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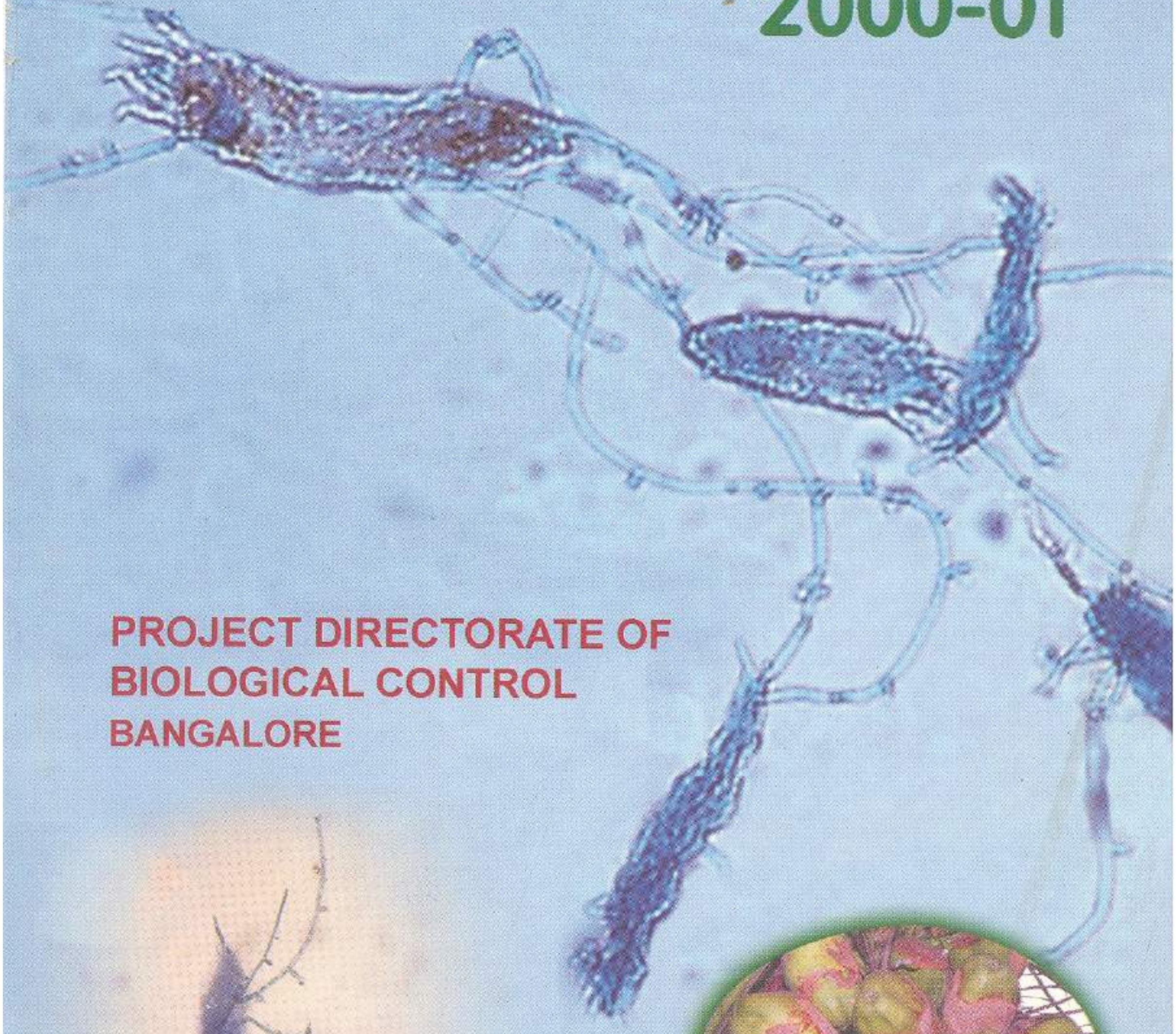
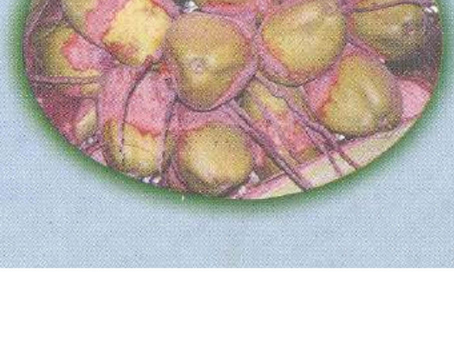


PROJECT DIRECTORATE OF
BIOLOGICAL CONTROL
BANGALORE



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Cover Coconut eriophyid mites *(Aceria guerreronis)* infected with the acaropathogenic fungus, *Hirsutella thompsonii*

Inset Left : Adult mite with typical synptoms of fungal infection

Right : Coconuts damaged by mite

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CONTENTS

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 teamwork, 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. It also standardisation and developed 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, 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 Technology for mass production of *Hirsutella thompsonii* for the control of coconut mite, *Aceria guerreronis* on coconut was assessed and standardized.

The eighth annual report of the Project Directorate embodies the endeavours of my scientist colleagues for the period from April 2000 to March 2001. 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 obtained again from Colombia as another consignment. *P. nasuta* and *P. coffea* has been field released but recoveries have not been good.

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

Cultures of 35 species of host insects, pathogens, phytonematodes and weeds including 25 parasitoids (including 11 strains), 19 predators, 4 weed control arthropods, 11 species and strains of insect pathogens, 326 species and strains of fungal and bacterial antagonists, 6 species and strains of entomopathogenic nematodes, 29 species and strains of fungi and bacteria against phytonematodes and 1 species of weed control pathogens are being maintained.

Sixty eight cultures of host insects and 135 cultures of natural enemies were sent to coordinating centers and other research organizations as nucleus cultures to facilitate their multiplication for field trials.

