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PROJECT DIRECTORATE OF BIOLOGICAL CONTROL
BANGALORE

PDBC RELEASES 'MYCOHIT' FOR COCONUT MITE CONTROL

Shri Allum Veerabhadrappa, Minister of Horticulture, Government of Karnataka, releasing 'Mycohit' (based on a strain of *Hirsutella thompsoni*) for the control of coconut mite, *Aceria guerreronis*

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Compiled & edited by	Dr. S.P. Singh, Dr.N.S.Rao, Dr.S.Ramani & Dr.(Ms.) J. Poorani
Cover	*Elasmus nephantidis* Rohwer, an important parasitoid of *Opisina arenosella* Walker
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PREFACE

The Indian Council of Agricultural Research, New Delhi, established Project Directorate of Biological Control during 1993 by upgrading the All India Co-ordinated Research Project on Biological Control of Crop Pests and Weeds. The Project Directorate has scaled new heights by virtue of concerted and systematic research efforts, effective team work, liberal work culture and disciplined financial and administrative support.

The Project Directorate 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 mapping the bio-diversity of natural enemies, introduction of potential natural enemies for managing exotic pests, standardisation and development of improved breeding and mass production techniques for natural enemies, developing 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 and tolerance to pesticides and development of biocontrol based technologies for pest management in crops like sugarcane, cotton, maize, tobacco, vegetable, fruit crops, etc. Several of these technologies have been transferred to private enterprises for commercial exploitation, including the recently developed endosulfan tolerant strain of the egg parasitoid, *Trichogramma chilonis*.

The seventh annual report of the Project Directorate embodies the endeavours of my scientist colleagues for the period from April 1999 to March 2000. 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.R.S.Paroda, Secretary, DARE & Director General, ICAR, New Delhi for his encouragement and valuable guidance. The support extended by Dr.Mangala Rai, Deputy Director General (Crop Science), ICAR, New Delhi is gratefully acknowledged. Dr.O.P.Dubey, Assistant Director General (Plant Protection), ICAR, New Delhi has always encouraged us, thus inspiring 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.

S.P.Singh

2. EXECUTIVE SUMMARY

2.1. Basic research

2.1.1. Introduction of natural enemies

Two parasitoids of the coffee berry borer, *Prorops nasuta* and *Phymastichus coffea* were imported from Colombia.

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

Eighty-three cultures of various host insects and 115 cultures of natural enemies were sent to coordinating centres and other research organizations as nucleus cultures to facilitate their multiplication for field trials.

2.1.3. Biosystematic studies on Indian predatory Coccinellidae

Taxonomic studies were done on 50 species of predatory coccinellids *Oenopia adelgivora* Poorani from Sikkim was described as a new species. One indeterminate species belonging to *Telsimia* Casey and an indeterminate genus and species nr. *Telsimia* were recognized. Five new species belonging to *Pseudaspidimerus*, *Scymnus (Pullus)*, *Microserangium*, *Protoplotina* and *Scotoscymnus* were reported. *P. flaviceps*, *P. uttami*, *P. mauliki*, and *Sticholotis*, and two genera, *Microserangium* and *Protoplotina* which are new records for India have been added to the checklist of Coccinellidae (excluding Epilachninae) of the Indian subregion.

2.1.4. Survey for natural enemies

The Lakshadweep islands were surveyed for *Aleurodicus dispersus* Russell, its host plants and natural enemies and two aphelinid parasitoids, *Encarsia guadeloupae* Viggiani (reported for the first time) and *Encarsia* sp. nr. *haitiensis* Dozier were found in the Minicoy island.

A fungal pathogen, *Fusarium coccophilum* on sugarcane whitefly, *Aleurolobus barodensis* has been recorded from Maharashtra. Survey in Wynad district of Kerala for natural enemies of pepper scale, *Lepidosaphes piperis* revealed a new species of *Pseudoscymnus*, *Jauravia* sp., an unidentified chrysopid, and a pathogenic fungus *Fusarium avenaceum*.

Higher parasitism by *Campoletis chlorideae* was recorded on *Helicoverpa armigera* larvae collected from Guntur (72%), Bhatinda (12.6%), Sriganganagar (16.7%) and Anand (26.8%).

2.1.5. Standardizing rearing/culturing techniques and biological studies on natural enemies

Studies on utilization of different mealy bug species viz., *Maconellicoccus hirsutus, Planococcus citri, P. lilacinus, Ferrisia virgata* and *Dysmicoccus* sp. to rear the coccinellids *Brumoides suturalis, Scymnus coccivora* and *Cryptolaemus montrouzieri* showed that *F. virgata* is best for multiplication of *B. suturalis* and *S. coccivora*, while *C. montrouzieri* can be multiplied equally well on *P. citri* and *P. lilacinus*.

Studies on optimum temperature for storage of *Brumoides suturalis* showed that the adults could be stored at 20°C for one month with no deleterious effect on fecundity and survival. The temperature condition of 26±0.5°C was found optimum for the development, survival, fecundity and predatory potential of *Sticholotis cribellata* on *Melanaspis glomerata*.

Cost of production for one adult beetle of *Scymnus coccivora* varied from Rs. 0.22 - 0.23 depending on the mealy bug host.

Life table statistics for *Ischiodon scutellaris* worked out during winter and summer in the laboratory showed that it is most amenable for laboratory multiplication during winter months.

Age specific fecundity studies with the syrphids *Paragus serratus* and *P. yerburiensis* reared on *Aphis craccivora* showed that *P. serratus* was able to double its population in 4.140 days while *P. yerburiensis* took 5.735 days.

The spiralling white fly predators, *Axinoscymnus puttarudriahi* and *Cybocephalus* sp. could recognize the parasitized white fly nymphs (by *E. guadeloupae*) and avoided preying on them.

2.1.6. Behavioural studies on natural enemies

Field experiments conducted to evaluate L-tryptophan as an ovipositional attractant for chrysopids and coccinellids indicated that L-tryptophan acted as an ovipositional attractant for coccinellids as there was increased oviposition. Tricosane helped in preconditioning *Chrysoperla carnea* larvae and also in acting as reinforcing agent as it increased predation of *H. armigera* eggs on treated plants.

Tritrophic interaction studies between *Trichogramma chilonis*, *Helicoverpa armigera* and genotypes of cotton and tomato revealed highest parasitization in MCU 5 (28.89%) amongst cotton genotypes and Arka Ahuti (50%) amongst tomato genotypes.

2.1.7. Artificial diet for host insects and natural enemies

Studies on the predatory efficiency of *Chrysoperla carnea* reared on beef liver based diet and on *Corcyra cephalonica* eggs revealed that both were equally efficient in feeding on *H. armigera* and *C. cephalonica* eggs. Semi-synthetic diet containing ground beef liver, defatted soybean and milk powder was found ideal for rearing anthocorid bug, *Cardiastethus exiguus* and was almost similar to rearing on *C. cephalonica* eggs.

2.1.8. Improved strains of trichogrammatids

The 'Endogram' strain of *Trichogramma chilonis* resistant to endosulfan was utilized to develop multiple insecticide tolerant strain to monocrotophos and fenvalerate and tolerance to higher dosages is seen.

Attempts to develop high temperature tolerant strain of *T. chilonis* have resulted in a strain which is now giving high parasitism and increased longevity at 36°C and 60% RH and is being subjected to further higher temperature.

Parasitising efficiency of different species and strains of *Trichogramma* on populations of *H. armigera* from ten different locations revealed that *T. chilonis* was superior among all species and could parasitise 85 – 95 per cent of the eggs from all locations.

2.1.9. Studies on insect viruses

Nuclear polyhedrosis viruses (NPVs) from *Crocidolomia binotalis* and *Corcyra cephalonica*, granulosis virus (GVs) from *Chilo sacchariphagus indicus* and *Spodoptera exigua*, baculoviruses from *Plusia signata*, *Thysanoplusia orichalcea* and *Mythimna separata*, were isolated.

Cross infectivity studies with granulosis virus (GV) of *Plutella xylostella* revealed its specificity. Good protection to *Sl*NPV up to 6 h of exposure to sunlight was afforded by an optical brightner (0.1%).

2.1.10. Fungal and bacterial antagonists

Nine isolates of *Trichoderma harzianum*, *T. virens* and *T. viride* showed inhibition of mycelial growth, reduced sclerotial production and significant inhibition of *Sclerotium rolfsii* by producing volatile and non-volatile antibiotics.

Root rot of chickpea caused by *S. rolfsii* in greenhouse was controlled to an appreciable extent through seed treatment with *T. viride* and *T. harzianum* with less disease incidence compared to fungicide and pathogen controls. Increased rhizosphere colonization and good growth promoting ability were also evident.

Dose-response studies with *T. harzianum* for biological control of fusarial wilt of redgram caused by *Fusarium udum* revealed that soil application of the bioagent was more effective than seed treatment at higher pathogen levels and there was a need for augmentative application of *T. harzianum* for obtaining effective control.

Shelf life studies on *T. harzianum* in different carrier materials proved kaolin to be better as compared to talc and bentonite as it retained high population of *T. harzianum* for up to 120 days and also proved its bioefficacy.

Antagonistic bacterial strain, *Pseudomonas putida* tried alone or in combination with *Trichoderma* spp. against red gram wilt caused by *Fusarium udum* was effective at lower pathogen levels of 0.1 and 1 lakh propagules/g of soil for up to 60 days after sowing, but was ineffective at higher pathogen levels (2 lakh propagules /g of soil).

2.1.11. Entomophilic nematodes

Amongst four entomophilic nematode species tested by soil column assay *Steinernema bicornutum* and *Heterorhabditis indica* recorded highest mortality (80-100 %) against *Spodoptera litura, Helicoverpa armigera, Opisina arenosella, Plutella xylostella* and *Phthorimaea operculella. S. bicornutum* and *H. indica* showed maximum progeny production in *S. litura* and *H. armigera. In vitro* mass production of EPN isolates of *Steinernema* spp. and *H. indica* in different artificial media showed that Wouts medium was most suitable with an average yield of 30-32 lakh ijs/250 ml flask. *S. carpocapsae, S. bicornutum, S. glaseri,* and *H. indica* evaluated for storage up to 2, 4, 6 and 8 weeks revealed that all the isolates stored well in distilled water at an ambient temperature of 28°C.

2.1.12. Biological control of plant parasitic nematodes

In vitro nematicidal effect of culture filtrate of *Pseudomonas fluorescens* was revealed through mortality of *Meloidogyne incognita, Heterodera cajani* and *Rotylenchulus reniformis* juveniles.

Verticillium chlamydosporium was found very effective in suppressing *M. incognita* on tomato by suppressing galls, parasitising more egg masses and increasing growth of tomato plants. The fungus cultured on sorghum grain and applied @ 10 g/plant was found to be best. Combined inoculation of *Pseudomonas fluorescens* and *Pasteuria penetrans* against *M. incognita* on tomato was better than individual inoculations. Considerable reduction of galls and egg masses of *M. incognita* in tomato was recorded with inoculation of *F. oxysporum* @ 6 x 10^3 cfu/g of soil

2.1.13. Weed pathogens

Parthenium populations from different districts in Karnataka as well as from across the country (six states) were susceptible to *Fusarium pallidoroseum* (10^8 conidia/mL) (isolate (WF(Ph)30) indicating the suitability of the pathogen as a candidate for parthenium control across the country. The addition of surfactants like Tween 20 and 80 as also hydrophilic substances like sodium alginate and gum arabic to increase the pathogenicity (increased necrotic area) of *F. pallidoroseum* to parthenium proved effective.

Host-range screening of several sunflower cultivars to *F. pallidoroseum* showed that no sunflower cultivar/accession reacted positively to *F. pallidoroseum*, even after keeping the inoculated plants for double the period than that for control parthenium plants. The specificity of the isolate WF(Ph)30 has thus been proved sufficiently for its use as a mycoherbicide for parthenium under varied field conditions.

2.1.14. Software development

A software "PDBC INFOBASE" was developed based on detailed information collected from private companies, 27 pest management centers, 10 Agricultural Universities, 7 ICAR institutes and 4 breeding laboratories (128 in all). The database provides information on bioagent producers in India, their addresses and the bioagents they produce and enables crop-wise, pest-wise and bioagent-wise searching in quick and detailed modes.

2.2. Biological suppression of sugarcane pests

Shoot borer activity in Coimbatore was not related to fluctuations of the weather, while the incidence of GV was positively related to the greater activity of the borer (July, November). Natural activity of *T. chilonis* was monitored during November and December by placing trap cards and parasitism was noticed. Mass culturing technique for different fungi (*Beauveria brongniarti, B. bassiana* and *Metarhizium anisopliae*) used against white grubs was perfected on a molasses-based media with good biomass and spore production. Bioassays of the three fungi against eggs and larvae showed *M. anisopliae* to be the best at 10^4 - 10^9 spores/ml as topical application.

Release of *Trichogramma chilonis* @50,000/ha 9 times at 10 days interval for

Chilo infuscatellus and 12 times at 10 days interval for *Chilo auricilius* proved effective with 57.2 and 64.2% reduction in damage, respectively, as compared to unreleased control in Ludhiana. Similarly *T. japonicum* released at the same rate six times at 10 days interval resulted in a 49.2% reduction in damage by *Scirpophaga excerptalis*. Large-scale field demonstrations through release of *T. chilonis* in different villages of Punjab showed considerable reduction in damage by different borers. Field evaluation of *Cotesia flavipes* and *Trichogramma chilonis* alone and in combination against stalk borer of sugarcane showed greater effectiveness when both the parasitoids were released together.

2.3. Biological suppression of cotton pests

Eight releases of *T. chilonis* (@1,50,000/ha) released as 200 strips of parasitized eggs (one strip for every 50m^2) reduced boll damage and recorded greater per cent parasitization and higher yield in trials at Coimbatore and Hyderabad.

Biocontrol based IPM modules consisting of different combinations including releases of *T. chilonis* @ 1,50,000/ha/week, release of *C. carnea* @10,000/ha/week, spray of *Ha*NPV @ 3×10^{12} POB/ha, mechanical collection of boll worm infested parts and putting them in a wire screen cage to enable parasitoids to escape, planting of maize, cowpea and castor as intercrop/trap crop, need based application of insecticides and installation of pheromone traps @10/ha for *H. armigera* were compared with judicious use of insecticides as per local agricultural university recommendation and routine spray adopted by the farmer in Ludhiana, Anand, Coimbatore and Hyderabad. At all locations the BIPM modules were superior in reducing boll damage, increasing the yield, conserving natural enemies and also recording a better Cost-Benefit ratio.

Demonstration trials to integrate a local population of *T. chilonis* with spray of insecticides proved effective for the control of bollworm in Ferozepur, Punjab.

2.4. Biological suppression of tobacco pests

The encapsulated formulation of entomopathogenic nematodes (*Steinernema carpocapsae* and *Heterorhabditis indicus*) at two dosages (1000 capsules and 2000 capsules/m^2) reduced the population of late third instar larvae of *S. litura* and seedling damage/m^2 in tobacco nurseries, but failed to prevent *S. litura* from reaching ETL (one late third instar larva or 6 seedlings damaged/m^2/nursery bed). The highest mean parasitization (18%) of *S. litura* eggs was obtained through release of *Telenomus* sp. @ 40,000/ha at four spots in four corners of the field.

BIPM of *S. litura* in irrigated FCV tobacco crop was successfully demonstrated at Kalavacherla (East Godavari district) on NLS-4 FCV tobacco variety involving collection and destruction of egg masses and tiny larvae on castor trap crop around tobacco, one release of *Telenomus remus* @ 40,000/ha four weeks after transplanting, two sprays of *Sl*NPV 3 x 10^{12} PIB/ha at 30 and 45 DAP, and acephate @ 1.0 kg/ha at 60 days after planting in comparison with farmer's practice of spraying insecticides alone. The percentage of plants infested was less in IPM blocks compared to chemical control and the cost-benefit ratio was found to be 1 : 1.54 for IPM as compared to 1 : 1.38 for farmer's practice.

2.5. Biological suppression of pulse crop pests

Biological control based management of pod borer complex in pigeon pea was tested through spray application of *Bt* (1.0 kg/ha), *Ha*NPV (1.5x10^{12} POB/ha), NSKE (5%) and endosulfan (350 a.i/ha) in different sequences and the results of trials in three centres revealed that spraying endosulfan three times at 15 days interval was best followed by alternate sprays of *Bt* and *Ha*NPV at Ludhiana and *Bt*-*Ha*NPV-endosulfan-*Bt* at Hyderabad and Coimbatore centres.

NPV based management of *H. armigera* in chickpea in a farmer's field at S.S.Kulam (Coimbatore) revealed that pod damage was significantly less and the yield high in plots sprayed with *Ha*NPV - endosulfan alternation and *Ha*NPV - NSKE (5%) alternation.

The trial on the NPV based management of *H. armigera* on chickpea alone and in combination with several adjuvants in Bathinda (Punjab) revealed that after the first spray the larval population was lower in NPV+Gur+Ranipol+Teepol+Cotton seed oil and NPV+Teepol only, while after the second spray the larval population was lower in all NPV based treatments.

2.6. Biological suppression of oilseed crop pests

The efficacy of *Metarhizium anisopliae* and *Bacillus popilliae* against white grubs in groundnut was tested in Anand with treatments consisting of furrow application at the time of sowing of *M. anisopliae* (0.5 kg/h), *B. popilliae* (0.5 kg/h) and seed treatment of chlorpyriphos (5.0g. *a.i.*/kg seed)). Maximum plant stand and yield was observed in *M. anisopliae* treatment followed by chlorpyriphos.

2.7. Biological suppression of rice pests

Biocontrol based IPM modules involving releases of *T. chilonis* and *T. japonicum* @ 50,000, 75,000/ha/week at different crop stages for the management of stem borer and leaf folder in rice tested at Jorhat, Ludhiana, Coimbatore and Pune showed lesser incidence of the pests and increased yields as compared to routine insecticide schedules.

Survey and quantification of natural enemy complex in rice revealed the presence of several predators and parasitoids at all the locations. The predominant predator in Thrissur was *Cyrtorhinus lividipennis* followed by spiders and coccinellids. The predators included spiders, coleopterans, dragonflies, damselflies, crickets, grasshoppers and preying mantids while parasitoids comprised *Tetrastichus* sp., *Telenomus* sp., *Cotesia* sp., *Xanthopimpla* sp., *Temelucha* sp., *Amauromorpha* sp., *Phanerotoma* sp., *Trichogramma* sp. and *Stenobracon* sp. in Coimbatore. Nineteen species of spiders including *Tetragnatha javana, Araneus inustus, Oxyopes javanus, Neoscona theisi, Leucauge celebesiana* and *Tetragnatha virescens* were recorded in Ludhiana. Amongst egg parasitoids, *Telenomus dignoides, Psix lacunatus* and *Trichogramma japonicum* were important while among larval parasitoids *Cotesia ruficrus* and *Charops brachypterum* were predominant in Ludhiana.

2.8. Biological suppression of coconut pests

The bacterium, *Pseudomonas alcaligenes* isolated from grubs of *Oryctes rhinoceros* was identified as an opportunistic pathogen attacking the under stress grubs with baculo virus infection. *Aspergillus flavus* isolates obtained from *Stephanitis typicus* and *Opisina arenosella* could cross infect each other. *Endochus inornatus, Euagorus plagiatus* and *Rhynocoris fuscipes* were identified as important reduviid predators of *S. typicus*.

Mass multiplication studies at Kayangulam with *Apanteles taragamae* utilizing early instar caterpillars of *O. arenosella* revealed maximum percentage parasitism on the first two days of exposure although egg laying continued up to 15 days.

2.9. Biological suppression of fruit crop pests

A total of five natural enemies including the aphelinid parasitoid, *Encarsia azimi* and four predators *viz*., *Scymnus* sp., *Cryptolaemus montrouzieri, Cheilomenes sexmaculata* and *Acletoxenus indicus* were recorded on the ash whitefly, *Siphoninus phyllireae* infesting pomegranate. Studies on the egg parasitoids of *Deudorix isocrates* in pomegranate revealed the presence of *Ooencyrtus papilionis* and *Telenomus* sp. at

Bangalore. The incidence of pomegranate fruit borer, *Deudorix epijarbas* was observed during June-July and the eupelmid, *Anastatus* sp. was recorded as an egg parasitoid in Solan.

The hairy caterpillar, *Thiacides postica* on ber was parasitized by *Exorista* sp., *Chaetexorista* sp., *Charops obtusus*, *Apanteles creatonoti*, and a nuclear polyhedrosis virus. Pupae of *Trabala vishnou*, a leaf-eating caterpillar of pomegranate were parasitized to an extent of 33.3 to 52.38% by an unidentified ichneumonid and also by the fungus *Paecilomyces farinosus* at Bangalore.

Surveys made in Kerala, Tamil Nadu and Karnataka for the natural enemies of spiralling whitefly revealed a total of 11 natural enemies. The whitefly was found heavily parasitised (20-70%) by *Encarsia ?haitiensis* and *E. guadeloupae* on guava. *Cybocephalus* sp., *Cryptolaemus montrouzieri*, *Axinoscymnus puttarudriahi* and *Triommata coccidivora* were observed as predators of the whitefly in Bangalore. The survey for parasitoids of the spiralling white fly in Thrissur district revealed parasitization by *Encarsia* sp. near *meritoria* (=*Encarsia ?haitiensis*) from 0 to 46.72 per cent. Several predators and an unidentified hymenopteran parasitoid of the spiralling whitefly were recorded in Coimbatore.

Woolly apple aphid population monitored throughout the year at weekly intervals along with the natural enemy activity at Solan showed that *Aphelinus mali* was consistently present and its activity synchronized with that of the aphid.

Surveys in Srinagar, Baramulla, Budgam, Pulwama and Anantnag districts of Jammu & Kashmir to ascertain the woolly aphid infestation and association of natural enemies revealed the presence of *Aphelinus mali* and seven predators, *Pharoscymnus flexibilis, Adalia tetraspilota, Eupeodes confrater, Episyrphus balteatus, Coccinella septempunctata* and *Chilocorus infernalis.*

Incidence of San Jose Scale and its parasitoids was monitored at different altitudes and it was found that the scale density varied from 63 to 150 and the per cent parasitism from 40.00 to 74.67. Recovery and establishment of *Encarsia perniciosi* and *Aphytis proclia* released in the field at different locations in Srinagar revealed that the parasitoids were well established in all the localities with 24.8 to 77.7% parasitism.

The two-spotted spider mite (TSSM) *Tetranychus urticae* and the European red mite (ERM) *Panonychus ulmi* have emerged as pests in Kinnaur district and *Stethorus* sp., anthocorids, chrysopids, predatory thrips and mites were observed preying on these mites.

Predatory potential and development of *Ischiodon scutellaris* on pomegranate aphid, *Aphis punicae* was studied and it was found that during its development the syrphid larva consumed a total of 486.10 aphids and 8.30 days were required to complete larval development.

Nine neem formulations, two neem products and four conventional pesticides were tested on *Trichogramma chilotraeae* parasitized eggs of *Deudorix isocrates* sprayed with chemicals. Conventional pesticides had greater detrimental effect on the adult emergence than botanicals. Similar results were obtained when the parasitoids were exposed to treated leaves of pomegranate with endosulfan and carbaryl having greater knockdown and proving more toxic than neem formulations and products.

2.10. Biological suppression of vegetable crop pests

Trichogrammatoidea bactrae @ 2.5 lakh adults per hectare against *P. xylostella* on cabbage (a total of 5 releases at weekly intervals) in comparison with endosulfan three sprays at weekly intervals produced more reduction in larval population and increase in yield in Bangalore. Similar trials conducted at Hyderabad resulted in a decline from 3.6 larvae per plant to 0.6 per plant in released plots with recovery of *T. bactrae* suggesting successful establishment of the parasitoid.

The comparative field efficacy of various commercial *Bt* formulations against *Plutella xylostella* revealed 'Halt' to be the most effective in Bangalore while in Hyderabad Biobit proved to be more effective followed by Dipel. Amongst five *Bt* formulations, Biobit DF, Agree, Halt, Biolep and Dipel 8L each @ 0.5 kg/ha tested in Solan on cauliflower, it was found that Biobit and Biolep were best in reducing larval population.

A field trial to evaluate *T. chilonis* against shoot and fruit borer, *Leucinodes orbonalis* on brinjal (five releases @ 40,000 to 60,000 adults per ha per release) showed that the borer damage gradually reduced in parasitoid released plot. The field testing of commercial *Bt* formulations, *viz*. Dipel and Delfin (@ 1.0 kg/ha at weekly interval from flower initiation) against brinjal shoot and fruit borer showed that the per cent borer damage to the fruits was lower in Delfin treated plots (10.44%), followed by Dipel (15.50%) in Bangalore, while in Pune, Delfin resulted in minimum fruit infestation and maximum yield.

Management of tomato fruit borer, *Helicoverpa armigera* was attempted through different biocontrol based management practices which included *T. pretiosum* alone @ 50,000 adults/ha/release, *Ha*NPV alone sprayed @ 250 LE/ha (1.5×10^{12} POB), in different combinations and release rates and it was found that parasitoid release five times and 2 sprays of NPV recorded lesser mean fruit borer damage and higher yield in Bangalore while in Pune five releases of *T. pretiosum* and three sprays of HaNPV recorded the least fruit damage. In Hyderabad the lowest mean larval population, the lowest fruit damage and the highest yield was recorded in *T. pretiosum* released 5 times with 3 sprays of *Ha*NPV.

Field evaluation, demonstration and assessment conducted in a farmer's field in a village near Hyderabad through five releases of *T. pretiosum* at weekly intervals @ 50,000/ha/release starting from flower initiation revealed more parasitization of eggs, lesser fruit damage and low larval population thus proving that *T. pretiosum* is successful in keeping a check on *H. armigera* populations in tomato ecosystem.

2.11. Biological suppression of potato pests

The cost of production of *Copidosoma koehleri* for releases @ 2,00,000 adults or 5,000 mummies per ha was found to be Rs. 750/-, with PTM as host, while for *Chelonus blackburni* @ 60,000 pupae or adults/ha, the cost of production was found to be Rs. 4110/- with PTM as host and Rs.1310/- with *Corcyra cephalonica* as host.

Four releases of egg-larval parasitoid, *C. koehleri* @ 50,000 adults/ha/release, commencing from 45 days after planting were most effective in reducing the foliage and tuber infestation of potato tuber moth and gave maximum yield of marketable potatoes during *Kharif* and *Rabi* seasons. Release of *C. koehleri* @ 5000 mummies/ha in plastic vials (i.e. 1250 mummies/ha/release, four releases at weekly interval) was most effective when compared with release of adults.

Utilization and evaluation of *C. koehleri, C. blackburni* and microbial agents against PTM in country stores (*Arnies*) revealed that the initial release of *C. koehleri* @ 5 adult pairs/kg tubers recorded least tuber infestation (10.66 %) after one month of storage. Large-scale evaluation of *C. koehleri* and *C. blackburni* against PTM in country stores (*Arnies*) conducted at a village near Pune revealed that release of *C. blackburni* @ 2 adults/kg tubers was most effective after one month, while after 2½ months the treatment with *C. koehleri* @ 5 pairs of adults/kg tubers released 4 times at fortnightly intervals resulted in minimum tuber infestation.

Spraying of *Sl*NPV @ 750 LE/ha (4.5 x 10^{12} POB/ha) or 500LE/ha (3.0 x 10^{12} POB/ha) was the most effective and on par with *B. thuringiensis* @ 0.5kg/ha in controlling *S. litura* on potato.

2.12. Biological suppression of weeds

Impact of *Neochetina eichhorniae, N. bruchi* and *Orthogalumna terebrantis* against *Eichhorniae crassipes* was most prominently visible in Anand (Gujarat), Thrissur (Kerala) and Pune (Mahrashtra) as evidenced by the presence of the larvae and adults in the bulbs as well as fresh damage observed on the leaves. In Disagmukh area of Sibsagar district (Assam) more than 1000 hectares of water body was cleared off by the action of the weevils and they further migrated to Lakhimpur, Sonitpur and Dibrugarh.

Field releases of *Cyrtobagous salviniae* weevils were continued in Vellanikkara, Moncompu and Kumarakom (Kerala) and infestation and damage to the water fern, *Salvinia molesta* could be noticed in almost all the locations with the field population varying from 1.0 to 4.3 per plant in different locations.

3. INTRODUCTION

3.1. Brief History

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 this erstwhile CIBC, Indian Station. The 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 two natural enemies (NEs) have been studied for utilisation against crop pests and weeds, out of which sixty one NEs could be successfully multiplied in the laboratory, thirty seven species have been recovered from the field, two are providing partial control, three substantial control and four are providing economic benefits worth million of rupees and twelve are augmented the same way as indigenous natural enemies. 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. Coccinellid predator *Curinus coeruleus* (Origin : South America) introduced from Thailand in 1988 has colonised on subabul psyllid. 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. Weevils have now established in 15 states. Saving on labour alone is Rs. 1120 per ha of weed mat.

An annotated checklist of the coccinellid fauna (excluding Epilachninae) of the Indian subcontinent which provides the faunal composition, recent name with all synonyms, type depository, distribution and selected bibliography for all the taxa has been prepared.

A sort of classical biological control has been achieved by the redistribution of *Epiricania melanoleuca*, a parasitoid of *Pyrilla perpusilla*. 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 twenty six egg parasitoids, six egg-larval parasitoids, thirty nine larval/ nymphal parasitoids, twenty six predators and seven species of weed insects. 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* & *Telenomus remus* preferred to parasitise *Spodoptera litura* larvae and eggs, respectively, on castor and beet root. *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, *Sticholotis madagassa, Eucelatoria bryani, Senometopia (=Carcelia) illota, Allorhogas pyralophagus, Copidosoma koehleri, Hyposoter didymator, Cotesia marginiventris, Leptomastix dactylopii, Sturmiopsis inferens, Pareuchaetes pseudoinsulata*, etc. have been determined. Superior strains of *Trichogramma chilonis* have been determined for cotton, sugarcane and tomato crops. 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* has been established which will facilitate the multiplication of obligate microorganisms. 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*. The inundative release of *T. chilonis* and *T. japonicum* has proved to be effective in suppressing the population of sugarcane tissue borers. *T. chilonis* has proved to be effective against maize stem borer, *Chilo partellus*. BIPM modules for cotton crop have been formulated comprising the use of oxydemeton methyl (0.03%), releases of *Chrysoperla carnea, T. chilonis* and spray of *Ha* NPV . The module could increase yield, conserve naturally occurring biotic agents and increase the benefit as compared to insecticidal sprays. *Ha* NPV has given encouraging results in the suppression of *H. armigera* on pulses. Integration of *Telenomus remus, Chrysoperla carnea*, insect pathogens and neem seed kernal suspension was successful in the management of *S. litura* on tobacco. 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, Minicoy and Androth-(Lakshadweep) and Andaman Islands. 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.

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
Establishment	03.33	79.25	82.58
TA	01.93	02.00	03.93
Works	65.40	01.00	66.40
Tools, Plants & Furniture	32.72	-	32.72
Library books and journals	01.84	02.14	03.98
Other contingent expenditure	21.39	18.21	39.60
Total	126.61	102.60	229.21

* Excluding co-ordinating centres

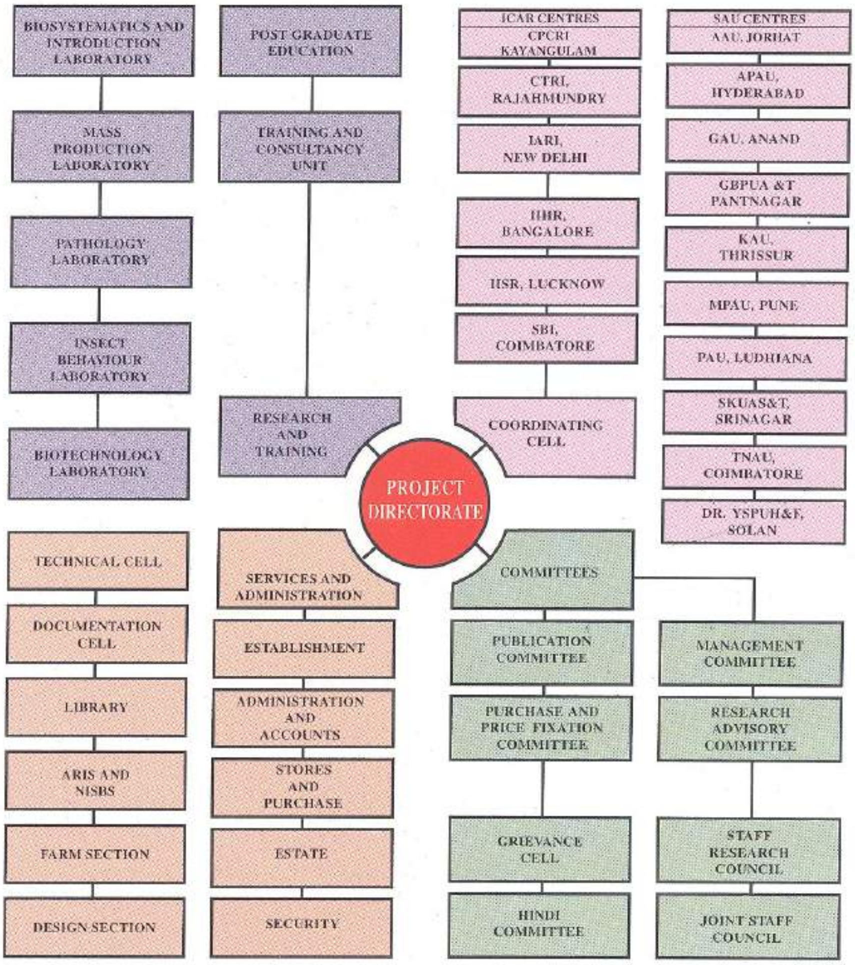
Centre-wise budget (ICAR share)

Name of the centre	Amount sanctioned (Rs. in lakhs)	Total expenditure (Rs. in lakhs)
CPCRI, Kayangulam	*	
CTRI, Rajahmundry	*	
IARI, New Delhi	*	
IIHR, Bangalore	*	
IISR, Lucknow	*	
SBI, Coimbatore	*	
AAU, Jorhat	3.87	3.80
ANGRAU, Hyderabad	4.37	4.37
GAU, Anand	8.85	10.81
KAU, Thrissur	6.45	9.11
MPKV, Pune	4.95	4.37
PAU, Ludhiana	7.43	8.55
SKUAS&T, Srinagar	5.43	5.43
TNAU, Coimbatore	6.36	6.36
YSPUH&F, Nauni, Solan	4.54	4.13
GBPUA&T, Pantnagar	1.11	1.11

* Since the Project has been merged with Non-Plan no separate budget account has been maintained by ICAR Institute-based centres

PROJECT DIRECTORATE OF BIOLOGICAL CONTROL BANGALORE

Organisational Chart



3.6 Staff position

Category	Posts sanctioned up to 31-03-2000 *	Posts filled up to 31-03-2000	Vacant positions
PDBC, Bangalore			
Scientific	25	19	6
Technical	21	3	3
Administrative	8	8	-
Supporting	6	6	-
SAU-based Centres			
Scientific	21	17	2
Technical	31	31	-
Administrative	1	1	-
ICAR Institute-based Centres			
Scientific	12	10	2
Technical	38	38	-

* including IX Plan posts sanctioned

4. RESEARCH ACHIEVEMENTS

4.1. Introduction of natural enemies

Cultures of *Prorops nasuta* and *Phymastichus coffea*, parasitoids of the coffee berry borer were obtained from Cenicafe, Colombia with an import permit of the Coffee Board. The parasitoids were successfully cultured in the quarantine and the cultures handed over to the Coffee Board for further trials. Field release of the parasitoid *Prorops nasuta* is being contemplated in high altitude areas of Palani hills with running blossoms and a continuous infestation of berry borer. In the case of *P. coffea* the culture is not doing very well though it could be cultured to a limited extent in the laboratory.

4.2. Biosystematic studies on Indian predatory Coccinellidae

4.2.1. Taxonomic studies on coccinellids

Continuing the taxonomic studies on the predatory coccinellid fauna of the Indian region, 50 species belonging to 16 genera under nine tribes and five subfamilies were studied. The break up of the species studied groupwise is as follows:

In the subfamily Scymninae, eight species belonging to *Scymnus* Kugelann [*coccivora* Ayyar, *castaneus* Sicard, *xerampelinus* Mulsant, *kawamurai* (Ohta), *nubilus* Mulsant, *pyrocheilus* Mulsant, *apiciflavus* Mulsant, three indeterminate species and a new species predatory on *Pseudooregma* sp. infesting bamboo] and two species belonging to *Nephus* Mulsant [*regularis* Sicard, ?*tagiapatus* (Kamiya) and two indeterminate species] were studied. An apparently new genus nr. *Keiscymnus* Sasaji was studied. In the tribe Aspidimerini, four species of *Pseudaspidimerus* Kapur [*flaviceps* (Walker), *uttami* Kapur, *mauliki* Kapur and a new species predatory on *Aphis gossypii* Glover] and two species of *Cryptogonus* Mulsant [*kapuri* Ghorpade and *orbiculus fulvocinctus* Mulsant] were studied. Three species of *Ortalia* Mulsant [*quadripunctata* Gorham, *yunnanensis* Pang and Mao and an indeterminate species] were studied under the tribe Ortaliini.

In the subfamily Sticholotidinae, two species belonging to *Microserangium* Miyatake (Serangiini) and *Protoplotina* Miyatake (Plotinini), five species belonging to *Sticholotis* Crotch [*cribellata* Sicard, nr. *obscurocincta* Sicard, *marginalis* Kapur, nr. *quadrisignata* Weise, *duodecimmaculata* Canepari and two indeterminate species] and five species belonging to *Jauravia* Motschulsky [*pallidula* (Motschulsky), *dorsalis* (Weise), *quadrinotata* Kapur, *soror* (Weise), *limbata* (Motschulsky), *pubescens* (F.) and two indeterminate species] (Sticholotidini), and one new species belonging to *Scotoscymnus* Weise (Sukunahikonini) were studied.

In the subfamily Coccinellinae, two species each under *Oenopia* Mulsant [*mimica* Weise and *walteri* (Sicard)] and *Micraspis* Chevrolat [*allardi* (Mulsant), *yasumatsui* Sasaji and one indeterminate species] and one species belonging to *Harmonia* Mulsant [*sedecimnotata* (F.)] were studied. The indeterminate species of *Oenopia* from Sikkim reported last year was described as *O. adelgivora* Poorani, new species.

Under the subfamily Chilocorinae, one indeterminate species belonging to *Telsimia* Casey and an indeterminate genus and species nr. *Telsimia* were studied.

4.2.2. Updation of the checklist of Coccinellidae (excluding Epilachninae) of the Indian subregion

Among the species studied during this period, *P. flaviceps*, *P. uttami*, *P. mauliki*, and *S. duodecimmaculata*, hitherto not known from India, are new records. Two genera, namely, *Microserangium* and *Protoplotina* are recorded for the first time from India. All these new records were added to the checklist of Coccinellidae of the region. The checklist was further updated with the addition of several new distribution records.

In all, five new species belonging to *Pseudaspidimerus*, *Scymnus (Pullus)*, *Microserangium*, *Protoplotina* and *Scotoscymnus* were reported this year. One new genus nr. *Telsimia* was also reported from Karnataka.

4.3. Surveys for natural enemies

4.3.1. Survey for the parasitoids of spiralling whitefly and spread of the aphelinids

The Lakshadweep islands were surveyed for *Aleurodicus dispersus* Russell, its host plants and natural enemies. The whitefly was recorded on 30 host plants in Minicoy and 11 in Kavaratti during 1999. Two aphelinid parasitoids, *Encarsia guadeloupae* Viggiani (reported for the first time) and *Encarsia* sp. nr. *haitiensis* Dozier were found in the Minicoy island in addition to some predators. They have been introduced serendipitously into our country. They have also been successfully introduced into the mainland and established very well in areas in and around Bangalore. *Encarsia* sp. nr. *haitiensis* Dozier has already been reported.

The islands of Minicoy, Amini, Kadmath, Agatti and Kavaratti were surveyed during March 2000. The whitefly was found only on 11 host plants in Minicoy, 34 host plants in Amini and 54 host plants in Kavaratti. The pest was found to be severe on banana, papaya, tapioca, guava, etc. A host plant list for the islands has been prepared. The presence of the coccinellid predator, *A. puttarudriahi* was found in one plot of banana in Kavaratti where the infesation was also found to be less. Amongst the five islands in the Lakshadweep the infestation of the whitefly was only seen in Minicoy, Kavaratti and Agatti. The parasitoids were not seen in the last two islands and the infestation was very severe in them. The activity of the parasitoids, *Encarsia* (?)*haitiensis* and *E. guadeloupae* was seen in Minicoy and the infestation of whitefly was also found to be less severe as compared to last year. *Axinoscymnus puttarudriahi* and *Cybocepahlus* sp. were also seen active there. The Agric. Dept. officials were fully briefed about the parasitoid so that they can collect and distribute the same in other islands like Kavaratti and Agatti, where the infestation is severe and the parasitoids are not present. Introduction of these parasitoids has been initiated in the islands of Kavaratti and Agatti.

Survey in and around Bangalore for natural enemies revealed in addition to the above two aphelinids the presence of *A. puttarudriahi*, *Cybocephalus* sp., *C. montrouzieri*, *Acletoxenus* sp., *Notiobiella* sp., *Leucopis* sp. and an unidentified coniopterygid. The aphelinids had spread to many areas and were observed up to Tumkur and also recorded in Amruthahalli and nearby areas.

The presence of the whitefly was seen in many areas and the pest was recorded on tapioca (61.4 nymphs/leaf), guava (14.7 nymphs/leaf and 22.5 nymphs/leaf), *Cassia* sp. (10.1/leaf).

4.3.2 Occurrence of a fungal pathogen on sugarcane whitefly, *Aleurolobus barodensis*

Surveys for natural enemies of *Aleurolobus barodensis* were undertaken in Pune and Dhule areas of Maharashtra, Vijayawada and Vuyyuru of Andhra Pradesh, Mandya and Gowribidnur districts of Karnataka in 1999. A fungal pathogen, *Fusarium coccophilum* (Desm.) Wr. & Rg. was recorded for the first time from Maharashtra. The average natural mortality was 8.30 per cent with a range of 2.20 to 12.80 per cent during rainy season. Pathogenicity was proved on healthy pupae on sugarcane plants after giving uniform spray coating of spores on the leaf sheath. Mean mortality of 33.20 and 58.97 per cent, respectively, were recorded at 5 and 10 days after application. Apart from this, *Jauravia* sp., *Anegleis cardoni* (Weise), *A.* (*Pseudoanegleis*) *perrotteti* (Mulsant) and *Apertochrysa* sp. were also recorded.

4.3.3. Record of natural enemies of *Melanaspis glomerata* and *Hemiberlesia lataniae*

Surveys were conducted in Mandya and Gowribidanur areas of Karnataka and Pune and Dhule areas of Maharashtra for collection of natural enemies of *M. glomerata* and *H. lataniae*. Two encyrtid parasitoids *viz.*, *Botryoideclava bharatiya* and *Adelencyrtus mayurai* and three coccinellids *viz.*, *Chilocorus nigrita*, *Pharoscymnus horni* and *Sticholotis cribellata* were recorded. *S. cribellata* was found to feed on *H. lataniae* on agave in Thondebhavi area of Karnataka. *S. cribellata* has been recorded for the first time as a predator on both species of scales.

4.3.4. Occurrence of new natural enemies of *Lepidosaphes piperis*

Survey was conducted at Vythiri, Kalpeta and Meenangadi of Wynad district of Kerala for natural enemies of pepper scales. Infestation by *Lepidosaphes piperis* during January was very high in Vythiri and Mennangadi. A new species of *Pseudoscymnus*, an unidentified chrysopid, *Jauravia* sp. and a pathogenic fungus *Fusarium avenaceum* (Fr.) Sacc. were collected. Pathogenicity of this fungus was proved on healthy pepper scale and *Lepidosaphes* sp. infesting croton after giving uniform spray coating of spores on the leaf sheath. Two species of encyrtids and predators, *Sticholotis* sp. and *Cybocephalus* sp. were also found to feed on this scale.

4.3.5. Records of natural enemies of bamboo aphid, *Pseudooregma* sp., white tailed mealybug, *Ferrisia virgata* and subabul psyllid, *Heteropsylla cubana*

Pseudooregma sp. was found to feed on ornamental bamboo from January to March. A new species of *Scymnus* was also recorded in Bangalore. *Notiobiella* sp. was found to feed on *H. cubana* during June and July on subabul. A species of *Ankylopteryx* was found to feed on *F. virgata* infesting *Cassia* sp. during January.

4.4. Rearing / culturing techniques for natural enemies

4.4.1. Studies on cost of production of *Scymnus coccivora*

The mealybug species *viz.*, *F. virgata*, *M. hirsutus* and *P. citri* were reared on sprouted potatoes by inoculating with gravid female mealybugs.

Five pairs of newly emerged adults of *S. coccivora* were released on respective mealybug species and allowed to feed and breed. Additional infested potatoes were added as and when required. Total number of beetles obtained at the end of each month (one generation is completed in 25 to 30 days) from each container were counted. Cost of production worked out taking into consideration fixed costs, labour charges and running costs on different mealy bug species.

Cost of production per beetle on *F. virgata*	=	Rs. 0.22
Cost of production per beetle on *M. hirsutus*	=	Rs. 0.225
Cost of production per beetle on *P. citri*	=	Rs. 0.229

4.5. Bioecological studies on natural enemies and laboratory hosts

4.5.1. Competitive displacement of *Ferrisia virgata*, *Planococcus citri* and *Planococcus lilacinus* by *Dysmicoccus* sp. during laboratory rearing

Studies were conducted on competition between *Dysmicoccus* sp. and other species of mealybugs *viz., Ferrisia virgata, Planococcus citri* and *Planococcus lilacinus*. *Dysmicoccus* sp. displaced *F. virgata* in the second generation itself, where per cent females of *Dysmicoccus* sp. were 92.92. In the next generation, *F. virgata* was down to 1.68% (Fig. 2). In case of *P. citri* and *P. lilacinus* displacement was relatively slower and after third generation, these species were displaced to the tune of 73.00 and 56.88 per cent, respectively. The dominance of *Dysmicoccus* sp. over other species of mealybugs may be due to its ability to settle even on unsprouted potatoes, higher ratio of females and high fecundity. Studies thus indicated that *F. virgata, P. citri* and *P. lilacinus* should be multiplied in isolation and care should be taken to remove naturally occurring contamination.

4.5.2. Studies on the parasitisation and biology of *Encarsia* spp. on *A. dispersus*

The percentage parasitism of *Encarsia* spp. recorded were: *Cassia* sp. (56.83 %), Guava (18.4 %), Papaya (92.4 %) and Tapioca (59.4 %) (the last two host plants being in Minicoy).

The longevity of the adults when fed with honey was 2.7 days and 2.3 days for *E. guadeloupae* and *E. haitiensis* while it was 1.01days and 1.0 day for the two species, respectively, in the absence of any food. In the presence of the host the adults lived for 8.0 days and 5.2 days in the case of *E. guadeloupae* and *E. haitiensis*, respectively. The pupal period (the days taken for emergence after blackening of the pupae inside the host nymph) was 7.32 days and 4.83 days for *E. guadeloupae* and *E. haitiensis*, respectively.

The pupal orientation was studied and it was found that almost all the parasitoid pupae of *E. guadeloupae* were facing the dorsum of the host and were oriented with the

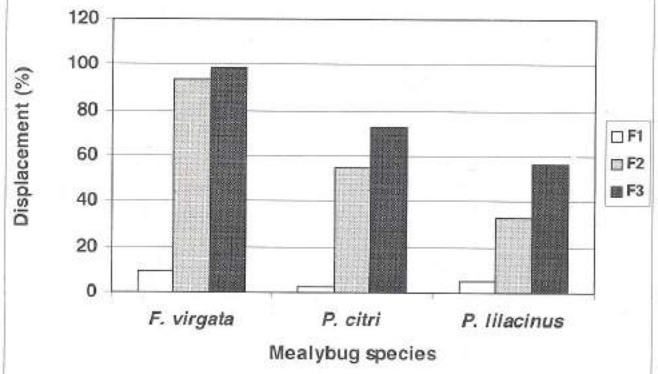


Fig. 2. Per cent displacement of various mealybug species by *Dysmicoccus* sp.

head towards the anterior of the host. This facilitated easy emergence without any rotation before emergence.

The movement of pupae of the two species was studied and it was found that there were distinct differences in the movement with *E. guadeloupae* showing intense movements only of the posterior portion of the pupae at great speed and *E. haitiensis* showing movement of the entire pupal body and in a slower manner. This could help in identifying the two parasitoid pupae.

4.5.3. Interaction studies between *Encarsia guadeloupae* and the predators *A. puttarudriahi* and *Cybocephalus* sp.

Interaction studies done to see if the predators could identify parasitised nymphs from unparasitised ones revealed that the adults did not feed on parasitised nymphs. No feeding was seen by both species of predators on parasitised nymphs, when offered alone or in combination with unparasitised nymphs. Both predators fed on 3-4 unparasitised nymphs in 24 hours. The adults emerged from the parasitised nymphs showing no damage to them. (Table 1)

Table 1. Interaction between *Encarsia guadeloupae, Axinoscymnus puttarudriahi* and *Cybocephalus* sp.

Nymphs provided	Number fed by the adults of	
	Axinoscymnus puttarudriahi	*Cybocephalus* sp.
Unparasitized nymphs only	3.91	3.50
Parasitized nymphs only	Nil	Nil
Per cent predatory adults dead	58.3	75.0
Parasitoid emergence	4.83 (95%)	4.92(98.3%)
Unparasitized + Parasitized (5+5)	3.33 + 0*	3.50 + 0*
Parasitoid emergence	4.92 (98.3%)	4.67 (93.3)

* No feeding of parasitized nymphs observed

4.5.4. Performance of *Telenomus remus* on *Spodoptera litura* infesting sunflower

The performance of *Telenomus remus* was evaluated on sunflower potted plants artificially infested with *S. litura* eggs. *T. remus* adults were released at the rate of 1 female per 40 *S. litura* eggs during April-May, September-October and December-January. Low parasitism was recorded during April-May (3.0%) and December-January (8.0%), whereas parasitism was higher during September-October (28.0%) (Fig. 3).

4.5.5. Fertility tables for *Campoletis chlorideae*

Fertility tables were constructed for laboratory reared (LR) and field collected (FC) *C. chlorideae*. The experiment was conducted at 26±2°C and RH of 65±2%. The fertility table parameters were calculated and are presented in Table 2 as comparative data for the two populations.

Clear differences were observed between the field collected (FC) and laboratory reared (LR) batches of *C. chlorideae* with respect to the fertility table parameters. The approximate duration of a generation and the net generation time were 22.21 and 20.64; and 22.01 and 20.11 in FC and LR, respectively. The net reproductive rate was higher (24.4) in FC in comparison to LR (5.1). The approximate intrinsic rate of increase and precise intrinsic rate of increase were 0.14 and 0.15, respectively, in the case of FC, whereas in LR the corresponding values were 0.08. The finite rate of increase was 1.16 in FC and 1.08 in LR. The weekly multiplication rate calculated was 2.76 and 1.76, respectively, in FC and LR. The FC batch could double its population in 4.66 days, whereas in LR batch the doubling time was 9.01 days. The hypothetical F_2 females were higher in FC (595.36) in comparison to LR (26).

Table 2. Comparison of the fertility table parameters for lab reared and field collected *Campoletis chlorideae*

Method of rearing	R_0	T_c	r_c	r_c	T	l	Weekly Multiplication rate	Doubling time (days)	Hypothetical F_2 females
FC	24.4	22.21	0.14	0.15	22.01	1.16	2.76	4.66	595.36
LR	5.1	20.64	0.08	0.08	20.11	1.08	1.76	9.01	26.00

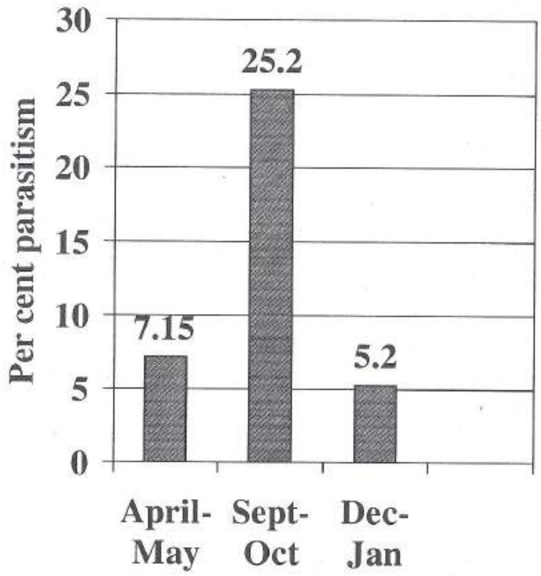


Fig. 3. Performance of *Telenomus remus* on *Spodoptera litura* infesting sunflower

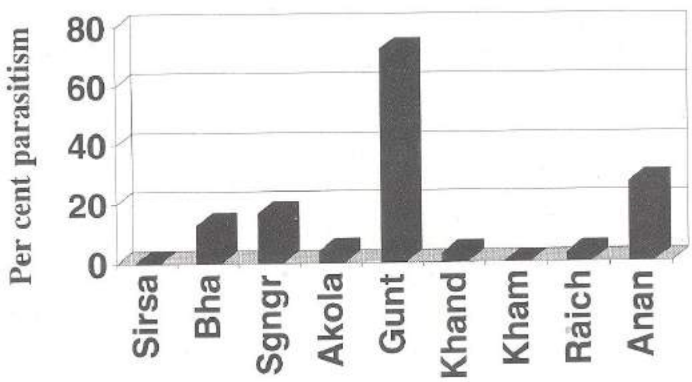


Fig. 4 Performance of *Campoletis chlorideae* from cotton crops in different regions

4.5.6. Performance of *Campoletis chlorideae* on *Helicoverpa armigera* from different ecosystems

H. armigera larvae were collected on cotton crop from different regions - Sirsa (Haryana), Bhatinda (Punjab), Sriganganagar (Rajasthan), Akola (Maharashtra), Guntur (AP), Khandwa (Maharashtra), Khammam (AP), Raichur (Karnataka) and Anand (Gujarat). The larvae from different regions were exposed to laboratory reared *Campoletis chlorideae* and the levels of population are presented in Fig 4. In the case of Sirsa and Khammam strains, parasitism was nil. Low level of parasitism was also recorded in the case of Akola (3.7%), Khandwa (2.8%) and Raichur (2.8%) strains. Higher parasitism was recorded in the case of larvae collected from Bhatinda (12.6%), Sriganganagar (16.7%) and Anand (26.8%). Maximum parasitism was recorded in Guntur population (72%).

The performance of lab reared and field collected (cotton and pulse crops) *C. chlorideae* adults were evaluated on field collected and lab reared *H. armigera* for their parasitism rates. The parasitoids from pulse ecosystem could not parasitize *H. armigera* larvae from the cotton ecosystem. However, the parasitoids collected from the cotton ecosystem could parasitize 44% larvae from the same ecosystem. In the control batch, (laboratory reared *C. chlorideae* exposed to laboratory reared *H. armigera*), 31.2% parasitism was recorded, whereas laboratory reared parasitoids could parasitize only 15.2% larvae of cotton ecosystem.

4.5.7. Effect of different non-aphid hosts on reproductive attributes of *Cheilomenes sexmaculata* and *Coccinella septempunctata*

C. sexmaculata and *C. septempunctata* adults were provided with non-aphid prey *viz*., *Planococcus citri*, *Maconellicoccus hirsutus*, *Ferrisia virgata*, *Aleurodicus dispersus* and *Heteropsylla cubana* and their reproductive attributes evaluated.

