a}	-	-	-	3.4^{a}
Control	38.2^{b}	21.6^{a}	29.2	19.2^{b}	34.31^{b}	14.1^{b}	4.2^{b}	4.18^{b}	9.31	-	-	14.12^{b}
									N.S.			

Ha - *Helicoverpa armigera*
Pf - Podfly *Melanagromyza* spp.
Pw - Pod wasp
Pm - Plume moth
*Data are means of four values, each value is total number / 10 plants
Means followed by similar letters in a column are not statistically different

Besides, *H. armigera*, pod fly and pod wasp were the other major pod borers. The number of these pod borers at various crop stages is presented in Table 121. Podfly numbers were lower (1.66) in *Bt–Ha*NPV–*Bt–Ha*NPV than in control (14.1) at maturity. Similar trend was seen on 135 DAS in the case of *H.armigera,* pod wasp and plume moth. At harvest time plume moth damage alone was seen in all the plots.

4.20.3. Alternate host plants of *Helicoverpa armigera* and natural enemies harboured by them

GAU, Anand

Studies were conducted to find alternate host plants during the off-season. *H. armigera* was observed on following host plants.

Period (2002 – 2003)	Host plant	Remarks
September – March	*Cassia occidentalis*	Eggs were found on the buds. Only one larva was found. The larvae failed to develop when reared in the laboratory on the same host. Eggs were found parasitised by *T. chilonis* to the tune of 90 %.
December – February	*C. angustifolia*	All stages of the pest were found. Eggs were found parasitised by *T. chilonis* and larvae were parasitised by *Charops obtusus*.
December – February	*Chenopodium album*	All stages were found regularly. Eggs and larvae were parasitized by *Trichogramma chilonis* and *Campoletis chlorideae*, respectively.
January – March	Bhongra	All the stages of the pest were found. Eggs were found parasitised by *T. chilonis*. Maximum percentage parasitism was 28 during January. The plants also harbor spiders (Crab spider, *Neoscona* and *Clubiona*). The plants were observed to thrive well during dry season also.
December – March	Matsgandha	Only eggs were found in small numbers. The mirid, *Nesidiocoris tenuis* was also found on the plant.
December – March	*Eclipta alba*	All stages were found.
January – February	Mustard	All stages were found.

Some of the host plants that harbor natural enemies found in the area were *Rustica* tobacco, bidi tobacco, marigold, maize, matsgandha, Cassia, starburr, parthenium, Duranta. amaranthus, *Lantana camara,* brinjal, sunnhemp and sesamum. They were found to harbour mirid bug, *Rhinocoris, Bracon* sp., *Geocoris sp., Trichogramma, Nabis,* crab spider, *C. sexmaculata, Xanthogramma,* anthocorid, *C. carnea,* and *T. chilonis.*

4.20.4. Effect of entomopathogenic nematode *Heterorhabditis* sp. against *Mylabris pustulata* and *Helicoverpa armigera* on pigeonpea

ANGRAU, Hyderabad

Different doses of *Heterorhabditis* sp. was evaluated against *Mylabris pustulata* and *Helicoverpa armigera* in pigeon pea. Spray application of the nematode @ 0.5, 1.0 and 2.0 billion/ha was given with an untreated control. The sprays were given during evening hours at 50 percent flower initiation stage of the crop. There was no incidence of *M. pustulata* and *H. armigera* was in low numbers.

The nematode treatments at all doses were superior to control in reducing larval populations of *H. armigera* (Table 122). The population decline was more 10 days after the

Table 122. Effect of entomopathogenic nematode, *Heterorhabditis* sp. on *H. armigera* in pigeon pea

Treatment	Pretreatment *H.armigera* populations	Post-treatment *H.armigera* populn. (No.)		Pod damage (%)	Yield/ ha
		7 Days	10 Days		
0.5 billion/ha	19.60 (4.48)	14.20 (3.82)	10.80 (3.36)	16.40 (23.76)	1296
1.0 billion/ha	18.80 (4.39)	9.60 (3.17)	4.40 (2.20)	11.80 (17.94)	1326
2.0 billion/ha	20.00 (4.52)	8.60 (3.01)	2.40 (1.68)	10.60 (18.76)	1422
Control	19.80 (4.50)	19.20 (4.43)	15.00 (3.93)	19.80 (26.17)	1281
CD (P=0.05)	NS	0.28	0.30	NS	NS

Figures in parentheses are transformed values spray in nematode applied plots. The percent pod damage also showed similar trend with least percent damage (10.6 and 11.8, respectively in 2.0 and 1.0 billion /ha dosages). In control the extent of damage was 19.80 per cent. Entomopathogenic nematodes at both 2.0 and 1.0 billion/ha fared better in suppressing *H. armigera* population with good yield returns.

TNAU, Coimbatore

Effect of entomopathogenic nematode *Heterorhabditis* sp. against *Mylabris pustulata* and *Helicoverpa armigera* on pigeonpea was studied at Puthur village, Thondamuthur, Coimbatore in pigeonpea var. CO4 under irrigated conditions. Three applications of the nematode at 0.5, 1.0 and 2.0 billion/ha using spray fluid of 500 l/ha in knapsack sprayer were given beginning at 50% flowering and twice at 10 days interval during evening hours. Insecticide check endosulfan 35 EC 0.07% was included for comparison. Irrigation was given the following day after each application.

H. armigera was the dominant pest during the reproductive phase of the crop. Application of nematode at 2.0 billion/ha was found to be comparable with endosulfan 0.07% in reducing the incidence of *H. armigera* at different periods of observation. Reduced dosage of nematode was found to be as effective as the highest during the second spray and was significantly inferior to it and endosulfan in the first and third spray (Table 123). *M. pustulata*

Table 123. Field efficacy of *Heterorhabditis* in the control of *Mylabris pustulata* on pigeonpea (CO4)

Treatments	*M. pustulata*/10 plants @3 branches/plant (days after spray) (Mean of five replications)									
	Pre-treatment	I			II			III		
		3	7	10	3	7	10	3	7	10
0.5 billion/ha	3.0	7.0b	4.4	0.8	2.2	1.6	1.6	1.2	2.2	0.4
1.0 billion/ha	3.2	6.6b	3.0	2.6	2.0	1.6	2.6	1.8	1.0	0.0
2.0 billion/ha	2.2	5.8b	2.2	2.0	2.0	1.8	2.0	0.8	1.6	0.2
Endosulfan (0.07%)	1.4	2.8a	1.2	1.0	1.2	2.2	1.8	1.4	1.4	0.6
Control	3.0	6.0b	2.6	2.8	1.8	2.8	1.0	1.0	2.0	0.4

In vertical columns, means followed by similar letters are not different statistically ($P = 0.05$) by DMRT population reduction was not significant due to nematode or insecticide application and was on par with control (Table 124). Samples from different plots indicated that nematode infestation ranged from 0.00-5.56% prior to the commencement of spray application and ranged from 0.00-19.04% at different periods of time among the treatments. The differences were not significant and comparable to control (Table 125). The pod damage ranged from 17.2-39.8%

Table 124. Field evaluation of *Heterorhabditis* sp. against *Mylabris pustulata* and *Helicoverpa armigera* infesting pigeonpea cv. CO4

Treatment	Cumulative beetle mortality (%) due to nematode on different days after field application (Mean of five replications)							Pod damage (%)	Grain yield (Kg/ha)
	Pre-treatment	I Spray			II Spray				
		3	7	10	3	7	10		
0.5 billion/ha	0.00	1.92	2.57	3.39	9.88	19.04	6.67	30.0b	794.2c
1.0 billion/ha	4.17	4.92	4.26	0.00	14.29	12.50	5.26	24.2ab	839.0bc
2.0 billion/ha	5.56	4.17	2.27	1.89	18.52	5.56	7.41	20.6a	902.8ab
Endosulfan (0.07%)	3.85	5.56	0.00	2.17	10.53	13.33	9.52	17.2a	935.0a
Control	0.00	2.33	3.92	3.70	11.43	11.76	6.67	39.8c	702.8d
	NS	NS	NS	NS	NS	NS	NS		

In vertical columns, means followed by similar letters are not different statistically (P = 0.05) by DMRT

Table 125. Field efficacy of *Heterorhabditis* in the control of *H.armigera* on pigeonpea (cv.CO4)

Treatments	*H. armigera* larvae/10plants @3 branches/plant (days after spray) (Mean of five replications)									
	Pre-	I			II			III		
	treatment	3	7	10	3	7	10	3	7	10
0.5 billion/ha	6.2	10.2	6.6ab	13.6b	7.8b	5.8a	4.4a	4.0b	4.4b	4.0c
1.0 billion/ha	6.6	11.6	6.2ab	12.2b	8.0b	5.2a	4.8a	3.8b	4.2b	3.4bc
2.0 billion/ha	6.6	13.6	6.0ab	7.0a	6.2b	4.2a	4.4a	2.4ab	2.6a	2.2ab
Endosulfan (0.07%)	7.4	7.2	5.4a	7.4a	4.6a	4.6a	5.6a	1.6a	2.6a	1.4a
Control	6.8	13.0	10.6b	14.0b	16.2c	12.6b	11.0b	8.2c	7.8c	6.8d
	NS	NS								

In vertical columns, means followed by similar letters are not different statistically (P = 0:05) by DMRT in different treatments. Application of nematode at 1-2 billion/ha was comparable to endosulfan 0.07% and superior to the lowest dose of nematode and control. The yield was significantly higher in nematode application and endosulfan compared to control. However, the insecticide and the nematode at the highest dose alone were superior to other treatments and the grain yield in these treatments was 935 and 882.8 kg/ha, respectively.

IIPR, Kanpur

The efficacy of EPNs (*Heterorhabditis indica*) against blister beetles was evaluated in a trial laid out at Kanpur during Kharif. In a block of early pigeonpea (var. UPAS 120) the crop was dusted with EPN formulation provided by PDBC, Bangalore.

The initial effectiveness of EPNs on the day of treatment was very high as over 90% mortality of beetles was recorded. It remained effective for 3 subsequent days causing 72-80 percent mortality of the beetles. After four days, the efficacy was drastically reduced and on sixth day only 26% mortality was recorded.

4.21 Biological suppression of rice pests

4.21.1. Survey and quantification of natural enemy complex in rice

AAU, Jorhat

Natural enemies of rice pests were surveyed in the farmers' fields at Bekajan village of Borholla, RARS, Titabar and ICR farm, AAU Jorhat at weekly intervals from the first week of July to middle of September, 2002. The predators included coleopterans, spiders, dragonflies, damselflies, crickets and grasshoppers and parasitoids *Cardiochiles philippensis*, *Bracon* sp., *Aulosaphes* sp., *Telenomus*, *Cotesia*, *Trichogramma*, etc. The extent of parasitism of leaf folder larvae by *Aulosaphes* sp. during kharif season was 10-12% that by *Bracon* sp. was 13-16%. *Cardiochiles philippensis* caused 8-10% parasitism. The extent of parasitism of stem borer eggs by *Trichogramma japonicum* was 15-23%. *Cotesia flavipes* was predominantly found during kharif, 2002. Among the spiders *Lycosa pseudoannulata* was the most common followed by *Lycosa madani*, *Argiope catenulata* and *Neoscona* sp.

PAU, Ludhiana

The survey on the natural enemy complex in rice ecosystem was carried out in farmers' field at village Behram (Distt Nawanshahr) at weekly interval during July-September 2002.

Three egg parasitoids, namely, *Telenomus dignoides*, *Trichogramma chilonis* and *T. japonicum* caused 49.19 per cent parasitization of *S. incertulas* eggs. *T. dignoides* was the most important parasitoid causing 40.17 per cent parasitization. *Stenobracon nicevillei* caused 5.55 per cent parasitization of *S. incertulas* larvae. Two larval parasitoids namely, *Bracon* sp. and *Cotesia* sp. and three unidentified larval parasitoids with 16.31 per cent parasitization were recorded from *C. medinalis*. The total larval parasitization was 21.86 per cent. *Tetrastichus* sp. was recovered from 2.63 per cent pupae of *C. medinalis*, while *Brachymeria* sp. were recovered from 11.52 per cent pupae of *S. incertulas*.

TNAU, Coimbatore

This work was undertaken in 3 locations in Coimbatore district. Among the predators, spiders constituted maximum numbers in Udumalpet area (18.1 and 19.2). In Coimbatore area, the number of spiders was less. Spiders, coccinellids, dragonflies and *Cyrtorhinus* were the predators observed in all the locations. Hymenopterans were seen in higher numbers than dipterans. The per cent parasitism on rice YSB was 4.3 in Malayandipattinam, 14.8 in second plot at same village, and 19.3 at Puthur.

KAU, Thrissur

A total of 51 species of spiders belonging to 9 families and 23 genera were recorded from selected rice fields of Thrissur district. Maximum number of species was recorded from the family Araenidae (12 species), followed by Salticidae (11 species) and Tetragnathidae (10 species). Most abundant species were *Lycosa pseudoannulata*, *Tetragnatha andamanensis*, *T. javana* and *Pardosa sumatrana*. *L. pseudoannulata*, *T. javana*, *T. andamanensis*, *T. mandibulata*, *Oxyopus sunandae* and *Pardosa sumatrana* were recorded almost throughout the crop season (Table 126).

4.21.2 Field evaluation of integrated use of *Trichogramma japonicum* and *Trichogramma chilonis* and use of *Bacillus thuringiensis* against stem borer and leaf folder

The results of trials conducted at AAU, KAU, MPKV and TNAU with the following treatments are presented.

Treatments:

T1: *T. japonicum* @ 50,000 adults/ha/release and *T. chilonis* @ 50,000 adults/ha/release – 3 simultaneous releases at weekly interval

T2: *T. japonicum* @ 1,00,000 adults/ha/ release and *T. chilonis* @ 1,00,000 adults/ha/ release – 3 simultaneous releases at weekly interval

T3: *Bt* application (Delfin WG) @ 1 kg/ha – 2 times at 15 days interval

Table 126. Spiders recorded in rice from Thrissur district, Kerala

Sl.No.	Family: Tetragnathidae	Sl. No.	Family: Theridiidae
1	*Tetragnatha mandibulata*	23	Two species of *Theridion*
2	*Tetragnatha cochinensis*	24	*Chrysso argyrodiformis*
3	*Tetragnatha andamanensis*	25	*Runcinia* sp.
4	*Tetragnatha javana*		Family: Oxyopidae
5	*Tetragnatha maxillosa*	26	*Oxyopes sunandae*
6	Two species of *Tetragnatha*	27	*Oxyopes ashae*
7	*Dyschiriognatha hawigtenera*		Family: Salticidae
8	*Orsinome* sp.	28	*Rhene* sp.
	Family: Araneidae	29	*Plexippus petersi*
9	*Argiope catenulate*	30	*Plexippus paykulli*
10	*Argiope pulchella*	31	*Plexippus* sp.
11	*Argiope aemula*	32	*Cosmophais* sp.
12	*Argiope* sp.	33	Four species of *Phidippus*
13	*Cyrtophora citricola*	34	*Bianor* sp.
14	*Cyrtophora cicatrosa*	35	*Salticus* sp.
15	*Neoscona nautical*		Family: Hersilidae
16	*Araneus ellipticus*	36	*Hersilia saviognyi*
17	*Neoscona rumpfi*		Family: Pisoridae
18	*Neoscona poonaensis*	37	*Pisaura* sp.
19	Four species of *Neoscona*	38	*Thalassius* sp.
	Family: Lycosidae		Family: Clubionidae
20	*Pardosa sumatrana*	39	*Clubiona* sp.
21	*Lycosa pseudoannulata*	40	*Castinarea* sp.
22	Five species of *Lycosa*		

T4: Chemical control: Two sprays of monocrotophos @ 1 lit/ha at 15 days interval and one spray of phosphamidon @ 300 ml/ha

T5: Untreated control

AAU, Jorhat

The trial was conducted in farmer's field at Borholla (Assam) during rabi, 2002. Dead heart percent was lowest (2.41%) in the 4th week after the release of *T. japonicum* + *T. chilonis* against 9.82% dead hearts in the unreleased plot. There were no differences between different treatments in checking the formation of dead heart. The white ear population was also low (2.94%) in the parasitoid released plot (Table 127).

The percent infestation of leaf folder was lowest in the released plot (2.10%) in the 4th week after the release of the parasitoids. The yield was highest (3559.20 kg/ha) in the *Trichogramma* released plot as compared to that in the control (2637.86 kg/ha) (Table 128). None of the treatments showed significant differences in damage and yield. The same experiment was also carried out during kharif, 2002 in the same locality and the results are presented in Tables 129 & 130. The results showed that parasitoid release treatments and insecticides were better than untreated control.

Table 127. Field evaluation of integrated use of *Trichogramma japonicum*, *Trichogramma chilonis* and *Bacillus thuringiensis* against leaf folder

Treatment	Pre release count	Per cent leaves damaged by leaf folder at weekly intervals			
		I	II	III	IV
T. japonicum + *T. chilonis* @ 50,000/ha	3.37	6.25	3.96	3.03	2.41
T. japonicum + *T. chilonis* @ 1,00,000/ha	4.18	6.16	4.39	3.80	3.20
Bt	4.69	5.61	4.30	3.63	4.01
Insecticide	4.61	5.40	4.37	3.91	3.50
Control	4.79	6.04	8.83	8.82	9.82
CD (P=0.05)	NS	NS	NS	NS	NS

Table 128. Field evaluation of integrated use of *Trichogramma japonicum*, *Trichogramma chilonis* and *Bacillus thuringiensis* against rice stem borer

Treatment	Pre release count	Per cent dead heart at weekly intervals				WEH %	Yield (kg/ha)
		I	II	III	IV		
T. japonicum + *T. chilonis* @ 50,000/ha	3.37	6.25	3.96	3.03	2.41	2.94	3559.20
T. japonicum + *T. chilonis* @ 1,00,000/ha	4.18	6.16	4.39	3.80	3.20	2.58	3509.11
Bt	4.69	5.61	4.30	3.63	4.01	4.18	3270.69
Insecticide	4.61	5.40	4.37	3.91	3.50	4.18	3302.23
Control	4.79	6.04	8.83	8.82	9.82	8.28	2637.86
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

Table 129.Field evaluation of integrated use of *Trichogramma japonicum*, *Trichogramma chilonis* and *Bacillus thuringiensis* against rice stem borer

Treatment	Pre release count	Per cent dead heart at weekly intervals				WEH %	Yield (kg/ha)
		I	II	III	IV		
T. japonicum + *T. chilonis* @ 50,000/ha	5.20	4.30	3.39	4.00	2.95	3.04	4169.23
T. japonicum + *T. chilonis* @ 1,00,000/ha	4.54	3.69	3.75	3.99	3.31	2.83	4206.86
Bt	5.08	3.61	3.85	4.41	4.17	3.32	3953.16
Insecticide	4.64	4.02	4.10	4.10	3.39	3.72	4108.80
Control	4.74	4.34	6.40	11.34	10.52	7.30	3313.43
CD (P=0.05)	NS	0.499	0.812	1.21	0.857	0.843	140.14

Table 130. Field evaluation of integrated use of *Trichogramma japonicum, Trichogramma chilonis* and *Bacillus thuringiensis* against leaf folder

Treatment	Pre released count	Per cent leaf folder damaged leaves at weekly intervals			
		I	II	III	IV
T. japonicum + *T. chilonis* @ 50,000/ha	3.78	3.37	3.16	2.66	2.16
T. japonicum+ *T. chilonis* @ 100,000/ha	3.44	2.66	3.16	2.58	1.96
Bt	3.53	3.84	2.56	2.90	2.95
Insecticide	3.51	4.04	3.35	2.79	3.01
Control	3.70	3.40	3.43	6.70	6.87
CD (P=0.05)	NS	0.497	0.524	0.497	0.584

KAU, Thrissur

The experiment was laid out during October 2002 at R.A.R.S., Pattambi

On 30 DAT the incidence of leaf folder was on par in *Trichogramma* released plots. It was least in chemical control (1.59) followed by untreated control (2.90). On 45 DAT there was no significant different between treatments in leaf folder infestation. But on 60 DAT the leaf folder incidence was on par in control and *Bt* sprayed plots. It was lowest in chemical control (1.22) followed by *T. japonicum* and *T. chilonis* 1,00,000/ha (2.92).

There were no significant differences between treatments in dead heart incidence at 30 DAT, 45 DAT and 60 DAT. White earheads were significantly low in all biocontrol treatments and significantly higher in untreated control.

Even though there were significant differences in leaf folder incidence and white earheads between treatments, it didn't affect the yield of the crop.

MPKV, Pune

The trial was laid out on the Research Farm of Agricultural Research Station, Karjat on transplanted rice variety 'Masuri'.

Three releases of *T. japonicum* + *T. chilonis* each @ 1,00,000 adults/ha/release were found to be the most effective and recorded minimum dead hearts (9.92%) and white ear heads (4.33%) due to stem borer and leaf folder infestation (6.65%). This treatment also recorded the maximum yield of 48.4 q/ha (Table 131).

Table 131. Efficacy of trichogrammatids against stem borer and leaf folder on rice

Treatment	Dead hearts (%)		White ear heads (%)	Leaf folder infestation (%)	Yield (q/ha)
	Pre-count	Post-count			
T. japonicum @ 50,000 adults/ha/ release + *T. chilonis* @ 50,000 adults/ha/ release	12.65 (20.73)	13.93 (21.90)	6.97 (15.24)	12.34 (20.42)	35.0
T. japonicum @ 1,00,000 adults/ha/ release + *T. chilonis* @ 1,00,000 adults/ha/ release	11.77 (20.00)	9.92 (18.31)	4.33 (11.94)	6.65 (14.88)	48.4
Bt @ kg/ha (Delfin WG)	12.30 (20.48)	16.10 (23.61)	6.38 (14.42)	9.97 (16.33)	43.2
Chemical control: Monocrotophos @ 1 lit/ha (2 spray) & Phosphamidon @ 300 ml/ha (1 spray)	12.99 (20.98)	18.11 (25.16)	9.68 (18.11)	8.80 (17.16)	38.0
Untreated control	11.94 (20.13)	22.01 (27.92)	17.04 (24.32)	17.69 (24.85)	26.6
CD (P=0.05)	(NS)	(2.42)	(2.91)	(2.74)	7.78

Figures in parentheses are angular transformations

TNAU, Coimbatore

The trial was conducted at Malayandipattinam in Udumalpet taluk on rice variety ADT-36.

On 30 DAS the per cent dead hearts were 13.82 and 8.16 in *Trichogramma* plots. On 37 DAS and 87 DAS and 94 DAS there were no significant differences in per cent dead heart or per cent white ears between treatments 1 and 2. Thus there was no significant difference in parasitism between *Trichogramma* releases of 50,000 and 1, 00,000/ha. The per cent damage by leaf folder was lowest (3.82%) in insecticide plot on 44 DAS. In *Trichogramma* released plots (@ 50,000/ha), the damage was 20.21% and was superior to *Bt* application (26.21). There were no significant differences in leaf folder damage on 37 and 44 DAS between 50,000 and 1,00,000/ha. On 44 DAS, 11.2 per cent parasitism of yellow

Table 132. Effect of biocontrol and insecticide application on dead hearts and white ears due to stem borer on (var. ADT 36)

Treatments	Number of applications	% damage by stem borer						Yield (kg/ha)
		% dead hearts			% white ears			
		30 DAS	37 DAS	44 DAS	80 DAS	87 DAS	94 DAS	
T. japonicum 50,000/ha + *T. chilonis* 50,000/ha	3	13.82[b]	21.32[a]	8.31[a]	3.02[a]	4.26[a]	3.11[a]	3712[a]
T. japonicum 1,00,000/ha + *T. chilonis* 1,00,000/ha	3	8.16[a]	20.32[a]	15.12[b]	3.01[a]	4.58[a]	4.06[a]	3756[a]
Bt (Delfin) 1 kg/ha	3	18.12[c]	18.01[b]	11.21[a]	5.02[b]	7.2[a]	7.89[b]	3421[b]
Monocrotophos 1 lit/ha – 2 rounds + Phosphamidon 300 ml/ha	2+1	22.38[d]	24.12[c]	14.02[b]	11.16[c]	8.12[b]	1.61[a]	3482[b]
Untreated Check	0	26.18[e]	32.86	40.12[c]	41.28[d]	31.12[c]	13.26	2912[c]

stem borer eggs by *Trichogramma* was observed in *Trichogramma* plot (@ 1, 00,000/ha) and it was on a par with *Trichogramma* @ 50000/ha (10.2%). The lowest parasitism was observed in insecticide plot (0.8 %) which was lower than the untreated check plot.

There were no significant differences in rice yield between these plots (3712 kg/ha and 3756 kg/ha, respectively). Insecticide treated plots yielded 3482kg/ha, as against 2912 kg/ha from the untreated check (Table 132).

4.21.3. Field evaluation of integrated use of trichogrammatids (PAU, Ludhiana)

Integrated use of *Trichogramma chilonis* and *T. japonicum* against leaf folder, *C. medinalis* and stem borer, *S. incertulas* of rice was evaluated in farmers' fields at village Sudhar (Distt. Ludhiana) and Fateh Jalal (Distt. Jalandhar). Two dosages of both the parasitoids (50,000 and 1,00,000/ha) were evaluated with chemical control (one spray of monocrotophos @ 1400ml/ha) and untreated control.

At Sudhar the lowest incidence of leaf folder was recorded in parasitoid released plot (@1,00,000 per ha) (1.50%) and chemical control (1.80%) and it was significantly lower than control (5.24%) and lower dosages (50,000/ha) of parasitoids (4.80%) (Table 133). The mean per cent dead hearts and white ears were also low in parasitoid released plot (1, 00,000 per ha) and chemical control. The highest yield (60.90q/ha) was obtained in parasitoid

Table 133. Field evaluation of integrated use of *Trichogramma japonicum* and *T. chilonis* against rice stem borer and leaf folder at village Sudhar (Ludhiana)

Treatment	Per cent leaves folded	Per cent dead hearts	Per cent white ears	Yield (q/ha)
T. chilonis + *T. japonicum* @ 50,000/ha*	4.80 (12.64)	3.90 (11.36)	4.62 (12.39)	56.10
T. chilonis + *T. japonicum* @ 1,00,000/ha*	1.50 (6.95)	1.90 (7.85)	2.30 (8.69)	60.90
Chemical control	1.80 (7.68)	2.10 (8.31)	2.20 (8.15)	60.50
Control	5.24 (13.22)	4.40 (12.09)	6.70 (14.99)	55.30
CD (P=0.05)	(1.03)	(1.24)	(0.89)	0.99

*Seven releases made at weekly interval 30 DAT
Variety PR 114
Plot size for each treatment 1ha except control where it was 0.4 ha.
One spray of monocrotophos@ 1400ml/ha
Figures in parentheses are arc sin transformed values

released plot (1, 00,000/ ha) and chemical control (60.50q/ha) and was significantly higher than control (55.30q/ha).

At Fateh Jalal the incidence of leaf folder and stem borer was low in all the treatments (Table 134), but significantly lower in released/sprayed plots as compared to control. The yield in chemical control was significantly higher (68.25q/ha) than parasitoid released plot (65.00q/ha) which in turn was significantly higher than control.

Table 134. Evaluation of Biocontrol based IPM in rice at Fateh Jalal (Distt. Jalandhar)

Treatment	Per cent leaves folded	Per cent dead hearts	Per cent white ears	Mean yield (q/ha)
Biocontrol*	0.75 (4.97)	0.79 (5.06)	0.97 (5.63)	65.00
Chemical control **	0.98 (1.69)	0.39 (3.41)	0.46 (3.88)	68.25
Control	1.10 (5.98)	1.22 (6.33)	1.44 (6.86)	63.80
CD (P=0.05)	(0.92)	(1.32)	(1.03)	1.02

* 7 releases of both the parasitoids (*T. chilonis* and *T. japonicum*) @ 1,00,000/ha at weekly interval, 30 DAT

** One spray of monocrotophos @1400ml/ha

Figures in parentheses are arc- sin transformed values

Variety: PR 116

Plot size: 0.2 ha for each treatment

4.21.4. Evaluation of biocontrol based IPM in rice

AAU, Jorhat

Biocontrol based IPM was evaluated in comparison with chemical control in a farmer's field at Borholla during Rabi, 2002. The release of *Trichogramma* @ 50,000/ha checked the formation of dead hearts significantly (2.66% to 5.29%) whereas the percentage of dead hearts in the unreleased plot ranged from 5.37% to 9.49%. The lowest population of dead heart was observed in the 4th week after release of *Trichogramma* and the white ear head population was also low in the *Trichogramma* released plot (Table 135). Biocontrol and chemical control were more or less on par in checking leaf folder damage (Table 136).