2.1.3. Biosystematic studies on Indian predatory Coccinellidae

Genus *Diomus* Mulsant was recorded for the first time from India. A new species of *Synonychimorpha* Miyatake was recorded from Karnataka and Kerala. The genus *Pseudaspidimerus* Kapur was revised. Two new species, *Microserangium brunneonigrum* Poorani and *Pseudaspidimerus infuscatus* Poorani were described. The annotated checklist of the coccinellid fauna including Epilachninae has been updated. An identification guide to predatory coccinellids is under preparation.

2.1.4. Survey for natural enemies

Several indigenous predators of the spiralling whitefly, including 15 species of coccinellids, were recorded during surveys. The aphelinids, *Encarsia ?haitiensis* and *E. guadeloupae* have firmly established and spread to other areas. Both the *Encarsia* spp. were introduced into the Lakshadweep islands of Kavaratti and Agatti, where the parasitoids were not present earlier.

Pseudohypatopa pulverea was recorded feeding on the scales, *Hemiberlesia lataniae* and *Coccus* sp.

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

The striped mealy bug, *Ferrisia virgata* and the cowpea aphid, *Aphis craccivora* were successfully used for multiplication of the coccinellid, *Harmonia octomaculata* in the laboratory.

Similarly, the scales, *Melanaspis glomerata* and *Coccus* sp. were found appropriate to multiply the coccinellids, *Sticholotis cribellata* and *Pharoscymnus horni*.

A temperature of 10°C was found suitable for storing 2-3-day-old *Ischiodon scutellaris* pupae for up to nearly three weeks with only a slight reduction in longevity and fecundity of emerging adults as compared to ambient temperature (27 °C).

Though no deterioration in parasitism and emergence was noticed in *Eriborus argenteopilosus* reared on *Spodoptera litura*, sex ratio was badly affected due to continuous laboratory rearing within four generations (1.3% females), when compared to field collected adults (68.77% females). Sex determination to ensure higher percentage of females in consignments could be made in *E. argenteopilosus* by using weight (>43 mg), length (>8.6 mm) and width (>3.6 mm) of cocoons.

Net house studies indicated that *Telenomus remus* and *Trichogramma chilonis* could successfully parasitise *S.litura* and *Helicoverpa armigera* eggs, respectively, on soybean with good rates of parasitism and adult emergence.

In net house studies, *Campoletis chlorideae* recorded a higher parasitism of 4- day-old *H. armigera* larvae on chickpea when larvae were preconditioned on the plants for 24 h as compared to just released larvae.

Adults of the spiralling whitefly predator, *Axinoscymnus puttarudriahi* were found to feed on 137.5 whitefly nymphs during a mean adult life span of 55.25 days.

2.1.6. Behavioural studies on natural enemies

Highest parasitization of *H. armigera* eggs by *T. chilonis* was recorded on cotton genotypes DHB-435 (42.22%) and CPD-447(42.22%) in a multiple choice test with 15 genotypes. Response of *T. chilonis* to the volatiles released by the leaves of the genotype DHB-105 was highest (63.33%) and to Hybrid-6 the lowest (6.66%).

Electroantennogram studies on the response of *H. armigera* to green volatiles (synomones) released by *Solanum viarum* and *Tagetes* sp. revealed higher response to *S. viarum* as compared to *Tagetes* sp. In Y-tube olfactometer studies the response of *T. chilonis* to the leaves and flowers of *Tagetes* sp. was more than *S. viarum*.

Field studies on the efficiency of L-tryptophan (0.66%) as an ovipositional attractant for *Chrysoperla carnea* revealed that more number of eggs were laid on treated cotton plants as compared to untreated plants. Pentacosane and tricosane, both at 0.01%, increased the parasitising efficiency of *T. chilonis* in the laboratory and field.

2.1.7. Artificial diets for host insects and natural enemies

Spodoptera litura could be reared successfully with higher per cent adult emergence, greater per cent females among emerged adults and more number of fertile eggs on a diet using a mixture of kabuligram, groundnut oil cake, casein, cysteine, cholesterol and Wesson's salt mixture.

A new beef liver-based artificial diet was developed and tested for rearing *Chrysoperla carnea* and 85% survival was obtained. *Mallada boninensis* could also be successfully reared on a beef liver-based diet.

Artificial diets have been synthesised for rearing *Cheilomenes sexmaculata, Coccinella septempunctata, Chilocorus nigrita* and *Cryptolaemus montrouzieri*. Biochemical profiles of prey insects and artificial diets are being studied to refine the diets further.

2.1.8. Improved strains of trichogrammatids

Attempts to develop a high temperature tolerant strain of *T. chilonis* have resulted in a strain which is giving high parasitism (85%) and increased longevity (4 days) at 36°C and 60% RH after 48 generations of rearing. It is now being subjected to further higher temperature of 36 ± 1.5°C and after 15 generations 59% parasitism and 2 days longevity is being observed.

The 'Endogram' strain of *T. chilonis* resistant to endosulfan (0.05%) was utilized to develop multiple insecticide tolerant strain to higher dosages of endosulfan, monocrotophos and fenvalerate. It has developed further tolerance to endosulfan (0.0875%), monocrotophos (0.06%) and fenvalerate (0.0015%) after rearing for 36 generations. In SDS-PAGE profiles three new protein bands were appearing in pesticide tolerant *T. chilonis* as compared to the susceptible strain.

The insecticide tolerant strains could parasitise *H. armigera* eggs even on just sprayed (endosulfan, monocrotophos, fenvalerate, cypermethrin, dimethoate, acephate) cotton plants, with increased parasitism 5-7 days after spraying in net house studies.

2.1.9. Studies on insect viruses and fungi

Nuclear polyhedrosis viruses from *Sesamia inferens* and *Agrotis segetum*, granulosis virus from *A. segetum*, insect poxviruses from *A. segetum*, *Helicoverpa armigera* and *Holotrichia consanguinea* and cytoplasmic virus from *Earias vittella* have been isolated. Microsporidian pathogens have been isolated from *S. inferens* and *H. consanguinea*.