Adults of *C. sexmaculata* fed voraciously on *F. virgata*, *H. cubana* and *A. dispersus*. The mealybugs, *viz*., *P. citri* and *M. hirsutus* were also preyed upon. There were significant differences in longevity of females and males fed on these hosts. Higher longevity was recorded on *F. virgata* (45.60 and 39.70 days in females and males, respectively) and *H. cubana* (42.65 and 39.80 days in females and males, respectively). Highest fecundity was recorded on *F. virgata* (94.20 eggs/female) followed by *H. cubana* (48.00 eggs/female) and *A. dispersus* (28.90).

All the biological parameters of *C. septempunctata* were drastically affected when fed with non-aphid hosts, except *F. virgata*. It laid more eggs and lived longer when fed with *F. virgata* as compared to other non-aphid hosts. However, adult longevity and fecundity on *F. virgata* were significantly lowest as compared to control.

During winter when there is a decline in *F. virgata* population, *H. cubana* and *A. dispersus* population is high. These two hosts may be used as supplementary food source for adults of *C. sexmaculata* when aphids and mealybugs are scarce.

4.5.8. Development of life tables for *Ischiodon scutellaris*

Life tables were constructed based on laboratory and small plot studies on cowpea (var. C 152 in a 5x4 m plot) in two seasons, *viz*., March - May (summer) and August - October (winter). Eggs were obtained in the laboratory and transferred to cowpea plants with infestation of *Aphis craccivora*.

Life table statistics for *I. scutellaris* for winter and summer in laboratory and small plots show different trends in the survival of this species in the laboratory and the field. Low trend index values in the field (0.994 and 0.957 for winter and summer, respectively) reveal that various mortality factors were responsible for decline in the population. There was low survival as revealed by SG values, which were 0.323 and 0.223 for field experiments during winter and summer, respectively (Table 3). Generation survival in the field during winter was affected to the maximum in the pupal stage (k=0.285), followed by second and third instar larvae (k=0.057) which was mainly due to parasitoids and bacterial pathogens, respectively. In summer also, pupae (k=0.430) and third instar larvae (k=0.155), were affected to the maximum and causes of mortality were parasitism and bacterial infection.

In the laboratory, trend index values were relatively higher (1.385 and 0.977 for winter and summer, respectively) indicating that mortality factors exerted less pressure. Trend index (1.385) higher than unity in winter confirms its amenability for laboratory multiplication during winter months.

Table 3. Trend index (TI) and generation survival (SG) for *Ischiodon scutellaris* during winter and summer in laboratory and field

Parameter	Laboratory studies		Field studies	
	Winter	Summer	Winter	Summer
Trend Index (TI)	1.385	0.977	0.994	0.957
Generation Survival (SG)	0.508	0.498	0.323	0.223

There was relatively higher generation survival in the laboratory as revealed by SG values, which were 0.488 and 0.471 for winter and summer, respectively. A comparison of the key mortality factors showed that the generation survival in the laboratory was affected to the maximum in the third larval instar both in winter (k=0.179) and summer (k=0.202) and mortality agents were bacterial pathogens.

K values of reproducing females for laboratory were 0.3131 and 0.3098 for winter and summer, respectively, as against 2.00 and 2.1903 for winter and summer in field. This indicated higher percentage of males in the laboratory during both winter and summer as compared to field conditions where sex ratio was equal.

4.5.9. Biotic potential of three coccinellids on various mealybug species

Cryptolaemus montrouzieri, *Brumoides suturalis* and *Scymnus coccivora* were field collected and initially reared in the laboratory on their natural hosts and then on *Maconellicoccus hirsutus*, *Planococcus citri*, *P. lilacinus*, *Ferrisia virgata* and *Dysmicoccus* sp. reared on pumpkins in the laboratory. .

C. montrouzieri took significantly higher time on *Dysmicoccus* sp. (31.6 days) than on all other species provided, however, total developmental time for *B. suturalis* and *S. coccivora* on *Dysmicoccus* sp. did not differ significantly with other hosts (Table 4). Total developmental period of *C. montrouzieri* ranged from 26.9 to 31.6 days, *B. suturalis* 19.9 to 23.0 days and *S. coccivora* 16.9 to 21.3 days. *F. virgata* was found to be better with regard to the developmental period for all the three coccinellids.

Table 4. Development period of three coccinellids on various mealybug hosts

Host	Developmental period															
	Egg				Larva				Pupa				Total			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
M. hirsutus	4.2	4.3	4.1	4.20	14.6	11.8	9.5	11.96	9.0	6.3	5.6	6.96	27.8	22.4	19.2	23.13
P. citri	4.1	4.3	4.0	4.13	13.9	12.0	9.2	11.70	8.9	6.3	5.8	7.00	26.9	22.6	19.0	22.83
P. lilacinus	4.2	4.2	4.2	4.20	14.0	12.3	9.3	11.86	9.0	6.4	5.9	7.10	27.2	22.9	19.3	23.13
F. virgata	4.1	4.0	3.9	4.00	14.5	9.9	8.2	10.86	8.5	6.0	4.8	6.43	27.1	19.9	16.9	21.30
Dysmicoccus sp.	4.2	4.2	4.3	4.23	18.2	12.4	11.1	13.90	9.2	6.41	5.9	7.16	31.6	23.0	21.3	25.30
	4.16	4.20	4.10		15.04	11.68	9.46		8.92	6.28	5.60		28.1	22.16	19.14	

1 - *Cryptolaemus montrouzieri*; 2- *Brumoides suturalis* 3- *Scymnus coccivora*

CD (P=0.05)	Predators	0.8186
	Hosts	1.0568
	Predator x Host	1.8304

Host consumption rate by grubs of *C. montrouzieri*, *B. suturalis* and *S. coccivora* ranged from 17.3 to 25.2; 14.5 to 19.7 and 7.7 to 10.9 mealybugs per day, respectively. Similarly, host consumption by adult ranged from 39.2 to 65.6; 45.8 to 25.6 and 29.8 to 10.2 mealybugs per day, respectively (Table 5). Preference of adult and grubs of *C. montrouzieri* and *B. suturalis* was similar.

Table 5. Host consumption by grubs and adults of three coccinellids on various mealybug hosts

Host	Host consumption (number/day)							
	Grub				Adult			
	1	2	3	Mean	1	2	3	Mean
M. hirsutus	22.9	16.1	9.7	16.23	54.9	28.2	19.4	34.17
P. citri	25.2	15.4	9.5	16.70	65.6	31.6	15.9	37.70
P. lilacinus	24.8	14.9	9.5	16.40	64.6	32.5	14.9	37.33
F. virgata	23.8	19.7	10.9	18.13	51.3	45.8	29.8	42.30
Dysmicoccus sp.	17.3	14.5	7.7	13.17	39.2	25.6	10.2	25.00
	22.8	16.12	9.46		55.12	32.74	18.04	

1 - *Cryptolaemus montrouzieri*; 2- *Brumoides suturalis* 3- *Scymnus coccivora*

Feeding potential of grub CD (P=0.05)	Predators	0.6651
	Hosts	0.8587
	Predator x Host	1.4873
Feeding potential of adult CD (P=0.05)	Predators	0.6742
	Hosts	0.8704
	Predator x Host	1.5076

C. montrouzieri produced highest progeny on *P. citri* (229 eggs/female) which was followed by *P. lilacinus* (219) and *M. hirsutus* (215). *B. suturalis* and *S. coccivora* laid maximum eggs when fed with *F. virgata*. All the three predators produced least progeny on *Dysmicoccus* indicating its unsuitability. Longevity of *C. montrouzieri* ranged from 75 to 25 days; *B. suturalis* 41 to 55 days and *S. coccivora* 33 to 72 days on different hosts. *C. montrouzieri* lived longer on all the hosts except *Dysmicoccus* sp. *S. coccivora* lived longer when fed with *F. virgata* but *B. suturalis* exhibited equal longevity on *F. virgata* and *P. citri* (Table 6).

It can be thus inferred that *F. virgata* should be used as host for multiplication of *B. suturalis and S. coccivora*. *C. montrouzieri* can be multiplied equally well on *P. citri* and *P. lilacinus*.

Table 6. Preoviposition period, fecundity and longevity of three coccinellids on various mealybug hosts

Host	Pre-oviposition period				Fecundity (eggs/female)				Longevity (days)			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
M. hirsutus	5.2	4.2	4.0	4.46	215	138	53	135.33	73	53	61	62.33
P. citri	5.0	4.9	4.8	4.90	229	179	49	152.33	75	49	59	61.00
P. lilacinus	5.0	4.7	4.7	4.80	219	161	46	142.00	73	47	55	58.33
F. virgata	5.2	3.8	3.9	4.30	207	203	59	156.33	71	55	72	66.00
Dysmicoccus sp.	7.9	5.8	6.2	6.63	35	122	31	62.66	25	41	33	33.00
	5.66	4.68	4.72		181.0	160.6	47.60		63.40	49.00	56.00	

1 - *Cryptolaemus montrouzieri* 2- *Brumoides suturalis* 3- *Scymnus coccivora*

Pre-oviposition period	CD (P=0.05)	Predators	0.440
		Hosts	0.5680
		Predator x Host	Not significant
Fecundity	CD (P=0.05)	Predators	1.1371
		Hosts	1.4127
		Predator x Host	2.4469
Longevity	CD (P=0.05)	Hosts	1.4680
		Predator x Host	2.5426
		Predator	Not significant

4.5.10. Age specific fecundity of *Paragus serratus* and *Paragus yerburiensis*

The stock cultures of *P. serratus* and *P. yerburiensis* were initiated from larvae collected from the field and reared on *Aphis craccivora* under laboratory conditions. Figures 5 and 6 illustrate age specific fecundity and longevity of both syrphids on *A. craccivora.*

P. serratus had a maximum life span of 53 days. Maximum mean progeny per day was attained on the 6^{th} day of oviposition. The first mortality within the cohort occurred on the 7^{th} day and increased thereafter (Fig 5). The average number of eggs laid per female was 41.8 and the sex ratio was 1: 0.94 (male: female).

P. yerburiensis had a maximum life span of 44 days. Maximum mean progeny per day was attained on the 7^{th} day of oviposition. The first mortality within the cohort occurred on the 2^{nd} day and increased rapidly after 8^{th} day (Fig. 6). The average number of eggs laid per female was 16.8 and the sex ratio was 1: 1.12 (male: female).

Population indices revealed that *P. serratus* had higher gross reproductive rate than *P. yerburiensis*. This value differed from the net reproductive rate in both species. The approximate generation time (T_c) was 34.553 in *P. serratus* which approximated the true generation time (T) of 34.088 days. The corresponding values in *P. yerburiensis* were 30.069 and 31.009. *P. serratus* had capacity to multiply by 12.33 times while *P. yerburiensis* was able to multiply by 4.85 times in a generation. The intrinsic growth rate (r_c) was higher (0.0727) in *P. serratus* than in *P. yerburiensis* (0.0523).

In *P. serratus* r_m value was slightly higher than r_c value while for *P. yerburiensis* r_m value was lower than r_c value. The finite rate of increase (?) was 1.182 and 1.128 for *P. serratus* and *P. yerburiensis*, respectively, *i.e.* population increased on an average by 11.82% each day in *P. serratus* and 11.28% in *P. yerburiensis*. With daily finite rate of increase of 1.097, the population of *P. serratus* was able to multiply 3.228 times every week, while *P. yerburiensis* was able to multiply 2.330 times per week. Likewise the hypothetical female population in F_2 generation was 152.088 for *P. serratus* and 23.493 for *P. yerburiensis*. *P. serratus* was able to double its population in 4.140 days while *P. yerburiensis* took 5.735 days to double its population.

With the measured parameters *viz*., x, l_x and r_m, *P. serratus* population would eventually assume a stable age distribution, wherein 31.12% individuals will be in the egg stage, 37.98% in larva, 16.18% in pupal stage and only 14.72% would be adults. In *P. yerburiensis*, on reaching the stable age distribution, egg, larvae, pupae and adults would contribute 20.18, 33.95. 19.41 and 26.46%, respectively, to the total population.

4.5.11. Studies on optimum temperature for storage of *Brumoides suturalis* adults

B. suturalis was multiplied on *F. virgata* on pumpkins in the laboratory prior to the initiation of experiments. Adults were stored at 10°, 15°, 20° C and at room temperature (26 ± 1.5° C). Observations on per cent mortality were recorded at 7, 15, 30, 45, 60,75 and 90 days.

Mortality of *B. suturalis* adults differed significantly between 10, 15 and 20° C (Fig. 7). It was clear that 10° C and 15° C were lethal for storage of adults. At 20° C, there was significantly less mortality up to 45 days (21.14%) than at 26°C (53.78%). Fecundity was greatly affected when stored at 10 and 15° C (Fig. 8). At 20° C, fecundity was 192.8, 191.5, 176.6 and 163.4 at 7, 15, 30 and 45 days of storage, respectively. At room temperature, fecundity up to 15 days was similar to that stored at 20° C, but it was significantly lower when adults stored at 30 days were compared.

Survival of adult predators after removal from storage declined drastically at 10 and 15° C within seven days of storage. However, at 20°C, survival was significantly higher as compared to other treatments. There was 12.38 per cent reduction in survival of adults stored at 20° C for 30 days. However, reduction in fecundity of adults stored at 20°C for 30 days was only 8.4 per cent as compared to those stored for seven days. At 26°C, there was a sharp decline in fecundity and survival after only 15 days of storage. Developmental period of grub was prolonged with increase in storage period. Developmental period was 14.47, 15.15, 16.55, 17.58, 18.77 and 18.67 days at 7, 15, 30, 45, 60 and 75 days of storage, respectively at 20°C.

The results demonstrated that *B. suturalis* adults could be stored at 20°C for one month with affordable reduction in fecundity and survival and less prolongation of larval period after removal from storage.

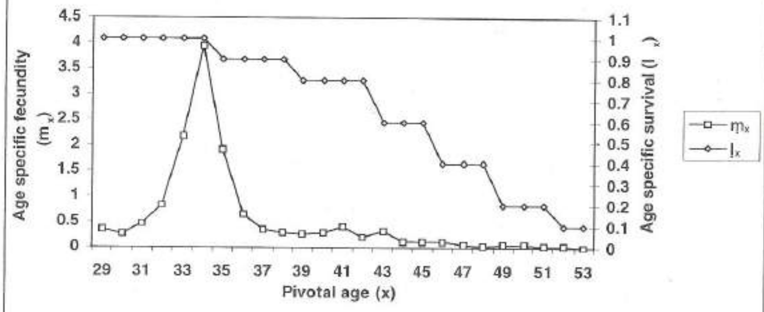


Fig. 5. Age specific survival and fecundity of *Paragus serratus*

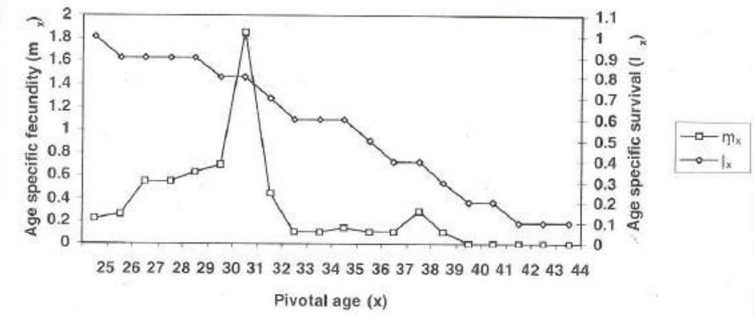


Fig. 6. Age specific survival and fecundity of *Paragus yerburiensis*

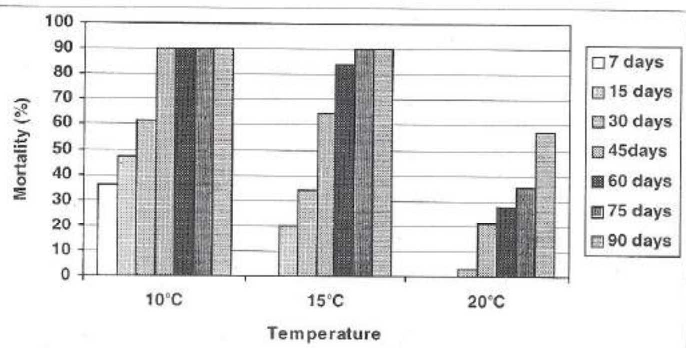


Fig. 7. Per cent mortality of *Brumoides suturalis* adults at different temperatures

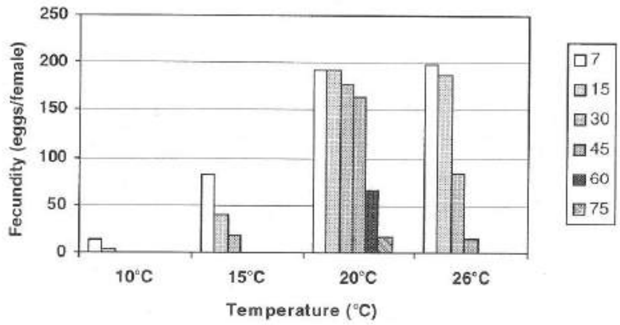


Fig. 8. Fecundity of *Brumoides suturalis* stored at different temperatures

4.5.12. Effect of temperature on development, fecundity and predatory potential of *Sticholotis cribellata*, a predator of *M. glomerata*

Effect of temperature on development, fecundity and predatory potential of *Sticholotis cribellata*, a potential predator of sugarcane scale, *M. glomerata* was studied at 22, 24, 26, 28 and 30°C.

The larval duration at 22, 24, 26, 28 and 30°C was 30.2, 21.2, 19.5, 16.8 and 12.9 days respectively (Fig. 9). The larval survival was significantly high at 26°C, which was on par with the survival at 24°C (Fig. 10). There was no significant difference in survival at 22 and 30°C. Similarly, significantly similar per cent of larvae survived at 24 and 28°C. The duration of pupal stages at 22, 24, 26, 28 and 30°C were 12.9, 10.7, 8.6, 7.6 and 6.5 days, respectively, and survival was 70.0, 82.5, 86.08,70.65 and 61.49 per cent, respectively. Pupal survival was also highest at 26°C, was retarded above 28 and below 24°C (Fig. 9). The longevity of *S. cribellata* adult at 22 °C was 75.9 days and it was reduced from 61.20 to 39.80 days, with the increase in temperature from 24 to 26°C (Fig. 10). There was no significant difference in adult survival at 26 and 28°C. However, it was reduced significantly to 29.9 per cent at 30°C. At 22 °C the beetle became inactive and the rate of feeding was very slow.

Significant increase in egg laying was observed as the temperature increased from 22°C to 26°C and it decreased significantly at 28 and 30°C (Fig. 11). The average number of eggs laid per female at 22, 24, 26, 28 and 30°C were 9.8, 39.20, 47.60, 19.90 and 10.80, respectively. The grub consumed 11.9, 18.1, 19.2,17.9 and 15.2 crawlers per day at 22, 24, 26, 28 and 30°C (Fig. 12). The corresponding values for the adult were 32.8, 45.0, 45.1, 45.0 and 38.2 crawlers per day. Adult and larval feeding potential was significantly higher at 30°C than at 22°C.

The results of this study indicated that the optimum temperature conditions for the development, survival, feeding potential and fecundity of *S. cribellata* were 26±0.5°C.

4.6. Studies on behavioural response of natural enemies and tritrophic interaction

4.6.1. L-tryptophan as an ovipositional attractant for chrysopids and coccinellids on cotton under field conditions

Field experiments were conducted to evaluate L-tryptophan as an ovipositional attractant for chrysopids and coccinellids. The first experiment was conducted when the crop was about 60 days old. Three-day-old L-tryptophan (0.66%) was prepared by acid hydrolysis and oxidation methods and sprayed. One litre solution was sprayed for around 40 to 50 plants and the number of eggs, larvae, pupae and adult chrysopids were counted before and after treatment in the treated and untreated plants. The activity of chrysopids and coccinellids was very low in the field before and after treatment and no egg laying was noticed. The experiment was repeated on 120 days old crop. The dissolution in the hydrolysis method was complete, but in the oxidation method, dissolution was incomplete suggesting that acid hydrolysed L-tryprtophan is better than oxidized L-tryptophan. No activity of chrysopids could be recorded before and after the treatment. However increased oviposition by the coccinellids was noticed in the treated area in comparison to untreated area. This indicated that L-tryptophan acts as an ovipositional attractant for coccinellids.

4.6.2. Kairomones for preconditioning larvae of *Chrysoperla carnea*

A mass priming experiment was conducted to increase the efficiency of the larvae of *Chrysoperla carnea* against *Helicoverpa armigera*. The kairomonal solutions were prepared and sprayed in the petri dish using an atomiser. On the cotton plants, eggs of *H. armigera* were glued on the leaves from 3 to 8 nodal leaves @ 5 eggs per leaf. After drying the petri dish under shade, early third instar larvae of *C. carnea* were retained in the petri dish for half an hour and then released on the cotton plants. The number of eggs consumed was counted after 24 hours. Twenty plants were used for each replication and each treatment was replicated 10 times. The average number of eggs consumed in 20 plants was computed and considered as one replication. The larvae exposed to n-tricosane recorded more predation compared to others (Table 7).

Table 7. Predatory potential of *C.carnea* larvae after mass priming

Treatment	Number of eggs consumed
Tricosane (0.2%)	13.87
Tricosane (0.1%)	6.00
Abdominal extracts of *H. armigera* (10 females/5ml)	7.79
Control	3.94
CD (P=0.05)	2.85

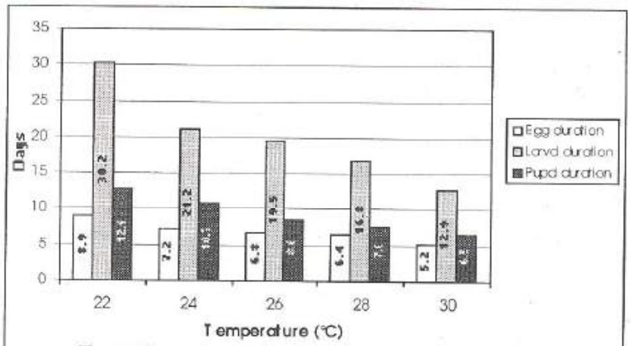


Fig. 9. Effect of temperature on egg, larval and pupal period of *Sticholotis cribellata*

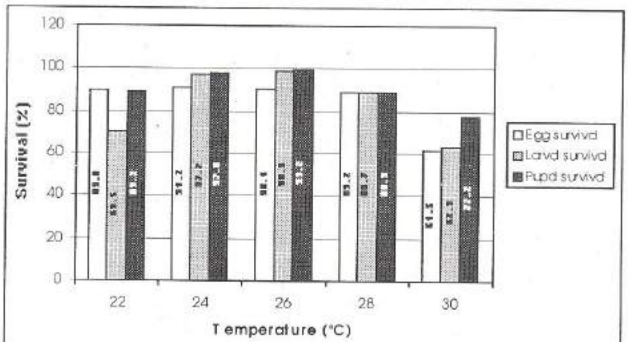


Fig. 10. Effect of temperature on egg, larval and pupal survival of *Sticholotis cribellata*

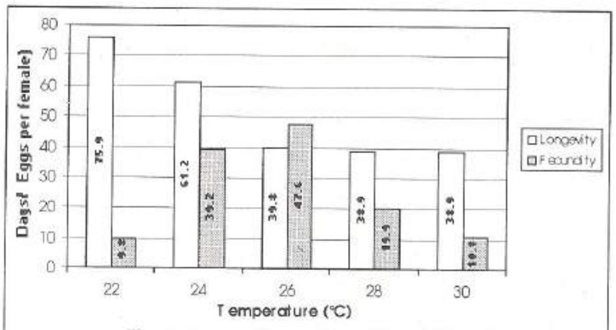


Fig. 11 . Longevity and fecundity of *Sticholotis cribellata* at different temperatures

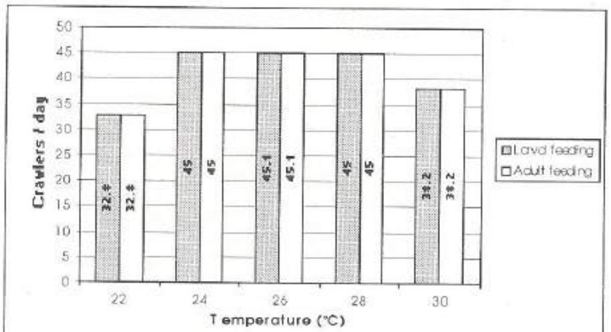


Fig. 12. Fedding potential of *Sticholotis cribellata* at different temperatures

4.6.3. Kairomones as reinforcing agents for the larvae of *Chrysoperla carnea*

Kairomone formulations were prepared with n-tricosane (1%), and scales of *H. armigera* using emulsifiers. On cotton plants, eggs of *H. armigera* were glued on 3 to 8 nodal leaves @ 5 eggs per leaf. The cotton plants were sprayed with the kairomonal solution and after drying for half an hour, the larvae of *C. carnea* were released @ two larvae per plant. The number of eggs consumed was counted on the next day. On the third day only eggs were glued without releasing any larvae and the number of eggs consumed was counted on the next day. Ten cotton plants were used for each replication and each treatment was replicated ten times.

The results indicated that the predation increased on the plants treated with tricosane and was better than the control. The predation potential was lower on the third day compared to that of one day (Table 8). However, the larvae were retained on treated plants even on the third day.

Table 8. Reinforcing of *C. carnea* using kairomones

Treatment	Number of eggs consumed on	
	First day	Third day
Scale extract of *H. armigera*	19.38	10.76
Scale ext. of *C. cephalonica* (120mg)	18.41	11.39
Scale ext. of *C. cephalonica* (160mg)	17.15	9.19
Tricosane (1mg in 100 ml)	20.28	8.8
Control	3.94	0.34
CD (P=0.05)	5.99	5.83

4.6.4. Behavioural response of coccinellids to kairomones in wind tunnel and multiple choice experiments

'Y' tube olfactometer studies were conducted with the adults of *Cheilomenes sexmaculata* and *Coccinella septempunctata*. Fifteen adults were starved for 24 hours and released on the stem of the 'Y' tube and kairomones were maintained at one arm and hexane/water on the other arm. The number of adults reaching the kairomone/control was recorded at the end of 30 minutes.

Results indicated that the number of adults reaching the kairomone arm in the case of *C. sexmaculata* was not significant. However, *C. septempunctata* adults reaching the kairomone arm were significantly more, indicating that L-trypophan showed some attraction in the case of *C. septempunctata* (Table 9).

Table 9. Orientation behaviour of adult coccinellids to kairomones in 'Y' tube olfactometer

Treatment*	*Cheilomenes sexmaculata*		*Coccinella septempunctata*	
	Kairomone	Hexane	Kairomone	Hexane
0.33lt/ah	4.4	5.6	7.1	2.9
0.66lt/ah	5.2	4.8	8.2	1.8
0.33lt + 0.66val	4.8	5.2	5.4	4.6
0.66lt + 0.66val	5.6	4.4	8.3	1.2
0.66val	4.3	5.7	4.8	5.2
Control	5.1	4.9	5.1	4.9
Wilcoxons signed rank test	Not significant		Significant	

lt/ah - L-tryptophan acid hydrolised; val - valine

L-tryptophan did not elicit any behavioural response in *C. sexmaculata* and no egg laying was noticed in multiple-choice tests also.

4.6.5. Kairomonal attraction of *Cotesia flavipes* to the frass extracts of *C. partellus*

The EAG studies with acetone extracts of the frass obtained from feeding of *C. partellus* on sorghum, maize and artificial diet revealed a definite attraction of the parasitoid adults even at low concentrations.

4.6.6. Tritrophic interaction studies

4.6.6.1. *Trichogramma chilonis*, *Helicoverpa armigera* and cotton genotypes

Three experiments were conducted on tritrophic interaction between *Trichogramma chilonis*, *Helicoverpa armigera* and cotton genotypes. Ten genotypes were evaluated under multiple choice in polyhouse conditions. Ten eggs (one-day-old) of *H. armigera* were placed on each plant individually at flowering stage. One-day-old *T. chilonis* females were released the next day from a central point for parasitization. After three days the leaves were removed and per cent parasitization recorded. Pooled data of the three experiments revealed significant difference between the cotton genotypes in per cent parasitization of *H. armigera* eggs by *T. chilonis* (Table 10). Highest mean parasitization was observed on MCU-5 (28.89) followed by MCU-7 (27.78), Kanchan (27.64), Anjali (27.14) and Savita (27.14) and all these genotypes were on par. Lowest parasitization was recorded on G-27 (12.21) followed by C-256.4 (13.33) and HLS-72 (15.56).

Table 10. Mean parasitization of *Helicoverpa armigera* eggs by *Trichogramma chilonis* on different genotypes of cotton

Genotype	Mean per cent parasitization
C-256.4	13.33 (17.71)
G-27	12.21 (18.19)
HLS72	15.56 (22.95)
MCU-5	28.89 (32.33)
MCU-7	27.78 (31.23)
SRT-1	18.89 (25.33)
Anjali	21.12 (27.14
Kanchan	22.23 (27.64
Suman	17.78 (24.59)
Savita	21.11 (27.14)
CD (P=0.05)	(5.41)

4.6.6.2. Tritrophic interaction between tomato genotypes, *H. armigera* and *T. chilonis*.

An experiment was conducted on tritrophic interaction between tomato genotypes, fruit borer *H. armigera* and the egg parasitoid, *T. chilonis* in a polyhouse under multiple choice conditions. Twelve genotypes were evaluated. Numerically highest parasitisation (50.00%) was recorded on Arka Ahuti followed by Anand-1 (46.66%), Challenger-1 (43.00%) and Varalakshmi (40.00). However, statistically there was no significant difference between the genotypes.

4.6.6.3. Mean EAG response of *H. armigera* to the green volatiles released by leaves and flowers of different genotypes of tomato

Electrophysiological response of adult females of *H. armigera* to green volatiles (synomones) released by leaves and flowers of 12 different genotypes of tomato was studied through EAG. Highest response was shown to synomones released by leaves of Arka Ahuti (-0.684mv) followed by Anand-1 (-0.668mv), Pusa Ruby (-0.509mv) and Arka Saurabh (-0.442mv). Similarly, maximum response was given to synomones released by flowers of Arka Ahuti (-0.251mv) follwed by Anand-1 (-0.240mv), Arka Saurabh (-0.163mv) and Arka Meghali (-0.163mv).

4.6.6.4. Olfactometer response of *Trichogramma chilonis* to synomones released by leaves, flowers and fruits of different genotypes of tomato

The data on mean per cent response of *Trichogramma chilonis* to the synomones released by leaves, flowers and fruits of different genotypes of tomato showed that response to synomones released by leaves varied from 40.00 to 73.33 per cent. Highest population (73.33%) was attracted to the leaves of Arka Ahuti followed by Anand-1 (66.67%). Similar trend was found in case of flowers and fruits. Comparatively, Anjali and 101 Super attracted lower numbers.

4.6.6.5. Trapping and identification of green volatiles (Synomones) released by different cotton genotypes

Synomones released by leaves and bolls of cotton were trapped in specially designed trap for two hours by passing pure air on the top of leaves. The volatiles were extracted by using hexane and then concentrated in a refrigerated vacuum concentrator. The concentrated volatiles were identified using GCMS. Out of 36 compounds identified from leaves, Alpha –Pinene, Pentadecane, Octadecane, Heptadecane, Nonadecane and Eicosane were found in all the genotypes. Next most common compounds were Beta- Pinene, Limonene, Dodecane, Tridecane, Tetradecane, Hexadecane, 1,2-benzene dicarboxylic acid, Docosane, Phenol 1,2-4-bis, Heneicosane and Junipene. Other compounds are specific to some genotypes.

From cotton bolls of 9 genotypes (C-256.4, HLS-72, MCU-5, MCU-7, SRT-1, Anjali, Kanchan, Suman and Savita), 37 compounds of green volatiles were identified. The most common were Alpha–Pinene, Beta-Pinene, Limonene, Dodecane, Pentadecane, Hexadecane and Nonadecane and these occur in all the genotypes. Tridecane, Tetradecane, Heptadecane, Tetradecene and Hexadecene are the other compounds, which are found in 70 to 90% genotypes tested. Other compounds are specific to some genotypes. Some compounds, namely Z0-13- methl-11, tetradecen-1-ol; 9-octadecenal and 13-Tetradecenal were found only in bolls of some genotypes and not in leaves.

4.6.6.6. Trapping and identification of green volatiles (synomones) released by different tomato genotypes

The green volatiles released by leaves of ten genotypes of tomato (Anjali, 101 Super, Varalakshmi, Challenger, Arka Meghali, A. Saurabh, A. Vikash, A. Ahuti, Arka Ashish and Pusa Ruby) included twenty seven compounds. Of these Alpha –Pinene, Pentadecane, Heptadecane and Octadecane were found in all the genotypes. Beta-Pinene, Hexadecane, and Nonadecane were observed in 90% cases. The other common fractions (40-60%) were Dodecane, Tridecane, Tetradecane, Tetracosane, 1,2-Benzene dicarboxylic acid, Heneicosane and Heptadecene. Delta-elemene, Eugenol and Caryophyllene were trapped from only Pusa Ruby. Similarly, eicosane was found only in Arka Ahuti and Linoleic acid in Anjali.

The data on synomones trapped from flowers of these tomato genotypes revealed the presence of 23 identified fractions. Dodecane, Hexadecane, Heptadecane, Octadecane and Nonadecane were identified from all the genotypes. Tetradecane, Pentadecane, Sabinene, Tridecane and Alpha –Terpinene were found in 70-80% genotypes. Eicosane was trapped from leaves of Arka Ahuti and flowers of Arka Ahuti, Arka Vikas, Arka Saurabh and Arka Meghali. However, Hexacosane, Heneicosane and Docosane were found only in Challenger-1, Arka Saurabh and Varalakshmi, respectively.

Among the eighteen compounds identified on green volatiles released by fruits of 9 different genotypes of tomato, Pentadecane, Hexadecane, Heptadecane, Tetradecane, Dodecane, Alpha –Pinene and Sabinene were most common. Azulene and Alpha –Terpinene were trapped from five specific genotypes. Docosane was found only in A. Ahuti and Nonadecane in Anjali.

4.7. Artificial diets for host insects

4.7.1. Rearing of *Spodoptera litura* completely on semi-synthetic diet

An experiment was conducted to investigate if *S. litura* could be reared completely on semi-synthetic diet with *Cynodon dactylon* powder. To provide token stimulus *C. dactylon* powder (5.0g) was added to the existing semi-synthetic diet.

Newly hatched larvae were directly transferred to the semi-synthetic diet and the culture monitored for five generations. The per cent survival, pupal weight, developmental time, longevity and fecundity were recorded (Fig. 13). In the first generation, per cent survival was 60%, pupal weight was 0.396 and 0.426 g, respectively, for male and female and 220 larvae were produced per female. During the third generation more than 62% pupation was recorded and pupal weight was 0.390 and 0.378 g for male and female, respectively. The fecundity per female was 200. During the fifth generation, survival was 90% and pupal weight 0.414 and 0.443 g for male and female pupae, respectively.

4.8. Studies on artificial diets for natural enemies

4.8.1. Semi-synthetic diet for *Chrysoperla carnea*

C. carnea adults reared on semi-synthetic diet and *C. cephalonica* eggs were provided with 30 per cent honey solution (in water), 50 per cent protinex (in water) and castor pollen grains. Growth attributes *viz.*, the egg hatch rate (%), larval and pupal duration, pupation rate, adult emergence (%), longevity and fecundity were recorded for both semi-synthetic diet and *Corcyra* egg reared adults. Beef liver based diet was found to be the best with reference to increased pupation (90 %), adult emergence (89 %) and fecundity (372 eggs/female). Further, *C. carnea* was reared on the above diet for eight generations and the growth parameters were compared with the *Corcyra* reared predators. Per cent pupation and adult emergence of semi-synthetic diet reared predators compared favourably with those of *Corcyra* fed *C. carnea*, but the fecundity was much reduced (Table 11).

Table 11. Comparative biology of *C. carnea* reared on semi-synthetic diet and *C. cephalonica* eggs

Generation number	Pupation (%)		Adult emergence (%)		Fecundity (number/female)	
	Semi-synthetic diet	Natural diet	Semi-synthetic diet	Natural diet	Semi-synthetic diet	Natural diet
F_0	90	90	89	89	372	674
F_1	88	90	88	89	302	667
F_2	88	90	81	89	312	652
F_3	89	90	87	89	345	631
F_4	86	88	75	83	374	592
F_5	88	89	79	88	522	674
F_6	85	89	82	86	381	561
F_7	80	88	71	83	320	598
F_8	81	86	74	77	298	478
Mean	86.1	88.9	80.7	85.9	358	614

An attempt was made to encapsulate the beef liver diet using sodium alginate (1 %) and calcium chloride (1.4 %) for rearing *C. carnea*. Encapsulated semi-synthetic diet became shrivelled and dried in 4 h.

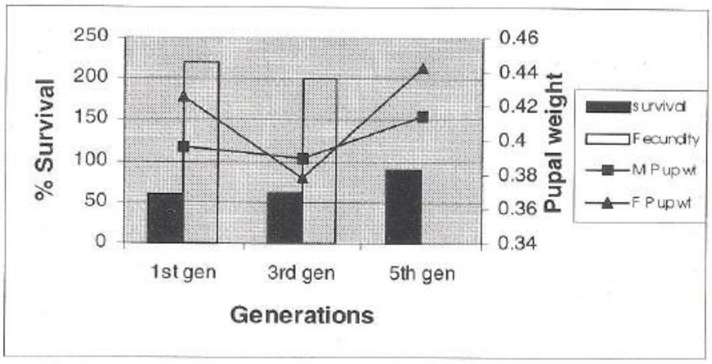


Fig. 13. Rearing of *Spodoptera litura* in cynodon based semi-synthetic diet

4.8.2. Studies on the predatory efficiency of diet reared *C. carnea*

Tobacco plants were naturally infested with the aphid, *Myzus persicae*. The predators *viz*., diet reared *C. carnea*, natural diet reared *Cheilomenes sexmaculata*, and *Ischiodon scutellaris* were released at 1: 50 (predator: prey ratio) against *M. persicae*. Maximum care was taken to remove other pests and natural enemies. Preliminary observations revealed that *C. sexmaculata* consumed more aphids followed by diet reared *C. carnea* and *I. scutellaris*. An experiment was also conducted to test the feeding efficiency of semi-synthetic diet and *Corcyra* egg reared *C. carnea* on *H. armigera* eggs and *Corcyra* eggs. The number of eggs consumed by the larvae was recorded daily till pupation. Feeding efficiency of diet and *Corcyra* egg reared *C. carnea* on *Helicoverpa* and *Corcyra* eggs was 583 eggs/larva and 491 eggs/larva (diet reared) and 641 eggs/larva and 560 eggs/ larva (*Corcyra* reared), respectively.

4.8.3. Biochemical analysis of semi-synthetic diet and prey insects

Biochemical analysis (protein, lipids, carbohydrate) of beef liver based diet for *C. carnea*, *C. cephalonica* eggs and *H. armigera* eggs was done. Percentage of protein and carbohydrate present in eggs and diet were estimated by Folin Ciocalteu and Phenol-sulphuric acid method, respectively. The total lipid content was determined by evaporating the final chloroform: petrol extract to dryness. Maximum carbohydrate was present in beef liver-based diet. The percentage of protein was relatively more in *Corcyra* and *Helicoverpa* eggs when compared to beef-liver-based diet (Table 12). Effort to increase the protein content in the semi-synthetic diet on par with the natural prey has to be made.

Table 12. Biochemical analysis of preys and artificial diet of *C. carnea*

Prey/diet	Protein (%)	Lipid (%)	Carbohydrate (%)	Total (%)
Semi-synthetic diet	2.2	4.3	9.2	15.7
Corcyra eggs	6.4	6.9	7.6	20.9
Helicoverpa eggs	6.2	5.0	8.1	19.3

4.8.4. Semi-synthetic diet for rearing of *Mallada astur*

Beef liver diet was also tested for rearing *M. astur*. Growth parameters were compared between semi-synthetic diet and *Corcyra* reared *M. astur* (Table13).

Table 13. Development of semisynthetic diet for *Mallada astur*

Growth parameter	Semi-synthetic diet reared *M. astur*	*Corcyra* reared *M. astur*
Larval period (days)	17.0	9.0
Pupal weight (mg)	3.2	6.7
Pupation (%)	82	86
Adult Emergence (%)	75	79
Fecundity (no/female)	149	194
Longevity (days)	42	51

4.8.5. Development of semi-synthetic diet for *Coccinella septempunctata* and *Cheilomenes sexmaculata*

Among the four diets tested for rearing *C. septempunctata*, one gave 39% pupation, 34% adult emergence and 45 days longevity as compared to 60 %, 58 % and 65 days, respectively in the case of aphid reared beetles. Ground beef liver with egg yolk based diet was tried for rearing *Cheilomenes sexmaculata* and the per cent pupation and adult emergence were 40 and 24 %, respectively. The beetles reared on the diet failed to lay eggs.

4.8.6. Semi-synthetic diet rearing of anthocorid bug, *Cardiastethus exiguus*

Two-day-old nymphs were taken in glass vials (4.5x2 cm) and provided with a piece of cotton. Semi-synthetic diet with ground beef liver plus defatted soybean plus milk powder was found to be better with reference to adult formation (78 %). The fecundity and longevity of diet reared adults were 14 eggs/female and 41 days, respectively. The adult formation, fecundity and longevity of natural diet reared adults were 91 %, 71 eggs/female and 65 days, respectively.

4.9. Evaluation of improved and selected species / strains of egg parasitoids

4.9.1. Development of high temperature tolerant strain of *T. chilonis*

The experiment was initiated by getting host eggs parasitized by *T. chilonis* from temperature ranges of 30 to 35°C in BOD incubator in two different humidity ranges, i.e. 35 and 70%. The experiment was initiated at 33°C with the aim to achieve adult survival for > 5 days and parasitism > 90 per cent at temperature of 37°C. During this year parasitoids were reared at 36°C and RH 60%. In each generation about 2000 eggs were exposed to female parasitoids. The exposure was done for 24 hours and observation was recorded on per cent parasitism and longevity of parasitoids. The humidity was maintained by keeping exposure vials inside plastic containers with moist sponge.

Results showed that after 48 generations of constant rearing, the parasitoids are now showing adaptability to this temperature with constantly high parasitism and increased longevity (Table 14).

Table 14. Development of high temperature (36°C) tolerant strain of *T. chilonis*

Generation	Per cent parasitism	Adult longevity (days)
1	30	2
5	40	2
10	45	2
15	60	2
20	70	3
25	70	4
30	70	4
35	75	5
40	80	5
45	80	6
48	82	6

4.9.2. Evaluation of multiple insecticide resistant/tolerant strain of *T. chilonis*

This study was started in 1997-98 and was continued with endosulfan, monocrotophos and fenvalerate in the laboratory. Modified plastic tubes with both ends open (measuring 20 x 5 cm) were sprayed with the insecticide solution. After drying, about 1000 adults were released in each tube. An egg card containing about 8000 *Corcyra* eggs (0.5 cc) was introduced in each tube to obtain further generations. In the endosulfan exposure resistance/tolerance study, 12 generations to 2.50 ml/l and 24 generations to 2.75 ml./l were exposed. In monocrotophos treatment, 36 generations were exposed to @ 1.50 ml./l and in fenvalerate, 09, 21 and 6 generation have been exposed to dosages @ 0.05, 0.75 and 0.10 ml./l.

An experiment was started with 'Endogram' strain to develop multiple insecticide tolerant strain of *Trichogramma chilonis*. The results suggested that this strain has now become tolerant to 2.75 ml/l of endosulfan and 1.5 ml/l of monocrotophos and the parasitoids have been now shifted to 0.10 ml/l of fenvalerate. The parasitism on fenvalerate is about 50% and survival about 10% after 6 hours of constant exposure (Table 15).

Table 15. Exposure of *Trichogramma chilonis* adults to insecticides

Insecticide	Dosage (ml/l)	Number of generations	Per cent parasitism	Per cent adult survival
Endosulfan	2.50	12	90	30
Endosulfan	2.75	24	90	20
Monocrotophos	1.50	36	80-90	50
Fenvalerate	0.05	09	70-90	10
Fenvalerate	0.75	21	70-90	20
Fenvalerate	0.10	06	50	10

4.9.3. Parasitising efficiency of different species and strains of *Trichogramma* on populations of *Helicoverpa armigera*

This experiment was carried out by exposing species and strains adapted or used against *Helicoverpa armigera* to ten different populations of *H. armigera* collected in cotton ecosystem from all over India. The collections were made from Bhatinda (Punjab), Sirsa (Haryana), Sriganganagar (Rajasthan), Khandwa (Madhya Pradesh), Anand (Gujarat), Akola (Maharashtra), Guntur and Khammam (Andhra Pradesh), Raichur (Karnataka) and Coimbatore (Tamil Nadu). These populations were reared on artificial diet and first generation eggs were utilised for the experiment.

In each population 100 eggs of *H. armigera* were pasted on card and two one-day-old females of respective species/strains were released in insect rearing cages measuring 30 cm^3 for 24 h. In each rearing cage, a bouquet of cotton twigs was provided and the egg card was hung from the bouquet. Each exposure was replicated 10 times. The experiment was conducted in the laboratory at temperature of 26±1°C and RH 50 – 70%.

Results indicated that *T. chilonis* was superior among all species tested for *H. armigera*. It parasitised eggs to the tune of 85 – 95 per cent (Table 16).

Table 16. Parasitism of *Helicoverpa armigera* eggs collected from different states of the country by various species / strains of trichogrammatids

Species	Parasitization of eggs collected from different states (%)	Strains collected from	Parasitization of eggs collected from different states (%)
T. brasiliense	70-85	*H. armigera*	53-71
T. chilonis	85-95	*Chilo* spp.	23-48
T. evanescens	60-70	*S. litura*	29-40
T. pretiosum	75-85		
T. armigera	60-65		

4.10. Studies on insect pathogens

4.10.1. Survey for nuclear polyhedrosis viruses (NPVs) and granulosis virus (GV) of insect pests

Nuclear polyhedrosis viruses from cabbage leaf webber, *Crocidolomia binotalis* and rice moth, *Corcyra cephalonica* have been isolated. Pathogenicity tests against first and second instars proved positive in both cases. From field collected (Mandya, Karnataka) sugarcane internode borer, *Chilo sacchariphagus indicus* and beet army worm, *Spodoptera exigua*, granulosis viruses (GVs) were isolated. Baculoviruses from *Plusia signata* and *Thysanoplusia orichalcea* were isolated. While testing the cross infectivity of *Plutella xylostella* GV against *Mythimna separata*, a baculovirus from *Mythimna separata* was isolated.

4.10.2. Cross infectivity, safety and persistence tests

Granulosis virus (GV) of sugarcane internode borer, *Chilo sacchariphagus indicus* was cross infective to *Chilo infuscatellus*. Cross infectivity of GV of *Plutella xylostella* to *Plusia signata, Thysanoplusia orichalcea* and *Mythimna separata* against at all stages was negative thereby showing its specificity. *Plusia signata* baculovirus was not infective to *Plutella xylostella*.

Spodoptera exigua NPV was safe to common predator, *Chrysoperla carnea* and silkworm, *Bombyx mori*.

To find out the persistence and protection of *Spodoptera litura* nuclear polyhedrosis virus against sunlight, studies were conducted with an optical brightner at 0.1% concentration. Neonate larvae of *S. litura* were treated with polyhedral inclusion bodies of NPV of *S. litura* @ 10^{3} PIB/diet container which was exposed to sunlight for 6hr (1000 to 1600 hrs). Unexposed PIBs of *S. litura* NPV served as control at the concentration. The study revealed cent per cent mortality in both treatments.

4.11. Studies on fungal and bacterial antagonists

4.11.1. Biological control of root rot of chickpea

4.11.1.1. *In vitro* inhibition of *Sclerotium rolfsii*

All *Trichoderma* spp. (nine isolates) showed more than 39% inhibition of mycelial growth of *S. rolfsii*. Maximum inhibition was obtained with PDBCTV 24 (87.7%), followed by PDBCTV 23 (83.7%) and PDBCTVs 12 (81.1%). Among *T. harzianum* isolates PDBCTH 10 gave maximum inhibition (79.2%).

The sclerotial production was reduced significantly by all antagonists (76.8-96.9%). All *Trichoderma* isolates recorded more than 75% reduction in sclerotial production. Maximum inhibition of sclerotial production was by *T. viride*, PDBCTV 26 (96.9%) followed by *T. viride*, PDBCTV 23 (95.6%), *T. virens*, PDBCTVs 12 (95.2%) and *T. harzianum*, PDBCTH 10 (95%).

4.11.1.2. Production of volatile and non-volatile antibiotics

All *Trichoderma* isolates showed significant inhibition of *S. rolfsii* by producing volatile and non-volatile antibiotics. The per cent reduction in mycelial growth of *S. rolfsii* due to non-volatile antibiotics produced by various *Trichoderma* isolates ranged between 40.9 and 76.7, whereas the per cent reduction due to volatile antibiotics ranged between

32 and 49.4. *T. viride* isolates (PDBCTV 23 and PDBCTV 26) and *T. virens* (PDBCTVs 12) gave more than 70 % inhibition by non-volatile antibiotics. *T. virens* showed maximum inhibition (49.4%) by volatile antibiotics. *T. viride* (PDBCTV 20) and two *T. harzianum* isolates (PDBCTH 10 and PDBCTH 13) gave more than 40% inhibition.

4.11.1.3. Biological control of root rot of chickpea in greenhouse

All treatments with antagonist seed treatment showed significantly less disease incidence compared to fungicide and pathogen controls at 6 weeks. The root and collar rot incidence was 18-48% whereas in fungicide treatment it was 58% (Table 17). In pathogen control there was 84% incidence of root/collar rot of seedings. There was not much increase in disease incidence after 3 weeks. At 6 weeks maximum disease control (55.4%) was achieved with *T. viride* isolates PDBCTV 23 and 24 and *T. harzianum* isolate PDBCTH 10. All *Trichoderma* treatments were superior to fungicide treatment.

Table 17. Effect of *Trichoderma* spp. on root/collar rot incidence

Antagonist	Root/collar rot incidence (%)*		Disease control (%)	
	After 3 weeks	After 6 weeks	After 3 weeks	After 6 weeks
T. viride (PDBCTV 20)	34.0 (35.6)	38.0 (38.0)	32.9	38.6
T. viride (PDBCTV 21)	32.0 (34.3)	40.0 (39.2)	34.4	37.0
T. viride (PDBCTV 23)	16.0 (23.3)	18.0 (24.9)	46.7	55.4
T. viride (PDBCTV 24)	14.0 (21.7)	18.0 (24.9)	48.2	55.4
T. viride (PDBCTV 26)	30.0 (33.1)	34.0 (35.5)	35.9	42.0
T. harzianum (PDBCTH 10)	14.0 (21.7)	18.0 (24.9)	48.2	55.4
T. harzianum (PDBCTH 12)	44.0 (41.5)	48.0 (43.9)	25.1	30.2
T. harzianum (PDBCTH 13)	48.0 (43.9)	48.0 (43.9)	22.1	30.2
T. virens (PDBCTVs 12)	26.0 (30.6)	30.0 (33.1)	39.0	45.4
Control 1(Fungicide)	42.0 (40.3)	58.0 (49.6)	26.7	21.8
Control 2 (*S. rolfsii*)	76.8 (60.8)	84.0 (66.7)	0.0	0.0
CD (P=0.05)	4.3	5.0		

* Average of five replications; Figures in parentheses are angular transformations

4.11.1.4. Chickpea rhizosphere colonization by *Trichoderma* spp.

The population of all bioagents on seed after seed treatment ranged between log 4.15 and 4.89 (Table 18). At two weeks, population of *Trichoderma* on each root varied between log 3.6 and 4.58. Population of all *Trichoderma* species increased up to 4 weeks (around 10^5 cfu/root) and thereafter did not change much except with *T. harzianum* (PDBCTH 10) where from log 4.96 at 4 weeks it increased to log 5.3 by 6 weeks. In general the rhizosphere population of all *Trichoderma* isolates reached around 10^5 cfu/root by 4 weeks from around 10^{3-4} cfu/root at 2 weeks which is indicative of their rhizosphere colonizing ability.

Table 18. Chickpea rhizosphere colonization by *Trichoderma* species

Antagonist	Population of bioagents on seed (log cfu/seed)	Rhizosphere population of *Trichoderma* spp. (log cfu/ root)* (after weeks)		
		2	4	6
T. viride (PDBCTV 20)	4.15	3.60	4.99	4.74
T. viride (PDBCTV 21)	4.31	3.70	4.83	4.79
T. viride (PDBCTV 23)	4.81	4.58	5.09	4.95
T. viride (PDBCTV 24)	4.58	4.03	5.25	5.05
T. viride (PDBCTV 26)	4.71	3.59	5.05	5.00
T. harzianum (PDBCTH 10)	4.89	4.32	4.96	5.30
T. harzianum (PDBCTH 12)	4.35	3.62	5.09	4.93
T. harzianum (PDBCTH 13)	4.54	3.97	4.97	4.89
T. virens (PDBCTVs 12)	4.57	3.66	5.21	5.09
Control	0.00	0.00	0.00	0.00
CD (P=0.05)	0.07	0.18	0.08	0.08

*Average of bioagent population on 5 roots

4.11.1.5. Plant growth-promoting ability of *Trichoderma* spp.

Seed treatment with all *Trichoderma* isolates resulted in significantly more per cent chickpea seedling emergence compared to control (Table 19). The root length and shoot length in all bioagent treatments were also significantly high. Maximum vigour index (3491.6) was obtained with *T. viride* (PDBCTV 24). Significantly high dry weight of shoots and roots was observed in treatments with *T. viride* isolates PDBCTV 23, 24 and 26 and *T. harzianum* isolate PDBCTH 10. Number of secondary roots was significantly more in all bioagent treatments compared to untreated control. This study clearly establishes the growth promoting ability of *Trichoderma* spp.

Table 19. Effect of seed treatment with *Trichoderma* species on chickpea plant growth

Antagonist	Germination (%)	Shoot length (cm)	Root length (cm)	Vigour index	Dry weight of shoot(mg)	Dry weight of roots(mg)	Number of secondary roots
T. viride (PDBCTV 20)	76.6 (61.1)	21.7	9.7	2392.6	151.2	32.8	9.2
T. viride (PDBCTV 21)	74.4 (59.6)	18.7	8.4	2018.8	148.8	35.0	13.2
T. viride (PDBCTV 23)	82.4 (65.2)	21.3	11.7	2720.0	165.6	52.4	23.4
T. viride (PDBCTV 24)	88.8 (70.5)	24.4	14.3	3491.6	197.8	55.6	22.4
T. viride (PDBCTV 26)	80.8 (64.0)	20.0	9.8	2411.6	163.8	37.8	15.4
T. harzianum (PDBCTH 10)	86.4 (68.4)	23.7	9.8	2922.8	201.2	61.2	19.2
T. harzianum (PDBCTH 12)	75.2 (60.1)	23.4	8.2	2377.8	137.6	31.2	12.8
T. harzianum (PDBCTH 13)	74.5 (59.6)	21.3	7.4	2136.4	132.8	35.6	13.0
T. virens (PDBCTV 12)	80.8 (64.0)	21.0	9.4	2471.6	153.6	32.0	12.4
Control	73.6 (59.1)	14.26	5.6	1193.4	128.6	29.8	7.8
CD (P=0.05)	(1.9)	1.9	1.6	229.3	12.3	7.7	2.9

Figure in parentheses are angular transformations

4.11.2. Dose-response studies in biological control of fusarial wilt of redgram

An attempt was made to quantify biological control by studying the efficacy of various doses of *Trichoderma harzianum* at various levels of *Fusarium udum*, the incitant of wilt in pigeonpea. Identifying the need to use high pathogen inoculum dose to measure biocontrol efficacy, fusarial wilt sick plots with three levels of pathogen concentrations *viz.*, log 3.04, 4.98 and 5.34 colony forming units (i.e. approx. 0.1, 1 and 2 lakh propagules) per gram of soil were identified.