Table 135. Evaluation of biocontrol based IPM in rice during rabi, 2002

Treatment	Pre release count	Per cent dead heart at weekly intervals				WEH %	Yield (kg/ha)
		I	II	III	IV		
Biocontrol	4.10	5.29	3.95	3.00	2.66	2.96	3554.58
Chemical Control	4.34	4.81	3.85	3.14	2.71	4.23	3491.86
Control	4.53	5.37	9.39	9.20	8.75	9.49	2702.35
CD (P=0.05)	NS	NS	0.638	0.834	0.832	0.990	130.27

Table 136. Evaluation of biocontrol based IPM in rice during rabi, 2002

Treatment	Pre released count	Per cent leaf folder damaged leaves at weekly intervals			
		I	II	III	IV
Biocontrol	2.55	2.54	2.16	2.50	2.26
Chemical Control	2.80	2.71	2.26	2.41	2.05
Control	2.84	2.83	3.09	5.85	6.32
CD (P=0.05)	NS	0.285	0.307	0.480	0.392

The results of a similar trial conducted at Borholla during kharif, 2002 revealed significantly better control of stem borer and leaf folder in biocontrol and chemical control plots (Table 137 & 138). The yield was marginally higher in parasitoid-released plots than in insecticide treated plots.

Table 137. Evaluation of biocontrol based IPM in rice during kharif, 2002

Treatment	Pre release count	Per cent dead heart at weekly intervals				WEH %	Yield (kg/ha)
		I	II	III	IV		
Biocontrol	4.24	5.05	4.43	3.85	3.10	2.86	4127.49
Chemical control	4.65	4.90	4.46	4.09	3.25	2.78	4074.97
Control	4.21	5.22	7.58	10.83	12.21	7.30	3400.31
CD (P=0.05)	NS	NS	0.761	0.690	0.934	0.454	68.93

Table 138. Evaluation of biocontrol based IPM in rice during kharif, 2002

Treatment	Pre released count	Per cent leaf folder damaged leaves at weekly intervals			
		I	II	III	IV
Biocontrol	2.32	2.61	2.75	2.02	2.03
Chemical control	2.32	2.48	2.68	2.02	1.94
Control	2.71	2.85	3.47	5.6 0	5.43
CD (P=0.05)	NS	NS	0.325	0.242	0.286

The field recovery of *T. japonicum* was estimated by placing *Corcyra* egg cards and 20-25% recovery was obtained.

TNAU, Coimbatore

Evaluation of biocontrol based IPM in rice was conduced at Malayandipattinam in Udumalpet taluk on IR-20 rice.

Treatments

T_1 - Six releases of *Trichogramma* 50,000/ha at weekly interval from appearance of 2-5 moths of stem borer /leaf folder

T_2 - Endosulfan (0.07%) – 6 sprays

T_3 - Control (untreated check)

The per cent dead hearts were the lowest in *Trichogramma* released plots as against endosulfan treated plot at all crop stages (Table 139). Similar results were noted with respect to per cent white ears. The yield was 3916 kg/ha in *Trichogramma* release plot as against 2740 kg/ha in untreated check.

The per cent damage by leaf folder at 44 DAS per cent damage in *Trichogramma* plot was 18.6 as against 16.1 in endosulfan plots. In untreated check it was higher (28.6). Similar trends were seen on 30 and 37 DAS (Table 140).

The per cent parasitism of stem borer eggs was highest in *Trichogramma* plot on 30, 37 and 44 DAS. The same was insignificant in endosulfan treated plots and even less than that in untreated check.

Table 139. Effect of biocontrol and insecticide application on stem borer damage and yield

Treatments	Damage by stem borer						Yield (kg/ha)
	% Dead Hearts			% White ears			
	30 DAS	37 DAS	44 DAS	80 DAS	87 DAS	94 DAS	
Eight releases of *Trichogramma* 50,000/ha	24.8	11.2[a]	14.2[a]	3.2[a]	11.6[a]	13.1[a]	3916[a]
Endosulfan (0.07%)	24.1	28.6[b]	18.8[b]	3.6[a]	12.8[a]	19.2[b]	3642[b]
Untreated Check	26.1	29.6[b]	31.2[c]	8.9[b]	26.8[b]	28.1[c]	2740[c]
CD (P=0.05)	NS						

Data are means of ten values

Table 140. Damage by rice leaf folder and parasitism of rice stem borer eggs by *Trichogramma* spp. in biocontrol based IPM plot

Treatment	Per cent damage by leaf folder			Per cent parasitism of stem borer eggs by *Trichogramma* spp.		
	30 DAS	37 DAS	44 DAS	30 DAS	37 DAS	44 DAS
Trichogramma 50,000/ha	9.8[a]	11.2[a]	18.6[a]	38.2	36.1	19.2
Endosulfan (0.05%)	11.6[a]	19.6[b]	16.1[a]	0.1	0.2	-
Untreated check	38.1[b]	39.2[c]	28.6[b]	2.3	3.2	1.2

Values are means of ten values

KAU, Thrissur

The experiment was laid out during October 2002 with three treatments and eight replications at RARS, Pattambi. Observations were recorded on stem borer and leaf folder incidence and yield data. There was no significant difference between treatments in the case of leaf folder incidence.

In the case of stem borer incidence there was no significant difference in treatments on 30 DAT and 45 DAT. At the time of harvest white earhead count was highest in control plot (3.64) and significantly lower in Neem + biocontrol applied plot (0.92) and insecticide treated plot (0.96). In terms of yield all the treatments were on par (Table 141).

Table 141. Percentage infestation of stem borer and yield data

Treatments	30 DAT (D.H.)	45 DAT (D.H.)	60 DAT (D.H.)	White earhead/m^2	Yield (kg/ha)
Neem + Biocontrol	6.01 (-1.251)	0.99 (-2.225)	4.65 (-1.382)	0.92 (-2.305)	4652.5
Chemical control	8.33 (-1.202)	1.50 (-2.071)	0.99 (-2.148)	0.96 (-2.231)	4493.75
Control	3.98 (-1.545)	1.83 (-2.033)	2.95 (-1.632)	3.64 (-1.605)	4525.00
CD (P=0.05)	NS	NS	0.47	0.505	NS

Figures in parentheses are transformed values

4.21.5. Large-scale demonstration of biocontrol in farmers' field

KAU, Thrissur

Large-area demonstration of biocontrol was carried out at farmers field at Korrkkenchery Panchayath, Thrissur district and compared with chemical control. Plot size was 1 ha for each treatment. In the biocontrol treatment *Trichogramma* spp. were released seven times at weekly interval starting from 30 DAT @ 1,00,000/ha. Two sprays of monocrotophos (0.05%) were given in chemical control.

Stem borer and leaf folder infestation was very low in all the treatments (Table 142) and there was no significant difference in leaf folder damage, deadheart or white earheads. The population of natural enemies in control and biocontrol plots was higher when compared to chemical control plot (Table 143).

Table142. Percentage leaf folder incidence, white ear heads and grain weight

Treatments	25 DAT	45 DAT	60 DAT	White ear head count/m^2
Chemical control	4.17	0.79	0.54	4.00
Biocontrol	1.32	0.94	0.38	4.31
Control	3.82	0.54	0.98	5.00
CD (P=0.05)	NS	NS	NS	NS

Table 143. Count of natural enemies (mean of two samples)

Natural enemies	Biocontrol	Chemical control	Control
Damsel fly	6.0	2.5	5.0
Spiders	11.5	3.0	9.0
Coccinellids	3.0	2.5	2.5
Cyrtorhinus	8.5	1.5	8.5
Hymenopterans	12.5	8.5	15.5

PAU, Ludhiana

Large scale demonstration of IPM (seven releases of *T. chilonis+T. japonicum* each @ 1,00,000 per ha per week, starting 30 DAT + one application of Padan 4G@ 25kg/ha) was compared with chemical control (two applications of Padan 4G @ 25kg/ha + one spray of monocrotophos @ 1400ml/ha) and untreated control. The experiment was conducted in farmers' fields at village Karni Khera (Distt. Ferozepur) on Pusa Basmati-1.

The lowest incidence (2.10%) of leaf folder was recorded in chemical control and it was significantly lower than IPM (2.70%), which in turn was significantly lower than control (8.90%) (Table 144). The per cent dead hearts and white ears in IPM and chemical control were significantly lower than control. The highest yield (52.50q/ha) was obtained in chemical control, which was on par with IPM (50.60q/ha), but significantly higher than control (43.80q/ha).

Table 144. Demonstration and evaluation of of IPM in rice at Karni Khera (Distt. Ferozepur)

Treatment	Per cent leaves folded	Per cent dead hearts	Per cent white ears	Mean yield (q/ha)
IPM*	2.70 (9.44)	4.60 (12.36)	5.20 (13.16)	50.60
Chemical control **	2.10 (8.31)	4.10 (11.65)	5.30 (13.29)	52.50
Control	8.90 (17.33)	18.21(24.32)	11.20 (19.53)	43.80
CD (P=0.05)	(0.45)	(1.12)	(0.49)	2.20

* One application of Padan @25kg/ha + 7 releases of parasitoids (*T. chilonis + T. japonicum* @ 1,00,000/ha at weekly interval), 30 DAT.

** Two applications of Padan@ 25kg/ha and 1 spray of Monocrotophos @1400ml/ha

Variety : Pusa Basmati-

Plot size: 40ha for IPM, 2ha for chemical control and 0.4ha for chemical control

4.21.6. Development of rearing technique for key natural enemies of rice hispa (AAU, Jorhat)

Attempts were made to develop rearing techniques for the key natural enemies of rice hispa. In the field-collected samples, egg parasitoids *Trichogramma* sp. and *Oligosita* sp. only were recovered during August-September. *Scutibracon hispae* was not found in the kharif, 2002. *Trichogramma* sp. and *Oligosita* sp. were reared on *Corcyra* eggs for one generation.

4.22 Biological suppression of oilseeds crop pests

4.22.1. Bio-Intensive IPM of *Spodoptera litura* on groundnut (TNAU, Coimbatore)

Bio-Intensive IPM of *Spodoptera litura* trial was evaluated in a field at Aliyar Nagar, Coimbatore district with ALR-3 groundnut variety This variety has an expected yield of 1886 kg/ha in 115 days.

Treatments

T_1 - Biointensive IPM

- i. Castor was sown as a trap crop one week before planting groundnut
- ii. Two releases of *Telenomus remus* @ 40,000 / ha – three weeks after planting, when egg masses were observed on castor
- iii. Three need based sprays of *Sl*NPV 3 x 10^{12} POBs/ha

T_2 - Chemical control - four rounds of insecticide

Spodoptera litura incidence started around 30th day after planting. There were no significant differences in their population between BIPM plot and farmers' field. Starting from 60th day significantly lower numbers were observed in BIPM plot (38.1) than chemical control plot (112.3) (Table 145).

The groundnut yield was 1962 kg/ha from BIPM plot whereas control plot yielded 1643 kg/ha (Table 146). Per cent parasitization was higher in BIPM plots on 45, 60 and 75th day as against chemical control /farmers' method.

4.22.2. Evaluation of *Nomuraea rileyi* against *Spodoptera litura* and *Helicoverpa armigera* on groundnut (TNAU, Coimbatore)

Evaluation of *Nomuraea rileyi* against *Spodoptera litura* and *Helicoverpa armigera* on groundnut was carried out at Aliyar Nagar, Pollachi, Coimbatore District on groundnut var. ALR-3. Three applications of the fungus formulations were given commencing from 60 days after sowing using low volume applicator. Insecticide check chlorpyriphos 20 EC and endosulfan 35 EC were included for comparison.

Table 145. Population of *Spodoptera litura* larvae during the cropping period

Treatment	Population (no./100 plants) on groundnut					Population (no./100 plants) on castor				
	30	45	60	75	90	30	45	60	75	90
BIPM	6.1	642.2	120.3	38.1	19.2	3.0	104.2	32.1	29.1	16.9
Chemical control/ Farmers' method	18.1	769.2	242.1	112.3	65.1	4.0	117.2	164.1	28.2	2.9
CD (P=0.05)	21.2	32.6	38.12	24.21	8.26	2.92	19.6	29.2	3.8	6.2

Table 146. Per cent parasitisation of *Spodoptera litura* on groundnut and yield

Treatment	Per cent parasitization (DAS) with out castor as trap crop				Per cent parasitization (DAS) with out castor as trap crop				Yield	C:B
	30	45	60	75	30	45	60	75		
BIPM	6.8	19.7	21.7	29.6	9.1	2.6	11.6	24.1	1962	1:1.873
Chemical control / Farmers' method	0.9	0.8	1.1	3.2	0.1	2.1	3.2	1.2	1643	1:1.541
CD (P=0.05)	NS	3.3	4.1	8.6	1.21	1.8	2.1	3.2		

Table 147. Field efficacy of formulations of *Nomuraea rileyi* (5×10^{11} spores/ha) in the control of *H.armigera* and *S. litura* on groundnut (mean of five replications)

Treatment	*S. litura*/10 plants						*H. armigera*/10 plants					
	Spray I		Spray II		Spray III		Spray I		Spray II		Spray III	
	PT	10DAT	PT	10DAT	PT	9DAT	PT	10DAT	PT	10DAT	PT	9DAT
N. rileyi aqueous suspension	3.2	1.4a	3.4ab	1.0a	0.2	0.2	1.0	0.4a	1.4	4.8b	1.2a	0.8a
N. rileyi oil in water emulsion	2.2	1.4a	2.4a	1.2a	0.6	0.0	0.6	0.2a	2.0	3.0ab	0.4a	0.4a
Insecticide*	3.0	0.4a	1.8a	0.2a	0.0	0.0	1.0	0.0a	1.0	2.2a	0.2a	0.0a
Control	2.8	9.2b	6.2b	6.6b	0.8	0.2	1.0	2.6b	3.2	9.0c	5.0b	5.20b

In vertical columns, means followed by similar letters are not different statistically (P = 0.05) by DMRT

* Spray I= chlorpyriphos 250g/ha; spray II and III = endosulfan 350g/ha

S. litura occurrence was earlier than *H. armigera*. The application of fungus formulations was found to be better than control and as effective as insecticide treatment (Table 147). Significantly more numbers of mycosed cadavers (1.4 – 2.8) were found in the fungus treatments after second and third round of application. The foliar damage was maximum in control while it was significantly reduced in insecticide treatment, which was on par with the fungus formulations. The yield was significantly higher in insecticide application, which was on par with the oil in water formulation. Aqueous suspension was found to be on par with the other fungus formulation and better than control (Table 148).

Table 148. Field efficacy of formulations of *Nomuraea rileyi* (5×10^{11} spores/ha) in the control of *H.armigera* and *S. litura* on groundnut (mean of five replications)

Treatment	Foliar damage(%)						Yield
	Spray I		Spray II		Spray III		(kg/ha)
	PT	10DAT	PT	10DAT	PT	9DAT	
N. rileyi aqueous suspension	28	28	20a	22a	36ab	20a	1817.2b
N. rileyi oil in water emulsion	34	38	14a	22a	24a	22a	1830.0ab
Insecticide*	32	28	10a	20a	18a	28a	1890.6a
Control	34	44	40b	46b	52b	64b	1619.2c

In vertical columns, means followed by similar letters are not different statistically (P = 0.05) by DMRT

* Spray 1= chlorpyriphos 250g/ha; spray II and III = endosulfan 350g/ha

4.22.3. Laboratory evaluation of *Verticillium lecanii* against mustard aphid, *Lipaphis erysimi* (PAU, Ludhiana)

Verticillium lecanii (cultured on PDA) was evaluated against mustard aphid, *Lipaphis erysimi* under laboratory conditions at three concentrations (10^6, 10^7 and 10^8 conidia/ml). The mortality of the aphids was recorded up to 96 hours of treatment.

The mortality of the aphids started after 24 h and up to 72 h of treatment there was no significant difference between different treatments and control (Table 149). However, after 96 h of treatment, the highest mortality (40.0%) was recorded in higher dose (10^8 conidia/ml) of *V. lecanii* and it was significantly higher than control, but on par with the other two concentrations.

Table 149. Effectiveness of *Verticillium lecanii* against mustard aphid under laboratory conditions

Treatments	Per cent mortality of mustard aphids (hours after spray)			
	24	48	72	96
V. lecanii (10^6 conidia/ml)	6.66	13.38	23.33	23.33 (28.76)
V. lecanii (10^7 conidia/ml)	13.33	13.33	30.00	33.33 (34.91)
V. lecanii (10^8 conidia/ml)	13.33	36.66	36.66	40.00 (39.13)
Control	3.33	10.00	10.00	10.00 (14.99)
CD (P=0.05)	NS	NS	NS	(16.88)

Figure in parentheses are arc-sin transformed values

4.23 Biological suppression of coconut pests

4.23.1. Field evaluation of *Hirsutella thompsonii* formulations against coconut mite

PDBC, Bangalore

Two new formulations of the fungus *Hirsutella thompsonii* were evaluated along with the already available formulation Mycohit against the coconut mite (*Aceria guerreronis*) through multilocation trials.

PDBC conducted a trial at 'Gupta Farms' at Lakkenahalli village, Magadi taluk, Bangalore Rural district, Karnataka. Two new formulations (LG and OS) along with Mycohit were compared with Hostathion (Triazophos 40%EC, Aventis). The treatments were as follows:

1. Mycohit (10 g/L),
2. Mycohit-LG20 (10 mL/L),
3. Mycohit-OS (10 mL/L),
4. Hostathion (5 mL/L),
5. Control.

All the treatments were applied thrice as sprays at 15-day intervals. The first, second and third sprays were done on 06.07.2002, 21.07.2002 and 07.08.2002, respectively. Pre-treatment analysis for live mites was done with samples obtained from the 4th and 5th bunches. The 2nd and 3rd bunches were tagged with green and yellow wires for the post-treatment observations on the 45th day (20.08.2002) and pre-harvest damage grading (22.02.2003). The results are presented in Table 150.

Table 150. Field evaluation of *H. thompsonii* formulations at Lakkenahalli, Bangalore Rural district, Karnataka

Treatment	Live mites (no./mm^2)				Pre-harvest damage grading		
	Pre-treatment		Post-treatment				
	4th bunch	5th bunch	Tagged bunch 1	Tagged bunch 2	Tagged bunch 1	Tagged bunch 2	Tagged Mean
Mycohit	5.19	6.06	0.29	1.28	3.24	3.02	3.13
Mycohit-LG20	5.97	6.67	0.35	1.74	2.84	3.16	3.00
Mycohit-OS	4.96	6.03	0.46	1.61	3.12	2.61	2.87
Hostathion	5.76	4.72	1.72	3.05	3.07	3.34	3.21
Control	4.27	4.56	5.18	5.35	3.03	3.41	3.22
CD (P=0.05)	NS	NS	1.66	2.08	NS	NS	NS

Note: Post-treatment counts on the 45th day from first application.

All the three formulations significantly reduced number of live mites/ 1 mm^2 on the nut surface of samples collected from the tagged bunches 1 & 2. The figures for Mycohit, -LG20 and -OS were 0.29 & 1.28, 0.35 & 1.74 and 0.46 & 1.61, respectively. The corresponding figures for Hostathion and control were 1.72 & 3.05 and 5.18 & 5.35, respectively. Mycohit-OS showed a reduction of 10.87% in mean (tagged bunches 1 and 2) pre-harvest damage over control. However, there was no significant reduction in nut damage in both the tagged bunches.

CPCRI, Kayangulam

Final observations on damage index were recorded in October 2002 for the experiment initiated during April 2002 at Mavelikkara, Alappuzha district, Kerala. (Table 151)

Table 151. Field evaluation of *H. thompsonii* formulations at Mavelikkara, Kerala

Treatment	Live mites (no./mm²)				Pre-harvest damage grading	
	Pre-treatment		Post-treatment			
	4th bunch	5th bunch	Tagged bunch 1	Tagged bunch 2	Tagged bunch 1	Tagged bunch 2
Mycohit	3.50	8.05	13.90	5.57	4.02	3.84
Wettable sulphur	10.38	6.45	2.28	6.32	4.38	3.98
Azadirachtin	8.08	10.55	4.53	2.34	3.55	3.27
Control	7.18	7.06	4.22	10.45	3.46	2.07

Two sets of new field trials were conducted during 2002-03. The treatments were Mycohit, - Mycohit LG20, - Mycohit OS, Azadirachtin and control.

The population and infestation index of the tagged bunches were pooled together and subjected to statistical analysis (Table 152 & 153).

Table 152. Field evaluation of *H. thompsonii* formulations at Pullukulangara, Alappuzha district, Kerala

Treatment	Live mites (no./mm²)				Pre-harvest damage grading	
	Pre-treatment		Post-treatment			
	4th bunch	5th bunch	Tagged bunch 1	Tagged bunch 2	Tagged bunch 1	Tagged bunch 2
Mycohit	19.22	25.44	4.54	3.31	3.83	3.63
Mycohit-LG20	18.14	19.02	4.95	3.59	4.07	3.54
Mycohit-OS	23.48	15.82	5.07	8.31	3.31	3.80
Azadirachtin	31.83	16.97	2.80	5.71	3.18	4.10
Control	24.42	21.29	7.82	9.04	3.83	3.53

Table 153. Field evaluation of *H. thompsonii* formulations at Valiakulangara, Kollam district, Kerala

Treatment	Live mites (no./mm^2)				Pre-harvest damage grading (8-9 month maturity)	
	Pre-treatment		Post-treatment			
	4th bunch	5th bunch	Tagged bunch 1	Tagged bunch 2	Tagged bunch 1	Tagged bunch 2
Mycohit	5.92	6.91	5.50	2.75	2.26	2.03
Mycohit-LG 20	9.81	6.61	3.22	4.48	1.80	2.48
Mycohit-OS	2.55	11.99	0.05	3.60	1.93	1.80
Azadirachtin	9.80	11.63	3.85	1.95	2.25	2.24
Control	10.10	8.37	2.90	6.95	1.70	2.40

Data on population count showed that there was no significant difference among the treatments. However, in all the treatments including control, significant differences were observed between the pre-and post-treatment population of the mite (Table 154).

Table 154. Population count of mites in the trial with Mycohit

Treatment	Trial 1 (Pullukulangara) Live mites (no./mm^2)			Trial 2 (Valiakulangara) Live mites (no./mm^2)		
	Pre-treatment	Pre-treatment	Mean	Pre-treatment	Pre-treatment	Mean
Mycohit	24.410	3.924	14.167	6.420	4.166	5.293
Mycohit-LG20	18.950	4.283	11.617	8.218	2.973	5.596
Mycohit-OS	19.649	6.745	13.197	7.274	1.388	4.331
Azadirachtin	23.151	4.252	13.702	6.646	2.501	4.574
Control	23.029	9.272	16.151	9.241	4.574	7.105
Mean	21.838	5.695	13.767	7.560	3.199	5.380
CD between pre- and post-treatments	5.194		(Gen. Mean)	2.366		(Gen. Mean)

The mean infestation index of nuts at maturity did not differ significantly among the treatments including control (Table 155).

Table 155. Pre-harvest damage grading of nuts at maturity in the trial with Mycohit

Treatment	Trial 1 (Pullukulangara)	Trial 2 (Valiakulangara)
Mycohit	3.732	2.267
Mycohit-LG20	3.807	1.754
Mycohit-OS	3.552	1.688
Azadirachtin	3.642	1.921
Control	3.558	1.942
S.E./trial	1.14	0.85
General mean	3.66	1.91
CD (P=0.05)	NS	NS

ANGRAU, Hyderabad

Different formulations of Mycohit (*H. thompsonii*) were evaluated against the coconut eriophyid mite under field conditions in Andhra Pradesh. The treatments consisted of i) Mycohit, ii)Mycohit-LG20, iii) Mycohit-OS, iv) Triazophos 40EC and v) Control.

Field application of *H. thompsonii* formulations against the coconut mite resulted in no mycelial fragments on the mite colonies in any of the observations recorded at 45 days after spray application (Table 156). As a result no significant reduction in the population of the mite was observed. Similar trend was also noticed in other treatments. The damage scores recorded in tagged bunch 1 and tagged bunch 2 also failed to give any logical conclusions.

A parallel trial conducted at Agricultural Research Station, Ambajipeta with the same set of treatments also gave similar results (Table 157).

KAU, Thrissur

Two field experiments were laid out during August and October 2002 for the management of the coconut mite with five treatments and 12 replications in the coconut plantation of College of Horticulture, Vellanikkara.

Table 156. Field evaluation of *H. thompsonii* formulations at Ambajipeta, East Godavari district, Andhra Pradesh

Treatment	Live mites (no./mm^2)				Pre-harvest damage grading	
	Pre-treatment		Post-treatment			
	4th bunch	5th bunch	Tagged bunch 1	Tagged bunch 2	Tagged bunch 1	Tagged bunch 2
Mycohit	18.61 (4.21)	36.39 (5.61)	8.33 (4.14)	25.97 (4.52)	4.16 (2.15)	3.83 (2.07)
Mycohit-LG 20	19.97 (4.27)	12.75 (3.25)	19.83 (4.25)	27.08 (4.81)	4.22 (2.17)	4.02 (2.11)
Mycohit-OS	17.22 (3.78)	23.75 (4.64)	10.28 (2.93)	21.56 (4.20)	4.43 (2.22)	4.28 (2.18)
Triazophos 40EC	25.00 (4.980)	12.61 (3.43)	18.11 (4.25)	24.03 (4.77)	4.16 (2.15)	4.58 (2.23)
Control	25.94 (5.01)	32.08 (5.63)	30.53 (5.42)	32.81 (5.64)	4.24 (2.17)	4.29 (2.18)
CD (P=0.05)	NS	1.41	0.97	NS	NS	NS

Table 157. Field evaluation of *H. thompsonii* formulations at Ambajipeta, East Godavari district, Andhra Pradesh

Treatment	Live mites (no./mm^2)				Pre-harvest damage grading	
	Pre-treatment		Post-treatment			
	4th bunch	5th bunch	Tagged bunch 1	Tagged bunch 2	Tagged bunch 1	Tagged bunch 2
Mycohit	16.17 (3.94)	16.39 (3.86)	13.14 (3.61)	13.80 (3.56)	2.64 (1.74)	3.47 (1.98)
Mycohit-LG 20	18.00 (3.96)	7.56 (2.69)	8.30 (2.79)	11.56 (3.28)	3.57 (2.00)	3.92 (2.09)
Mycohit-OS	16.50 (3.73)	12.47 (3.49)	16.81 (3.83)	17.17 (3.96)	3.80 (2.06)	3.80 (2.06)
Triazophos 40EC	12.64 (3.36)	16.31 (3.65)	16.53 (3.83)	6.11 (2.46)	2.86 (1.81)	3.26 (1.92)
Control	18.06 (4.01)	15.36 (3.73)	14.64 (3.86)	9.86 (3.14)	3.98 (2.10)	4.38 (2.20)
CD (P=0.05)	NS	NS	NS	0.96	0.23	0.11

Note: Figures in parentheses are transformed values

In the first trial, post-treatment count of live mites/mm^2 area in the two tagged bunches was significantly lower in all the three Mycohit formulations and wettable sulphur than that in control (Table 158).

Table 158. Field evaluation of *H. thompsonii* formulations at Vellanikkara, Thrissur district, Kerala (Population count of live mites/mm^2)

Treatment	Trial 1				Trial 2			
	Pre-treatment		Post-treatment		Pre-treatment		Post-treatment	
	4th bunch	5th bunch	Tagged bunch 1	Tagged bunch 2	4th bunch	4th bunch	Tagged bunch 1	Tagged bunch 2
Mycohit	2.025	3.750	1.723 (1.161)	1.435 (1.398)	2.410	2.590	1.260 (1.229)	1.120 (1.190)
Mycohit-OS	4.530	4.500	2.220 (1.236)	1.640 (1.440)	2.490	1.640	1.720 (1.436)	1.590 (1.289)
Mycohit-LG20	3.040	3.410	1.080 (0.758)	0.082 (1.177)	1.970	1.620	0.910 (1.144)	1.150 (1.220)
Wettable sulphur	3.220	3.310	1.460 (1.370)	1.450 (1.379)	1.680	1.810	0.610 (0.893)	0.990 (1.145)
Control	2.940	1.340	4.090 (1.782)	3.115 (2.080)	4.140	2.440	4.290 (2.026)	3.960 (2.068)
CD (P=0.05)			0.508	0.473			0.404	0.378

Note : Figures in parentheses are $\sqrt{x+0.5}$ transformed values

In the second trial, post-treatment counts of live mites in the two tagged bunches were significantly higher in control as compared to other treatments. Wettable sulphur treated tagged bunches recorded the lowest live mite population. In the case of the tagged bunch 1, Mycohit and Mycohit-LG20 were on par with wettable sulphur, while in the tagged bunch 2 all the Mycohit versions were comparable with wettable sulphur.

In the first trial, the pre-harvest damage grading on nuts did not show a significant reduction due to the application of Mycohit formulations. However, the nut damage score in wettable sulphur treatment was significantly lower in the tagged bunch 1. All the treatments were on par in the damage intensity on tagged bunch 2 (Table 159).