Bioassay studies on *A. segetum* (NPV concentration 3.4 x 10^{7}/ml) resulted in 100 % mortality in first and second instar larvae within six days, more than 80% mortality in third and fourth instar larvae, 10-20% mortality in fifth instar larvae and no mortality in sixth instar larvae. LD_{50} on 7th and 10th days after treatment was found to be 1.06 x 10^{6} POBs/ml and 4.45 x 10^{5} POBs/ml, respectively. Leaf area consumed and body weight were also found to be lower in treated larvae.

Histopathological study of entomopoxvirus on *H. armigera* and *G. mellonella* revealed that the fat bodies were most severely affected among different sites of infection.

Fungal pathogens have been isolated from *H. armigera*, *Plutella xylostella* and *Chilo partellus*. *Nomuraea rileyi* has been cultured on SMAY medium for inoculation tests on *H. armigera*, *S. litura* and *P. xylostella*.

A water dispersible powder (WDP) formulation of *Bacillus thuringiensis* named Pusa *Bt* has been formulated and bioassayed against *S. litura*.

2.1.10. Fungal and bacterial antagonists

Soil application of *Trichoderma harzianum* (PDBCTH 10) and *T. viride* (BDBCTV 23) at 5 g of powder formulation mixed in 1 kg of FYM effectively controlled fusarium wilt and Rhizoctonia wet root rot of chickpea and also gave higher yields. Soil application (10g in 1 kg of FYM) of *T. harzianum* prior to sowing was more effective than seed treatment (10 g/kg of seed) in controlling fusarial wilt of pigeonpea caused by *Fusarium udum* and resulted in better plant growth and yield. The bioagents were able to proliferate for up to 30 days after inoculation.

Seed treatment at 5g/kg of seed of talc based formulations of the bacterial antagonists, *Pseudomonas putida* (PDBCAB 19) and *P. fluorescens* (PDBCAB 2) was found promising against fusarium wilt and rhizoctonia wet root rot of chickpea. The bacterial antagonists were also effective against fusarium wilt of pigeon pea as seed treatment.

Shelf life studies indicated that viable propagules of *T. harzianum* were retained in conidial formulation for up to 180 days at room temperature. Seven fungicides were evaluated for their compatibility with *T. harzianum* and carbendazim at 25 ppm itself was found toxic.

Tryptic Soya Broth, Nutrient Broth and King's B Broth were found suitable for mass culturing *Pseudomonas fluorescens*.

2.1.11. Entomopathogenic nematodes

Wouts' medium was found suitable for the multiplication of *Steinernema carpocapsae* and *Heterorhabditis indica* with average yields of 44 lakhs/250 ml flask. The dog biscuit+beef extract media was found very good for mass producing *S. carpocapsae* with yields of 75 lakhs/250 ml flask.

Steinernema carpocapsae and *S. bicornutum* were found effective against *S. litura, H. armigera, O. arenosella, P. operculella* and *P. xylostella* in laboratory assays. *Galleria mellonella* (final instar) was found to be most suitable in terms of progeny production of *Steinernema* spp. and *Heterorhabditis* spp. as compared to *H. armigera, S. litura, P. xylostella* and *P. operculella*.

Isolates of *S. bicornutum, H. indica* and *S. carpocapsae* were found effective at higher doses (1-2 billion IJs/ac) against the brinjal fruit borer, *Leucinodes orbonalis* both *in vitro* and under field conditions.

Formulations with talc, Talc+china clay and alginate were evaluated for shelf life at 15°C. Talc+china clay formulation retained maximum viability and pathogenicity for 90 days as compared to the other two.

2.1.12. Biological control of plant parasitic nematodes

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 grains or wheat grains and applied @ 10 g/plant was found to be the best.

2.1.13. Weed pathogens

The mycoherbicidal potential of *Lasiodiplodia theobramae, Nigrospora oryzae, Phoma chrysanthemicola* and *P. eupyrena*, the pathogens isolated locally from *Parthenium hysterophorus*, were evaluated and all of them were found capable of producing the disease after inoculation.

Natural occurrence of *Alternaria spp.* and *Cercospora spp.* was noticed in water bodies with *Eichhornia crassipes* infestation. Leaves damaged by the weevils, *Neochetina spp.* and the mite, *Orthogalumna terebrantis* were readily infected by *Alternaria eichhorniae, A. alternata* and *Cercospora sp.* and the highest severity (6-67) was achieved through the inoculation of mite damaged leaves with *A. eichhorniae*. Studies on the interactive effect of the three pathogens through inoculation tests showed that the most potent was a combination of all the three pathogens.

2.1.14. Software development

An expert system for controlling pests of oilseeds and pulses is under preparation for which keys for identification of the major pests along with their damage symptoms are being got ready. CD version of the expert system, "BIORICE", is now available. In the development of a National Information System on Biological Suppression of crop pests a CD version of the software "PDBC INFOBASE" has been developed with illustrations and pictures.

A knowledge base system for *Helicoverpa armigera* and its natural enemies is being developed by creating a database in MS-Access on the biology of the pest, its host plants, distribution, natural enemies, etc.

2.2. Biological suppression of sugarcane pests

Egg masses of *Scirpophaga excerptalis* were parasitised to the extent of 43% by *Telenomus dignoides* while those of *Chilo infuscatellus* by *T. chilonis* (7.6%) and *T. chilotraeae* (5.8%), *Chilo auricilius* by *T. chilonis* (7.1%) and *Acigona steniellus* by *T. chilonis* (6.7%) in Nawanshahar district of Punjab. Amongst the natural enemies of the shoot borer, *C. infuscatellus* in Coimbatore the tachinid, *Sturmiopsis inferens* and the granulosis virus were recorded almost throughout the year. The sex ratio of field populations of *S. inferens* in different months generally remained male biased but in laboratory populations the sex ratio tended to be female biased with higher mating rates.

A formulation of *Beauveria brongniartii*, mass cultured on molasses media and formulated with press-mud, at 10^{12} - 10^{14} spores/acre as a single treatment as well as in combination with chlorpyriphos gave effective control of white grubs in Coimbatore. Sulphur and $CaSO_4$ at all concentrations significantly reduced the radial growth of *B. bassiana, B. brongniartii* and *M. anisopliae* but did not affect spore production. Paraquat was found toxic to *B. bassiana, B. brongniartii* and *M. anisopliaea* whereas glyphosate was more toxic to *B. bassiana* than the other two fungi.