Bioagent was applied as seed coat (@10 and 20 g/kg seed) and soil amendment (@ 0.5 and 1 kg/ 9 m^2 area). At $10^{3.04}$ cfu level of pathogen, the soil amendment of bioagent @ 0.5 and 1.0 kg resulted in 32.73 and 15.17% disease incidence, respectively, by 90 days (Table 20). Seed treatments at two levels resulted in 58.73 and 49.10% disease

Table 20. Efficacy of bioagent in reducing disease incidence at an average *Fusarium udum* level of log 3.04 cfu/g of soil

Treatment	Per cent disease incidence (days)*			Bioagent population (log cfu/gm of soil) (days)			
	30	60	90	15	30	45	60
Soil treatment 0.5kg/9 m^2	1.80 (7.70)	13.83 (21.79)	32.73 (34.88)	7.54	7.88	7.88	8.01
Soil treatment 1.0kg/9 m^2	0.67 (2.71)	7.57 (15.96)	15.17 (22.91)	7.91	8.02	8.03	8.08
Seed treatment 10 g/kg seed	8.37 (16.78)	29.77 (33.06)	58.7 (50.04)	2.31	4.36	4.39	4.34
Seed treatment @ 20 g/kg seed	3.60 (10.90)	18.13 (25.19)	49.10 (44.48)	2.76	4.45	4.45	4.39
Pathogen control	9.60 (18.04)	38.47 (38.33)	76.67 (61.14)	-	-	-	-
Carbendazim @ 2 g/kg seed	1.87 (7.84)	33.57 (35.40)	72.80 (58.58)	-	-	-	-
CD (P=0.05)	1.01	3.49	5.31	0.16	0.07	0.06	0.08

* Values in parentheses are angular transformations

incidence. There was no significant difference in disease incidence between fungicide and pathogen treatments. At higher pathogen levels viz.,log 4.98 and 5.34 cfu/g of soil, the disease incidence recorded at 90 days ranged between 55.6 and 70.23% in soil treatments (Table 21 and 22). Even at highest pathogen density, soil amendment @ 1 kg/m^2 gave about 30% control.

In general, soil application of the bioagent was found to be more effective than seed treatment at higher pathogen levels, which may be due to higher population of bioagent in the rhizosphere. The bioagent population reached more than 10^8 cfu/g in treatments with soil application by 60 days, whereas in seed treatments bioagent population reached a maximum of $10^{4.62}$ cfu/g by 45 days and started declining. The results obtained in this study clearly show the need for augmentative application of *T. harzianum* for obtaining effective control of wilt of pigeonpea at higher pathogen concentrations.

Table 21. Efficacy of bioagent in reducing disease incidence at an average *Fusarium udum* level of log 4.98 cfu/g of soil

Treatment	Per cent disease incidence (days)*			Bioagent population (log cfu/gm of soil) (days)			
	30	60	90	15	30	45	60
Soil treatment 0.5kg/9 m^2	4.20 (11.82)	36.57 (37.21)	58.60 (49.96)	7.59	7.78	7.87	8.09
Soil treatment 1.0kg/9 m^2	3.40 (10.60)	28.13 (32.03)	55.60 (48.22)	7.94	8.12	8.10	8.16
Seed treatment 10 g/kg seed	8.70 (17.14)	46.57 (43.03)	80.73 (64.02)	2.32	4.31	4.50	4.35
Seed treatment 20 g/kg seed	7.83 (16.24)	39.53 (38.96)	77.20 (61.50)	2.66	4.59	4.62	4.51
Pathogen control	14.33 (22.21)	47.27 (43.43)	90.90 (72.48)	-	-	-	-
Carbendazim 2 g/kg seed	3.80 (11.20)	44.90 (42.07)	75.57 (60.45)	-	-	-	-
CD (P=0.05)	2.09	3.70	6.34	0.06	0.10	0.05	0.12

* Values in parentheses are angular transformations

Table 22. Efficacy of bioagent in reducing disease incidence at an average *Fusarium udum* level of log 5.34 cfu/g of soil

Treatment	Per cent disease incidence (days)*			Bioagent population (log cfu/gm of soil) (days)			
	30	60	90	15	30	45	60
Soil treatment 0.5kg/9 m^2	7.07 (15.41)	40.23 (39.36)	70.23 (56.94)	7.24	7.84	8.05	8.12
Soil treatment 1.0kg/9 m^2	5.13 (13.08)	36.13 (36.93)	61.27 (51.51)	7.45	8.08	8.20	8.25
Seed treatment 10 g/kg seed	8.70 (17.14)	48.23 (43.99)	85.40 (67.55)	2.35	4.39	4.41	4.35
Seed treatment 20 g/kg seed	7.83 (16.24)	45.20 (42.24)	87.87 (69.65)	2.72	4.56	4.62	4.36
Pathogen control	15.67 (23.30)	48.27 (44.01)	92.23 (73.89)	-	-	-	-
Carbendazim 2 g/kg seed	3.80 (11.20)	44.90 (42.07)	87.30 (69.17)	-	-	-	-
CD (P=0.05)	1.78	3.81	2.97	0.05	0.07	0.08	0.06

* Values in parentheses are angular transformations

4.11.3. Evaluation of various inert powders as carrier materials of *Trichoderma*

4.11.3.1. Shelf life of *T. harzianum* in various carrier materials

The initial population of *T. harzianum* was estimated to be more than 10^7 cfu/g (Table 23) in all the three carrier materials tested. The minimum recommended population of fungal bioagents in any seed treatment formulation is more than 10^6 cfu/g. A significant decline in *Trichoderma* population was noticed in all carrier materials at 120 days. Kaolin retained significantly high population of *T. harzianum* than talc and bentonite at 30 days. In bentonite the viable propagules number declined below 10^6 (log 5.759) by 60 days. Talc and kaolin retained more than 10^6 viable propagules for up to 90 days and by 120 days declined below the optimum level. At 90 and 120 days kaolin retained significantly high population than talc. Bentonite was least suitable since a drastic decline in the *Trichoderma* population was noticed after 120 days (log 2.979).

Table 23. Shelf life of *T. harzianum* in various carrier materials

Carrier	Log cfu/g after days					
	0	30	60	90	120	Mean
Talc	7.615	7.123	6.742	6.110	5.259	6.298
Kaolin	7.600	7.236	6.783	6.285	5.815	6.275
Bentonite	7.454	6.886	5.759	4.433	2.979	6.244
Mean	7.556	7.082	6.428	5.609	4.684	

CD (P=0.05): Carrier - 0.093; Days - 0.072 and Interaction - 0.161

4.11.3.2. Bioefficacy of powder formulations at different storage periods

There was a significant reduction in plant population after seed treatment with *T. harzianum* formulations at different storage periods (Table 24). Seed treatment with kaolin and talc formulation of the bioagent recorded more than 50% plant stand even after 120 days of storage. Kaolin treatment recorded more plant stand than talc and bentonite at different storage periods. Bentonite recorded more than 50% plant stand at 0, 30 and 60 days of storage and thereafter there was a drastic reduction in plant stand due to disease. Seed treatment with bentonite formulation stored for 120 days recorded only 34.8% plant stand. From these studies it can be concluded that kaolin and talc are better carriers of *T. harzianum*.

Table 24. Efficacy of *T. harzianum* applied through various carrier materials at different storage periods in reducing root rot caused by *Rhizoctonia solani* in chickpea

Treatment	Per cent plant stand (days)					
	0	30	60	90	120	Mean
Talc	70.00 (56.81)	67.75 (55.44)	66.50 (54.66)	61.50 (51.66)	54.50 (47.58)	80.06 (53.23)
Kaolin	77.25 (61.55)	73.25 (58.88)	70.00 (56.79)	63.00 (52.54)	56.75 (48.88)	85.06 (55.73)
Bentonite	63.50 (52.84)	59.25 (50.34)	52.25 (46.29)	36.75 (37.30)	31.25 (33.98)	60.75 (44.15)
Control	23.25 (28.80)	22.00 (27.93)	21.00 (27.24)	22.00 (27.96)	22.75 (28.48)	27.75 (28.08)
Mean	58.50 (50.00)	55.56 (48.15)	52.44 (46.25)	45.81 (42.36)	41.31 (39.73)	
CD (P=0.05):Formulation -1.25; Days- 1.12 and Interaction- 2.51						

Values in the parentheses are angular transformations

4.11.4. *In vitro* and pot culture studies with bacterial antagonists

Seven isolates (PDBCAB 30 to 36) were screened for *in vitro* antagonism in dual culture on TSA (Tryptic Soya Agar) against five fungal pathogens, *viz*., *Botrytis cinerea, Macrophomina phaseolina, Sclerotium rolfsii, Rhizoctonia solani* and *Fusarium udum*. Six fluorescent pseudomonads were selected as potential antagonists. Four isolates were effective against *S. rolfsii, R. solani* and *F. udum* (inhibition zones ranging from 32 to 56 mm). Two isolates (PDBCAB 34 and 36) were highly effective against *M. phaseolina*. Previously identified antagonist *Pseudomonas putida* (PDBCAB 19) and *Bacillus subtilis* were also screened for antagonism against *F. udum* and were effective by exhibiting inhibition zones of 40 and 37 mm, respectively. *F. udum* was targeted by *P. putida* (PDBCAB 19) under greenhouse conditions in pots. Eighty per cent of the plants survived after 60 days of growth whereas in infected control only 20 per cent of the plants survived.

4.11.5. Identification of isolated antagonistic bacteria

Initial identification was carried out as per Bergey's Manual of Systematic Bacteriology (8th edition, 1984). The six new isolates were identified as *Pseudomonas fluorescens*. They produced a fluorescent pigment on King's B medium but not on $FeCl_3$ - amended King's B medium. All of them showed positive reaction for Kovac's oxidase test, arginine dihydrolase and gelatin liquefaction.

4.11.6. Formulation of potential bacterial antagonists

Talc based formulations of all the selected antagonists were prepared for *in vivo* screening by adding 10 g of carboxymethyl cellulose (CMC) to 1.0kg of talc powder. The carrier was sterilized and 400 ml of the bacterial suspension containing $9x10^8$ cfu/ml was added. Talc and kaolin based formulations of *P. putida* (PDBCAB 19) were prepared using Potato Dextrose Broth (PDA) as culture. Talc based formulation of *P. putida* (PDBCAB 19) was selected for screening against *F. udum* in a wilt sick plot at UAS, GKVK campus, Bangalore.

4.11.7. Field testing of selected antagonistic bacterial strains alone or in combination with *Trichoderma* spp.

A wilt sick redgram plot was selected for screening of *Pseudomonas putida* (PDBCAB 19) both singly as well in combination with *Trichoderma* spp. The main pathogen present in the plot was isolated from infected redgram plants and identified as *Fusarium udum*.

Three pathogen levels, *viz.*, log 3.04, 4.98 and 5.34 colony forming units (i.e. approx. 0.1, 1 and 2 lakh propagules/g of soil) were ascertained. The random distribution of the pathogen in each plot was verified. Talc based formulations of the selected bioagents were used to target *F. udum* in the identified sick plot and treatments were distributed to cover the three pathogen levels.

Observations were taken on the per cent diseased plants at 30, 60 and 90 days after sowing. During the first 30 days only 2 to 3% diseased plants were observed in plots where seeds were treated with *P. putida* (PDBCAB 19) alone @ 10 and 5 g/kg or in combination with *Trichoderma harzianum* (PDBCTH 10) where the pathogen level was 3.04 cfu/g of soil (Table 25). Lowest diseased/wilted plants (1.66%) were observed in fungicide treated plot. About 7 to 10% diseased plants were recorded in pathogen control and in *P. putida* soil treated plots. At 60 days also, 4 to 7% diseased plants were recorded in *P. putida* seed treated plot or in combination with *Trichoderma*, but in *P. putida* soil treated plots 13% of the plants were diseased. In control or fungicide treated plot, 34-38% diseased plants were observed. At 90 days 23-36% of the plants were diseased in *P. putida* seed treated or in combination with *Trichoderma*. However, *P. putida* soil treatment was not effective enough and was almost on par with pathogen control where 73 to 76% of the plants were diseased.

Table 25. Performance of antagonists against *Fusarium udum* (average level of log 3.04 cfu/g of field soil).

Treatments	Per cent diseased plants (days)*		
	30	60	90
P. putida (PDBCAB 19) @ 10 g/kg seed	2.33 (8.74)	4.00 (11.48)	26.66 (31.00)
P. putida (PDBCAB 19) @ 5 g/kg seed	3.33 (10.50)	7.00 (15.18)	36.66 (37.22)
P. putida + *T. harzianum* (PDBCTH 10) @ 10 g/kg seed	2.33 (8.74)	4.33 (11.94)	23.33 (28.78)
P. putida (PDBCAB 19) @ 0.5kg/9 m^2	7.33 (15.68)	13.33 (21.34)	66.66 (54.78)
Pathogen Control	9.66 (18.08)	38.33 (38.24)	76.67 (61.14)
Carbendazim @ 2 g/kg seed	1.66 (7.33)	34.00 (35.67)	73.00 (58.70)
CD (P=0.05)	2.07 3.16	6.42	

*Figures in parentheses are angular transformations

Results on disease incidence in plots having 4.98 cfu/g of soil were also similar with that in plots having 3.04 cfu/g of soil during the first 60 days after sowing (Table 26). However, at 90 days, disease incidence increased in *P. putida* seed treated or in combination with *Trichoderma* wherein only about 37 – 55% of the plants survived. Again *P. putida* soil treatment was not effective. In pathogen control only 9% of the plants survived. All the treated plots showed slightly better disease control than fungicide treated plots.

Table 26. Performance of antagonists against *Fusarium udum* (average level of log 4.98 cfu/g of field soil).

Treatments	Per cent diseased plants (days)*		
	30	60	90
P. putida (PDBCAB 19) @ 10 g/kg seed	3.00 (9.88)	13.33 (21.34)	46.66 (45.00)
P. putida (PDBCAB 19) @ 5 g/kg seed	4.00 (11.48)	18.33 (25.11)	63.33 (52.78)
P. putida + *T. harzianum* (PDBCTH 10) @ 10 g/kg seed	3.00 (9.88)	11.66 (19.89)	53.33 (46.92)
P. putida (PDBCAB 19) @ 0.5kg/9 m^2	14.33 (22.11)	36.66 (37.22)	66.66 (54.78)
Pathogen Control	14.66 (22.50)	47.66 (43.65)	91.00 (72.56)
Carbendazim @ 2 g/kg seed	3.66 (11.02)	44.66 (41.94)	75.66 (60.590
CD (P=0.05)	3.74	4.55	7.04

*Figures in parentheses are angular transformations

Biological control of *F. udum* present at a higher average level of 5.34 cfu/g of soil proved difficult. At 30 days almost all the treatments were on par with each other except in case of fungicide treated plot which showed highest plant stand (96%) (Table 27). The combination of *P. putida* and *Trichoderma* gave slightly better control (91% plant stand). At 60 days *P. putida* seed treated or in combination with *Trichoderma* gave better disease control by showing 74-77% plant stand when compared to pathogen control (52%). After 90 days of sowing all the treatments including fungicide treatment proved ineffective in suppressing the disease.

The results indicated that at a higher pathogen level in the field, control of the pathogen by any means is difficult.

Table 27. Performance of antagonists against an average *Fusarium udum* level of log 5.34 cfu/gm of field soil

Treatments	Per cent diseased plants (days)*		
	30	60	90
P. putida (PDBCAB 19) @ 10 g/kg seed	11.66 (19.89)	26.66 (31.00)	70.00 (57.00)
P. putida (PDBCAB 19) @ 5 g/kg seed	15.00 (22.60)	40.00 (39.15)	80.00 (63.93)
P. putida + *T. harzianum* (PDBCTH 10) @ 10 g/kg seed	8.66 (17.10)	23.33 (28.78)	76.66 (61.22)
P. putida (PDBCAB 19) @ 0.5kg/9 m^2	15.00 (22.60)	38.33 (38.19)	86.66 (68.85)
Pathogen Control	15.66 (23.29)	48.33 (44.04)	92.66 (74.32)
Carbendazim @ 2 g/kg seed	4.00 (11.48)	45.00 (42.12)	87.33 (69.61)
CD (P=0.05)	5.45	7.11	9.16

*Figures in parentheses are angular transformations

4.12. Studies on entomophilic nematodes and nematophagous fungi/bacteria

4.12.1. Survey, isolation, identification and distribution of entomophilic nematodes

A total of 91 soil samples were collected from different crop habitats and agroclimatic zones covering three states and four positive samples obtained-one each from lemon, bhindi, coconut and rose (one *Steinernema* sp. and three *Heterorhabditis* spp.).

4.12.2. Bioefficacy of entomophilic nematode (EPN) isolates against insect pests

Steinernema glaseri, *S. carpocapsae* (PDBC EN 6.11 and PDBC EN 1.3), *S. bicornutum* (PDBC EN 3.1) and *H. indica* (PDBC EN 13.3) were tested against *S. litura*, *H. armigera*, *O. arenosella*, *P. xylostella* and *P. operculella* for evaluating bioefficacy by soil column assay. *S. bicornutum* (PDBC EN3.1) and *H. indica* (PDBC EN 13.3) consistently recorded highest mortality (80-100 %) against all insects tested. *S. glaseri, S. carpocapsae* (PDBC EN 6.11), *S. bicornutum* (PDBC EN 3.1) and *H. indica* (PDBCEN 13.3) proved efficient against *S. litura* (80 % mortality after 96 h). *S. bicornutum* (PDBC EN 3.1) and *H. indica* (PDBCEN 13.3) caused 100% mortality of *H. armigera* larvae 96 h post exposure. Against *O. arenosella, S. glaseri* and *S. carpocapsae* (PDBC EN 6.11) were very effective compared to other isolates (100% mortality). Bioefficacy of all the isolates tested against *P. operculella* and *P. xylostella* was on par with 80-100% mortality (Table 28).

4.12.3. Bioefficacy of EPN isolates against *Holotrichia* sp.

S. carpocapsae (PDBC EN 7.2, PDBC EN 6.11 and PDBC EN 1.3), *S. bicornutum* (PDBC EN 2.1 and PDBC EN 3.1), *S. glaseri* and *H. indica* (PDBC EN 13.3) were tested against grubs of *Holotrichia* sp. in the laboratory by soil column assay. Nematodes were inoculated @ 750 IJs /grub. Among *Steinernema* spp., only *S. glaseri* infected and successfully multiplied inside *Holotrichia* sp. Virulence of *H. indica* PDBC EN 13.3 and PDBC EN 6.71 was on par showing 77–88 % mortality of grubs 120 h after inoculation.

4.12.4. Progeny production of EPN isolates

Progeny production of *S. carpocapsae* (PDBC EN 7.2, PDBC EN 6.11 and PDBC EN 1.3), *S. glaseri, S. bicornutum* (PDBC EN 3.1) and *H. indica* (PDBC EN 13.3) was evaluated in *S. litura* and *H. armigera. S. bicornutum* (PDBC EN 3.1) and *H. indica* (PDBC EN 13.3) recorded maximum progeny production in both. Among *S. carpocapsae* isolates, PDBC EN 6.11 recorded higher yield in *S. litura. S. carpocapsae* PDBC EN 1.3 recorded maximum yield in *H. armigera.* Progeny production of *S. glaseri* did not show any difference between the hosts. *S. carpocapsae* PDBC EN 7.2 recorded the lowest yield in both insects. (Table 29).

Table 28. Bioefficacy of EPN isolates against different insect pests

Nematode isolate	Per cent mortality of last instar larvae (hours after inoculation)																			
	Spodoptera litura				*Helicoverpa armigera*				*Opisina arenosella*				*Phthorimaea operculell,*				*Plutella xylostella*			
	24	48	72	96	24	48	72	96	24	48	72	96	24	48	72	96	24	48	72	96
S. glaseri	0	20	60	80	0	40	60	60	20	20	100	-	20	40	80	80	20	80	100	-
S. carpocapsae (PDBC EN 6.11)	0	20	60	80	0	40	80	80	0	20	60	100	0	20	60	80	20	60	100	-
S. carpocapsae (PDBC EN 1.3)	0	0	40	60	0	20	60	80	0	20	60	80	0	0	40	60	0	40	60	80
S. bicornutum (PDBC EN 3.1)	0	40	60	80	0	40	80	100	20	40	80	80	20	60	80	100	60	100	-	-
H. indica (PDBCEN 13.3)	0	60	80	80	20	80	100	-	20	60	80	80	20	80	80	80	80	100	-	-

Table 29. Yield of IJs of EPN from *S.litura* and *H.armigera*

Nematode	Average yield of Ijs / larva (in lakhs) from	
	S. litura	*H. armigera*
S. glaseri	0.24	0.21
S .bicornutum PDBC EN 3.1	1.05	0.94
S. carpocapsae PDBC EN 7.2	0.16	0.28
S. carpocapsae PDBC EN 6.11	0.90	0.68
S. carpocapsae PDBC EN 1.3	0.48	0.45
H. indica PDBC EN 13.3	0.99	1.15

4.12.5. Quality assessment of EPN isolates by one-on-one bioassay

Different populations of nematodes *viz. S. bicornutum* (PDBC EN 3.1, PDBC EN 3.2, PDBC EN 2.1), *S. carpocapsae* (PDBC EN 1.3, PDBC EN 1.4, PDBC EN 6.11, PDBC EN 7.2, PDBC EN 13.1), *S. glaseri*, unidentified *Steinernema* spp. (PDBC EN 11.1, PDBC EN 13.21, PDBC EN 14.1), *H. indica* (PDBC EN 6.71 PDBC EN 13.3, PDBC EN 13.22) and unidentified *Heterorhabditis* sp. (PDBC EN 13.4 EN 13.6, PDBC EN 14.2) were tested for quality assessment by one on one bioassay. A 64-well tray was used as the experimental arena, one Ij of 20 different populations added to each well with a single last instar *G. mellonella* larva. After incubating the tray at ambient temperature for 48,72 and 96 h, mean per cent mortality of *G. mellonella* larvae recorded. Only *S. bicornutum* PDBC EN 3.1, PDBC EN 3.2 and *H. indica* PDBC EN 6.71 recorded 50% mortality after 48 h followed by *S. carpocapsae* PDBC EN 7.2, *Steinernema* sp. PDBC EN 14.1 and *Heterorhabditis* sp 14.2 with 25% mortality. Maximum mortality (62.5%) was observed with *S. bicornutum* PDBC EN 3.1 and PDBC EN 3.2 after 72 h.

4.12.6. *In vitro* production of EPN isolates

Different artificial media *viz.*, Wouts, soy flour + egg yolk, soy flour+cholestrol and dog biscuit+beef extract were tested for the mass production of *Steinernema* spp. and *H. indica*. The standard Wouts medium was suitable for all nematodes with an average yield of 30-32 lakhs/250 ml flask. *S. carpocapsae* isolates multiplied in all the media as compared to *S. bicornutum* and *H. indica* isolates. *S. carpocapsae* PDBC EN 1.3 and PDBC EN 1.4 recorded the highest yield (65.71 lakhs/250 ml flask) in soy flour + egg yolk medium followed by *S. glaseri* (65.35 lakhs) in dog biscuit + beef extract. *H. indica* multiplied only in Wouts and soy flour + cholesterol with higher yield (42.75 lakhs) in the latter (Table 30).

Table 30. Multiplication of nematode isolates on artificial media

Nematode isolate	Wouts	Soyflour + egg yolk	Soyflour + choles-terol	Dog biscuit + beef extract
S. carpocapsae PDBC EN 7.2	30.19	50.79	38.70	44.69
S. carpocapsae PDBC EN1.3	33.22	65.72	34.1	50.55
S. carpocapsae PDBC EN1.4	31.42	64.68	30.22	34.89
S. glaseri	18.47	43.76	22.62	55.65
H. indica PDBC EN13.3	35.85	Did not multiply	42.75	Did not multiply

4.12.7. Storage of EPN at ambient temperature

S. carpocapsae (PDBC EN1.3, PDBC EN 1.4), *S. bicornutum* (PDBC EN 3.1), *S. glaseri*, and *H. indica* (PDBC EN 13.3, PDBC EN 6.71) were evaluated for storage capacity at ambient temperature (28°C). Per cent survival of nematodes was recorded after 2, 4, 6 and 8 weeks of storage. All the isolates stored well at ambient temperature in distilled water during the period. Compared to *Heterorhabditis* sp., *Steinernema* spp. showed better storage capacity (Table 31). Least mortality on storage was observed with *S. carpocapsae* PDBC EN 1.3, PDBC EN 1.4 and *S. bicornutum* PDBC EN 3.1 and highest in *H. indica* PDBC EN 13.3 and PDBC EN 6.71.

Table 31. Survival of nematode isolates after storage at ambient temperature

Nematode isolate	Per cent survival of EPN (after weeks)			
	2	4	6	8
S. carpocapsae PDBC EN1.3	100	100	100	99.2
S. carpocapsae PDBC EN 1.4	100	100	99.2	99.6
S. glaseri	100	100	100	98.4
S. bicornutum PDBC EN 3.1	100	100	100	99.2
H .indica PDBC EN 13.3	100	100	98.8	98.0
H .indica PDBC EN 6.71	100	100	99.6	98.4

4.12.8. Formulations of EPN

S. carpocapsae PDBC EN 1.3, PDBC EN 7.2 and *H. indica* PDBC EN 13.3 formulated in wheat bran-vermiculite and talc @ 2 lakhs IJs/10 g of formulation were tested for viability under 15°C and room temperature. Shelf life was more for talc formulation irrespective of nematodes used, under both temperatures. The poor shelf life of wheat bran-vermiculite formulation was due to fungal infection. In talc formulation with liquid paraffin, nematodes survived up to 15-21 days in ambient temp. and 15°C. Nematodes in wheat bran-vermiculite survived for 7-10 days. The lower temperature enhanced the shelf life of both formulations.

4.12.9. Infectivity assay of different EPN isolates

Infectivity of talc formulated *S. carpocapsae* (PDBC EN 1.3, PDBC EN 7.2) and *H. indica* was tested against last instar *S. litura* and *H. armigera* larvae by soil column assay. Highest mortality (100%) of *S. litura* and *H. armigera* larvae was observed with *H. indica* PDBC EN 13.3 after 96 h exposure followed by 66-77 % mortality with *S. carpocapsae* PDBC EN 1.3 (Table 32). Per cent mortality of *S. litura* and *H. armigera* larvae increased as the time of exposure increased.

Table 32. Bioefficacy of talc formulated infective juveniles against *S. litura* and *H. armigera*

Nematode Isolate	Per cent mortality of larvae (hours)					
	Spodoptera litura			*Helicoverpa armigera*		
	48	72	96	48	72	96
S.carpocapsae PDBC EN 1.3	11.11	44.44	66.66	22.22	44.44	77.77
S.carpocapsae PDBC EN 7.2	0.0	11.11	44.44	11.11	33.33	55.55
H.indica PDBC EN 13.3	22.22	44.44	100.0	33.33	66.66	100.0

4.13. Nematophagous fungi against plant parasitic nematodes

4.13.1. Nematicidal effect of culture filtrate of *Pseudomonas fluorescens* against plant parasitic nematodes

The *in vitro* nematoxic effect of *P. fluorescens* against *M. incognita, Heterodera cajani* and *Rotylenchulus reniformis* was evaluated by recording mortality of juveniles at 12, 24 and 48 interval. The mortality of the juveniles started from 12 onwards and increased with time (Table 33). In distilled water there was no mortality of juveniles up to 48 h but in the Kings B broth, there was mortality after 24h and at 48 h (4.3 per cent in *M. incognita*; 4.6 per cent in *H. cajani* and 5 per cent in *R. reniformis*).

Table 33. Nematicidal effect of filtrate of *Pseudomonas fluorescens* against plant parasitic nematodes

Treatments	Per cent mortality of second stage juveniles		
	12h	24h	48h
Water alone + Mi	0.0	0.0	0.0
Water alone + Hc	0.0	0.0	0.0
Water alone + Rr	0.0	0.0	0.0
Broth + Mi	0.0	2.3 (8.7)	4.3 (12.0)
Broth + Hc	0.0	2.0 (7.9)	4.6 (12.4)
Broth + Rr	0.0	4.0 (11.4)	5.0 (12.8)
Filtrate + Mi	11.0 (19.3)	73.0 (58.7)	94.0 (75.8)
Filtrate + Hc	8.6 (17.0)	60.6 (51.1)	85.0 (67.2)
Filtrate + Rr	10.6 (19.1)	72.6 (58.4)	95.0 (77.1)
CD (P=0.05)	1.2	2.5	2.1

Mi- *Meloidogyne incognita;* Hc- *Heterodera cajani,* ; Rr- *Rotylenchulus reniformis*
Figures in parentheses are angular transformed values.

4.13.2. Efficacy of *Verticillium chlamydosporium* against *Meloidogyne incognita* on tomato

Considerable suppression of galls and egg masses was observed in *V. chlamydosporium* treated pots (Table 34). The degree of suppression of nematode by *V. chlamydosporium* varied with the substrates used. In *V. chlamydosporium* treated plants the number of galls ranged 41-78 galls/root and was 48-72 per cent less over nematode alone treatment. Among the treatments, fungus cultured on sorghum grain and applied at the rate of 10g/plant produced least galls (41 galls/ root) followed by fungus cultured on sorghum applied @ 5g/plant and the reduction was 73 and 71 per cent, respectively, over nematode alone treatment.

About 41 to 70 per cent reduction of egg masses was observed using *V. chlamydosporium* cultured on different substrates. Fungus cultured on all substrates parasitized the egg masses and eggs of *M. incognita* to the extent of 39 to 70 and 51 to 89 per cent, respectively. *V. chlamydosporium* cultured on sorghum grain applied @10g/plant as well as 5g/plant was superior to other substrates in terms of parasitization of egg masses and eggs.

Table 34. Effect of *V. chlamydosporium* cultured on different substrates on *M. incognita* reproduction on tomato

Treatments	Number of galls /g root*	Number of egg masses / g root*	Nematode population/ 200g soil*	Per cent parasitization *	
				Egg masses	Eggs
Sorghum 5g + Mi	44.0 (6.6)	35.0 (5.9)	215.0 (14.7)	63.6 (35.0)	69.6 (22.5)
Sorghum 10g + Mi	41.0 (6.4)	28.0 (5.3)	192.6(13.9)	70.0 (41.7)	89.3 (32.8)
Maize (broken) 5g + Mi	56.0 (7.5)	40.6 (6.4)	240.0(15.5)	50.6 (20.8)	63.3 (17.8)
Maize (broken) 10g + Mi	55.0 (7.4)	38.3 (6.2)	231.0(15.2)	51.6 (26.8)	65.3 (25.3)
Wheat bran 5g + Mi	61.0 (7.8)	43.6 (6.6)	236.6(15.4)	45.6 (18.1)	41.6 (14.6)
Wheat bran 10g + Mi	59.0 (7.7)	41.6 (6.5)	233.3(15.3)	47.0 (22.5)	62.6 (19.4)
Wheat (broken) 5g + Mi	50.0 (7.1)	34.3 (5.9)	216.6(14.7)	53.0 (32.6)	63.0 (19.0)
Wheat (broken) 10g+Mi	49.0 (7.0)	31.0 (5.6)	209.3(14.5)	56.0 (39.0)	71.6 (27.0)
Rice 5g + Mi	78.0 (8.8)	55.8 (7.4)	260.0(16.1)	39.0 (14.2)	51.3 (12.4)
Rice 10g +Mi	71.0 (8.4)	33.3 (7.3)	260.0(16.1)	41.0 (16.0)	53.6 (17.6)
Mi alone	151.0(12.3)	95.0 (9.8)	420.0(20.5)	-	-
Control	0.0	0.0	0.0	-	-
CD (P=0.05)	0.3	0.2	0.8	2.3	2.6

Mi = Meloidogyne incognita; * Figures in parantheses are √ transformed values
** Figures in parentheses are Arc sine transformed values.

A significant increase in growth of tomato plants was observed in *V. chlamydosporium* treated pots. Among the treatments, fungus cultured on sorghum grain and applied @ 10g/plant recorded significantly greater plant height (34.1cm), root length (31.6 cm) and root weight (18.8g).

Generally *V. chlamydosporium* applied @ 10g/plant was better than application of 5g/plant in terms of nematode control, parasitization and rhizosphere colonization of the fungus. Final CFU and rhizosphere colonization of fungus revealed that all the substrates supported the establishment of *V. chlamydosporium* in soil and tomato root system, respectively (Table 35). Sorghum and wheat grain were superior substrates for *V. chlamydosporium* fungal colonization.

Table 35. Evaluation of substrates for growth of *V. chlamydosporium* and their effect on growth of tomato and CFU of the fungus

Treatments	Plant height (cm)	Root length (cm)	Root weight (g)	Final CFU of the fungus (harvesting)*	Fungal rhizosphere colonization (CFU x 10^4)*
Sorghum 5g + Mi	31.6	29.2	17.4	33.0 (5.7)	14.6 (3.8)
Sorghum 10g + Mi	34.1	31.6	18.7	44.3 (6.7)	29.3 (5.4)
Maize (broken) 5g + Mi	29.6	24.9	16.1	12.6 (3.6)	9.3 (3.1)
Maize (broken)10g + Mi	31.5	25.0	16.6	20.3 (4.5)	18.6 (4.3)
Wheat bran 5g + Mi	29.2	22.0	17.0	9.6 (3.1)	6.3 (2.5)
Wheat bran 10g + Mi	30.0	22.4	17.0	14.6 (3.8)	11.0 (3.3)
Wheat (broken) 5g + Mi	31.8	28.6	17.7	29.0 (5.4)	10.6 (3.3)
Wheat (broken) 10g+Mi	33.6	29.5	18.0	40.3 (6.4)	20.6 (4.5)
Rice 5g + Mi	21.1	18.8	14.7	6.0 (2.4)	4.6 (2.1)
Rice 10g +Mi	22.3	19.1	15.7	7.6 (2.8)	9.3 (3.1)
Mi alone	18.9	17.3	7.8	-	-
Uninoculated control	35.8	33.3	21.2	-	-
CD at 5 %	1.5	1.4	0.8	0.3	(0.4)

Mi = Meloidogyne incognita; * Figures in parentheses are √ transformed values

4.13.3. Effective dosages of *Verticillium chlamydosporium* against *Meloidogyne incognita* on tomato

The effective dosage of *V. chlamydosporium* to control *M. incognita* was investigated through a pot culture experiment. The fungus was multiplied on sorghum grain to get 11 x 10^5 chlamydospores/g of sorghum. Four dosages *viz.*, 5, 10, 15 and 20 g were tested. Increase in plant height was observed by application of *V. chlamydosporium*. Maximum plant height was recorded in uninoculated control followed by fungus applied @ 10g/plant and 15g/plant (Table 36). Application of fungus at higher dose (20g/plant) did not show any significant difference for plant height. There was an increase in root weight observed by increasing the dosage level. Among the dosages, 20g/plant recorded maximum root weight (19.0g) followed by 15g/plant (18.6g).

Among the dosages tested, fungus applied @ 15 and 20g/plant recorded least nematode population (220) followed by fungus applied @ 10g/plant and all the three were statistically on par. The same trend was observed in galls and egg masses/g root. With increase in dosage there was an increase in parasitization of eggs.

Table 36. Effective dosage of *Verticillium chlamydosporium* against *M. incognita* on tomato

Treatments	Plant height (cm)	Root weight (g)	Nematode population 200 g soil*	Galls/g root*	Egg masses/g root*	Per cent parasitization of eggs**
Uninoculated Control	33.9	19.3	0.0 (0.71)	0.0 (0.71)	0.0 (0.71)	0.0
Mi – alone	18.3	8.1	315.0 (19.70)	141.3 (11.90)	82.8 (9.10)	0.0
Fungus 5 g + Mi	31.8	15.8	257.5 (16.10)	60.0 (7.77)	43.8 (6.70)	59.8 (50.6)
Fungus 10 g + Mi	33.8	17.8	300.0 (15.00)	45.7 (6.80)	35.6 (6.00)	67.5 (55.2)
Fungus 15 g + Mi	33.8	18.6	220.0 (14.80)	42.5 (6.60)	34.5 (5.90)	68.3 (55.7)
Fungus 20 g + Mi	33.4	19.0	220.0 (14.80)	40.5 (6.40)	34.8 (5.90)	70.5 (57.1)
CD (P=0.05)	1.4	0.9	0.5	0.5	0.3	1.3

Mi- *Meloidogyne incognita;* *Figures in parentheses are √ transformed values;
** Figures in parentheses are Arcsine transformed values

4.13.4. Combined efficacy of *Pseudomonas fluorescens* and *Pasteuria penetrans* against *Meloidogyne incognita* on tomato

Combined efficacy of *Pseudomonas fluorescens* (Pf) and *Pasteuria penetrans* (Pp) against *M. incognita* was evaluated under potted condition with tomato. *P. penetrans* was multiplied in tomato roots and the spore load/g root powder was 1.9 x 10^6. The pots were mixed with *P. penetrans* @ 10^4 spores/pot. *P. fluorescens* was cultured in Kings B agar. The experiment was terminated 70 days after nematode inoculation. There was an increase in growth parameters recorded with individual and combined inoculation of the bacterial agents. Least number of galls/g of root (48.5) was recorded in combined inoculation than individual inoculation (Table 37). The same trend was observed in egg masses/g root. *P.fluorescens* or *P.penetrans* didn't inhibit or enhance each other in terms of growth and multiplication. Least nematode population was observed with combined inoculation than the individual inoculations of the bacterial agents.

Table 37. Combined efficacy of *Pseudomonas fluorescens* and *Pasteuria penetrans* against *M. incognita* on tomato

Treatments	Plant height (cm)	Root weight (g)	Galls/g root	Egg masses/ root	Pasteuria parasitiz- ation(%)	Bacterial coloniz- ation (CFUx1 10^8)	Nematode population 200 g of soil
Un-inoculated control	34.2	17.8	0.0 (0.7)	0.0 (0.7)	0.0	0.0	0.0 (0.7)
Mi alone	18.7	8.3	142.7(11.9)	88.7 (9.4)	0.0	0.0	420.6(20.5)
Pf + Mi	32.5	13.7	64.0 (8.0)	37.5 (6.1)	0.0	26.3	172.5(13.1)
Pp + Mi	28.5	12.7	67.2 (8.2)	33.0 (5.2)	66.5	0.0	122.5(11.0)
Pf + Pp + Mi	33.9	15.3	48.5 (7.0)	17.0 (4.1)	65.75	26.2	102.5(10.2)
CD (P=0.05)	1.6	1.1	0.3	0.6	4.2	0.2	0.5

Mi-*Meloidogyne incognita;* Pf- *Pseudomonas fluorescens;* Pp-*Pasteuria penetrans*
Figures in parentheses are √ transformed values.

4.13.5. Efficacy of *Fusarium oxysporum* against *Meloidogyne incognita* on tomato

Efficacy of *F. oxysporum* (isolated from eggs of *M. incognita* and found effective against *M. incognita* under laboratory condition) was evaluated under potted condition against *M. incognita* on tomato. The fungus was cultured on PDA medium for 10 days and harvested along with the medium, macerated with sterile waster and mixed with one kg soil and CFU of the fungus/g soil was found to be 6x10^3. Juveniles were inoculated @ 1000/seedling.

Observations on the growth parameters and nematode reproduction were recorded after 70 days. Maximum plant height was recorded in uninoculated control plants (35.1 cm) followed by fungus isolate1 (34.4 cm) and fungus isolate 2 (34.8 cm) and all the three were on par with each other. There was an increase in plant height and root weight with the application of *F. oxysporum* (Table 38).

Considerable reduction of galls and egg masses was recorded with inoculation of *F. oxysporum*. Fungal isolate 1 was more effective than isolate 2. Less nematode population was recorded with isolate1 (232.5 /200 g soil) than isolate 2 (240.0 /200 g soil) but both were on par. About 65.7 per cent parasitization of egg masses and 68.5 per cent parasitization of eggs were recorded with *F. oxysporum* isolate1.

Table 38. Efficacy of *Fusarium oxysporium* against *M. incognita* on tomato

Treatment	Plant height (cm)	Root weight (g)	Number of galls/ g root	Egg masses/ root	Nematode population 200 g soil	Parasi-tization of eggs masses (%)	Parasi-tization of eggs (%)
Control	35.1	19.8	0.0 (0.7)	0.0 (0.7)	0.0 (0.7)	0.0	0.0
Fungus isloate 1 alone	34.7	18.6	0.0 (0.7)	0.0 (0.7)	0.0 (0.7)	0.0	0.0
Fungus isolate 2 alone	34.8	18.2	0.0 (0.7)	0.0 (0.7)	0.0 (0.7)	0.0	0.0
Mi alone	18.8	8.8	147.2 (12.1)	83.7 (9.1)	382.5 (19.5)	0.0	0.0
Fungus isolate 1 + Mi	27.5	16.8	73.0 (8.5)	49.5 (7.1)	232.5 (15.2)	65.7	68.5
Fungus isolate 2 + Mi	26.4	15.8	89.5 (9.4)	52.0 (7.2)	240.0 (15.5)	60.0	61.7
CD (P=0.5)	2.3	1.1	0.4	0.3	0.4	5.5	2.1

Figures in parentheses are $\sqrt{}$ transformed values.

4.13.6. Efficacy of *Verticillium chlamydosporium* cultured on different substrates against *Rotylenchulus reniformis* on sunflower

Considerable suppression of egg masses of *R. reniformis* was observed in *V. chlamydosporium* treated pots. All the substrates favoured the multiplication of *V. chlamydosporium*. The degree of suppression varied with the substrate. Least number of females (64.3) was recorded in sorghum applied @ 10g/pot. The fungus cultured on sorghum grain and applied at the rate of 10g/plant recorded least egg masses (22.6 egg masses/g root) followed by that on broken wheat grain and applied @ 10g/plant (41.0 egg masses/g root). Nematode population in soil was lowest when *V. chlamydosporium* cultured on sorghum was applied @10g/plant (433.3 nematodes/100g soil) followed by fungus cultured on broken wheat grain and applied @ 10g/plant (510.0 nematodes/100g soil) (Table 39). Fungus cultured on all the substrates parasitized the eggs of *R. reniformis* to the extent of 35.6 to 72.6 per cent.

A significant increase in growth of sunflower was observed in *V. chlamydosporium* treated pots when compared to nematode alone treatment. Fungus cultured on sorghum grain and applied @ 10g/plant recorded significantly greater plant height (71.0 cm) and was on par with uninoculated control.

Table 39. Efficacy of *Verticillium chlamydosporium* cultured on various substrates against *Rotylenchulus reniformis* on sunflower

Treatment	Plant height (cm)	Number of females/*	Egg masses /root*	Nematodes/ 100 g soil*	Per cent parasitization of eggs*
Sorghum 5 g +Mi	64.7	72 (8.5)	49.3 (7.1)	653.3 (25.5)	63.0 (52.5)
Sorghum 10 g +Mi	71.0	64.3 (8.0)	22.6 (5.7)	433.3 (20.8)	72.6 (58.4)
Maize 5 g +Mi	60.0	95.3 (9.7)	63.6 (8.0)	716.6 (26.7)	55.0 (47.8)
Maize 10 g +Mi	61.3	98.3 (9.9)	61.0 (7.8)	690.0 (26.2)	52.0 (46.1)
Wheat bran 5 g +Mi	60.0	84.3 (9.2)	73.3 (8.5)	760.0 (27.5)	44.0 (41.5)
Wheat bran 10 g +Mi	59.3	120.0(10.9)	66.6 (8.2)	756.6 (27.5)	49.3 (44.6)
Wheat grain 5 g +Mi	64.0	72.6 (8.5)	44.0 (6.6)	653.3 (25.5)	59.3 (50.3)
Wheat grain 10 g Mi	69.3	74.0 (8.2)	41.0 (6.6)	510.0 (22.5)	65.6 (54.1)
Rice 5 g +Mi	57.3	108.0(10.4)	75.0 (8.6)	950.0 (30.8)	53.6 (35.4)
Rice 10 g +Mi	60.0	100.0 (9.8)	71.0 (8.4)	860.0 (29.3)	35.6 (36.6)
Nematode alone	57.3	163.3(12.7)	98.3 (9.9)	1616.6 (40.2)	0.0 (0.7)
Uninoculated control	72.3	0.0 (0.7)	0.0 (0.7)	0.0 (0.7)	0.0 (0.7)
CD (P=0.05)	2.9	0.8	0.3	0.7	3.1

Mi-*Meloidogyne incognita;* *Figures in parentheses are √ transformed values;

** Figures in parentheses are Arcsine transformed values

4.14. Survey, identification and utilization of plant pathogens for the biological control of weeds

4.14.1. Studies on *Fusarium pallidoroseum*, a potential mycoherbicide for parthenium

Based on the investigations carried out during 1996-1999 the identified isolate WF(Ph)30 of *Fusarium pallidoroseum* (Cooke) Sacc. (=*F. semitectum* Auct.), a leaf-spotting pathogen, was taken up for in-depth studies and the development of a mycoherbicide.

4.14.1.1. Culture and propagation of the pathogen

A single-spore isolate of *F. pallidoroseum* was propagated on potato dextrose agar (PDA) so as to get a constant supply of the same for different experiments. Stock cultures were stored at 4-5°C either on PDA (freshly prepared or proprietary) slants, 1/2 PDA, 1/5 PDA or potato carrot agar (PCA) and in some cases in potato dextrose broth (PDB).

4.14.1.2. Susceptibility of different parthenium populations to *Fusarium pallidoroseum*

The susceptibility of many parthenium populations from different districts in Karnataka as well as from across the country was determined. Seed samples collected since 1997 in Bangalore Urban (Hebbal, Bangalore City), Bangalore Rural (Hoskote), Mandya, Mysore, Hassan, Tumkur, Kolar, Chitradurga, Chikmagalur, Shimoga, Davangere, Bellary, Dharwad, Raichur, Gulbarga and Bidar districts of Karnataka were cleaned and stored in the dark until further use. Similarly, parthenium seeds obtained from Tamil Nadu, Andhra Pradesh, Maharashtra, Punjab, Gujarat and Delhi, were also processed and used for the studies.

Seedlings were raised in pots. *F. pallidoroseum* (10^8 conidia/mL) was inoculated onto the plants and the reaction, based on presence or absence of typical lesions, was assessed on a minimum of 10 plants for each sample.

All the parthenium populations from all over Karnataka were found susceptible to the isolate WF(Ph)30 (Fig.14). Total susceptibility (100%) was observed in the case of samples brought from Bangalore Urban (Hebbal, Bangalore City), Mandya, Mysore, Hassan, Tumkur and Bellary districts. The minimum susceptibility (80%) was recorded with the populations collected in Kolar, Chikmagalur, Dharwad and Raichur. However, the overall mean susceptibility was as high as 91.10%, indicating that there are not many resistant populations of parthenium.

All the parthenium biotypes from six different states were found to be susceptible to *F. pallidoroseum* (Fig.15). Hundred per cent susceptibility was recorded in the biotypes

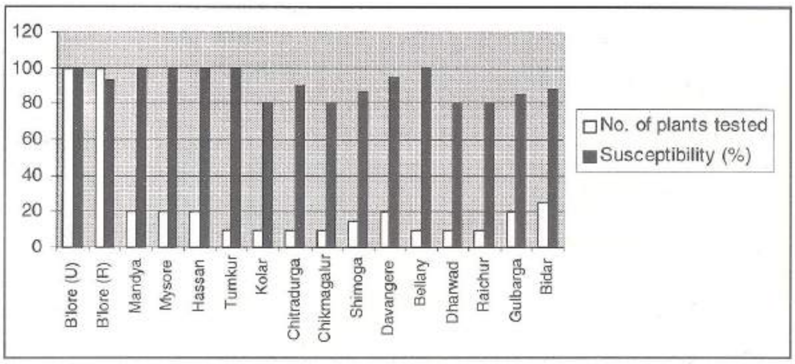


Fig. 14 Susceptibility of parthenium populations from various districts of Karnataka to *F. pallidoroseum*

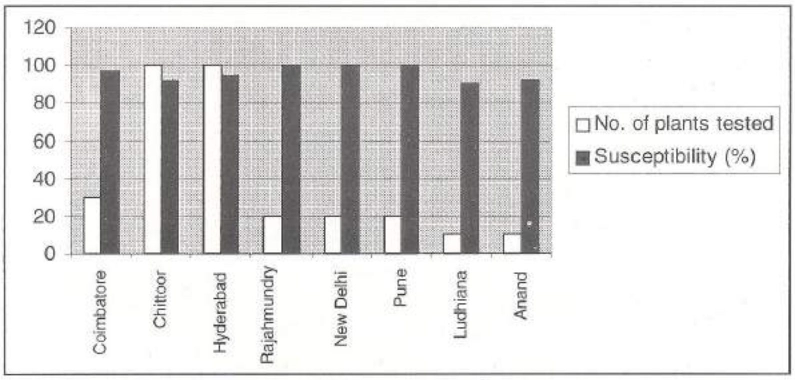


Fig. 15 Susceptibility of parthenium populations from various places in India to *F. pallidoroseum*

from Rajahmundry (Andhra Pradesh), New Delhi and Pune (Maharashtra). The least susceptible (90%) sample was from Ludhiana (Punjab). Overall, more than 90 per cent susceptibility was observed, indicating the suitability of the pathogen as a candidate for parthenium control across the country.

4.14.1.3. Effect of surfactants on the pathogenicity of *F. pallidoroseum* to parthenium

To evaluate the effect on the infection process and assess the pathogenicity of *F. pallidoroseum* some common surfactants, *viz*., Tween 20, Tween 80, glycerol and Triton X-100 were tried. Conidial inoculum was prepared by suspending a mixture of macro and microconidia (10^8/mL) as mentioned earlier and each surfactant was added at the rate of 1 mL/L separately. The inoculum without a surfactant served as control. Parthenium plants of 5-7 leaf stage were inoculated and maintained under ambient conditions. After two weeks of inoculation, the leaves of each plant sprayed with the fungus were counted and visually rated individually for disease symptoms using a 0-6 scale suggested by Pfirter and Defago (1998) (0 = no disease; 1 = 0-5%; 2 = 6-25%; 3 = 26-75%; 5 = >95% of leaf surface with necrosis; 6 = leaf dead). The total necrotic leaf area was obtained 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 a rating x and N is the total number of leaves treated.

Significant differences were evident among all the four surfactants in terms of pathogenicity of *F. pallidoroseum* (Table 40). A huge difference in disease production was observed with the addition of a surfactant to the inoculum, the control plants showing only 50.41% disease. The best was Tween 80, which caused a necrotic leaf area of 90.57% followed by Tween 20 (89.93%). The least effective surfactant was Triton X-100 with a necrotic leaf area of 60.96%. Overall, the addition of surfactants resulted in better pathogenicity of the fungus.

Table 40. Effect of certain surfactants on the pathogenicity of *F. pallidoroseum* to parthenium

Surfactant	Necrotic leaf area (%)
Tween 20	89.93 (70.94)
Tween 80	90.57 (72.12)
Glycerol	71.73 (57.88)
Triton X-100	60.96 (51.33)
Control (sterile water)	50.41 (45.23)
CD (P=0.05)	0.88

Figures in parentheses are angular-transformed values

4.14.1.4. Effect of hydrophilic substances on the pathogenicity of *F. pallidoroseum* to parthenium

The utility of some hydrophilic substances in promoting leaf wetness and thereby increasing the pathogenicity of *F. pallidoroseum* to parthenium was examined. Conidial inoculum was prepared as mentioned earlier and each hydrophilic substance was added in such a way that the final concentration of the substance was 0.5%. The inoculum without any hydrophilic substance served as control. Parthenium plants of 5-7 leaf stage were inoculated and allowed to develop disease under ambient conditions. After 2 weeks of inoculation, the leaves of each plant sprayed with the fungus were counted, visually rated individually for disease symptoms and the total necrotic leaf area was obtained.

The performance of *F. pallidoroseum* was observed to be affected because of the presence of hydrophilic substances in the inoculum (Table 41). The best treatment was gum arabic, which produced the maximum necrotic leaf area of 94.63%. Sodium alginate (90.00%) came close to gum arabic in increasing the pathogenicity of the fungus. It is clear that addition of a hydrophilic substance to the inoculum enhances the disease causing ability of the pathogen.

Table 41. Effect of certain hydrophilic substances on the pathogenicity of *F. pallidoroseum* to parthenium

Hydrophilic substance	Necrotic leaf area (%)
Gum arabic	94.63 (76.61)
Polyacrylamide	62.89 (52.47)
Carboxy methyl cellulose	70.75 (57.26)
Sodium alginate	90.00 (71.56)
Control (sterile water)	51.67 (45.96)
CD (P=0.05)	0.88

Figures in parentheses are angular-transformed values

4.14.1.5. Additional host-range screening

A specialized host range screening was undertaken especially to give more emphasis to the internationally accepted centrifugal phylogenetic system. Sunflower was taken up for intensive investigation because of its close taxonomic relationship with parthenium. A total of 21 cultivars/accessions (ARM 238, ARM 242, ARM 243, ARM 245, ARM 246, ARM 248, ARM 249, PCSH 243, PCSH 245, MSFH 8, MSFH 17, SFL 103, SFL 107, PAC 36, DSH 1, DRGP 1, KBSH 1, Jwalamukhi, Sungene 85, 6D-1R and Morden) were taken up for the screening. All the plants were grown in pots on a mixture of soil and farmyard manure. Two methods of screening viz., the detached leaf technique (*in vitro*) and *in vivo* method consisting of intact plants were employed. Two concentrations (1×10^8 and 5×10^8 conidia/mL) of *F. pallidoroseum* were tested and the suspension was evenly brushed on both surfaces of the leaves. Observations were taken every day for any visible signs of infection for up to a week. In the second method, intact healthy plants were sprayed with the conidial suspension and covered with polythene bags to maintain a high humidity for 48 h.

No sunflower cultivar/accession was found to react positively to *F. pallidoroseum,* even after keeping the inoculated plants for double the period that was followed for the control parthenium plants. This special host-range testing concentrating only on sunflower indicated that the results obtained in the preliminary assessment of a few sunflower cultivars were enough to show the immunity of sunflower to *F. pallidoroseum.* The specificity of the isolate WF(Ph)30 has been proved to be sufficient for its use as a mycoherbicide for parthenium under varied field conditions.

4.14.2. Pathogens of water hyacinth and their evaluation

Surveys and isolation and purification procedures were continued to record new and already known pathogens of water hyacinth. Individual water hyacinth plants were placed in plastic pots (5" diameter) and inoculun of either spore (1×10^6 spores/mL) or mycelial inoculum (20% w/v) on the pathogenicity of the isolated fungi applied to the laminae until runoff occurred. Control plants were sprayed only with sterile water. All the plants were covered with clear polythene bags for 48 h to maintain a high relative humidity. Several *Fusarium* spp., *Alternaria* spp., *Lasiodiplodia theobromae*, and *Rhizoctonia* sp. were found to be the causative agents of the leaf spots and blights on water hyacinth (Table 42). All the fungi could reproduce the symptoms on detached as well as intact leaves of the host.