In the second trial wettable sulphur treated nuts showed significantly lower damage (1.73 and 1.71) followed by Mycohit-LG20 treated nuts (2.67 and 2.40)

Table 159. Field evaluation of *H. thompsonii* formulations at Vellanikkara, Thrissur district, Kerala (Pre-harvest damage grading of nuts)

Treatment	Trial 1		Trial 2	
	Tagged bunch 1	Tagged bunch 2	Tagged bunch 1	Tagged bunch 2
Mycohit	3.72 (2.045)	3.88 (2.085)	3.12 (1.884)	3.19 (1.897)
Mycohit-OS	3.39 (1.956)	3.72 (2.044)	2.81 (1.806)	2.86 (1.824)
Mycohit-LG20	3.79 (2.062)	3.26 (1.928)	2.67 (1.762)	2.40 (1.682)
Wettable sulphur	2.69 (1.771)	3.84 (2.073)	1.73 (1.480)	1.71 (1.475)
Control	3.163 (1.903)	3.60 (2.011)	3.38 (1.962)	3.81 (2.071)
CD (P=0.05)	0.171	NS	0.177	0.195

Note: Figures in parentheses are transformed values

Analysis of co-variance was also worked out to study the influence of pre-count over post count and damage intensity. The results showed that there was no significant influence of pre count and there was only treatment effect in the two trials.

UAS, Dharwad

The trial was conducted in Dharwad district, Karnataka. Two new formulations along with Mycohit were compared with wettable sulphur. The treatments were Mycohit (10 g/L), Mycohit-LG20 (10 mL/L), Mycohit-OS (10 mL/L), Wettable sulphur (5 g/L) and Control.

The data presented in Table 160 indicated that there was no significant difference among the treatments a day before spray in recording number of mites and eggs of the coconut mite. However, all the three formulations of *H. thompsonii* were found to be on par with wettable sulphur but significantly superior over untreated check. Mycohit-LG20 recorded the least number of mites.

Table 160. Field evaluation of *Hirsutella thompsonii* formulations in Dharwad

Treatment	Live mites (no./mm^2)	
	Pre-treatment	Post-treatment
Mycohit	7.47	1.74
Mycohit-LG20	8.08	0.65
Mycohit-OS	8.75	1.59
Wettable sulphur	9.60	1.04
Control	10.26	7.85
CD (P=0.05)	NS	1.71

4.23.2. Studies on seasonal incidence of *Opisina* and its natural enemies

CPCRI, Kayangulam

Samples were collected at monthly intervals from two locations. The seasonal incidence of *Opisina* and natural enemies are presented in Table 161 & 162. Average percentage parasitism by *Brachymeria* spp. was 34% and by *Apanteles taragamae* 41.2%.

Table 161. Seasonal incidence of *Opisina* and its parasitoids (Location 1. Ambalappuzha)

Months	*Opisina arenosella* population and parasite count /100 leaf lets					
	Opisina	*Goniozus*	*Elasmus*	*Brachymeria*	*Apanteles*	Others
April 2002	152	-	18	-	7	
May	158	-	12	-	2	
June	160	2	-	4	1	
July	169	-	-	2	6	
August	63	-	-	2	-	
September	134	-	-	5	7	
October	96	-	-	-	-	
November	125	-	-	-	2	
December	20	-	30	5	2	
January	99	2	30	-	2	
February	194		21	28	3	1 *Xanthopimpla* 1 *Bracon* 7 *Pediobius*
March 2003	298		90		17	10 *Bracon*

Table 162. Seasonal incidence of *Opisina* and its parasitoids (Location 2. Vazhappally)

Months	*Opisina arenosella* population and parasite count /100 leaf lets					
	Opisina	*Goniozus*	*Elasmus*	*Brachymeria*	*Apanteles*	Others
April 2002	321	22	-	5	2	
May	150	24	-	-	5	
June	275				16	
July	150	24	16	2	6	
August	133	-	-	-	4	
September	117	15		3	16	
October	239			2	7	
November	118				5	
December	23		20		5	64 *Trichospilus*
January	200	2	21			
February	258			8	2	
March 2003	198		150	16	4	3 *Pediobius* 3 *Eurytoma*

KAU, Thrissur

In two locations of Thrissur district (Irinjalakkuda and Ayyanthole), the seasonal incidence of *Opsinia arenosella* and its natural enemies was studied.

During May percent leaf infestation was 34.06 at Irinjalakkuda and 38.72 at Ayyanthole. There was a decrease in infestation level during July. From September onwards an increasing trend was observed up to March 03. The infestation levels during December-March 03 were significantly higher in the two locations, the highest being in March (67.56% and 59.34%, respectively).

Leaflet infestation was low during July 2002 in the two locations. From September 2002 onwards it showed an increasing trend up to March 2003. Significantly higher leaflet infestation was observed during September 2002-March 2003, the highest being in March (>60%)

Irinjalakkuda

During May 2002, *Opisina* count on 100 leaflets was 82 and it decreased to 52 in July 2002 and 34 in September 2002. In October it started increasing (99) and the population was high during December 2002-March 2003 (141-146). Maximum parasitism was recorded in May 2002 (42.31%) followed by September 2002 (36.84%).

Ayyanthole

Maximum pest population was recorded in March 2002 (98) and minimum in July 2002 (27.03). During December 2002 only early instar larvae were collected and so no parasitism was recorded. Maximum parasitism was recorded only in September 2002 (36). The predominant parasitoids recorded. from the two locations were *Brachymeria nosatoi* and *Apanteles* sp. The anthocorid predator *Cardiastethus* sp. was also observed.

4.24 Biological suppression of fruit crop pests

4.24.1. Evaluation of *Trichogramma chilotraeae* and *T. chilonis* for the control of *Deudorix isocrates* on pomegranate (IIHR, Bangalore)

Trichogramma chilotraeae collected from the eggs of *D. isocrates* in the field in 1998 was maintained on the eggs of *C. cephalonica* in the laboratory. A field experiment was conducted during February - May 2002 to evaluate its performance against *D. isocrates.* Five releases were made from the time of fruit set at weekly intervals @ one lakh/ ha per release. There was a marginal reduction in the fruit damage on the released plants. A mean of 29.40% fruit damage was recorded on parasitoid-released plants as compared to 34.62% in check.

Trichogramma chilonis was evaluated against *D. isocrates* during August-November 2002. Parasitoids were released @ 5,00,000/ha. A mean of 23.55% fruit damage was recorded on the plants on which parasitoids were released as compared to 36.74% in check.

4.24.2. Efficacy of *Cryptolaemus montrouzieri* against *Rastrococcus invadens* on ber (IIHR, Bangalore)

Severe infestation of *R. invadens* was observed on six-year-old ber plants in May 2002 in Block No.2, IIHR Farm. The first samples revealed the absence of natural enemies on *R. invadens*. A mean of 507.67 mealybugs/plant (4 shoots) was observed. *C. montrouzieri* was released @ 50/plant on 1st and 15th May 2002. The mealybug population declined to 20.00 by 16th June and no mealy bugs were observed on 1st July 2002.

4.24.3. Field efficacy of *Trichogramma chilonis* against the ber fruit borer *Meridarches scyrodes* (IIHR, Bangalore)

Releases of *T. chilonis* were initiated in July 2002 and continued up to September at weekly intervals. Five releases were made from the time of fruit set at weekly intervals @ one lakh/ha per release. A mean of 28.20% fruit damage was recorded on the parasitoid released plants as compared to 81.00 % in the check.

4.24.4. Spread of *Encarsia* spp. on spiraling whitefly (IIHR, Bangalore)

Surveys were carried out in Karnataka, Tamil Nadu and Andhra Pradesh during 2002-2003 for *Encarsia* spp. on spiralling whitefly. *Encarsia guadeloupae* was collected in all the locations except Coimbatore. *E. haitiensis* was collected in Sirsi, Coimbatore and Puttur. In some areas both *E. haitiensis* and *E. guadeloupae* occurred together. In addition to *Encarsia* spp. *Axinoscymnus puttarudriahi*, *Cybocephalus* sp, *C. montrouzieri* and *Chrysopa* spp. were also encountered. *Encarsia guadeloupae* was distributed in several areas in Karnataka and Andhra Pradesh where the parasitoids were absent.

4.24.4.1 Role of *Encarsia* spp. in the suppression of spiralling whitefly

Guava

A field study was initiated in February 2000 to study the role of *Encarsia* spp. in suppressing *A. dispersus* on guava. There was no activity of parasitoids prior to February 2000. Inoculative release of 187 *E.* sp. nr. *meritoria* adults that emerged from the samples collected at Thiruvananthapuram, Kerala, was made on guava at Hosallipalaya in February 2000. A steady decline in the population of spiralling whitefly was observed, and a very low level of 3.40/leaf was recorded during February 2003. *E.* sp. nr. *meritoria* was found to be the only major natural enemy encountered initially up to October 2000, which was displaced steadily later by *E. guadeloupae*. A mean of 28.92% parasitism was observed in March 2000 following the release of *E.* sp. nr. *meritoria* and later *E. guadelopae* and the parasitism steadily increased up to 92.52% by February 2003 (Table 163).

The density of the spiralling whitefly was not significantly correlated with weather factors except morning relative humidity. The partial regression coefficients of the spiralling whitefly and weather factors were also found to be non-significant. However there was highly significant and negative relationship ($r = -0.837$) between the spiralling whitefly population and the parasitism by *Encarsia* spp. Host plants such as *Canna indica*, *Carica papaya*, *Poinsettia pulcherrima*, *Hibiscus rosasinensis*, *Musa* sp., *Punica granatum* and *Terminalia catappa* grown in the same orchard also supported the build up of these two *Encarsia* spp. causing 60.74% to 85.92% parasitism, respectively, during February 2003 (Table 164).

Table 163. Population of spiralling whitefly in relation to parasitism by *Encarsia* spp. and weather factors on guava in Bangalore North

Month	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Parasitoids			White flies (Nos.)
	Max	Min.	Morn.	Even.		Proportion (%)	Parasitism (%) E.m.	E.g	
February2000	29.4	16.0	65.5	44.7	39.0	0.00	—	—	117.10
March	32.2	14.9	54.2	29.8	0.0	28.92	100.00	0.00	110.00
April	33.9	19.6	60.3	35.8	19.8	53.60	100.00	0.00	98.00
May	32.3	20.4	63.7	46.7	73.6	57.83	100.00	0.00	100.00
June	29.3	19.6	74.2	60.8	115.7	58.00	100.00	0.00	62.00
July	28.4	18.1	74.1	58.9	67.4	60.20	100.00	0.00	52.30
August	27.7	19.0	79.3	66.3	251.8	50.12	100.00	0.00	40.10
September	28.4	19.3	79.0	62.4	196.0	55.16	100.00	0.00	38.20
October	28.8	17.3	82.7	58.9	203.8	53.20	100.00	0.00	34.30
November	27.8	14.9	69.5	49.1	9.0	58.10	92.12	7.88	35.00
December	27.5	13.6	68.4	44.6	0.4	60.25	80.15	19.85	32.20
January2001	29.4	13.6	64.3	41.3	6.0	62.20	84.20	15.80	30.10
February	32.1	15.9	59.6	30.5	0.0	66.12	81.16	18.84	25.70
March	33.1	17.5	57.7	32.4	1.6	63.40	76.74	23.26	23.40
April	32.5	19.2	68.2	43.6	206.4	72.55	80.26	19.74	19.10
May	33.0	20.6	63.8	43.5	30.2	70.20	75.40	24.60	20.30
June	29.3	20.3	68.5	54.7	9.8	70.18	74.36	25.64	22.10
July	28.8	20.6	75.1	60.2	96.0	68.15	76.30	23.70	16.10
August	27.7	19.2	80.3	66.8	114.9	75.41	70.38	29.62	14.30
September	28.9	18.2	82.5	64.1	283.2	70.20	73.40	26.60	12.20
October	27.6	18.7	80.8	69.2	96.4	68.30	70.15	29.85	10.30
November	27.6	16.2	76.2	61.1	2.6	79.51	71.43	28.57	12.20
December	26.5	12.8	73.8	53.4	17.0	73.40	70.30	29.70	10.10
January2002	28.4	14.2	77.3	51.8	0.0	77.21	30.40	69.60	10.30
February	29.6	14.3	64.2	38.6	0.0	82.10	28.57	71.43	8.35
March	34.8	16.3	58.1	30.3	0.0	80.42	15.28	84.72	9.40
April	34.8	20.2	65.8	31.9	9.0	85.17	12.12	87.88	12.50
May	33.0	21.2	71.2	47.9	126.4	82.30	9.30	90.70	9.30
June	29.1	20.1	76.0	60.3	64.5	80.21	7.10	92.90	10.10
July	28.4	18.0	74.0	59.0	44.0	68.77	0.00	100	8.40
August	27.7	19.1	79.2	66.4	10.9	65.50	0.00	100	13.35
September	28.5	19.0	80.0	63.0	56.2	71.20	0.00	100	9.85
October	27.6	18.7	80.8	69.2	96.4	73.12	0.00	100	6.00
November	27.8	14.9	69.5	49.1	0.0	80.56	0.00	100	5.60
December	27.5	13.6	68.4	44.6	0.0	84.20	0.00	100	4.80
January2003	29.4	13.6	64.3	41.3	0.0	81.25	0.00	100	6.30
February	32.1	15.9	59.6	30.5	0.0	92.52	0.00	100	3.40

Table 164. Correlation of spiralling whitefly population with parasitism by *Encarsia* sp. nr. *meritoria* and *E. guadeloupae* and weather factors on guava at Bangalore

Variable	Y (Whitefly)
X_1 (Maximum temperature)	0.235
X_2(Minimum temperature)	-0.034
X_3 (Morning humidity)	0.434*
X_4(Evening humidity)	-0.309
X_5 (Rainfall)	-0.055
X_6 (Parasitism)	-0.837**

* Significant at P = 0.05 ** Significant at P = 0.01

A comparison of pest population in February 2000 with those in 2001,2002 and 2003 revealed that the number of whiteflies declined by 78.10, 92.92 and 97.10%, respectively, after first, second and third year, respectively, after parasitoid release on guava. A linear multiple regression model developed to express the spiralling whitefly population using abiotic and biotic factors showed that 80% of the variation could be explained (Table 165). Further, step-wise regression procedure was employed to arrive at a multiple regression model which showed that about 70% of the whitefly population could be predicted by one factor, namely parasitism by *Encarsia* spp. The weather factors remained mostly unchanged in all the three years (2000 to 2003). The only difference between these years was in the activity of the parasitoids *Encarsia* sp. nr. *meritoria* and *E. guadeloupae*, which played a major role in suppressing the spiralling whitefly.

Table 165. Stepwise regression analysis for assessing the most important factor influencing *A. dispersus* populations on guava

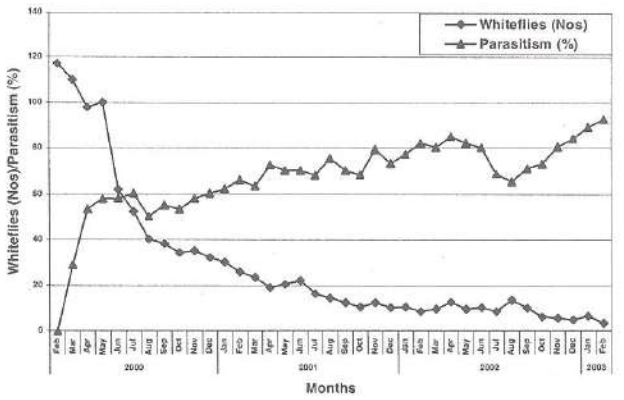
Variable	Regression Statistic		
	b	S.E. (b)	t
Dependent variable Y (Whitefly population) (Intercept a = 135.27)			
Independent variable			
X_6 (Parasitism)	-1.60	0.19	8.52**

** Significant at P = 0.01 R^2=0.70

Banana

Field studies were conducted from January 2000 to December 2001 on banana cultivar Monthan infested with spiralling whitefly at Hebbal, Bangalore North, to study the role of *E. guadeloupae* and weather factors in the suppression of spiralling whitefly. The data collected on the population of spiralling whitefly and the parasitism by *E. guadeloupae*

Fig.5 Population of spiralling whitefly in relation to parasitism by *Encarsia* spp. on guava



were subjected to statistical analysis in 2002-2003. The population of *A. dispersus* was found to be 49.85/leaf in January 2000, which had increased to 116.85/leaf in March 2000. Subsequently, the whitefly population declined to a very low level of 1.10/leaf during December 2001 (Fig. 5). During the study period, one parasitoid (*E. guadeloupae*) and six predators were collected. *E. guadeloupae* was found to be the only major natural enemy causing 20.70% parasitism in January 2000, which increased to 95.68% by December 2001 (Table 166). The density of the spiralling whitefly was positively correlated with maximum temperature and negatively correlated with relative humidity and parasitism by *E. guadeloupae*. A linear multiple regression model developed to express the whitefly population using abiotic and biotic factors showed that 81.67% of the variation could be explained (Table 167). Further, step-wise regression procedure was employed to arrive at a multiple regression model which showed that about 67.94% of the whitefly population could be predicted by one factor, namely parasitism by *E. guadeloupae*. The weather factors remained mostly unchanged in both years (2000 & 2001). The only difference between the two years was in the

Table 166. Population of spiralling whitefly in relation to weather factors and the parasitism by *E. guadeloupae* on banana in Bangalore North

Month (2000-01)	Temperature (°C)		Relative humidity (%)		Rainfall (mm)	Parasitism (%)	Whiteflies (Nos.)
	Max.	Min.	Morn.	Even.			
January	28.5	13.4	61.3	41.4	0.0	23.03	49.85
February	29.4	16.0	65.5	44.7	39.0	25.53	67.40
March	32.2	14.9	54.2	29.8	0.0	33.25	116.85
April	33.9	19.6	60.3	35.8	19.8	33.14	114.00
May	32.3	20.4	63.7	46.7	73.6	33.92	75.00
June	29.3	19.6	74.2	60.8	115.7	32.54	26.85
July	28.4	18.1	74.1	58.9	67.4	51.73	19.10
August	27.7	19.0	79.3	66.3	251.8	57.67	15.25
September	28.4	19.3	79.0	62.4	196.0	40.42	10.10
October	28.8	17.3	82.7	58.9	203.8	44.81	14.35
November	27.8	14.9	69.5	49.1	9.0	42.70	12.50
December	27.5	13.6	68.4	44.6	0.4	49.70	5.30
January	29.4	13.6	64.3	41.3	6.0	58.10	2.60
February	32.1	15.9	59.6	30.5	0.0	69.48	1.45
March	33.1	17.5	57.7	32.4	1.6	67.51	5.30
April	32.5	19.2	68.2	43.6	206.4	63.75	3.45
May	33.0	20.6	63.8	43.5	30.2	60.26	6.30
June	29.3	20.3	68.5	54.7	9.8	66.15	5.30
July	28.8	20.6	75.1	60.2	96.0	67.85	4.81
August	27.7	19.2	80.3	66.8	114.9	65.52	4.00
September	28.9	18.2	82.5	64.1	283.2	75.42	3.80
October	27.6	18.7	80.8	69.2	96.4	86.04	3.30
November	27.6	16.2	76.2	61.1	2.6	90.71	2.22
December	26.5	12.8	73.8	53.4	17.0	95.68	1.10

Table 167. Correlations of spiralling whitefly population with the parasitism by *E. guadeloupae* and weather factors on banana at Bangalore

Variable	Y (Whitefly)
X_1 (Maximum temperature)	0.235
X_1 (Maximum temperature)	0.474*
X_2(Minimum temperature)	- 0.013
X_3 (Morning humidity)	- 0.537*
X_4(Evening humidity)	- 0.463*
X_5 (Rainfall)	- 0.235
X_6 (Parasitoid)	- 0.679*

* Significant at P = 0.05

parasitism by *E. guadeloupae* from 25.53% in January 2000 to 95.68% in December 2001 which played a major role in suppressing the spiralling whitefly (Table 168).

Table 168. Step -wise regression analysis for assessing the most important factor influencing *A. dispersus* populations on banana

Variable	Regression Statistic		
	b	S.E. (b)	t
Dependent variable Y (Whitefly population) (Intercept a = 88.40)			
Independent variable X_6 (Parasitism)	-1.16	0.28	4.34**

** Significant at P = 0.01 R^2=67.94

4.24.4.2 Safety of botanicals and conventional pesticides to *E. guadeloupae* (IIHR, Bangalore)

A total of eight conventional pesticides and nine botanicals were screened for residual toxicity on the adults of *E. guadeloupae*. Mortality of adult was recorded after 24 hrs of exposure. Monocrotophos was the most persistent causing very high mortality for up to 21 days of application (Table 169). Fungicides showed less residual toxicity to the adults. Many of the botanicals proved very safe after 7 days of application

Table 169. Effects of pesticides on *Encarsia guadeloupae*

Treatments	Concentration	% Mortality (days after application)					
		1	3	7	14	21	28
	Insecticides						
Monocrotophos	0.05%	80	60	40	20	20	0
Phosphamidon	0.10%	80	40	20	0	0	0
Endosulfan	0.05%	100	40	20	20	0	0
Carbaryl	0.10%	100	100	90	50	0	0
Confidar	0.007%	60	100	20	0	0	0
	Botanicals						
NSKE	4.00%	0	0	0	0	0	0
Neem rich	2.00%	0	0	0	0	0	0
Neem oil	2.00%	40	20	0	0	0	0
Neem gold	2.00%	20	20	0	0	0	0
Nivar	2.00%	0	0	0	0	0	0
Neemazal	2.00%	20	20	0	0	0	0
Neem guard	2.00%	0	0	0	0	0	0
Nimbicidin	2.00%	20	0	0	0	0	0
Pongamia oil	2.00%	40	40	20	0	0	0
	Fungicides						
Mancozeb	0.20%	20	0	0	0	0	0
Copper oxychloride	0.20%	20	20	0	0	0	0
Dinocap	0.10%	40	20	0	0	0	0
Check(Water)	-	0	0	0	0	0	0

4.24.5. Survey on the natural enemies of spiralling whitefly (KAU, Thrissur)

Whitefly infested leaves (containing last stage nymphs) of guava and chilli were collected from the fields in Thrissur district at fortnightly/monthly intervals during April 02-March 03. Highest parasitism of 41.52% was recorded on guava during April 2002 and the lowest (1.44) during January 2003. In the case of chilli the highest parasitism recorded was 61.22 per cent during April 2002. Natural parasitism by *Encarsia* spp. was noticed throughout the period of observation. Comparatively higher parasitism was observed in chilli (7.88-61.22) than in guava (1.44-41.52).

4.24.6. Evaluation of *Metarhizium anisopliae* against mango hopper, *Idioscopus niveosparsus* (IIHR, Bangalore)

Five spore concentrations of *M. anisopliae* viz., 1.0 x 10^{10}, 1.0 x 10^{9}, 1.0 x 10^{8}, 1.0 x 10^{7} and 1.0 x 10^{6} spores/ml were evaluated against different stages of mango hopper (II, III, VI instar nymphs and adults) in the laboratory. Results showed that all the concentrations of the fungus were effective in inflicting 68.13 to 100% mortality to the hoppers in 48-72 hours of incubation (Table 170). The highest concentration of 1.0 x 10^{10} spores/ml recorded cent per cent mortality to all stages of the hoppers tested.

Table 170. Effect of *Metarhizium anisopliae* against mango hopper, *Idioscopus niveosparsus*

Treatment	Mean % mortality				Mean
	II instar	III instar	VI instar	Adults	
Fungus @ 1.0 x 10^{10} spores/ml	100.00	100.00	100.00	100.00	100.00
Fungus @ 1.0 x 10^{9} spores/ml	100.00	100.00	98.75	98.75	99.38
Fungus @ 1.0 x 10^{8} spores/ml	100.00	96.25	93.75	80.00	92.50
Fungus @ 1.0 x 10^{7} spores/ml	96.25	87.50	81.25	65.00	82.50
Fungus @ 1.0 x 10^{6} spores/ml	77.50	77.50	61.25	56.25	68.13
Control	00.00	00.00	00.00	00.00	00.00
Mean	78.96	76.88	72.50	61.25	56.25

4.24.7. Efficacy of *Bt* formulations in controlling ber borer, *Meridarches scyrocdes* (IIHR, Bangalore)

The comparative efficacy of commercial *Bt* products (Delfin, Dipel and Halt) was evaluated against *M. scyrodes* on ber. Application @ 1 kg/1 at weekly intervals was started with the peanut formation of fruits till harvest. Weekly observations were made on the percent fruit damage, till harvest. Delfin recorded the minimum damage (20.54%) followed by Dipel (32%) and Halt (35%). Application of Decis at 0.025 % was the most effective (only 1.0 per cent damage). All the treatments were found to be significantly better than control.

4.24.8. Screening of *Bt* products against Pomegranate fruit borer *D. isocrates* (IIHR, Bangalore)

The *Bt* products Halt, Dipel, Delfin, Biolep were evaluated against pomegranate fruit borer *D. isocrates*. The formulations were tested @ 1 kg/lt against the standard check treatment Decis (0.025%) and untreated control. Biolep was found to be the most effective (4.4% damage) followed by Dipel (4.5%), Halt and Delfin (10.0%) and Decis (10.2%).

4.24.9. Evaluation of *Verticillium lecanii* against *Planococcus citri* on pomegranate (IIHR, Bangalore)

Three concentrations of *V. lecanii* (1.0×10^6, 1.0×10^7 and 1.0×10^8 spores/ml with Triton X at 1 %) were evaluated against different stages of pomegranate mealy bug on pumpkins in the laboratory at 25- 28° C and 40-60% R. H. Results indicated no mortality at all the concentrations to egg, larval and adult stages. However at 80-90% R. H. and 20°C the fungus at 1×10^8 caused 100 per cent mortality of the eggs of the mealy bug.

4.24.10. Supply of natural enemies (SKUAS&T, Srinagar)

San Jose scale, *Quadraspidiotus perniciosus* parasitoids were multiplied in the laboratory and for field release. 20,423 *Aphytis procila* and 23,904 *Encarsia perniciosi* were reared in the laboratory and out of these, 18384 *Aphytis* spp. and 21969 *Encarsia* spp. were released in the field during May-October 2002.

4.24.11. Incidence of San Jose scale and wooly apple aphid and its natural enemies at different altitudes

San Jose scale

Studies were carried out in five districts of Kashmir valley and the results indicated that altitude does not play any role in the incidence of the pest and its natural enemies. However, the percent infestation of the pest at higher altitudes was comparatively lower than lower altitudes.

On San Jose scale, the predators, *Chilocorus infernalis* and *Coccinella* sp. and the parasitoid, *Aphytis* sp. and *Encarsia* spp. were recorded.

Apple woolly aphid

The apple woolly aphid population was not found during March-April and the incidence started from July onwards and ended in November 2002. Parasitism too was observed during July-November (8-20%) with the highest in the last week of August. *Aphelinus mali* and three predators, namely, *Chilocorus* sp., *Coccinella* sp. and *Pharoscymnus* sp. were found associated with the aphid. Altitude did not play any role, but trees having poor sanitation had more pest attack.

4.24.12. Biological control based IPM in apple orchards (SKUAS & T, Srinagar)

Studies were conducted to find out the effect of various dormant oils on the San Jose scale and its natural enemies. It was found that Diesel oil emulsion (1:5), D.C Tron Plus (2%) natural tree oil (2%), Ipol (25) and water did not hamper the emergence of natural enemies in the month of July.

4.24.13.Mite infestation on rajmah beans and apple leaves and their natural enemies (YSPUH&F, Solan)

Survey was conducted in Kinnaur in September-October 220, to record *Tetranychus urticae* infestation on rajmah beans, which is often grown as an intercrop in apple orchard.

At Regional Horticultural Research Station, Sharbo, the mite population cm^{-2} on leaflets varied from 12 to 27 (18±2.2 SE). Nymphs of thrips, adults and larvae of a staphylinid beetle and adult *Stethorus* beetles were seen feeding on *T. urticae*. Population of *Stethorus* sp. and unidentified staphylinid beetle was 0.1 and 0.2/leaflet, respectively. The larval population of the staphylinid was 1.6±0.95, while that of thrip nymphs and anthocorid bug was 1.9±0.094 and 0.14±0.14, respectively.

At Ribba, *T. urticae* population was 377-1655 (949±352.8), 253-905 (517±143.2) and 170-1518 (678±250) [or 6-28, 6-31 and 3-44 cm^{-2} area] on top, middle and bottom leaflets. The predator population/leaflet was quite low [0-3 (mean 0.6), 0-1 (0.2) and 0-3 (0.8) on top, middle and bottom leaflets, respectively]. On apple leaves collected from trees in the fields having rajmah beans, in addition to two spotted spider mite, the infestation of the European red mite (*Panonychus ulmi*) was also present. The population of *T. urticae* and *P. ulmi* was 2-37 (8.5±1.89) and 0-7 (1.1±0.46) mites cm^{-2}, respectively. The predator population was 0-1 (0.3±0.21)/leaflet.