Large-scale field demonstrations carried out in collaboration with three sugar mills in Punjab clearly showed that the release of the egg parasitoid, *T. chilonis* @ 50,000 per ha at 10 days interval during July – October reduced the incidence of stalk borer, *C. auricilius*, with just 1.36, 4.10 and 12.50 per cent incidence as compared to 6.03, 11.20 and 20.20 per cent in control plots in the three sugar mill areas.

2.3. Biological suppression of cotton pests

Different IPM modules, which included release of biocontrol agents, were evaluated at Anand, Coimbatore, Pune, Hyderabad and Ludhiana in comparison with insecticidal schedule and control. The bud and boll damage as well as the population of sucking pests were significantly lower in IPM module than control and insecticidal treatments in Anand. It was also found that since IPM plots received less spray of chemical insecticides the parasitism levels recorded were high due to conservation of natural enemies. Similar results were seen in Coimbatore where *Earias vittella, Pectinophora gossypiella* and sucking pests occurred in significantly lesser numbers in the pest management modules than in control. In Pune the population of sucking pests was significantly low in IPM module and insecticidal schedule plots while the population of *Chrysoperla carnea* and coccinellids per 25 plants were 56.87 and 43.50, respectively, in IPM module and only 11.62 and 10.87, respectively, in insecticide treated plots. In Hyderabad the results were similar with regard to pest damage and population of natural enemies and it was also found that cost-benefit ratio was highest in IPM module. In Ludhiana the integration of *T. chilonis* with insecticides proved more effective than insecticides alone and untreated control in terms of boll damage and higher yield.

Field evaluation of inundative release of *T. chilonis* in combination with *Chrysoperla carnea* against cotton pest complex in comparison with insecticidal spray and untreated control in Anand showed that the damage due to *E. vittella* and *P. gossypiella* in the release plot and insecticides plots were less than the control plot and higher parasitism was recorded by the bollworm parasitoids *Aleiodes aligharensi, T. chilonis* and *Agathis* sp. in the release plot than other plots. The impact of inundative release of *C. carnea* against sucking pest of cotton in Anand also showed that the population of leafhoppers, aphids and whiteflies was significantly lower in release plots as compared to control.

Evaluation of *Bt* products for the control of *H armigera* in cotton done at Coimbatore revealed that the *Bt* products (Delfin, Spic-bio) gave effective control of bollworms, supported larger numbers of natural enemies and gave higher yields as compared to untreated control.

2.4. Biological suppression of tobacco pests

Talc based formulation of *Steinernema carpocapsae* was compared with *Sl*NPV and chlorpyriphos for the control of *Spodoptera litura* in tobacco nursery in Rajahmundry and the results indicated that EPN at 1,2 and 4 x10^5 IJs, EPN at 1x10^5 IJs + *Sl*NPV at 1.5x10^{12} PIB, *Sl*NPV alone at 1.5x10^{12} PIB and chlorpyriphos at 0.05% gave superior protection to tobacco seedlings from damage caused by *S. litura* over untreated control with significant reduction in number of *S. litura* larvae. With increase of EPN doses there was a significant reduction in population of *S. litura* and EPN in combination with *Sl*NPV was superior to all the doses of EPN and *Sl*NPV alone in reducing the larval population.

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 in two centres and the results revealed that spraying endosulfan three times at 15 days interval was best followed by alternate sprays of *Ha*NPV and NSKE at Coimbatore while *Bt* – *Ha*NPV – *Bt* - *Ha*NPV application sequence and endosulfan were found best at Anand centre.

Effect of *Heterorhabditis* sp. at 0.5, 1 and 2 billion Ijs/ha on *H. armigera* in pigeon pea was tested in the field at Hyderabad center and the results suggested that the nematodes at 1.0 billion/ha and 2.0 billion/ha were equally effective in minimizing the larval populations of *H. armigera*, reducing pod damage and increasing the yield in pigeon pea.

Large-scale demonstration of *Bt*-*Ha*NPV-endosulfan-*Bt* sequential application in pigeon pea for the management of pod borer complex in the farmer's field near Hyderabad proved its effect recording lesser number of larvae and pod damage as compared to farmer's practice, higher yield of 735 kg/ha as compared to 310 kg/ha in farmer's practice and greater cost benefit ratio of 1:3.29 than the 1:2.51 recorded in the farmer's practice.

Pod damage was just 5.60% in plots sprayed with *Ha*NPV ($1.5x10^{12}$ POB/ha) – endosulfan (350g/ha) alternation and 5.11% in *Ha*NPV ($1.5x10^{12}$ POB/ha) – NSKE (5%) alternation as compared to 8% in plots sprayed with *Ha*NPV ($1.5x10^{12}$ POB/ha) + adjuvants and 7.8% in plots sprayed with endosulfan (350g/ha) alone in trials to evaluate NPV based management of *H. armigera* in chickpea in Coimbatore. The same combinations also recorded higher yields than other treatments.

2.6. Biological suppression of rice pests

Evaluation of integrated use of *Trichogramma japonicum* and *T. chilonis* by simultaneously releasing them at 0.5 and 1 lakh/ha at weekly interval from 20 DAT (3 releases), *Bacillus thuringiensis* at 1kg/ha at 40 and 55 DAT and need based insecticide protection with monocrotophos at 1lit/ha (2 rounds at 40 and 55 DAT) and phosphamidon at 300 ml/ha against rice stem borer and leaf folder was done at Coimbatore, Pune, Ludhiana and Jorhat. At all the four centers reduced stem borer (both white ears and dead heart) and leaf folder incidence and increased parasitism of stem borer and leaf folder eggs by *Trichogramma* spp. was recorded as also higher yield in parasitoid released plots and these were comparable with insecticide schedule and *Bt* sprayed plots. The higher dosage of 1 lakh/ha was found to be better than the lower dosage of 0.5 lakh/ha.