Table 42. New pathogenic mycobiota recorded on water hyacinth

Lake	Fungal species	Plant part affected	Symptoms
Yelahanka	*Lasiodiplodia theobromae* Pat., *Alternaria* spp., *Fusarium* spp., *Cercospora* sp.	Lamina	Leaf spot/blight
Hebbal	*Alternaria* spp.	Lamina	Leaf spot/blight
Nagawara	*Rhizoctonia* sp. *Lasiodiplodia theobromae* Pat.	Lamina	Leaf blight
Channapatna	*Alternaria* sp., *Fusarium* spp.	Lamina	Leaf blight
Doddabommasandra	*Alternaria* sp., *Fusarium* spp.	Lamina	Leaf spot
Jakkur	*Alternaria* sp., *Fusarium* spp.	Lamina	Leaf spot

4.15. Cultures of host insects/parasitoids/predators/nematodes/antagonists/ pathogens

4.15.1. Host cultures

Cultures of *Corcyra cephalonica, Spodoptera litura, Phthorimaea operculella, Opisina arenosella, Chilo partellus, Agrotis ipsilon, Sesamia inferens, Helicoverpa armigera, Mythimna separata, Achoea janata, Sesamia inferens, Plutella xylostella, Aphis craccivora, Ferrisia virgata, Maconelicoccus hirsutus, Planococcus citri, P. lilacinus* and *Hemiberlesia lataniae*, are being maintained on natural food or artificial diet.

4.15.2. Parasitoids

Campoletis chlorideae, *Eriborus argenteopilosus*, *Copidosoma koehleri*, *Telenomus remus*, *Leptomastix dactylopii*, *Chelonus blackburni*, *Cotesia flavipes*, *C. plutellae*, *Goniozus nephantidis*, *Brachymeria nephantidis*, *B. nosatoi*, *Adelencyrtus mayurai*, *Coccidoxenoides peregrinus* and eleven species of *Trichogramma* and its different strains were maintained.

4.15.3. Predators

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

4.15.4. Insects pathogens

Nuclear polyhedrosis viruses of *H. armigera* and *S. litura* and granulosis virus of *P. xylostella* are being maintained on their host insects.

Antagonistic fungi maintained (with number of isolates in parantheses) are *Trichoderma harzianum* (49), *T. viride* (32), *T. hamatum* (6), *T. virens* (19), *T. koningi* (12), *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 putida* (1), *Pseudomonas* spp. (4), *Alcaligenes odorans* (1), *Bacillus pantotheticus* (1) and *Bacillus subtilis* (2).

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

The nematophagous fungi / bacteria maintained are *Arthobotrys cladodes* var. *macroides*, *A. oligospora*, *Dactylella brochopaga*, *Exophiala pisiphila*, *Fusarium oxysporum* (4 isolates), *F. sporotrichoides*, *Gliocladium deliquescens*, *G. virens* (6 isolates), *Paecilomyces lilacinus* (5 isolates), *Phoma glomerata*, *Trichoderma harzianum*, *T. viride*, *T. koningii*, *T. pseudokoningii*, *Verticillium chlamydosporium*, *V. lecanii*, *V. suchlosporium*, Bacteria *Pasteuria penetrans* (5 isolates) and *Pseudomonas fluorescens* (3 isolates).

An isolate of parthenium leaf spot disease WF(Ph)30 of *Fusarium pallidoroseum* (Cooke) Sac. (=*F. semitectum* Auct.) is maintained for detailed studies as a candidate to control the weed.

4.16. Shipments of host insects and natural enemies

During the reporting period, 83 cultures of various host insects and 115 cultures of natural enemies were sent to coordinating centres and other research organizations as nucleus cultures to facilitate their multiplication and establishment.

4.17. Software development for identifying and suggesting biological control measures for different crop-pests using a PC

A software "PDBC INFOBASE" was developed based on detailed information collected from private companies, 27 pest management centers, 10 Agricultural Universities, 7 ICAR Institutes and 4 Breeding Laboratories (128 in all).

Different institutes and companies produced twentyseven parasitoids. *Trichogramma chilonis* was produced by maximum number of institutes and companies (12) followed by *T. japonicum* (11), *T. brasiliense* (6), *T. achaeae* (5) and *Chelonus blackburni* (4). Eleven predators were produced by different institutes and companies. *Cryptolaemus montrouzieri* was produced by 8 institutes and companies followed by *Chrysoperla carnea* (4). Antagonist *Trichoderma viride* was produced by 14 institutes and companies. Six institutes and companies produced bacterial formulations. Entomopathogenic fungi were produced by 4 institutes and companies. Entomopathogenic nematodes also were produced by 4 institutes and companies. Viral formulation *Ha*NPV was produced by 21 institutes and companies, *Sl*NPV was produced by 16 institutes and companies. GV was produced by only TNAU.

The data base provides information on bioagent producers in India, their addresses and the bioagents they produce. Crop-wise, pest-wise and bioagent-wise grouping of bioagent producers is available to enable easy searching, both in quick mode and detailed mode.

4.17.1. Knowledge base system of *Helicoverpa armigera* and its natural enemies

A database is being created on *H. armigera*, its host plants, distribution and its natural enemies. A prediction model to forecast the pest is being constructed.

4.18 Biological suppression of sugarcane pests

4.18.1 Survey for seasonal fluctuation studies on natural enemies of sugarcane borers (PAU, Ludhiana and SBI, Coimbatore)

The survey and seasonal fluctuation studies on natural enemies of sugarcane borers were carried out at two locations - Pragpur and Sofipind (Jalandhar) and at Behram (Nawanshahr). The survey was carried out at weekly interval during April 1999 to March 2000. 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. The mean total parasitization of various stages of sugarcane borers by different parasitoids is presented in Table 63.

Pupal parasitism was very low in nature and only 8.6 per cent pupae of *A. steniellus* were parasitized. *T. chilonis* was recovered from eggs of all the four borers, while *T. dignoides* and *T. japonicum* was recovered from *S. excerptalis*. *G. nicevillei* was recorded from all the borers, while *C. flavipes* was observed on all the borers except top borer. *S. inferens* was found in case of early shoot borer and stalk borer.

Shoot borer was active at Coimbatore throughout the observation period, i.e. June 1999 - March 2000, with peaks during July (11.2%) and November (16.8%), 1999. *Sturmiopsis inferens* was also active almost throughout this period, except in August and October 1999, with peaks in September 1999 (8.3%) and March 2000 (16.7%). The braconid *Cotesia flavipes* was active only during November 1999. The incidence of granulosis virus (GV) was generally higher than that of parasitoids throughout the observation period.

Shoot borer activity was not related to any of the five density independent factors (Table 64). However, the activity of *S. inferens* was positively related to maximum temperature and negatively related to afternoon RH. While *C. flavipes* and GV were not related to weather factors, fungi were negatively related to minimum temperature.

Density dependent relationships amongst shoot borer and natural enemies (Table 65) showed that the activity of GV was positively related to that of the borer while the other natural enemies did not show any relationship with the borer.

Table 63. Parasitoid complex of sugarcane bores in nature in Punjab during 1999-2000

Pest	Stage	Number collected and reared		Parasitoid	Per cent parasitism	
		Jalandhar	Nawanshahr		Jalandhar	Nawanshahr
Chilo infuscatellus	Egg mass	-	38	*Trichogramma chilonis*	-	7.8
				T. chilotraeae	-	10.5
				Total	-	**18.3**
	Larva	-	215	*Cotesia flavipes*	-	7.9
				Sturmiopsis inferens	-	9.8
				Glyptomorpha nicevillei	-	5.1
				Bracon sp.	-	4.2
				Total		**27.0**
	Pupa	-	27	-	-	-
Chilo auricilius	Egg mass	-	15	*T. chilonis*	-	6.7
				Total	-	**6.7**
	Larva	211	217	*C. flavipes*	2.3	12.3
				S. inferens	11.3	16.3
				G. nicevillei	2.1	11.9
				Campyloneurus mutator	0.8	2.6
				Total	**14.6**	**43.1**
	Pupa	124	138	-	-	-
Scirpophaga excerptalis	Egg mass	27	152	*Telenomus dignoides*	41.1	37.5
				T. chilonis	0.3	3.9
				T. japonicum	0	7.9
				Total	**41.4**	**49.3**
	Larva	312	325	*G. nicevillei*	2.1	14.8
				Isotima javensis	0.1	11.4
				Rhaconotus scirpophagae	0	13.5
				Topobracon sp.	0	1.5
				Total	**2.2**	**41.2**
	Pupa	-	35	-	-	-
Acigona steniellus	Egg mass	-	7	-	-	-
	Larva	-	88	*Cotesia flavipes*	-	11.9
				G. nicevillei	-	4.8
				Total	-	**16.7**
	Pupa	-	36	*Tetrastichus* sp.	-	5.7
				Xanthopimpla stemmator	-	2.9
				Total	-	**8.6**

Table 64. Correlation matrix for shoot borer and natural enemy incidence *vs* weather parameters at Coimbatore

Factor	Minimum temperature	Maximum temperature	Relative humidity		Total Rainfall
			Forenoon	Afternoon	
Shoot borer (%)	0.118	-0.038	-0.135	0.029	-0.017
S. inferens	-0.203	0.574*	-0.089	-0.615*	-0.346
C. flavipes	-0.063	-0.399	0.353	0.248	0.437
GV	0.256	0.057	-0.431	-0.086	-0.219
Fungi	-0.493*	-0.320	0.420	0.128	-0.069
* P < 0.05					

Table 65. Correlation matrix for shoot borer and natural enemy incidence at Coimbatore

Factor	Shoot borer (%)	*S. inferens*	*C. flavipes*	GV	Fungi
Shoot borer (%)	-	-0.029	0.030	0.619*	0.119
S. inferens		-	0.198	0.090	0.073
C. flavipes				-0.182	0.136
GV					-0.025
Fungi					-
* P < 0.05					

4.18.2. Field studies on *Trichogramma chilonis* against borers of sugarcane (PAU, Ludhiana)

4.18.2.1. *Chilo infuscatellus*

The experiment was carried out in a farmer's field at Chak Hakim (Kapurthala). *T. chilonis* was released 9 times at 10 days interval during April-June @ 50,000/ha. The plot size was one ha for release and 0.4 ha for control. The incidence of the early shoot borer was recorded on the basis of 100 canes from five spots in the plot during July. The results of the study are presented in Table 66 and showed that there was a 57.2% reduction in damage in released plots as compared to control.

Table 66. Evaluation of *Trichogramma chilonis* for the control of *Chilo infuscatellus*

Treatment	Incidence of *C. infuscatellus* (%)	Reduction in damage over control (%)
Release	6.60	57.2
Control	15.4	-

*Nine releases of *T. chilonis* @ 50,000 per ha at 10 days interval during April-June.

4.18.2.2. *Chilo auricilius*

The experiment was carried out at a farmer's field at Chak Hakim (Kapurthala) and Regional Research Station Kheri (Sangrur). Twelve releases were made at 10 days interval during July-October @ 50,000/ha. The incidence of stalk borer was recorded on the basis of 100 canes per plot during November. The incidence of the stalk borer was 8.6 and 3.0 per cent in released fields as compared to 18.4 and 14.0 per cent in control plots at Chak Hakim and Kheri, respectively. The mean incidence was 5.8 per cent in release fields as compared to 16.2 in control and resulted in 64.2 per cent reduction in the incidence.

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

The experiment for the evaluation of *T. japonicum* was carried out on variety COJ 64 at Sugarcane Research Station, Jalandhar. Six releases of *T. japonicum* were made at 10 days interval during July-August and a field without release was kept as control. The incidence of top borer was recorded during November on the basis of 100 canes in each plot. The incidence of top borer was 7.1 per cent in release field as compared to 13.5 per cent in control, which resulted in 49.2 per cent reduction in damage.

4.18.4. Demonstration of *Trichogramma chilonis* for the control of *Chilo auricilius* (PAU, Ludhiana)

To demonstrate the efficacy of *T. chilonis* for the control of stalk borer, *C. auricilius*, two locations, namely Behram (District: Nawanshahr) and Khudi Kalan (District: Sangrur) were selected. The plot size was 5 ha at Behram and 16 h at Khudi Kalan. The egg parasitoid, *T. chilonis* was released @ 50,000 per ha at 10 days interval during July to October. The incidence of stalk borer was recorded during November on the basis of 100 canes each from 5 spots in each plot. The results of the study showed considerable reduction in damage in released plots (Table 67).

Table 67. Demonstration of *T. chilonis* for the control of *Chilo auricilius*

Treatment	Per cent incidence of stalk borer			Reduction
	Behram (Nawanshahr)	Khudi Kalan (Sangrur)	Mean	over control (%)
T. chilonis	8.2	4.4	6.3	53.3
Control	17.4	9.6	13.5	-

Plot size was 5 ha at Behram and 16 ha at Khudi Kalan; *T. chilonis* was released @ 50,000/ha at 10 days interval during July to October

Large-scale field demonstrations were also carried out in collaboration with three sugar mills of the state. The egg parasitoid, *T. chilonis* was released @ 50,000 per ha at 10 days interval during July-October. Mechanical control measures were carried out against other sugarcane borers at regular interval during April-July. The incidence of different sugarcane borers was recorded at fortnightly interval from different villages in three sugar mill areas. The mean incidence of stalk borer is presented in Table 68. For comparison the incidence of the stalk borer was recorded from the non-IPM fields.

Table 68. Biocontrol based IPM in different sugar mills

Name of the mill	Area	Per cent incidence of stalk borer	
		IPM*	Control
Morinda Co-operative Sugar Mills Ltd., Morinda	1500	1.20	5.70
Doaba Cooperative Sugar Mills Ltd., Nawanshahr	1000	3.53	8.58
Nahar Co-operative Sugar and Allied Industries, Amloh	1500	13.15	37.50
Mean		5.96	17.26
Reduction in damage over control (%)		65.45	-

* *Trichogramma chilonis* was released @ 50,000/ha at 10 days interval during July to October. Mechanical control of other sugarcane borers was carried out at regular interval during April to July.

4.18.5. Field studies on *Cotesia flavipes* and *Trichogramma chilonis* against stalk borer of sugarcane (PAU, Ludhiana)

The experiment on the field evaluation of *Cotesia flavipes* and *Trichogramma chilonis* against stalk borer of sugarcane was carried out at a farmer's field at village Chak Hakim (District: Kapurthala). The plot size was 2 ha for *T. chilonis*, one ha for *C. flavipes* and 0.4 ha for remaining treatments. *T. chilonis* was released @ 50,000 per ha at 10 days interval and *C. flavipes* @ 10,000 per ha at 20 days interval during July to October.

All the treatments except single release of *C. flavipes* proved effective for the control of stalk borer (Table 69). When both the parasitoids were released together it increased the effectiveness. The pooled data for three years is also given (Table 70) and it showed similar results.

Table 69. Effectiveness of sequential releases of *Trichogramma chilonis* and *Cotesia flavipes* for the control of *Chilo auricilius*

Treatment	No. of releases / period	Per cent incidence of stalk borer	Reduction in damage over control
T. chilonis	12 (July-October)	8.8	51.6
C. flavipes	1 (September)	16.6	8.8
C. flavipes	6 (July-October)	10.4	42.9
T. chilonis + *C. flavipes*	12+6 (July-October)	7.3	59.9
Control	-	18.2	-

T. chilonis was released @ 50,000/ha at 10 days interval and *C. flavipes* @ 10,000/ha at 20 days interval

Table 70. Efficacy of sequential releases of *Trichogramma chilonis* and *Cotesia flavipes* for the control of *Chilo auricilius* over three years

Treatment	Number of releases/ period	Per cent incidence of stalk borer				Reduction in damage over control (%)
		1997	1998	1999	Mean	
T. chilonis	12 (July –October)	10.8	12.9	8.8	10.8	55.2
C. flavipes	1 (September)	18.4	22.9	16.6	19.3	11.9
C. flavipes	6 (July –October)	14.4	16.2	10.4	13.7	37.9
T. chilonis + *C. flavipes*	12+6 (July -October)	8.4	10.1	7.3	8.6	65.3
	Control	-	21.2	26.3	18.2	21.9 -

T. chilonis was released @ 50,000 /ha at 10 days interval and *C. flavipes* @ 10,000/ha at 20 days interval

4.18.6. Role of parasitoids in controlling sugarcane pyrilla, *Pyrilla perpusilla* (PAU, Ludhiana)

The population of the pest and its natural enemies were recorded at regular interval in Morinda mill area. The pest appeared in the second fortnight of July and the maximum population was recorded during October. The nymphal and adult parasitoid, *Epiricania melanoleuca* appeared in the second fortnight of August and the parasitization was 8.33 per cent. With the increase in pest population the per cent parasitization and number of cocoons increased and reached maximum level during October. The egg parasitoid, *Tetrastichus* sp. appeared during first fortnight of September and maximum parasitization (81.76%) was recorded during second fortnight of October. In Amloh mill area, the pyrilla appeared during July and maximum population of the pest was recorded during September. All the stages of the parasitoid, *E. melanoleuca* were found on the crop during September and their population increased during October. Similarly, the egg parasitoid appeared during September when 9.4 per cent eggs were parasitized. The egg parasitism increased to 12.6 per cent during October.

4.18.7. Studies on the egg parasitoid *Trichogramma chilonis* (SBI, Coimbatore)

4.18.7.1. Dispersal studies

Dispersal ability of *Trichogramma chilonis* was assessed by placing *Corcyra* trap cards in concentric circles of 1, 2, 5, 7 and 10 m in eight directions. In the first trial, 2 cc-parasitized cards, i.e. 20 times the normal dose recommended for field release, were fixed in the centre. The trap cards collected 24h later were examined for per cent parasitism and per cent emergence in the laboratory; trap cards placed at 1m radius in different directions without parasitized cards in the centre served as control. In the second trial, a set-up similar to that used in trial-I, without parasitoids released at the centre, served as control. The dose of parasitoids used was twice the normal dose (0.2 cc). In trial-I, parasitism (0.3 - 33.3%) was noticed in release plots in all the directions and distances with no specific trend; parasitism was also noticed in control (2.7 - 12.6 %). The emergence rates were more or less same in release plots (33.3 - 90.1%) and control plots (25.0 - 65.4%). In trial-II, per cent parasitism was in the range of 0.8 - 12.4 and 0.1-6.8 and per cent emergence was 4.6-57.2 and 5.6 - 66.2 in release plots and control plots, respectively.

4.18.7.2. Natural activity of *T. chilonis*

Natural activity was monitored in November and December 1999 by placing trap cards in eight directions in the field. Parasitism in trap cards was generally noticed in both months, though in a few directions. Parasitoid emergence was 100.0 and 66.7% in both the trials.

4.18.8. Studies on the fungus *Beauveria brongniarti* against white grub (SBI, Coimbatore)

4.18.8.1. Mass culturing technique

Beauveria brongniarti was cultured on molasses-based media in an attempt to standardize an economic mass-culturing technique. Radial growth, biomass production and spore production of the fungus on a molasses concentration range of 1.5 - 4.5% were on par with or higher than on standard media. Two fungi - *B. bassiana* and *Metarhizium anisopliae* evaluated for comparison also showed more or less similar results.

To standardize the quantity of molasses-based media for spore production, a range of 100 - 500 ml of 3% molasses was used for culturing the fungus in a 1-litre container. Spore production for all quantities remained more or less same (Table 71) but was less for 100 ml of molasses.

Table 71. Spore production of *Beauveria brongniarti* on 3% molasses media

Molasses (ml)	Mean spore production (actual)	Mean spore production (100^{-1} ml)
100	0.75×10^{10}	0.75×10^{10}
200	2.02×10^{10}	1.01×10^{10}
300	2.55×10^{10}	0.85×10^{10}
400	3.80×10^{10}	0.95×10^{10}
500	3.93×10^{10}	0.79×10^{10}

4.18.2.2. Bioassay against white grub

Bioassay of *B. brongniarti* against eggs of white grub at 10^4-10^9 spores / ml by topical application produced low levels (<13.3%) of infection (Table 72). *B. bassiana* also produced low levels (<13.3%) of infection whereas *M. anisopliae* showed higher levels (<86.7%) of infection at the same concentration range. *B. brongniarti* bioassayed against grown-up larvae of white grub at a concentration range of 10^4 - 10^9 spores / box showed lower mortality range in second instar than in third instar (Table 73). *B. bassiana* also showed a similar trend whereas *M. anisopliae* showed the opposite trend.

Table 72. Bioassay of three fungi against white grub eggs

Dosage (spores/ml)	Per cent infection		
	Beauveria brongniarti	*Beauveria bassiana*	*Metarhizium anisopliae*
10^4	3.3	6.7	6.7
10^5	3.3	0.0	33.3
10^6	10.0	3.3	33.3
10^7	3.3	0.0	86.7
10^8	10.0	6.7	30.0
10^9	13.3	13.3	86.7
Control	0.0	0.0	0.0

Table 73. Bioassay of three fungi against late instar white grub

Dosage (spores/box)	Per cent infection in second instar			Per cent infection in third instar		
	Bbr	*Bb*	*Ma*	*Bbr*	*Bb*	*Ma*
10^4	26.7	13.3	6.7	26.7	6.7	6.7
10^5	6.7	6.7	6.7	26.7	6.7	0.0
10^6	13.3	13.3	13.3	13.3	6.7	0.0
10^7	20.0	40.0	0.0	60.0	13.3	13.3
10^8	40.0	33.3	40.0	100.0	60.0	13.3
10^9	60.0	53.3	20.0	93.3	93.3	6.7
Control	0.0	0.0	0.0	0.0	0.0	0.0

Bbr : *Beauveria brongniarti*; Bb : *Beauveria bassiana* and Ma : *Metarhizium anisopliae*

4.19. Biological suppression of cotton pests

4.19.1 Identification of host plants which harbor arthropod natural enemies (TNAU, Coimbatore)

The cotton crop sown during kharif 1999 (September 1999 to March 2000) in Tamil Nadu Agricultural University farm as well as farmer's holdings in and around Coimbatore was observed for natural enemies. Sorghum, chillies and weeds such as *Amaranthus* spp., *Abutilon indicum, Croton sparsiflorus, Euphorbia* sp., *Parthenium hysterophorus, Trianthema* and *Tridax* sp. were also observed for the presence of arthropod natural enemies during the crop period. Predators such as coccinellids, chrysopids, preying mantids, syrphids, dragonflies, reduviids and parasitoids, *Trichogramma* spp., *Telenomus* spp., and *Cotesia* sp. were recorded.

4.19.2. Standardization of release technology for *Trichogramma chilonis*

4.19.2.1 TNAU, Coimbatore

A field trial was laid out with the following treatments.

i. 1,50,000 parasitoids per ha per week (eight releases) - one hundred strips of parasitized eggs of *T. chilonis* (one bit per 100m²)

ii. 1,50,000 parasitoids per ha per week (eight release) - two hundred strips of parasitized eggs of *T. chilonis* (one bit per 50 m^2)

iii. Eight releases of *T. chilonis* @ 1,50,000 adult parasitoids per ha per week (ensure well distributed releases)

iv. Control (Untreated)

Note: Blanket application of recommended insecticides for elimination of sucking pests. Need based application after eight releases of *T. chilonis*.

Among different treatments, the mean damage to bolls was found to be significantly less in plots released with adults followed by 200 strips/ha. The percentage of parasitism and yield were also found to be significantly high in plots released with adults, followed by 200 strips/ha (Table 74).

Table 74. Evaluation of release methods of *T. chilonis* against bollworm complex of cotton

Treatment	Mean per cent boll damage* (fortnight)						Per cent parasitization of *H. armigera* eggs	Yield (kg/ha)
	Pre-count	1	2	3	4	5		
100 strips	15.20 (22.95)	13.25 (21.32)	12.40 (20.62)	11.6 (19.91)	10.70 (19.09)	10.25 (18.67)	11.20	1640
200 strips	16.25 (23.73)	13.50 (21.56)	12.8 (20.96)	10.8 (19.19)	9.4 (17.85)	9.0 (17.46)	15.60	1820
Adults	14.50 (22.38)	12.70 (20.88)	10.80 (19.19)	10.2 (18.63)	9.0 (17.46)	8.8 (17.26)	17.25	1915
Control	16.00 (23.58)	18.20 (25.25)	19.20 (25.99)	20.8 (27.13)	20.60 (26.99)	21.20 (27.42)	10.20	920
CD (P=05)	NS	0.24	0.82	0.76	1.15	0.94		92.00

Figures in parentheses are transformed values

4.19.2.2. ANGRAU, Hyderabad

With the same objective, an experiment was conducted at Agricultural Research Station, Warangal (ANGRAU) in an area of 1500 m^2. Fixed number of *T. chilonis* @ 1,50,000/ha/week was released for 8 times in the following release methods.

i. 100 strips of parasitised egg cards (one bit for 100 m^2)

ii. 200 strips of parasitized egg cards (one bit for 50 m^2)

iii. Uniformly distributed release of adults

The observation on incidence of bollworms was recorded in terms of square and boll damage at 15 days interval. The eggs of *H. armigera* were collected and observed in laboratory to note the per cent egg parasitization by *T. chilonis* in different treatments. Among the three release methods, release of 200 strips of parasitized egg cards gave promising results with the lowest square damage (6.01%), boll damage (4.97%), and the highest egg parasitization (37.57%) and yields (10.68 q/ha) (Table 75).

Table 75. Efficiency of *T. chilonis* against *H. armigera* in different release methods

Method of release of *T. chilonis* *	Per cent damage		Per cent parasitization of *H. armigera* eggs	Yield (q/ha)
	Squares	Bolls		
100 strips of parasitised egg cards	9.26	7.89	20.00	8.30
200 strips of parasitized egg cards	6.01	4.97	37.57	18.68
Release of adult parasitoids	7.06	5.51	25.54	9.70
Control	12.11	10.57	9.57	6.00

* @ 1,50,000 /ha / week

4.19.3. Evaluation of biocontrol based IPM module

4.19.3.1. PAU, Ludhiana

The experiment on the evaluation of biocontrol based IPM module was conducted at the Regional Research Station, Bathinda. The plot size was 0.4 ha for each of the following treatments:

Treatment 1 (IPM module-I)

i) Need based application of insecticides for the control of sucking pests.

ii) Sixteen releases of *Trichogramma chilonis* @ 1,50,000 per ha per week during July to October.

iii) Release of *Chrysoperla carnea* @ 10,000 per ha on the appearance of sucking pests.

iv) *Ha*NPV spray @ 1.5 x 1012 POB per ha on the appearance of *Helicoverpa armigera*.

Treatment 2 (IPM module-II)

i) Need based application of insecticides for the control of sucking pests.

ii) Eight releases of *T. chilonis* @ 1,50,000 per ha per week during July to October.

iii) Release of *C. carnea* @ 10,000 per ha on the appearance of sucking pests.

iv) Need based application of insecticides for the control of bollworms during September-October.

Treatment-3

PAU spray schedule

Treatment 4 (Control)

Need-based application for the control of sucking pests

To record the incidence of bollworms, 10 plants were selected at random, infested and healthy bolls were recorded to work out the per cent infestation. For egg parasitism, at least 25 eggs of *H. armigera* were collected from each plot four times during the season to record parasitism. The seed cotton yield was recorded on whole plot basis.

No egg parasitism was observed in PAU spray schedule (Table 76). In IPM module-I, 6.8 to 14.8 per cent parasitism was recorded only in the first fortnight of September (2.0 to 6.3 %). However, in control 1.7 to 3.3 per cent parasitism was recorded (mean=2.4%). The bollworm damage in control (78.7%) was significantly higher than all other treatments. The damage in IPM module-II was lowest (45.2%) and was significantly lower than IPM module-I and PAU spray schedule.

Table 76. Evaluation of IPM modules for the control of bollworm complex on cotton at RRS, Bathinda

Treatment	Per cent parasitization of *H. armigera* eggs					Bolls damaged (%)	Yield (q/ha)
	8-9-'99	15-9-'99	29-9-'99	6-10-'99	Mean		
PAU spray Schedule	0	0	0	0	0	57.30 (49.23)	3.50
IPM I	10.3	12.0	6.8	14.8	11.0	59.70 (50.51)	2.8
IPM II	2.0	6.3	0	0	2.1	45.20 (42.27)	3.9
Control	1.7	2.6	3.3	1.9	2.4	78.70 (62.54)	0.7
CD (P=0.05)	-	-	-	-	-	(6.24)	0.6

The cotton leaf curl virus heavily infected the crop and the yield was very low in all the treatments. However, all the treatments gave significantly higher yield than control (0.7q/ha). Highest yield (3.9 q/ha) was obtained in IPM module-II and it was significantly higher than IPM module-I and PAU spray schedule.

The pooled data of three years (1997 to 1999) reveal that the bollworm damage in IPM module-II was lowest (28.6%) and the reduction in damage was 50.0 per cent as compared to control (Table 77). The egg parasitism was highest (10.2%) in IPM module-I followed by 3.9 per cent in control. The parasitism in PAU spray schedule (0.3%) and IPM module-II (1.3%) was very low. The mean yield was highest (7.1 q/ha) in PAU spray schedule followed by 6.6 q/ha in IPM module-II (Table 78). The yield was very low in control (3.7 q/ha). The increase in yield over control was 45.9, 78.4 and 91.9 per cent in IPM module-I, IPM module-II and PAU spray schedule, respectively.

Table 77. Efficacy of biocontrol based IPM for the control of cotton bollworms in terms of damage and egg parasitism

Treatment	Per cent bolls damaged				Egg parasitization in *H. armigera*			
	1997	1998	1999	Mean	1997	1998	1999	Mean
PAU spray schedule*	10.3	37.0	57.3	34.9	0.8	0.0	0.0	0.3
IPM I**	18.8	39.0	59.7	39.2	15.7	4.0	11.0	10.2
IPM II***	13.2	27.5	45.2	28.6	17.0	0.0	2.1	1.3
Control+	33.5	58.9	78.7	57.0	9.4	0.0	2.4	3.9

* Six to nine sprays for the control of sucking pests and bollworms

** Sixteen releases of *T. chilonis* during July to October @ 1,50,000/ha/week, one release of *C. carnea* @ 10,000/ha and one spray of *Ha*NPV @ $1.5x10^{12}$ POB.

*** Eight releases of *T. chilonis* during July-August @ 1,50,000/ha/week, one release of *C. carnea* @ 10,000/ha and one spray of *Ha*NPV @ $1.5x10^{12}$ POB.

\+ Only 3 sprays were given for the control of bollworm complex in PAU spray schedule and IPM module-II.

Table 78. Efficacy of biocontrol based IPM modules for the control of cotton bollworms in terms of yield

Treatment	Yield (q/ha)				Increase in yield over control (%)
	1997	1998*	1999**	Mean	
PAU spray schedule*	16.9	1.00	3.50	7.10	91.9
IPM I**	13.0	0.50	2.80	5.40	45.9
IPM II***	14.5	1.40	3.90	6.60	78.4
Control	10.4	0.10	0.70	3.70	-

* The crop was damaged by heavy rain (300 mm) between Sept. 17 and Sept.24, 1998.

** High incidence (more than 50%) of cotton leaf curl virus

4.19.3.2. GAU, Anand

To evaluate the efficacy of IPM module against pest complex (var. Hybrid-10) an experiment was laid out at Agronomy Farm, B. A. College of Agriculture, Gujarat Agricultural University, Anand with four treatments and ten replications.

T1 (IPM Module-1)

i. Mechanical collection of bollworm infested parts and putting them in wire screen cage.

ii. Random planting of maize @ 10% of cotton plants.

iii Three releases of *Chrysoperla carnea* @ 10,000 larvae (2-3 days old)/ha/week synchronizing with the appearance of the pests.

iv. Eight releases of *Trichogramma chilonis* each @ 1,50,000/r/ha/week synchronizing with the appearance of the pest.

T2 (IPM module 2)

i. Mechanical collection of bollworm infested parts and putting them in wire screen cage.

ii. Random planting of maize @ 10% of cotton plants.

iii Three releases of *Chrysoperla carnea* @ 10,000 larvae (2-3 days old)/ha/week synchronizing with the appearance of the pests.

iv. Eight release of *Trichogramma chilonis* each @ 1,50,000/ha/week synchronizing with the appearance of the pest.

v. Need based application of monocrotophos 0.03 % and endosulfan 0.07 % after 8th release of *T. chilonis*.

T3 (Insecticidal Module)

As per GAU recommendation.

Observations were taken on the incidence of aphids, jassids, thrips and whiteflies. The entire plot (0.2 ha) was divided into 10 equal divisions. From each division 5 plants were selected at random and tagged. The observations on the population of aphid, jassid, whitefly and thrips were recorded from three randomly selected leaves of each tagged plant from lower, middle and upper regions at fortnightly interval. To record the incidence of bollworms healthy and damaged buds/bolls were counted from each tagged plant and the extent of damage (%) was worked out for each replication at fortnightly interval. The eggs and larvae of bollworms were collected fortnightly covering the whole plot under different treatments and were kept individually in glass vials to record the extent of parasitism. The mummified larvae (due to parasitism by *Rogas*) observed in field were also collected and added to the number of larvae collected while working out per cent parasitism.

Number of predators like *Chrysoperla carnea* (eggs + larvae), *Cheilomenes sexmaculata* (eggs + larvae + pupae + adults), *Geocoris* sp. (adults), spiders, staphylinids, etc. were also recorded on each tagged plant at fortnightly interval. Cotton yield was also recorded and economics of treatments was worked out.

Results presented in Table 79 reveal that the bud and boll damage was significantly low in IPM module I and II over control as well as insecticidal treatments. Both IPM modules gave significantly better protection to buds and bolls. The bollworm damage to the locules was also significantly low in IPM blocks. The population of sucking pests was also significantly lower in IPM modules than in control. The releases of *Chrysoperla* gave significantly better protection against aphid, jassid and whitefly.

Since IPM plots received less spray of chemical insecticides many of the bio-agents were conserved (Table 80 and 81). The noteworthy amongst them were bollworm parasites *Rogas aligharensi, T. chilonis* and *Agathis* sp (Table 82). Amongst the predators *Chrysoperla, Cheilomenes, Geocoris* and staphylinids were prominent. On the other hand population of these natural enemies was greatly hampered due to application of chemical insecticide. It was also observed that inter cropping of maize with cotton enhanced the activity of *C. sexmaculata* (3.03/plant) in cotton crop in IPM blocks (Table 83 and 84).

Table 79. Population of sucking insects and bollworms in different treatments on cotton hybrid 10

Treatments	Sucking pest/15 leaves			% damage by boll worms				Yield kg/ha	ICBR
	Aphid	Jassid	Whitefly	Bud	Boll	Locules			
						Earias vitella	*Pectinophora gossypiella*		
IPM-I	6.05* (35.60)	1.96 (2.87)	1.89 (2.57)	12.60** (4.16)	16.99 (8.55)	14.60 (6.35)	25.86 (19.02)	2555	1:6.50
IPM-II	6.09 (36.16)	2.03 (3.13)	1.99 (2.96)	12.51 (4.69)	16.34 (7.92)	15.10 (6.79)	25.54 (18.59)	2583	1:5.64
Insecticides	9.85 (96.05)	2.45 (5.04)	2.33 (4.43)	18.69 (10.28)	23.72 (16.19)	17.98 (9.53)	30.62 (25.94)	1872	1:2.41
Control (156.94)	12.56 (7.43)	2.90 (6.62)	2.76 (16.36)	23.85 (23.80)	29.20 (23.77)	29.18 (37.62)	37.83	1444	
CD (P=0.05)	1.08	0.14	0.16	2.91	2.67	2.11	2.94	2.13	

*$\sqrt{x+1}$ transformation; ** Arc sine per cent transformations and figures in parentheses are transformed values

Table 80. Population of bioagents per 25 plants in various treatments

Month	*Chrysoparla*				*C. sexmaculata*				*Geocoris*				Staphylinidae			
	IPM I	IPM II	INS	CON	IPMI	IPMII	INS	CON	IPMI	IPMII	INS	CON	IPMI	IPMII	INS	CON
August I	33	27	20	30	58	50	22	50	11	10	6	10	-	-	-	-
August II	45	34	21	38	62	65	19	41	18	17	9	15	-	-	-	-
September I	80	70	25	50	55	60	30	50	13	12	5	8	-	-	-	-
September II	120	105	15	30	40	38	15	30	9	9	4	6	-	-	-	-
October I	105	90	8	35	19	16	8	15	9	11	3	6	9	5	6	7
October II	86	40	10	25	17	10	7	11	10	8	5	7	12	7	4	8
November I	35	18	7	15	15	5	4	12	12	7	4	8	10	3	3	7
Mean	72	54.86	15.14	31.86	38.00	34.86	15.00	29.86	11.71	10.57	5.14	8.57	4.43	2.14	1.86	3.14

The effect of IPM also reflected in the yield. The yield in IPM-I and IPM-II was 2555 kg/ha and 2583 kg/ha, respectively, which was significantly superior to control (1444 kg/ha). Both IPM modules proved effective against cotton pests giving higher ICBR (Table 79).

Table 81. Mean % parasitism by *T. chilonis* in eggs and *R. aligharensi* in larvae of *E. vittella* in different treatments (1999-2000)

Parasite	IPM I	IPM II	Insecticide	Control
1. Egg parasitism by *T. chilonis*	25.26	26.00	9.00	12.40
2. Larval parasitism by *R. aligharensi*	19.07	19.98	9.64	18.99
3. Larval pupal parasitism by *Agathis* sp.	33.08	32.59	24.00	28.89

Table 82. Parasitoids from *E. vittella* collected from IPM plots

Month	Treatment	Total collected			Parasitoids recorded
		Larva	Pupa	Adult	
July	IPM I	15	1	2	*Apanteles* sp.
	IPM II	20	2	1	
August	IPM I	65	3	2	*Agathis* sp.
	IPM II	50	2	3	
September	IPM I	40	1	2	*Agathis/Rogas/Bracon/Apanteles*
	IPM II	45	3	2	
October	IPM I	25	2	1	*Agathis/Rogas/Bracon*
	IPM II	20	1	1	

Table 83. Average number of *C. sexmaculata* on maize and cotton in IPM modules

Period	IPM	Control	SD	Error	't'
P1	3.50	12.50	7.92	2.5	-3.48
P2	3.60	3.40	2.37	0.75	4.81
P3	2.00	0.50	2.22	0.70	2.13
Pooled	3.03	5.47	6.60	1.21	-1.94

Table 84. Average number of *C. sexmaculata* on cotton in IPM modules and isolated control

Period	IPM	Control	SD	Error	't'
P1	3.50	1.90	2.63	0.83	1.92
P2	3.60	1.80	2.30	0.73	2.48
P3	2.0	1.10	1.66	0.53	1.71
Pooled	3.03	1.60	2.19	0.40	3.58

4.19.3.3. TNAU, Coimbatore

In the field trial laid out in a farmer's field at S.S. Kulam, five management practices, *viz.*, IPM module 1, IPM module 2, TNAU spray schedule, farmer's practice and untreated control, were compared for the control of sucking insects (aphids and jassids) and bollworms.

IPM module 1	Planting of maize @ 10 per cent of cotton plants, blanket application of dimethoate (0.05%) at 30 DAS, three releases of *Chrysoperla carnea* @ 10,000 larvae (2-3 days old) per week/ha *viz.*, 40, 47, 54 days after sowing (DAS) five releases of *Trichogramma* @ 1,50,000/ha/week starting from 70 DAS and one need based application of *Ha*NPV $3x10^{12}$ POB/ha on 110 DAS.
IPM module 2	Similar to IPM module 1, but instead of NPV spray, monocrotophos @ 0.03 per cent was sprayed on 110 DAS.
TNAU spray	Application of five rounds of insecticides with dimethoate, endosulfan, monocrotophos, schedule quinalphos and chlorpyriphos on 50, 65, 80, 95 and 110 days after sowing, respectively These insecticides were sprayed as and when the pest crossed economic threshold level.
Farmer's practice	Eight rounds of insecticidal sprays without following ETL.

In the field trial it was found that the incidence of sucking pests, *viz.*, leafhoppers and aphids was significantly less in BIPM plots followed by TNAU spray schedule (need based) (Table 85). Bollworm damage was also less in the same treatments. Per cent parasitism of both eggs and larvae was found to be higher in biocontrol based IPM module I followed by II. The yield of cotton was significantly higher in BIPM module I followed by need based application of insecticides (Table 86 and 87).

Table 85. Population of sucking pests in different treatments

Treatments	Leafhoppers/plant (Days after sowing)	
	40	50
BIPM module I	0.55	0.68
BIPM module II	0.75	0.99
TNAU spray schedule	0.83	1.30
Farmers' practice	0.98	1.62
Control (untreated)	1.18	1.77
CD = (0.05)	0.16	0.29

Table 86. Boll damage and yield under different treatments

Treatment	Mean per cent damage of bolls*						Yield kg/ha
	Pre count	1	2	3	4	5	
BIPM Module I	16.2 (23.73)	14.20 (22.14)	12.20 (20.27)	8.6 (17.05)	8.0 (16.43)	9.2 (17.66)	1840
BIPM Module II	17.40 (24.65)	14.80 (22.63)	13.80 (21.81)	11.6 (19.91)	9.6 (18.05)	10.2 (18.63)	1725
TNAU Spray schedule	15.50 (23.19)	14.0 (21.97)	13.6 (21.64)	11.40 (19.73)	9.4 (17.85)	9.75 (18.19)	1730
Farmers' practice	16.25 (23.73)	15.2 (22.95)	14.8 (22.63)	13.60 (21.64)	10.75 (19.14)	11.0 (19.37)	1460
Control	15.80 (23.42)	18.2 (25.25)	20.2 (26.71)	23.6 (29.06)	26.4 (30.92)	29.5 (32.90)	875
CD (P=0.05)	NS	0.62	0.84	1.25	1.66	0.73	102.00

*The observations were recorded at 15 days interval.

Table 87. Natural enemies and extent of parasitism in different treatments

Treatments	Egg parasitism (%)			Larval parasitism (%)			Predators (No./10 plants)		
	Ha	Ev	Pg	Ha	Ev	Pg	Pm	Co	Sp
BIPM module I	12.50	7.0	5.4	9.40	5.2	3.2	2	3	3
BIPM module II	10.80	6.2	4.0	8.2	4.6	2.8	0	6	6
TNAU schedule	9.0	6.4	3.0	7.6	3.5	2.50	0	2	-
Farmers' practice	7.0	5.3	3.4	6.2	2.8	2.60	1	3	2
Control	10.50	6.8	4.8	8.0	3.6	2.85	0	2	3

Ha: *Helicoverpa armigera,* Ev: *Earias vittella,* Pg: *Pectinophora gossypiella,* Pm: Preying mantids, Co: coccinellids and Sp: spiders

4.19.3.4. ANGRAU, Hyderabad

Biological control based Integrated Pest Management module for cotton pests was evaluated at Agricultural Research Station, Warangal (ANGRAU) with 4 different modules and control. The modules are:

i. BIPM module-I

- mechanical collection of bollworm infested plant parts and putting them in wire screen cage.
- sowing of cowpea as an intercrop between two rows of cotton
- random planting of maize @ 10% of cotton plants
- sowing of castor seed as trap crop at the border @ 50 plants/ha.
- seed treatment with imidacloprid @ 5 g/kg seed.
- three releases of *Chrysoperla carnea* @ 10,000 larvae/ha/week synchronizing with the occurrence of sucking pests.
- installation of pheromone traps @ 10/ha for *H. armigera*.
- eight releases of *T. chilonis* each @ 1,50,000/ha/week synchronizing with the appearance of eggs of bollworms.
- need based application of *Ha*NPV @ 3 x 10^{12} POB/ha (500 LE/ha)

ii. *BIPM module-II*

All the above inputs were followed except the last one where need based application of *Ha*NPV was replaced by need based application of monocrotophos, acephate and triazophos after 8 releases of *T. chilonis*.

iii. *Judicious use of insecticides*

Monocrotophos, chlorpyriphos, endosulfan, quinalphos, triazophos and acephate were sprayed as and when needed.

iv. *Farmer's practice*

Chlorpyriphos, monocrotophos, oxydemeton methyl, acephate, endosulfan, triazophos, quinalphos + blitox, nimbicidine and cypermethrin were sprayed.

v. Control

No insecticidal spray was given.

Parallel observations were recorded in all the modules. Data on sucking pests was collected by observing the number of jassids per leaf and per cent aphid infested plants. Presence of bollworms in different modules was recorded by counting the number of *H. armigera* eggs and larvae per plant basis. The damage percentage was calculated by recording squares damaged by *Earias* sp., bolls damaged by *H. armigera* and locules damaged by pink bollworm. Data on natural enemies were collected by counting number of coccinellids, spiders and predatory mites per plant basis. Yield was compared in different modules for kapas on q/ha basis. Finally the inputs and outputs were pooled to calculate and compare cost benefit ratio in different modules.

Jassid and aphid incidence was very low in all the modules as compared to control (Table 88). However, in aphid incidence there seems to be much variation in judicious use of insecticides (JUI) and Farmer's practice to that of IPM modules I and II where the incidence is lower. Eggs collected from JUI practice and farmer's practice were higher than that collected from module I and II. In terms of damage, the damage by *H. armigera* was lowest in JUI and farmer's practice closely followed by IPM modules I & II where as in control higher damage levels were recorded. However, the damage by pink bollworm was low in IPM modules I and II closely followed by JUI and Farmer's practice. In terms of its natural enemy abundance of coccinellids and spiders, more population was recorded in IPM modules and also in control where as very less natural enemy population was recorded in JUI method and farmer's practice. The kapas yield was highest in farmers practice and JUI method followed by moduleI and II where as the lowest yield was recorded in control. Cost-benefit ratio was highest in IPM module I followed by module II, JUI and farmer's practices.

Table 88. Development of IPM module for cotton pests

Particulars		IPM Module-I	IPM Module-II	ANGR-AU method	Farm-er's pract ice	Con-trol
Sucking pests	Jassids (No./leaf)	0.84	0.87	0.82	0.78	1.02
	Aphids (per cent	4.00	4.00	8.00	6.00	15.00
Boll worms	Eggs / plant	0.61	0.72	1.09	1.83	1.77
	Larvae /plant	0.69	0.75	0.79	0.78	0.87
Per cent	Squares	9.60	8.71	7.74	7.76	16.60
	Boll	9.36	9.06	6.95	7.47	11.48
	Pink bollworm damage	23.74	24.01	26.03	20.03	34.70
	Locule damage	50.30	49.36	62.16	56.14	60.50
Number of natural enemies	Coccinellids/plant	3.10	2.71	0.63	0.41	1.75
	Spiders/plant	1.98	2.01	0.53	0.82	1.22
	Predatory mites/plant	2.79	2.54	1.81	1.95	2.13
Yield	Kapas	12.05	11.97	14.10	15.78	9.50
	Cowpea	1.22	11.70	-	-	-
Cost-Benefit ratio		1:3.17	1:3.05	1:2.49	1:1.25	-

4.19.3.5. Demonstration of IPM in cotton (PAU, Ludhiana)

During 1999, a local population (Bathinda population) of *T. chilonis* was evaluated in integration with insecticides for the control of bollworm complex at village Khuban (District: Ferozepur). The plot size was 9 acres for each treatment. Eight releases of *T. chilonis* were made @ 1,50,000 per ha per week during August-October basis of 30 plants on September 2 and 28. The eggs of *H. armigera* were collected from both fields three times (September 8^{th}, 15^{th} and 22^{nd}) to observe parasitization. The seed cotton yield was recorded on whole plot basis.

The mean bolls damage was 1.78 per cent in the plot where *T. chilonis* was released along with insecticides as compared to 6.0 per cent in insecticides alone, and resulted in 70.3 per cent reduction in damage. The parasitization of *H. armigera* eggs was more (10.5%) in released field as compared to insecticidal sprays (0.7%). Similarly, the seed cotton yield was higher (7.76 q/ha) where releases were integrated with insecticidal sprays. The increase in yield was 44.5 per cent than the insecticidal sprays alone (5.37 q/ha). It shows that the local population of *T. chilonis* can be integrated with insecticidal sprays and better results can be obtained.

The bolloworms damage in the nearby control was 41.30 per cent and the yield was 87 kg/ha. Seven insecticidal sprays (cypermethrin, chlorpyriphos, quinalphos, chlorpyriphos, endosulfan, and quinalphos) were given in both the plots.

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

Demonstration of Biointensive IPM of *Spodoptera litura* in irrigated tobacco at Kalavacherla (East Godavari District) resulted in a net profit of Rs 37,000/- as compared to chemical control (farmer's practice) with a net profit of Rs 26,200/-. The CB ratio for BIPM practice was 1:1.54 and for chemical control it was 1:1.38.

4.20.1 Testing efficacy of encapsulated formulation of entomopathogenic nematodes against *S. litura* in tobacco nurseries.

Two entomopathogenic nematodes, *viz.*, *Steinernema carpocapsae* and *Heterorhabditis indicus* in encapsulated forms formulated by PDBC, Bangalore, were tested at 1000 capsules and 2000 capsules/m^2 for their efficacy against late third instar larvae of tobacco caterpillar, *S. litura* in the CTRI tobacco nursery at Rajahmundry.

Beds of 1m^2 were prepared. *Steinernema carpocapsae* and *Heterorhabditis indicus* were incorporated on the top 3" of soil. Immediately after incorporation of entomopathogenic nematodes, six-week-old tobacco seedlings @ 450 /m^2 were planted and caged with wire mesh to prevent migration and bird predation. One week after planting, late third instar laboratory reared larvae of *S. litura* @ 30 /m^2 were released. Two days after release observations were recorded on the number of surviving larvae and number of seedlings damaged/m^2. The results are presented in Table 89.

Table 89. Efficacy of encapsulated formulations of entomopathogenic nematodes against *Spodoptera litura* in tobacco nurseries

Treatments	Number of larvae /m^2	Number of seedlings damaged /m^2
Steinernema carpocapsae 1000 capsules/m^2	18.50	175.25
Steinernema carpocapsae 2000 capsules/m^2	11.25	122.75
Heterorhabditis indicus 1000 capsules/m^2	20.25	183.75
Heterorhabditis indicus 2000 capsules/m^2	15.25	147.00
Untreated control	28.00	201.75
CD (P=0.05)	2.89	29.60

S. carpocapsae @1000 capsules/m^2, 2000 capsules/m^2 and *H. indicus* at 1000 capsules/m^2, 2000 capsules/m^2 significantly reduced the population of late third instar larvae of *S. litura* and number of seedlings damaged by *S. litura*/m^2 two days after inoculation but both the entomopathogenic nematodes failed to prevent (*S. litura* from reaching ETL) the tobacco nurseries. The ETL fixed for *S. litura* was one late third instar larvae or 6 seedlings damaged/m^2 /nursery bed.

4.20.2. Demonstration of bio-intensive IPM of *S. litura* in irrigated FCV tobacco crop

An area of one hectare at Kalavacherla in East Godavari district of A.P, irrigated NLS-4 FCV tobacco variety planted in the 1st week of November was taken up for demonstration of biointensive IPM of *S. litura* in comparison with farmer's practice with K-326 variety planted in ha. Castor (var. Aruna) was sown around tobacco crop, one week before planting tobacco.

The IPM methods adopted were:

1. Collection & destruction of egg masses and tiny larvae on castor trap crop around tobacco
2. One release of *Telenomus remus* @ 40,000/ha four weeks after transplanting
3. First spray of *Sl*NPV 3 x 10^{12} PIB/ha 30 days after planting

4. Second spray of *Sl*NPV 3 x 10^{12} PIB/ha 40 days after planting
5. Acephate @ 1.0 kg/ha at 60 days after planting

Farmer's practices adopted were:

1. Two sprays of quinalphos @ 0.250 l/ha at 10 DAP & 20 DAP
2. One spray of chlorpyrifos @ 1.5 1/ha at 30 DAP
3. One spray of acephate @ 1 Kg/ha at 60 DAP

Percentage of plants infested was recorded at 70 DAP in 100 plants at four places selected at random for both IPM and chemical control. Ten plants at random were sampled for natural enemies.

Among natural enemies (parasitoids) recorded on tobacco *Peribaea orbata* was the most predominant followed by *Chelonus* and *Apanteles*. Among predators, coccinellids appeared in good numbers between 45-60 DAP and reduviid (*Harpactor costalis*) was also common. The ubiquitous appearance of *Nesidiocoris tenuis* was noticed in all the observations. Their numbers ranged from 10-20 adults/plant.

The mean percentage plants infested were significantly less in all four IPM adopted blocks compared to chemical control (values > 1.60 are significant). (Table 90).

Table 90. Mean percentage of plants infested in farmer's practice and IPM plots

Observation block	Mean per cent plants damaged		z-value
	Farmer's method	IPM	
I	32	7	
II	36	22	
III	27	18	
IV	29	19	11.50

The cost of cultivation, yield and economics of IPM practice and farmer's method are presented in Table 91 and the C : B ratio was found to be 1 : 1.54 for IPM as compared to 1 : 1.38 for farmer's practice.

Table 91. Cost of cultivation and economics of IPM and farmer's practice in tobacco

Parameter	IPM	Farmer's method
Cost of cultivation	67,100	67,100
Cost of plant protection for *S. litura*	900	1,200
Gross expenditure	68,000	68,300
Yield (q)	300	270
Gross income (expected) (Rs.3,500/q)	1,05,000	94,500
Net profit (expected)	37,000	26,200
CB ratio	1:1.54	1.1.38

4.20.3. Determination of number of spots/ha for release of *Telenomus* sp.

To determine the number of spots for release of *Telenomus remus* @ 40,000/ha were split equally into the following treatments:

1. Center of the field (one spot)
2. Diagonal corners (two spots)
3. Four corners of the field (four spots).

A distance of 20 m was maintained between two spots. One hundred randomly selected tobacco plants for each treatment were sampled for egg masses and *T. remus* parasitization.

It was observed that highest mean per cent parasitization (18) was obtained from release of *Telenomus* at 4 spots in four corners of the field followed by single spot release at the center of the field with 15% parasitization, whereas release at 2 spots at the two diagonal corner of the field resulted in 12 % mean per cent parasitization of egg masses. The results were presented in Table 92.

Table 92. Determination of number of spots/ha for release of *Telenomus* sp.

Treatment	Number of egg masses/100 plants	Number of parasitised egg masses	Mean per cent parasitization
Mean per cent parasitization			
One spot (center of field)	11	4	15
Two spots (diagonal/corners)	12	3	12
Four spots (four corners of field)	16	6	18

4.21. Biological suppression of pulse crop pests

4.21.1. Biological control based management of pod borer complex on pigeon pea

Effect of sequential application of various bioagents in pigeonpea against *H. armigera* was tested through a field trial in randomized block design (RBD) with six treatments replicated four times. Spray application of *Bt*, *Ha*NPV, NSKE and endosulfan was done in different sequences twice at 10 days interval. First spray was given at flower initiation stage and subsequent 3 sprays were given at 10 days interval except in endosulfan treatment where the interval of 15 days was maintained. The treatments were (i) *Bt-Ha*NPV-*Bt-Ha*NPV (ii) *Bt-Ha*NPV-endosulfan-*Bt* (iii) Endosulfan-*Bt-Ha*NPV-*Bt* (iv) NSKE-*Bt-Ha*NPV-*Bt* (v) Endosulfan-endosulfan-endosulfan and (vi) Control. Dosage tested were *Ha*NPV $1.5x10^{12}$ POB/ha *Bt* 1.0 kg/ha, endosulfan @ 350 a.i/ha and NSKE 5%.

TNAU, Coimbatore

Pod damage recorded seven days after each spray in all the treatments was significantly less than control. The seed damage in endosulfan treated plots and *Bt-Ha*NPV-endosulfan-*Bt* treated plots was significantly less when compared to other treatments. The yield of redgram was also high in the same treatments (Table 93).