At Skibba, *T. urticae* population on rajmah beans was quite high. It was 771-22.5 (1249.6±265), 420-1479 (883.9±179.7) and 435-1500 (768.9±190.1) mites per top, middle and bottom leaflet [10-44 (29±14.97), 17-34 (24.2±6.38) and 14-41 (23.4±11.03) mites cm^{-2}]. In this area, predator population per leaflet was 2-4 (2.6±0.89), 0-2 (0.8±0.83) and 0-3 (1.4±1.52). Predators were midge like larvae, nymphs of thrips and staphylinid larvae. In a small group of apple trees, live mite population was negligible but attack symptoms and a few eggs of both mite species were noticed. Such larvae had 0-3 (average 1.1) predatory mites/leaf.

4.24.14. Activity of pomegranate fruit borer and its parasitoids (YSPUH&F, Solan)

The pomegranate fruit borer *Deudorix epijarbas* was noticed in June 2002 when 4.2 per cent fruits were found infested. During June-August, 1.9-30.1 per cent fruits were infested. In July 50 percent eggs were parasitized by *Telenomus*, while in August, 83.3 per cent eggs were parasitized (equally by *Telenomus* and *Anastatus*). Releases of *Trichogramma chilonis* at two-week interval (1000 parasitized *Corcyra* eggs/tree) during July-August did not yield any positive results.

4.25 Biological suppression of vegetable crop pests

4.25.1. Survey of natural enemies of vegetable crop pests

MPKV, Pune

Field surveys for natural enemies of important pests of potato (PTM, aphids, *S. litura*), tomato (*H. armigera*), cole crops (*P. xylostella, H. armigera*, aphids), brinjal (*L. orbonalis*, mites) and okra (*Earias* spp., *H. armigera*) were undertaken throughout the crop growing seasons.

The leaf mining PTM larvae were found to be parasitized by *Apanteles* spp. and *Bracon* spp. to the extent of 2.95 – 7.04% and 4.35 – 8.56%, respectively, during kharif and rabi seasons. The coccinellids *Cheilomenes sexmaculata* and *Coccinella septempunctata* were noticed in potato fields after 35 days of planting (0.65 grub/plant), and their population peaked (3.48 grubs/plant; 2.15 beetles/plant) at 68 days after planting during kharif season. However, the coccinellids population was low (0.02 – 1.05 grubs/plant; 0.01 – 0.75 beetles/ plant) during rabi season. Syrphids were also recorded in potato fields in kharif. *S. litura* larvae were found infected with *N. rileyi* and on an average 2.15 infected larvae per plant were recorded a week before potato harvest in kharif season.

In tomato fields, NPV infected *H. armigera* larvae were found.

In cabbage and cauliflower fields, parasitism by *Cotesia plutellae* was 6.78 – 14.65% between 35 and 75 days after planting. The syrphid maggots were also recorded in the aphid colonies.

SKUAS & T, Srinagar

Larval parasitoids of *Pieris brassicae* was observed from second week of May till last week of September. *Brevicoryne brassicae* was parasitised by some unidentified parasitoids from first week of April and continued up to October maximum being in June (5%). The parasitoids have collected and sent to IARI, New Delhi for identification.

4.25.2. Management of tomato fruit borer (GAU, Anand)

Different treatments were evaluated for the management of tomato fruit borer, *H. armigera at* GAU, Anand as detailed below.

T_1: T. *pretiosum* @ 50,000 adults/ha/release five times at weekly intervals + *Ha* NPV @ 1.5 x 10^{12}/ha 3 sprays- first spray 5 days after release of parasitoids and subsequent sprays at weekly intervals.

T_2: T. *pretiosum* @ 50,000 adults/ha/release five times at weekly intervals +*Ha* NPV 1.5 x 10^{12}/ha 2 sprays – first spray 5 days after release of parasitoids and subsequent sprays at 10 days intervals.

T_3: T. *pretiosum* @ 50,000 adults/ha/release five times soon after observing eggs in the field (release tricho bits 5 m apart).

T_4: *Ha* NPV alone @ 1.5 x 10^{12} sprays/ha 5 sprays at weekly intervals.

T_5: Control

The population of *H. armigera* was very low. However, T. p. + *Ha* NPV 3 sprays was found to be superior to control and on par with the other treatments (Table 171).

Table 171. Effectiveness of different treatments against *H. armigera* on tomato

Treatments	Egg/5 Plants	Larvae/ 5 plants	Percent damage	Mean percent parasitism	Yield (q/ha)
TP+NPV 3 sprays	1.53 (1.34)	1.30 (0.69)	8.78 (2.33)	24.77	765.50
TP+ 2 sprays	1.62 (1.62)	1.51 (1.28)	11.34 (3.87)	22.94	750.50
TP alone	1.73 (1.99)	1.59 (1.53)	13.95 (5.81)	20.16	706.00
NPV alone	1.95 (2.89)	1.65 (1.72)	14.70 (6.44)	8.13	694.00
Control	2.31 (4.34)	1.89 (2. 57)	19.73 (11.40)	9.60	585.00
CD (P=0.05)	0.13	0.90	4.53	-	73.85

4.25.3. Integrated pest management of tomato fruit borer (GAU, Anand)

The IPM module against tomato fruit borer, *H. armigera* was evaluated in comparison with farmer's practice in a field trial at Anand.

I. IPM

1. Interspersing marigold with tomato
2. Inundative release of *Trichogramma chilonis* @ 1,00,000/week synchronizing with *H. armigera* oviposition in tomato.
3. Hand picking of *H. armigera* at weekly interval and placing them in field cages to facilitate escape of parasites like *Campoletis chlorideae, Eriborus* sp., *Apanteles* sp., etc.
4. Perching sites for insectivorous birds (50 perches /ha.)
5. Need based application of *Ha*NPV @ 1.5 X 10^{12} POB /ha.(250 LE / ha.)

II. NonIPM (Farmers' practice)

The population of *H. armigera* was very low in both IPM and insecticidal control (Table 172), however IPM was better than farmers' practice in all parameters.

Table 172. Effectiveness of different treatments against *H. armigera* on tomato

Treatments	IPM	Non IPM (Insecticide)
Eggs / 20 plants	1.40	1.81
Larvae / 20 plants	0.53	1.19
Percent damage	3.51	6.54
Percent parasitism	25.52	7.76
Yield q. / ha	808	736

4.25.4. Natural enemies of *Helicoverpa armigera* on tomato (YSPUH&F, Solan)

Infestation of tomato fruit borer, *H. armigera* was low on the crop transplanted in the first week of April. The incidence of *H. armigera* was negligible by 19th standard week. Two weeks later, 12.3% plants were having eggs (2.4 eggs/ infested plant) and 66.7% eggs were found parasitized by *Trichogramma chilonis*. In 23rd standard week, 9% plants were with eggs (1/plant) and only on 3% plants, young larvae were seen.

4.25.5. Evaluation of *Tr. bactrae* with other methods of control (IIHR, Bangalore)

In a field trial, NSP 4% + *T. bactrae,* Bt + *T. bactrae* and *T. bactrae* alone were evaluated against DBM on cabbage. *Trichogrammatoidea bactrae* was released @ 2.5 lakh adults per hectare. A total of 6 releases were made at weekly intervals . Three sprays of NSP and Bt were given. The results are presented in Table 173. NSP and *Bt* in combination with *T. bactrae* recorded lesser population of *P. xylostella* than *T. bactrae* alone.

Table 173. Population of diamondback moth in different treatments

Date of observation	Mean DBM/plant		
	NSP	*Bt*	*T. bactrae*
05-12-2002	0.85	0.4	0.75
13-12-2002	0.15	0.2	0.7
20-12-2002	0.8	0.65	0.95
27-12-2002	0.3	0.4	1.45
03-01-2003	0.55	0.95	1.8
10-01-2003	0.4	0.65	2.25
18-01-2003	0.3	0.35	2.1
Mean	0.48	0.51	1.43

The yield was comparatively more in NSP + *T. bactrae* treatment (40t/ha) and *Bt* + *T. bactrae* (38t/ha) treatments than with *T. bactrae* releases alone (26t/ha).

4.25.6. Control of *Leucinodes orbonalis* using *Bt* on brinjal (MPKV, Pune)

In a trial at the Research Farm of Entomology Section, College of Agriculture, Pune the commercial *Bt* product Halt was applied @ 500, 1000, 1500 and 2000 g/ha at weekly interval from flower initiation stage for controlling *L. orbonalis* and compared with endosulfan 0.07% as insecticidal check.

Three sprays of Halt @ 2 kg/ha at weekly interval starting from initiation of flowering were found to be the most effective and recorded minimum fruit infestation (4.49%) and maximum marketable fruit yield (149.9 q/ha). It was, however, on par with lower dose of 1.5 kg/ha (Table 174).

Table 174. Efficacy of *B. thuringiensis* against *L. orbonalis* on brinjal

Treatment	Fruit infestation (%)	Yield of marketable fruits (q/ha)
B. thuringiensis @ 500 g/ha	12.34 (20.51)	108.0
B. thuringiensis @ 1000 g/ha	10.10 (18.51)	123.5
B. thuringiensis @ 1500 g/ha	6.35 (14.53)	141.9
B. thuringiensis @ 2000 g/ha	4.49 (12.16)	149.4
Endosulfan 0.07%	18.31 (25.32)	110.4
Untreated control	30.45 (33.44)	82.1
CD (P=0.05)	(0.83)	4.01

Figures in parentheses are angular transformations

4.26 Biological suppression of potato pests (MPKV, Pune)

4.26.1. Standardization of mass release technology for parasitoids *Copidosoma koehleri* and *Chelonus blackburni* against PTM under field conditions

An experiment was conducted in farmers' filed at village Peth (Dist. Pune) for three consecutive years during *rabi* 1999 to 2002 on potato var. Kufri Jyoti. The parasitoids were released as mummies/pupae placed in perforated plastic vials or gelatinous capsules and as adults.

Pooled analysis of three years data revealed that releases of *C. koehleri* @ 5,000 mummies/ha in four equal doses at weekly interval in perforated plastic vials (2 x 1.5 cm size) hung 5 m apart in potato field 45 days after planting (DAP) recorded minimum PTM leaf mines (0.29 mines/m row), least tuber infestation (5.92%), maximum recovery (19.86%) and higher tuber yield (231.03 q/ha) (Table 175). However, releases of adults showed higher benefit-cost ratio (1:23.08) but additional returns were comparatively lower (Table 176). Hence, the former method of release was tested on large area of potato during rabi 2002-2003 and found effective against PTM (Table 177).

Table 175. Economics of parasitoid use for the control of PTM on potato

Treatment	Cost of treatments			Increase in yield over control	Additional receipt due to treatment (q/ha)	ICBR (Rs.)
	Parasitoids+ materials/ ha (Rs.)	Labour Charges (Rs.)	Total cost (Rs.)			
C. koehleri @ 5000 mummies/ ha in plastic vials	1150	200	1350	70.5	24675	1:18.28
C. koehleri @ 5000 mummies/ ha in gel. capsules	1375	200	1575	47.24	16534	1:10.50
C. koeheri @ 2 lakh adults/ha	750	200	950	62.64	21924	1:23.08
C. blackburni @ 60,000 pupae/ ha in plastic vials	1710	200	1910	66.77	23370	1:12.24
C. blackburni @ 60,000 pupae/ ha in gel. Capsules	1935	200	2135	34.7	12145	1:5.69
C. blackburni @ 60,000 adults/ha	1310	200	1510	59.2	20720	1:13.72
Untreated control	–	–	–	–	–	–

Cost of treatments:

1. *C. koehleri* (2 lakh adults or 5000 mummies/ha) = Rs. 750
2. *C. blackburni* (60,000 adults or pupae/ha) = Rs.1310
3. Cost of perforated plastic vials (Re.1/vial x 400 vials/ha) = Rs.400
4. Cost of gel. capsules (Re.0.25/capsule x 2500 capsule/ha) = Rs.625
5. Labour charges Rs.100/-per man-day (0.5 labour man day/application x 4 rel.)
6. Potato = Rs.350/q

Table 176. Evaluation of mass release technique of *Copidosoma koehleri* against PTM

Treatment	Leaf mines/m row*		Parasitism through recovery ** (%)	Tuber ** infestation (%)	Marketable tuber yield (q/ha)
	Pre-count	Post-count after four releases			
C. koehleri @ 5000 mummies/ ha in perforated plastic vials	2.58 (1.75)	0.64 (1.08)	23.51 (28.82)	5.44 (13.38)	201.5
Control	2.42 (1.70)	2.97 (1.85)	1.60 (4.51)	23.95 (29.22)	149.6
CD (P=0.05)	(NS)	(0.12)	(4.35)	(2.19)	15.51

Figures in parentheses are * $\sqrt{x+0.5}$ and ** angular transformations

Table 177. Efficacy of different methods of release of parasitoids against PTM on potato under field conditions (pooled means of three years – 1999-2000 to 2002-2003)

Treatment	Pre-count	Leaf mines/m row* Post-count, after weeks from initial release				Parasitoid recovery	% parasitism of PTM larvae (%)	Av tuber infestation ** q/ha	Tuber yield
		I	II	III	IV				
C. koehleri @ 5000 mummies/ha in plastic vials	2.52 (1.71)	2.40 (1.67)	1.55 (1.41)	0.80 (1.10)	0.29 (0.88)	64.34	19.86	5.92 (14.06)	231.03
C. koehleri @ 5000 mummies/ha in gelatinous capsules	2.35 (1.65)	2.58 (1.72)	1.84 (1.51)	1.15 (1.25)	0.69 (1.07)	57.99	13.28	9.42 (17.83)	207.77
C. koehleri @ 2 lakhs adults/ha	2.47 (1.68)	2.62 (1.74)	2.00 (1.55)	0.98 (1.18)	0.65 (1.05)	63.16	15.15	6.89 (15.21)	223.17
C. blackburni @ 60,000 pupae/ha in plastic vials	2.36 (1.66)	2.40 (1.65)	1.38 (1.35)	0.78 (1.11)	0.38 (0.93)	60.45	17.70	6.61 (14.90)	227.30
C. blackburni @ 60,000 pupae/ha in gelatinous capsules	2.31 (1.65)	2.51 (1.70)	1.82 (1.49)	1.11 (1.24)	0.89 (1.16)	49.19	9.06	11.15 (19.48)	195.23
C. blackburni @ 60,000 adults/ha	2.40 (1.67)	2.55 (1.72)	1.62 (1.43)	0.97 (1.18)	0.49 (0.98)	62.43	15.17	7.35 (15.73)	219.73
Untreated control	2.39 (1.68)	2.78 (1.77)	4.02 (2.06)	4.00 (2.05)	2.69 (1.73)	–	–	– (32.23)	160.53
CD (P=0.05)	NS	(0.072)	(0.23)	(0.26)	(0.17)			(1.43)	8.66

Figures in parentheses are * $\sqrt{x+0.5}$ and ** angular transformations

4.26.2. Evaluation of release methods of parasitoids, *C. koehleri* and *Chelonus blackburni* and microbial agents against PTM on potato in country stores (*Arnies*)

Release of parasitoids and microbials for PTM control in country stores was evaluated. Release of *C. koehleri* @ 1 mummy/4 kg tubers and *C. blackburni* @ 2 adults/kg tubers at 15 days interval was found to be the most effective method of release for parasitoids in *Arnies*. The application of *Bt* @ 1g/kg of tubers at 30 DAT was on par with *C. koehleri*. Disease development by application of GV was found to be 44.95% (Table 178).

Table 178. Evaluation of release methods of parasitoids and microbial agents against PTM in country stores (*Arni)* of potato

Treatment	% tuber infestation after		Parasitism/ Disease development (%)
	30 DAT	75 DAT	
C. koehleri @ 5 pairs/ kg tubers	13.71 (21.69)	24.92 (29.95)	33.20
C. koehleri @ 1 mummy/4 kg tubers	13.34 (21.41)	23.83 (29.16)	36.86
C. blackburni @ 2 adults/kg tubers	14.50 (22.38)	26.31 (30.82)	34.93
C. blackburni @ 2 pupae/kg tubers	15.00 (22.79)	28.21 (32.04)	26.61
GV @ 6x10^9 OBs /kg tubers	16.63 (24.03)	33.73 (35.52)	44.95
Bt @ 1 g/kg tubers	14.44 (22.32)	29.99 (33.18)	24.16
Untreated Control	24.33 (29.53)	43.53 (41.26)	–
CD (P=0.05)	(2.36)	(3.34)	

Figures in parentheses are angular transformations

4.26.3. Evaluation of plant foliage powders on parasitism by *C. koehleri* and PTM emergence

Effect of finely ground foliage powders of *Vitex negundo*, lantana and neem on *C. koehleri*, per cent parasitism and emergence of PTM adults was studied in the laboratory. Amongst the plant foliage powders tested against *C. koehleri* for their toxicity at 24, 48 and 72 hrs after exposure, *V. negundo* 5% w/w was observed to be comparatively safer and recorded higher parasitism of 18.50% (Table 179).

Table 179. Effect of plant foliage powders on parasitism of *C. koehleri* and PTM emergence

Treatment	% Mortality of *C. koehleri* at			% parasitism due to *C. koehleri*	% PTM emergence
	24 hr	48 hr	72 hr		
C. koehleri alone @ 5 pairs/ kg tubers	–	–	–	62.67	25.50
C. koehleri @ 5 pairs/kg tubers + *Vitex negundo* (5% w/w)	40.0	20.0	10.0	18.50	33.65
C. koehleri @ 5 pairs/kg tubers + *Lantana camara* (5% w/w)	50.0	30.0	10.0	12.25	32.60
C. koehleri @ 5 pairs/kg tubers + *Azadirachta indica* (5% w/w)	40.0	20.0	20.0	13.75	30.85'
Paddy straw (5% w/w)	–	–	–	–	45.67

Observations are based on five replications

4.26.4. Evaluation of different entomopathogens against *Spodoptera litura* on potato

Application of *Sl*NPV @ 3 x 10^{12} POBs/ha was found most effective against *S. litura* in potato field with minimum surviving larvae/plant (0.19) and tuber infestation (11.40%) and maximum larval mortality (87.50%) and yield of marketable tubers (203.0q/ha) (Table 180).

Table 180. Efficacy of different entomopathogens against *S. litura* on potato

Treatment	Mean no. of larvae/plant*		Larval ** mortality (%)	Tuber ** infestation (%)	Yield (q/ha)
	Pre-count	Post-count			
*Sl*NPV @ $3x10^{12}$ POBs/ha	0.60 (1.04)	0.19 (0.83)	87.50 (72.11)	11.40 (19.68)	203.0
B. thuringiensis (Delfin WG) @ 0.5 kg/ha	0.62 (1.06)	0.30 (0.89)	77.50 (62.14)	15.69 (23.24)	195.6
B. bassiana @ $1x10^{12}$ conidia /ha	0.59 (1.04)	0.46 (0.97)	42.50 (40.67)	22.06 (27.98)	182.6
N. rileyi @ $1x10^{12}$ conidia/ha	0.77 (1.12)	0.31 (0.90)	55.00 (47.95)	19.45 (26.11)	192.8
Endosulfan 0.07%	0.64 (1.06)	0.34 (0.91)	57.50 (49.39)	19.95 (26.48)	186.1
Untreated control	0.67 (1.08)	0.86 (1.16)	15.00 (22.52)	35.60 (36.61)	151.0
CD (P=0.05)	(NS)	(0.06)	(12.32)	(3.59)	15.27

4.27 Biological suppression of weeds

4.27.1. Biological control of water hyacinth by *Neochetina eichhorniae* and *N. bruchi*

AAU, Jorhat

Successful control of water hyacinth has been achieved by the exotic weevils *Neochetina eichhorniae* and *N. bruchi* at Alengmara, Disangmukh and Samuguri. The adult count varied from 1.04 to 3.16 and damage scars from 29.16 to 87.52.

ANGRAU, Hyderabad

A trial was carried out to assess the effect of *N. eichhorniae* weevil and *O. terebrantis* mite on water hyacinth. Two thousand weevils (*N. eichhorniae*) and 2000 mites (*O. terebrantis*) supplied by PDBC, Bangalore were released in four ponds in two villages, viz., Hassan Nagar and Talabkatta near Hyderabad @ 500/pond separately in July 2002.

The average damage caused by weevils was 15.35 in September, 2002 and 27.50 in March 2003. The weevil population increased from 0.93/plant in September 2002 to 2.75/

plant in March, 2003. The mite population also increased from 17.13/plant in September 2002 to 34.51/plant in March 2003.

GAU, Anand

The weevils have adapted to the new environment very well as evidenced by the presence of the larvae and adults in the bulbs as well as fresh damage observed on the leaves. The adult count of *N. eichhorniae* and *N. bruchi* varied from 1.7 to 3.8 and 2.0 to 4.7 per plant, respectively during different periods. The number of scars was found to vary from 75 to 260 per leaf during 2002-03.

KAU, Thrissur

Samples of water hyacinth were drawn from three locations in two districts during June 02-March 03 and the weevils were present in all the locations (0.9 to 5.6 per plant). Mite populations/leaf ranged from 40.6 to 135.44 and mines/leaf varied from 2.52 to 3.36.

MPKV, Pune

Two ponds with water hyacinth were selected and 2000 adults of *Neochetina* spp. and 40 leaves containing mites, *O. terebrantis* were released in the first week of April 2002.

The damage to leaves due to the weevils increased from 13.75 in June 2002 to 39.20% in March 2003, with increase in weevil in population from 1.05 to 3.20 weevils/plant. The mite population also increased from 15.48 to 68.50 mites/leaf during this period.

PAU, Ludhiana

The weevils collected from a pond near Ludhiana were released at four locations in four districts during 2002. Their impact was not evaluated as weeds had dried due to drought and extreme winter.

4.27.2. Management of *Parthenium hysterophorus* using *Zygogramma bicolorata*

KAU, Thrissur

Two fifty adults of *Z. bicolorata* received during April 2002 from PDBC, Bangalore were released in Thrissur district, during August 02, 1500 beetles were released in three areas of Thrissur district, but they didn't establish in the released areas. A survey was conducted at Palghat district during November 2002 and 15 beetles were collected.

PAU, Ludhiana

Two hundred and fifty adults of *Z. bicolorata* were released in one acre area near Mehli (Distt. Nawanshahr) on 17-09-2003. The released field had uniform growth of *Parthenium* and was undisturbed. After one month, no life-stage of the beetle was found on the plants which had nearly dried due to the drought and later due to the extreme winter. The fresh growth of weed has started in March 2003 but the beetle was not found there.

YSPUH&F, Solan

At Nauni, field activity of the beetle was noticed only in third week of July, though adults started appearing from diapausing population in the first week of February 2003 in the laboratory. Oviposition commenced within a week and continued till August end and scattered egg laying was seen in September. Beetles reared in the laboratory were released at two spots where these were not present. At one location, recovery was 32% after 9 days of release and 26.7% after 17 days in September.

In October 2002, a survey was carried out in three districts of Himachal Pradesh, *viz.*, Kangra and Una (subtropical submontane region) and Solan (subtemperate and subhumid mid hill region) at 90-1200 m altitude. The beetle was present in three locations, *viz.*, Pragpur and Jwalaji in Kangra district and Una in Una district. In Kangra, 13.7 and 29.3% plants were attacked at Pragpur and Jwalaji, respectively, whereas in Una, 53.1% plants were attacked. Population of the beetle and its developing stages per plant was 1.7, 2.5 and 6.5, respectively, at these three locations.

Usually in patches where *Mirabilis jalapa* growth occurred, there was no growth of the weed.

4.27.3. Monitoring and evaluation of *Cyrtobagous salviniae* on *Salvinia molesta* (KAU, Thrissur)

Sampling of *Salvinia* plants was done from seven locations from Thrissur and one location from Ernakulam district during June 02-March 03. Weevils were present in all the locations except at Vytilla. Very thick mat was observed at Vytilla. The weevil population was 0.30-8.30 in different locations.

4.27.4. Survey and quantification of natural enemies of *Mimosa rubicaulis* subsp. *himalayana* (AAU, Jorhat)

Mimosa rubicaulis subsp. *himalayana* (Family: Mimosaceae), a thorny creeper is occupying most of the grazing areas of Kaziranga National Park, Assam. At present about 50 hectares of grazing areas are occupied by this weed in different forest ranges like Kohora, Bagori, Aromora, Agaratali, etc. The weed is spreading and causing drastic reduction of grazing land for wild herbivores such as rhinoceros, deer, buffalo and elephants in Kaziranga National Park. It also climbs over hedges and tall trees in forest hedge plants, tea gardens, orchids, etc.

This weed is very difficult to control manually because of its thorny structure and chemical control at the Kaziranga National Park is not possible. An attempt was made to survey the natural enemies of this weed at Kaziranga National Park. Only *Atractomorpha crenulata* has been recorded so far, but no damage symptoms were observed due to feeding.

5. TECHNOLOGY ASSESSED AND TRANSFERRED

5.1. Technology assessed

5.1.1 Mass production of natural enemies of coconut leaf eating caterpillar

Technology for mass production of *Goniozus nephantidis* and training on release techniques for control of coconut leaf eating caterpillar has been imparted.

5.1.2 Standardization of mass release technology for *Goniozus nephantidis* under field conditions

Technology for release of *Goniozus nephantidis* by releasing on the trunk against coconut leaf eating caterpillar was assessed and standardized.

5.1.3 Superior strains selection of parasitoids

Superior strains selected for multiple resistance heat tolerant and host searching ability of *Trichogramma chilonis* was assessed at different agro-climatic regions for the control of cotton bollworm

5.1.4 Evaluation of improved strains of *Nomuraea rileyi*

Improved strains of *Nomuraea rileyi* were assessed in different locations for control of pests in groundnut and cotton.

6. EDUCATION AND TRAINING

6.1 Education

Ms. Rinku Verma submitted Ph.D. thesis entitled, "Biological suppression of water hyacinth in relation to pollution levels and its environmental impacts" to Mysore University, Mysore, in November, 2002.

6.2 Training

Mr. P. K. Sonkusare, Technical Officer (T-5) attended a training programme on "SPSS" from 27th May to 1st June 2002 at Indian Agricultural Statistics Research Institute, New Delhi

Dr. S. Ramani, Senior Scientist attended a refresher course on "Information Technology in Agriculture" from 12th June to 2nd July 2002 at National Academy of Agricultural Research Management, Hyderabad

Mr. Satendra Kumar, Technical Officer (T-5) attended a workshop-cum-training programme in Hindi from 18th to 22nd June 2002 at National Academy of Agricultural Research Management, Hyderabad

Ms. I. M. Dautie, Assistant Administrative Officer and Mr. Ajit Desai, Cashier attended a training programme on "Computer Applications for Administrative and Financial Management" from 17th to 27th July 2002 at National Academy of Agricultural Research Management, Hyderabad

Mr. P. K. Sonkusare, Technical Officer (T-5) and Mr. P. Vanaraju, Assistant attended a training programme on "Financial Management System" from 9th – 10th September 2002 at University of Agricultural Sciences, Bangalore

Dr. N. Bakthavatsalam, Senior Scientist attended a training programme on "Safety aspects in the research applications of Ionising Radiations" from 23rd September to 1st October 2002 at Centre for Training and Certification in Radiological Safety (CT&CRS), Anushaktinagar, Mumbai

Dr.(Ms.) Chandish R. Ballal, Senior Scientist attended a training programme on "Biocontrol in IPM" from 6th – 26th November 2002 at Centre of Advanced Studies in Entomology, Tamil Nadu Agricultural University, Coimbatore.

Dr. Prashanth Mohanraj, Senior Scientist attended a training programme on "Biocontrol in IPM" from 6th – 26th November 2002 at Centre of Advanced Studies in Entomology, Tamil Nadu Agricultural University, Coimbatore.

Dr. B. Ramanujam, Senior Scientist attended a refresher course on "Information Technology in Agriculture" from 3rd – 23rd December 2002 at National Academy of Agricultural Research Management, Hyderabad.

Dr. T. Venkatesan, Scientist SS attended a refresher course on "Information Technology in Agriculture" from 3rd – 23rd December 2002 at National Academy of Agricultural Research Management, Hyderabad.

Dr. N. S. Rao, Principal Scientist attended a training programme on "Development of Instructional Material on Multimedia" from 6th - 15th January 2003 at CSA University of Agriculture and Technology, Kanpur.

7. AWARDS AND RECOGNITIONS

Dr. M. Nagesh, Dr. S. S. Hussaini and Dr. S. P. Singh were presented the best paper award in poster session for their paper, "Toxicity of cell-free culture filtrates of *Xenorhabdus* and *Photorhabdus* spp. of symbiotic bacteria to some Lepidopteran larvae" during the Symposium on Biological Control of Lepidopteran Pests held in Bangalore on 17th & 18th July 2002

8. LINKAGES AND COLLABORATION IN INDIA AND ABROAD INCLUDING EXTERNAL PROJECTS

8.1. NATP funded project entitled "Team of Excellence for Human Resource Development in Biological Control" with a total budget of Rs.86.17 lakhs for a period of four years from 1999-2000 to 2002-2003. The project is operative at Project Directorate of Biological Control, Bangalore, and the clients are scientists from various State Agricultural Universities, traditional universities and ICAR Institutes. This project will have linkage with all the institutes interested in biocontrol of crop pests and weeds.