Biocontrol based IPM modules involving releases of *T. chilonis* and *T. japonicum* @ 1 lakh/ha/week at different crop stages for the management of stem borer and leaf folder were tested in the farmers' fields at Jorhat (kharif and rabi), Ludhiana, and Thrissur and the results showed lesser incidence of the pests and increased yields as compared to routine insecticide schedules and untreated control.

Survey and quantification of natural enemy complex in rice revealed the presence of several predators and parasitoids at all the locations. The predominant natural enemies in Thrissur consisted of hymenopteran parasitoids followed by predatory mirids, spiders and coccinellids. Predators which included spiders, coleopterans, dragonflies, damselflies, crickets, grasshoppers and preying mantids constituted 16-21%, while parasitoids comprising *Tetrastichus* sp., *Telenomus* sp., *Cotesia* sp. and *Trichogramma* sp.constituted 11-13% while the rest were pest species in Coimbatore. Seventeen species of spiders belonging to seven families were recorded throughout the crop season in Ludhiana and *Tetragnatha javana* was most common followed by *Araneus inustus*, *T. virescens* and *Oxyopes javanus*. The extent of parasitism of leaf folder by larval parasitoid *Bracon* sp. during kharif season varied from 15% to 20% in Jorhat and *Trichogramma* spp. was recorded during the last week of September and the extent of parasitism of stem borer eggs was 23.3%.

2.7. Biological suppression of coconut pests

'Mycohit', the mycoaracicide formulation of *Hirsutella thompsonii*,was evaluated against the coconut mite, *Aceria guerreronis* along with the acaricide Dicofol (Kelthane) and untreated control, in Bangalore, Kayangulam and Thrissur. In Bangalore a steady increase in the percentage of dead colonies in trees treated thrice at 14 day interval was observed. The highest mortality of 75% was realized at 63 DAT in the case of the fungus formulation while in the acaricide treatment it was 60% at 49 DAT after spraying twice. In unsprayed trees a maximum natural mortality of 7% was observed. In Kayangulam and Thrissur the evaluation is continuing and results are awaited.

2.8. Biological suppression of fruit crop pests

Releases of *T. chilotraeae* reduced the fruit damage due to the pomegranate fruit borer *Deudorix isocrates* in Bangalore with just 14.15 % fruit damage as compared to 24.24% damage in control trees. The eggs of the fruit borer, *Deudorix epijarbas* in Solan were parasitised to an extent of 59.2% and amongst the emerged parasitoids, 93.1% were the scelionid, *Telenomus ?cyrus* and 6.9% were the eupelmid, *Anastatus* sp. nr. *kashmirensis*. *T. chilonis* releases to control the ber fruit borer, *Meridarchis scyrodes* in Bangalore was effective as the mean fruit damage in released plants was 22.33% as compared to 34.95% in check.

The natural enemies of spiralling whitefly, *E. ?haitiensis* and *E. guadeloupae* were recorded in Karnataka, Kerala, Maharashtra and Tamil Nadu. *E. guadeloupae* adults were released in February on guava in an orchard near Bangalore and 14.47% parasitised whitefly nymphs were seen in March which gradually increased to 62.74% in June. Parasitisation by these aphelinids from 0-66.6 per cent was noticed in Thrissur on different host plants with a maximum of 66% on chillies during October.

Woolly apple aphid population and those of its natural enemies monitored throughout the year at weekly intervals at Solan showed that *Aphelinus mali* was consistently present while chrysopids and coccinellids were encountered during April - June, and syrphids during June, November and February. Similar surveys in Srinagar, Baramulla, Pulwama, Budgam and Anantnag districts of Jammu and Kashmir revealed the presence of *Aphelinus mali* in all areas parasitising 20-34% of the aphids from May-September, and the predators *Chilocorus infernalis*, *Coccinella septempunctata*, *Pharoscymnus batteatue* and *Chrysoperla confrator*. Observations on the impact of the release of the parasitoids of San Jose scale showed a parasitisation of 20 to 54% in Anantnag, Pulwama, Budgam, Baramulla and Srinagar districts and that both *Aphytis* sp. and *Encarsia* spp. have established well.

In laboratory trials in Bangalore all the botanicals one day after application proved nontoxic to *T. chilotraeae* while both carbaryl and monocrotophos proved highly toxic. Neem gold, Econeem, Nimbicidin all at 0.03 % and NSKE 4% were found non-toxic to adults of *E. guadeloupae* soon after application but neem oil, Neem azal and Neem mark were toxic. Effect of insecticides on natural enemies of woolly apple aphid was seen in Solan and it was concluded that *C. carnea* can be safely released after 10, 7 and 5 days of the spray of chlorpyriphos, methyl parathion and endosulfan, respectively. Chlorpyriphos, endosulfan, methyl parathion, imidacloprid and thiamethoxam did not affect the over wintering population of *A. mali* and the adults emerged from the mummified aphids.

2.9. Biological suppression of vegetable crop pests

The incidence of the green house whitefly, *Trialeurodes vaporariorum* has been noticed in Solan on ornamentals and vegetable crops. Natural enemies recorded on the whitefly include the coccinellid, *Serangium montazerii* and the aphelinid *Encarsia tarnsvena*.

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 x 10^{12} POB), in different combinations, release rates and number of applications and it was found that parasitoid release five times and 2 or 3 sprays of NPV recorded lesser mean fruit borer damage and higher yield in Bangalore, Pune and Hyderabad. The yields recorded were also more in biocontrol plots than other treatments.

Evaluation of *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 resulted in reduction in larval population and increase in yield in Bangalore. Similar trials conducted at Hyderabad resulted in a decline from 3.2 larvae per plant to 0.58 per plant in released plots with recovery of *T. bactrae*. The releases of *T. bactrae* @ 50,000 adults/ha/ release 5 times at weekly interval commencing 25 days after planting was found superior to control in Pune, with an average surviving population of 9.1 larvae/10 plants as against 12.86 average surviving larvae/10 plants and 233.5q/ha yield in control. The ICBR realized due to this treatment was 1:55.64.