Table 93. Incidence of pod borer complex in pigeonpea and yield

Treatment	Initial damage	Mean per cent pod borer damage after 7 days of				Seed damage (%)	Yield kg / ha
		I spray	II spray	III spray	IV spray		
Bt – *Ha*NPV – *Bt* – *Ha* NPV	24.25 (29.50)	13.25 (21.34)	10.25 (18.67)	9.30 (17.76)	8.70 (17.66)	4.75 (12.59)	810
Bt – *Ha*NPV – endosulfan – *Bt*	22.15 (28.08)	11.25 (19.60)	9.30 (17.76)	8.60 (17.05)	7.65 (16.05)	4.20 (11.83)	860
Endosulfan - *Bt* – *Ha*NPV – *Bt*	26.45 (30.96)	13.20 (21.30)	12.45 (20.62)	10.60 (18.00)	9.75 (18.19)	5.15 (13.12)	720
NSKE – *Bt*-*Ha*NPV-*Bt*	28.25 (31.97)	14.25 (22.18)	12.20 (20.44)	11.30 (19.64)	9.25 (17.71)	5.30 (13.31)	820
Endosulfan (Three times)	26.20 (30.79)	11.75 (19.50)	9.25 (17.71)	7.8 (16.22)	7.45 (15.84)	4.20 (11.83)	890
Control (Untreated)	24.30 (29.53)	29.50 (32.90)	28.35 (32.17)	27.65 (31.73)	19.70 (26.35)	8.50 (16.95)	520
CD (P=0.05)	NS	0.76	0.87	0.85	0.65	0.56	30.00

PAU, Ludhiana

The experiment was conducted in a farmer's field at village Boparai (Ludhiana) with a plot size of 100 m^2. The data on pod damage was recorded on the basis of 10 plants in each plot, 5 days after the last spray. The damage to the seeds was recorded at maturity on the basis of 100 seeds from each plot. The data on the seed yield was recorded on whole plot basis.

The pod damage was 13.71 per cent in the control and it was significantly higher than all the combinations except NSKE-*Bt*-*Ha*NPV-*Bt* (Table 94). The lowest incidence (4.83%) was recorded in endosulfan and it was on par with alternate sprays of *Ha*NPV and *Bt*, but was significantly better than all other combinations. The seed damage in all the treatments was significantly lower than control (38.49%). The lowest seed damage was recorded in endosulfan (16.62%) and it was on par with alternate sprays of *Ha*NPV and *Bt* (19.84%) and *Bt*-*Ha*NPV-endosulfan-*Bt* (21.14%) and was significantly lower than the remaining treatments. The grain yield in all the treatments except NSKE-*Bt*-*Ha*NPV-*Bt* was significantly higher than control (6.05 q/ha). Highest yield (12.14 q/ha) was obtained with endosulfan and it was on par with alternate sprays of *Ha*NPV and *Bt* (10.32 q/ha) but was significantly better than all other combinations.

Table 94. Efficacy of different combination of biopesticides for the control of pod borer complex of pigeonpea

Treatment	Mean pods infestation	Mean seed Damage	Grain yield (q/ha)
Bt-*Ha*NPV-*Bt*-*Ha*NPV	6.98 (15.30)	19.84 (26.37)	10.32
Bt-*Ha*NPV-Endosulfan-*Bt*	8.71 (16.99)	21.14 (27.32)	8.97
Endosulfan-*Bt*-*Ha*NPV-*Bt*	9.53 (17.81)	20.21 (26.51)	9.62
NSKE-*Bt*-*Ha*NPV-*Bt*	11.07 (19.33)	29.53 (32.89)	6.88
Endosulfan	4.83 (12.56)	16.62 (23.89)	12.14
Control	13.71 (21.65)	38.79 (38.49)	6.05
CD(P=0.05)	(3.65)	(4.82)	2.29

The pooled data of three years presented in Table 95 revealed that the pod infestation in all the treatments was lower than control (23.00%). The infestation of pod borers was lowest (7.37%) in endosulfan. Among the biopesticides the lowest incidence was recorded in alternate sprays of *Ha*NPV and *Bt*. The mean seed damage was lowest (16.06%) in endosulfan followed by 18.42 per cent in alternate sprays of *Ha*NPV and *Bt*. All the treatments had increased the grain yield than control (6.07 q/ha). The highest yield (11.84q/ha) was recorded from endosulfan sprayed plots. Among the biopesticides alternate sprays of *Ha*NPV and *Bt* gave the highest yield (10.65 q/ha).

ANGRAU, Hyderabad

Variety ICPL-87 was used and plots size was 50 m^2. *BTK*-II (Bioasp) @ 1.0 kg/ha was used as *Bt* product and sprays administered during evening hours. Larval population was counted on ten randomly selected plants per plot before and seven days after each spray. Per cent pods damaged was estimated on 10 randomly selected plants per plot.

Table 95. Efficacy of different combinations of biopesticides for the control of pod borer complex of pigeonpea

Treatment	Mean pod infestation (%)				Mean seed damage			Grain yield (q/ha)			
	1997	1998	1999	Mean	1998	1999	Mean	1997	1998	1999	Mean
Bt-*Ha*NPV-*Bt*-*Ha*NPV	11.60 (19.79)	15.10 (24.87)	6.98 (15.30)	11.22	17.00	19.84 (26.37)	18.42	12.91	8.73	10.32	10.65
Bt-*Ha*NPV-Endosulfan-*Bt*	13.30 (21.01)	17.60 (24.82)	8.71 (16.99)	13.20	18.50	21.14 (27.32)	19.82	12.44	6.80	8.97	9.40
Endosulfan- *Bt*-*Ha*NPV-*Bt*	16.60 (23.96)	19.50 (26.18)	9.53 (17.81)	15.21	24.00	20.21 (26.51)	22.10	11.54	6.46	9.62	9.20
NSKE-*Bt*-*Ha*NPV-*Bt*	19.90 (26.41)	22.10 (28.00)	11.07 (19.33)	17.69	26.26	29.53 (32.89)	27.89	8.58	5.38	6.88	6.94
Endosulfan	5.90 (13.97)	11.40 (19.72)	4.83 (12.56)	7.37	15.50	16.62 (23.89)	16.06	14.32	9.07	12.14	11.84
Control	24.10 (29.34)	31.20 (33.98)	13.71 (21.65)	23.00	31.00	38.79 (38.49)	34.89	8.09	4.08	6.05	6.07
CD (P=0.05)	(4.58)	(4.12)	(3.65)	-	NS	(4.82)	-	3.05	1.21	2.29	-

All treatments were superior to control both in reducing larval population and extent of damage (Table 96). There was significant difference in the yield of control plot and treatment plots. In the treatment where 3 sprays of endosulfan were given the lowest mean larval population (12.75) was recorded. Among the rest, sequential application of *Bt-Ha*NPV-endosulfan-*Bt* recorded lowest mean larval population (12.94) followed by *Bt-Ha*NPV-*Bt-Ha*NPV (16.88). As far as pod damage is concerned similar trend was noticed, with endosulfan recording the lowest pod damage (10.73%) followed by *Bt-Ha*NPV-endosulfan-*Bt* (19.06%) and *Bt-Ha*NPV-*Bt-Ha*NPV (22.03%). Endosulfan gave the highest yield (773 kg/ha) followed by *Bt-Ha*NPV-endosulfan - *Bt* (718 kg/ha).

Table 96. Effect of different sequential applications of various bioagents against *H. armigera* on pigeonpea

Treatment	Precount of larval population Average	Larval population 7 days after spray (on 10 plants)				Mean larval popul-ation	Per cent pod damage	Yield (kg/ha)
		I	II	III	IV			
*Bt-Ha*NPV-*Bt-Ha*NPV	22.00 (4.68)	25.50 (5.04)	13.25 (3.62)	12.50 (3.52)	16.25 (4.01)	16.88 (4.11)	22.03 (27.98)	615
*Bt-Ha*NPV-endosulfan-*Bt*	18.05 (4.30)	19.75 (4.43)	13.50 (3.67)	10.50 (3.24)	8.00 (2.81)	12.94 (3.60)	19.06 (25.86)	718
Endosulfan-*Bt-Ha*NPV-*Bt*	23.75 (4.87)	20.75 (4.53)	16.75 (4.08)	17.50 (4.17)	11.00 (3.31)	16.50 (4.06)	(28.07)	678
NSKE-*Bt-Ha*NPV-*Bt*	23.50 (4.83)	26.00 (5.09)	20.75 (4.55)	15.50 (3.92)	18.00 (4.23)	20.60 (4.48)	23.80 (29.16)	545
Endosulfan (3 sprays)	21.50 (4.63)	17.00 (4.11)	37.75 (3.86)	10.25 (3.16)	8.75 (2.94)	12.75 3.56)	10.73 (19.12)	773
Control	22.25 (4.71)	37.75 (6.14)	43.25 (6.57)	36.00 (5.99)	30.25 (5.50)	36.81 (6.07)	38.06 (38.06)	380
CD (P=0.05)	NS	(0.55)	(0.48)	(0.63)	(0.57)	(0.20)	(2.89)	66.30

Sequential application of *Bt-Ha*NPV-endosulfan-*Bt* proved on par with endosulfan treatment. The treatment where *Bt* and *Ha* NPV were sprayed alternatively also proved to be promising with lower larval population and pod damage and higher yield (Table 96).

The results of the trial in the three centres revealed that spraying endosulfan three times at 15 days interval was best followed by alternate sprays of *Bt* and *Ha*NPV at Ludhiana and *Bt-Ha*NPV-endosulfan-*Bt* at Hyderabad and Coimbatore centres.

4.21.2. NPV based management of *Helicoverpa armigera* in chickpea

TNAU, Coimbatore

A field trial was laid out in a farmer's field at S.S.Kulam with following treatments in a randomized block design replicated four times.

1. *Ha*NPV ($1.5x10^{12}$POB/ha) + 10% crude sugar + 10% cotton kernel extract + 0.1% egg yolk + 1% ranipal
2. *Ha*NPV ($1.5x10^{12}$POB/ha) alone + 0.5% teepol
3. *Ha*NPV - NSKE (5%) alternation
4. *Ha*NPV - endosulfan (350g a.i./ha) alternation
5. Endosulfan (350g a.i./ha)
6. Control

The sprays were given whenever population exceeded 2 larvae/10 plants. Totally there were two sprays during the season. Pod damage was significantly less and the yield high in plots sprayed with *Ha*NPV - endosulfan alternation and *Ha*NPV - NSKE 5 per cent alternation (Table 97).

Table 97. Efficiency of combinations of biopesticides for the control of pod borer in chickpea

Treatment	Pre-count (per cent pod damage)	Mean per cent pod borer damage after 7 days		Seed damage (%)	Yield kg/ha
		I spray	II spray		
*Ha*NPV + 10% crude sugar + 10 % CSKE	22.25 (28.15)	14.75 (22.60)	10.25 (18.67)	6.25 (14.48)	966
*Ha*NPV + 0.5% teepol adjuvant	18.50 (25.48)	13.60 (21.64)	9.75 (18.20)	7.25 (15.62)	1067
*Ha*NPV - NSKE alternation	18.50 (25.48)	11.20 (19.55)	6.50 (14.77)	4.50 (12.25)	1148
*Ha*NPV- Endosulfan alternation	21.25 (27.46)	10.25 (18.67)	6.50 (14.77)	4.25 (11.90)	1196
Endosulfan	24.30 (24.53	12.25 (20.49)	10.40 (18.81)	6.70 (15.00)	973
Control-untreated	22.50 (28.32)	24.25 (29.50)	28.25 (32.11)	13.25 (21.24)	657
CD (P=0.05)	NS	1.05	1.60	1.25	5.8

PAU, Ludhiana

The experiment on the NPV based management of *H. armigera* on chickpea was carried out at Regional Research Station, Bathinda. The experiment was carried out in a randomized block design with four replications in a plot size of 100m². *Ha*NPV alone and in combination with different adjuvants was tested in a two-spray schedule. The population of *H. armigera* was recorded from 10 plants selected at random 5 days after each spray. The per cent pods damaged were recorded on the basis of 10 plants in each plot. The grain yield was recorded on whole plot basis.

The data presented in Table 98 reveal that after the first spray the larval population was significantly lower in NPV+Gur+Ranipol+Teepol+Cotton seed oil and NPV+Teepol only. However, after second spray the larval population was significantly lower in all the treatments than control. The pod damage was significantly lower than control and all other treatments were on par with control. The yield varied from 1.68 q/ha in control to 2.78 q/ha in NPV+different adjuvants, but the differences were not significant.

Table 98. Evaluation of *Ha*NPV for the control of *Helicoverpa armigera* on chickpea

Treatment	Mean larval population /plant*		Per cent pods damaged **	Yield (q/ha)
	After first spray	After second spray		
NPV+Gur+Ranipol +Teepol + Oil	0.20 (0.44)	0.30 (0.54)	28.66 (32.25)	2.78
NPV + Teepol	0.22 (0.47)	0.37 (0.60)	26.51(30.95)	2.53
NPV	0.40 (0.62)	0.27 (0.52)	26.47(30.92)	2.36
NPV/Endosulfan	0.32 (0.57)	0.27 (0.50)	26.75(31.08)	2.59
Endosulfan	0.37 (0.61)	0.15 (0.38)	11.12(19.39)	2.65
Control	0.42 (0.65)	0.55 (0.77)	32.68(34.80)	1.68
CD (P=0.05)	(0.14)	(0.10)	(5.29)	NS

* Figures in parentheses are √ transformation

** Figures in parentheses are arc sine transformation

4.22. Biological suppression of oilseed crop pests

4.22.1 Testing *Metarhizium anisopliae* and *Bacillus popilliae* against white grubs in groundnut (GAU, Anand)

To evaluate the efficacy of *Metarhizium anisopliae* and *Bacillus popilliae* against white grubs in groundnut an experiment was laid out at farmers' field in Nava village of Kapadvanj District using variety Gujarat G2 with four treatments replicated six times. The four treatments were furrow application at the time of sowing of *Metarhizium anisopliae* (0.5 kg/h), *Bacillus popilliae* (0.5 kg/h), seed treatment of chlorpyriphos (5.0g. *a.i.*/kg seed)) and an untreated control.

The initial grub population at the time of ploughing was 3.8 grubs/m^2. Crop damage assessment was done by recording plant mortality and yield. Maximum plant stand (17.63) was observed in the plots treated with *M. anisopliae*, followed by chlorpyriphos (17.55). The plots treated with *B. popilliae* and control showed plant stand of 17.54% and 17.04%, respectively. Similar results were also exhibited in the yield records with *M. anisopliae* giving a maximum yield of 932 kg/h.

4.22.2. Biological control of mustard aphid, *Lipaphis erysimi* (PAU, Ludhiana)

The experiment was conducted at Regional Research Station, Bathinda in a randomized block design with three replications in a plot size of 250m^2. The bioagents were released/sprayed twice at 20 days interval. The population of the mustard aphid was recorded from 10 plants (10 cm central shoot) selected at random in each plot at weekly interval. The population of the syrphid larvae was recorded from 10 plants (10 cm central shoot) selected at random, twice in the season.

The mustard aphid appeared late in the season on the crop. On Feb, 22 and March 3, 2000 there was no significant difference in the mustard aphid population in biocontrol and control. However, the population in sprayed plants was significantly lower than control. The population on March 17 declined considerably and the population in biocontrol plot was significantly lower than the control plot. The population of the syrphid fly larvae was comparatively low in insecticidal sprays than biocontrol and control plots. The yield in the insecticidal spray (13.85 q/ha) was significantly higher than control (9.53 q/ha) which was on par with *I. scutellaris* (10.90 q/ha) and *V. lecanii* (11.22 q/ha) (Table 99).

The mustard aphid appeared late in the season and for a short span, no valid conclusion could be made of the effect of biocontrol treatments.

Table 99. Evaluation of biocontrol agents for the control of mustard aphid

Treatment	Mean number of aphids/plant			Mean number of syrphid larvae per plant		Yield (q/ha)
	22-2-'00	3-3-'00	17-3-'00	8-3-'00	17-3-'00	
Ischiodon scutellaris (1000 adults/ha)	116.7 (10.75)	115.5 (10.71)	16.3 (4.02)	0.2	1.4	10.90
Verticillium lecanii (10^8 conidia/ml)	125.0 (10.89)	103.8 (10.03)	14.6 (3.83)	0.4	1.0	11.22
Chemical control (Methly demeton 625 ml/ha)	3.8 (2.01)	4.4 (2.19)	16.5 (4.09)	0	0.2	13.85
Control	168.8 (13.02)	152.3 (10.34)	27.5 (5.33)	0.2	0.6	9.53
CD (P=0.05)	(3.70)	(4.20)	(1.27)	-	-	2.45

Releases of *I. scutellaris* and spraying of *V. lecanii* were done on February 15, 2000 and March 6, 2000; One spray of Methyl demeton was done on February 15, 2000 and Figures in parentheses are √ transformation.

4.23. Biological suppression of rice pests

4.23.1 Field evaluation of *Trichogramma japonicum* and *T. chilonis* against rice stem borer and leaf folder

4.23.1.1. AAU, Jorhat

The experiment for the evaluation of *T. japonicum* and *T. chilonis* against rice stem borer and leaf folder was conducted in the farmer's field at Kakadonga, Dergaon during rabi 1999. In this experiment *Trichogramma japonicum* and *T. chilonis* @ 50,000/ ha and 1,00,000/ha were released at weekly interval and a need-based spray of insecticide was also given. The dead heart per cent was 8.35% in the unreleased plot against 2.04%, 4^{th} week after the field release of the parasitoids while it was just 2.22% 3^{rd} week after the field release of the egg parasitoids against 8.00% in the unreleased plot. There was no difference between the release rates and need based insecticidal application in checking the formation of dead heart (Table 100). The per cent infestation of leaf folder was lowest (1.77%) in the 4^{th} week after the field release of egg parasitoids as against 5.33% in the unreleased plot (Table 101).

Table 100.Evaluation of *T. japonicum* and *T. chilonis* against rice stem borer (Rabi)

Treatment	Pre released	Per cent dead hearts due to stem borer (at weekly interval)				Per cent white ear heads	Yield kg/ha
		1	2	3	4		
T. japonicum +*T. chilonis* @ 50,000 / ha	3.17	3.86	3.14	2.22	2.04	2.90	4373
T. japonicum + *T.chilonis* @ 1,00,000 / ha	3.24	3.51	2.67	2.34	2.97	2.98	4107
Insecticide	3.30	4.22	3.91	2.53	2.39	2.18	4026
Control	3.51	4.99	4.71	8.00	8.35	7.56	3182
CD (P=0.05)	NS	0.98	1.15	1.13	1.07	0.68	339.05

Table 101.Field evaluation of *T. japonicum* and *T. chilonis* against rice leaf folder (Rabi)

Treatment	Pre-release population	Mean infestation of leaf folder (at weekly interval)			
		1	2	3	4
T. japonicum + *T. chilonis* @ 50,000/ha	2.19	2.49	2.11	1.99	1.77
T. japonicum + *T. chilonis* @ 1,00,000/ha	1.68	2.78	2.54	2.05	2.28
Need based insecticide	1.33	2.86	3.06	2.19	2.06
Control	2.50	2.50	4.23	5.06	5.33
CD(P=0.05)	NS	NS	0.81	0.61	1.22

The evaluation was also done during Kharif 1999 in the farmer's field at Dewangaon, Kakajan The results presented in Table 102 reveals that the per cent dead heart was 2.40% in the 4[th] week after the field release of *Trichogramma* @ 50,000/ha against 10.86% in the unreleased plot followed by 2.10% dead heart in the 6[th] week after the field release of the parasite against 9.08% dead heart in the unreleased plot. The white ear head population was lowest (1.65%) in the released plot against 8.93% in the unreleased plot. The leaf folder damage was lowest (0.99%) in the 4[th] week after the field release of *Trichogramma* @ 50,000/ha against 4.26% in the unreleased plot (Table 103). *Bt* was unable to bring down dead heart or white ear percentages and was also not so effective for leaf folder.

Table 102.Evaluation of *T. japonicum, T. chilonis* and *Bt* against rice stem borer (Kharif)

Treatment	Pre released	Per cent dead hearts at weekly interval						White ear heads (%)	Yield (Kg/ ha)
		1	2	3	4	5	6		
T. japonicum+ *T. chilonis* @ 50,000/ha	1.68	2.50	2.31	3.30	2.40	2.89	2.10	3.50	4176
T. japonicum+ *T. chilonis* @ 1,00,000/ha	1.35	2.44	2.69	3.56	2.58	2.30	2.76	1.65	4101
Bt (Delfin)	2.20	3.42	2.88	3.98	4.13	4.01	4.28	2.51	3723
Insecticide	1.62	2.71	2.99	2.08	3.32	4.42	4.37	2.52	4069
Control	3.91	2.40	7.13	9.56	10.86	10.48	9.08	8.93	3276
CD(P=0.05)	NS	NS	0.98	0.64	1.06	1.78	2.06	0.95	576.98

Table 103.Evaluation of *T. japonicum, T. chilonis* and *Bt* against rice leaf folder (Kharif)

Treatment	Pre released	Mean per cent leaf folder damaged leaves at weekly intervals					
		I	II	III	IV	V	VI
T. japonicum @ 50,000/ha	0.78	1.01	1.13	1.52	0.99	1.70	1.76
T. japonicum @ 1,00,000/ha	0.84	1.12	1.16	1.39	0.95	2.91	2.72
Bt (Delfin)	2.63	1.38	1.55	1.54	0.64	2.66	1.95
Insecticide	0.99	1.19	0.98	1.35	1.44	3.09	1.36
Control	1.94	1.79	4.00	3.64	4.26	5.30	3.36
CD (P=0.05)	NS	0.66	0.51	0.53	0.40	0.74	1.06

The field recovery of the *T. japonicum* was estimated by placing *Corcyra* egg cards and recovery was to the extent of 18-21%.

4.23.1.2. KAU, Thrissur

The experiment was laid out during October 1999 in confounded block design with five treatments and eight replications. Observations on leaf roller and stem borer infestation were recorded from five hills in each replication. Per cent infestation of rice leaf folder and rice stem borer was low to draw any conclusions.

4.23.1.3. PAU, Ludhiana

The experiment on the evaluation of *Trichogramma chilonis* and *T. japonicum* against leaf folder of rice and stem borer was conducted in farmer's field at Khudi Kalan (District Sangrur). Simultaneous releases of *T. chilonis* and *T. japonicum* were made 30 DAT at three dosages i.e. 50,000, 75,000 and 1,00,000 per ha per week. The plot size was 0.4 ha for each treatment. The per cent leaves folded and per cent dead hearts were recorded on the basis of 10 hills each from 3 spots at 75 DAT. Per cent white ears were recorded near maturity on the basis of 30 hills each from 3 spots in a plot. The yield was recorded on whole plot basis (Table 104).

Table 104. Effectiveness of *T. chilonis* and *T. japonicum* for the control of leaf folder and stem borer of rice at Khudi Kalan (Sangrur, Punjab)

Treatment	Per cent leaves folded	Per cent dead hearts	Per cent white ears	Yield (q/ha)
T. chilonis + *T. japonicum* 1,00,000/ha	3.27 (10.29)	2.60 (9.22)	4.07 (11.60)	65.72
T. chilonis + *T. japonicum* 75,000/ha	7.67 (15.98)	4.33 (11.86)	5.17 (12.97)	60.48
T. chilonis + *T. japonicum* 50,000/ha	10.43 (18.79)	8.00 (16.37)	11.67 (19.90)	58.08
Monocrotophos @ 1.4 l /ha	4.77 (12.55)	2.40 (8.85)	3.50 (10.76)	65.01
Control	14.07 (21.98)	10.37 (18.71)	16.80 (24.14)	50.68
CD (P=0.05)	(3.30)	(3.69)	(3.87)	4.01

*Eight releases were made at seven days interval, commencing from 30 days after transplanting

Figures in parentheses are arc sin transformation

The evaluation of different dosages of *T. chilonis* and *T. japonicum* was carried out for four years (1996 to 1999). The data presented in Table 105 indicate that the mean incidence of leaf folder was 20.1 per cent in control while the incidence in insecticidal spray was 6.7 per cent. The incidence in the plots where the parasitoids were released @ 1,00,000 per ha was 8.0 per cent. The dead hearts were minimum (1.9%) in higher dosages of both the parasitoids, while the incidence was 2.5 per cent in the insecticidal spray as compared to 8.2 per cent in the control (Table 106). The higher dosage of the parasitoid recorded white ears only to the extent of 7.2 per cent while the lower dosages were less effective (Table 107). The yield in all the treatments was significantly higher than control (48.66 q/ha) except lower dosage of the parasitoid (52.32 q/ha) (Table 108). The highest yield (62.58 q/ha) was obtained in insecticidal spray and it was on par with higher dosages of the parasitoid (62.18q/ha) but was significantly higher than the lower and medium dosages of the parasitoids.

Table 105. Effectiveness of *T. chilonis* and *T. japonicum* for the control of rice leaf folder from 1996-99

Treatment	Per cent leaves folded			
	1996	1997	1999	Mean
T. chilonis + *T. japonicum* 50,000/ha	19.7 (26.36)	18.4 (25.44)	10.4 (18.79)	16.2
T. chilonis + *T. japonicum* 75,000/ha	17.5 (24.75)	12.8 (20.96	7.8 (15.98)	12.7
T. chilonis + *T. japonicum* 1,00,000/ha	14.5 (22.38)	6.2 (14.38)	3.3 (10.29)	8.0
Monocrotophos @ 1.4 l /ha	8.3 (16.75)	7.0 (15.30)	4.8 (12.55)	6.7
Control	22.9 (28.60)	23.2 (28.81)	14.1 (21.98)	20.1
CD (P=0.05)	(1.86)	(6.35)	(3.30)	

* Six, nine and eight releases were made at 7-10, 7 and 7 days interval during 1996, 1997 and 1999, respectively.

Table 106. Effectiveness of *T. chilonis* and *T. japonicum* for the control of stem borer from 1997-99

Treatment	Per cent dead hearts			
	1997	1998	1999	Mean
T. chilonis + T. japonicum 50,000/ha	6.6 (14.82)	6.8 (15.80)	8.0 (16.37)	7.1
T. chilonis + T. japonicum 75,000/ha	4.0 (11.54	3.7 (11.12)	4.3 (11.86)	4.0
T. chilonis + T. japonicum 1,00,000/ha	1.5 (7.60)	1.7 (7.53)	2.6 (9.22)	1.9
Monocrotophos @ 1.4 l /ha	2.8 (9.63)	2.2 (8.49)	2.4 (8.85)	2.5
Control	6.6 (14.83)	7.7 (16.15)	10.4 (18.71)	8.2
CD (P=0.05)	(6.04)	(2.98)	(3.69)	

* Nine, eight and eight releases were made at 7 days interval in each year from 1997, 1998 and 1999, respectively

Table 107. Effectiveness of *T. chilonis* and *T. japonicum* for the control of rice stem borer from 1996 to 1999 in Punjab.

Treatment	Per cent white ears				
	1996	1997	1998	1999	Mean
T. chilonis + T. japonicum 50,000/ha	23.4 (28.90)	15.0 (22.82)	12.5 (20.70)	11.7 (19.90)	15.6
T. chilonis + T. japonicum 75,000/ha	21.0 (25.25)	9.0 (17.49)	5.5 (13.59)	5.2 (12.97)	10.2
T. chilonis + T. japonicum 1,00,000/ha	16.6 (24.07)	3.3 (10.49)	5.0 (12.92)	4.1 (11.60)	7.2
Monocrotophos @ 1.4 l /ha	12.6 (20.75)	3.7 (11.08)	5.0 (12.92)	3.5 (10.76)	6.2
Control	26.3 (30.82)	19.0 (25.85)	16.5 (23.97)	16.8 (24.14)	19.7
CD (P=0.05)	(3.64)	(4.83)	(3.31)	(3.87)	

· Six, nine, eight and eight releases were made at 7-10, 7, 7 and 7 days interval during 1996, 1997, 1998 and 1999, respectively.

Table 108. Effectiveness of *T. chilonis* and *T. japonicum* for the control of rice stem borer and leaf folder from 1996 to 1999 in the Punjab

Treatment	Yield (Q/ha)				
	1996	1997	1998	1999	Mean
T. chilonis + *T. japonicum* 50,000/ha	50.46	44.62	56.10	58.08	52.32
T. chilonis + *T. japonicum* 75,000/ha	51.23	50.69	61.60	60.48	56.00
T. chilonis + *T. japonicum* 1,00,000/ha	55.24	64.76	63.00	65.72	62.18
Monocrotophos @ 1.4 l /ha	60.38	62.61	62.00	65.01	62.50
Control	48.71	39.94	55.30	50.68	48.66
CD (P=0.05)	3.93	4.64	1.30	7.01	4.22

· Six, nine, eight and eight releases were made 7-10, 7, 7 and 7 days interval during 1996, 1997, 1998 and 1999, respectively.

It can be concluded that 6-9 releases of *T. chilonis* + *T. japonicum* each @ 1,00,000 per ha per week starting from 30 days after transplanting reduced the incidence of leaf folder and stem borer and increased the yield significantly. The releases of the parasitoids were as effective as insecticidal spray. However, the lower dosages (50,000 & 75,000 per ha) were less effective.

4.23.1.4. MPKV, College of Agriculture, Pune

A field experiment was conducted on the research farm of Agril. Research Station, Vadgaon Maval (Pune) on paddy crop (var. Ambemohor). The plot size was 50 m^2. The trial was laid out in RBD with five replications and six treatments. The treatments were *T. chilonis* @ 50,000 adults / ha /release six releases at weekly interval (T_1); *T. japonicum* @ 50,000 adults / ha / release-six releases at weekly interval (T_2); *T. japonicum* @ 50,000 adults / ha / release + *T. chilonis* @ 50,000 adults/ha/release three simultaneous releases at weekly interval(T_3); *T. japonicum* @ 1,00,000 adults / ha / release + *T. chilonis* @ 1,00,000 adults / ha /release- three simultaneous releases at weekly interval (T_4); Chemical control: three alternate sprays of endosulfan (0.07%) and monocrotophos 0.04% as per recommendation (T_5) and untreated control (T_6).

Releases of parasitoids and spray of insecticide were commenced 25 days after transplanting of the crop. Observations on white earheads/m^2 and yield per plot were recorded at harvest. For leaf folder, healthy and folded/damaged leaves per m row at 5 places in each treatment plot were recorded at weekly interval till termination of the treatment to compute per cent infestation.

Significant differences among treatments in respect of stem borer and leaf folder infestation, and yield of paddy was noticed (Table 109). The treatment with six releases of *T. japonicum* @ 50,000 adults/ha/release at weekly interval recorded minimum white ear heads (4.08%) due to stem borer, and it was on par with chemical control schedule. Release of *T. chilonis* @ 50,000 adults/ha/release six times at weekly interval and the chemical control schedule were found equally effective showing minimum leaf folder infestation (3.03%). Maximum yield (30.8 q/ha) was recorded with six releases of *T. japonicum* @ 50,000 adults/ha/release, and it was on par with other treatments except untreated control.

Table 109. Efficacy of trichogrammatids for the control of stem borer and leaf folder on rice

Treatment	White ear heads due to stem borer(%)	Leaf folder infestation	Yield (q/ha)
T. chilonis @ 50,000 adults/ha/release – six releases	5.15 (13.18)	3.03 (9.98)	24.0
T. japonicum @ 50,000 adults / ha/release– six releases	4.08 (11.68)	4.37 (12.11)	30.8
T. japonicum @ 50,000 adults/ha/release + *T. chilonis* @ 50,000 adults/ha/release –	5.01 (12.92)	4.06 (11.68)	28.6
T. japonicum @ 1,00,000 adults/ha/release + *T. chilonis* @ 1,00,000 adults / ha/release - three simultaneous releases	4.49 (12.25)	3.86 (11.39)	25.6
Chemical control : alternate sprays of endosulfan 0.07% and monocrotophos 0.04% - three sprays	4.21 (11.83)	3.03 (9.98)	28.8
Untreated control	7.39 (15.79)	6.35 (14.54)	21.2
C.D. (P=0.05)	0.20	0.11	8.52

Figures in parentheses are angular transformations

4.23.2. Evaluation of biocontrol based IPM in rice

4.23.2.1. AAU, Jorhat

Biocontrol based IPM was evaluated in comparison with chemical control in a farmer's field at Kakadonga, Dergaon during Rabi 1999. The release of *Trichogramma* @ 50,000/ha could check the dead heart significantly. The occurrence of the dead heart due to stem borer in the release plot ranged from 2.13% to 3.53% whereas the percentage dead heart in the control plot ranged from 4.92% to 10.15%. The white ear head population was also low (2.67%) in *Trichogramma* released plot as compared to control plot (9.52%) (Table 110). The leaf folder population was very low during rabi and the percentage leaf folder damaged leaves was lowest (1.13%) in the released plots compared to unreleased plot (4.51%) (Table 111).

Table 110. Effect of biocontrol based IPM on the incidence of rice stem borer (Rabi)

Treatment	Pre release	Per cent dead hearts at weekly intervals				White ear heads (%)	Yield kg/h
		1	2	3	4		
Biocontrol	6.17	3.40	2.13	3.58	3.53	2.67	4380
Chemical control	6.24	4.99	4.31	3.25	4.63	3.19	4135
Control	6.93	4.92	7.67	10.15	9.28	9.52	3182
CD (P=0.05)	NS	NS	1.24	1.29	1.03	1.00	320.23

Table 111. Effect of biocontrol based IPM on the incidence of leaf folder (Rabi)

Treatment	Prerelease	Per cent leaves damaged by leaf folder at weekly interval			
		1	2	3	4
Biocontrol	3.03	1.98	1.37	1.13	1.16
Chemical control	3.18	2.04	1.50	1.26	1.62
Control	3.18	2.88	2.02	4.51	3.58
CD (P=0.05)	NS	0.60	0.41	0.64	0.34

The results of a similar trial conducted at RARS, Titabar during Kharif 1999 revealed that significantly good control of stem borer was achieved in the released plot (2.54%) against the unreleased plot (7.35%) 6 weeks after the field release of *Trichogramma*. The white ear head population was also low (3.68%) in the *Trichogramma* release plot (3.68%) against the unreleased plot (8.23%) (Table 112). The leaf folder population was very low during the season. The lowest percentage of leaf folder damaged leaves of 1.32% was recorded 5 weeks after the field release of the *Trichogramma* against 5.73% in the unreleased plot (Table 113).

Table 112. Effect of biocontrol based IPM on the incidence of stem borer (Kharif)

Treatment	Pre release (per cent dead hearts)	Mean per cent dead heart at weekly intervals						White ear heads (%)
		I	II	III	IV	V	VI	
T. japonicum	3.37	2.30	3.70	2.22	2.06	2.41	2.54	3.68
Insecticide	2.57	2.17	1.89	1.59	1.62	1.69	2.35	3.33
Control	3.48	3.06	4.56	3.64	4.44	6.07	7.35	8.23
CD(P=0.05)		0.63	0.89	0.89	0.80	1.10	1.43	1.40

Table 113. Effect of biocontrol based IPM on the incidence of leaf folder (Kharif)

Treatment	Prerelease count	Per cent leaves damaged by leaf folder at weekly interval					
		1	2	3	4	5	6
T. japonicum	2.52	0.97	1.36	1.26	1.31	1.32	1.52
Insecticide	2.13	0.79	0.97	0.98	1.05	1.25	2.66
Control	3.31	1.76	2.10	1.33	3.15	5.73	5.54
CD (P=0.05)	NS	0.32	0.34	NS	0.36	0.62	0.71

4.23.2.2. KAU, Thrissur

The experiment was laid out in confounded block design during October 1999 with three treatments and eight replications. Observations on leaf folder, stem borer infestation and yield showed low infestation and no significant difference between the treatments neem + biocontrol and chemical control for total weight and grain weight, number of healthy ear heads present. Minimum number of white ear heads was seen in the treatment neem + biocontrol.

4.23.2.3. TNAU, Coimbatore

A field experiment was conducted to evaluate the efficacy of biocontrol based IPM in ASD 18 variety with three treatments.

i. Release of *T. japonicum* and *T. chilonis* @ 5,00,000/ha thrice after observing the moth activity to control yellow stem borer and leaf folder at weekly interval.
ii. Spraying of endosulfan (0.07%) thrice on 50^{th}, 70^{th} and 90^{th} days.
iii. Control

Biocontrol based IPM treatment recorded significantly higher yield and less yellow stem borer incidence followed by need based application of chemicals. The incidence of leaf folder in different treatments was below ETL throughout the cropping period and was on par with each other (Table 114).

Table 114. Evaluation of biocontrol based IPM in rice

Treatment	Stem borer damage (%)		White ear damage (%)		Lead folder damage (%)		Yield (kg/ha)
	30	45	90	110	60	75	
BIPM	4.8^{c}	4.1^{c}	5.1^{d}	7.3^{d}	3.8^{a}	1.8^{a}	6236^{a}
Need based protection	5.9^{b}	5.1^{b}	7.7^{c}	10.7^{c}	3.4^{a}	2.7^{a}	5744^{b}
Farmer's practice	6.2^{b}	6.0^{b}	8.3^{b}	11.4^{b}	3.7^{a}	3.4^{a}	5227^{c}
Untreated control	7.7^{a}	8.0^{a}	12.5^{a}	16.0^{a}	4.7^{a}	3.8^{a}	5113^{d}

Values with the same superscript do not differ significantly.

4.23.2.4. PAU, Ludhiana

The experiment on the evaluation of biocontrol based IPM on rice was conducted in farmer's field at village Khudi Kalan (District: Sangrur). Two egg parasitoids, *T. chilonis* and *T. japonicum* were released @ 1,00,000 each per week 30 DAT. Eight releases were made during the season. The releases were compared with endosulfan (0.07%) and control. The per cent leaf folder and dead hearts were recorded 75 DAT. The per cent white ears were recorded near maturity. The yield was recorded on whole plot basis. The results are given in Table 115. Biocontrol was better than chemical control and untreated control for all the parameters including yield.

Table 115. Evaluation of biocontrol based IPM on rice in the Punjab during 1999

Treatment	Per cent leaves folded	Per cent dead hearts	Per cent white ears	Yield (q/ha)
Biocontrol	3.62	2.17	3.98	66.10
Endosulfan (0.075)	4.13	2.90	4.16	65.72
Control	13.96	10.76	16.82	49.88

4.23.3. Survey and quantification of natural enemy complex in rice

4.23.3.1. AAU, Jorhat

At three locations of Jorhat district, *viz.*, Regional Agricultural Research Station, Titabar, Kakajan Village and instructional Cum Research Farm of Assam Agricultural University, weekly monitoring of population build up of natural enemies of rice insect pest was done. From each location, one 20-cent plot (var. Ranjit) was observed and the farmers were requested not to apply insecticides. The samples were collected at weekly interval with 5 double sweeps in four subplots each (4 m^2) from the last week of August to first week of November. The collected specimens were sent to Division of Entomology, Indian Agricultural Research Institute, New Delhi and Zoological Survey of India, Dehradun for proper identification. A checklist of parasitoids and predators were prepared.

Maximum mean per cent of phytophagous insects (64.07%) was recorded at RARS, Titabar followed by ICR Farm, AAU (61.99%) and Kakajan (58.39%). The phytophagous insects included mostly grasshopper, green leafhopper, rice skipper, gundhi bug, whorl maggot, yellow stem borer, leaf folder and case worm. Maximum per cent predators and parasitoids (30.75 and 10.84, respectively) were recorded at Kakajan. Altogether 24 predators and 28 parasitoids were identified from these three locations and the details are presented in Table 116 and 117.

Table 116.List of parasitoids of rice insect pests of Jorhat (var. Ranjit)

Scientific Name	Host	Host stage	Period of activity	Relative abundance
ORDER : HYMENOPTERA				
Family : Braconidae				
Cardiochiles philippiensis	Rice leaf folder	Larva	August/ October	+++
Bracon sp.	Rice leaf folder	Larva	September/ October	++
Aulosaphes sp.	Rice leaf folder	Larva	September/ October	++
Scutibracon hispae	Rice hispa	Larva	May/June/ August/ September	++
Cotesia flavipes	Yellow stem borer	Larva	September/ October	+++
Tropobracon sp.	Yellow stem borer	Larva	September/ October	+
Myosoma chinensis	Yellow stem borer	Larva	September/ October	++
Macrocentrus sp.	Not known	—	August/ September	++
Family : Ichneumonidae				
Temelucha sp.	Rice leaf folder	Larva	August/ September	++
Xanthopimpla flavolineata	Rice leaf folder	Larva	June/July/ September	++
Ischnojoppa luteator	Yellow stem borer			
Amauromorpha accepta	Yellow and white stem borer			
Family : Scelionidae				
Telenomus cyrus	*Nezara viridula*	Egg	May/June	++
Telenomus sp.	Yellow stem borer	Egg	March/ April	++

Telenomus dignus	Yellow stem borer	Egg	June/September / October	++
Telenomus remus	Yellow stem borer	Egg	September/ October	++
Telenomus rowani	Yellow stem borer	Egg	September/ October	++
Gryon sp.	Rice gundhi bug	Egg	June/July/ September	++
Family : Trichogrammatidae				
Trichogramma japonicum	Yellow stem borer	Egg	March/ April/ September/ October	++
Trichogramma chilonis	Yellow stem borer and leaf folder	Egg	March/ April/ September/ October	++
Family : Bethylidae				
Goniozus sp.	Rice leaf folder	Larva	October/ November	++
Family : Eulophidae				
Tetrastichus schoenobii	Yellow stem borer	Egg	September/ October	++
Chrysonotomyia spp.	Rice hispa	Egg/ Larva		
Family : Chalcididae				
Brachymeria excarinata	Rice leaf folder	Larva	June/July	+
Family : Elasmidae				
Elasmus sp.	Rice leaf folder	Larva	August/ September	+
Family : Pteromalidae				
Trichomalopsis apanteloctena				
Rice skipper	Larva		September/ October	++++
Family : Ceraphronidae				
Aphanogmus manilae	Not known			
Family : Vespidae				
Icaria ferruginea	Not known			
ORDER : DIPTERA				
Family : Tachinidae				
Halydaia luteicornis	Rice skipper	Larva	August	+

Relative abundance: + less common; ++Common; +++Abundant and ++++Probably hyperparasite

Table 117. List of predators of rice insect pests of Jorhat (Var. Ranjit)

Scientific name	Prey species	Predatory stage	Period of activity	Relative abundance
SPIDERS				
Lycosa pseudoannulata (Lycosidae : Araneae)	Green leaf hoppers & Plant hoppers	Both spiderlings and spiders	Throughout the Kharif season	+++
Oxyopes javanus *O. lineatipes*	Moths of stem borer & leaf folders, nymphs of gundhi bugs	Do season	Throughout the Kharif	+++
Argiope catenulata (Araneidae : Araneae)	Green leaf hoppers, Plant hoppers & Grasshoppers	Mainly adults	September/ October	+
Neoscona theisi *N. mukerjei* (Araneidae : Araneae)	Do	Do	September/ October	+
Tetragnatha sp. (Tetragnathidae : Araneae)	Green leaf hoppers & Plant hoppers	Do	Throughout the Kharif season	+++
ORDER : COLEOPTERA				
Family : Coccinellidae				
Micraspis sp.	Nymphs and adults of green leaf hoppers and thrips	Both grubs and adults	August-October	+++
Micraspis sp.			September	+
Harmonia octomaculatus			August-October	++

Cheilomenes sexmaculatus			August-September	+++
Coccinella transversalis			August-October	+++
Coccinella septempunctata			August-October	++
Propylea nr. *japonica*			September	+
Family : Carabidae				
Ophionea nigrofasciata	Leaf folder larvae	Adult	August-September	+++
Casnoidea ishii ishii	Leaf folder larvae	Not known	August-September	+
Anoplogenius microgonus	Not known	Not known	August	+
Family : Staphylinidae				
Paederus fuscipes	Leaf hoppers	Adults	August-October	++
ORDER : ODONATA				
Family : Libellulidae				
Crocothemis servila *Orthetrum savina* *Neurothermis tullia tullia*	Stem borer & leaf folder moths, green leaf hoppers	Adults	August-October	++ ++ ++
Family : Coenagrionidae				
Agriocnemis pygmaea *A. famina famina*	Stem borer and leaf folder moths, green leaf hoppers		August - October	+++ +++

ORDER :ORTHOPTERA				
Family : Tettigoniidae				
Conocephalus longipennis	Leaf hopper nymphs, stem borer eggs	Both nymphs and adults	August-September	++
Family : Gryllidae				
Metioche vittaticollis	Eggs of stem borer, leaf folder and nymphs of plant hoppers	Adults	August-September	+
ORDER : HEMIPTERA				
Family : Miridae				
Cyrtorhinus lividipennis	Green leaf hoppers	Adults	August-September	+

Relative abundance: +Less common; ++Common; +++ Abundant

4.23.3.2. KAU, Thrissur

In Thrissur district, two plots (20 cent) were identified at three panchayats for observations in the rabi season. Sweep net collections were done at weekly intervals. The arthropods obtained from the samples were counted, sorted out and identified up to species level, wherever possible. Phytophages constituted a major part of the total arthropods sampled and their mean number ranged from 30.17 (Mannuthy 2) to 251.5 (Avinissery 2) per net sweeping. Leafhoppers were predominant. The predominant predator was *Cyrtorhinus lividipennis* followed by spiders and coccinellids. Parasitoids were primarily represented by Hymenoptera and varied from 62.50 (Mannuthy 2) to 156.83 (Avinissery 1) in different sites.

4.23.3.3. TNAU, Coimbatore

In Coimbatore district, two plots of 20 cent area each at Agricultural Research Station, Aliyarnagar and Paddy Breeding Station, Tamil Nadu Agricultural University, Coimbatore with variety ADT 36 were fixed during September 1999. Samples were collected at weekly intervals in four subplots with 5 double sweeps in each sub plot. Egg masses of rice yellow stem borer were also collected and parasitism was recorded.

The predators include spiders, coleopterans, dragonflies, damselflies, crickets, grasshoppers and preying mantids. Parasitoids comprised *Tetrastichus* sp., *Telenomus* sp., *Cotesia* sp., *Xanthopimpla* sp., *Temelucha* sp., *Amauromorpha* sp., *Phanerotoma* sp., *Trichogramma* sp. and *Stenobracon* sp. Predators constituted between 19.23 to 23.12 per cent of all arthropods, parasitoids 8.20 ± 3.86 per cent and phytophagous insects 46.25 ± 6.80. Ear head bugs, leafhoppers, stem borers and leaf folders were the major pests.

4.23.3.4. PAU, Ludhiana

The surveys of natural enemies of rice pests were carried out in farmer's fields in Jalandhar and Sangrur districts at weekly interval from July to October 1999. The population of spiders was recorded by double sweeps. The immature stages of different pests were collected from the fields and brought to the laboratory for emergence of the parasitoids or the next stage of the pest.

Spiders were present in the rice ecosystem throughout the season. Nineteen species of spiders belonging to 8 families were recorded. Maximum population was recorded during mid-July to mid-August. *Tetragnatha javana* was the most predominant species (56.28) followed by *Araneus inustus* (12.2), *Oxyopes javanus* (6.430), *Neoscona theisi* (6.36), *Leucauge celebasiana* (6.29) and *Tetragnathus virescens* (3.93).

Three species each of egg and pupal parasitoids and 8 larval parasitoids were recorded from different pests of rice. The highest parasitism was by *Telenomus dignoides* (69.4%) followed by *Psix lacunata* (17.0%) and *Trichogramma japonicum* (2.3%). Among the larval parasitoids the highest parasitism was by *Cotesia ruficrus* (25.0%), followed by *Charops brachypterum* (10.0%). Parasitism by pupal parasitoid *Brachymeria* sp. was low (5.0%).

4.24. Biological suppression of coconut pests

CPCRI, Regional Station, Kayangulam

The opportunistic bacterium isolated from grubs of *Oryctes rhinoceros* was identified as *Pseudomonas alcaligenes*. The bacterium is present as a component of gut microflora of healthy grubs and could become an opportunistic pathogen when the grubs come under stress. Baculovirus disease was confirmed as one of the biotic stress factors. The bacterial infection thus has a negative influence over baculovirus, which is an important biocontrol agent of *O. rhinoceros*. Opportunistic bacterial infection in grubs increased during summer It was also found that occurrence of baculovirus infection in adults and grubs was influenced negatively by average minimum temperature. Occurrence of *Metarhizium anisopliae* was high during rainy season.

Aspergillus flavus isolates AF1 and AF2 obtained from *Stephanitis typicus* and *Opisina arenosella* could cross infect the other pest and bring about 100% mortality within 5-6 days. Biology and feeding potential of the predators of lace bugs, *Endochus inornatus, Euagorus plagiatus* and *Rhynocoris fuscipes* were studied. Egg to adult period were 75.0 ± 26.91, 59.20 ± 5.38; and 36.0 ± 4.5 days, respectively, for *E. inornatus, E. plagiatus* and *R. fuscipes.*

Mass multiplication of *Apanteles taragamae* on early instar caterpillars of *O. arenosella* is being done. Studies on biology of *A. taragamae* revealed that egg to adult period was completed in 17.92 ± 3.41 (female) and 19.80 ± 2.93 (male) days. Longevity of adults was 10.73 ± 4.92 and 11.20 ± 5.04 days for male and female, respectively. Maximum percentage parasitism occurred on the first two days of exposure of host larva although egg laying continued up to 15 days. Average percentage parasitism was 64.7 and 61.8%, under lab and field conditions respectively.

4.25. Biological suppression of fruit crop pests

4.25.1. Population of dynamics of ash whitefly *Siphoninus phyllireae* on pomegranate (IIHR, Bangalore)

The study on the seasonal incidence of ash whitefly, *S. phyllireae* and its parasitoid *Encarsia azimi* was done between January, 1998 and December, 1999. The data on leaf infestation (%), number of adult whiteflies and *E. azimi* emerged and per cent parasitism were recorded.

A total of six natural enemies including aphelinid parasitoid, *E. azimi* and five predators *viz., Scymnus* sp., *Cryptolaemus montrouzieri, Cheilomenes sexmaculata* and *Acletoxenus indicus* were recorded during April-December 1999. Among them only *E. azimi* was common. The predators were found in negligible numbers. The activity of *E. azimi* was found high in April and May causing up to 91.60% parasitism. The whitefly and *E. azimi* were found to be low in numbers from June-December.

4.25.2. Relative abundance of the parasitoids of *Deudorix isocrates* in pomegranate orchards (IIHR, Bangalore)

The two-year field study was conducted on five-year-old plants (var. Ganesh) and five plants chosen randomly for observations. Eggs of *D. isocrates* were collected monthly interval and kept individually in glass vials (3" x 1") to record emergence of parasitoids. During the study period only two parasitoids, *Telenomus* sp. and *Ooencyrtus papilionis* were recorded. Among them only *Telenomus* sp. was recorded almost throughout the year. The parasitism ranged from 20 to 66.67% in different months. During July and August more eggs of *D. isocrates* were collected and activity of *Telenomus* sp. was also more during these months.

4.25.3. Predatory potential and development of *Ischiodon scutellaris* on pomegranate aphid, *Aphis punicae* (IIHR, Bangalore)

Freshly laid eggs were kept individually in glass vials. On hatching, the larvae of *I. scutellaris* were offered individually with known number of freshly collected pomegranate aphids until the predator pupated. Prey consumption by *I. scutellaris* was computed instar wise. The number of aphids consumed during first, second and third instars averaged 106.90, 145.80 and 233.40, respectively. A single larva of *I. scutellaris* in its development consumed a total of 486.10 aphids. A total of 8.30 days was required to complete the larval development on *A. punicae*.

4.25.4. Management of sooty mould on the mealybug infested pumpkins (IIHR, Bangalore)

Mercuric chloride (0.58%), Copper oxychloride (4%), Kavach (1%), Roko (1%) and Benlate (0.1%) were tested by dipping pumpkins before infesting with the mealybugs in the solutions for 10 minutes. Benlate treatment had less sooty mould development.

4.25.5. Effect of botanicals and conventional pesticides on the pomegranate butterfly parasitoid, *Trichogramma chilotraeae*

Trichogramma chilotraeae was collected from the eggs of *Deudorix isocrates* and the culture built up on the frozen eggs of *Corcyra cephalonica* in the laboratory. A total of 15 chemicals (nine neem formulations, two neem products and four conventional pesticides) were tested for their effects on *T. chilotraeae*. Two sets of experiments were conducted. In the first set, the effect of various chemicals on immature stages (*i.e*) on the adult emergence was determined. The cards containing about 200 parasitized eggs were sprayed with different chemicals and allowed to dry. Parasitised eggs sprayed with water served as check. All the chemicals had detrimental effect on the adult emergence, more with conventional pesticides than botanicals. Per cent adult emergence varied from 40.18 (Nimbecidin) to 79.63 (Neemark). There was no adult emergence from the parasitized eggs treated with endosulfan and carbaryl.

In the second set of experiments, potted pomegranate plants were sprayed to run-off stage with different chemicals. The treated leaves after drying were kept individually in glass vials and 20 adults of *T. chilotraeae* released. A streak of honey was provided. Mortality of adults was recorded 1, 3, 6 and 24 after exposure. Conventional pesticides proved more toxic than the botanicals. All the neem formulations proved non-toxic/less toxic 6 hrs of exposure. Nivaar caused mortality up to 63% within 24 h of exposure and all others also caused some mortality (10 to 41%) during the same period (Table 118). All the four conventional pesticides had quick knock down effect causing 100% mortality within an hour of exposure. The botanicals were also found unsafe to *T. chilotraeae*, but were less toxic than the conventional pesticides. Nimbecidin, Neem gold, Neem azal, Rakshak, Neem rich and NSKE caused about 30% mortality within 24 h, while others were higher.

Table 118. Effect of botanicals and conventional pesticides on *Trichogramma chilotreae*

Treatment	Adult emergence (%)	Per cent mortality of adults (Hours after application)			
		1	3	6	24
Nimbecidin 0.3%	40.18	0.00	0.00	0.00	30.00
Neem gold 0.3%	71.70	0.00	0.00	0.00	25.00
Neem azal 0.3%	72.62	0.00	0.00	0.00	16.00
Neemark 0.3%	79.63	0.00	0.00	0.00	22.00
Rakshak 0.3%	53.49	0.00	0.00	0.00	36.00
Neem guard 0.3%	74.48	0.00	0.00	0.00	41.50
Econeem 0.3%	72.75	0.00	0.00	0.00	41.50
Nivaar 0.3%	60.00	0.00	20.00	30.00	63.15
Neem Rich 0.3%	70.34	0.00	0.00	0.00	24.00
Neem oil 2%	73.20	0.00	10.00	40.00	100.00
NSKE 4%	62.50	0.00	0.00	0.00	30.50
Endosulfan 0.07%	0.00	100.00	100.00	100.00	100.00
Deltamethrin 0.05%	31.10	100.00	100.00	100.00	100.00
Carbaryl 0.10%	0.00	100.00	100.0	100.00	100.00
Monocrotophos 0.05%	61.67	100.00	100.00	100.00	100.00
Check (Water)	90.86	0.00	0.00	0.00	0.00

E. guadeloupae causing up to 20-30% parasitism. *Cybocephalus* sp., *Cryptolaemus montrouzieri*, *Axinoscymnus puttarudriahi* and *Triommata coccidivora* were observed on guava in the villages around Erode during March 2000. In Karnataka, Bidar, Gulbarga, Bagalkote, Raichur, Belgaum, Dharwad, Davangere, Chitradurga, Tumkur, Bangalore North and South were surveyed and in all these districts spiralling whitefly incidence was observed on several horticultural plants. *E. ?haitiensis* was found to cause up to 50% parasitism in Chitradurga district whereas *E. guadeloupae* was dominant in Bangalore and Davangere.