8.2. NATP funded project entitled "Development of bio-intensive IPM modules in chickpea against *Helicoverpa armigera,* wilt and dry root rot" with a budget of Rs.24.60 lakhs for a period of four years from 2000-01 to 2002-2003. The project is operative at Indian Institute of Pulses Research, Kanpur, and Project Directorate of Biological Control, Bangalore, is one of the co-operating centres.

8.3. NATP funded project entitled "Control of leaf curl viral disease in cotton and development of protocols for mass multiplication of predators, parasites and insect pathogens" with a budget of Rs.6.44 lakhs for a period of three years from 1999-2000 to 2002-2003. The project is operative at Central Institute for Cotton Research, Nagpur, and Project Directorate of Biological Control, Bangalore, is one of the co-operating centres.

8.4. NATP funded project entitled "Development of an integrated pest management package for the eriophyid mite, *Aceria guerreronis* (Keifer) of coconut in the southern states" with a budget of Rs.12.34 lakhs for a period of three years from 2000-01 to 2002-2003. The project is operative at Tamil Nadu Agricultural University, Coimbatore, and Project Directorate of Biological Control, Bangalore, is one of the co-operating centres.

8.5 NATP funded project entitled "Development of IPM modules for oilseeds and nutritious cereals based production system" with a budget of Rs.15.31 lakhs for a period of three years from 2000-01 to 2002-2003. The project is operative at National Centre for Integrated Pest Management, New Delhi, and Project Directorate of Biological Control, Bangalore, is one of the co-operating centres.

8.6. NATP funded project entitled "Validation and promotion of IPM Technology in selected crops in different agro-ecological regions" with a total budget of Rs.33.94 lakhs for a period of two years and nine months (up to 31-12-2003). The project is operative at National Centre for Integrated Pest Management, New Delhi, and Project Directorate of Biological Control, Bangalore, is one of the co-operating centers. The clients are the staff from various co-operating centers of the project and Plant Protection Officers from KVKs. This project will have linkage with all the institutes interested in biocontrol of pests of cotton, pigeon pea, chickpea, groundnut, tomato, cabbage, mango and apple.

8.7. NATP (CGP) funded project entitled "Isolation of baculoviruses from larval Arctiidae (Lepidoptera) and standardization of mass production techniques of promising entomopathogenic strains" with a budget of Rs.18.28 lakhs for a period of three years from 2002-03 to 2004-2005.

8.8. NATP (CGP) funded project entitled "Improvement of formulation technology for entomopathogenic nematodes" with a budget of Rs.22.96 lakhs for a period of three years from 2002-03 to 2004-2005.

8.9. Based on the linkage developed, Coconut Board gave a further financial assistance of Rs.13.31 lakhs in the second phase for bioefficacy and biosafety tests and generation of data for registration of "Mycohit".

8.10. A linkage has been developed with Ministry of Agriculture, DARE, for mass production of quality biocontrol agents/biopesticides with a financial assistance of 483.00 lakhs with five centers and Project Directorate of Biological Control, Bangalore as the lead centre.

8.11. A linkage has been developed with Ministry of Agriculture, DAC, under Technology Mission on Cotton for development and evaluation of location specific IPM modules and for development of efficient strains with a financial assistance of 20.10 lakhs. The project is operative at Central Institute for Cotton Research, Nagpur and Project Directorate of Biological Control, Bangalore is one of the co-operating centres.

8.12. ICAR Cess funded project entitled, "Development of commercial formulations of antagonistic fungi (*Paecilomyces lilacinus* and *Pochonia chlamydosporium*) for biological control of *Meloidogyne incognita* and *Rotylenchulus reniformis*" with a budget of Rs.14.60 lakhs for a period of three years from 2002-2003 to 2004-2005. The project is operative at Project Directorate of Biological Control, Bangalore.

8.13. ICAR Cess funded project entitled, "Evolving and testing superior stains of *Steinernema* sp. and *Heterorhabditis* sp. against *Spodoptera litura* in field" with a budget of Rs.14.10 lakhs for a period of three years from 2002-2003 to 2004-2005. The project is operative at Project Directorate of Biological Control, Bangalore.

8.14. DBT funded project entitled, "Isolation, purification and characterization of novel insecticidal toxins from *Photorhabdus luminescens* and *Xenorhabdus* spp. of bacteria from entomopathogenic nematodes" with a budget of Rs.30.69 lakhs for a period of three years from 2002-2003 to 2004-2005.

9. AICRP / COORDINATION UNIT / NATIONAL CENTRES

With a view to fulfill the mandate given, the Project Directorate has divided the workload among six ICAR Institute based and ten State Agricultural University (SAUs) based co-ordinating centres based on infra-structural facilities and expertise available as follows:

Headquarters

Project Directorate of Biological Control, Bangalore (Karnataka) - Basic Research

ICAR Institute based centres

Central Plantation Crops Research Institute, Regional Station, Kayangulam (Kerala) - Coconut

Central Tobacco Research Institute, Rajahmundry (Andhra Pradesh) - Tobacco

Indian Agricultural Research Institute, New Delhi - Basic Research

Indian Institute of Horticultural Research, Bangalore (Karnataka) - Fruits & vegetables

Indian Institute of Sugarcane Research, Lucknow (Uttar Pradesh) - Sugarcane

Sugarcane Breeding Institute, Coimbatore (Tamil Nadu) - Sugarcane

State Agricultural University based centres

Assam Agricultural University, Jorhat (Assam) - Rice and weeds

Acharya N.G.Ranga Agricultural University, Hyderabad (Andhra Pradesh)	- Pulses, cotton, oilseeds, coconut & weeds
Govind Ballabh Pant University of Agricultural and Technology, Pantnagar (Uttar Pradesh)	- Plant diseases - antagonists
Gujarat Agricultural University, Anand (Gujarat)	- Cotton, pulses, vegetables & weeds
Kerala Agricultural University, Thrissur (Kerala)	- Weeds, rice, fruits & coconut
Mahatma Phule Krishi Vidyapeeth, Pune (Maharashtra)	- Potato, weeds, rice, vegetables, sugarcane and cotton
Punjab Agricultural University, Ludhiana (Punjab)	- Sugarcane, cotton, weeds, oilseeds, rice, & vegetables
Sher-E-Kashmir University of Agricultural Sciences & Technology, Srinagar (J & K)	- Temperate fruits & vegetables
Tamil Nadu Agricultural University, Coimbatore (Tamil Nadu)	- Rice, cotton, pulses, oilseeds, coconut & weeds
Dr.Y.S.Parmar University of Horticulture & Forestry, Solan (Himachal Pradesh)	- Fruits, vegetables & weeds

GENERAL / MISCELLANEOUS

10. LIST OF PUBLICATIONS

10.1 Publications in scientific journals

Project Directorate of Biological Control, Bangalore

Ballal, C. R. and Singh, S. P. (2003) The effectiveness of *Trichogramma chilonis* Ishii, *Trichogramma pretiosum* Riley and *Trichogramma brasiliense* (Ashmead) (Hymenoptera: Trichogrammatidae) as parasitoids of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) on sunflower (*Helianthus annuus* L.) and redgram (*Cajanus cajan* (L.) Millsp.). *Biocontrol Science and Technology,* **13:** 231-240.

Bajpai, N. K., Ballal, C. R., Singh, S. P. and Srinivasan, R. (2002). Net house studies on performance of *Campoletis chlorideae* on *Helicoverpa armigera* larvae infesting chickpea. *Indian Journal of Applied Entomology,* **16** (1): 22-24.

Bajpai, N. K., Ballal, C. R., Singh, S. P. and Rao, N. S. (2002) Preference of *Trichogramma chilonis* to *Helicoverpa armigera* in soybean ecosystem. *Indian Journal of Applied Entomology,* **16**(2): 35-37.

Bhumannavar, B. S. and Viraktamath, C. A. 2001. Rearing techniques for three species of *Othreis* (Lepidoptera: Noctuidae) and their ectoparasitoid, *Euplectrus maternus* Bhatnagar (Hymenoptera: Eulophidae). *Journal of Biological Control,* **15**(2): 189-192.

Bhumannavar, B. S. and Viraktamath, C. A. 2002. Biology, adult feeding, oviposition preference and seasonal incidence of *Othreis materna* (Linnaeus) (Lepidoptera: Noctuidae). *Entomon,* **27**(1): 63-78.

Biswas, D., Narayanan, K., and Chakraborty, M. 2002. Use of plant extract for the control of greater wax moth *Galleria mellonella. Biopesticide News,* **6**(2): 3-4.

Gopalakrishnan, C., Narayanan, K. and Anusuya, D. 2002. Determination of LD_{50} and LT_{50} of *Paecilomyces farinosus* (Holmskiold) Brown and Smith on larval instars of *Plutella xylostella* L. *Entomon,* **27** (3): 249-254 (2002).

Hussaini, S.S., Singh, S.P., Parthasarathy, R. and Shakeela V. 2002. Determination of dosage levels of *Steinernema bicornutum* and *Heterorhabditis indica* for *in vitro* use against *Agrotis ipsilon* Hufnagel (Noctuidae : Lepidoptera) *Entomon,* **27**: 313-317.

Hussaini, S.S., Singh, S.P. and M.Nagesh. 2002. *In vitro* and field evaluation of some indigenous isolates of *Steinernema* and *Heterorhabditis indica* against shoot and fruit borer, *Leucinodes orbonalis. Indian Journal of Nematology,* **32**: 63-65.

Hussaini, S.S., Singh, S.P., Parthasarathy, R. and Shakeela V. 2002. *In vitro* production of entomopathogenic nematodes in different artificial media. *Indian Journal of Nematology,* **32:** 44-46.

Hussaini, S.S., Nagesh, M. and Singh, S.P. 2002. Influence of total protein and lipids of the host insect larvae on yield and infectivity of *Steinernema carpocapsae* and *Heterorhabditis indica. Pest management in Horticultural Ecosystems,* **8**: 33-37.

Jalali, S. K. and Singh, S. P. 2001. Maize stalk borer *Chilo partellus* Swinhoe and its management in fodder maize. *Indian Farming,* **51**: 17 – 19.

Jalali, S. K. and Singh, S. P. 2002. Seasonal activity of stem borers and their natural enemies on fodder maize. *Entomon*, **27**: 137-146.

Jalali, S.K., Singh, S.P. and Venkatesan, T. 2002. Natural enemies of cotton bollworms in sprayed fields in different states of India. *National Journal of Plant Improvement*, **4**:

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11. LIST OF APPROVED ONGOING PROJECTS

Basic Research

Project Directorate of Biological Control, Bangalore

1. Biosystematic studies on predatory coccinellids
2. Biosystematic studies on Indian Tachinidae
3. Introduction and studies on exotic natural enemies of some important crop pests and weeds
4. Development of interactive identification key for important families of insect parasitoids and predators
5. Rearing and evaluation of natural enemies with special reference to scelionid, braconid, ichneumonid and anthocorid groups
6. Development of mass production techniques for dipteran (Diptera: Cecidomyiidae) and acarine (Arachnida: Acarina) predators for use in biological control programmes
7. Herbivore induced plant synomones and their utilization in enhancement of the efficiency of natural enemies
8. Host derived kairomones to enhance the efficiency of natural enemies
9. Development and use of insect viruses for the management of major pest complex of cruciferous crops
10. Development of improved formulations of NPV for management of *Helicoverpa armigera* and *Spodoptera litura* in tomato
11. Biocontrol of insect pests using entomopathogenic fungi and development of mycoinsecticides

12. Mass production, formulation and field testing of entomopathogenic nematodes against important lepidopteran pests

13. Biological suppression of plant parasitic nematodes exploiting antagonistic fungi and bacteria in specific cropping systems

14. Survey, identification and utilization of plant pathogens for the biological control of weeds with particular reference to parthenium and water hyacinth

15. Development and evaluation of improved strains of trichogrammatids, *Cheilomenes sexmaculata* and *Chrysoperla carnea* tolerant to insecticides, temperature and high host searching ability

16. Development and formulation of artificial diets for the rearing of coccinellids and anthocorids

17. Development and evaluation of artificial diets for *Opisina arenosella* and *Plutella xylostella* and studies on host-parasitoid interrelations

18. Software development for identifying and suggesting biosuppression measures for different crop pests using personal computer

19. Knowledge base system of *Helicoverpa armigera* and its natural enemies

Indian Agricultural Research Institute, New Delhi

1. Basic studies and maintenance of *Bacillus thuringiensis* strains

2. Studies on formulations of microbial pesticides - based on baculoviruses and *Bacillus thuringiensis*

G.B. Pant University of Agriculture and Technology, Pantnagar

1. Development of mixed formulation of *Pseudomonas fluorescens* and *Trichoderma harzianum*

2. Biodiversity in antagonistic *Trichoderma* and *Pseudomonas*

3. Studies on methods for bio-priming of seeds of different crops

4. Field demonstrations

At Co-ordinating Centres

Biological suppression of crop pests and weeds

Central Plantation Crops Research Institute, Kayangulam

Coconut

1. Field testing of *Hirsutella thompsonii* formulations supplied by PDBC against coconut mite
2. Studies on seasonal incidence of *Opisina* and natural enemy population

Central Tobacco Research Institute, Rajahmundry

Tobacco

1. Biointensive integrated pest management of *Helicoverpa armigera* in irrigated FCV (NLS) tobacco
2. Identification and utilization of bio-control agents of *Spodoptera exigua* an emerging pest of solanaceous crops

Indian Institute of Horticultural Research, Bangalore

Tropical and Subtropical Fruit Crops

1. Survey for the natural enemies of spiralling whitefly
2. Colonization of *Encarsia* sp. against spiralling whitefly
3. Evaluation of *Trichogramma chilonis* against pomegranate and ber fruit borers
4. Evaluation of *Bt* formulations against ber and pomegranate fruit borers
5. Evaluation of *Verticillium lecanii* against mango leafhoppers and pomegranate mealybugs

Vegetables

1. Survey for natural enemies of vegetable crop pests
2. Evaluation of *Trichogrammatoidea bactrae* against *Plutella xylostella* on cabbage
3. Control of *Leucinodes orbonalis* using *Bacillus thuringiensis* on brinjal
4. Evaluation of EPN against brinjal shoot and fruit borer, *Leucinodes orbonalis* on brinjal

Indian Institute of Sugarcane Research, Lucknow

Sugarcane

1. Large scale demonstration of *Trichogramma chilonis* against early shoot borer

Sugarcane Breeding Institute, Coimbatore

Sugarcane

1. Survey and seasonal fluctuation studies of natural enemies of borers
2. Large scale demonstration of *Trichogramma chilonis* against early shoot borer
3. Evaluation of *Beauveria brongniartii* against white grubs

Assam Agricultural University, Jorhat

Rice

1. Survey and relative abundance of natural enemy complex in rice
2. Field evaluation of integrated use of *Trichogramma japonicum, T. chilonis* and *Bacillus thuringiensis* against rice stem borer and leaf folder
3. Evaluation of biocontrol based IPM in Rice
4. Development of rearing techniques for key natural enemies of rice hispa and screening insecticides against them

Weeds

1. Assessment of impact of *Neochetina eichhorniae, N. bruchi* and *Orthogalumna terebrantis* in suppressing water hyacinth
2. Survey and quantification of natural enemies of *Mimosa rubicaulis* sub sp. *himalayana*

Acharya N. G. Ranga Agricultural University, Hyderabad

Cotton

1. Biointensive integrated pest management of cotton pests
2. Identification of host plants harbouring arthropod natural enemies

Pulses

1. Effect of entomopathogenic nematode *Heterorhabditis* sp. against *Mylabris pustulata* and *Helicoverpa armigera* in pigeonpea

2. BIPM in pigeonpea with special reference to pigeonpea pod borer complex

Coconut

1. Field testing *Hirsutella thompsonii* formulations supplied by PDBC against coconut mite

Weeds

1. Assessment of impact of *Neochetina eichhorniae, N. bruchi* and *Orthogalumna terebrantis* in suppressing water hyacinth

Gujarat Agricultural University, Anand

Cotton

1. Biointensive integrated pest management of cotton pests
2. Field evaluation of inundative releases of *T. chilonis* in combination with *Chrysoperla carnea* against cotton pest complex
3. Impact of inundative releases of *Chrysoperla carnea* against pest complex
4. Testing Efficacy of *Heterorhabditis indica* and *Steinernema carpocapsae* against *Helicoverpa armigera* in cotton

Pulses

1. Demonstration of *Bt-Ha*NPV- *Bt-Ha*NPV in pigeonpea for the management of pod borer complex in farmers field in 1 ha area (GAU)
2. Effect of entomopathogenic nematode *Heterorhabditis* sp. against *Mylabris pustulata* and *Helicoverpa armigera* in pigeonpea
3. BIPM in pigeonpea with special reference to pigeonpea pod borer complex

Vegetables

1. Survey for natural enemies of vegetable crop pests
2. Evaluation of *Trichogramma chilonis* against *Plutella xylostella* on cabbage
3. Evaluation of different commercial formulations of *Bacillus thuringiensis* against *Plutella xylostella* on cabbage
4. Management of tomato fruit borer
5. Integrated pest management of tomato fruit borer

Weeds

1. Assessment of impact of *Neochetina eichhorniae, N. bruchi* and *Orthogalumna terebrantis* in suppressing water hyacinth

Kerala Agricultural University, Thrissur

Rice

1. Survey and relative abundance of natural enemy complex in rice
2. Field evaluation of integrated use of *Trichogramma japonicum, T. chilonis* and *Bacillus thuringiensis* against rice stem borer and leaf folder
3. Evaluation of biocontrol based IPM in Rice

Coconut

1. Field testing of *Hirsutella thompsonii* formulations supplied by PDBC against coconut mite
2. Studies on seasonal incidence of *Opisina* and natural enemy population

Tropical and Subtropical Fruit Crops

1. Survey for the natural enemies of spiralling whitefly

Weeds

1. Assessment of impact of *Neochetina eichhorniae, N. bruchi* and *Orthogalumna terebrantis* in suppressing water hyacinth
2. Assessment of impact of *Cyrtobagous salviniae* in suppressing *Salvinia molesta*

Mahatma Phule Krishi Vidyapeeth, College of Agriculture, Pune

Sugarcane

1. Large scale demonstration of *Trichogramma chilonis* against early shoot borer

Cotton

1. Biointensive integrated pest management of cotton pests

Rice

1. Survey and relative abundance of natural enemy complex in rice

Vegetables

1. Survey for natural enemies of vegetable crop pests
2. Evaluation of *Trichogrammatoidea bactrae* against *Plutella xylostella* on cabbage
3. Evaluation of different commercial formulations of *Bacillus thuringiensis* against *Plutella xylostella* on cabbage
4. Control of *Leucinodes orbonalis* using *Bacillus thuringiensis* on brinjal

Potato

1. Standardization of mass release technology for parasitoids *Copidosoma koehleri* and *Chelonus blackburni* against PTM under field conditions
2. Evaluation of release methods of parasitoids *Copidosoma koehleri* and *Chelonus blackburni* and microbial agents against PTM, *Phthorimaea operculella* on potato in country stores
3. Effect of plant products on parasitoids of PTM
4. Evaluation of different entomopathogens for the control of *Spodoptera litura* on potato

Weeds

1. Assessment of impact of *Neochetina eichhorniae*, *N. bruchi* and *Orthogalumna terebrantis* in suppressing water hyacinth

Punjab Agricultural University, Ludhiana

Sugarcane

1. Survey and seasonal fluctuation studies of natural enemies of borers
2. Large scale demonstration of *Trichogramma chilonis* against early shoot borer
3. Large scale demonstration of *Trichogramma chilonis* against *Chilo auricilius*

Cotton

1. Biointensive integrated pest management of cotton pests

Rice

1. Survey and relative abundance of natural enemy complex in rice
2. Field evaluation of integrated use of *Trichogramma japonicum*, *T. chilonis* and *Bacillus thuringiensis* against rice stem borer and leaf folder

3. Evaluation of biocontrol based IPM in Rice

Oilseeds

1. Biological control of mustard aphid, *Lipaphis erysimi*

Vegetables

1. Management of tomato fruit borer

Weeds

1. Assessment of impact of *Neochetina eichhorniae, N. bruchi* and *Orthogalumna terebrantis* in suppressing water hyacinth

Sher-e-Kashmir University of Agricultural Sciences & Technology, Srinagar

Temperate Fruit Crops

1. Biocontrol based IPM in apple orchards
2. Monitoring of the San Jose scale and woolly apple aphid along with their natural enemies as well as ground flora as reservoir of natural enemies in apple orchards
3. Studies on the distribution and emergence pattern of parasitoids of *Lymantria* spp.

Vegetables

1. Survey for natural enemies of vegetable crop pests

Tamil Nadu Agricultural University, Coimbatore

Cotton

1. Biointensive integrated pest management of cotton pests
2. Identification of host plants harbouring arthropod natural enemies
3. Evaluation of *N. rileyi* against *Helicoverpa armigera*

Pulses

1. NPV-based management of *H. armigera*
2. Effect of entomopathogenic nematode *Heterorhabditis* sp. against *Mylabris pustulata* and *Helicoverpa armigera* in pigeonpea
3. BIPM in pigeonpea with special reference to pigeonpea pod borer complex

Rice

1. Survey and relative abundance of natural enemy complex in rice
2. Field evaluation of integrated use of *Trichogramma japonicum, T. chilonis* and *Bacillus thuringiensis* against rice stem borer and leaf folder
3. Evaluation of biocontrol based IPM in Rice

Oilseeds

1. Evaluation of *Nomuraea rileyi* against *Spodoptera litura / Helicoverpa armigera* on groundnut
2. Biointensive IPM of *S. litura* in irrigated groundnut

Coconut

1. Field testing of *Hirsutella thompsonii* formulations supplied by PDBC against coconut mite
2. Studies on seasonal incidence of *Opisina* and natural enemy population

Weeds

1. Assessment of impact of *Neochetina eichhorniae, N. bruchi* and *Orthogalumna terebrantis* in suppressing water hyacinth

Dr.Y. S. Parmar University of Horticulture and Forestry, Solan

Temperate Fruit Crops

1. Monitoring of the San Jose scale and woolly apple aphid along with their natural enemies as well as ground flora as reservoir of natural enemies in apple orchards
2. Survey for insect and mite pests and their natural enemies on field crops
3. Studies on predators of phytophagous mites

Vegetables

1. Distribution and abundance of *Helicoverpa armigera* on crops, weeds and forest flora along with their natural enemies

Weeds

1. Parthenium control with *Zygogramma bicolorata*, a case study under mid hill conditions

12. CONSULTANCY, PATENTS, COMMERCIALIZATION OF TECHNOLOGY

Consultancy service was arranged for

- EAG and GC-MS analysis for samples received from various organizations
- Quality biocontrol agents were supplied to different research and development departments of central and state governments
- Multicellular trays were supplied to various State Agricultural Universities and ICAR Institutes for rearing *Helicoverpa armigera*

Patents applied for

- Development of artificial diet for the rearing of *Chrysoperla carnea* (Stephens) on 25th January 2003
- Development of multiple insecticides tolerant strain of egg parasitoid, *Trichogramma chilonis* (Ishii) on 25th January 2003
- Development of high temperature tolerant strain of egg parasitoid, *Trichogramma chilonis* Ishii on 21st March 2003

13. MEETINGS HELD AND SIGNIFICANT DECISIONS MADE

13.1 Significant decisions and recommendations made in seventh Research Advisory Committee Meeting held on 24th and 25th September 2002

Recommendations

1. A quantitative survey of spiralling whitefly and its natural enemies particularly *Encarsia gudaloupe* may be undertaken to see the impact of natural enemies.
2. A cess fund project may be prepared on the biological control of B-biotype of *Bemisia tabaci*.
3. A one-day workshop may be organized on EPN to consolidate the current status of research on EPN and identify future areas of research.
4. Attempts may be made to identify a strain/formulation of *Nomuraea rileyi* suitable for dry weather conditions.
5. Interaction with Coffee Board on the establishment of exotic natural enemies and use of fungal pathogens for the biological suppression of coffee berry borer.

6. Research on Biological control of Plant Pathogens may be strengthened in the following areas

   (i) Research on management of stem bleeding of coconut with antagonistic organisms may be taken-up which will create a big impact.

   (ii) A large number of strains of Pseudomonads should be screened for high efficacy against plant pathogens and nematodes and high rhizosphere competence.

   (iii) Basic studies may be undertaken to select pseudomonads with high glucanase and chitinase activities.

   (iv) The available cultures of antagonistic organisms may be deposited with the National Bureau of Agriculturally Important Microorganisms.

   (v) Since the work on antagonistic organisms is important, ICAR may be addressed to fill-up the vacancy of Scientist (Plant Pathology).

   (vi) A one-day meet on antagonistic organisms may be organized in order to identify potential research needs.

7. The committee appreciated very much the ongoing project on development of software on National Information system on biological control of crop pests and knowledge base system on *Helicoverpa armigera* and suggested that high quality software should be brought out for sale. The pest distribution map generated by NCIPM may be consulted to improve the software. Pictures, animation and multimedia need to be included in the software under preparation.

8. A scientist can be trained on the use of the software "climex" to predict establishment of exotic pests and their natural enemies.

9. In view of the introduction of transgenic cotton, it is important to study the scope of using biocontrol agents on transgenic crops. A cess fund project may be proposed on this aspect.

10. The scientist working on genetic improvement of *Trichogramma* may interact with Entomologist at PAU, who has identified a strain of *Trichogramma* from a high temperature area. The genetically improved multi-pesticide tolerant strain should be tested for tolerance to some of the new groups of insecticides.

11. New focus may be given to conservation biocontrol through crop habitat diversity and selective use of pesticide. A cess fund project may be proposed.

12. Four or five laboratories (ICAR/SAU) may be identified for supply of nucleus cultures of NPVs and to test the quality before spraying.

13. Trials on use of EPNs against white grubs infesting arecanut may be taken up with the help of Central Plantation Crops Research Institute, Kasaragod, Rajasthan Agricultural University, Durgapura, and for critical evaluation by the National Centre for Integrated Pest Management, New Delhi. If necessary a network project can be proposed on this aspect.
14. Combination of neem cake with efficient strains of *Paecilomyces* to manage plant parasitic nematodes may be taken up for field trials.
15. Integrated approach can be made to control plant diseases using fungal antagonists.
16. Attempts may be made to import weed pathogens from Mexico for the control of Parthenium.
17. Attempts may be made to patent products and processes developed by the PDBC. Proper records need to be maintained for facilitation of these activities.
18. Economics may be taken into account for production of host insects on artificial diets and a substitute with cheaper ingredients may be tried for rearing *Spodoptera exigua*.
19. Feedback on the impact of training on validation of IPM technology in different crops may be obtained.
20. The possibility of integrating biocontrol agent with botanicals and pheromones should be explored.
21. Attempts may be made to identify antagonistic organisms, which can suppress both the nematode pest and plant pathogens.

General Remarks

i. Biocontrol technology should be refined to face the challenges of globalization.
ii. Just like seed-village programme, NPV and *Trichogramma* production units may be set- up at the villages by the unemployed rural youth and women.
iii. Greater emphasis should be given for biocontrol of pests of pigeonpea.
iv. Since there is outbreak of woolly aphid on sugarcane, surveys may be undertaken to record potential natural enemies.
v. Information available on baculovirus and its production technology may be published in the form of a booklet.
vi. Success stories in biocontrol may be brought out in the form of publications.
vii. Attempts may be made to obtain cultivable land from either NDRI/IVRI or on lease basis for conducting field experiments by the PDBC.

13.2 Significant decisions made in Management Committee Meeting held on 10-2-2003

1. The Management Committee recommended for the redeployment/creation of three scientific posts, two technical assistant posts and one assistant finance & accounts officers post proposed in the X Plan on priority basis.

2. The Committee recommended to include civil works (construction of quarantine building with glass house and net house as per the specifications given by CABI, addition of first floor on the existing Trainers' Hostel with light structure, extension of pathology laboratory by replacing the old A/c roof structure, addition of first floor over existing pathology laboratory annexe, glass house on the roof top of the existing main laboratory building, to raise the height of the compound wall, acoustic enclosure and repair of campus roads, reclamation of land, levelling, fencing, purchase of farm equipment, construction of quarters, etc.) proposed in the X Plan.

3. The Committee recommended for all the 44 items included under equipment list for the proposal in the X Plan.

4. The Committee approved the proposal for appointing two private doctors (Dr.(Ms.) P. V. Mahalakshmi and Dr. Vishwanath M. Patil) as AMAs for a period of two years with effect from 01.04.2003.

5. A recommendation has been made to de-reserve the post of scientist (Plant Pathology) earmarked for physically handicapped and reserved to any of the other two scientific posts (Principal Scientist or Senior Scientist).

6. The proposal of filling up of the post of Technical Assistant (T-4) as cook and a Junior Hindi Typist was agreed and recommended to take up the issue with the Council for approval on priority basis.