Field evaluation of *T. chilonis* releases totaling 5 lakh adults/ha compared with the insecticide cypermethrin at 0.5 ml/lit. for the control of the shoot and fruit borer, *Leucinodes orbonalis* on brinjal done in Bangalore showed that the mean borer damage in the release plot was 12.65% as against 23.10% in control and 14.70% in the cypermethrin treatment. The yield data showed that there was 57.08% and 35.64% increase in yield in parasitoid and cypermethrin treatments over the control.

The comparative field efficacy of various commercial *Bt* formulations against *P. xylostella* revealed that all the *Bt* formulations and endosulfan were effective in reducing the larval build up on cabbage over control in Hyderabad. Among the various *Bt* formulations tested, Biobit proved to be effective in keeping a check on DBM with least mean number of larvae (17.00) followed by Dipel (21.93). The results of the trial in Pune revealed that Delfin WG @ 1kg/ha treatment recorded minimum surviving larvae/plant (2.00) and maximum yield (314.7 q/ha) and was found to be most effective.

Trials conducted on the control of *L. orbonalis* on brinjal using commercial formulations of *Bt* in Pune revealed that five sprays of Delfin WG @ 1kg/ha was best as it recorded least fruit infestation (8.93%) and maximum yield (136.5 q/ha). The commercial formulation, Spic-bio (*Bacillus thuringiensis* var. *kurstaki*) was found effective against *H. armigera*, *P. xylostella* and *C. binotalis* at different dosages (1-1.75 ml/lt.) and periods in Bangalore.

The serpentine leaf miner, *Liriomyza trifolii* was parasitised to the extent of 6.62% by the indigenous parasitoid, *Hemiptarsenus varicornis* in Bangalore. The second instar larvae of the leaf miner was the most preferred stage and parasitism ranged from 25% to 61%. Imidacloprid, cypermethrin, pongamia oil, NSKE, chlorothalonil, mancozeb and copper oxy chloride were found safe to *H. varicornis*. Residual toxicity studies with monocrotophos and phosphamidon to *H. varicornis* showed that monocrotophos was moderately toxic up to 21 days after spray and phosphamidon least toxic up to 14 days after treatment and then safe.

2.10. Biological suppression of potato pests

Releases of *Copidosoma koehleri* @ 50,000 mummies/ha in four equal doses at weekly interval in perforated plastic vials hung 5 m apart in the field 45 days after planting was found to be the best release method as it recorded least damage by *Phthorimaea operculella* and maximum tuber yield in Pune. Releases of adult *C. koehleri* and *C. blackburni* were found to be superior to control as it recorded less leaf mines and infested tubers but greater yield of marketable potatoes. Carry over to the stores was higher in case of *C. blackburni* (6.74%) than *C. koehleri* (5.94%). Release of *C. koehleri* @ 1 mummy/4 kg tubers in country stores was most effective and recorded minimum tuber infestation (11.36%) after one month of storage and was similar to release of *C. blackburni* @2 pupae/kg tubers.

The entomopathogens, *Beauveria bassiana*, *Nomuraea rileyi*, *Bacillus thuringiensis* and *Sl*NPV were evaluated for the control of *S. litura* on potato and it was found that *Sl*NPV @ 500 LE/ha recorded maximum larval mortality (85%) and minimum tuber infestation (8.83%) with higher marketable tuber yield of 209.1 q/ha and was as effective as *B. thuringiensis* (Delfin WG) @ 0.5 kg/ha.

2.11. Biological suppression of weeds

Monitoring and evaluation of *Neochetina eichhorniae*, *N. bruchi* and *Orthogalumna terebrantis* was continued at Thrissur and Jorhat. Water hyacinth plants from Alappuzha, Kottayam, Thrissur and Ernakulam were observed and the weevils were recorded in greater numbers during July in all locations, while mites were more during November. In Assam it was observed that the dispersal of the weevil has occurred in the districts of Sonitpur, Lakhimpur, Dibrugarh, Sibsagar, Jorhat, Golaghat, Nowgaon and Kamrup with stunted growth of the weed accompanied by less flowering.

3. INTRODUCTION

3.1. Brief History

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

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

3.2. Past achievements

Eighty 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 millions 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. *Cephalonomia stephanoderis* introduced in 1995-96 for the biological suppression of coffee berry borer, *Hypothenemus hampei* has established in several coffee growing areas.

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

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

Breeding techniques for 48 host insects have been standardised including rearing on semi-synthetic diet and the cost of production has been worked out. Improved laboratory techniques have been worked out for the multiplication of twenty six egg parasitoids, six egg-larval parasitoids, thirty nine larval/ nymphal parasitoids, twenty six predators and seven species of weed insects. An acrylic multi-cellular rearing unit was devised for rearing *Helicoverpa armigera*. Semi-synthetic diet developed for *Chrysoperla carnea* and *Cheilomenes sexmaculata*.

Mass culturing methods for aphidophagous syrphids, predatory anthocorids and several coccinellids developed.

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

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

Suitable low temperatures for short term storage of trichogrammatids, *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. Endosulfan tolerant strain of *Trichogramma chilonis* was developed for the first time and the technology transferred to a private company for large scale production. High temperature and multiple insecticide tolerant strains of *T. chilonis* being developed. Different pesticides have been screened against 37 natural enemies for identifying relatively safer ones to be used in BIPM. Primary cell culture from the embryos of *Spodoptera litura* has been established which will facilitate the multiplication of obligate microorganisms. Baculoviruses from several lepidopterous hosts were identified and cross infectivity studied. Physico-chemical characters of NPVs of *Spodoptera exigua* and *Galleria mellonella* analysed.

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

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

Hirsutella thompsonii was found effective against coconut mite, *Aceria guerreronis* and developed as a formulation called 'Mycohit'.

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

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

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

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

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

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

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

Softwares PDBC INFOBASE, giving information about bioagent producers, and BIOCOT, giving information about biocontrol measures for cotton pests, developed.