KAU, Thrissur

A survey for the identification of natural enemies of spiralling whitefly was conducted in Thrissur district. Whitefly infested leaves of brinjal, chillies, guava, tomato, rubber, grapes, mulberry, etc. were collected from the field and observed in the laboratory for parasitoids and predators. Parasitization by an aphelinid parasitoid, *Encarsia* sp. near *meritoria* was noticed on last instar nymphs and ranged from 0 to 46.72 per cent on different host plants.

TNAU, Coimbatore

Periodical samples of guava and citrus damaged by spiralling whitefly were collected during April-March' 2000 in Coimbatore and Erode districts. *Cryptolaemus, Chilocorus, Scymnus, Cheilomenes* and *Chrysoperla* sp. and a hymenopteran parasitoid were recorded.

4.25.8.2. Colonization of *Encarsia* spp. on spiralling whitefly (IIHR, Bangalore)

To colonize both *E. guadeloupae* and *E. ?haitiensis* in several areas adults of *E. guadeloupae* and *E. ?haitiensis* were released at Ivarakandapura, Hessaraghatta, Hebbal and Anandanagar on whitefly infested guava plants. At Ivarakandapura, the parasitoid activity was noticed in the third week of March on guava and poinsettia plants. *E. guadeloupae* was found established well on these host plants and the extent of parasitism was up to 32%.

4.25.9. Incidence of *E. guadeloupae* on spiralling whitefly on banana (IIHR, Bangalore)

Banana plants (var. Mondan) were found infested with the spiralling whitefly in December'99 and the samples were collected at fortnightly intervals to record the number of healthy and parasitised nymphs in a marked area of 4 cm^2. The parasitism ranged from

23.40 to 36.02% by only *E. guadeloupae*. The activity of the parasitoid was low in December and high in March.

4.25.10. Seasonal abundance of woolly apple aphid in relation to natural enemies

Dr.YSPUH&F, Nauni, Solan

Woolly apple aphid population was monitored throughout the year at weekly intervals along with the natural enemy activity at Solan. Mean colony number, size and aphid coverage increased during April-May from 2.2 to 19.2, 0.11 to 0.35 cm and 0.15 to 11.2 cm, respectively, on the marked twigs. Parasitization by *Aphelinus mali* was prominent in May and at its peak by mid-June and so the aphid population declined to minimum in the first week of August (colony number 0.3, size 0.08 and coverage 0.08 cm). During June-August also *A. mali* was the main natural enemy. Population of the aphid remained low till mid October and later increased to another peak.

Among natural enemies, *A. mali* was consistently present and its activity synchronized with that of the aphid. This year, adult emergence from the overwintering mummified aphids commenced by mid-February and continued till mid-March. Other natural enemies were chrysopids with main period of activity in June-July and syrphids with activity in June and December-January. Coccinellids were noticed only twice in the year on experimental replicates.

Eggs and larvae of syrphids of six species were collected from the ground flora and apple trees in the orchard as well as from the nearby areas. Amongst these, three species overwintered as full-fed larvae with emptied alimentary canal and only one species could successfully overwinter in the larval stage.

SKUAS&T, Srinagar

Srinagar, Baramulla, Budgam, Pulwama and Anantnag districts were surveyed to ascertain the woolly aphid infestation in the fruit orchards. The orchards with woolly aphid infestation were divided into subblocks consisting of 10 trees, samples were collected from each experiment site and observed in the laboratory. The mean number of colonies/ plant ranged 6.00 – 31.10 in the locations surveyed.

Observations on the association of natural enemies with the pest were recorded at fortnightly intervals. An aphelinid parasitoid, *Aphelinus mali* and as many as six predators (*Pharoscymnus flexibilis, Adalia tetraspilota, Eupeodes confrater, Episyrphus balteatus, Coccinella septempunctata* and *Chilocorus infernalis*) were found on the aphid. The per cent parasitism by *Aphelinus mali* during the observational period increased from 33.65 (May) to 69.50 (September).

4.25.12. Impact of release of *Chrysoperla carnea* on woolly apple aphid (Dr.YSPUH&F, Nauni, Solan)

Releases of *C. carnea* larvae (2-3 day-old) were made @ 1 larva/colony of the aphid in November after its population started increasing on selected branches of trees. Mean size of the colony and coverage of the aphid declined to 28.7 and 25.4%, respectively, 17 days after release as compared with no decline in colony size and an increase in spread by 58.6% in control.

4.25.13. Parasitization of apple green aphid on apple (Dr.YSPUH&F, Nauni, Solan)

Apple green aphids (*Aphis pomi*) were controlled during mid-July and kept for parasitoid emergence. Among these, 52.9% were with parasitoid emergence hole and 21.2% were with hyperparasitoid emergence hole. The parasitoid has been tentatively identified as *Trioxys* sp.

4.25.14. Phytophagous mites on apple and their natural enemies (Dr.YSPUH&F, Nauni, Solan)

Recently, two-spotted spider mite (TSSM) *Tetranychus urticae* and the European red mite (ERM) *Panonychus ulmi* have emerged as pests in Kinnaur district. The ERM was recorded from three localities, *viz.* Nichar, Sharbo and Telangi where the average population of the mite was 62, 71 and 152 mites/leaf, respectively. A coccinellid, *Stethorus* sp. was observed, besides anthocorids, chrysopids, predatory thrips and mites preying on these mites.

4.25.15. Incidence of San Jose Scale at different altitudes (SKUAS&T, Srinagar)

Extensive survey was conducted in the valley at different locations and at different altitudes. The scale density varied from 63 to 150 and the per cent parasitism from 40.00 to 74.67.

A total of 1,08,436 parasitoids of *Encarsia perniciosus* and *Aphytis proclia* were bred in the laboratory on San Jose scale reared on pumpkins and out of these, 58,958 were released in the field at different locations. The scale infested twigs were collected from different release sites at intervals to find out the per cent parasitism and impact of the artificial release of these parasitoids in the orchards. Per cent parasitism of San Jose scale during July – December 1999 ranged from 24.8 to 77.7. Both species of parasitoids (*A. proclia* and *E. perniciosi*) were well established in all the localities.

4.25.16. Collection of local *Trichogramma* spp. from fruit crop ecosystem (Dr.YSPUH&F, Nauni, Solan)

Attempts were made to collect local species of *Trichogramma* by placing eggs of *Corcyra cephalonica* in apple orchards at Nauni and Mashobra (Shimla), but no emergence was recorded. Egg clusters of *Archips termias* were also collected from apple trees but none were found parasitized. On pomegranate and tomato, *Trichogramma chilonis* could be collected.

4.26. Biological suppression of vegetable crop pests

4.26.1. Evaluation of *Trichogrammatoidea bactrae* against *P. xylostella* on cabbage IIHR, Bangalore

Cabbage var. Maharani was planted in 100 m^2 area. A total of five plots were made with 20 m^2 area. The entire area was subjected to parasitoid release. A separate 100 m^2 area was located at an isolated distance for chemical (endosulfan 3 sprays at weekly interval) and control treatments. *Trichogrammatoidea bactrae* was released @ 2.5 lakh adults per hectare before primordial formation (10 days from transplanting). A total of 5 releases were made at weekly intervals. Since it was difficult to observe eggs of *P. xylostella* under field conditions, level of larval population of *P. xylostella* was used as a tool to assess the effect. Every week prior to release of egg parasitoid, observation was made on larval population from 10 heads per plot.

The larval population gradually reduced to 1.0/plant by fourth week from 3.20 and almost maintained the same in parasitoid release plot (Table 119). In endosulfan treated plot the reduction was not much with a mean of 2.08 per plant from 3.80/plant. A reduction of 45.26 and 62.63% in the larval population in endosulfan and parasitoid release plot, respectively, over control was observed. Thus release of egg parasitoid was found to be superior to even insecticide treated plot. There was 29.53 – 33.86 % increase of yield in treatments over control.

percentage of females was 64.6 and 68.6, respectively, on these two respective hosts. Parasitized eggs of *C. cephalonica* could be stored up to 10 days after 5 days of the parasitization at 15°C to get 50% emergence.

4.26.2. Evaluation of different formulations of *Bacillus thuringiensis* against *Plutella xylostella*

IIHR, Bangalore

The comparative field efficacy of various commercial *Bt* formulations against *Plutella xylostella* revealed that all the formulations gave effective control (1.0 – 2.0 / plant), as compared to unsprayed control (5.20/plant). 'Halt' was very effective and recorded least larval population of 1.0/plant (Table 120). The yield was also high in 'Halt' treated plot (72.5 kg/plot) as compared to other *Bt* formulations (55.5–60.0 kg/plot).

Table 120. Effect of *Bt* formulations against larval populations of *Plutella xylostella* on cabbage

Treatment	Mean larval count (10 plants)		Percent reduction over control	Total yield (kg/plot)	percent increase over control
	Before spray	After spray			
Delfin @ 1g/l	4.26	1.50	71.2	55.5	8.46
Halt @ 1g/l	4.64	1.00	80.8	72.5	29.93
Dipel @ 1g/l	4.24	1.28	75.4	58.0	12.41
Biobit @ 1g/l	4.28	2.00	61.5	60.0	15.33
Endosulfan @ 2ml/l	4.64	2.80	51.9	55.0	7.64
Control	4.38	5.20	-	50.8	-

ANGRAU, Hyderabad

To test the efficacy against diamondback moth (DBM) in cabbage (Var. Golden Acre), seven *Bt* formulations, *viz.*, Dipel, Spicturin, *BTK*-I, *BTK*-II, Biobit, Delfin and Halt were utilized @ 1.0 kg/ha and compared with endosulfan (0.07%) and untreated control. Each treatment was replicated thrice and the plot size was 25 m². The treatments were administered during evening hours starting from peak primordial formation stage. A total of 5 sprays were given with 10 days interval. Observations were recorded on no. of *P. xylostella* larvae on 10 randomly selected plants from each plot at weekly interval.

Biobit proved to be more effective in keeping a check on DBM with least mean number of larvae (17.60) (Table 121), followed by Dipel (21.53). Endosulfan was also equally effective and was on par with Biobit. Biobit yielded maximum marketable cabbage (52.67 q/ha) and was on par with endosulfan (53.67 q/ha).

Table 121. Evaluation of different *Bt* formulations for their effectiveness against *P. xylostella* in cabbage

Treatment (kg/ha)	Pre count	Mean larval population at weekly intervals (10 plants)					Mean larval popula-tion	Yield (kg/ha)
		I	II	III	IV	V		
Dipel (1.0)	6.67 (2.55)	21.33 (4.61)	32.00 (5.65)	34.33 (5.85)	15.33 (3.91)	4.66 (2.16)	21.53 (4.64)	30.67
Spicturin (1.0)	9.00 (3.00)	24.33 (4.93)	44.66 (6.68)	41.66 (6.45)	16.33 (4.03)	5.00 (2.23)	26.40 (5.14)	34.67
Btk I (1.0)	12.00 (3.46)	23.33 (4.82)	37.33 (6.10)	39.33 (6.37)	14.66 (3.82)	6.00 (2.44)	24.13 (4.91)	39.33
Btk II (1.0)	7.00 (2.82)	23.00 (4.78)	42.00 (6.47)	43.00 (6.55)	11.33 (3.36)	5.33 (2.29)	24.93 (4.99)	35.00
Biobit (1.0)	9.33 (3.01)	16.00 (3.99)	29.00 (5.38)	29.66 (5.44)	10.33 (3.21)	3.00 (1.71)	17.60 (4.20)	52.67
Delfin (1.0)	9.33 (3.05)	27.00 (5.18)	41.33 (6.42)	45.66 (6.75)	12.66 (3.55)	7.00 (2.64)	26.73 (5.16)	32.33
Endosulfan (0.07%)	10.33 (3.20)	20.33 (4.43)	31.66 (5.62)	32.00 (5.66)	9.66 (3.10)	3.33 (1.79)	19.27 (4.39)	53.67
Halt (1.0)	11.33 (3.35)	22.60 (4.76)	37.00 (6.28)	39.33 (6.27)	15.00 (3.87)	5.33 (2.29)	23.87 (4.88)	38.33
Control	10.00 (3.11)	39.33 (6.27)	55.30 (7.43)	59.33 (7.70)	31.66 (5.62)	16.66 (4.05)	40.47 (6.36)	25.67
CD (P=0.05)	NS	(0.48)	(0.54)	(0.35)	(0.43)	(0.54)	(0.20)	3.74

Figures in parentheses are transformed values

Dr.YSPUH&F, Nauni, Solan

Five formulations of *Bacillus thuringiensis* var. *kurstaki*, viz. Biobit DF (32000 IU/mg), Agree (16000 IU/mg), Halt (55000 IU/mg), Biolep (16000 IU/mg) and Dipel 8L (17600 IU/mg), each @ 0.5 kg/ha taking 32000 IU/mg potency as base, and endosulfan 0.05%, were applied twice (in April and May, 1999) when larval populations (*P. xylostella, Pieris brassicae, Crocidolomia binotalis, Plusia* spp., *H. armigera*, etc.) had appeared on cauliflower crop. Before spray, larval population was counted on 10 randomly observed plants in 20 m^2 plots. Post-treatment count was taken four days after first spray and five days after second spray. Observations were also made on predators (all stages of coccinellids and syrphids) after second spray.

Larval count of *P. xylostella* per 10 plants was very low after first spray, but when all lepidopteran larvae were considered it was reduced by Biobit, Biolep and endosulfan in comparison to pretreatment count. Predator population was significantly different in post-treatment count with least population in endosulfan.

4.26.3. Natural parasitization of *Crocidolomia binotalis* by *Bracon hebetor* (Dr.YSPUH&F, Nauni, Solan)

Larvae of the cabbage webber, *Crocidolomia binotalis*, were found parasitized (29 out of 361 larvae seen, i.e. 8% parasitization) by an idiobiont ectoparasitoid, *Bracon hebetor* from mid-June to mid-September (temperature range: 23-32 °C; mean 26.4°C), a female laid 421-819 eggs in an oviposition period of 25-40 days. The pre-oviposition period was 2-4 days, while post-oviposition period was negligible (0-1 day); adult survival was 32 to 43 days. From mid-September to mid-November, when mean temperature was 22.1°C (range: 15-26 °C), fecundity was 494-622 with an oviposition period of 30 days and longevity of 36-71 days. When offered larvae of *Corcyra cephalonica* for parasitization, the oviposition began at 45, 48 and 53 day age. These laid 609, 183 and 60 eggs (mean 284) during 61, 31 and 19 days of oviposition. The females survived for 106, 87 and 68 (mean 87) days.

4.26.4. Evaluation of *Trichogramma chilonis* against shoot and fruit borer *Leucinodes orbonalis* on brinjal (IIHR, Bangalore)

A field trial with egg parasitoid *T. chilonis* was conducted to evaluate its performance against shoot and fruit borer *Leucinodes orbonalis* on brinjal var. Kalpatharu. Parasitoids were first released 15 days after transplanting in 625m^2 area and continued till seventh harvest @ 40,000 to 60,000 adults per ha per release. A total of 5, 00, 000 adults

/ha were released. The fruit borer damage was considered for assessing the potential of the parasitoid. The borer damage was gradually reduced to 9.20% in parasitoid released plot, whereas in control, fruit damage was between 18.10 and 28.53%. Mean borer damage in parasitoid released plot was 13.97% as against 23.50% in control (Table 122). The data showed an increase of 49.23% in yield over control in parasitoid released plot.

Table 122. Effect of egg parasitoid, *Trichogramma chilonis* against *Leucinodes orbonalis* on brinjal

Treatment	Mean Percentage fruits bored	Per cent reduction over control	Total marketable yield plot (kg)	Increase over control (%)
Trichogramma chilonis	13.97	40.55	23.25	49.23
Cypermethrin @ 0.5ml / 1	17.00	27.66	22.00	41.20
Control	23.50	-	15.58	-

4.26.5. Control of *Leucinodes orbonalis on* brinjal using commercial *Bt* formulations

4.26.5.1 IIHR, Bangalore

The comparative field efficacy of commercial *Bt* formulations, *viz*. Dipel and Delfin against shoot and fruit borer of brinjal was tested through application of five rounds of Delfin @ 1 kg/ha at weekly interval, right from flower initiation. Delfin was found better than Dipel. The percentage borer damage to the fruits was significantly lower in Delfin treated plots (10.44%), followed by Dipel (15.50%) and cypermethrin (17.00%) as compared to 23.50% damage in control plot (Table 123). An increase in yield of 58.3, 56.0 and 50.0% over untreated control was observed in Delfin, Dipel and cypermethrin treated plots.

Table 123. Effect of *Bt* commercial formulations against *Leucinodes orbonalis* on brinjal

Treatment	Mean Percentage fruits bored	Per cent reduction over control	Total marketable yield plot (kg)	Increase over control (%)
Dipel @ 1g/l	15.50	34.0	28.40	56.0
Cypermethrin @ 0.5ml/l	17.00	27.7	25.00	50.0
Delfin @ 1g/l	10.44	55.6	30.00	58.3
Control	23.50	-	12.50	-

4.26.5.2 MPKV, College of Agriculture, Pune

A field experiment was conducted on transplanted brinjal seedlings (var. Manjari Gota) in 25 m^2 plots. The trial was laid out in RBD with three replications and seven treatments. Efficacy of five *Bt* formulations was compared with endosulfan 0.07% as check. Application of treatments was commenced at flower initiation stage of the crop and five sprays were given at weekly interval. Observations on per cent fruit infestation and yield of marketable fruits were recorded by counting and weighing healthy and infested fruits from the treatment plots at each picking.

All the treatments were significantly superior to control in reducing fruit infestation and increasing the yield of marketable fruits (Table 124). Delfin WG @ 1 kg/ha gave minimum of 9.54 per cent fruit infestation and maximum of 126.09 q/ha yield, and it was significantly superior to other *Bt* formulations and endosulfan.

Table 124. Efficacy of *B. thuringiensis* formulations against *L. orbonalis* on brinjal

Treatment	Fruit infestation (%)	Yield of marketable fruits (q/ha)
Delfin WG @ 1.0 kg/ha	9.54(17.95)	126.09
Dipel 8 L @ 1.0 kg/ha	12.68(20.79)	115.42
Halt @ 1.0 kg/ha	17.06(24.35)	97.91
Biolep @ 1.0 kg/ha	19.53(26.21)	99.84
Biobit @ 1.0 kg/ha	15.66(23.26)	109.07
Endosulfan (0.07%)	16.01(23.58)	99.74
Control	31.86(34.33)	71.61
CD (P=0.05)	2.61	7.70

Figures in parentheses are angular transformations

4.26.5.3 ANGRAU, Hyderabad

Efficacy of *Bt* formulations Dipel and Delfin was compared with control and endosulfan treatment. Each treatment was replicated 5 times and the sprays were given during evening hours at 10 days interval with first spray starting from flower initiation stage. Observations were recorded on per cent fruit damage 7 days after the spray.

Mean per cent damage by *L. orbonalis* showed no significant difference between treatments due to very heavy incidence of fruit borer (22.60 to 50.85).

4.26.6. Management of tomato fruit borer, *Helicoverpa armigera*

4.26.6.1 IIHR, Bangalore

Tomato var. Pusa Ruby was planted in 500 m^2 during October- March 1999 for trials against *H. armigera* using egg parasitoid *Trichogramma pretiosum* and *Ha*NPV at varying doses. The following treatments were tried.

- *i.* *T. pretiosum* alone @ 50,000 adults/ha/release five times from flower initiation period. Tricho cards were cut into bits and tied in every plot in the middle (5 m apart)
- *ii.* *Ha*NPV alone was sprayed @ 250 LE/ha (1.5 x 10^{12} POB). A total of 5 sprays were made at weekly intervals
- *iii.* *T. pretiosum* @ 50,000 adults/ha/release five times at weekly intervals + *Ha* NPV @ 250 LE/ha – 3 sprays; first spray 5 days after release of parasitoids and subsequently at weekly intervals
- *iv.* *T. pretiosum* was released as above and *Ha*NPV was sprayed twice at the above concentration, first spray 5 days after release and second after 10 days of spray
- v. Control.

Observation was made on 5 plants in each plot at weekly interval for parasitism. The per cent borer damage on fruit was assessed during harvest. The data presented in Table 125 revealed that there was no natural parasitism in the field. The per cent parasitism obtained in the treatment was mainly due to the releases of *T. pretiosum*. Per cent parasitism from 55.65 to 59.10 was obtained.

The larval population ranged from 0.86 to 0.98 per plant before treatments were imposed. The increase in larval population was steadily observed in control compared to treatments. The mean larval population was 0.48 in NPV alone (five times sprayed) plots and 0.56 in parasitoid released plot. Among treatments with parasitoid & NPV 2 and 3 sprays, there was not much difference (0.50 to 0.52). The first two harvests showed higher fruit borer damage than the rest of the harvests. However, the mean fruit borer damage was between 12.61 and 17.48 % in various treatments compared to control recording 27.64% fruit borer damage. The parasitoid release treatment recorded 36.05% yield increase over control. Other treatments recorded between 37.75% and 46.25% increase of yield over control. The treatment with parasitoid release and 2 sprays of NPV was better.

Table 125. Effect of *Ha*NPV and *Trichogramma pretiosum* against tomato fruit borer

Treatment	Percent parastism (mean of ten		Larval count (mean of ten plants		Per cent redu-ction over control	Mean per fruits bored at harvest	Per cent reduction in fruit borer infest-ation over control	Total yield (kg/ plot)	Percen-tage inc-rease over cont-rol
	Before treatment	After treatment	Before treatment	After treatment					
*Ha*NPV @ 250 LE/ha (5 prays)	0.0	3.2	0.90	0.48	85.14	13.37	51.62	24.80	40.59
*Ha*NPV @ 250 LE/ha (3 prays) + parasitoid @ 2,50,000 adults/ha	0.0	55.65	0.86	0.52	83.52	16.55	40.12	24.30	37.75
*Ha*NPV @ 250 LE/ha (2 sprays) + parasitoid @ 2,50,000 adults/ha	0.0	57.50	0.96	0.50	84.52	12.61	54.38	25.80	46.25
Parasitoid @ 2,50,000 Adults/ha	0.0	59.50	0.88	0.56	82.66	17.48	36.76	24.00	36.05
Control	0.0	5.0	0.98	3.23	-	27.64	-	17.64	-

4.26.6.2 MPKV, College of Agriculture, Pune

A field trial was conducted at College of Agriculture, Pune, by transplanting tomato seedlings (var. Pusa Ruby) in 25 m^2 plots. The trial was laid out in RBD with four replications and treatments as detailed under IIHR, Bangalore.

Observations on larval population from 5 plants per plot were recorded a day before initiation of treatment applications and post-counts at weekly interval till termination of experiment. At each fruit picking, per cent fruit infestation and yield of marketable fruits was recorded.

All the treatments were significantly superior over control in reducing the larval population, fruit infestation and increasing the yield of marketable fruits (Table 126). Five sprays of *Ha*NPV @ 250 LE/ha (1.5×10^{12} POBs/ha) gave minimum surviving larval population (2.60 larvae / 5 plants) and maximum of 328.18 q / ha marketable fruit yield. It was, however, on par with five releases of *T. pretiosum* @ 50,000 adults/ha/ release + three sprays of *Ha*NPV @ 250 LE/ha and five releases of *T. pretiosum* @ 50,000 adults/ha/release + two sprays *Ha*NPV @ 250 LE/ha. Release of *T. pretiosum* @ 50,000 adults/ha/release, five times at weekly interval was also statistically on par with five sprays of *Ha*NPV @ 250 LE/ha for fruit yield. The treatment with five releases of *T. pretiosum* @ 50,000 adults/ha/release + three sprays of *Ha*NPV @ 250 LE/ha recorded the least fruit damage (10.55%) and it was significantly superior to rest of the treatments.

Table 126. Efficacy of *T. pretiosum* and *Ha*NPV against tomato fruit borer

Treatment	Average surviving larval population / 5 plants*		Fruit Infestation (%)**	Yield of marketable fruits (q/ha)
	Pre-count	Post-count		
T. pretiosum @ 50,000 adults / ha / release - 5 releases	10.61 (3.32)	3.70 (2.04)	18.15 (25.25)	273.63
*Ha*NPV @ 250 LE/ha ($1.5x\ 10^{12}$ POBs/ha) – 5 sprays	12.70 (3.64)	2.60 (1.76)	14.29 (22.22)	328.18
T. pretiosum @ 50,000 adults / ha/release - 5 releases + *Ha*NPV 250 LE/ha – 3 sprays	13.74 (3.77)	2.95 (1.85)	10.55 (19.00)	286.61
T. pretiosum @ 50,000 adults / ha / release – 5 releases + *Ha*NPV 250 LE/ha – 2 sprays	12.20 (3.56)	3.20 (1.92)	14.94 (22.71)	283.15
Untreated control	12.80 (3.64)	7.30 (2.79)	31.31 (34.02)	127.69
CD (P=0.05)	(NS)	(0.18)	(1.70)	64.70

Figures in parentheses are * $\sqrt{x+0.5}$ and ** angular transformations; Surviving population of the larvae is the mean of five post-counts.

ANGRAU, Hyderabad

An experiment was conducted to know the effectiveness of *Trichogramma pretiosum* release in combination with spray application of *Ha*NPV. Trial was conducted with var. Pusa Ruby by undertaking 5 treatment combinations including control as given under IIHR, Bangalore.

All the treatment combinations were significantly superior over the control (Table 127). The lowest mean larval population (2.15), the lowest fruit damage (4.11%) was recorded when *T. pretiosum* 50,000/ha/release 5 times with 3 sprays of NPV @ 250 LE/ha which also recorded the highest yield (127.50 q/ha) and was significantly superior to others.

Table 127. Biocontrol based management of tomato fruit borer, *H. armigera*

Treatment	Pre-count of larval population	Average larval population at weekly interval (five plants)					Mean larval population	percent bored fruits	Yield (q/ha)
		I	II	III	IV	V			
T. pretiosum @ 50,000adults / ha / week for 5 times	10.25 (3.18)	9.75 (3.12)	6.25 (2.49)	2.75 (1.73)	3.25 (1.89)	3.75 (2.06)	5.15 (2.20)	5.69 (13.78)	100.00
Five sprays of *Ha*NPV @ 1.5 x 10^{12} LE at weekly interval	11.25 (3.35)	7.50 (2.73)	5.75 (2.37)	3.00 (1.61)	3.50 (1.98)	3.25 (1.89)	4.60 (2.14)	5.15 (13.06)	106.25
T. pretiosum @ 50,000 adults / ha / week 5 times + Three sprays of *Ha* NPV @ 1.5 x 10^{12} LE	11.50 (3.39)	2.75 (1.64)	2.50 (1.79)	2.25 (1.57)	1.50 (1.35)	1.75 (1.44)	2.15 (1.43)	4.11 (11.66)	127.50
T. pretiosum @ 50,000 adults / ha / week 5 times + Two sprays of *Ha* NPV @ 1.5 x 10^{12} LE	10.50 (3.22)	6.75 (2.59)	4.50 (2.08)	5.00 (2.32)	4.25 (2.15)	4.25 (2.16)	4.95 (2.22)	5.42 (10.23)	76.25
Control	11.50 (3.37)	12.25 (3.50)	11.25 (3.34)	9.75 (3.18)	10.00 (3.23)	10.30 (2.95)	8.25 (3.21)	18.16 (25.21)	47.50
CD (P=0.05)	NS	(0.34)	(0.82)	(0.76)	(0.66)	(0.55)	(0.37)	(4.84)	19.04

Figures in parentheses are transformed values

4.26.7. Field evaluation and assessment of *Trichogramma pretiosum* (ANGRAU, Hyderabad)

A farmer's field of 0.20 ha was selected in the village Peddashapur near Shamshabad for the purpose of demonstrating the effectiveness of *T. pretiosum* against *Helicoverpa armigera*. Five releases of *T. pretiosum* were made at weekly intervals @ 50,000/ha/release starting from flower initiation. A control plot was selected about 500 m away from the release plot. Prior to every release, the eggs of *H. armigera* were collected from 25 randomly selected plants and reared in the laboratory to record per cent egg parasitism. At each picking per cent fruit damage was estimated and yield of marketable fruits recorded.

In the prerelease observation no egg parasitization was noticed. However, as the releases were being made the percent egg parasitism started increasing and reached the maximum of 42.9% (Table 128). In control plot there was no record of parasitization. The larval population after each release never exceeded 20 while in control it went up to 36. Less number of eggs and larvae were collected from released plot. Mean per cent fruit damage was 7.6 per cent as compared to 20.3% in control plot. It can be seen that *T. pretiosum* was successful in keeping a check on *H. armigera* populations in tomato ecosystem.

Table 128. Field evaluation of effectiveness and assessment of *Trichogramma pretiosum*

Number of release	Number of eggs collected from 25 plants		Number of larvae collected from 25 plants		Per cent egg parasitism	
	Release	Control	Release	Control	Release	Control
Prerelease	19	23	8	10	0	0
I release	15	29	22	31	26.7	0
II release	17	36	19	36	29.4	0
III release	11	27	8	27	36.4	0
IV release	7	19	6	18	42.9	0
V release	3	5	0	12	25.0	0

Mean per cent fruits bored Released plot : 7.6
Control plot : 20.3

4.2.6.8. Incidence of *H. armigera* and its natural parasitization

In tomato plots (cultivar Solan Bajar), first egg laying was noticed on April 26, when 4% plants were found infested. First egg parasitization (16.7%) by *Trichogramma chilonis* was noticed in the first week of May when 34% plants were infested with a mean larval density of 1.2. By mid-May, 58% plants were infested with a larval density of 1.5 and the parasitization was 50%. In the last week of May, first and third week of June, the plant infestation was 4, 14 and 10% (mean egg density of 1, 1.9 and 1.6/infested plant) and parasitization 50, 75 and 100%. Larval density was low and some larvae were being predated by wasps.

4.27. Biological suppression of potato pests (MPKV, College of Agriculture, Pune)

4.27.1. Field evaluation, recovery studies and standardization of the optimum dosage for release of parasitoids, *Copidosoma koehleri* and *Chelonus blackburni* against potato tuber moth (PTM)

Field experiments were conducted in farmer's field at village Peth (Pune) during *Kharif* and *Rabi* seasons. The potato variety Kufri Jyoti was raised in a 50m^2 plot. The experiment was laid out in RBD with three replications and eight treatments. The treatments comprised of four releases of *Copidosoma koehleri* @ 50,000, 37,500 and 25,000 adults/ha/release, *Chelonus blackburni* @ 15,000, 10,000 and 5,000 adults/ha/release at weekly interval, two sprays of endosulfan (0.05%) at 10 days and a control. Releases of parasitoids and sprays of endosulfan were commenced 45 and 52 DAP, respectively.

Observations on leaf mines / m row at 5 places in each treatment plot were recorded a day before parasitoid release and post-counts at weekly interval till termination of treatments. Recovery of parasitoids (% parasitism) was studied by placing egg-sheets, each containing 50 eggs at 5 different spots in each treatment plot after second release of the parasitoids and rearing them out in the laboratory. At harvest, tubers from unit areas at three spots were collected from each plot separately to record PTM infestation. Yield data were recorded by sorting out the marketable tubers from treatment plots.

All the treatments were significantly superior to control in reducing the leaf mines/m row during II, III and IV week after initiation of treatments (Table 129) during *Kharif* 1999. Four releases of *C. koehleri* @ 50,000 adults/ha/release recorded least PTM mines on leaves and was most effective. It was however, on par with similar releases of *C. koehleri* @ 37,500 adults/ha/release and *C. blackburni* @ 15,000 adults/ha/release. Least tuber infestation and maximum yield were obtained in four weekly releases of *C. blackburni* @ 15,000 adults / ha / release followed by *C. koehleri* @ 50,000 adults / ha / release.

Table 129. Efficacy of parasitoids against PTM based on leaf mines, tuber infestation and yield of potato (Kharif)

Treatment	Pre-count*, leaf mines/m row	Number of leaf mines/m row after week*				% Parasitism (Recovery)	% Tuber infes-tation**	Yield (q/ha)
		I	II	III	IV			
C. koehleri @ 50,000 adults/ha/rel.	1.00 (1.22)	0.87 (1.17)	0.47 (0.98)	0.33 (0.91)	0.13 (0.80)	28.40 7.48	(15.87)	206.3
C. koehleri @ 37,500 adults/ha/rel.	1.13 (1.27)	1.00 (1.22)	0.53 (1.02)	0.47 (0.98)	0.27 (0.88)	41.20 9.43	(17.88)	191.0
C. koehleri @ 25,000 adults/ha/rel.	0.93 (1.19)	0.93 (1.19)	0.87 (1.17)	0.66 (1.08)	0.33 (0.91)	27.2012.05	(20.31)	173.0
C. blackburni @ 15,000 adults/ha.rel.	0.93 (1.19)	0.93 (1.19)	0.53 (1.02)	0.47 (0.98)	0.20 (0.84)	59.20 7.36	(15.70)	211.2
C. blackburni @ 10,000 adults/ha/rel.	1.00 (1.22)	0.86 (1.16)	0.73 (1.11)	0.53 (1.01)	0.33 (0.91)	49.60 9.90	(18.32)	185.7
C. blackburni @ 5,000 adults/ha/rel.	1.20 (1.30)	0.93 (1.19)	0.93 (1.19)	0.66 (1.08)	0.53 (1.02)	28.0012.80	(20.96)	163.7
Endosulfan 0.05%	1.07 (1.56)	1.07 (1.25)	1.20 (1.30)	0.60 (1.04)	0.47 (0.98)	- 10.18	(18.59)	198.0
Untreated control	0.93 (1.19)	1.00 (1.22)	1.47 (1.40)	1.26 (1.33)	1.13 (1.27)	- 18.57	(25.54)	142.3
CD (P=0.05)	(NS)	(NS)	(0.10)	(0.15)	(0.10)	-	(1.71)	19.15

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

In a similar experiment conducted during *Rabi* 1999-2000 all the treatments were significantly superior over control in reducing the leaf mines during II, III and IV weeks after initiation of parasitoid releases, tuber infestation and increasing the yield of marketable potatoes. Four releases of *C. koehleri* @ 50,000 adults/ha/release at weekly interval were effective in reducing the leaf mines, tuber infestation and gave maximum of 220.0 q/ha tuber yield (Table 130). It was, however, on par with four releases of *C. koehleri* @ 37,500 adults/ha/release and *C. blackburni* @ 15,000 and 10,000 adults /ha/release in respect of leaf mines and tuber infestation.

Recovery of the parasitoids was found to be dose dependent. *C. koehleri* @ 50,000 adults / ha / release was recovered to the highest extent (68.60%), followed by *C. blackburni* @ 15,000 adults / ha / release (65.10%).

Pooled analysis of three years data (1997-98 to 1999-2000) for both *Kharif* and *rabi* seasons revealed that all the treatments were significantly superior to untreated control in reducing the leaf mines, tuber infestation and increased the yield of marketable potatoes. Amongst the treatments, four releases of *C. koehleri* @ 50,000 adults / ha / release at weekly interval recorded minimum leaf mines, tuber infestation, maximum of 203.3 q/ha tuber yield during Kharif season (Table 131). It was, however, on par with similar releases of *C. koehleri* @ 37,500 adults/ha/release, *C. blackburni* @ 15,000 and 10,000 adults/ ha/release in respect of leaf mines. As regards the tuber infestation, four releases of *C. blackburni* @ 15,000 adults/ha/release was on par with *C. koehleri* @ 50,000 adults/ ha/release. Maximum yield of potatoes (203.3 q/ha) was recorded with *C. koehleri* @ 50,000 adults/ha/release followed by *C. blackburni* @ 15,000 adults/ha/release, *C. koehleri* @ 37,500 adults/ha/release, *C. blackburni* @ 10,000 adults/ha/release, and endosulfan 0.05%, all on par with each other (Table 132).

Four releases of *C. koehleri* @ 50,000 adults / ha / release, at weekly interval gave maximum increase in yield of potato to the extent of 67.11 q/ha during *Kharif* and 73.33 q/ha during *rabi* seasons (Table 133). It was followed by *C. blackburni* @ 60,000 adults/ha, *C. koehleri* @ 1.5 lakh adults/ha and *C. blackburni* @ 40,000 adults / ha. Considering the economics, releases of *C. koehleri* @ 1.5 to 2.0 lakh adults / ha was highly cost effective for the control of PTM in the field during *Kharif* and *Rabi* seasons.

Four releases of egg-larval parasitoid, *C. koehleri* @ 50,000 adults/ha/release, commencing from 45 days after planting was most effective in reducing the foliage and tuber infestation of PTM and gave maximum yield of marketable potatoes during *Kharif* and *rabi* seasons. The dose could also be reduced to 1.5 lakh adults / ha (four releases of *C. koehleri* @ 37,500 adults/ha/release at weekly interval) with similar control.

Table 130. Efficacy of parasitoids against PTM based on leaf mines, tuber infestation and yield of potato (Rabi)

Treatment	Pre-count*, leaf mines/m row	Number of leaf mines/m row after week*				% Parasitism (Recovery)	% Tuber infes-tation**	Yield (q/ha)
		I	II	III	IV			
C. koehleri @ 50,000 adults/ha/rel.	1.86 (1.53)	2.06 (1.60)	1.26 (1.32)	0.46 (0.97)	0.26 (0.87)	68.60	8.18 (16.64)	220.0
C. koehleri @ 37,500 adults/ha/rel.	1.86 (1.53)	2.26 (1.66)	1.40 (1.37)	0.60 (1.04)	0.46 (0.97)	57.70	9.08 (17.55)	209.1
C. koehleri @ 25,000 adults/ha/rel.	2.00 (1.58)	2.46 (1.72)	1.46 (1.40)	1.00 (1.22)	0.86 (1.16)	42.80	13.26 (21.39)	187.1
C. blackburni @ 15,000 adults/ha.rel.	1.93 (1.55)	2.20 (1.64)	1.33 (1.35)	0.53 (1.01)	0.40 (0.94)	65.10	8.76 (17.26)	215.0
C. blackburni @ 10,000 adults/ha/rel.	1.93 (1.55)	2.26 (1.66)	1.53 (1.42)	0.66 (1.07)	0.66 (1.07)	55.00	11.77 (20.09)	204.1
C. blackburni @ 5,000 adults/ha/rel.	2.20 (1.64)	2.33 (1.68)	1.83 (1.52)	1.20 (1.30)	1.00 (1.22)	34.20	15.62 (23.26)	164.8
Endosulfan 0.05%	2.06 (1.60)	2.46 (1.72)	2.13 (1.62)	0.93 (1.19)	0.93 (1.19)	-	11.74 (20.00)	197.4
Untreated control	2.26 (1.66)	2.53 (1.74)	2.66 (1.77)	2.60 (1.76)	1.93 (1.55)	-	25.12 (30.07)	152.3
CD (P=0.05)	(NS)	(NS)	(0.16)	(0.16)	(0.24)	-	(0.91)	3.45

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

Table 131. Efficacy of parasitoids against PTM based on leaf mines, tuber infestation and yield of Potato-Kharif (Pooled analysis of 1997-98, 1998-99 and 1999-2000)

Treatment	Pre-count*, leaf mines/m row	Number of leaf mines/m row after week*				% Parasitism (Recovery)	% Tuber infes-tation**	Yield (q/ha)
		I	II	III	IV			
C. koehleri @ 50,000 adults/ha/rel.	1.02 (1.23)	1.17 (1.21)	0.48 (0.99)	0.31 (0.90)	0.13 (0.79)	61.54	8.70 (17.08)	203.3
C. koehleri @ 37,500 adults/ha/rel.	1.08 (1.25)	1.23 (1.26)	0.62 (1.05)	0.46 (0.98)	0.24 (0.86)	47.16	11.07 (19.13)	186.9
C. koehleri @ 25,000 adults/ha/rel.	1.06 (1.25)	1.32 (1.27)	0.84 (1.15)	0.71 (1.10)	0.32 (0.91)	34.35	15.30 (22.32)	160.7
C. blackburni @ 15,000 adults/ha.rel.	0.95 (1.20)	1.10 (1.21)	0.48 (0.99)	0.41 (0.96)	0.27 (0.82)	59.42	8.82 (17.17)	203.1
C. blackburni @ 10,000 adults/ha/rel.	1.08 (1.25)	1.26 (1.25)	0.62 (1.05)	0.55 (1.02)	0.28 (0.87)	45.43	11.74 (19.90)	181.8
C. blackburni @ 5,000 adults/ha/rel.	1.10 (1.26)	1.32 (1.27)	0.84 (1.15)	0.75 (1.12)	0.44 (0.97)	31.02	15.31 (22.89)	155.0
Endosulfan 0.05%	1.02 (1.23)	1.38 (1.28)	0.64 (1.12)	0.55 (1.02)	0.38 (0.94)	-	12.44 (20.50)	183.6
Untreated control	1.06 (1.25)	1.40 (1.28)	1.55 (1.45)	1.30 (1.34)	1.08 (1.26)	-	23.70 (28.87)	136.3
CD (P=0.05)	(NS)	(NS)	(0.12)	(0.13)	(0.12)	-	(1.98)	23.39

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

Table 132. Efficacy of parasitoids against PTM based on leaf mines, tuber infestation and yield of potato - Rabi (Pooled analysis of 1997-98, 1998-99 and 1999-2000)

Treatment	Pre-count*, leaf mines/m row	Number of leaf mines/m row after week*				% Parasitism (Recovery)	% Tuber infes-tation**	Yield (q/ha)
		I	II	III	IV			
C. koehleri @ 50,000 adults/ha/rel.	5.44 (2.43)	4.81 (2.12)	2.77 (1.66)	2.02 (1.98)	0.62 (1.02)	66.79	8.35 (16.99)	221.6
C. koehleri @ 37,500 adults/ha/rel.	5.40 (2.42)	5.82 (2.27)	3.48 (1.80)	2.62 (2.18)	1.10 (1.21)	53.70	10.09 (18.70)	203.4
C. koehleri @ 25,000 adults/ha/rel.	5.70 (2.48)	6.24 (2.33)	4.46 (2.02)	3.21 (2.41)	1.84 (1.45)	40.72	14.78 (23.02)	179.1
C. blackburni @ 15,000 adults/ha.rel.	4.81 (2.30)	4.71 (2.11)	2.39 (1.58)	2.33 (2.03)	0.68 (1.06)	61.32	8.76 (17.44)	217.9
C. blackburni @ 10,000 adults/ha/rel.	5.00 (2.34)	5.46 (2.21)	2.86 (1.71)	2.66 (2.15)	1.13 (1.23)	48.52	11.25 (19.88)	199.6
C. blackburni @ 5,000 adults/ha/rel.	5.96 (2.54)	5.64 (2.24)	3.37 (1.94)	3.24 (2.38)	2.59 (1.49)	36.44	15.60 (23.56)	167.0
Endosulfan 0.05%	5.39 (2.42)	6.15 (2.32)	2.53 (1.67)	2.95 (2.23)	1.66 (1.41)	-	12.45 (21.02)	189.5
Untreated control	5.64 (2.47)	6.99 (2.44)	5.71 (2.29)	5.37 (2.99)	3.71 (1.95)	-	26.09 (31.21)	148.3
CD (P=0.05)	(NS)	(NS)	(0.30)	(0.11)	(0.28)	-	(0.82)	3.30

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

Table 133. Economics of biological control of PTM on potato

Treatment	Cost of treatment			Kharif			Rabi		
	Cost of parasitoids per/ha (Rs.)	Labour charges (Rs.)	Total cost (Rs.)	Increase in yield due to treat-	Additional receipt due treat-ment(Q/ha)	ICBR	Increase in yield over control (Q/ha)	Additional receipt due to treat-ment(Rs.)	ICBR
C. koehleri @ 2.0 lakh adults/ha	750	100	850	67.11	23489	1:27.63	73.33	25666	1:30.20
C. koehleri @ 1.5 lakh adults/ha	563	100	663	50.65	17728	1:26.74	55.17	19310	1:29.13
C. koehleri @ 1.0 lakhs adults/ha	375	100	475	24.42	8547	1:17.99	30.85	10798	1:22.73
C. blackburni @ 60,000 adults/ha	1310	100	1410	66.87	23405	1:16.60	69.61	24364	1:17.28
C. blackburni @ 40,000 adults/ha	873	100	973	45.57	15950	1:16.39	51.32	17962	1:18.46
C. blackburni @ 20,000 adults/ha	437	100	537	18.79	6577	1:12.25	17.79	6227	1:11.60
Endosulfan 0.05%	815	300	1115	47.42	16597	1:14.88	41.19	14417	1:12.93
Untreated control	-	-	-	-	-	-	-	-	-

Cost: *C. koehleri* 2 lakh adults = Rs.750/-
C. blackburni 60,000 adults = Rs.1310/-
Endosulfan 35 EC (Endocel) = Rs.304/- per litre, Rs.165/- per 500 ml and Rs.42/- per 100 ml.
Labour charges : Rs.50/- per man day
Labour units required for parasitoid application = 0.5 per rel. x 4 rel. = 2 man days
For spraying = 3 labours x 2 sprays = 6 man days
Potato = Rs.350/- per q.
ICBR = Index of Cost : Benefit Ratio

4.27.2. Standardization of mass release technology for parasitoids, *Copidosoma koehleri* and *Chelonus blackburni* against PTM under field conditions

The experiment was conducted in farmer's field at village Peth (Pune) during *Rabi* - 1999-2000. Potato (var. Kufri Jyoti) was raised in 20 x 10 m^2 plots. The trial was laid out in RBD with three replications and seven treatments. The treatments comprised of inundative releases of C. *koehleri* through mummies @ 5000 per ha by placing them in perforated vials hanging in field 5m apart, using gelatinous capsules with holes placed on ridges, and as adults @ 2 lakh/ha, inundative releases of *C. blackburni* through pupae @ 60,000 per ha using perforated vials hung in the field, placing them in gelatinous capsules with holes on ridges, and as adults @ 60,000 per ha. Releases of parasitoids were carried out in four equal doses starting 45 days after planting the crop. Observations on leaf mines/m row were taken at 5 spots in each treatment plot, a day before initiation of parasitoid release and post-counts at weekly interval till termination of treatment applications. Recovery of parasitoids was studied by displaying egg-sheets each containing 50 eggs at 5 different spots in each treatment. Recovery of parasitoids (% parasitism) was also recorded by collecting 20 to 30 leaf-mining larvae from each treatment plot after four releases of the parasitoids. These egg and larval stages were further reared in the laboratory on punctured tubers as well as on potato leaves till formation of PTM pupae or mummies / pupae of the parasitoids. At harvest, tuber samples from 2 x 2m area from each plot at 3 places were collected to record tuber infestation. Yield data was recorded and further computed to q/ha.

All the treatments were significantly superior to control in reducing leaf mines/m row during III and IV weeks after initiation of treatment schedule, tuber infestation and increasing the yield of marketable potatoes (Table 134). Release of parasitoid, *C. koehleri* @ 5000 mummies/ha in plastic vials (i.e. 1250 mummies/ha/release, four releases at weekly interval) which gave minimum mines/m row, tuber infestation and maximum tuber yield, was most effective. Maximum recovery of the parasitoids through retrieval (63.45%) as well as through collection of leaf mining larvae from treatment plots (20.00%) was obtained by releasing *C. koehleri* in plastic vials followed by release of adults of *C. koehleri* (61.9%) and *C. blackburni* (60.85%)

4.27.3. Large-scale evaluation, recovery and carryover of parasitism of *C. koehleri* and *C. blackburni* against PTM from field to storage

The experiment was conducted in farmer's field on potato var. Kufri Jyoti at Shiroli, Rajgurunagar (Pune) during *rabi*-1999-2000. The plot size was 0.20 ha which was further divided into 7 subplots. Inundative releases of *C. koehleri* @ 50,000 adults/ ha/release and *C. blackburni* @ 15,000 adults/ha/release were followed four times at

Table 134. Efficacy of different methods of release of parasitoids against PTM under field conditions

Treatment	Leaf mines/m row*					Per cent parasitism		Average tuber** infestation (%)	Yield of marketable tuber (q/ha)
	Pre-count	Post-count after release (weeks)				Through retrieval	Through recovery		
		I	II	III	IV				
C. koehleri @ 5,000 mummies/ha in plastic vials	1.26 (1.32)	1.00 (1.22)	0.86 (1.16)	0.13 (0.78)	0.06 (0.74)	63.45 (13.73)	20.00	5.63	229.6
C. koehleri @ 5,000 mummies/ha in gelatinous capsules	1.06 (1.24)	1.13 (1.27)	1.06 (1.24)	0.33 (0.90)	0.26 (0.86)	57.40 (19.33)	10.00	10.96	209.2
C. koehleri @ 2 lakh adults/ha	1.00 (1.22)	1.26 (1.32)	1.06 (1.24)	0.20 (0.82)	0.20 (0.82)	61.90 (15.11)	12.00	6.80	229.3
C. blackburni @ 60,000 pupae/ha in plastic vials	1.06 (1.24)	0.80 (1.13)	0.73 (1.10)	0.26 (0.86)	0.13 (0.78)	58.95 (14.72)	16.66	6.46	227.7
C. blackburni @ 60,000 pupae/ha in relatinous capsules	1.00 (1.22)	1.00 (1.22)	0.80 (1.13)	0.33 (0.90)	0.33 (0.90)	35.10 (20.09)	6.67	11.80	194.6
C. blackburni @ 60,000 adult/ha	1.13 (1.27)	1.26 (1.31)	0.80 (1.13)	0.26 (0.86)	0.13 (0.78)	60.85 (15.59)	15.00	7.23	224.7
Untreated control	1.26 (1.32)	1.33 (1.34)	1.60 (1.44)	1.60 (1.44)	1.80 (1.41)	- (32.03)	-	28.13	162.4
C.D. (P=0.05)	(NS)	(NS)	(NS)	(0.12)	(0.15)	-	-	(0.56)	1.73

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

weekly interval commencing from 45 days after planting. The carryover of parasitism from field to storage was recorded by collecting 20 kg infested tubers from the treatment plots at harvest. The potatoes were placed separately in plastic baskets on a layer of sieved soil. Record of number of PTM pupae and/or mummies of *C. koehleri* and pupae of *C. blackburni* was kept to workout per cent parasitism carried from field to stored potatoes. Remarkable differences were not noticed between the two parasitoids in terms of leaf mines and parasitization levels. As regards the carryover of parasitism, it was 6.93 per cent for *C. koehleri* and 4.23 per cent in case of C. *blackburni* (Table 135).

4.27.4. Evaluation of *Copidosoma koehleri, Chelonus blackburni* and microbial agents against PTM in country stores (*Arnies*)

Miniatures of seven *Arnies* each of 20-kg capacity were prepared under shade. Potatoes harvested from *Rabi* crop were obtained, and healthy marketable tubers used for setting up *Arnies*. GV and *B. thuringiensis* were applied before arranging the *Arnies*; and parasitoids were released after their construction. All the *Arnies* were covered with double layer of grass and paddy straw as per the local practice. Then twenty-five newly emerged pairs of PTM were released in the vicinity of *Arnies* for creating artificial infestation. Observations on per cent tuber infestation due to PTM from each treatment in 3 replications were recorded 1 and 2 ½ months (at termination) after application of treatments.

All the treatments were significantly superior to control (Table 136). The initial release of *C. koehleri* @ 5 adult pairs/kg tubers recorded least tuber infestation (10.66 %) after one month and on par with rest of the bioagents except GV. Releases of *C. blackburni* @ 1 adult/kg tubers at fortnightly interval resulted in minimum of 20.33 per cent tuber infestation after 2½ months and it was on par with *C. koehleri* @ 1 pair of adult/ kg tubers at fortnightly interval.

Table 135. Large-scale evaluation, recovery and carryover of parasitism of *C. koehleri* and *C. blackburni* from field to store

Treatment	Leaf mines/m row*					Per cent parasitism		Average tuber** infestation (%)	Yield (q/ha)	Per cent carry-over
	Pre-count	Post-count after release (weeks)				Through retrieval	Through recovery			
		I	II	III	IV					
C. koehleri @ 50,000 adults/ha/ release(four releases)	2.01 (1.58)	2.43 (1.70)	1.28 (1.32)	0.37 (0.92)	0.28 (0.87)	63.50 (16.44)	14.00	8.01	234.8	6.93
C. blackburni @ 15,000 adults/ha/ release (four releases)	2.24 (1.64)	2.45 (1.71)	1.23 (1.30)	0.48 (0.98)	0.34 (0.90)	60.65 (16.88)	16.00	8.45	236.8	4.23
Untreated control	2.11 (1.60)	2.40 (1.69)	2.71 (1.78)	2.54 (1.74)	2.05 (1.59)	- (30.99)	-	26.54	150.4	-
C.D. (P=0.05)	(NS)	(NS)	(0.11)	(0.21)	(0.58)	-	-	(0.93)	26.68	-

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

Table 136. Efficacy of parasitoids and microbial agents against PTM in country stores (*Arnies*)

Treatment (dose/kg tubers)	Per cent tuber infestation after	
	One month	Two and half months
C. koehleri @ 1 pair of adults at fortnightly interval	13.13 (21.24)	22.00(27.95)
C. koehleri @ 5 pairs of adults as initial release	10.66(19.09)	24.06(29.40)
C. blackburni @ 1 adult at fortnightly interval	13.21(21.30)	20.33(26.79)
C. blackburni @ 2 adults as initial release	12.20(20.44)	29.66(33.00)
GV @ 1 LE as initial application	13.88(21,97)	32.33(34.65)
B. thuringiensis @ 1 g as initial application	13.22(21.35)	22.24(28.11)
Control	35.33(36.45)	50.00(45.00)
CD (P=0.05)	(2.31)	(1.50)

Figures in parentheses are angular values.

4.27.5. Large-scale evaluation of *Copidosoma koehleri* and *Chelonus blackburni* against PTM in country stores (*Arnies*)

Four *Arnies* (local stores) of potato each of 10-15 q capacity were selected at village Karegaon and Peth (Pune) for release of parasitoids, and one more *Arni* of 7 q capacity was kept as untreated control. The *Rabi* harvested potatoes were used for constructing *Arnies*. After a week, the parasitoid releases were initiated and four releases were carried out at fortnightly interval. Observations on tuber infestation were recorded by collecting 100 tubers in 3 repeats from each *Arnies* and sorting out healthy and infested tubers. The observations were recorded 1 and 2 ½ months after release of the parasitoids.

All the treatments were significantly superior over control in reducing tuber infestation at 1 and 2½ months after initiation of releases of parasitoids (Table 137). Amongst the treatments, release of *C. blackburni* @ 2 adults/kg tubers was most effective in recording 11.25 per cent tuber infestation in the *Arnies* after one month. It was, however, on par with *C. koehleri* @ 1 mummy / 4 kg tubers and *C. blackburni* @ 2 pupae/kg tubers. After 2 ½ months i.e. at termination of *Arnies*, the treatment with *C. koehleri* @ 5 pairs of adults/kg tubers released 4 times at fortnightly interval gave minimum per cent tuber infestation followed by *C. blackburni* @ 2 adults / kg tubers (17.00 %).

Table 137. Efficacy of parasitoids against PTM in country stores of potato

Treatment	Per cent tuber infestation, after	
	One month	Two and half months
C. koehleri @ 5 pairs of adults / kg tuber	14.75(22.56)	16.00 (23.52)
C. koehleri @ 1 mummy / 4 kg tubers	11.50(19.74)	22.00 (27.95)
C. blackburni @ 2 adults / kg tubers	11.25(19.51)	17.00 (24.16)
C. blackburni @ 2 pupae / kg tubers	11.50(19.77)	26.50 (30.98)
Control	33.00(35.05)	59.50 (50.52)
CD (P = 0.05)	(2.55)	(1.98)

Figures in parentheses are angular transformations

4.27.6. Cost of production of *Copidosoma koehleri* and *Chelonus blackburni*

4.27.7.1.*Copidosoma koehleri*

Production of host insect – PTM

Food requirement of PTM was estimated by taking 0.5kg potatoes in each plastic bowl and ten separate lots maintained for experimentation. The egg-sheets of PTM each having 100 to 600 eggs were released in the different bowls on punctured potatoes and number of pupae and emergence of moths was recorded. Maximum number of pupae (235) and moths (225) was obtained when 500 eggs of PTM were released on 0.5kg potatoes and so was found best.