7. The Management Committee considered and approved the proposal for importing foreign equipment and opening an LC for equipment proposed in the X Plan.

8. The Committee approved for the up gradation of two computers to Pentium IV along with two printers and three software subject to the availability of funds.

9. The Committee approved the up gradation of image analysis system subject to the availability of funds under Non-plan.

10. The Committee has recommended for the up gradation of existing computers attached to Shimadzu Amino acid analyser along with Shimadzu work station LC10-VP software subject to the availability of funds under Non-plan.

13.3 Monthly Staff Research Council Meeting

Monthly scientific, technical and administrative staff meetings were held separately on every third Friday of the month and the detailed proceedings were sent to the Council for information. During the meetings discussions were held on the work done, in different projects, general difficulties faced and solutions for the same.

14. PARTICIPATION OF SCIENTISTS IN CONFERENCES, MEETINGS, WORKSHOPS, SYMPOSIA, etc. IN INDIA AND ABROAD

Project Directorate of Biological Control, Bangalore

Dr.R.J.Rabindra participated in

RAC meeting of Central Sericultural Germplasm Resources Centre, Hosur on 19th April 2002

Meeting to discuss the progress of the NATP project on 'Improvement of commercial scale production of NPV of *Helicoverpa armigera* and *Spodoptera litura* and Management of coconut mite *Aceria guerreronis* at TNAU, Coimbatore on 20th and 21st April 2002

Review meeting of the NATP on 'Development of an integrated pest management package for the eriophyid mite (*Aceria guerreronis* Keifer) of coconut in southern states' at Central Tuber Crops Research Institute, Sreekariyam, Trivandrum on 29th April 2002

Review Meeting of the NATP (CGP) project on Improvement of commercial scale production of NPV of *Helicoverpa armigera* and *Spodoptera litura* organised by the National Director, NATP, New Delhi at TNAU, Coimbatore on 29th and 30th May 2002

Discussions regarding ICAR-ICIPE collaboration for development of joint programme on biological control of *Helicoverpa* with Dr.Amerika Singh, Director, NCIPM, New Delhi on 5th July 2002

Review Meeting of NATP project on 'Development of an integrated pest management package for the Eriophyid Mite (*Aceria guerreronis* Keifer) of coconut in the Southern States at TNAU, Coimbatore on 26th July 2002

Annual Review Workshop of NATP MM Sub-project on Validation and Promotion of IPM Technology in selected crops in different Agro-ecological regions held at NBPGR, New Delhi on 8th and 9th August 2002

Divisional discussion for preparing X plan proposal in respect of PDBC, Bangalore at ICAR, New Delhi on 22nd August 2002

Brain Storming Session in the Department of Biotechnology, New Delhi for evolving a nation wide network programme for the management of *Parthenium* through an integrated approach on 29th August 2002

Review meeting of research projects of Andhra Pradesh-Netherlands Biotechnology Programme at Biotechnology Unit, Institute of Public Enterprises, Hyderabad on 3rd and 4th October 2002

Tenth National Horticulture Conference organized by the Horticulture Commissioner, Govt. of India, Ministry of Agriculture, Department of Agriculture and Cooperation, Krishi Bhavan, New Delhi at Scope Auditorium, New Delhi on 18th and 19th October 2002

FAO-EU IPM programme for cotton in Asia-Training of Facilitators (TOF) and held participatory discussion on NPV and *Bt* and their role in cotton IPM held at WALMI, Dharwar on 25th October 2002

Review meeting of the approved sub-projects under the mission mode in theme areas of IPM, Socio-economics and post harvest technology and agricultural engineering organized at the Tamil Nadu Agricultural University, Coimbatore by the NATP on 28th and 29th October 2002

Third discussion Meeting on Applied Chemical Ecology: Implications of Induced Resistance and Transgenic in Insect-Plant Interactions held at Chennai on 30th November 2002

Meeting called by the Department of Biotechnology, New Delhi on 20th January 2003

6th Agricultural Science Congress of NAAS at IISS, Bhopal on 13th February 2003

CAS training programme and delivered a special lecture on Genetic improvement of biocontrol agents to the trainees at Haryana Agricultural University, Haryana on 25th February 2003

Interactive Workshop on IPM called by the NATP at NCIPM, New Delhi from 26th to 28th February 2003

Meeting in Krishi Bhavan, New Delhi in the office of Horticulture Commissioner of the concerned scientists involved in the research on coconut mite and deliberated on the issue in detail to prepare a road map for the effective management of coconut mite for onward transmission to the Planning Commission on 10th March 2003

Dr.P.L.Tandon participated in

Biological Control of Lepidopteron pests held at Bangalore during July17-18, 2002 and Co-chaired Session IV.

NATP Interactive Workshop on Integrated Pest Management held at NCIPM, New Delhi during February 26-28, 2003.

Workshop on Intellectual Property Assets in Business Development (IPABD) held at NPL, Jamsedpur during February 10-11,2003 and acted as expert in HRD in IPRs discussion.

Sixth Research Advisory Committee Meeting of Indian Institute of Vegetable Research during December 30-31, 2002 as member RAC.

Dr.K.Narayanan participated in

Symposium on Biological Control of Lepidopterous Pests at Bangalore on 17th and 18th July 2002

ICAR-CABI Workshop on Biopesticide formulation and Application at PDBC, Bangalore on 9th to 13th December 2002

National Symposium on Sustainable Insect Pest Management held at Entomology Research Institute, Loyola College, Chennai on 6th and 7th February 2003

National Symposium on "Biomanagement of Insect pests" held at Annamalai University, Annamalainagar, Tamil Nadu on 29th to 31st March 2003

Dr.N.S.Rao participated in

Eleventh Biocontrol Workers' Group Meeting at Project Directorate of Biological Control, Bangalore on 19th and 20th July 2002

Annual Review Meeting of the NATP funded project entitled, "Validation and Promotion of IPM Technology in Selected Crops in Different Agro-ecological Regions" at Project Directorate of Biological Control, Bangalore on 4th and 5th April 2002

Annual Review Workshop of the DAC-ICAR funded project entitled, "Technology Mission on Cotton - Mini Mission I" at Central Institute for Cotton Research, Nagpur on 24th April 2002

Annual Review Workshop of the NATP funded project entitled, "Validation and Promotion of IPM Technology in Selected Crops in Different Agro-ecological Regions" at National Centre for Integrated Pest Management, New Delhi on August 8-9, 2002

Half-Yearly Review Meeting of the NATP funded project entitled, "Validation and Promotion of IPM Technology in Selected Crops in Different Agro-ecological Regions" at Agricultural Research Station (RAU), Durgapura, Jaipur on December, 17-18, 2002

Project Review Meeting of Team of Excellences held at Indian Institute of Horticultural Research, Bangalore on August 16-17, 2002

NATP Interactive Workshop on IPM at National Agricultural Science Centre, Todapur (Near Pusa Campus), New Delhi from 26th to 28th February 2003

Annual Review Workshop of the DAC-ICAR funded project entitled, "Technology Mission on Cotton - Mini Mission I" Sub project (Development of effective biocontrol agents and molecular techniques to improve antagonists" at Project Directorate of Biological Control, Bangalore on 10th March 2003

Annual Review Workshop of the DAC-ICAR funded project entitled, "Technology Mission on Cotton - Mini Mission I" at Central Institute for Cotton Research, Nagpur on 25th and 26th March 2003

Dr. B. S. Bhumannavar attended the following

Symposium on 'Biological Control of Lepidopteran Pests' at Bangalore on 17th & 18th July 2002

Eleventh Biocontrol Workers' Group Meeting held at PDBC, Bangalore on 19th & 20th July 2002

ICAR-CABI Workshop on 'Development of quarantine techniques for biocontrol agents' held at PDBC, Bangalore from 27th to 31st May 2002

ICAR-CABI post-workshop Consultancy on 'Development of quarantine techniques for biocontrol agents' held at PDBC, Bangalore from 26th November to 2nd December 2002.

Dr. (Ms.) Chandish R. Ballal attended the following

National Symposium on Bio-Management of Insect Pests held at Annamalai University, Annamalainagar, Tamil Nadu from 29th to 31st March 2003

Dr. S. Ramani attended the following

ICAR-CABI workshop on Development of Quarantine Techniques for Biocontrol agents held at PDBC, Bangalore from 27th to 31st May 2002

Symposium on Biological Control of Lepidopteran pests held at PDBC, Bangalore on 17th and 18th July 2002

RAC meeting of Silkworm Seed Technology Laboratory, Kodathi on 23rd and 24th September 2002

Dr. S. K. Jalali attended the following

Eleventh Biocontrol Workers' Group Meeting held at PDBC, Bangalore on 19th and 20th July 2002

FAO - EU IPM programme for cotton in Asia held at Training of Facilitators (TOF), Dharwad, Karnataka on 25th October 2002

National symposium on Bio-management of Insect Pests held at Department of Entomology, Annamalai University, Annamalainagar, Tamil Nadu, from 29th to 31st March 2003

Dr. B. Ramanujam attended the following

Symposium on Biological control of lepidopteran pests held at PDBC, Bangalore on 17th and 18th July 2002

National Horticultural Conference held at SCOPE Auditorium, CGO Complex, New Delhi on 18th and 19th October 2002

Dr. M. Nagesh attended the following

Symposium on Biological Control of lepidopteran pests held at PDBC, Bangalore on 17th and 18th July 2002

Dr. (Ms.) K. Veena Kumari attended the following

Symposium on biological control on lepidopteran pests held at PDBC, Bangalore on 17th and 18th July 2002

National Horticulture Conference held at SCOPE auditorium, New Delhi, on 18th and 19th October 2002

Dr. T. Venkatesan attended the following

Seminar for Industrialist Entrepreneurs in Production of Biocontrol Agents held at PDBC, Bangalore on 27th February 2002

Symposium on Biological Control of Lepidopteran Pests at Bangalore on 17th and 18th July 2002

Meeting on biological control of coconut black headed caterpillar held at Directorate of Horticulture, Lalbagh, Bangalore on 29th January 2003

BT- Cotton: Global Performance & Future Strategies held at Monsanto Research Centre, IISC Campus, Bangalore on 28th February 2003

Brain Storming Session on Coconut Development in Karnataka held at Directorate of Horticulture, Lalbagh, Bangalore on 22nd March 2003

Dr. (Ms.) J. Poorani attended the following

National Symposium on Biological Control of Lepidopteran Pests held at PDBC, Bangalore on 17th and 18th July 2002

ICAR-CABI Workshop on Development of Plant Quarantine Techniques held at PDBC, Bangalore from 27th to 31st May 2002

Eleventh Biocontrol Workers' Group Meeting held at PDBC, Bangalore on 19th and 20th July 2002

Dr. P. Sreerama Kumar attended the following

Second Annual Review-cum-Planning Workshop (2001-02) at Central tuber Crops Research Institute (CTCRI), Thiruvananthapuram on 29th April 2002

ICAR-CABI Workshop on Development of Plant Quarantine Techniques held at PDBC, Bangalore from 27th to 31st May 2002

National Steering Committee Meeting on the Coconut Eriophyid Mite held at Coconut Development Board at Lalbagh, Bangalore on 14th June 2002

Symposium on Biological Control of Lepidopteran Pests held at Bangalore on 17th and 18th July 2002

Eleventh Biocontrol Workers' Group Meeting" held at PDBC, Bangalore on 19th and 20th July 2002

Special Meeting of the Scientists of NATP on the Development of an integrated pest management package for the eriophyid mite (*Aceria guerreronis* Keifer) of coconut in the southern states held at PDBC, Bangalore on 6th August 2002

ICAR-CABI Post-Workshop on Consultancy on Development of Quarantine Facility held at PDBC, Bangalore from 26th November to 2nd December 2002

Inauguration of Nucleus Seed Garden-cum-Demonstration Centre of the Shri Adichunchanagiri Matt held at Mayasandra, Tumkur district on 13th November 2002

State level technical committee meeting on coconut mite control convened under the chairmanship of the Director (Horticulture), Government of Karnataka held at the Mini Meeting Hall, Lalbagh, Bangalore on 27th November 2002

ICAR-CABI Workshop on Biopesticides Formulations and Application held at PDBC, Bangalore from 9th to 13th December 2002

Discussion on coconut mite management held at the Alumni Association of the University of Agricultural Sciences (UAS), Bangalore on 11th July 2002

Meeting convened by Hon'ble Minister for Agriculture, Government of Karnataka to discuss about the action to be taken to mitigate the problem of the coconut mite and convened at Vidhana Soudha. The first meeting was held on 16th April 2002

National Symposium on Prospecting of Fungal Diversity and Emerging Technologies and 29th Annual Meeting of Mycological Society of India held at the Agharkar Research Institute, Pune on 6th and 7th February 2003

Meeting regarding coconut mite control programme and control of other pests and diseases on horticultural crops convened under the chairmanship of the Secretary (Horticulture), Government of Karnataka held at M. S. Building, Bangalore on 17th February 2003

NATP Interactive Workshop on Integrated Pest Management held at National Bureau of Plant Genetic Resources (NBPGR), New Delhi from 26th to 28th February 2003

Dr. K. Srinivasa Murthy attended the following

Symposium on Biological control of Lepidopteran Pests held at Bangalore on 17th and 18th July 2002

Eleventh Biocontrol Workers' Group Meeting held at PDBC, Bangalore on 19th and 20th July 2002

Training programme on Biological Control of Crop Pest in different Cropping systems under the NATP funded project entitled, "Team of Excellence for Human Resource Development in Biological Control" held at PDBC, Bangalore from 11th November 2002 to 9th January 2003

Central Tobacco Research Institute, Rajahmundry

S. Gunneswara Rao and Dr. P. Venkateswarlu attended the

Eleventh Biocontrol Workers' Group Meeting held at PDBC, Bangalore on 19th & 20th July 2002

National Symposium on Biological control of Lepidopterous pests held at IAT, Bangalore on 17th & 18th July 2002

S. Sitaramaiah, S. Gunneswara Rao and Dr. P. Venkateswarlu attended National symposium on tobacco: Facing future challenges held at ITA auditorium, Guntur from 23rd to 25th January 2003

Indian Institute of Horticultural Research, Bangalore

Dr. A. Krishnamoorthy participated in the following

Symposium on Biological control of lepidopteran pests held at Bangalore on 17th & 18th July 2002

International Conference on Vegetables held at Bangalore from 11th to 14th November 2002

Eleventh Biocontrol Workers' Group Meeting held at PDBC, Bangalore on 19th & 20th July 2002

Dr. C. Gopalakrishnan attended the following

Symposium on Biological control of lepidopteran pests held at Bangalore on 17th & 18th July 2002

ICAR-CABI workshop on "Biopesticide formulations and applications" held at PDBC, Bangalore from 9th to 13th December 2002

International Conference on Vegetables held at Bangalore from 11th to 14th November 2002

National Symposium on Bio-Management of Insect Pests held at Annamalai University, Chidambaram from 29th to 31st March 2003

Dr. M. Mani attended the following

Symposium on biological control of lepidopteran pests held at PDBC, Bangalore on 17th & 18th July 2002

Eleventh Biocontrol Workers' Group Meeting held at PDBC, Bangalore on 19th & 20th July 2002

Global Conference on Banana and Plantains held at Bangalore from 28th to 31st October 2002

International Conference on Vegetables held at Bangalore from 11th to 14th November 2002

National Symposium on Sustainable insect pest management held at Loyola College, Chennai on 6th & 7th February 2003

Meeting of Grape growers held at Department of Horticulture, Government of Andhra Pradesh, Hyderabad on 14th & 15th March 2003

National Symposium on Bio-Management of Insect Pests held at Annamalai University, Annamalai Nagar from 28th to 30th March 2003

Dr. (Ms.) P.N. Ganga Visalakshy attended the following

National Symposium on Sustainable insect pest management held at Loyola College, Chennai on 6th & 7th February 2003

Eleventh Biocontrol Workers' Group Meeting held at PDBC, Bangalore on 19th & 20th July 2002

Sugarcane Breeding Institute, Coimbatore

Dr. S. Easwaramoorthy attended the following

64th Annual Convention of Sugar Technologists' Association of India held at Cochin from 17th to 19th August 2002

2nd International Conference on Integrated Pest Management in Relation to Safe Agricultural Products and Healthy Environment held at Giza, Egypt from 21st to 24th December 2002

Assam Agricultural University, Jorhat

Dr. A. Basit, Prinicpal Scinetist and Dr. D. K. Saikia, Senior Scientist, AICRP on biological control of crop pests and weeds attended the Eleventh Biocontrol Workers' Group Meeting held at Project Directorate of Biological Control, Bangalore on 19th & 20th July 2002

Acharya N. G. Ranga Agricultural University, Hyderabad

Dr.A.Ganeswara Rao and Dr. S. J. Rahman attended the following

National Seminar on "Biological control of Lepidopteran Pests held at Bangalore on 17th & 18th July 2002.

National Seminar on "Resources Management in Plant Protection During Twenty First Century" held at NPPTI, Rajendranagar, Hyderabad on 14th & 15th November 2002.

Dr.S.J.Rahman participated in *Janmabhoomi* programme of Govt. of Andhra Pradesh as Resource person from 1st to 10th June 2002

Gujarat Agricultural University, Anand

Dr. D. N. Yadav attended the review meeting of RAC at CTRI, Rajhamundry on 27th & 28th January 2003.

Dr. D. N. Yadav, Dr. B. H. Patel, and Dr. J. J. Jani attended the Eleventh Biocontrol Workers' Group Meeting held at PDBC, Bangalore on 19th & 20th July 2002

Mahatma Phule Krishi Vidyapeeth, Pune

Dr. D. S. Pokharkar, Asstt. Entomologist attended the following

Symposium on Biological Control of Lepidopteran pests held at PDBC, Bangalore on 17th & 18th July 2002

State level seminar on Pest Management for Sustainable Agriculture at MAU, Parbhani, on 6th & 7th February 2003

Dr. S. A. Ghorpade, Entomologist attended the Eleventh Biocontrol Workers' Group Meeting held at PDBC, Bangalore on 19th & 20th July 2002

Punjab Agricultural University, Ludhiana

Dr. K.S. Brar participated in the following

Half yearly review on MM Sub project P.O., Validation and Promotion of IPM Technology in Selected Crops in Different Agro-ecological Regions held at Durgapura Rajasthan on 17th & 18th December 2002

Annual review workshop of project evaluation of locations specific IPM modules for eco-friendly and sustainable cotton production, MME-1 held at NCIPM, New Delhi on 10th March 2003

Dr. Neelam Joshi attended training on "Mass production of NPV and fungal pathogen at PDBC Bangalore from 16th to 22nd December 2002

Dr. Maninder Shenhmar and Mr. Jagmohan Singh participated in the following

Symposium on "Biological Control of Lepidopteran Pests" held at PDBC, Bangalore on 17th & 18th July 2002

Eleventh Biocontrol Workers' Group Meeting held at PDBC, Bangalore on 19th & 20th July 2002

National Seminar on Integrated Pest Management in the Current Century held at BCKV, Nadia, West Bengal on 28th & 29th November 2002

15. WORKSHOPS, SEMINARS, SUMMER INSTITUTES, FARMERS' DAY, etc., ORGANIZED BY THE PROJECT DIRECTORATE

15.1. Organized

ICAR-CABI workshop on "Development of Plant Quarantine Techniques" at PDBC, Bangalore from 27th to 31st May 2002

Symposium on Biological Control of Lepidopteran Pests was held at Bangalore on 17th & 18th July 2002

Eleventh Biocontrol Workers' Group Meeting on Biocontrol of Crop Pests and Weeds at PDBC, Bangalore on 19th & 20th July 2002

Seventh Research Advisory Committee Meeting was held at PDBC, Bangalore on 24th & 25th September 2002

ICAR-CABI Consultancy workshop on "Creation of Quarantine facilities" at PDBC, Bangalore from 26th November to 2nd December 2002

ICAR-CABI Workshop on "Biopesticides Formulations and Application" held at PDBC, Bangalore from 9th to 13th December 2002

Brain Storming session on "Entomopathogenic nematodes" at PDBC, Bangalore on 22nd & 23rd January 2003

15.2. Celebrated

National Technology Day on 11th May 2002

Central Vigilance Awareness Week from 31st October to 6th November 2002

KISAN DIWAS day on 23rd December 2002

16. DISTINGUISHED VISITORS

Project Directorate of Biological Control, Bangalore

Dr. Panjab Singh, Secretary, Department of Agricultural Research & Education and Director General, Indian Council of Agricultural Research, Krishi Bhavan, New Delhi on 25th April 2002 and 11th November 2002

Dr. M. P. Yadav, Director, Indian Veterinary Research Institute, Izatnagar on 25th April 2002

Dr. Mangala Rai, Deputy Director General (Crop Science), Indian Council of Agricultural Research, Krishi Bhavan, New Delhi on 4th May 2002

Dr. S. Kannaiyan, Vice Chancellor, Tamil Nadu Agricultural University, Coimbatore on 9th July 2002

Shri Hukumdeo Narayan Yadav, Hon'ble Minister of State for Agriculture on 31st October 2003

Dr. Dilip K. Arora, Director, National Bureau of Agriculturally Important Microbes, New Delhi on 28th October 2002

Dr. Gautam Kalloo, Deputy Director General (Horticulture and Crop Sciences), Indian Council of Agricultural Research, Krishi Bhavan, New Delhi on 13th November 2002

Dr. Kirti Singh, Ex-chairman, ASRB (ICAR), New Delhi on 14th November 2002

17. PERSONNEL

Project Directorate of Biological Control, Bangalore

Dr.R.J.Rabindra	Project Director
Dr.P.L.Tandon	Principal Scientist
Dr.K.Narayanan	Principal Scientist
Dr.N.S.Rao	Principal Scientist
Mr.S.R.Biswas	Principal Scientist
Dr.S.S.Hussaini	Principal Scientist
Dr.B.S.Bhumannavar	Principal Scientist
Dr.(Ms.)K.Veena Kumari	Senior Scientist
Dr.Prasanth Mohanraj	Senior Scientist
Dr.S.Ramanujam	Senior Scientist
Dr.N.Bakthavatsalam	Senior Scientist
Dr.S.Ramani	Senior Scientist
Dr.(Ms.)Chandish R.Ballal	Senior Scientist
Dr.M.Nagesh	Senior Scientist

Dr.S.K.Jalali	Senior Scientist
Mr.Sunil Joshi	Scientist SS (on study leave)
Dr.T.Venkatesan	Scientist SS
Dr.(Ms.)J.Poorani	Scientist SS
Dr.P.Sreerama Kumar	Scientist SS
Dr.K.Srinivasa Murthy	Scientist SS
Mr.R.Rangeshwaran	Scientist (on study leave)
Ms.M.Pratheepa	Scientist
Dr.(Ms.)P.Sadhana	Scientist

Central Plantation Crops Research Institute, Regional Station, Kayangulam

Dr.(Ms.) Chandrika Mohan	Scientist (SS)
Dr.Murali Gopal	Scientist

Central Tobacco Research Institute, Rajahmundry

Mr.S.Sitaramaiah	Principal Scientist
Mr.S.Gunneswara Rao	Scientist SS

Indian Agricultural Research Station, New Delhi

Dr.K.L.Srivastava	Principal Scientist

Indian Institute of Horticultural Research, Bangalore

Dr.M.Mani	Principal Scientist
Dr.A.Krishnamoorthy	Principal Scientist
Dr.C.Gopalakrishnan	Senior Scientist
Dr.(Ms.) P. N. Ganga Visalakshy	Senior Scientist

Indian Institute of Sugarcane Research, Lucknow

Dr.N.K.Tewari	Senior Scientist
Dr.R.K.Tanwar	Scientist

Sugarcane Breeding Institute, Coimbatore

Dr.J.Srikanth	Scientist SS

Assam Agricultural University, Jorhat

Dr.A.Basit	Principal Scientist
Dr.D.K.Saikia	Senior Scientist

Acharya N.G.Ranga Agricultural University, Hyderabad

Dr.A.Ganeswara Rao	Principal Scientist
Dr.S.J.Rahman	Senior Scientist

Govind Ballabh Pant University of Agricultural Sciences & Technology, Pantnagar

Dr.U.S.Singh	Professor

Gujarat Agricultural University, Anand

Dr.D.N.Yadav	Principal Research Scientist
Dr.D.M.Mehta	Associate Research Scientist
Mr.J.J.Jani	Assistant Research Scientist (SS)

Kerala Agricultural University, Thrissur

Dr.(Ms.) S.Pathummal Beevi	Associate Professor
Dr.(Ms.) K.R. Lyla	Assistant Professor

Mahatma Phule Krishi Vidyapeeth, Pune

Dr.S.A.Ghorpade	Entomologist
Dr.D.S.Pokharkar	Assistant Entomologist

Punjab Agricultural University, Ludhiana

Dr.S.Maninder	Entomologist
Shri. Jagmohan Singh	Assistant Entomologist
Dr. Neelam Joshi	Assistant Microbiologist
Sri Inderpal Singh	Assistant Entomologist

Sher-e-Kashmir University of Agriculture and Technology, Srinagar

Dr.G.M.Zaz	Head
Dr.Abdul Majeed Bhat	Junior Scientist
Mr.R.K.Tikoo	Junior Scientist

Tamil Nadu Agricultural University, Coimbatore

Dr.R.Balagurunathan	Associate Professor
Dr.N.Sathiah	Assistant Professor

Y.S.Parmar University of Horticulture and Forestry, Nauni, Solan

Dr.P.R.Gupta — Senior Entomologist
Dr.Anil Sood — Assistant Entomologist

18. ANY OTHER RELEVENT INFORMATION SUCH AS SPECIAL INFRASTRUCTURAL DEVELOPMENT

18.1 Equipments

The infrastructural facilities were strengthened and equipments (Centrifuges, Ultra refrigerated centrifuge, digital electronic balance, research microscope, ultra sonicator, freeze drier, UV spectophotometer, orbital shaker, water bath shaker) and audio-visual aids (videocamera, Home theatre, public address system, LCD along with electronic board and computer) were procured during 2002-03.

18.2. Library

The library has a collection of 1,654 books, 1093 volumes of journals, 47 bulletins and several miscellaneous publications including several reprints on various aspects of biological control. Eleven foreign and ten Indian Journals have been subscribed. CABPEST CD has been upgraded up to February 2003. New CD - Crop Protection Compendium – 2002 was procured.

18.3. Aris Cell

A CD-server was installed in the library for making available the databases in different laboratories. Cable connection was established for a better and quicker internet connectivity.

18.4. National Insect Reference Collection

The PDBC has 3,495 authentically identified species belonging to 216 families under 16 orders. The collection includes representatives of the orders Hymenoptera, Coleoptera, Hemiptera, Orthoptera, Strepsiptera, Thysanoptera, Neuroptera, Diptera, Lepidoptera, etc. encompassing crop pests, parasitoids and predators. The information is available in the form of a catalogue.

18.5. Buildings

No new buildings were constructed during this period

18.6. Technology developed for the benefit of women in agriculture

18.6.1. Technology available

Technology developed on the following aspects is well suited for adoption by household women folk particularly in rural areas. The materials required are locally available and even illiterate women with some training can easily use the technology for production. The produced natural enemies can be used against key crop pests in the household farms and also for sale at the village level to other farmers.

1 Mass production and use of nuclear polyhedrosis viruses of *Spodoptera litura* and *Helicoverpa armigera* for use in tomato, cotton and pigeon pea.

2. Mass production and use of trichogrammatids for use in sugarcane, cotton and rice.

3. Mass production and use of chrysopids for use of sucking pests in cotton, fruit crops and vegetables.

4. Mass productions of coccinellids for the control of mealy bugs, scale insects and aphids in fruit and plantation crops.

5. Mass production and release technique for *Goniozus nephantidis* for the control of coconut leaf eating caterpillar.

18.6.2. Training programmes organized

Training programmes were organized on various aspects of biological control of crop pests. During the year 2002-03 the participation of women in different training programmes were as follows.

Institute training programmes on mass production of quality biocontrol agents		4 participants
NATP Project "Team of Excellence for Human Resource Development in Biological Control"		
	Six months duration	1 participant
	Two months duration	8 participants
NATP Project " Validation and Promotion of IPM Technology in Selected Crops in Different agro-ecosystems"		
	10 days duration	8 participants

Impact analysis of the training programmes conducted showed that there was improved awareness among the women trained.