3.3. Mandate

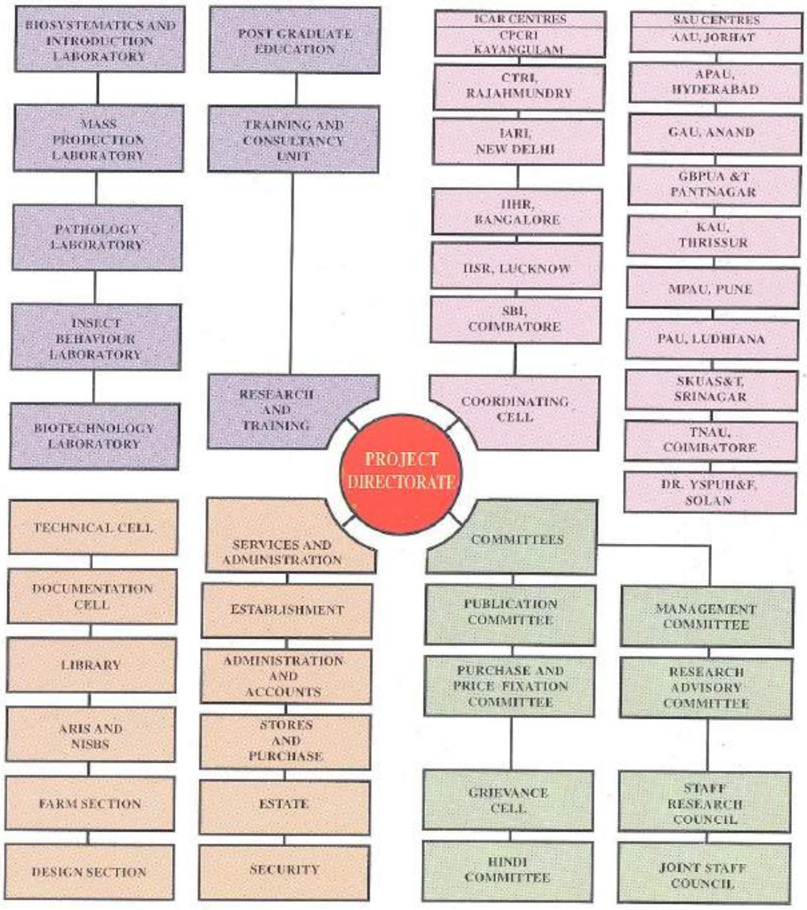
* To evolve effective schedules for biological suppression of important crop pests, diseases, nematodes and weeds.
* To quantify the natural enemy biodiversity and its role in regulation of pest population and serve as a national repository of natural enemies.
* To serve as a nodal agency for introduction, exchange and conservation of biological suppression agents at the national level.
* To co-ordinate research on biological suppression aspects at the national level and to serve as a linkage with international agencies.
* To develop state of the art national information system on biological suppression (NISBS), disseminate information and impart training on latest technologies in biological control.

3.4. Organisational set-up

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

PROJECT DIRECTORATE OF BIOLOGICAL CONTROL BANGALORE

Organisational Chart



3.5. Financial statement

Head	Plan*	Non-plan	Total
Pay & allowances	46.16	81.41	127.57
TA	05.00	02.00	07.00
Other charges including equipment	45.90	28.00	73.90
Works/petty works	51.44	07.00	58.44
Total	148.50	118.41	266.91

* 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	4.10	4.56
ANGRAU, Hyderabad	4.80	**
GAU, Anand	8.24	12.80
KAU, Thrissur	5.10	14.32
MPKV, Pune	3.70	12.78
PAU, Ludhiana	8.45	10.57
SKUAS&T, Srinagar	4.00	5.24
TNAU, Coimbatore	3.60	**
YSPUH&F, Nauni, Solan	4.30	4.13
GBPUA&T, Pantnagar	2.90	**

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

** Expenditure details not furnished

3.6 Staff position

Category	Posts sanctioned up to 31-03-2000 *	Posts filled up to 03-2000	Vacant positions
PDBC, Bangalore	25	23	2
Scientific	21	18	3
Technical			
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. Importation of natural enemies

Cultures of *Prorops nasuta* and *Phymastichus coffea*, parasitoids of the coffee berry borer were obtained again from Colombia with an import permit of the Coffee Board. The parasitoids were successfully quarantined and the cultures handed over to the Coffee Board for further trials. Field release of the parasitoid *Prorops nasuta* was done in the high altitude areas of Palani hills where running blossoms and a continuous infestation of berry borer is present. Recoveries were very poor. In the case of *P. coffea* the culture is not doing very well in our conditions though it could be cultured in the quarantine successfully.

4.2. Biosystematic studies on Indian predatory Coccinellidae

4.2.1. Taxonomic studies on coccinellids

Aponephus Booth was found to be a synonym of the genus *Nephus*, on closer examination. *Ortalia yunnanensis* Pang & Mao, reported as a first record from India last year, was found to be a junior synonym of *Ortalia horni* Weise described from Sri Lanka. *Pseudaspidimerus mauliki* Kapur was recorded for the first time from northeastern India and *P. siamensis* Kapur reported last year was found to be its synonym. The new species of *Pseudaspidimerus* Kapur and *Microserangium* Miyatake reported last year were described as *P. infuscatus* Poorani, and *Microserangium brunneonigrum* Poorani, respectively. *Diomus* Mulsant was recorded for the first time from India. A new species of *Synonychimorpha* Miyatake was recorded from Kerala and Karnataka. *Psyllobora bisoctonotata*, a species hitherto unknown from southern India, was collected from Bangalore and Raichur, Karnataka.

4.2.2. Updation of the checklist of Coccinellidae of the Indian subregion

The annotated checklist of Coccinellidae of the Indian region was updated with new distribution records and nomenclatural changes. Species of the subfamily Epilachninae from the Indian subcontinent (numbering about 75) were also added to the checklist, with all details. Now, the entire coccinellid fauna of the Indian subcontinent, including all the subfamilies, has been catalogued.

4.2.3. Identification guide

Compilation of an identification guide to predatory coccinellids of the region was continued. So far, about 90 species have been completed. Illustrations of diagnostic characters were made and host and distribution records were added for these.