Fecundity of PTM

Twenty-five pairs of newly emerged adults of PTM were caged in a glass jar covered with double layer of black muslin cloth for oviposition. Moths were provided with honey solution (20%) during oviposition period i.e. for 6 days (Table 138). The egg count was taken daily.

Table 138. Fecundity of PTM

Days after caging	Total number of eggs from 25 pairs	Average eggs /female
1	586	23.44
2	287	11.48
3	207	8.28
4	356	14.24
5	85	3.40
6	15	0.60
Total	1536	61.44

Hatching percentage of PTM eggs: Number of eggs hatching from three lots of 100 eggs each was recorded and it was found that the avearge hatching percentage was 95%.

The production cost of PTM eggs from moths emerged out from 0.5kg potatoes was worked out and the cost of production of *C. koehleri* then worked out.

1.	Number of eggs obtained from 225 moths reared on 0.5 kg potato	- 7680
2.	Potatoes required for rearing the larvae hatched from 7680 eggs (considering 95% hatching)	- 17 kg
3.	Number of eggs available for parasitization by keeping 40% eggs and	- 4600 eggs
	for maintenance of host and parasitoid parasitoid as nucleus culture	
4.	Number of eggs parasitized (considering 78.25% parasitization based on previous studies)	- 3600 eggs
5.	Number of adults of *C. koehleri* emerged from 3475 mummies (considering av. 45 adults per mummy based on previous studies)	- 1,56,375 adults
6.	Quantity of potatoes required for production of *C. koehleri* – (2 lakh adults or 5000 mummies) per ha (considering other losses)	- 30 kg

Item-wise expenditure for production of *C. koehleri* per ha

i.	Cost of potato of 30 kg (Rs.10/- per kg)	-	Rs. 300/-
ii.	Labour charges for rearing, cleaning and other maintenance, etc.	-	Rs. 300/-
iii.	Chemicals / muslin / other material, cost	-	Rs. 150/-
	Total cost / ha		**Rs. 750/-**

Thus, the cost of production of *C. koehleri* for releases @ 2,00,000 adults or 5,000 mummies per ha is Rs. 750/-. It could be minimized by large-scale production.

4.27.7.2. *Chelonus blackburni*

The production of this parasitoid could be undertaken on PTM or *Corcyra* eggs.

I. Cost of production of *C. blackburni* using PTM as host

Utilizing the data on PTM production as given under C. koehleri the following calculation was done for parasitization of C. blackburni.

1.	Number of parasitoids of *C. blackburni* emerged from 3475 pupae (based on previous studies)	-	2790 adults
2.	Quantity of potatoes required for production of 60,000 pupae or adults per ha	-	366 kg

Item wise expenditure for production of *C. blackburni* per ha:

1.	Cost of potato of 366 kg (Rs.10/- per kg)	-	Rs. 3660/-
2.	Labour charges for rearing, cleaning and maintenance, etc.	-	Rs. 300/-
iii.	Chemicals, muslin, other materials, etc.	-	Rs. 150/-
	Total cost / ha	-	**Rs. 4110/-**

Considering the rate of release of *C. blackburni* (60,000 pupae or adults/ha), the cost of production of the parasitoid to treat one ha area is Rs. 4110 /- which could be minimized on its large-scale production.

II. Cost of production of *C. blackburni* using *Corcyra cephalonica* as host

C. blackburni accepts the factitious host, *C. cephalonica* and parasitizes its eggs under laboratory conditions.

One adult of *C. blackburni* is reported to parasitize 70-100 eggs of *Corcyra*. Hence, about 100 adults were used to parasitize 0.25 cc, i.e. 5000 eggs of *Corcyra* pasted on cards. Such parasitized egg-strips (100 to 1000 eggs) were reared on 200-g crushed grains of wheat and emergence of adults of *C. blackburni* and *Corcyra* were (Table 139).

Table 139. Number of eggs parasitized

Number of eggs released / bowl	Quantity of crushed grains (g)	Number of *C. blackburni* adults emerged	Number of *Corcyra* moths emerged	Total
100	200	35	27	62
200	200	86	109	195
300	200	176	56	232
350	200	90	103	193
400	200	70	89	159
500	200	160	78	238
550	200	121	22	143
600	200	53	196	249
700	200	122	96	218
800	200	190	74	264
850	200	218	100	318
1000	200	207	124	231

The results showed that when 850 eggs of *C. cephalonica* were parasitized and inoculated in 200 g crushed wheat grains, as many as 218 adults of *C. blackburni* and 100 moths of *Corcyra* were obtained and was considered ideal.

Cost of production then was worked out as under

1.	Rate of release of *C. blackburni* against PTM in field	-	60,000 adults/ha
2.	Number of parasitoids obtained from 200 g crushed wheat grains	-	218 adults
3.	Quantity of food material required for rearing parasitised *Corcyra* larvae to obtain 60,000 adults of *C. blackburni*	-	55 kg
4.	Cost of food material (Rs.10/- per kg)	-	Rs. 550/-
5.	Crushing charges @ Rs.2/- per kg.	-	Rs. 110/-
6.	Supplementary nutrition required and disinfectant charges, etc.	-	Rs. 300/-
7.	Laboratory rearing charges, etc.	-	Rs. 350/-
8.	Total production cost of parasitoids/ha, excluding laboratory facilities	-	Rs.1310/-

Thus, the production cost of *C. blackburni* (60,000 adults/ha) when reared on *Corcyra* culture is Rs.1310/- per ha.

4.27.8. Field evaluation of SlNPV and *Bacillus thuringiensis* in comparison with endosulfan against *Spodoptera litura* on potato

A field experiment was conducted during *Kharif* - 1999 with var. Kufri Jyoti on farmer's field at village Peth (Pune) with six treatments and four replications (RBD). The spraying was carried out during evening hours. After one hour, 10 larvae from each treatment plot were collected along with treated foliage and further reared under laboratory conditions for one week. The larvae were provided with fresh food daily by collecting the treated foliage from the respective plots. Observations on larval mortality and yield per plot were recorded.

All the treatments were significantly superior over control (Table 140). Spraying of *Sl*NPV @ 750 LE/ha (4.5 x 10^{12} POBs/ha) which gave maximum of 95.00 per cent larval mortality and 230.0 q/ha tuber yield, was the most effective treatment and was on par with *Sl*NPV @ 500 LE/ha (3.0 x 10^{12} POBs/ha) and *B. thuringiensis* @ 0.5 kg/ha in respect of yield.

Table 140. Efficacy of *Sl*NPV and *B. thuringiensis* against *Spodoptera litura* on potato

Treatment	Larval mortality (%)	Yield of marketable tubers (q/ha)
*Sl*NPV @ 250 LE/ha (1.5 x 10^{12} POBs/ha)	70.00 (56.95)	184.00
*Sl*NPV @ 500 LE/ha (3.0 x 10^{12} POBs/ha)	82.50 (65.47)	210.00
*Sl*NPV @ 750 LE/ha (4.5 x 10^{12} POBs/ha)	95.00 (80.78)	230.00
B. thuringiensis @ 0.5 kg/ha	85.00 (67.87)	229.00
Endosulfan 0.05 %	72.50 (58.60)	188.50
Untreated control	15.00 (22.50)	137.60
C.D. (P = 0.05)	(10.46)	19.48

Figures in parentheses are angular transformations

Pooled analysis of three years' data (1997- 98 to 1999-2000) revealed that all the treatments were significantly superior over control (Table 141). Amongst the treatments, spraying of *Sl*NPV @ 750 LE/ha (4.5 x 10^{12} POBs/ha) proved to be the best and was on par with *Sl*NPV @ 500 LE/ha (3.0 x 10^{12} POBs/ha) and *B. thuringiensis* @ 0.5 kg/ha. The cost: benefit ratio was high for the treatments with *Sl*NPV (Table 142).

4.27.9. Survey of natural enemies of PTM and other important pests of potato

The leaf mining larvae of PTM were parasitized by *Apanteles* sp. and *Bracon* sp. to the extent of 3.7-7.4 and 4.8-10.1 per cent, respectively, during *rabi* season. The coccinellid predators *Cheilomenes sexmaculata* and *Coccinella septempunctata* were recorded after 35 days of planting (0.5 grub / adult per plant); its population peaked (3.5 grubs/plant; 2 beetles/plant) 65 days after planting during *Kharif*. However, these ladybird beetles were very meager during *Rabi* and noticed only when the crop was two months old. In local storage of potato, no parasitism or predation was noticed during April-May, 1999, but with the commencement of rains the predatory dermestid, *Evorinea indica* was noticed.

Spodoptera litura was found to be serious during *Kharif* (August-September 1999). The larvae of *S. litura* was found to be infected with *Nomuraea rileyi* and on an average 4.6 infected larvae per plant were seen a week before harvest.

Table 141. Efficacy of *Sl*NPV and *B. thuringiensis* against *Spodoptera litura* on potato (Pooled analysis of 1997-98, 1998-99 and 1999-2000)

Treatment	Per cent larval mortality				Yield of marketable tubers (q/ha)			
	1997-98	1998-99	1999-2000	Pooled Mean	1997-98	1998-99	1999-2000	Pooled Mean
*Sl*NPV @ 500 LE/ha (3.0×10^{12} POBs/ha)	80.00 (64.34)	85.00 (67.50)	82.50 (65.47)	82.50 (65.77)	168.2	196.4	210.0	191.6
*Sl*NPV @ 750 LE/ha (4.5×10^{12} POBs/ha)	87.50 (69.54)	90.00 (74.14)	95.00 (80.78)	91.68 (74.82)	184.5	209.6	230.0	208.0
Bacillus thuringiensis @ 0.5 kg/ha (Delfin WG)	75.00 (60.64)	77.50 (62.15)	85.00 (67.87)	80.00 (63.55)	169.6	192.1	229.0	196.9
Endosulfan 0.05%	67.50 (55.44)	67.50 (55.44)	72.50 (58.60)	69.17 (56.50)	139.3	169.8	188.5	165.9
Untreated control	12.50 (20.47)	7.50 (13.83)	15.00 (22.50)	11.66 (18.93)	123.7	140.1	137.6	133.9
CD = (P = 0.05)	(11.67)	(12.60)	(10.94)	(10.94)	38.63	33.55	21.67	29.86

Figures in parentheses are angular transformations

Table 142. Economics of treatments with *Sl*NPV and *B. thuringiensis* for the control of *S. litura* on potato

Treatment	Cost of treatments (Rs.)			Increase in yield due to treatment (q/ha)	Additional income due to treatment (Rs.)	ICBR
	Cost of microbial agent/ha (Rs.)	Labour charges (Rs.)	(Total cost of application (Rs.)			
*Sl*NPV @ 500 LE/ha (3.0x10 POBs/ha)	750	150	900	57.6	20160	1:22.40
*Sl*NPV @ 750 LE/ha (4.5x10 POBs/ha)	1125	150	1275	73.9	25865	1:20.29
B. thuringiensis @ 0.5 kg/ha (Delfin WG)	1500	150	1650	63.0	22050	1:13.37
Endosulfan 0.05%	469	150	619	31.8	11130	1:17.98
Untreated control	-	-	-	-	-	-

Rate of potato = Rs.350/- per qt.

Cost of *Sl*NPV = Rs.750/- per lit (500 LE)

Delfin WG = Rs.3000/- per kg.

Endosulfan = Rs.304/- per lit; Rs.165/- per 500 ml

Labour charges = Rs.50/- per day (Three labour per spray)

ICBR = Cost: Benefit Ratio

4.28. Biological suppression of weeds

4.28.1. Monitoring, evaluation and impact assessment of *Neochetina eichhorniae*, *N. bruchi* and *Orthogalumna terebrantis* against *Eichhorniae crassipes*

4.28.1.1 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 varied from 2.00 to 6.52 per plant and feeding scares from 50 to 250 per leaf during 1999.

4.28.1.2 AAU, Jorhat

In Disagmukh area of Sibsagar district more than 1000 hectares of water body was cleared off by the action of this exotic weevil last year. The weevils further migrated to Lakhimpur, Sonitpur and Dibrugarh from the initial release area (AAU Campus, Jorhat). The weevil has dispersed to eight districts of Assam through aerial migration and Brahmaputra river and its tributaries. Stunted growth of water hyacinth accompanied by less flowering was observed in all districts, *viz.*, Sonitpur, Lakhimpur, Dibrugarh, Sibsagar, Jorhat, Golaghat, Nagaon and Kamrup. In Chataibill of Sonitpur district, the local farmers have utilized some cleared off areas for boro rice cultivation. The weevils have adapted to the new environment very successfully as evidenced by the presence of the larvae and adult weevils along with fresh damage on the leaves. The adult counts varied from 0.60 to 3.68 per plant and feeding scars from 36.16 and 195.80 per leaf.

4.28.1.3 KAU, Thrissur

Sampling of water hyacinth plants from Alleppey, Kottayam, Ernakulam and Thrissur was done during June 1999, September 1999 and December 1999. *O. terebrantis* has established all over the release sites and in the neighboring locations, with almost 100 per cent infestation. The number of mites varied from 8.40 to 146.84/leaf and the score for mites/leaf was 1.80 – 3.36.

4.28.1.4 MPKV, College of Agriculture, Pune

There was considerable increase in weevil and mite population from June to December (Table 143).

Table 143. Efficacy of *Neochetina* spp. and *Orthogalumna terebrantis* in suppressing the water hyacinth

Month	Leaf feeding due to *Neochetina* spp.		Average number of weevils / plant	Average number of mites/leaf
	Score	Damage %*		
June 1999				
Pond – I	1.00	12.25 (0 – 20)	1.02	9.00
Pond – II	1.20	13.65 (0 – 25)	1.03	11.50
September 1999				
Pond – I	1.10	14.35 (0 – 20)	1.20	13.00
Pond – II	1.15	23.15 (5 – 45)	1.32	13.50
December 1999				
Pond – I	1.40	30.52 (5 – 55)	2.85	17.80
Pond – II	1.95	32.55 (10-60)	3.02	20.15
March 2000				
Pond – I	1.35	28.30 (5 – 65)	2.70	16.00
Pond – II	1.65	22.40 (10-50)	2.95	14.80

* Figures in parentheses are range of leaf area damaged

4.28.2. Monitoring and evaluation of *Cyrtobagous salviniae* (KAU, Thrissur)

Field releases of *C. salviniae* weevils continued from College of Horticulture, Vellanikkara, Rice Research Station, Moncompu and the Regional Agricultural Research Station, Kumarakom. Samples of *Salvinia molesta* were collected from Thrissur and Kottayam districts to assess the field population of *C. salviniae*. Infestation could be noticed in almost all the locations and the field population of weevil varied from 1.0 to 4.3 per plant in different locations.

4.28.3. Potential of *Zygogramma bicolorata* on parthenium in mid hills of Himachal Pradesh (Dr.YSPUH&F, Nauni, Solan)

Although some diapausing females started egg laying in the second week of March 1999 and laid eggs till July end, those that remained in the soil continued to be in diapause till second week of May.

In the field at Nauni, first activity of the beetle was noticed in second week of June but population remained very low till August. Egg laying was to the extent of 0.9/ plant in September and maximum in the first fortnight of October, which declined to 0.1/

plant by third week of November. No beetle activity was noticed after November in the field. Beetles pupated in first week of September, entered into reproductive diapause in mid-October and were in this state till March-end.

At Solan, where beetles were released last year, no recovery was obtained. Newly hatched and first instar larvae (50-150/plant) were released in the end of August to the first week of October on selected healthy plants where no beetle activity existed. However, these larvae did not establish. Solan at an altitude of 1500 m seems to be the marginal area for its activity. Even at altitude of 1250 m, it had remained confined to some patches and has spread to nearby areas very slowly during the last three years.

4.29. Research achievements made in the lateral funded projects

4.29.1. Use of semiochemicals to increase biocontrol potential of predators and parasitoids (DBT funded project, Principal Investigator: Dr.N.Bakthavatsalam)

Kairomones were used to induce oviposition by *Chrysoperla carnea*, parasitoids of coconut caterpillar on the non host *Corcyra cephalonica* and to increase the searching ability of *Goniozus nephantidis* and *Trichogramma chilonis*. Docosane, tricosane and hexadecane were effective attractants for *T. chilonis* and could induce parasitization of more number of eggs as compared to untreated control. The combination of gallery wash and pupal wash extract was found to be most effective in attracting *Brachymeria nephantidis*. The body, larval, pupal and egg wash of *Helicoverpa armigera* was also analyzed for its volatile components and Heptadecane was found to be the major component of all the extracts. Preliminary studies were conducted using electroantennogram (EAG) to find out response of *Cotesia flavipes* to kairomones. Higher EAG response was noticed from extracts of frass derived from *C. partellus* feeding on maize than frass from artificial diet. In field studies with the scale extract fortified with n-tricosane, higher parasitisation by *T. chilonis* was observed on cotton treated with kairomone.

4.29.2. Biological control of *Agrotis* spp. with entomophilic nematodes (DBT funded project, Principal Investigator: Dr.S.S.Hussaini)

Bioefficacy of *S. carpocapsae* PDBC EN 6.11, *S. bicornutum* PDBC EN 3.1, *S. glaseri* and *H. indica* PDBC EN 13.3 against *A. ipsilon* varied at different temperatures *viz.* 10°C, 15°C, 25°C and 32°C with rate of infection being 100% at 25°C and 32°C. *S. glaseri, S. bicornutum* PDBC EN 3.1 and *H. indica* PDBC EN 13.3 were found promising against *A. ipsilon* with 100% mortality 96 h post exposure. *A. ipsilon* reared on chickpea leaves was more susceptible to *S. bicornutum* PDBC EN 3.1 and *H. indica* PDBC EN

13.3 with 100% mortality at 48h post exposure. *A. ipsilon* larvae reared on tomato, castor and artificial diet were susceptible to all isolates tested with 50-100% mortality at 72h. *Agrotis* larvae reared on pumpkin were least susceptible to *H. indica* and *S. bicornutum* isolates tested with 83 and 60 % mortality, respectively, at 96 h post exposure. Progeny production of *Steinernema* spp. and *H. indica* isolates from *Agrotis* larvae reared on artificial diet ranged from 2.4-3.8 lakhs, much higher than production when reared on host plants. Talc formulation of nematodes proved better with 42.8 - 85.7% mortality of *Agrotis ipsilon* larvae than alginate capsule formulation. Application of nematodes mixed with water was found to be the most effective with 52.3-90.5% mortality.

4.29.3. Biocontrol of maize tissue borers using entomophilic nematodes (ICAR ad-hoc scheme, Principal Investigator: Dr.S.S.Hussaini)

Out of 136 samples baited in eight states, five yielded entomopathogenic nematodes of which two belonged to *Heterorhabditis indica* (PDBC EN 14.3 and PDBC EN 6.71) and two to *Steinernema* spp. (PDBC EN 13.21 and PDBC EN 14.1). Pot culture experiment indicated that infestation of *C. partellus* on maize plants sprayed with 1000 IJ/plant was lower than those plants sprayed with 500 IJ/plant. In bioefficacy tests against third instar larvae of *C. partellus*, *H. indica* (PDBC EN 6.71) was found to be superior. Quinalphos was most deleterious to *H. indica* (PDBC EN 14.3) reducing activity by 70.4-100%, 120 h after exposure. Endosulfan and fenvalerate were compatible with EPN. *H. indica* isolates were found to tolerate desiccation longer (48 h) than *Steinernema* spp. (24 h). Infectivity and progeny production were not adversely affected by desiccation. Formulations such as alginate capsule, wheat bran pellets and talc were found better in terms of nematode survival and pathogenicity. Shelf life of alginate capsule formulation was much better as compared to other formulations. Among the different media tested (distilled water, liquid paraffin and glycerin) for storage at 8 and 24°C, liquid paraffin was found most suitable for both *Steinernema* spp. and *H. indica* isolates. At 15°C, distilled water was better than glycerin and liquid paraffin for all isolates. Steinernematids survived better than heterorhabditids in different media.

4.29.4. Developing strategies for the management of parthenium weed in India using fungal pathogens (CABI-ICAR Collaborative Project: Principal Investigator: Dr. P. Sreerama Kumar)

The most pathogenic isolate [WF(Ph)3; IMI 378270] of *Cryptosporiopsis* sp. was evaluated further. The effect of some common surfactants (Tween 20, Tween 80, glycerol and Triton X-100) on the pathogenicity of *Cryptosporiopsis* sp. was assessed and Tween 80 caused a necrotic leaf area of 94.80%. The utility of some hydrophilic substances in promoting leaf wetness and thereby increasing the pathogenicity of

Cryptosporiopsis sp. to parthenium was examined using the mycelial inoculation technique. The performance of *Cryptosporiopsis* sp. was affected because of the presence of hydrophilic substances in the inoculum. The best among them was gum arabic, which produced the maximum necrotic leaf area of 97.16%. Sodium alginate (84.80%) was next only to gum arabic in increasing the pathogenicity of the fungus.

4.29.5. National repository of natural enemies of crop pests and weeds (DBT funded project, Principal Investigator : Dr. S.P. Singh)

Strains of *Trichogramma chilonis* and *T. japonicum* were collected from sugarcane, rice, maize, tur and cotton ecosystems in Punjab and sorghum ecosystem from Dharwad district and Sriganganagar (Rajasthan). Nucleus cultures of five coccinellid predators, viz., *Cheilomenes sexmaculata, Chilocorus nigrita, Cryptolaemus montrouzieri, Coccinella septempunctata* and *Scymnus coccivora* were continuously maintained in the laboratory. Nucleus cultures of *Neochetina eichhorniae, N. bruchi, Orthogalumna terebrantis, Cyrtobagous salviniae* and *Zygogramma bicolorata* collected from in and around Bangalore were maintained. Braconids viz., *Cotesia plutellae, Cotesia flavipes* and *Myosoma chinensis* were collected from Hoskote, Adugodi, Rajankunte, Jakkur and Doddajala in and around Bangalore and also from New Delhi. Species of chrysopids maintained were *Mallada astur, Mallada boninensis, Apertochrysa* sp., *Ankylopteryx* sp.-1 and *Ankylopteryx* sp.-2. Cultures of *Telenomus remus, Telenomus* sp. and *Oomyzus ?sokolowskii* were maintained on *Spodoptera litura* eggs. Multiplication of two anthocorids *Orius tantillus* and *Cardiastethus exiguus* in the laboratory has been prefected. *Goniozus nephantidis, Brachymeria nosatoi, B. nephantidis, Elasmus nephantidis, Apanteles taragamae* and *Bracon hebetor* were collected from *Opisina arenosella* in different locations. *Campoletis chlorideae* and *Eriborus argenteopilosus* were the two potential ichneumonids multiplied on *Spodoptera litura*. Attempts were made to produce a multicellular tray for the mass rearing of lepidopterous host insects which would in turn help in the production of ichneumonids in large numbers. An encyrtid parasitoid *Leptomastix dactylopii* was recovered from field collected mealybugs.

More than hundred isolates of fungi showing antagonistic potential against pathogenic fungi were isolated from rhizosphere and rhizoplane soil samples of cereals, pulses, oil seeds, vegetables, fruits, spices and plantation crops from different parts of the country. Extensive surveys were undertaken in Bangalore Urban, Bangalore Rural, Mandya, Mysore, Dharwad, Bidar, Gulbarga, Raichur, Bellary and Chitradurga districts of Karnataka State for collecting various fungal pathogens of parthenium. *Nomuraea rileyi* and *Beauveria bassiana* were found to infect *Helicoverpa armigera* and *Spodoptera litura* in Khammam District of Andhra Pradesh during December. The entomopathogenic fungi, *Hirsutella nodulosa* and *Verticillium lecani* were obtained from SBI, Coimbatore and CPCRI, Kayangulam, respectively. Nematode pathogens were isolated from adult nematodes and egg masses, purified, identified and maintained in axenic form.

4.29.6. Team of Excellence for Human resource development in biological control (NATP funded project, Principal Investigator : Dr. S.P. Singh)

The project has been sanctioned for a period of four years with an object of developing a critical mass of young scientists in modern biocontrol techniques for key crop pests in different agro ecosystems. The first batch of two months training was completed on 04.03.2000. Nine candidates from peninsular India attended the training programme. Components of training programme included training on mass production, storage, shipment, field release and impact assessment of natural enemies of crop pests in different cropping systems and the trainees were exposed to both theoretical and practical aspects of production of biocontrol agents. The first batch of six months training programme started on 03-01-2000 with three candidates and the trainees are undergoing intensive training and hands-on experience on mass production of trichogrammatids and chrysopids, biological suppression of lepidopterous pests and microbial control of insect pests.

4.29.7. NATP Project on control of leaf curl viral disease in cotton and development of protocols for mass multiplication of predators, parasites and insect pathogens (CCPI - Dr. (Ms.) Chandish R. Ballal)

The project sanctioned for four years aiming at development of protocols for mass multiplication of bioagents with a budget allocation of 6.44 lakhs. Work is envisaged on identification of promising bioagents in cotton ecosystem, development of mass production protocols for novel bioagents, refinement of mass production protocols for known bioagents and economisation of production process.

4.29.8. Developing a mycoacaricide for suppressing the coconut mite (Coconut Development Board (CDB), Ministry of Agriculture, Government of India, Principal investigator : Dr P. Sreerama Kumar)

In Tamil Nadu, surveys were carried out in and around Coimbatore district, paying particular attention in the areas near Pollachi and Udumalpet, which are some of the worst affected places. *In situ* observations on both fallen and harvested nuts indicated the association of the acarogenous pathogen, *Hirsutella thompsonii,* with the mite in 10-25% of the samples. The pathogen was isolated from the mites for the first time and a total of 15 isolates were purified and studied for pathogenicity and virulence. The isolate MF(Ag)5, has shown the most desirable characteristics for development as a mycoacaricide. *H. thompsonii* (10^6 spores/mL), when applied as a spray or through direct injection into the perianth, was able to cause up to 70% mortality of the mites. The pathogen multiplied on sorghum (the fermentation product of the pathogen containing both mycelial fragments and spores) showed promise in the field. The pathogen was formulated suitably and the product ('Mycohit') taken up for further trials. Since *Verticillium lecanii* showed some promise in controlling the mite during initial studies, various concentrations viz., 10^6, 10^7 and 10^8 conidia/mL were tested against the mite. The fungus at a minimum concentration of 10^6 spores/mL caused mortality up to 50-60%, when the conidial suspension was directly applied into the perianth. A talc-based formulation of the pathogen was also effective when applied either as a dry application or as a suspension in water. Apart from *V. lecanii*, other entomopathogens viz., *Beauveria bassiana* (3 isolates) and *Nomuraea rileyi* were also studied for their potential against the mite. Though the fungi were able to colonize the inner region of the perianth, they were unable to infect the mites.

4.29.9. Implications of tritrophic interactions in the biological control of some important crop pests (ICAR Cess fund project : Principal Investigator: Dr.N.Bakthavatsalam)

In EAG studies adult females of *Helicoverpa armigera* showed more response than males to extracts of cotton varieties Kanchana, G-27and C-256.4. Adult females of *Chrysoperla carnea* showed comparatively better response than males and among the cotton varieties tested, Savitha, LRK-516, C256.4 evoked better response and boll extracts of Savitha and LRK 516 recorded more response. When sunflower varieties were tested adult females of *H. armigera* showed more response. *C. carnea* males showed higher response and variety KBSH-1 showed more response.

Cotton was found to have several terpenoids like alpha pinene, myrcene, etc., which are considered as important volatiles invoking behavioural responses. *H.armigera* showed highest response in hexanol, pentanol and caryophyllene oxide. In case of *C. carnea*, response was higher to hexanol, alpha pinene and caryophyllene. Orientation behaviour of *C. carnea* was studied to various cultivars of cotton through wind tunnel and 'H' tube studies and varieties HLS 72, MCU 7 and Suman recorded more oviposition in wind tunnel studies. In 'H' tube studies MCU-7 and C-256.4 recorded more oviposition. The vegetative parts of 10 cotton cultivars were tested for ovipositional preference by *C. carnea* and *H. armigera*. The highest oviposition was recorded on MCU-7 by *C. carnea* where as more number of eggs were laid on the C-256.4 by *H. armigera*. The orientational response studies with *H. armigera* and *C. carnea* to caryophyllene oxide, linalool, pentanol and hexanol showed highest attraction to pentanol followed by caryophyllene oxide.

5. TECHNOLOGY ASSESSED AND TRANSFERRED

5.1. Technology assessed

5.1.1. Potential *Pseudomonas* isolates

Antagonistic strains of *Pseudomonas fluorescens* (PDBCAB2) and *P. putida* (PDBCAB 19) for the control of wilt and root rot pathogens *Sclerotium rolfsii, Rhizoctonia solani, Macrophomina phaseolina, Fusarium oxysporum* f. sp. *ciceris, F. oxysporum* f. sp. *udum* and *Pythium* spp. were released.

5.1.2. Nucleopolyhedrovirus for the control of *Spodoptera exigua*

Project Directorate has come out with a multiple embedded nucleopolyhedrovirus (NPV) for the control of beet armyworm, *Spodoptera exigua*. *Se*NPV is highly effective @ 2×10^6 PIBs/ml and safe to the mulberry silkworm, *Bombyx mori* and predator *Chrysoperla carnea*. It is highly cross infective to *S. litura*.

5.1.3. Granulosis virus for the control of *Plutella xylostella*

Project Directorate has come out with a potential granulosis virus (GV) for the control of diamondback moth, *Plutella xylostella*. It is safe to *Cotesia plutellae, Chrysoperla carnea* and *Bombyx mori*. It is not cross infective to other lepidopteran pests.

5.2. Technology transferred

5.2.1. Control of water hyacinth

Technology transfer services was provided in supply and release technique of *Neochetina eichhorniae, N. bruchi* and *Orthogalumna terebrantis* for the control of water hyacinth in Bhindawas lake at Panchkula, Rothak District, Haryana.

5.2.2. Control of scale insect, *Lepidosaphes* sp.

Technology transfer service was provided in the supply and release technique of *Chilocorus nigrita* for the control of scale insect, *Lepidosaphes* sp. on arecanut palms. About 4000 adult beetles and 2500 eggs were released in Dakshina Kannada District, Karnataka.

6. EDUCATION AND TRAINING

6.1. Education

Ms.Chandish R.Ballal was awarded Ph.D. for her thesis entitled, "Studies on the feasibility of using biocontrol measures for developing a bio-intensive IPM programme for the management of *Helicoverpa armigera* (Hubner) (Lepidoptera : Noctuidae)" from Mysore University on 18-09-1999.

Miss Rinku Verma has registered for her Ph.D. under the guidance of Dr.S.P.Singh, Project Director and is working on her thesis problem, on "Biological suppression of water hyacinth in relation to pollution levels and its environmental impact".

6.2 Training

Mr.P.K.Sonkusare, Technical Officer (T-5) (Computer) and Mr.Anjaneya Valmiki, Technical Assistant (T-III-3) (Computer Assistant), attended a training programme on " LAN networking and MS Office" from 20th to 23rd April, 1999 at National Academy of Agricultural Research Management, Hyderabad.

Mr.Anjaneya Valmiki, Technical Assistant (T-III-3) (Computer Assistant), attended a training programme on "Windows-95 and Office-97" from 2nd to 7th August, 1999 at National Informatics Centre, Bangalore.

Mr.H.Jayaram, Technical Assistant (T-II-3) (Library Assistant), attended a training programme on "Library Automation and Networking" from 9th to 13th August, 1999 at INSDOC Regional Centre (CSIR Complex), Taramani, Chennai.

Mr.H.Jayaram, Technical Assistant (T-II-3) (Library Assistant), attended a training programme on " Internet for Agriculture Information Communication" from 21st to 24th December, 1999 at National Institute of Agricultural Extension Management, Hyderabad.

Ms.I.M.Dautie, Assistant Administrative Officer, attended a refresher course on " Improving Administrative and Financial Management in ICAR Institutes" from 30th November to 6th December 1999 at National Academy of Agricultural Research Management, Hyderabad.

Dr.P.Sreerama Kumar, Scientist, attended a training programme on "Development of a biocontrol strategy for the management of the alien perennial weed *Mikania micrantha* in tree crop based farming systems in India" from 17th to 28th January, 2000 at CABI Bioscience, UK Centre (Ascot), Berkshire.

7. AWARDS AND RECOGNITIONS

Dr.S.P.Singh was a resource person for the the summer schools on "Microbial control in India: prospects and perspectives" held at Tamil Nadu Agricultural University, Coimbatore on 5th May, 1999 and on "Emerging Trends in the Use of Bioagents for Crop Production" held at College of Agriculture, Pune on 27th June, 1999.

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.96.69 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 will be 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 1999-2000 to 2002-2003. The financial sanction has, however covered only ninth plan period (up to 31.03.2002). 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 A linkage has been developed with Coconut Board and a project has been formulated with a financial assistance of Rs.3.00 lakhs to develop a mycoacaricide for suppressing coconut mite.

8.4. A linkage has been developed with CABI Bioscience, United Kingdom with a financial assistance of Rs.4,95,000/- for developing strategies for the management of parthenium weed in India using fungal pathogens.

8.5. A linkage has been developed with Coffee Board, Bangalore for quarantine screening of coffee berry borer parasitoids.

9. AICRP / COORDINATION UNIT / NATIONAL CENTRES

With a view to fulfil the mandate given, the Project Directorate has divided the workload based on infrastructural facilities and expertise available among six ICAR Institute based and ten State Agricultural University (SAUs) based co-ordinating centres and the following are the crops allotted.

Head quarters

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 on insect pathogens
Indian Institute of Horticultural Research, Bangalore (Karnataka)	-	Fruits & Vegetables
Indian Sugarcane Research Institute, Lucknow (Uttar Pradesh)	-	Sugarcane
Sugarcane Breeding Institute, Coimbatore (Tamil Nadu)	-	Sugarcane

State Agricultural University based centres

Assam Agricultural University, Jorhat (Assam)	-	Rice & weeds
Acharya N.G.Ranga Agricultural University, Hyderabad (Andhra Pradesh)	-	Pulses, cotton & vegetables
Govind Ballabh Pant University of Agricultural Sciences & Technology, Pantnagar (Uttar Pradesh)	-	Plant diseases (pulses & oilseeds)
Gujarat Agricultural University, Anand (Gujarat)	-	Cotton, oilseed and weeds

Kerala Agricultural University, Thrissur (Kerala)	-	Weeds, rice and fruit crops
Mahatma Phule Krishi Vidyapeeth, Pune (Maharashtra)	-	Potato, sugarcane, rice vegetables & weeds
Punjab Agricultural University, Ludhiana (Punjab)	-	Sugarcane, cotton, pulses, rice & oil seeds
Sher-E-Kashmir University of Agricultural Sciences & Technology, Srinagar (Jammu & Kashmir)	-	Temperate fruits & vegetables
Tamil Nadu Agricultural University, Coimbatore (Tamil Nadu)	-	Rice, cotton & pulses
Dr.Y.S.Parmar University of Horticulture & Forestry, Solan (Himachal Pradesh)	-	Temperate fruits, vegetables & weeds

GENERAL / MISCELLANEOUS

10. LIST OF PUBLICATIONS

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11. LIST OF APPROVED ON-GOING PROJECTS

Basic Research

Project Directorate of Biological Control, Bangalore

1. Introduction and studies on the exotic natural enemies of some lepidopterous insect pests.
2. Introduction and studies on the exotic natural enemies of some dipterous and homopterous insect pests.
3. Biosystematic studies on predatory coccinellids.
4. Development of mass production techniques for parasitoids
5. Development of viable mass production techniques for predators
6. Behaviour ecology of the potential parasitoids to enhance their efficiency in biological suppression of key crop pests
7. Use of semiochemicals to improve the efficiency of important predators
8. Studies on insect viruses
9. Survey, identification and utilization of entomopathogenic nematodes against some important lepidopterous and coleopterous insect pests
10. Biological control of plant parasitic nematodes with fungi and bacteria with special reference to *Paecilomyces lilacinus* and *Pasteuria penetrans*
11. Biological control of soil borne and other plant pathogenic fungi by antagonistic fungi and development of biofungicides
12. Biological control of soil borne plant pathogens by antagonistic bacteria and development of bacterial biocontrol agents
13. Survey, identification and utilization of plant pathogens for the biological control of weeds with particular reference to parthenium and water hyacinth
14. Evaluation of improved and selected species/strains of egg parasitoids
15. Evaluation of artificial diet, release rates and genetic improvement of important predators
16. Evaluation and development of artificial diet for important lepidopterous pests
17. Software development for identifying and suggesting biocontrol measures for different crop pests using PC
18. Development of national information system on biological suppression of crop pests

NATP funded projects at PDBC, Bangalore

1. Team of Excellence for HRD in Biological Control
2. Control of leaf curl viral disease in cotton and development of protocols for mass multiplication of predators, parasitoids and insect pathogens

Indian Agricultural Research Institute, New Delhi

1. Basic studies and maintenance of *Bacillus thuringiensis* strains
2. Basic studies on baculovirus of *Achaea janata, Chilo partellus* and *Agrotis ipsilon*
   (a) Characterization of baculoviruses
   (b) Studies on formulations of microbial pesticides based on baculoviruses and *Bacillus thuringiensis.*

G.B.Pant University of Agriculture and Technology, Pantnagar

1. Demonstration of biocontrol agents *Trichoderma virens* (TV) and *Trichoderma harzianum* (TH) against diseases in farmers' field .
2. Development of mixed formulation of TV/TH and *Pseudomonas fluorescens* .
3. Integration of biocontrol agents and micronutrients and/or plant defense inducers for the management of economically important plant diseases.
4. Mass multiplication (approximately 500 kg each) of *T. virens, T. harzianum* and *Pseudomonas fluorescens* (possibly mixed formulation also) for supply to the farmers.

At Co-ordinating centres

Biological suppression of crop pests and weeds

Sugarcane

1. Large scale demonstration and recovery studies on *T. chilonis* against tissue borers (MPKV, PAU)
2. Survey of natural enemies of sugarcane borers (SBI, PAU).
3. Identification and evaluation of a temperature tolerant strain of *Trichogramma chilonis* against shoot borer (PAU).

4. Evaluation of *Beauveria brongniartii* against white grubs (SBI).

   (a) Field trial
   (b) Mass production of the fungus
   (c) Compatibility studies

5. Sequential releases of egg parasitoid *T. chilonis* and larval parasitoid *Cotesia flavipes* against sugarcane stalk borer (PAU)

Cotton

1. Biointensive integrated management of cotton pests (GAU, MPKV, ANGRAU, TNAU, PAU) .
2. Field evaluation of inundative releases of *T. chilonis* in combination with *Chrysoperla carnea* against cotton pest complex (GAU)
3. Impact of inundative releases of *Chrysoperla carnea* against pest complex (GAU).
4. Identification of host plants which harbour arthropod natural enemies (ANGRAU, TNAU).
5. Studies on the natural enemy complex of *Helicoverpa armigera* (PAU).
6. Evaluation of different *Bt* products for efficacy against cotton bollworm complex (TNAU)
7. Colonisation and establishment of *Chelonus blackburni* in cotton (GAU, TNAU)

Tobacco

1. Biointensive IPM of *S. litura* in irrigated FCV tobacco (CTRI)
2. Testing efficacy of encapsulated formulation of entomopathogenic nematodes against *Spodoptera litura* in tobacco nurseries at CTRI, Rajahmundry and Anand (Bidi tobacco), in collaboration with PDBC, Bangalore (CTRI)
3. Determination of *T. remus* release spots/ha in tobacco field (CTRI)

Pulse crops

1. Large scale field demonstration of *Ha*NPV on pigeonpea in farmers' field for the control of *Helicoverpa armigera* (GAU)

2. Large scale testing of *Bt* and *Ha*NPV on pigeonpea for the management of *Helicoverpa armigera* in farmers' field (ANGRAU)
3. NPV based management of *Helicoverpa armigera* on chickpea (TNAU, PAU)
4. Effect of entomopathogenic nematode against *Mylabris pustulata* and *Helicoverpa armigera* on pigeonpea (ANGRAU)

Rice

1. Field evaluation of integrated use of *Trichogramma japonicum*, *T. chilonis* and *Bt* against rice stem borer and leaf folder (KAU, AAU, MPKV).
2. Evaluation of biocontrol based IPM on rice (KAU, AAU, TNAU, PAU).
3. Survey and quantification of natural enemies in rice (KAU, AAU, TNAU, PAU).
4. Survey for the identification of entomopathogenic microorganisms of major pests of paddy (KAU, TNAU, PAU).
5. Development of rearing techniques for key natural enemies of rice hispa and also screening of insecticides against them (AAU).

Oilseed crops

1. Evaluation of commercial preparation of *Beauveria* against root grubs in groundnut (GAU).
2. Testing efficacy of encapsulated formulation of entomopathogenic nematodes against root grubs in groundnut (GAU).
3. Biological control of mustard aphid, *Lipaphis erysimi* (PAU).
4. Surveillance of natural enemy complex of sunflower insect pests (PAU).
5. Biosuppression of *Helicoverpa armigera* on sunflower (PAU).

Coconut

1. Seasonal fluctuations in *Opisina* and natural enemy population in endemic areas (CPCRI).
2. Search for bioagents of *Stephanitis typica* and studies on predatory efficiency of promising predators (CPCRI).
3. Testing commercial formulations of microbial agents against red palm weevil (CPCRI).

Fruit crops

1. Population dynamics of ash whitefly and its natural enemies on pomegranate (IIHR).
2. Evaluation of *Mallada astur* and *Encarsia* spp. in the suppression of spiralling whitefly on guava (IIHR).
3. Survey for the natural enemies of spiralling whitefly (KAU).
4. Relative abundance of egg parasitoids on pomegranate fruit borer (IIHR & Dr. YSPUH & F).
5. Evaluation of *Trichogramma chilotraeae* against pomegranate fruit borer (IIHR).
6. Incidence of phytophagous mites on apple and their natural enemies (Dr.YSPUH&F).
7. Collection of local *Trichogramma* spp. from apple orchards (Dr.YSPUH&F).
8. Seasonal incidence of San Jose scale and woolly aphid and their natural enemies at different locations and preparation of a model for woolly aphid population with respect to biotic and abiotic factors (Dr.YSPUH & F).
9. Field evaluation of biotic agents in apple orchards, especially against woolly apple aphid with *Chrysoperla carnea* in high altitudes (Dr.YSPUH&F).
10. To study the effectiveness of commonly recommended pesticides on the parasites and predators of San Jose scale (SKUAS&T).
11. To observe the impact of parasitisation of San Jose scale at already released sites (SKUAS&T).
12. Mass multiplication of *Encarsia* spp. and *Aphytis* spp. in the laboratory and their subsequent release (SKUAS&T).

Vegetable crops

1. Survey for natural enemies of vegetable crop pests (GAU, Dr.YSPUH&F, ANGRAU, MPKV, IIHR).
2. Integrated pest management of tomato fruit borer (IIHR, GAU, MPKV, ANGRAU, PAU).
3. Evaluation of different formulations of *Bacillus thuringiensis* against *Plutella xylostella* on cabbage (IIHR, MPKV, GAU, Dr,YSPUH&F, ANGRAU).
4. Evaluation of *Trichogrammatoidea bactrae* against *P. xylostella* (IIHR, ANGRAU, MPKV).

5. Field evaluation of *Trichogramma* sp. against *Plutella xylostella* (GAU).
6. Evaluation of *Trichogramma chilonis* and different *B.t.* formulations for the control of *Leucinodes orbonalis* on brinjal (MPKV, ANGRAU, IIHR).
7. Evaluation of *Nomuraea rileyi* against *H. armigera* in tomato (IIHR).

Potato pests

1. Survey and quantification of natural enemies of potato pests (MPKV).
2. Evaluation of *Copidosoma koehleri* and *Chelonus blackburni* and microbial agents against PTM, *Phthorimaea operculella* on potato in country stores (MPKV).
3. Evaluation of different foliage powders for their safety to parasitoids of PTM in storage conditions (MPKV).
4. Standardization of mass release technology for *Copidosoma koehleri* and *Chelonus blackburni* against PTM under field conditions (MPKV).
5. Large scale evaluation, recovery and carryover of parasitism of *C. koehleri* and *C. blackburni* against PTM from field to storage (MPKV).
6. Development of bio-control based IPM for potato pests (MPKV)
7. Evaluation of different entomopathogens for the control of *Spodoptera litura* on potato (MPKV).

Weeds

1. Assessment of impact of *Neochetina eichhorniae, N. bruchi* and *Orthogalumna terebrantis* in suppressing water hyacinth (KAU, MPKV, AAU).
2. Evaluation of fungal pathogens in combination with *Neochetina eichhorniae* and *Orthogalumna terebrantis* in suppressing water hyacinth (KAU).
3. Assessment of impact of *Cyrtobagous salviniae* in suppressing *Salvinia molesta* (KAU).
4. Biological control of *Mikania micrantha* depending upon the availability of material (AAU).
5. Parthenium control with *Zygogramma bicolorata*, a case study under mid-hill conditions (Dr.YSPUH&F).

12. CONSULTANCY, PATENTS, COMMERCIALISATION OF TECHNOLOGY

Consultancy services were provided to Government of Haryana in controlling water hyacinth using biocontrol agent at Bhindawas Lake during 1999-2000. During July 1999-September 1999, 3,02,624 adult weevils and 8,00,000 mites were released and established in this lake.

Consultancy service was provided to M/s Maharashtra Hybrid Seeds Company Limited, Mumbai, to study the susceptibility of *Helicoverpa armigera* and other lepidopterans to *Bt* proteins. The consultancy fee is Rs.7,50,137/- and 50% of the total project cost was realised at the commencement of the project.

Consultancy service was provided to identify the pheromones/kairomones of the cashew stem borer to National Research Centre for Cashew Research, Puttur, and realised an amount of Rs.500/- per sample.

Biocontrol agents were supplied to different Research and Development Departments of Centre and State Governments. 27 multicellular tray units were supplied to various State Agricultural Universities for rearing *Helicoverpa armigera*.

An amount of Rs.57,835/- was obtained from sale of technical bulletins.

Training was given to various Plant Protection Specialists on the Mass Production of Biocontrol Agents. During 1999-2000, 23 trainees were trained.

13. MEETINGS HELD AND SIGNIFICANT DECISIONS MADE:

13.1 Significant decisions and recommendations made in the Fourth Research Advisory Committee Meeting held on 06-04-1999

1. It was observed that while importing natural enemies for trials against exotic pests it should be planned to import 2-3 shipments at short intervals to enable proper establishment.
2. It was thought appropriate to get ready an illustrative/pictorial guide to common predatory coccinellids and also to act as a centre for identification of predatory coccinellids.
3. Measures to be thought and attempted to overcome the problem of male biased sex ratio in *Campoletis chlorideae* in laboratory rearing.
4. Comparison of artificial diets to be made for *Spodoptera litura* incorporating the leaf powders of the most common host plants.
5. Promotion of conservation concept for syrphid predators on *Aphis craccivora* in different crop systems should be explored so that recommendations can emerge for appropriate crops. Trials can be taken up in different crops by the co-ordinating centres on the efficiency of syrphids.
6. Female moths to be used to get egg laying in different varieties/species of cotton and then the reaction seen for *Trichogramma* sp. parasitisation on *H. armigera*.
7. Since the cost of trichosane/other kairomones is high, the method of spot application should be worked out carefully and the efficiency and economic of this should be worked out. Cheaper indigenous substitutes should also be tried for use.
8. Attempts to be made to work out combinations of antagonists like *Trichoderma harzianum* and *Pseudomonas fluorescens* alone or in combination with fungicides to see effective seed treatment for protection of chickpea wilt. Field trials to see most effective antagonistic bacteria should be initiated.
9. Further work to be done with the two parthenium pathogens identified for efficacy and host specificity.
10. A meeting of workers on parthenium may be arranged to assess the present status of the work and what needs to be done further.
11. Work to be initiated to identify pesticide tolerant strains by electrophoresis or other biochemical methods.

12. Heat tolerant strains of *Trichogramma* should be for more than 36°C and they have to be tried in the field during summer to get realistic picture.

13. Pictures of symptoms, pests and their stages to be included in the expert system to make it effective and useful to the non-expert.

14. It was suggested to take up mass multiplication of the entomophilic nematodes and work out field application techniques against *Chilo partellus*.

15. More field oriented studies to make the results more meaningful.

16. Technologies in the pipeline need to be tested by collaborating with other institutes/ SAUs/KVKs for better interaction with end users/farmers.

13.2 Significant decisions made in Management Committee Meetings

Meeting held on 07.04.1999:

1. The committee has recommended for spilling over the VIII Plan works to be proposed in the IX plan due to cost escalation. The committee also approved the prioritization of the works approved in EFC.

2. The names of the two doctors Dr.Vishwanath N. Patil, Ganganagar, Bangalore and Dr.(Mrs.)P.V.Mahalakshmi, Sanjaynagar, Bangalore were approved for appointment as authorized medical attendants.

3. The committee recommended a proposal to send to ICAR for recognizing hospitals like Baptist Hospital, Hebbal,, Bangalore; Rajmahal Vilas Hospital, Sanjaynagar, Bangalore; Jayadeva Institute of Cardiology, Bangalore and Hospital for Orthopaedics, Sports medicines, Arthritis, Neuro and Accident Trauma, Magrath Road, Bangalore along with list of rates compared to CGHS rates.

4. Replacement of the old ambassador car was recommended.

Meeting held on 15.03.2000

1. The names of the two doctors Dr.Vishwanath N. Patil, Ganganagar, Bangalore and Dr.(Mrs.)P.V.Mahalakshmi, Sanjaynagar, Bangalore were approved for appointment as authorized medical attendants.

2. The committee approved post-facto purchase of equipments such as Liquid Scintillation Counter, Growth Chambers, SLR Camera, Gel Electrophoresis unit, Gel drying apparatus, PCR machine with accessories, UV apparatus, Binocular and Compound Research Microscope, Moisture analyser, Stereozoom Binocular

Microscopes and upgradation of the existing electrophoresis unit, vacuum dryer, Willey mill and Insect sampler

3. The committee approved the replacement of old modi xerox photocopier with Model MX5834, which is under DGS&D rate contract.

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 and the duties discharged by the technicians and general difficulties faced and the 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.S.P.Singh participated in

A seminar on 'Improving Tea Productivity, Quality and Quantity through Integrated Pest Management and Nutrient Management System' held at Tingri, Tejpur (Assam) on 15th and 17th June 1999.

National Seminar on "Sustainable Horticultural Production in Tribal Regions" held at Central Horticultural Eeperimental Station (Indian Institute of Horticultural Research), Ranchi, on 25th and 26th July, 1999.

Brainstorming Session on Holistic Review of Import and Export of Beneficial Organisms convened at PDBC on 27 October 1999.

A workshop on "Invasive weeds in India" from 2nd to 4th November, 99 at Kerala Forest Research Institute, Peechi, organized by KFRI and CABI Bioscience (A Division of CAB International), UK Centre.

National Horticulture Conference on 26th November, 1999 held at Vigyan Bhavan, New Delhi.

National Symposium on Crop Pest and Disease Management: Challenges for the Next Millennium held at Mahatma Phule Krishi Vidhyalaya, Rahuri, on 27th and 28th November 1999.

Second and Final Session on Holistic Review of Import and Export of Beneficial Organisms convened at PDBC on 29 December 1999

National Seminar on "Oilseeds and Oils- Research and Development Needs for the Millennium" on 2nd February, 2000 at Hyderabad.

Group Meeting on "Insect Sex Pheromones and a Brain Storming Session on Natural Biological Control in Rice Ecosystems" on 10th February, 2000 at Directorate of Rice Research, Hyderabad.

A Meeting on "New Bioactive Molecules from Plant Sources" organized by Indian Institute of Chemical Technology, Hyderabad, on 14th February, 2000.

A seminar on "Strategies for management of coconut mites" organised at Institution of Agricultural Technologists, Bangalore, on 15th February 2000.

An interface meeting of Biotechnologist / Breeder / Pathologist / Entomolgist and Biocontrol: national / international status on 22nd and 23rd March, 2000 at Punjab Agricultural University, Ludhiana.

Dr.K.Narayanan attended

the Symposium on Biotechnology of Plant Protection on 25-27th February 2000 at Banaras Hindu University, Varanasi

Dr.P.L.Tandon attended

Group discussion on Awareness programme on Intellectual Property Rights during 12-13 November, 1999 at Directorate of Rice Research, Hyderabad

Workshop on Intellectual Property Rights and Agricultural Growth from 7th to 9th December, 1999 at National Academy of Agricultural Research Management, Hyderabad in collaboration with Institute of Public Enterprise, Hyderabad

Dr.S.S.Hussaini attended

Brainstorming Session on Holistic Review of Import and Export of Beneficial Organisms convened at PDBC on 27 October 1999.

Second and Final Session on Holistic Review of Import and Export of Beneficial Organisms convened at PDBC on 29 December 1999

Dr.Chandish R.Ballal attended

a two-day All India Conference on Implementation of the guidelines and norms laid down by the Honourable Supreme Court of India regarding Sexual Harrassment and gender justice at Taj Residency, Bangalore from 31.5.1999 to 1.6.1999.

the NATP interaction workshop at CRIDA, Hyderabad from 5th to 8th October 1999 on IPM – Chickpea and formulated the project.

Dr.S.Ramani participated in

34th Annual Rice Group Meeting held at Directorate of Rice Research, Hyderabad.

Brainstorming Session on Holistic Review of Import and Export of Beneficial Organisms convened at PDBC on 27 October 1999.

Second and Final Session on Holistic Review of Import and Export of Beneficial Organisms convened at PDBC on 29 December 1999

Dr.S.P.Singh, Dr.N.S.Rao, Dr.(Ms.) Chandish R. Ballal and Mr.S.K.Jalali participated in

State level workshop on financing for production of biopesticides on 15th March 2000 at Bangalore.

Dr.S.P.Singh, Dr.P.L.Tandon, Dr.K.Narayanan, Dr.N.S.Rao, Mr.S.R.Biswas, Dr.S.S.Hussaini, Dr.N.Bakthavatsalam, Dr.(Ms.) Chandish R.Ballal, Dr.S.Ramani, Mr.S.K.Jalali, Mr.R.Rangeshwaran, Mr.Sunil Joshi, Dr.T.Venkatesan, Dr.(Ms.) J.Poorani,.Dr.Sreerama Kumar, Dr.R.D.Prasad, Dr.C.Shankarnarayanan and Ms.M.Pratheepa participated in

VIII Biocontrol Workers' Group Meeting held on 25-26 October 1999 at Project Directorate of Biological Control, Bangalore

Dr.P.Sreerama Kumar participated in

Group Meeting on Coconut Eriophyid Mite held on 22 October 1999 at the Centre for Plant Molecular Biology, Seminar Hall, Tamil Nadu Agricultural University, Coimbatore.

Panel Discussion on the "Strategies for the Management of Coconut Mite" held on 15 February 2000 at the Institution of Agricultural Technologists, Bangalore.

Review Meeting on Coconut Eriophyid Mite held on 18 February 2000 at the Seminar Hall, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore

Brainstorming Session on Holistic Review of Import and Export of Beneficial Organisms convened at PDBC on 27 October 1999.

Second and Final Session on Holistic Review of Import and Export of Beneficial Organisms convened at PDBC on 29 December 1999

15. WORKSHOPS, SEMINARS, SUMMER INSTITUTES, FARMERS' DAY, ETC., ORGANIZED BY THE PROJECT DIRECTORATE

A brainstorming session on "Critical issues in mass production of parasitoids and predators" was organized on 13th May 1999.