2. निष्पादित सारांश

2.1 मौलिक अनुसंधान

भारत सरकार के पादप संरक्षण सलाहकार से बारह प्राकृतिक शत्रु कीटों को आयात करने की स्वीकृति पत्र प्राप्त हुआ। सीआम खरपतवार, *क्रोमोलीना ओडोरेटा* के प्रति जाँच परीक्षण करने के लिए इन्डोनेशिया से गॉल फ्लाई, *सेसीडोकेरस कोनेक्सा* प्राप्त की गई।

2.1.2 परपोषी कीटों और, प्राकृतिक शत्रु कीटों का रखरखाव, बहोत्पादन और भेजना

परपोषी कीटों की 22 प्रजातियाँ, परजीवी कीटों की 25 (*ट्राइकोग्रामा* के 11 विभेद और *टेलीनोमस* के 3 विभेद), 19 परभक्षी कीटों, 4 खरपतवार नियंत्रण करने वाले आरथ्रोपोड्स, 4 कीट रोगाणुओं, बी टी की 7 प्रजातियाँ, कवकीय एवं जीवाणुवीय प्राकृतिक शत्रुओं की 326 जातियों एवं विभेदों, कीट रोगाण्विक सूत्रकृमियों के चार विभेद और जातियाँ, पादप सूत्रकृमियों के साथ कवक एवं जीवाणु की 24 प्रजातियाँ और विभेदों तथा खरपतवार नियंत्रण के लिए एक रोगाणु के संवर्धनों को पाला जा रहा है।

294 खेपों (57 परपोषी कीट, 65 परभक्षी कीट, 78 परजीवी कीट, 63 कीट रोगाणुओं, 17 एन्टागॉनिस्ट और 14 खरपतवार कीटों) को विभिन्न अनुसंधान संगठनों / निजी कम्पानियों / विश्वविद्यालयों / किसानों को न्युक्लियस संवर्धन या उत्पाद के रूप में भेजा गया। *हेलीकोवर्पा आर्मिजेरा* को पालने वाली 40 बहुकोष्ठीय ट्रे और परजीवी कीटों को पालने वाले 10 पिंजडों को भी भेजा गया।

2.1.3 जीववर्गीकरण अध्ययन

2.1.3.1 कोक्सीनेलिड

एक सूची तैयार की गई जिसमें 400 प्रजातियाँ (छः उपप्रजातियों सहित) जो कि 79 वंशों, 22 जातियों और पाँच उपकुलों के अन्तर्गत आती हैं। दो प्रजातियाँ *ओर्टेलिया माईन्युटा* वीज (बंगलोर, कर्नाटक से) और *एलोनेडा* (= *सायफोकेरिया*) *डूवेओसेलाई* (मूल्सेन्ट) (नागालैण्ड से) भारत मे पहली बार पाये गये। भारतीय उपमहाद्वीप के कृषि पारिस्थितिक तन्त्र में प्राय: पाये जाने वाले कोक्सीनेलिडों की 125 प्रजातियों को पहचानने के लिए गाइड तैयार की गई।

2.1.3.2 टेकिनिडे

दो उपकुलों वाले प्रतिदर्शनों, गोनीने और टेकीनिने का अध्ययन किया जा रहा है। टेकिनिडों मे से *विन्थेमिया* प्रजाति को अनेक लेपिडोप्टेरनों परपोषी कीटों मे से फल छेदक मौथ, *आथेरिस मेटेरना* के प्रति घातक पाये गये।

2.1.4 प्राकृतिक शत्रु कीटों का सर्वेक्षण

फली वेस्प, *टेनेओस्टिगमोइ्स कजानिने* के प्रति एक युपेल्मिड परजीवी कीट *नीऐनास्टेटस* स्पे. को आभिलेखित किया गया। पपीते पर सर्पिलाकार श्वेत मक्खी का अत्याधिक परजीवीकरण 68.45% जनवरी मे पाया गया। *ऐ. डिस्पर्सस* की संख्या को पिछलें वर्षों की तुलना में इस वर्ष सभी परपोषियों पर अत्याधिक कम पाया गया।

गन्ने के वुली माँहू, *सीरेटोवेक्यूना लेनिजेरा* के प्राकृतिक शत्रु कीटों की प्राप्ति के लिए कर्नाटक के उत्तरी जिलों में और पश्चिमी महाराष्ट्र में सर्वेक्षण किया गया। *डाइफा एफिडिवोरा* (पायरेलिडे), *डायडिआॅप्सिस एग्रोटा* (सिरफिडे), *काइलोमीनस सेक्समेकुलेटा, ऐनिसोलेम्निया डाइलेटाटा, साइनोनाइका ग्रेन्डिस* (कोक्सीनेलिडे) को माँहू को उपभोग करते पाया गया।

2.1.5 पालने की तकनीकों का मानकीकरण और प्राकृतिक शत्रु कीटों का अध्ययन

प्रयोगशाला में *ओरीअस टेन्टिलस* की 12 पीढ़ियों को अल्ट्रा वायलेट उपचारित *को. सीफेलोनिका* के अण्डों पर लगातार गुणित किया गया। *एम्ब्लिसिअस लोनिस्पाइनोसस* को अत्यधिक मात्रा मे उत्पादित करने के लिए पालने की विधि का मानकीकरण किया गया।

स्पो. लिट्यूरा के लारवों और *के. क्लोरिडिए* प्रौढ़ो का पीड़क परजीवी कीट का उचित अनुपात अध्ययन मे पाया कि 1:5 का अनुपात होने पर 80.57% परजीवीकरण और 1:15 के अनुपात होने पर 81.95% परजीवीकरण पाया गया। पीड़क कीट और परजीवी कीट के 1:5 या 1:15 अनुपातों से कीट संख्या को क्रमश: 79.64 और 81.10 प्रतिशत तक कम किया गया। *का. एक्जिगुअस* की संख्या *ओ. एरेनोसेल्ला* पर तब अधिक पायी गयी जब पीड़क कीट छोटी अवस्थाओं मे थे। *एनकार्सिआ गुआडेलोउपे, ए. डिस्पर्सस* के केवल प्रथम निरुपीय निम्फ को ही परजीवित कर पाते हैं।

2.1.6 प्राकृतिक शत्रु कीटों का व्यवहारिक अध्ययन

व्हाइटफील्ड, बंगलोर में केरोमोन उपचारित *को. सिफेलोनिका* के अंडो के कार्डों को कपास की पत्तियों पर लगा कर उस पर एल-ट्रायप्टोफेन घोल का छिड़काव करने से उपचारित प्लाटों में क्राइसोपिडों की संख्या अधिक बढी पाइ गई। ई ए जी अध्ययन में पाया कि परपोषी लारवे के लारवल वाश के प्रति *केम्पोलेटिस क्लोरिडिए* अधिक आकर्षित होते दिखाई दिए।

टमाटर की 10 प्रजातियों / संकर प्रजातियों पर *ट्रा. किलोनिस* द्वारा *हे. आर्मिजेरा* के अण्डों के परजीवीकरण के प्रभाव का अध्ययन किया गया और पाया कि अर्का आलोक और पुसा रूबी प्रजातियों पर अत्याधिक 26.66 प्रतिशत परजीवीकरण होता है।

जी सी एम एस की मानक विधियों को अपनाकर टमाटर की 10 प्रजातियों / संकर प्रजातियों की पत्तियों और फलों के वोलेटाइल्स मे गुणवत्ता और मात्रात्मक विभिन्नता का निरीक्षण किया गया। इस विधि से इनका परीक्षण, पृथककरण और पहचान की गई।

2.1.7 परपोषी कीटों और प्राकृतिक शत्रु कीटों के लिए कृत्रिम आहार

नारियल की पत्ती को खाने वाले कीट *ओपिसिना एरेनोसेल्ला* को सोया और टोडी पाम की पत्तियों के पाउडर पर आधारित एक कृत्रिम आहार पर सफलता पूर्वक पाला जा सका। परजीवी कीट, *गोनीओजस निफेन्टिडिस, ब्रेकीमेरीया निफेन्टिडिस* और *ब्रे. नोसेटोई* इस कृत्रिम आहार पर पाले गये परपोषी कीटों पर अपना पूर्ण विकास करते हैं। *प्लुटेल्ला जाइलोस्टेल्ला* को पालने के लिए पातगोभी पत्ती के पाउडर आधारित कृत्रिम आहार को उत्तम पाया गया और परजीवी कीट *कोटेशिया प्लुटेल्ले* को पालने के लिए, कृत्रिम आहार पर पाले गये लारवे भी उतने ही उत्तम पाये गये जितने कि सरसों के नवोद्भिदों पर पाले गये *प्लु. जाइलोस्टेल्ला* के लारवे।

क्रा. कारनिया को पालने के लिए कृत्रिम आहार के संग्रहण की अच्छी विधि विकसित की गई, कृत्रिम आहार को फ्रिज मे 5° से.ग्रे. पर एक वर्ष तक रखा जा सकता है और सफलता पूर्वक परभक्षी कीटों के उपयोग मे लाया जा सकता है।

2.1.8 प्रकृतिक शत्रु कीटों के विभेदों का सुधार

2.1.8.1 *ट्राइकोग्रामा किलोनिस* और *ट्राइकोग्रामा जेपोनिकम* के विभेदों में उच्च तापमान सहिष्णुता का विकास

क्षेत्रीय केन्द्र (सी आई सी आर) कोयम्बत्तुर में, कपास पर क्षेत्र परीक्षण किया गया जिसमें अनोपचारित क्षेत्र की अपेक्षा तापमान सहिष्णु विभेद *ट्रा. किलोनिस* द्वारा अत्याधिक परजीवीकरण (16%) और कम से कम गूलर क्षति (4.4%) पायी गयी।

क्षेत्रीय अनुसंधान केन्द्र, करनाल मे गन्ने के स्टॉक बेधक *काइलो आरीसिलिअस* के प्रति *ट्रा. किलोनिस* के तापमान सहिष्णु विभेद के परीक्षण मे पाया की उन प्लॉट मे जिनमें कि तापमान सहिष्णु विभेद परजीवी कीट छोडे गये थे उनमें और अनोपचारित प्लॉट मे क्रमश: 7.3% तीव्रता के साथ 53.7% बेधक कीट ग्रसन एवं 11.2% तीव्रता के साथ 68.9% बेधक ग्रसन पाया गया।

ट्रा. जेपोनिकम के अधिक तापमान सहिष्णु विभेद तैयार करने के प्रयास किये जा रहे हैं। जब तापमान 32 से 38° से.ग्रे. बढाया तो ज्यादा परजीवीकरण अभिलेखित किया गया।

2.1.8.2 कीटनाशकों के सहिष्णु *ट्राइकोग्रामा किलोनिस* का चयन

एन्डोसल्फान, मोनोक्रोटोफॉस और फेनवालीरेट के सहिष्णु तीनों विभेदों को मिलाकर सभी कीटनाशकों का उपयोग करते हुए अलग से पाला गया, जिससे कि इनमें सभी कीटनाशकों के प्रति सहिष्णु विभेद तैयार किये जा सके।

2.1.8.3 गुजरात, कर्नाटक और तमिलनाडू मे कपास गूलरों के प्रति कीटनाशक सहिष्णु विभेद के गुणन का मूल्यांकन

गु.कृ.वि.वि., आनन्द, क्षेत्रीय केन्द्र (सी.आई.सी.आर.), कोयम्बत्तुर, कृषि विज्ञान विश्वविद्यालय, धारवाड, और त.ना.कृ.वि.वि., कोयम्बत्तुर के सहयोग से क्षेत्रीय जाँच परीक्षण करने के लिए कपास गूलरों के प्रति कीटनाशक सहिष्णु विभेद की प्रभाव दक्षता देखने के लिए परजीवी कीटों की सहिष्णु विभेद को 1,50,000/ हे. की. दर से छोडा गया और उनकी तुलना प्रयोगशाला मे पाले गये सामान्य परजीवी कीटों से की गई। कोयम्बत्तुर में किये गये जाँच परीक्षण में जहाँ परजीवी कीटों को 15 दिनों के अंतराल पर 3 बार छोड़ा गया वहाँ पर परजीवीकरण 9.4% और गूलर क्षति 4% पायी गयी जबकि अनोपचारित क्षेत्र मे अण्डों का परजीवीकरण नही पाया गया और गूलर क्षति 10.5% पायी गयी। गु.कृ.वि.वि., आनन्द मे, बहुकीटनाशक सहिष्णु विभेद छोडे गये क्षेत्र में गूलर कम क्षतिग्रस्त, अण्डों का परजीवीकरण अत्यधिक और उपज अत्यधिक पायी गयी। त.ना.कृ.वि.वि., कोयम्बत्तुर मे किये गये परीक्षण दर्शाते है कि लारवों का ग्रसन कम पाया गया और गूलर कम क्षतिग्रस्त पाये गये और उपज अत्यधिक पायी गयी।

कृ.वि.वि.वि., धारवाड मे कपास गूलरों के प्रति विभेद परीक्षण मे पाया गया कि विभिन्न कीटनाश को के प्रयोग के बाद प्रयोगशाला मे पाले गये सामान्य *ट्रा. किलोनिस* द्वारा अण्ड परजीवीकरण (12.63%) पाया गया, जबकि सहिष्णु विभेद छोडे गये क्षेत्र मे परजीवीकरण अत्यधिक (25.42%) पाया गया।

2.1.8.4 ट्राइकोग्रामा की विभिन्न प्रजातियों की अधिक परपोषी ढूँढने की क्षमता विभेद का चयन

ट्राइकोग्रामा की विभिन्न प्रजातियों की अधिक परपोषी ढूँढने की क्षमता वाले विभेद के चयन के अध्ययन मे पाया कि इन विभेदों मे परपोषी ढूँढने कि क्षमता 10 पीढियों तक रहती है और परजीवी कीटों की परजीवीकरण क्षमता 36.9 - 72.4% जबकि पिंजडे में लगातार पाले गये परजीवी कीटों की परजीवीकरण क्षमता 53.6 - 77% होती है।

2.1.8.5 'ट्राइको' कार्डों का खेत में छोड़ने के लिए संग्रहण

खेत मे छोडने की प्राथमिकता के आधार पर 8 - 9 दिन वाले परजीवित अण्डों के कार्ड को बी.ओ.डी. में 15° से.ग्रे. तापमान पर संग्रहित करने के लिए उत्तम पाया गया। 8 दिन वाले परजीवित अण्ड कार्ड को 7 दिनों तक और 9

दिन वाले परजीवित कार्ड को 3 दिनों तक संग्रहित करने के बाद बी.ओ.डी.से बाहर निकलने के 2.30 घन्टे के बाद सारे प्रौढ परजीवी कीट बहर निकल आते हैं।

2.1.9 कीट रोगाण्विक विषाणुओं और कवकों का अध्ययन

ट्राइकोप्लुसिया नी, स्पोडोप्टेरा एक्जिगुआ, क्रोसीडोलोमिया बाइनोटेलिस, ओपिसिना ऐरेनोसेल्ला, काइलो इनफस्कटेलस, क्राइसोपरला कारनीया और *काडरा कोटेल्ला* के न्यूक्लियोपोलीहैड्रो विषाणुओं को पृथक किया गया और इनकी रोगाण्विक क्षमता का परीक्षण किया गया। *काडरा कोटेल्ला* से एक नीओग्रेग्राइन प्रोटोजोआ रोगाणु, *मेटेसीआ डिसपार* को पृथक किया गया।

नोम्युरिया रिलेई को कानोडिया बीजाणु उत्पादन 5% दानेदार यीस्ट में अधिकतम और सस्ती पायी गयी। *नो. रिलेई* के कोनोडिया उत्पादन के लिए उचित द्रव माध्यम के जाँच परीक्षण में चावल का निष्कर्ष (5%) + दानेदार यीस्ट (5%) को सभी पृथककरणों में उचित पाया गया। सभी पृथककरणों के कोनाइडल उत्पादन के लिए तापमान 25° से.ग्रे. और आर्द्रता 70 - 90% उचित पाया गया।

ठोस माध्यम पर वायुवीय कोनिडिया और स्थाई संवर्धनों पर द्रवीय कोनिडिया के उपयोग के 10 दिनों के बाद 40-80% *स्पो. लिटयूरा* मृत पाये गये। फ्रिज मे 5 - 8° से.ग्रे. तापमान पर, चार महीने संग्रहण पर पाँचो पृथककरणों के बीजाणुओं की पर्याप्त संख्या (10^9/ग्राम) पायी गयी।

2.1.10. *बेसीलस थ्युरिन्जिएन्सिस* के नये डब्लयू डी पी नियमन को तैयार करने के लिए अल्ट्रा वायलेट संरक्षण

भा.कृ.अनु.सं., नई दिल्ली में, *बेसीलस थ्युरिन्जिएन्सिस* के नये डब्लयू डी पी नियमन मे अल्ट्रा वायलेट संरक्षण मिलाने से, नियमन को अल्ट्रा वायलेट उदभासन करने के बाद प्रयोग करने पर, *हे. आर्मिजेरा* के प्रति घातकता अधिक पायी गयी। संरक्षणो में रानिपाल की अपेक्षा कोन्गो रेड 1% सान्द्रता सर्वोत्तम पायी गयी।

2.1.11 कवकीय और जीवाणुवीय प्राकृतिक शत्रु

ट्रा. हरजिएनम, पी डी बी सी टी एच - 10 और *ट्रा. विरिडिए*, पी डी बी सी टी वी-23 का बहुगुणन उत्पादन अध्ययन में, गुड-सोया माध्यम (गुड-50 ग्राम / ली. और सोया आटा - 10 ग्राम / ली.) को 10 लीटर क्षमता वाले फर्मेन्टर का प्रयोग करने से दोनो पृथककरणों का जैव उत्पाद फर्मेन्टेशन के 4 दिनों के बाद बहुत अधिक देखा गया। इन-विट्रो अंत: क्रिया अध्ययन दर्शाता है कि *ट्रा. हराजिएनम* और *ट्रा. विरिडे* के अनेक विभेद एक दूसरे में संयोजित हो जाते हैं।

प्रयोगशाला में पाले गये परपोषी कीट *कोरसेरा सीफेलोनिका* और *साईटोट्रोगा सिरेलेल्ला* को *ट्राइकोडर्मा हरजिएनम, ट्रा. विरिडिए* और *ट्रा. वाइरेसेन्स* के बहोत्पादन के लिए प्रयोग करने पर पाया कि *साइटोट्रोगा* उपयोग करने पर अत्याधिक बीजाणु बनते है और *ट्राईकोडर्मा* की तीनों प्रजातियों की कालोनी अधिक बनती है और यह ज्वार अधोस्तर की अपेक्षा उत्तम पायी गयी।

गो.ब.प.कृ.वि.वि.एवं.प्रौ., पन्तनगर मे किया गया अध्ययन दर्शाता है कि बीज जैव-रंजक के लिए *ट्राइकोडर्मा* पाउडर (10 ग्राम टी एच + 10 ग्राम गोबर की खाद पाउडर + 5 ग्राम अराबिका गोंद 50 मि.ली. पानी मे यह एक कि.ग्रा. बीज के लिए) से बीज उपचारित करने से विशेषकर ऊसर मृदा में चावल, गैंहू, मटर, मसूर, अरहर, टमाटर, बैंगन, शिमला मिर्च, पातगोभी, फूलगोभी और मिर्च के नवोद्भिद जल्दी और एकसमान निकलते हैं, नवोद्भिदों की वृद्दि अच्छी होती है, बीज और मृदा से पैदा होने वाले रोगों के प्रति संरक्षण प्राप्त होता है।

उत्तरांचल प्रदेश के पहाडी और मैदानी क्षेत्रों के किसान गोबर की खाद में *ट्रा. हरजियनम* के उत्पादन को अपने खेतों मे ही उत्पादित कर रहे हैं। इस प्रौद्योगिकी का प्रदर्शन किया गया और सब्जियों और अन्य फसलों की कार्बनिक खेती करने वाले इस प्रौद्योगिकी को अपना रहे हैं।

2.1.12 कीट रोगण्विक सूत्रकृमि

स्टेइनर्नेमा कार्पोकेप्से और *हेटेरोरहाब्डिटस इन्डिका* का शीघ्र और सस्ता उत्पादन करने के लिए वर्मिकुलाइट के प्रयोग की विधि विकसित की गई। श्वेत ग्रब, *हो. लेपिडोफोरा* के प्रति *स्टेइनर्नेमा* के पृथककरण की अपेक्षा *हेटेरोरहाब्डिटस* के पृथक करण अधिक प्रभावी पाये गये। *प्लु. जाइलोस्टेल्ला* के लारवों के प्रति *स्टे. कार्पोकेप्से* और *हे. इन्डिका* का रोगाण्विकता परीक्षण किया गया, जिससे प्रदर्शित होता है कि यह 72 घंटे मे 96% और 98% लारवों के लिए घातक है।

2.1.13 पादप परजीवी सूत्रकृमियों का जैविक नियंत्रण

सूत्रकृमियों के अण्डों के सेने और परजीवीकरण क्षमता के लिए, पानी-अगर माध्यम की अपेक्षा कॉर्न-मील-अगर माध्यम उत्तम पाया गया। ठोस अधोस्तरों जैसे स्पेन्ट माल्ट वेस्ट, कपास बीज मील, गैंहू का चौकर और पोन्गामिआ केक 9 दिनों मे ही उनकी मायसिलिया की वृद्दि को बढाता है, क्लेमॉयडों बीजाणु अधिक मात्रा में बनते है तथा कार्न मील अगर के प्रति ग्राम की दशा में क्लेमॉयडों बीजाणु अधिक बनते हैं। टॉल्क, लकडी का बुरादा और वर्मिकुलाइट नियमन 10 महीने के संग्रहण के बाद भी 80-60% बीजाणु सक्रिय होते हैं। टॉल्क और लकडी का बुरादा वाले, नियमन भी जड़-ग्रन्थि सूत्रकृमियों की संख्या को 48 और 39% तक कम करते हैं और रेनिफोर्म सूत्रकृमियों की संख्या को 42 और 34% तक कम कर देते हैं।

मिनि प्लॉट परीक्षण मे पाया गया कि किसान के खेत में, जड-ग्रन्थि सूत्रकृमि से ग्रसित टमाटर की फसल मे *पा. लिलेसिनस* के टॉल्क नियमन और कार्बनिक सुधार संयोजन की विधि के विकास परीक्षण दर्शाते हैं कि वर्मिकम्पोस्ट मे अण्डों का परजीवीकरण सबसे अधिक और सूत्रकृमियों की संख्या मे कमी पायी गयी। इसके बाद क्रमश: नीम की खली, फार्म कम्पोस्ट और पेलेटाइज्ड कार्बनिक खाद पाये गये।

2.1.14 खरपतवार रोगाणु

पार्थेनियम के महत्वपूर्ण जैव कारक *फ्यूजेरियम पेलिडोरोसीयम* के बह्वेत्पादन द्रवीय माध्यम में किया गया और इसको पाउडर, तेलीय इमल्शन, एल्जिनेट गोलियाँ और पेस्टा दानेदार रूप मे नियमन बनाया जाता है। यद्यपि ग्रीनहाउस दशाओं मे इस नियमन के दो छिड़काव उत्तम पाये गये, परन्तु यह क्षेत्रीय दशाओं में प्रभावी सिद्द नही हुऐ।

जलकुंभी के एक रोगाणु *आल्टरनेरिया अल्टरनेटा* को फर्मेन्टेशन विधि द्वारा उत्पादन किया गया और पाउडर, तेल इमल्शन, एल्जिनेट गोलियां और पेस्टा दानेदार रूप में नियमन तैयार किया गया। खुली हवा मे इसके दो छिडकाव से ये रोगाणु काफी पनपते हैं। सबसे अधिक प्रचंडता (8.6) पाउडर नियमन से होती है। जलीय फर्न *सेल्विनिया मोलेस्टा*, जलीय लेटयूस *पिस्टा स्ट्रोटिओट्स* और एलीगेटर खरपतवार *आल्टरनेन्थेरा फाइलोक्सेरॉयडस* के परपोषी विशेष परीक्षण मे पाया कि *अल्टरनेरिया* और *कैर्कोस्पोरा* जाति इनके लिए रोगाण्विक या विषैले नही हैं।

2.1.15 सॉफ्टवेयर का विकास

धान के कीटों के लिए जैविक नियंत्रण के लिए एक्सपर्ट सिस्टम ''बायोराईस'' विकसित किया गया है। वैज्ञानिकों, अनुसंधानकर्ताओं, विस्तार कार्यकर्ताओं, निजी कम्पनियों और किसानों को, *हे. आर्मिजेरा* और इसके प्राकृतिक शत्रु कीटों के बारे में जानकारी उपलब्ध कराने के लिए एक सी डी ''हेलिको - इन्फो'' विकसित की गई है।

2.2 गन्ने के हानिकारक कीटों का जैविक नियंत्रण

पं.कृ.वि.वि., लुधियाना मे गन्ने कि हानिकारक कीटों के प्राकृतिक शत्रु कीटों का अनुवीक्षण पूरे वर्ष किया गया, जिसमे पाया गया कि पंजाब में फसल मौसम के दौरान *का. इनफसकटेलस*, *का. आरीसीलियस* और *स्कि. एकसपटेलिस* के अण्ड परजीवी कीट (ट्राइकोग्रामेटिड्स) और लारवा परजीवी कीट (*को. फ्लेविपस*, *स्टे. नीसेविलेई*, *स्ट. इन्फेरेन्स*, *आ. जवेन्सिस*, *रे. स्किरपोफेगे*) अत्यधिक सक्रिय पाये गये। कोयम्बत्तुर मे *स्ट. इनफेरेन्स* पूरे वर्ष सक्रिय पाये गये। हरियाणा मे *स्टे. इनफेरेन्स* तना बेधक और गुरुदासपुर बेधक पर और अगोला बेधक पर *आ. जवेन्सिस* प्राय: पाये गये। करनाल, हरियाणा में, *पा. परपुसिल्ला* के अण्ड परजीवी कीट *ओ. पोपीलियोनिस* और निम्फ तथा प्रौढ परजीवी कीट *इ. मीलेनोल्यूका* पाये गये।

पं.कृ.वि.वि., लुधियाना में, अप्रैल - जून माह के दौरान तना बेधक *का. इन्फस्कटेलस* के ग्रसन को कम करने के लिए पडान 5 जी को 25 कि.ग्रा. / हे. की दर से और *ट्रा. किलोनिस* को 10 दिनों के अन्तराल पर 50,000/ हे. की दर से 8 बार छोडने पर बेधक के ग्रसन को प्रभावी एवं समान रूप से सफल पाया गया, यह क्षेत्रीय अध्ययन 4 स्थानों पर किया गया।

परवारानगर, महाराष्ट्र मे बडे स्तर पर जैव नियंत्रण का प्रदर्शन किया गया। इसके अन्तर्गत 10 दिनों के अन्तराल पर *ट्रा. किलोनिस* को 50,000/- हे. की दर से छोडने पर तना बेधक का ग्रसन प्रभावपूर्ण ढंग से कम किया गया। म.फु.कृ.वि., पुणे में भी इसी प्रकार के प्रदर्शन में *ट्रा. किलोनिस* को 50,000 प्रौढ / हे. / बार के दर से 8 बार छोडने पर प्रभावी पाया गया, परजीवीकरण अधिक और डेड हर्ट बनने मे कमी पायी गयी। पंजाब के फिरोजपुर जिले के करनी खेडा गाँव में 40 हेक्टेयर से भी अधिक क्षेत्र मे स्टॉक बोरर के नियंत्रण के लिए *ट्रा. किलोनिस* की दक्षता का सफलतापूर्वक प्रदर्शन किया गया।

करनाल में *ब्यु. बेसीयाना* के 10^6-10^{10} बीजाणु / मि.ली. को पानी के साथ टीपाल 0.05% की मात्रा में मिलाकर बीजाणु निलंबन को छिडकाव करने से लारवे अधिक ग्रसित मिले और खेत मे गन्ने की उपज अधिक प्राप्त हुई।

ग.प्र.सं, कोयम्बत्तुर मे *ब्यु. ब्रोन्गनिआर्टी* के वाहक लिग्नाइट और वार्मिकास्टिंग का प्रयोग करने पर *हे. सेरेटा* के तीसरे निरूप के ग्रब्ज के लिए घातक पाया गया। *ब्यु. बेसीआना, ब्यु. ब्रोन्गनिआर्टी* और *मे. एनाईसोप्लिए* के प्रति क्लोरपायरीफोस और कार्बेन्डेजिम अत्यधिक विषैले पाये गये क्योंकि ये इनकी जैव दक्षता और बीजाणु उत्पादन को बुरी तरह प्रभावित करते हैं। ब्यु. ब्रोन्गनिआर्टी, *ब्यु. बेसीयाना* और *मे. एनाइसोप्लिए* का प्रयोग, क्रा. कारनीया, केन्चुए, *लेम्पिटो मोरीटाई*, कॉमनकार्प *साइप्रीनस कारपीओ* के लिए सुरक्षित पाया गया किन्तु मकडी, *सा. सीकेट्रासा* के लिए यह 16% घातक सिद्द हुआ।