A preliminary meeting was conducted on 30th August 1999 at National Centre for Integrated Pest management, New Delhi, to discuss various issues to be included in the brainstorming session (on holistic review of import and export of beneficial organisms) held on 27th October 1999.

Eighth Biocontrol Workers' Group Meeting was organized on 25-26, October, 1999.

A brainstorming session on holistic review of import and export of beneficial organisms held on 27th October 1999.

Second brainstorming session on holistic review of import and export of beneficial organisms held on 29th December 1999.

16. DISTINGUISHED VISITORS

Project Directorate of Biological Control, Bangalore

Dr.S.Jayaraj, Former Vice Chancellor, Tamil Nadu Agricultural University, Coimbatore (24-4-1999)

Dr.Kaul, Officer on Special Duty, NATP (24-4-1999)

Dr.S.B.Sharma, Division of Nematology, Indian Agricultural Research Institute, New Delhi (6-5-1999)

Prof.Jeff Waage, Director, Biological Pest Management, CABI Bioscience, UK Centre,United Kingdom (18-5-1999)

Dr.S.T.Murphy, CABI Bioscience, UK Centre,United Kingdom (21-6-1999)

Dr.Willem Coetzer, Weeds Research Division, Plant Protection Research Institute, South Africa (8-7-1999)

Dr.N.L.Srivastava, Special Secretary-Agriculture, Government of India, New Delhi (5-8-1999)

Dr.Semere Amlesom, Ministry of Agriculture, Eritrea (25-8-2000)

Dr.D.C.Sreekantappa, Former Member of Parliament, Birur (14-9-1999)

Dr.O.P.Dubey, Assistant Director General (PP), Indian Council of Agricultural Research, New Delhi (28-10-1999)

Dr.R.N.Singh, Acting Director, National Centre for Integrated Pest Management, New Delhi (26-10-1999)

Dr.Darshan Singh, Professor and Head, Department of Entomology, Punjab Agricultural University, Ludhiana (26-10-1999)

Dr.R.J.Rabindra, Professor and Head, Department of Entomology, Tamil Nadu Agricultural University, Coimbatore (26-10-1999)

Dr.S.Lingappa, Professor and Head, Department of Entomology, University of Agricultural Sciences, Dharwad (26-10-1999)

Dr.Sakuntala Sibasupramaniam, Monsanto, Saint Louis, USA (16-11-1999)

Dr.Garry Hill, CABI Bioscience, Ascot, Berkshire SL5 7TA, UK (30-11-1999)

Dr.Jaime Orzco Hoyos, Cenicafe, Mani Zales, Colombia (22-2-2000)

Dr.Minshad Ali Ansari, Nematologist from Belgium (22-2-2000)

Acharya N.G.Ranga Agricultural Univeristy, Hyderabad

Dr.O.P.Dubey, ADG (PP), ICAR inspected the progress of research of the scheme on 17-11-1999.

Dr.S.P.Singh, Project Director, PBDC, Bangalore inspected the progress of research of the scheme on 09-02-2000.

Gujarat Agricultural University, Anand

Dr.P. Joshi, Director (Research), RAU, Bikaner (03-05-1999)

Dr.S.L.Mehta, DDG (Education), ICAR, New Delhi (03-07-1999)

Dr. S.Z. Sithde, IPM Experts, Zimbabwe (27-11-1999)

Dr. Shyam Sundar Rao, P.C. Ornithology Project, Hyderabad (December 1999)

Dr. S.P. Singh, Project Director, PDBC, Bangalore (18/20-12-1999)

Mahatma Phule Krishi Vidyapeeth, Pune

Dr. N. Ramakrishnan, Ex.Head, Div. of Entomology, IARI, N.Delhi (12-11-1999)

Dr. S.P. Singh, Project Director, PDBC, Bangalore (28-11-1999)

Dr. Calhawha Jenny, Department of Biotechnology, Switzerland, and Dr. Ganguli, DBT, New Delhi, (05-02-2000)

Punjab Agricultural University, Ludhiana

Dr S.P.Singh, Project Director, Project Directorate of Biological Control Bangalore (30-09-1999 and 22-03-2000)

Prof. A.F.G. Dixon, Emeritus Scientist, School of Biological Sciences, Univeristy of East Anglia, Norwich, UK (18-01-2000)

Dr O.P. Dubey, ADG (PP), I.C.A.R., New Delhi (04-02-2000)

Dr M.K. Upadhyaya, Department of Plant Science, University of British Columbia, Vancouver, Canada (17-02-2000)

17. PERSONNEL

Project Directorate of Biological Control, Bangalore

Dr.S.P.Singh	Project Director
Dr.P.L.Tandon	Principal Scientist
Dr.K.Narayanan	Principal Scientist
Dr.N.S.Rao	Senior Scientist
Mr.S.R.Biswas	Senior Scientist
Dr.S.S.Hussaini	Senior Scientist
Mr.B.S.Bhumannavar	Senior Scientist
Dr.N.Bakthavatsalam	Scientist (SS)
Dr.(Ms.)Chandish R.Ballal	Scientist (SS)
Dr.S.Ramani	Scientist (SS)
Mr.S.K.Jalali	Scientist (SS)
Mr.R.Rangeshwaran	Scientist
Mr.Sunil Joshi	Scientist
Dr.T.Venkatesan	Scientist
Dr.(Ms.)J.Poorani	Scientist
Dr.P.Sreerama Kumar	Scientist
Dr.R.D.Prasad	Scientist
Dr.C.Sankaranarayanan	Scientist
Ms.M.Pratheepa	Scientist
Dr.(Ms.)P.Sadhana	Scientist

Central Plantation Crops Research Institute, Regional Station, Kayangulam

Ms. Chandrika Mohan	Scientist (SS)
Dr.Murali Gopal	Scientist

Central Tobacco Research Institute, Rajahmundry

Shri.S.Sitaramaiah	Senior Scientist
Shri.S.Gunneswara Rao	Scientist

Indian Agricultural Research Station, New Delhi

Dr.K.L.Srivastava	Senior Scientist

Indian Institute of Horticultural Research, Bangalore

Dr.M.Mani	Senior Scientist
Dr.A.Krishnamoorthy	Senior Scientist
Mr.C.Gopalakrishnan	Scientist (SS)
Mrs.P.N.Ganga Visalakshy	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

Assam Agricultural University, Jorhat

Dr.A.Basit	Professor
Mr.B.Bhattacharya	Junior Entomologist

Acharya N.G.Ranga Agricultural Univeristy, Hyderabad

Dr.A.Ganeswara Rao	Senior Sceintist
Dr.S.J.Rahman	Scientist

Govind Ballabh Pant University of Agricultural Sciences & Technology, Pantnagar

Dr.U.S.Singh	Associate 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

Kerala Agricultural University, Thrissur

Dr.(Ms.) S.Pathummal Beevi	Associate Professor
Dr.(Ms.) K.R. Lyla	Assistant Professor

Mahatma Phule Krishi Vidyapeeth, Pune

Dr.D.S.Pokharkar	Assistant Entomologist

Punjab Agricultural University, Ludhiana

Dr. Maninder	Entomologist
Shri. Jagmohan Singh	Assistant Entomologist
Dr Neelam Joshi	Assistant Microbiologist
Dr.(Mrs.) Snehdeep Kaur	Assistant Entomologist

Sher-e-Kashmir University of Agriculture and Technology, Srinagar

Dr.G.M.Zaz	Entomologist
Mr.R.K.Tikoo	Assistant Entomologist

Tamil Nadu Agricultural University, Coimbatore

Dr.P.Sivasubramanian	Associate Professor
Smt.K.Bhuvaneswari	Assistant Professor

Y.S.Parmar University of Horticulture and Forestry, Nauni, Solan

Dr.P.R.Gupta	Senior Entomologist
Dr.Anil Sood	Assistant Entomologist

१९. निष्पादित सारांश

१९.१ मौलिक अनुसंधान

१९.१.१ प्राकृतिक शत्रुओं का उपोदघात

कॉफी फल बेधक के दो परजीवी कीटों, *प्रोरोप्स नेसुटा* और *फायमेस्टिकस कॉफीए* को कोलम्बिआ से लाया गया एवं संगरोध प्रयोगशाला में परीक्षण किया गया।

१९.१.२ परपोषी कीटों और प्राकृतिक शत्रुओं का रख-रखाव, उत्पादन और भेजना

अनेक परपोषी कीटों के ८३ संवर्धनों और प्राकृतिक शत्रुओं के ११५ संवर्धनों को समवर्गीय केन्द्रों एवं अन्य अनुसंधान संगठनों को न्यूक्लियस संवर्धनों के रूप में भेजा गया, जिससे कि क्षेत्रीय परीक्षणों के लिए उन्हें गुणित किया जा सके।

१९.१.३ देशी परभक्षी कीट कोक्सीनेलीडे का जैव सैद्धान्तिक अध्ययन

कोक्सीनिलिड की ५० प्रजातियों का अध्ययन करने पर पाया कि इनकी एक प्रजाति *स्कोटोस्किमनस* से संबंध रखती है। सिक्किम से एक नई प्रजाति *ओएनोपिआ एडेल्गिवोरा* पूरणी अभिलेखित हुई। एक अनियत प्रजाति जो कि *टेल्सिमिआ* कैसेई और एक अनियत वंश और जाति नियर *टेल्सिमिआ* पहचानी गई। पाँच नई प्रजातियाँ जो कि *स्युडोपिडिमेरस, स्किमनस (पुलस), माइक्रोसिरेन्जियम, प्रोटोप्लोटिना* और *स्कोटोस्किमनस* अभिलेखित की गई। *पी. फ्लेविसेप्स, पी. उत्तमी, पी. सीआमेन्सिस, ओ. युनानेन्सिस* और *एस. डुओडेसिमेकुलेटा* जो कि भारत में पहली बार अभिलेखित पाई गई और *माइक्रोसिरेन्जियम* और *प्रोटोप्लोटिना* दो वंश जो कि भारत और पूरे दक्षिण एशिया में पहली बार अभिलेखित हुए हैं, इनको भारतीय उपमहाद्वीप की कोक्सीनेलीडे (एपिलोक्निए को छोड़कर) की सूची में शामिल कर लिया गया है।

प्राकृतिक शत्रुओं के लिए सर्वेक्षण

एल्युरोडिकस डिस्पर्सस रसल के परपोषी पौधों और प्राकृतिक शत्रुओं के लिए लक्षद्वीप

में सर्वेक्षण किया गया जिसके अन्तर्गत मिनीकॉय द्वीप में दो एफिलिनिड परजीवी कीट *एनकार्सिआ गुआडेलोऊपे* विज्ञानी (जो कि भारत में पहली बार पाया गया) अभिलेखित हुआ है और *एनकार्सिआ* जाति नियर *हाइटिएन्सिस डोजियर* पाये गये।

महाराष्ट्र में गन्ने की श्वेत मक्खी, *एल्युरोलोबस बेरोडेन्सिस* पर एक कवक रोगाणु *फ्युजेरियम कोकोफायलम* अभिलेखित किया गया। केरल राज्य के वाइनाड जिले में प्राकृतिक शत्रुओं का सर्वेक्षण करने पर काली मिर्च के शल्क कीट *लेपिडोसेफस पिपेरिस* के ऊपर एक नई प्रजाति का *स्युडोस्किमनस, जेअरेविआ* प्रजाति, एक बिना पहचान का क्राइसोपिड और एक कवकीय रोगाणु *फ्युजेरिअम एवेनास्यिम* प्राप्त हुए।

केम्पोलेटिस क्लोरिडिए के द्वारा *हेलीकोवर्पा आर्मिजेरा* के लारवों का परजीवीकरण सर्वेक्षण में गुन्टुर (७२%), भटिण्डा (१२.६%)] श्री गंगानगर (१६.७%) और आनन्द में (२६.८%) अत्याधिक परजीवीकरण पाया गया।

१९.१.५ प्राकृतिक शत्रुओं की पालने/संवर्धन तकनीकों का मानकीकरण और जैविक अध्ययन

मेकोनेलिकोकस हिर्सुटस, प्लेनोकोकस सिट्राई, प्ले. लिलेसिनस, फरिसिआ विरगेटा और *डाइस्मिकोकस* प्राजति की विभिन्न मीलीबगों की प्रजातियों के उपयोग का अध्ययन *ब्रुमायडस सुचुरेलिस, स्किमनस कोक्सीवोरा* और *क्रिप्टोलेमस मोन्ट्रयुजिएरी* कोक्सीनेलीडों को पालने के अध्ययन में देखा गया कि *ब्रु. सुचुरेलिस* और *स्कि. कोक्सीवोरा* के गुणन के लिए *फे. विरगेटा* अतिउत्तम है, जबकि *क्रि. मोन्ट्रयुजिएरी* को *प्ले. सिट्राई* और *प्ले. लिलेसिनस* दोनों पर अच्छी प्रकार गुणित किया जा सकता है।

ब्रुमॉयडस सुचुरेलिस को संग्रहण करने के लिए उचित तापक्रम के अध्ययन में देखा गया कि इस कीट के प्रौढ़ को २०° C पर एक महीने तक संग्रहित किया जा सकता है और इस दौरान उसकी जनन क्षमता और जीवन काल पर बुरा प्रभाव नहीं पडता। *मेलानस्पिस ग्लोमेराटा* के ऊपर *स्टिकोलोटिस क्रिबेलाटा* की वृद्धि काल, जनन क्षमता और परभक्षण समर्थता के लिए २६ ± ०.५°C तापक्रम उचित पाया गया।

स्किमनस कोक्सीवोरा की उत्पादन लागत परपोषी मीलीबग पर निर्भर करती है यह लागत ०.२२ से ०.२३ पैसे प्रति बीटल हो सकती है।

इश्चिओडोन स्कुटेलेरिस की सांख्यकीय जीवन तालिका का सर्दी और गर्मी के समय अध्ययन में देखा गया कि सर्दी के महिनों में इनको प्रयोगशाला में गुणित करना आसान है।

पेरागस सेराटस और *पे. येरयुरिएन्सिस* सिरफिडों के आयु विशेष जनन क्षमता के अध्ययन में पाया कि इनकों *एफिस क्रेक्सीवोरा* के ऊपर पालने पर *पे. सेराटस* की संख्या ४.१४० दिनों में दोगुणी हो गई जबकि *पे. येरब्युरिएन्सिस* को ५.७३५ दिनों का समय लगा।

सर्पिलाकार श्वेत मक्खी के परभक्षी कीट *एक्सिनोस्किमनस पुट्टारूद्रैहया* और *सिबोसीफेलस* स्पे. श्वेत मक्खी के परजीवित अण्डो (*ए. गुआडेलोऊपे* के द्वारा) को पहचान जाते हैं और उनका भक्षण नहीं करते हैं।

१९.१.६ प्राकृतिक शत्रुओं का व्यवहारिक अध्ययन

क्राइसोपिडों और कोक्सीनेलिडों को अण्डनिक्षेपण के लिए प्रेरित करने वाले रसायन एल-ट्रायप्टोफेन के मूल्यांकन के लिए अध्ययन किया, इस अध्ययन में पाया गया कि एल-ट्रायप्टोफेन कोक्सीनेलिडों को अण्डनिक्षेपण के लिए प्रेरित करता है जिससे कि अण्डनिक्षेपण अधिक पाया गया। ट्राइकोसेन *क्राइसोपरला कारनीआ* के लारवों की दशाओं को सुधारने के लिए उचित पाया गया और इसके पौधों पर प्रयोग से *हे. आर्मिजेरा* के अण्डों के प्रति उनकी भक्षण क्षमता अधिक पाई गई।

ट्राइकोग्रामा किलोनिस, हेलिकोवर्पा आर्मिजेरा और कपास एवं टमाटर के वंशानुप्रकार के त्रिकोणीयात्मक अंत: क्रिया के बीच अध्ययन में पाया कि कपास की प्रजातियों में एम सी यु ५ (२८.८९%) और टमाटर की प्रजातियों में अर्का आहुति (५०%) में अत्याधिक परजीवीकरण पाया गया।

१९.१.७ परपोषी कीटों और प्राकृतिक शत्रुओं के लिए कृत्रिम आहार

बीफ यकृत और *कोरसेरा सिफेलोनिका* के अण्डों पर पले *क्राइसोपरला कारनीआ* की भक्षण क्षमता के अध्ययन में पाया कि वे दोनो *हे. आर्मिजेरा* और *को. सिफेलेनिका* के अण्डों के भक्षण की एक समान क्षमता रखते थे। एन्थोकोरिड बग, *कार्डिआस्टिथस एक्जिगुअस* को पालने के लिए पिसा हुआ बीफ यकृत, वसा रहित सोयाबीन और दूध के पाऊडर से बना अर्द्ध

संश्लेषित आहार उत्तम पाया गया और यह *को. सिफेलोनिका* के अण्डों पर पालने के समान ही प्रभावी था।

१९.१.८ ट्राइकोग्रामेटिडों के विभेदों में सुधार

एन्डोसल्फान की सहिष्णुता वाले *ट्राइकोग्रामा किलोनिस* के एन्डोग्राम विभेद को अन्य कीटनाशकों के प्रति सहिष्णु विभेद बनाने के लिए मोनोक्रोटोफॉस और फेनवेलीरेट के प्रति उपयोग किया गया और इनमें कीटनाशको की अधिक मात्रा के प्रति सहिष्णुता देखी गई।

ट्रा. किलोनिस के अधिक तापक्रम सहिष्णु विभेद तैयार करने के प्रयास में पाया गया कि एक विभेद जो कि ३६° से. ग्रे. तापक्रम और ६०% आपेक्षित आर्द्रता पर अधिक परजीवीकरण करता है और आयुकाल भी अधिक होता है तथा इससे भी अधिक तापक्रम पर प्रयास चल रहे हैं।

हे. आर्मिजेरा के अण्डों पर १० विभिन्न क्षेत्रों में *ट्राइकोग्रामा* की विभिन्न प्रजातियों और विभेदों के परजीवीकरण क्षमता के अध्ययन में पाया गया कि सभी प्रजातियों में *ट्रा. किलोनिस* अतिउत्तम पाया गया और सभी क्षेत्रों से ८५-९५ प्रतिशत अण्डों के परजीविकरण के परिणाम प्राप्त हुए।

१९.१.९ कीट विषाणुओं पर अध्ययन

क्रोसीडोलोमिआ बाइनोटेलिस और *कोरसेरा सिफेलेनिका* से न्यूक्लियर पोलीहेड्रोसिस विषाणुओं (एन पी वी), *काइलो सेकारिफगस इन्डिकस* और *स्पोडोप्टेरा एक्जिगुआ* से कणिकामय विषाणुओं (जी वी) तथा *प्युसिआ सिग्नेटा, थाइसेनेप्लुसिया ओरीकेल्सिआ* एवं *मायथिम्ना सेपरेटा* से बेक्युलो वायरस पृथक किये गये।

प्लुटेल्ला जाइलोस्टेल्ला के कणिकामय विषाणुओं (जी वी) के परस्पर संक्रमण में इसने अपनी विशेषता दर्शाई। सूर्य के प्रकाश की प्रकाशीय तीव्रता (०.१%) में ६ घन्टें रखने के बाद *स्पो*. एन पी वी से अच्छा संरक्षण पाया गया।

१९.१.१० कवकीय और जीवाणुवीय प्राकृतिक शत्रु

ट्राइकोग्रामा हरजिएनम, ट्रा. विरेन्स और *ट्रा. विरिडे* के ९ पृथक्करणों ने कवक जाल की वृद्धि कम करने वाले चल और अचल प्रति जैव कारकों को उत्पादित करके स्कलेरोशियल उत्पादन में कमी और *स्कलेरोशियम रोल्फसाई* के प्रति रोधिता दर्शाई है।

ग्रीन हाऊस दशाओं में *स्क. रोल्फसाई* द्वारा होने वाले चने के जड़ सडन रोग को *ट्रा. विरिडे* और *ट्रा. हरजिएनम* द्वारा बीजपचार करने से प्रभावपूर्ण ढ़ग से नियंत्रित किया और इसके प्रयोग से राइजोस्फेयर की संख्या और पौधे की अच्छी वृद्धि देने की क्षमता भी पाई गई।

अरहर में फ्युजेरिअल विल्ट पैदा करने वाले *फ्युजेरिअम उदम* के नियंत्रण के लिए *ट्रा. हरजिएनम* की मात्रा के प्रभाव अध्ययन में पाया गया कि अत्याधिक रोगाणु स्तर पर जैव कारक का बीजोपचार की अपेक्षा मृदाउपचार अत्यधिक प्रभावशाली होता है तथा इनका सफलतापूर्वक नियंत्रण करने के लिए *ट्रा. हजिएनम* के आवर्धनशील प्रयोग की आवश्यकता है।

ट्रा. हरजिएनम का विभिन्न पदार्थो संवहन के शैल्फ जीवन अध्ययन में पाया कि टाल्क और बेनोनाइट की तुलना में केओलिन श्रेष्ठ है क्योंकि इससे *ट्रा. हरजिएनम* १२० दिनों में अधिक संख्या में पैदा होता है और इसने अपनी जैव क्षमता भी सिद्ध की है। अरहर में विल्ट पैदा करने वाले *फ्यूजेरिअम उदम* के प्रति *स्युडोमोनाज प्युटिडा* प्राकृतिक शत्रु को अकेले और *ट्राइकोडर्मा* स्पे. के साथ मिलकर परीक्षण करने पर पाया कि यह मृदा में बुआई के ६० दिनों के बाद रोगाणुओं के ०.१ और १ लाख प्रोपेग्युल्स/ग्राम के कम स्तर के लिए प्रभावी है जबकि रोगाणुओं के अधिकतम स्तर (२ लाख प्रोपेग्युल्स/ग्रा.) के प्रति अप्रभावी पाया गया।

१९.१.११ कीटाहारी सूत्रकृमि

स्पोडोप्टेरा लिट्यूरा, हेलिकोवर्पा आर्मिजेरा, ओपीसिना एरेनोसेल्ला, प्लुटेल्ला जाइलोस्टेल्ला और *थ्योरिमिआ ओपरकुलेल्ला* के प्रति चार कीटाहारी सूत्रकृमि प्रजातियों के परीक्षण में पाया गया कि *प्लुटेल्ला जाइलोस्टेल्ला* और *थ्योरिमिआ ओपरकुलेल्ला* के प्रति *स्टेइनरनेमा बाइकोर्नुटम* और *हेटेरोरहब्डिटिस इन्डिका* ने अधिकतम घातकता (८०-१००%) दिखाई। *स्टे. बाइकोर्नुटम* और *हे. इन्डिका* ने *स्पो. लिट्यूरा* और *हे. आर्मिजेरा* कीट में अधिकतम पीढ़ीयों का उत्पादन दर्शाया। *स्टेइनरनेमा* स्पेसीज और *हे. इन्डिका* का विभिन्न

कृत्रिम माध्यम में ई पी एन पृथक्करणों के *इन विट्रो* बहुगुणन उत्पादन में पाया कि वाउटस माध्यम श्रेष्ठ है। इससे औसतन ३०-३२ लाख आई जे एस/२५० मिली. फ्लास्क उत्पादन मिलता है। *स्टे. कार्पोकेप्से, स्टे. बाइकोर्नुटम, स्टे. ग्लेसीएरी* और *हे. इन्डिका* को २, ४, ६ और ८ सप्ताहों के लिए संग्रहण में देखा गया कि सभी पृथक्करणों को आसवित जल में २८° से. ग्रे. तापमान पर ठीक तरह से रखा जा सकता है।

१९.१.१२ पादप परजीवी सूत्रकृमियों का जैविक नियंत्रण

इन विट्रो में *स्युडोमोनाज फ्लुओरेसेन्स* के संवर्धन के निस्यंदक के सूत्रकृमिनाशी प्रभाव के अध्ययन में पाया कि *मिलॉयडोगाइने इनकोग्निटा, हेटेरोडेरा कजानी* और *रोटीलेन्कुलस रेनिफोर्मिस* के प्रति घातकता के आधार पर यह अत्यंत प्रभावी है।

टमाटर में *वर्टिसिलियम क्लेमायडोस्पोरियम* को *मी. इन्कोग्निटा* का नियंत्रण करने के लिए प्रभावी पाया गया जिससे गाल्स के नियंत्रण, अधिक अण्डों के परजीवीकरण और टमाटर के पौधों की अधिक वृद्धि पाई गई। जवार के बीजों पर कवक संवर्धन और प्रति पौधा १० ग्राम की दर से प्रयोग श्रेष्ठ पाया गया। *मी. इन्कोग्निटा* के प्रति टमाटर पर *स्युडोमोनाज फ्लुओरेसेन्स* और *पास्टेयुरिआ पेनेट्रेन्स* का एक साथ प्रयोग करना, अकेले-अकेले प्रयोग करने की अपेक्षा उचित पाया गया। मृदा में *फ्यू. आक्सीपोरम* को ६×१०^{३} सी एफ यू/ग्राम की दर से प्रयोग करने से टमाटर में गाल्स के बनने और *मी. इन्कोग्निटा* के अण्डों के समूहों में बहुत कमी पाई गई।

१९.१.१३ खरपतवार रोगाणु

कर्नाटक के कई जिलों के साथ-साथ देश के अनेक राज्यों (६ राज्यों) में पार्थेनियम घास *फ्यूजेरिअम पेलिडोरोसीअम* ($१०^{६}$ कोनिडिआ/मिली.) से बहुत अधिक ग्रसित पाया गया जो इस बात का सूचक है कि यह रोगाणु पूरे देश में पार्थेनियम को नियंत्रण करने के लिए अच्छा जैव कारक है। इसके अतिरिक्त जलीय पदार्थ जैसे सोडियम एल्जिनेट और अरेबिक गोंद *फ्यू. पेलिडोरोसीअम* की सक्रियता को बढ़ाते हैं।

१९.१.१४ सॉफ्टवेयर का विकास

एक सॉफ्टवेयर **"पी डी बी सी इन्फोबेस"** का विकास किया गया जो कि निजी कम्पनियों, २७ पीडक प्रबंधन केन्द्रों, १० कृषि विश्व विद्यालयों, ७ भा.कृ.अनु. प. संस्थानों और ४ कीट पालने वाली प्रयोगशालाओं (कुल १२८) से प्राप्त की गई सूचनाओं को एकत्रित करके बनाया गया। आँकड़े आधारित सूचना जिसमें भारत में जैव कारक उत्पादकों के नाम, पते और कौन-कौन से जैव कारक वे उत्पादित करते हैं, उनकों फसल क्रमवार, कीट क्रमवार और जैव कारक क्रमवार दिया गया है और जिनकी जल्दी से और विस्तार पूर्वक सूचना सामने आ जाती है।

१९.२ गन्ने के हानिकारक कीटों का जैविक दमन

कोयम्बटूर में कोंपल बेधकों की सक्रियता पर मौसम के बदलाव का कोई प्रभाव नहीं दिखाई दिया जबकि बेधकों की सक्रियता (जुलाई, नवम्बर) पर जी वी की संक्रमणता का सकारात्मक प्रभाव दिखाई दिया। नवम्बर और दिसम्बर के महीनों में प्रपंच कार्ड रखकर *ट्रा. किलोनिस* की प्राकृतिक सक्रियता का अनुवीक्षण किया और परजीवीकरण पाया गया। विभिन्न कवकों (*ब्युवेरिआ ब्रोन्गनिआरटी, ब्यु. बेसिआना* और *मेटारहाइजियम एनाईसोप्लिए*) को सफेद लट के प्रति प्रयोग करने के लिए शीरा आधारित माध्यम पर अच्छे जैव गुणन और बीजाणु उत्पादन के लिए अधिक गुणन उत्पादन तकनीक अपनाई गई। अण्डों और सूँडियों के प्रति तीन कवकों के जैव विश्लेषण में देखा कि *मे. एनाइसोप्लिए* को $१०^{४}$ -$१०^{९}$ बीजाणु/मिली. की दर से प्रयोग अति उत्तम होता है। लुधियाना में, *काइलो इनफस्कटेलस* के नियंत्रण के लिए *ट्राइकोग्रामा किलोनिस* को ५०,००० प्रति हेक्टेयर की दर से १० दिनों के अन्तराल पर ९ बार और *काइलो अरिसीलीअस* के नियंत्रण के लिए १० दिनों के अन्तराल पर १२ बार प्रयोग करने से जैव कारकों के प्रयोग न करने की तुलना में क्रमशः ५७.२ और ६४.२% क्षति में कमी पाई जिससे इनकी प्रभाव की सिद्धता साबित हुई। इसी प्रकार *ट्रा. जेपोनिकम* को उसी दर से १० दिनों के अन्तराल पर प्रयोग करने से *सिरपोफेगा एक्सर्पटेलिस* के द्वारा होने वाली क्षति को ४९.२% कम पाया गया। पंजाब के अनेक गाँवों में *ट्रा. किलोनिस* को बड़े क्षेत्रीय स्तरों पर प्रदर्शनों में पाया कि इन्होंने विभिन्न बेधकों द्वारा की जाने वाली क्षति को सराहनीय स्तर तक कम किया। किसान के खेतों में गन्ने के वृंत्त बेधकों के प्रति *कोटेशिआ फ्लेविपस* और *ट्राइकोग्रामा किलोनिस* को अकेले-अकेले और दोनो को एक साथ प्रयोग का क्षेत्रीय विश्लेषण किया और यह पाया कि जब दोनों परजीवी कीटों को खेत में एक साथ छोड़ा जाता है तो

बेहतर परिणाम मिलते हैं।

१९.३ कपास के हानिकारक कीटों का जैविक दमन

कोयम्बटूर और हैदराबाद में किये गये परीक्षणों में पाया कि *ट्रा. किलोनिस* के (१,५०,००/हे. की दर से) परजीवित अण्डों की २०० पट्टियों (एक पट्टी प्रत्येक ५० मी.^{2} की दर से) को ८ बार छोड़ा गया तो गूलरों की क्षतिग्रस्तता काफी कम हुई और इस तकनीक को उत्कृष्ट तकनीक पाया गया, क्योंकि इस तकनीक के प्रयोग करने से परजीवीकरण प्रतिशत अधिक पाया गया और उपज अत्यधिक प्राप्त हुई। *हे. आर्मिजेरा* के नियंत्रण के लिए जैव नियंत्रण आधारित आई पी एम विधियों जो कि विभिन्न मेल वाली थी जैसे *ट्रा. किलोनिस* को १,५०,०००/हे./सप्ताह, *क्रा. कारनीआ* को १०,०००/हे./सप्ताह, *हे* एन पी वी को ३X१०^{१२} पी ओ बी/हे. की दर से छिड़काव, गूलर सूँडियों से ग्रसित भागों का हाथों से एकत्रीकरण और उनको जालीदार पिंजड़ों में रखना जिससे कि उनसे निकलने वाले परजीवी कीट पिंजड़े से बाहर निकल सकें, मक्का, लोबिया और अरण्डी को अन्तः फसल /प्रपंच फसल के रूप में उगाना, आवश्यकता अनुसार सुरक्षित कीटनाशकों का प्रयोग और १० फेरोमोन प्रपंच/हेक्टेयर लगाना, की तुलना लुधियाना, आनंद, कोयम्बटूर और हैदराबाद में वहीं के क्षेत्रीय कृषि विश्व विद्यालयों द्वारा की गई अनुशंसा और किसानों द्वारा प्रायः किये जाने वाले रासायनिक छिड़काव से की गई। सभी क्षेत्रों में बी आई पी एम विधियाँ ही उत्तम पाई गई इन विधियों के अपनाने से गूलरों की क्षति कम हुई, उपज अधिक प्राप्त हुई, प्राकृतिक शत्रुओं को संरक्षण प्राप्त हुआ और लागत लाभ अनुपात बहुत अच्छा प्राप्त हुआ।

पंजाब के फिरोजपुर जिले में गूलर की सूँडियों के नियंत्रण के लिए *ट्रा. किलोनिस* के क्षेत्रीय परजीवी कीट और रासायनिक कीटनाशक के छिड़काव के प्रदर्शन, परीक्षण में प्रभावी पाये गये।

१९.४ तम्बाकू के हानिकारक कीटों का जैविक दमन

कीटाहारी सूत्रकृमियों के केप्सूल आधारित सूत्रबद्ध (*स्टेइनरनेमा कार्पोकेप्से* और *हेटेरोरहब्डिटिस इन्डिकस*) की दो मात्राओं (१००० केप्सूल्स और २००० कैप्सूल्स/मी.^{2}) की दर से प्रयोग करने से *स्पो. लिट्यूरा* के तीसरे निरूप के विकसित लारवों की संख्या कम हो जाती है और तम्बाकू की नर्सरी में नवोदभिदों की क्षति प्रति वर्ग मी. कम हो जाता है, किन्तु यह *स्पो.*

लिट्यूरा को आर्थिक सीमांत स्तर की दर (एक तिसरे निरूप की विकसित सूँडी या ६ क्षतिग्रस्त नवोदभिद पोधे/मी.²/नर्सरी क्यारी) तक पहुँचने से रोकने में असफल रहा।

खेत के चार कोनों में चारों जगह *टेलीनोमस रीमस* को ४०,०००/हे. की दर से छोड़ने पर *स्पो. लिट्यूरा* के अण्डों का अत्याधिक परजीवीकरण (१८%) पाया गया।

कलावछेरला (पूर्व गोदावरी जिले में) *स्पो. लिट्यूरा* के बी आई पी एम में सिंचित एफ सी वी तम्बाकू फसल का सफलतापूर्वक प्रदर्शन किया गया, सिंचित एन एल एस ४ एफ सी वी तम्बाकू की प्रजाति में प्रपंच फसल के रूप उगाकर तम्बाकू की फसल के आसपास से अरण्डी पर कीट के अण्डों के समूहों और छोटे-छोटे लारवों को एकत्रित करके नष्ट कर देते हैं, पौध रोपण के चार सप्ताह के बाद *टेलीनोमस रीमस* को ४०,०००/हेक्टेयर की दर से एक बार छोड़ना, *स्पो*. एन पी वी को ३x१०¹² पी आई बी/हे. की दर से रोपण के ३० और ४५ दिनों बाद दो बार छिड़काव करना और रोपण के ६० दिनों के बाद एसीफेट को १ किग्रा./हे. की दर से प्रयोग को किसान द्वारा किये गये केवल रासायनिक कीटनाशकों के प्रयोग की तुलना में बी आई पी एम उत्कृष्ट पाया गया। रासायनिक कीटनाशकों के प्रयोग की अपेक्षा आई पी एम विधियाँ अपनाने से ग्रसित पौधों की प्रतिशतता कम और लागत लाभ अनुपात १:१.५४ मिला जबकि किसान द्वारा अपनाई गई विधि से यह अनुपात १:१.३८ मिला। सिंचित तम्बाकू फसल में *स्पो. लिट्यूरा* के बी आई पी एम विधियों का प्रदर्शन कलावछेरला में किया गया जहाँ पर बी आई पी एम से लागत लाभ अनुपात १:१५४ और इसकी तुलना में रासायनिक नियंत्रण अपनाने से यह अनुपात १:१.३८ मिला।

१९.५ दलहनी फसलों के हानिकारक कीटों का जैविक दमन

अरहर में फली बेधकों के जैविक नियंत्रण आधारित प्रबंधन के लिए *बी टी* (एक किग्रा/हे.), *हे.* एन पी वी (१.५x१०¹² पी ओ बी/हे.), नीम बीज अर्क (५%) और एनडोसल्फान (३५० a.i./हे.) की दर से विभिन्न परिस्थितियों में प्रयोग करने पर तीन केन्द्रों पर किये गये परीक्षणों में पाया गया कि लुधियाना में १५ दिनों के अन्तराल पर ३ बार एन्डोसल्फान का छिड़काव अतिउत्तम तथा फिर *बी टी* और *हे*. एन पी वी का एकान्तरीय छिड़काव उत्तम पाया, हैदराबाद और कोयम्बटूर केन्द्रों में *बी टी- हे*. एन पी वी- एन्डोसल्फान- *बीटी* का प्रयोग उत्तम पाया गया।

कोयम्बटूर के एस. एस. कुलम क्षेत्र में किसान के चने के खेत में *हे. आर्मिजेरा* के एन पी वी आधारित प्रबंधन में *हे*. एन पी वी- एन्डोसलफान के एकान्तरीय छिड़काव और *हे*. एन पी वी- नीम बीज अर्क (५%) का एकान्तरीय छिड़काव करने से फलियाँ बहुत कम क्षतिग्रस्त पाई गई और उपज अत्धिक प्राप्त हुई।

पंजाब के भटिण्डा जिले में, चने में *हे. आर्मिजेरा* के एन पी वी आधारित प्रबंधन के परीक्षण में केवल एन पी वी और अन्य मिलाने वाले पदार्थों को मिलाकर प्रयोग करने से पाया गया कि एन पी वी + गुड + रानिपाल + टीपाल + कपास के बीज का तेल और केवल एन पी वी + टीपाल को पहली बार छिड़काव करने के बाद सूँडियों की संख्या कम थी जबकि दूसरे छिड़काव के बाद सभी एन पी वी आधारित उपचारित प्लाट में सूडियों की संख्या बहुत कम थी।

१९.६ तिलहनी फसलों के हानिकारक कीटों का जैविक दमन

आनन्द में मूँगफली में सफेद लटों के प्रति *मेटारहाइजियम एनाइसोप्लिए* और *बेसिलस पोपीलिए* की दक्षता के लिए बुआई करते समय हल की लीक में *मे. एनाईसोप्लिए* (०.५ किग्रा./हे.), *बे. पोपिलिए* और क्लोरोपायरिफोस (५ ग्राम /किग्रा बीज), के प्रयोग का परीक्षण किया गया। *मे. एनाईसोप्लिए* उपचारित अधिकतम पौधे खेत में खड़े थे और उपज अधिक मिली इसके बाद क्लोरोपायरिफोस से अच्छे परिणाम मिले।

१९.७ धान के हानिकारक कीटों का जैविक दमन

जोरहाट, लुधियाना, कोयम्बटूर और पुणे में धान के तना बेधक और पत्ती मोडक कीट के नियंत्रण के लिए जैव नियंत्रण आधारित आई पी एम विधियों के अन्तर्गत *ट्रा. किलोनिस* और *ट्रा. जेपोनिकम* को ५०,००० और ७५,००० प्रति हेक्टेयर प्रति सप्ताह की दर से फसल की विभिन्न अवस्थाओं पर छोड़ने पर कीटनाशकों के छिड़काव की तुलना में कीटों की ग्रसिता बहुत कम और उपज अधिक मिली।

धान में प्राकृतिक शत्रुओं की उपस्थिति के सर्वेक्षण के अन्तर्गत सभी क्षेत्रों में अनेक परभक्षी कीटों और परजीवी कीटों की उपस्थिति पाई गई। थ्रिसूर में *सिरटोरहईनस लिविडिपेनिस* सबसे अधिक इसके बाद मकडियाँ और कोक्सीनेलिड परभक्षी कीट पाये गये।

कोयम्बटूर में परभक्षी कीटों में मकड़िया, कोलियोप्टेरन्स, ड्रेगनफ्लाई, डेमसेलफ्लाई, झिंगुर, टिड्डे और परभक्षी कीट मेन्टिड्स जबकि परजीवी कीटों में *टेट्रास्टिकस* स्पे., *कोटेशिआ* स्पे., *जैन्थोपिम्पला* स्पे., *टेमेलुशा* स्पे., *एमेऊरोमोरफा* स्पे., *फेनीरोटोमा* स्पे., *ट्राइकोग्रामा* स्पे. और *स्टेनोब्रेकोन* स्पे. पाई गई। लुधियाना में मकड़ियों की *टेट्रागनाथा जेवाना*, *एरेनिअस इनुस्टस*, *आक्सीओपस जेवेनस*, *नीओस्कोना थेईसी*, *लुयुकेऊग सेलीबेसिआना* और *टेट्रागनाथस विरिसेन्स* सहित १९ प्रजातियाँ पाई गई। लुधियाना में *टेलीनोमस डिग्नॉयडस*, *सिक्स लेक्युनेटा* और *ट्राइकोग्रामा जेपोनिकम* प्रमुख अण्ड परजीवी कीट जबकि सूँडी परजीवी कीटों में *कोटेशिया रूफीक्रस* और *केरोपस ब्रेकीटेरम* प्रमुख थे।

१९.८ नारियल के हानिकारक कीटों का जैविक दमन

ओरिक्टस रहाईनोसेरस ग्रब से एक जीवाणु *स्युडोमोनाज एल्केलिजीन्स* को पृथक्क किया गया इसको एक अवसरवादी रोगाणु की तरह पाया गया जो कि बेक्युलो वायरस ग्रसित ग्रबों पर आक्रमण करता है। *एस्पर्जिलस फ्लेवस* को *स्टेफेनिटिस टिपिकस* और *ओपिसिना एरेनोसेल्ला* से पृथक किया गया और यह एक दूसरे को परस्पर संक्रमित कर सकता है। *स्टे. टिपिकस* के प्रमुख रेडयुविड बगों में *एन्डोकस इनोरनेटस*, *युएगोरस प्लेगिएटस* और *रहाइनोकोरिस फुस्किपेस* पहचाने गये।

कायन्गुलम में *ऐपेन्टेलस टेरेगामे* के बहुगुणन के लिए *ओ. एरेनोसेल्ला* के पहले ही निरूप के छोटी सूंडियों के उपयोग के अध्ययन में देखा गया कि पहले दो दिनों में उदभासित सूँडियों में अत्याधिक परजीवीकरण पाया गया, यद्यपि अण्डे देने की प्रक्रिया १५ दिनों तक निरन्तर चलती रहती है।

१९.९ फल वाली फसलों के हानिकारक कीटों का जैविक दमन

अनार को ग्रसित करने वाली राख श्वेत मक्खी *साइफोनीनस फाइलिरीए* के ऊपर एफेलिनिड परजीवी कीट *एनकार्सिआ आजिमि* और पाँच परभक्षी कीट *स्किमनस* स्पे., *क्रिप्टोलीमस मोन्ट्रोयुजिएरी*, *काइलोमीनस सेक्समेकुलेटा* और *एक्लिटोक्सिनस इन्डिकस* सहित कुल ६ प्राकृतिक शत्रुओं को अभिलेखित किया गया। बंगलोर में अनार के *डीयुडोरिक्स आइसोक्रेटस* के अण्ड परजीवी कीटों के अध्ययन में *ऊएनसिर्टस पेपिलिओनिस* और *टेलीनोमस* स्पे. की उपस्थिति पाई गई। सोलन में जुन-जूलाई माह के समय अनार के फल बेधक

डियुडोरिक्स एपिजर्बस का प्रकोप पाया गया और एक अण्ड परजीवी कीट के रूप में *युपेल्मिड एनास्टेटस* स्पे. अभिलेखित की गई।

बेर को बाल वाली सूँडी *थायासाइडस पोस्टिका* पर *एक्जोरिस्टा* स्पे., *केरोपस ओबटुसस*, और *एपेन्टिलस क्रिएटोनोटाई* द्वारा परजीवीकरण और एक न्युक्लियर पॉलीहेड्रोसिस विषाणु द्वारा ग्रसन पाया गया। बंगालोर में अनार की पत्ती भक्षक सूँडी *ट्राबाला विष्णौ* के प्युपे एक अनजान इक्नियुमोनिड द्वारा ३३.३ से ५२.३८% तक परजीवीत पाये गये और इनके प्युपे *पाएसीलोमायसस फेरीनोसस* नामक कवक से भी ग्रसित पाये गये।

सर्पिलाकार सफेद मक्खी के प्राकृतिक शत्रुओं के सर्वेक्षण के अध्ययन में केरल, तमिलनाडु और कर्नाटक में कुल ११ प्राकृतिक शत्रु पाये गये। अमरूद में सफेद मक्खी अत्यधिक परजीवित (२०-७०%) पाई गई। बंगलोर में सफेद मक्खी के परभक्षी कीटों में *एनकार्सिआ ? हेटिएन्सिस* और *ए. गुआडेलोउपे* द्वारा *साइबोसीफेलस* स्पे., *क्रिप्टोलीमस मोन्ट्र्यूजिएरी, एक्जिनोस्किमनस पुट्टारूद्रीआही* और *ट्राइओमाटा कोक्सीडोवोरा* पाये गये। थ्रिसूर में सफेद मक्खी के परजीवी कीटों के अध्ययन में *एनकार्सिआ* स्पे. *मेरिटोरिआ* के पास (=*एनकार्सिआ ? हाइटिएन्सिस*) के द्वारा ० से ४६.७२ प्रतिशत परजीवीकरण पाया गया। कोयम्बटूर में सफेद मक्खी के अनेक परभक्षी कीट और एक अनजान हायमेनोप्टेरन परजीवी कीट अभिलेखित किया गया।

सोलन में सेब के वुली माँहू की सँख्या और प्राकृतिक शत्रुओं की सक्रियता का अनुवीक्षण साप्ताहिक अन्तराल पर पूरे वर्ष किया गया जिसमें पाया कि *एफिलिनस माली* निरन्तर उपलब्ध था और इसकी सक्रियता माँहू की संख्या पर निर्भर करती है।

जम्मू और कश्मीर के श्रीनगर, बारामुला, बडगाम, पुलवामा और अनन्तनाग जिलों में वुली माँहू के संक्रमण और प्राकृतिक शत्रुओं की उपस्थिति के अध्ययन में *एफेलिनस माली* और सात परभक्षी कीटों *फेरोस्किमनस फ्लेकिसबिलिस, एडेलिआ टेरास्पिलोटा, युपिओडेस कनफ्रेटर, एपिर्सिर्फस बेल्टिइएटस, कोक्सीनेला सेप्टमपंकटेटा* और *काइलोकोरस इन्फर्नेलिस* पाये गये।

सेन जोस स्केल कीट के संक्रमण और इनके परजीवी कीटों का विभिन्न स्तरों पर अनुवीक्षण किया और पाया कि सेन जोस स्केल कीट की सघनता ६३ से १५० और ४०.६७ प्रतिशत परजीवीकरण पाया गया। श्रीनगर में विभिन्न क्षेत्रों में *एनकार्सिआ पेर्निसीओसस* और

एफाइटिस प्रोक्लिआ की पुनः प्राप्ति हुई और स्थापित पाये गये, इससे यह पता चला कि ये परजीवी कीट सभी क्षेत्रों में २४.८ से ७७.७ परजीवीकरण के साथ स्थाई हो गये हैं।

दो धब्बे वाली स्पाइडर माइट *टेट्रानिकस उर्टिके* और युरोपियन रेड माइट *पेनोनिकस उल्मी* किन्नौर जिले में नये हानिकारक कीट के रूप में उभर कर सामने आये और एन्नथोकोरिडों, क्राइसोपिडों, परभक्षी थ्रिप्स और माइटों के अलावा *स्टिथोरस* स्पे. इन माइटों को खाते पाये गये।

अनार के माँहू *एफिस पुनिके* पर *इश्चिओडोन स्कुटेलेरिस* की भक्षण समर्थतता और उनके विकास के अध्ययन में पाया कि सिरफिड का लारवा अपना विकास करने तक ४८६.१० माँहूओं को खाता है और अपने विकास में ८.३० दिनों का समय लेता है।

ट्राइकोग्रामा काइलोट्रीए के द्वारा परजीवित *डियुडोरिक्स आइसोक्रेट्स* के अण्डों पर नौ नीम सूत्रबद्धों, दो नीम उत्पादों और चार प्रचलित कीटनाशकों के छिडकाव का परीक्षण किया गया। वनस्पति से बने रसायनों की तुलना में रासायनिक कीटनाशकों का उपयोग करने पर, अण्डों से प्रौढ़ परजीवी कीट निकलने पर बुरा प्रभाव पड़ता है। इसी प्रकार अनार की पत्तियों पर एन्डोसल्फान और कार्बेरिल के प्रयोग, नीम सुत्रबद्धों और नीम उत्पादों की तुलना में बहुत विषैले साबित हुए।

१९.१० सब्जी वाली फसलों के हानिकारक कीटों का जैविक दमन

बंगलोर में पातगोभी के कीट *प्लुटेल्ला जाइलोस्टेल्ला* के नियंत्रण के लिए (साप्ताहिक अन्तराल पर कुल ५ बार) *ट्राइकोग्रामेटॉयडिए बेक्टरे* को २.५ लाख प्रौढ पति हैक्टेयर की दर की तुलना में एण्डोसल्फान को साप्ताहिक अन्तराल पर तीन बार छिड़कने से कीट की सूँडियों की सँख्या में कमी और उपज अधिक प्राप्त हुई। इसी तरह के परीक्षण हैदराबाद में किए गये, जिन प्लाटों में परजीवी कीट छोड़े गये थे, वहाँ पर ३.६ सूँडी प्रति पौधा से घटकर ०.६ सूँडी प्रति पौधा रह गई और *ट्रा. बेक्टरे* की पुनः प्राप्ति हुई इससे इन परजीवी कीटों के स्थाईपन की सफलता सिद्ध हुई।

प्लुटेल्ला जाइलोस्टेल्ला के प्रति अनेक व्यवसायिक *बी टी* सूत्रबद्धों के तुलनात्मक क्षेत्रीय दक्षता परीक्षण में बंगलोर में 'हाल्ट' सबसे अधिक प्रभावी जबकि हैदराबाद में 'बायोबिट'

१९.११ आलू के हानिकारक कीटों का जैविक दमन

कोपिडोसोमा कोईहेलरी (परपोषी कीट आलू कन्द मौथ) २,००,००० प्रौढ़ या ५,००० ममीज प्रति हेक्टेयर की दर से छोडने की उत्पादन लागत ७५० रुपये पायी गयी जबकि *किलोनस ब्लैकबर्नी* को ६०,००० प्युपे या प्रौढ़/हे. की दर से छोड़ने पर उत्पादन लागत ४,११० रुपये (आलू कन्द मौथ परपोषी कीट) और १,३१० रुपये (*कोरसेरा सीफेलोनिका* परपोषी कीट) पायी गयी।

आलू कन्द की मौथ *थ्योरीमीआ ओपरकुलेल्ला* द्वारा कन्दों को संक्रमण और पौधे को पत्ती रहित होने से बचाने के लिए बुआई के ४५ दिनों के बाद अण्डा-सूँडी परजीवी कीट *को. कोईहेलरी* को ५०,००० प्रौढ़/हे./बारी की दर से चार बार छोड़ने से प्रभावपूर्ण नियंत्रण होता है और खरीफ और रबी मौसम में आलू कन्दों की बाजार मूल्य योग्य उपज अत्यधिक मिलती है। प्रौढ़ों को छोड़ने की अपेक्षा *को. कोइहेलरी* को ५,००० ममीज/हे. की दर से प्लास्टिक की शीशीओं (यानि १२५० ममीज/हे./बारी, साप्ताहिक अन्तराल पर चार बार) में छोड़ना अत्यन्त प्रभावी होता है।

देशी भण्डारों (अर्नीज) में पी टी एम के प्रति *को. कोइहेलरी, की. ब्लैकबर्नी* और सूक्ष्मजीव कारकों के उपयोग और मूल्यांकन के अध्ययन में पाया गया कि *को. कोईहेलरी* को ५ प्रौढ़ जोड़े/किग्रा. आलू कन्द की दर से छोड़ने पर, संग्रहण के एक माह बाद कन्द में संक्रमण बहुत कम (१०.६६%) पाया गया। पुणे के पास के गाँव में देशी भण्डार (अर्नीज) में पी टी एम के प्रति *को. कोइहेलरी* और *की. ब्लैकबर्नी* के बड़े स्तर पर किए गये मूल्यांकन अध्ययन में पाया गया कि, *को. ब्लैकबर्नी* को २ प्रौढ़/किग्रा आलू कन्द की दर से छोड़ने पर एक महीने बाद अधिक प्रभावी पाया गया जबकि २ १/२ महीनों के बाद *को. कोईहेलरी* को ५ जोड़ी प्रौढ़/किग्रा. आलू कन्द की दर से १५ दिनों के अन्तराल पर चार बार छोड़ने पर कन्द कम संक्रमित होने के परिणाम प्राप्त हुए।

स्पो. एन पी वी को ७५० एल ई/हे. (४.५×१०^{11} पी ओ बी/हे.) या ५०० एल ई/हे. (३.०×१०^{12} पी ओ बी/हे.) बहुत प्रभावी पाये गये और आलू में *स्पो. लिट्यूरा* को नियंत्रित करने के लिए *बे. थ्यूरिन्जिएन्सिस* की ०.५ किग्रा./हे. की दर से प्रयोग को उचित पाया गया।

१९.१२ खरपतवारों का जैविक दमन

आइकोर्निए क्रेसीपस के प्रति *नीओकेटीना आइकोर्निए, नी. ब्रुकी* और *आर्थोगेलूम्ना टेरेब्रेन्टिस* के अनुवीक्षण, मूल्यांकन और इनके प्रभाव निर्धारण की जाँच में आनन्द (गुजरात), थ्रिसूर (केरल) और पुणे (महाराष्ट्र) में इन कीटों के लारवों और प्रौढ़ों को जलीय खरपतवार के कन्दों में स्पष्टतया देखा गया, साथ ही साथ नई पत्तियों पर इन कीटों द्वारा की गई क्षति के लक्षण साफ दिखाई दिए। शिबसागर (आसाम) जिले के दिसांगमुख क्षेत्र के जलाशयों में १००० हेक्टेयर से भी अधिक क्षेत्रफल में जलीय खरपतवार का इन परदेशी विविलों ने बिल्कुल सफाया कर दिया और इसके उपरान्त ये विविल लखीमपुर ,सोनितपुर और डिबरूगढ़ के प्रवासी हो गये।

सिरटोबेगस सेल्विनिए विविलों को वेल्लानिकारा, मोनकोम्पु और कुमाराकोम जिलों (केरल) के क्षेत्रों में लगातार छोड़ा जाता रहा और लगभग सभी इलाकों में जलीय फर्न *सेल्विनिआ मोलेस्टा* की क्षति पाई गई और विभिन्न इलाकों के क्षेत्रों में विविलों की संख्या १ से लेकर ४.३ प्रति पौधा तक पाई गई।

ACRONYMS

AAU	Assam Agricultural University, Jorhat
ANGRAU	Acharya N. G. Ranga Agricultural University, Hyderabad
CPCRI	Central Plantation Crops Research Institute, Kayangulam
CTRI	Central Tobacco Research Institute, Rajahmundry
GAU	Gujarat Agricultural University, Anand
GBPUA&T	Gobind Ballabh Pant University of Agriculture and Technology, Pantnagar
IARI	Indian Agricultural Research Institute, New Delhi
IIHR	Indian Institute of Horticultural Research, Bangalore
IISR	Indian Institute of Sugarcane Research, Lucknow
KAU	Kerala Agricultural University, Thrissur
MPKV	Mahatma Phule Krishi Vidyapeeth, Pune
PAU	Punjab Agricultural University, Ludhiana
SBI	Sugarcane Breeding Institute, Coimbatore
SKUAS&T	Sher-e-Kashmir University of Agricultural Science and Technology, Srinagar
TNAU	Tamil Nadu Agricultural University, Coimbatore
Dr. YSPUH&F	Dr. Y. S. Parmar University of Horticulture and Forestry, Solan

Prof. Jeff K. Waage, Director, Biological Press Management
CABI Bioscience, UK

Dr. Semere Amlesom, Director General, Ministry of Agriculture
Eritrea discussing mass production of natural enemies during his visit

Inauguration of Hindi Chethana Maas

Dr. P.L. Tandon, Principal Scientist, PDBC speaking on the occasion of World Food Day

Dr. O.P. Dubey, ADG (PP), ICAR, New Delhi, releasing an improved strain of *Trichoderma harzianum* during the eight biocontrol workers' group meeting

Participants at the Brainstorming Session on Holistic Review of important and export of beneficial organisms

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