गन्ने में वुली माँहू के लिए पुणे, सतारा, सांगली और कोल्हापुर जिलों मे सर्वेक्षण करने पर पाया गया कि वुली एफिड अगस्त से सितंबर, 2002 के दौरान गन्ने को 5-10% क्षतिग्रस्त करती है। पुणे के थिलेकारवाडी गाँव में एक कोक्सीनेलीड परभक्षी कीट *सा. ग्रान्डिस* को गन्ने के खेत मे अप्लावित रूप से नवम्बर 2002, माह के पहले सप्ताह मे छोडा गया और बाद मे इनकी पुन: प्राप्ति की गई। परभक्षी कीट *कोक्सीनेल्ला* स्पे., *काइलोमीनस* स्पे. न्युरोप्टेरन्स, *मलाडा* स्पे. और *डा. एफिडिवोरा* को मांहू पर भक्षण करते पाया गया लेकिन पुणे जिले मे इनकी संख्या कम पायी गयी। जबकि कोल्हापुर जिले में *डा. एफिडिवोरा* बहुतायत में मिला।

2.3. कपास के हानिकारक कीटों का जैविक नियंत्रण

कपास के हानिकारक कीटों का नियंत्रण करने के लिए आचार्य एन. जी. रंगा कृ.वि.वि., हैदराबाद, म.फु.कृ.वि., पुणे, त.ना.कृ.वि.वि., कोयम्बत्तुर और गु.कृ.वि.वि., आनन्द मे जैव - प्रबल समन्वित पीडक प्रबंधन प्रक्रियाओं की दक्षता का परीक्षण किया गया। अनोपचारित और किसानों द्वारा अपनाई जाने वाली प्रक्रियाँओं की अपेक्षा जैव प्रबलित समन्वित पीडक प्रबंधन प्रक्रिया अपनाने पर फुदकों और श्वेत मक्खियों की संख्या मे कमी, प्राकृतिक शत्रु कीटों जैसे कोकसीनेलिड, मकाडियों और लेसविंग्स कीट अधिक पाये गये तथा कपास की उपज अत्यधिक मिली। आनन्द और कोयम्बत्तूर में आई पी एम के अन्तर्गत कपास के साथ मक्का को अंत: फसल के रूप में उगाने पर *काइलोमीनस सेक्समेकुलेटा* की सक्रियता अधिक देखी गई। आनन्द में जैव कारक क्षेत्र अनेक प्राकृतिक शत्रु कीटों जैसे *एलीओडस एलीगारहेन्सिस, ट्रा. किलोनिस, अगेथिस, क्राइसोपरला, जीओकोरिस* और स्टेफिलिनिड्स को आश्रय प्रदान करते हैं।

तोण्डामुथुर, कोयम्बत्तुर जिले में कपास के हानिकारक कीटों के प्राकृतिक शत्रु कीटों को आश्रय देने वाले परपोषी पौधों और प्राकृतिक शत्रु कीटों की सक्रियता का फसल तथा अन्य परपोषी पौधो की समीप्यता को जानने के लिए गहन अनुवीक्षण किया गया। कपास, मक्का, फूलगोभी और टमाटर तथा खरपतवार जैसे *एब्युटिलोन इन्डिकम, सोलेनम नीग्रम, अरिस्टोलोशिकिया, हैबिस्कस फिक्युलोन्सिस, क्रोजोफोरा रोटलारी* और बन्ड घासों मे भी मकडियाँ, मेन्टिड्स, कोक्सीनेलिड्स, क्राइसोपिड्स और *रहाइनोकोरिस* स्पे. पायी गयी।

हे. आर्मिजेरा को नियांत्रित करने के लिए *नो. रिलेई* का जलीय निस्यंदन और पानी मे तेलीय इम्लशन को $5x10^{11}$ बीजाणु/ हे. की दर से छिडकाव करने पर वही परिणाम मिलते हैं जो कि एन्डोसल्फान (0.07%) का प्रयोग करने से मिलते हैं।

2.4 तम्बाकू के हानिकारक कीटों का जैविक नियंत्रण

जैव प्रबलित आई पी एम प्रक्रियायें अपनाने से, *हे. आर्मिजेरा* द्वारा गूलर और केप्सूल मे छेदों की क्षतिग्रस्तता प्रतिशत कम करता है। *केम्पोलेटिस क्लोरिडिए* छोडने से *स्पो. लिटयूरा* और *हे. आर्मिजेरा* के लारवों को 5-10% से 7-13% तक परजीवित करते हैं।

स्पो. एक्जिगुआ के अण्डों को *टेलीनोमस रीमस* को उदभासित करने पर *टे. रीमस* द्वारा 4-32% परजीवीकरण करते हैं। इसी प्रकार *स्पो. एक्जिगुआ* के लारवों को *ग्लायप्टेपेन्टेलस अफ्रीकेन्स* द्वारा उदभासित करने पर तम्बाकू के विभिन्न प्रकारों मे 9 से 31% परजीवीकरण पाया जाता है।

2.5 दलहनी फसलों के हानिकारक कीटों का जैविक नियंत्रण

आचार्य एन जी रंगा कृ.वि.वि., हैदराबाद मे अरहर के फली बेधक के जैव प्रबलित कीट प्रबंधन के परिणाम दर्शाते हैं कि हे. एन.पी.वी. और नीम बीज अर्क का एकान्तरित छिडकाव (हे.एन.पी.वी. - नीम बीज अर्क - *हे.*एन.पी.वी. - नीम बीज अर्क) का प्रयोग करने पर *हे. आर्मिजेरा* का सफलतापूर्वक नियंत्रण करने के साथ-साथ सूँडियों की संख्या कम और फली क्षतिग्रस्तता कम करने मे प्रभावी पाया गया। बी.आई.पी.एम. विधियाँ अपनाये गये क्षेत्र में वेस्पों और मक्खियों द्वारा फलियों की क्षतिग्रस्तता भी कम पायी गयी।

इसी प्रकार के परीक्षण त.ना.कृ.वि.वि, कोयम्बत्तुर मे भी किये गये लेकिन यहाँ पर बी.टी. - *हे.*एन.पी.वी. का एकान्तर प्रयोग करने पर *हे. आर्मिजेरा* की सूँडियों का सफलतापूर्वक नियंत्रण करने के साथ वेस्प और अन्य बेधकों द्वारा फली की क्षतिग्रस्तता को भी कम किया गया। अनोपचारित क्षेत्रों से केवल 886 कि.ग्रा. / हे. जबकि उपचारित क्षेत्रों से 1826 कि.ग्रा. /हे. उपज प्राप्त हुई।

गु.कृ.वि.वि., आनन्द मे बिना मौसम के समय मे वैकल्पिक परपोषी पौधों को पहचानने का अध्ययन किया गया इसमें दर्शाया गया कि *रस्टिका* तम्बाकू, बीडी तम्बाकू, गैंदा, मक्का, मत्सगंधा, केशिआ, स्टारबर, पार्थेनियम, डयूरेन्टा, अमेरेन्थस, *लेन्टाना कैमारा,* बैंगन, सनहैम्प और तिल की फसलें, प्राकृतिक शत्रु कीटों - *रहाइनोकोरिस, ब्रेकोन* स्पे., *जीओकोरिस* स्पे., *ट्राइकोग्रामा, नोबिस,* क्रेब स्पाइडर, *को. सेक्समेकुलेटा, जेन्थोग्रामा,* एन्थोकोरिड, *क्रा. कारनीआ* और *ट्रा. किलोनिस* को आश्रय प्रदान करते हैं।

त.ना.कृ.वि.वि., कोयम्बत्तुर में अरहर पर किये गये अध्ययन मे पाया कि *मायलेब्रिस पुस्तुलेटा* और *हे. आर्मिजेरा* के प्रति कीट रोगाण्विक सूत्रकृमि *हेटरोरहाब्डिटिस* स्पे. को 0.5, 1.0 और 2.0 बिलियन / हेक्टेयर की दर से प्रयोग करने पर *हे. आर्मिजेरा* द्वारा फली क्षति को कम किया जा सका और यह एण्डोसल्फान से तुलना मे उत्कृष्ट पाया गया। यद्यपि, *मा. पुस्तुलेटा* की संख्या मे अपरिहार्य कारण से कमी नही पायी गयी। भा.द.अनु.सं., कानपुर मे ब्लिस्टर बीटल के प्रति *हेटरोरहाब्डिटिज इन्डिका* की दक्षता का भी इसी प्रकार मूल्यांकन किया गया। कीट रोगाण्विक सूत्रकृमि उपचार का प्रभाव 3 दिनों तक प्रभावी पाया गया, उपचार वाले दिन 90% घातक और इसके बाद 72-80% घातक पाया गया।

2.6 धान के हानिकारक कीटों का जैविक नियंत्रण

आ.कृ.वि.वि., जोरहाट मे धान के हानिकारक कीटों के प्राकृतिक शत्रु कीटों का अनुवीक्षण किया गया। *ट्रा. जेपोनिकम* द्वारा तना बेधक के अण्डों का परजीवीकरण 15-23% पाया गया। *आलोसेफेस* स्पे. द्वारा खरीफ मौसम के दौरान पत्ती मोड़क सूँडियों का 10-12% परजीवीकरण पाया गया। मकडियों मे *लाइकोसा स्युडोएन्युलेटा* प्रायः पाया

गया इसके बाद *ला. मदानी, आर्जिओपे केटेन्युलेटा* और *निओस्कोना* स्पे. पाये गये। इसी प्रकार का अनुवीक्षण पं.कृ.वि.वि., लुधियाना में दर्शाते हैं कि *स्कि. इन्सर्टुलस* के अण्डों का *टेलीनोमस डिग्नोयड्स, ट्रा. किलोनिस* और *ट्रा. जेपोनिकम* के द्वारा 49.19 प्रतिशत परजीवीकरण करते हैं और केवल *टे. डिग्नोयड्स* द्वारा ही 40.17 प्रतिशत परजीवीकरण पाया गया। *का. मेडीनेलिस* पर *ब्रेकोन* स्पे. *कोटेशिआ* स्पे. और तीन अनभिज्ञ सूँडी परजवी कीटों के द्वारा 16.31 प्रतिशत परजीवीकरण अभिलेखित किया गया। के.कृ.वि.वि., थ्रिसुर में, धान के हानिकारक कीटों के प्राकृतिक शत्रु कीटों का सर्वेक्षण किया गया और मकडियों की कुल 51 प्रजातियों की सूची तैयार की गई ये 9 कुलों और 23 वंशों के अन्तर्गत आते हैं।

आ.कृ.वि.वि., जोरहाट में, क्षेत्रीय मूल्याँकन किया गया जिसमे तना बेधक और पत्ती मोडक कीट के प्रति *ट्रा. जेपोनिकम* और *ट्रा. किलोनिस* छोडने के साथ-साथ बी.टी. छिड़काव करने पर रबी और खरीफ मौसम मे पत्ती मोड़क कीट का ग्रसन प्रतिशत बहुत कम पाया गया। *ट्राइकोग्रामा* छोडे गये क्षेत्रों में उपज अत्याधिक (3559.20 कि.ग्रा./हे.) पायी गयी। म.फु.कृ.वि., पुणे में, *ट्रा. जेपोनिकम*+ *ट्रा. किलोनिस* प्रत्येक को 1,00,000 प्रौढ / हे. / बार की दर से तीन बार छोड़ना बहुत प्रभावी पाया गया और डेड हर्ट (9.92%), श्वेत बालियाँ (4.33%) और तना बेधक तथा पत्ती मोडक कीट का ग्रसन बहुत कम पाया गया। उपचारित क्षेत्रों में अत्याधिक उपज 4840 कि.ग्रा. / हे. पायी गयी।

पं.कृ.वि.वि., लुधियाना ने सुधार गाँव में किसान के खेत पर धान के पत्ती मोडक कीट, *ने. मेडीनेलिस* और *स्टे. इनसर्टुलस* के प्रति *ट्रा. किलोनिस* और *ट्रा. जेपोनिकम* के समन्वित प्रयोग का मूल्याँकन किया। परजीवी कीट छोडे गये (1,00,000/हे.) क्षेत्र में पत्ती मोडक का ग्रसन केवल 1.50%, रासायनिक नियंत्रण क्षेत्र में ग्रसन 1.80% और अनोपचारित क्षेत्र में 5.24% तथा कम मात्रा में परजीवी कीट छोडे गये (50,000 / हे.) क्षेत्र में 4.80% पाया गया। परजीवी कीट छोडे गये (1,00,000/हे.) और रासायनिक नियंत्रण क्षेत्रों मे डेड हर्ट और श्वेत बालियों का प्रतिशत माध्यम बहुत कम पाया गया। अनोपचारित क्षेत्र से उपज केवल 55.30 कुन्तल / हे. की अपेक्षा रासायनिक नियंत्रण से उपज केवल 60.50 कुंतल / हे. तथा इन दोनों की अपेक्षा परजीवी कीट छोड़े गये क्षेत्र से उपज अत्याधिक 60.90 कुन्तल / हे. प्राप्त होती है।

आ.कृ.वि.वि., जोरहाट द्वारा बोरहोला मे रबी और खरीफ मौसम के दौरान किसान के खेत में, रासायनिक नियंत्रण और जैव नियंत्रण आधारित आई.पी.एम. की तुलना का मूल्याँकन किया गया। *ट्राइकोग्रामा* को 50,000/हे. की दर से छोडने पर डेड हर्ट बनने को सफलतापूर्वक कम (2.66% से 5.29%) करता है। पत्ती मोडक कीट द्वारा क्षति को जैव नियंत्रण और रासायनिक नियंत्रण प्रयोग करने से सफलता पूर्वक नियंत्रित किया गया। *ट्रा. जेपोनिकम* की खेत से पुन: प्राप्ति के लिए, खेत में *कोरसेरा* के अण्डों के कार्ड को खेत में फसल पर चिपका कर आकलन किया गया और पुन: प्राप्ति प्रतिशत 20-25% पायी गयी। त.ना.कृ.वि.वि. द्वारा तमिलनाडू में आयोजित परीक्षणों मे पाया कि *ट्राइकोग्रामा* छोडे गये क्षेत्रों में डेड हर्ट और श्वेत बालियों का प्रतिशत बहुत कम पाया गया। परजीवी कीट छोडे गये क्षेत्रों

में पत्ती मोडक कीटों द्वारा क्षतिग्रस्तता भी कम पायी गयी। *ट्राइकोग्रामा* छोडे गये क्षेत्र में तना बेधक कीट के अण्डे अत्यधिक प्रतिशत परजीवी पाये गये। *ट्राइकोग्रामा* छोडे गये प्लाट मे उपज अत्याधिक 3916 कि.ग्रा. / हे. और अनोपचारित प्लाट से उपज अपेक्षाकृत कम केवल 2740 कि.ग्रा. / हे. प्राप्त हुई।

फिरोजपुर जिले के करनी खेडा गाँव में पं.कृ.वि.वि., लुधियाना द्वारा किसान के खेत पर आई.पी.एम. (*ट्रा. किलोनिस* सात बार छोडना + *ट्रा. जेपोनिकम* को पौध रोपण के 30 दिनों के बाद से प्रत्येक को 1,00,000 / हे. / सप्ताह की दर से + पडान 4 जी 25 कि.ग्रा. / हे. की दर से एक बार प्रयोग) का प्रयोग किया गया। आइ.पी.एम. और रासायनिक नियंत्रण से डेड हर्ट और श्वेत बालियों का प्रतिशत काफी कम और उपज भी बहुत ज्यादा प्राप्त हुई।

2.7 तिलहनी फसलों के हानिकारक कीटों का जैविक नियंत्रण

आलियार नगर, पोल्लाची मे त.ना.कृ.वि.वि. ने मूँगफली की फसल पर *स्पो. लिट्यूरा* और *हे. आर्मिजेरा* के प्रति *नो. रिलेई* का मूल्याँकन किया। इस कवक का पानी में निलंबन या पानी में तेलीय नियमन को $5x10^{11}$ बीजाणु / हे. की दर से प्रयोग करना दोनों कीटों को नियंत्रित करने के लिए उतना ही प्रभावी पाया गया जितना कि कीटनाशी उपचार प्रभावी होता है।

पं.कृ.वि.वि., लुधियाना में, प्रयोगशाला की दशाओं में सरसों के माहूँ कीट, *लिपेफिस एरीसीमाई* के प्रति *वर्टिसिलियम लेकेनाई* का मूल्याँकन किया गया। उपचार के, 96 घन्टों के बाद अधिक मात्रा (10^8 कोनिडिया / मि.ली.) की दर से प्रयोग करने पर अत्यधिक घातकता (40%) अभिलेखित की गई।

2.8 नारियल के हानिकारक कीटों का जैविक नियंत्रण

जै.नि.प.नि., बंगलोर, क्षेत्रीय केन्द्र (के.रो.फ. अनु.सं) कायान्गुलम, आचार्य एन.जी. रंगा कृ.वि.वि., हैदराबाद, के.कृ.वि.वि. थ्रिसुर और कृ.वि.वि.वि., धारवाड में अनेक जगहों पर नारियल की माइट, *असीरिया गुअेरीरोनिस* के प्रति *हिर्सुटेल्ला थोम्पसोनाई* कवक के दो नये नियमनों के साथ पहले से ही उपलब्ध माईकोहिट नियमन के मूल्यांकन परीक्षण किये गये। सभी उपचारों को 15 दिनों के अन्तराल पर तीन बार छिडकाव करके प्रयोग किया गया। इन सभी तीनों नियमनों ने नारियल की सतह पर जीवित माइट को प्रतिवर्ग मि.मी. सफलता पूर्वक कम किया। यद्यपि बंगलोर में किये गये परीक्षणों में नारियल में कम क्षति होने का कोई विशेष प्रभाव दिखाइ नही दिया। कायांगुलम में एक स्थान पर और हैदराबाद में दो स्थानों पर माइट की संख्या और क्षतिग्रस्त नारियलों की गणना करने पर उपचारों का कोई विशेष अन्तर दिखाई नही दिया। थ्रिसूर में दो स्थानों पर उपचार के बाद गणना करने पर जीवित माइट / मि.मी.^{2} का सभी तीनों माइकोहिट नियमन और गीली गंधक से उपचारित क्षेत्रों पर तथा अनोपचारित क्षेत्र से तुलना करने पर पाया गया कि उपचार करने से माइट की संख्या को सफलतापूर्वक कम किया गया है।

धारवाड में किये गये परीक्षण दर्शाते हैं कि *हि. थोम्पसोनाई* के तीनों नियमन, गीली सल्फर के समान प्रभावी पाये गये किन्तु अनोपचारित क्षेत्रों की तुलना मे उत्कृष्ट पाये गये।

क्षेत्रीय केन्द्र (के.रो.फ.अनु.सं), कायांगुलम में *ओपिसिना एरेनोसेल्ला* का पूरे वर्ष परजीवीकरण पाया गया। *ब्रेकीमेरीया* स्पे. द्वारा 34% और *एपेन्टेलस टेरेगामे* द्वारा 41.2% औसत प्रतिशत परजीवीकरण पाया गया। के.कृ.वि.वि., थ्रिसूर में पहले से ही प्रभावी परजीवी कीट *ब्रेकीमेरीया नोसेटोई*और *एपेन्टेलस* स्पे. के साथ-साथ एन्थोकोरिड परभक्षी कीट *कार्डिआस्टेथस* स्पे. अभिलेखित किये गये।

2.9 फल वृक्षों के हानिकारक कीटों का जैविक नियंत्रण

भा.बा.अनु.सं., बंगलोर में *ट्राइकोग्रामा काइलोट्रिए* को 1,00,000 / हे. की दर से साप्ताहिक अन्तराल पर 5 बार छोडने पर अनार के फलों को क्षति करने वाले कीट *डयडोरिक्स आइसोक्रेटस* की सीमांत मात्रा (29.40%) मे कमी हुई जबकि अनोपचारित क्षेत्रों के इन कीटों की प्रतिशतता 34.62% पायी गयी। सोलन में अनार के फल बेधक कीट *ड. एपिजर्बस* का प्रमुख परजीवीकीट *टेलीनोमस*स्पे. पाया गया जिनके द्वारा जुलाई - अगस्त माह के दौरान 50-83.3% परजीवीकरण पाया गया।

भा.बा.अनु.सं., बंगलोर में *ट्राइकोग्रामा किलोनिस* को 1,00,000 / हे. की दर से साप्ताहिक अन्तराल पर 5 बार छोडने के परिणाम स्वरूप, उपचारित वृक्ष पर बेर फल बेधक कीट *मेरीडार्कस सायरोडस* द्वारा फल की क्षति बहुत कम 28.80% पायी गयी जबकि अनोपचारित वृक्ष पर फल क्षति 81.00% पायी गयी। भा.बा.अनु.सं., बंगलोर में अमरूद पर कीट *ए. डिस्पर्सस* का क्षेत्रीय अध्ययन फरवरी 2000 से फरवरी 2003 तक किया गया। जिससे यह प्रदर्शित होता है कि *एनकार्सिया* स्पे. *मेरिटोरिया* जो पहले प्रमुख प्राकृतिक शत्रु कीट था वह स्थायी रूप से *ए. गुआडेलोउपे* के द्वारा विस्थापित हो गया। के. कृ.वि.वि., थ्रिसूर मे *एनकार्सिया* स्पे. का प्राकृतिक परजीवीकरण पूरे वर्ष देखा गया और अमरूद (1.44 - 41.52) की अपेक्षा मिर्च (7.88 - 61.22) में आधिक परजीवीकरण देखा गया। भा.बा.अनु.सं., बंगलोर में 8 परंपरागत कीटनाशक और 9 वानस्पतिक रसायनों का *ए. गुआडेलोउपे* के प्रौढ पर विषैलेपन अवशेष का जाँच परीक्षण किया गया और मोनोक्रोटोफॉस को घातकता के लिए अत्याधिक दीर्घस्थायी पाया गया, यहाँ तक कि प्रयोग के 21 दिनों के बाद भी घातकता बहुत अधिक पायी गयी।

भा.बा.अनु.सं., बंगलोर में आम के फुदके, *इडिओस्कोपस नीवीओस्पार्सस* के प्रति *मेटारहाईजियम एनाईसोप्लिए* का मूल्याँकन अध्ययन किया गया, जो यह दर्शाता है कि 48-72 घन्टों के अन्दर ही यह कवक (1.0×10^{10} बीजाणु / मि.ली. सान्द्रता) कीट के लिए बहुत घातक (68.13 से 100%) साबित होता है। बंगलोर में, अनार के फल बेधक

डि. आइसोक्रेटस के प्रति बी.टी. नियमनों, हाल्ट और डेल्फिन की अपेक्षा बायोलेप और डाइपेल की 1 कि.ग्रा. / लीटर दर बहुत प्रभावी पायी गयी।

सोलन में, सेनजोस स्केल के प्राकृतिक शत्रु कीट डीजल तेल इमल्शन (1:5), डी.सी. ट्रोन प्लस (2%), प्राकृतिक वृक्ष तेल (2%) और आइपोल (25) उपचार परीक्षण में सामान्य रूप से सक्रिय पाये गये।

2.10 सब्जियों वाली फसलों के हानिकारक कीटों का जैविक नियंत्रण

म.फु.कृ.वि., पुणे में आलूकन्द के पत्ती सुरंग करने वाले लारवे, *एपेन्टेलस* स्पे. और *ब्रेकोन* स्पे. द्वारा क्रमश: 2.95 - 7.04% और 4.35 - 8.56% परजीवित करते पाये गये। पुणे में, पातगोभी और फूलगोभी के कीट, *प्लु. जाइलोस्टेल्ला* के लारवे *को. प्लूटेल्ला* द्वारा परजीवित पाये गये।

भा.बा.अनु.सं., बंगलोर में केवल *ट्रा. बेक्ट्रे* के प्रयोग की अपेक्षा एन.एस.पी. और बी.टी. संयोजन के साथ *ट्रा. बेक्टरे* के प्रयोग करने से *प्लु. जाइलोस्टेल्ला* की संख्या कम पायी गयी और एन.एस.पी. + *ट्रा. बेक्ट्रे* उपचार से अधिक (40 टन/हे.) तथा बी.टी. + *ट्रा. बेक्टरे* उपचार से (38 टन / हे.), जबकि केवल *ट्रा. बेक्टरे* के प्रयोग करने से उपज कम (26 टन / हे.) प्राप्त हुई।

पुणे में, बैंगन के फल बेधक कीट, *ल्यूसिनोडेस ओर्बेनेलिस,* के प्रति बी.टी. (हाल्ट) को 2 कि.ग्रा. / हे. की दर से फूल आने के बाद, साप्ताहिक अन्तराल पर तीन छिडकाव करने से फलों का ग्रसन बहुत कम (4.49%) और बाजार योग्य फल की उपज अधिक (149.9 कुन्तल / हे.) प्राप्त हुई।

2.11 आलू की फसल के हानिकारक कीटों का जैविक नियंत्रण

पुणे में, तीन वर्षों तक किये गये परीक्षणों के आँकडे दर्शाते हैं कि पौध रोपण के 45 दिनों के बाद खेत में 5 मी. की दुरियों पर छेददार प्लास्टिक शीशियों (2x1.5 से.मी) में लटकाकर *को. कोइहेलरी* को 5,000 ममीज / हे. की दर से चार एक समान मात्राओं में आलू के खेत में छोडने पर आलूकन्द मौथ पत्ती सुरंग कीट बहुत कम (0.29 सुरंग / मीटर / पंक्ति), कन्द ग्रसन कम (5.92%) पाया गया, पुन: प्राप्ति अत्यधिक (19.86%) और कन्दों की अत्यधिक (231.03 कुंतल / हे.) उपज प्राप्त हुई।

भण्डार गृहों 'अर्नीज' मे *को. कोइहेलरी* 1 ममी / 4 कि.ग्रा. कन्द और *कि. ब्लैकबर्नी* 2 प्रौढ / कि.ग्रा. की दर से 15 दिनों के अन्तराल पर छोडने की विधि परजीवी कीटों को छोडने के लिए अत्यधिक प्रभावी पायी गयी। पुणे में,

आलू के खेतो में *स्पो. लिटयूरा* के प्रति *स्पो.* एन.पी.वी. $3x10^{12}$ पी.ओ.बी. / हे. प्रयोग करना अत्यंत प्रभावी पाया गया।

2.12 खरपतवरों का जैविक नियंत्रण

आसाम के अलेंगमारा, दिशांगमुख और समुगुडी क्षेत्रों में विदेशी विविल्स *नीओकेटिना आइकोर्निए* और *नी. ब्रूकी* ने जलकुंभी को सफलता पूर्वक नियंत्रित किया है। हैदराबाद के आसपास के चार तालाबों में छोडे गये विविल्स और माइट्स स्थापित हो गयी हैं। गु.कृ.वि.वि., आनन्द, के.कृ.वि.वि. थ्रिसूर और म.फु.कृ.वि., पुणे में विविलों के प्रौढों और लारवों की उपस्थिति और उनके द्वारा जलकुंभी को की गई ताजी क्षति जलकुंभी पर देखी गयी।

पूरे वर्ष किये गये सर्वेक्षणों से पता चलता है कि थ्रिसूर में सात स्थानों और ऐर्नाकुलम जिले में एक स्थान पर विविल, *सिरटोबेगस सेल्विनिए* के प्रौढ उपस्थित पाये गये।

Delegates of the Brainstorming Session on Entomopathogenic Nematodes

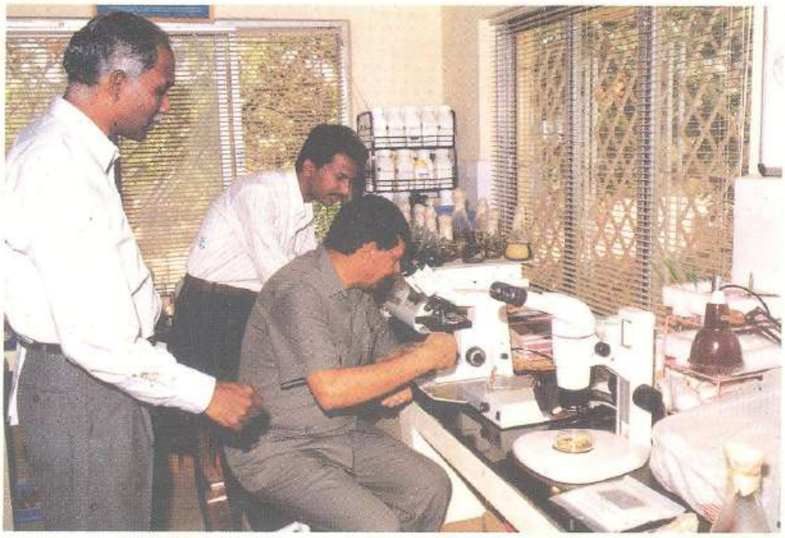
Hands on training on culture of *Plutella xylostella* parasitoids

Dr. S.P. Singh being felicitated during the XI Biocontrol Workers' Group Meeting

Discussions during ICAR-CABI Consultancy on the Quarantine Facility at PDBC

Deliberations during the ICAR-CABI workshop on Quarantine Techniques

Dr. Roy Bateman, CABI expert demonstrating application technology during the ICAR-CABI workshop on Biopesticides



Dr. Mangala Rai, Director General, ICAR, New Delhi observing *Hirsutella thompsonii* infected coconut mites

Shri Hukumdeo Narayan Yadav, Honourable Minister of State for Agriculture, Government of India, New Delhi during a visit