4.3. Survey for natural natural enemies

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

Several indigenous natural enemies of spiralling whitefly were encountered during surveys on different host plants. The indigenous natural enemies of the whitefly recorded were:

Neuroptera – *Notiobiella* sp., *Mallada astur*

Drosophilidae – *Acletoxenus indicus*
Chamaemyiidae – *Leucopis* sp.
Nitidulidae – *Cybocephalus* sp.

Coccinellidae – *Axinoscymnus puttarudriahi, Scymnus latemaculatus, S. nubilus, S. coccivora, Nephus regularis, Cryptolaemus montrouzieri, Chilocorus nigrita, Anegleis perrotteti, A. cardoni, Jauravia dorsalis, J. pallidula, Pseudoscymnus* sp., *Keiscymnus* sp., *Pseudaspidimerus trinotatus, Serangium parcesetosum*
Coniopterygidae – unidentified species

Surveys in and around Bangalore for natural enemies revealed that the aphelinids had spread to many areas and were observed up to Tumkur, Chitradurga and Davangere. Parasitisation rates in different hosts were - *Cassia siamea* 40%, cotton 21%, guava 11% and *Michelia champaka* 4% during April - July.

4.3.2. Field survey for natural enemies of *Helicoverpa armigera*

Surveys conducted in different agro-ecosystems in and around Bangalore for *Helicoverpa armigera* parasitoids revealed three species of parasitoids, *viz.*, *Campoletis chlorideae, Eriborus argenteopilosus* and an unidentified tachinid. The per cent parasitism ranged from 1.8 to 9.15.

4.3.3. Field surveys for natural enemies of homopteran pests

Field surveys carried out in pulse, sugarcane and cotton growing areas of Bangalore revealed the presence of *Pseudohypatopa pulverea* as a predator of *Melanaspis glomerata, Hemiberlesia lataniae* and *Coccus* sp.

4.3.4. Occurrence of bacterial pathogens on *Ischiodon scutellaris* larvae

The bacterium isolated from field collected larvae of *Ischiodon scutellaris* was identified as *Bacillus* sp. Two different bacteria *viz.*, *Citrobacter* sp. and *Aeromonas* sp. were isolated from laboratory reared larvae. The per cent mortality due to *Bacillus* sp. was 10.47, 26.67 and 7.12 in second instar larvae, third instar larvae and pupal stage during winter, whereas it was 4.52, 30.00 and 14.29 per cent during summer. In laboratory reared larvae, irrespective of stage, the total percent mortality due to *Citrobacter* sp. and *Aeromonas* sp. was 31.25 and 21.62 per cent in winter and 28.52 and 21.44 per cent, in summer, respectively.

4.4. Rearing / culturing techniques for host insects and natural enemies

4.4.1. Comparative biological parameters of scale hosts, *Coccus* sp. and *Pinnaspis strachani*

Squash (*Cucurbita pepo* L.) and pumpkin (*C. moschata* L.) were evaluated for culturing *P. strachani* and *Coccus* sp. Crawlers of *P. strachani*, and *Coccus* sp. were released on pumpkin and squash separately in cages measuring 30cm^3. The fecundity in each host was taken as scales settled per 100 cm^2. Time required to produce first generation crawlers, number of crawlers per 100 cm^2 of host substrate and longevity were also recorded.

Crawlers of *P. strachani* settled earlier on squash (1.2 days) than pumpkin (2.3 days), whereas *Coccus* sp. took equal time for settling both on squash (1.42 days) and pumpkin (1.5 days). Number of crawlers settled per 100 cm² was higher on squash in case of *P. strachani* (2442 numbers) as against 1956 numbers on pumpkin. However, *Coccus* sp. equally preferred squash (3460 numbers) and pumpkin (3500 numbers). The longevity of pumpkin and squash infested with *P. strachani* was more than two months but squash infested with *Coccus* sp. shattered in one month and pumpkin could withstand *Coccus* sp. population for 55 days only. Fecundity of *P. strachani* was 150-200 and 90-150 crawlers per female on squash and pumpkin, respectively. Corresponding fecundity of *Coccus* sp. was 250-300 and 300-325 crawlers per female. Nymphal period of *P. strachani* was 25-30 days on squash and 35-40 days on pumpkin. It was slightly higher in *Coccus* sp. with 35-37 days and 40-42 days on squash and pumpkin, respectively. Squash was suitable for multiplication of *P. strachani*, whereas both pumpkin and squash were equally suitable for *Coccus* sp. Higher fecundity, ability to settle and multiply fast on both hosts makes *Coccus* sp. better host for multiplication and maintenance of various predators in the laboratory.

4.4.2. Mass rearing of *Campoletis chlorideae*

An attempt was made to standardise the rearing of *C. chlorideae* to improve the parasitisation and sex ratio. The method adopted by Harrington *et al.* (1993) for rearing *Cotesia kazak* and *Hyposoter didymator* was followed. Mass exposures were done in 4 litre bottles with mesh base. Three different ratios were tried – 1:25, 1:20 and 1:15 for a period of 24 h. Two to threee-day old larvae were exposed to mated females after a pre-oviposition period of 24 h. After exposing the larvae for 24 h, parasitoids were removed, while the host larvae were allowed to remain in the container till they reached the third instar. Then the larvae were transferred to plastic ventilated bread boxes provided with host diet and paper napkins and folded butter paper strips. Unparasitised larvae were removed.

There was no marked improvement in the parasitisation and variations were observed in the parasitisation when different parasitoid-host ratios were used (Table 1). Per cent parasitism varied between 7.4 and 27.9. An improvement in the female progeny production was observed in this method. Though in the 1:25 ratio only 27.3% were females, in the other ratios tried, the female progeny varied between 37.9 and 53.6%. Observations were recorded on the most suitable substrate for *C. chlorideae* cocoon formation; 76.7% of the cocoons were formed on the tissue paper napkins, 14% on butter paper, 7.9% on the wall of the container and the rest on other substrates like diet surface, wire mesh on the lid, etc. indicating that tissue paper was the most preferred substrate for cocoon formation.

Table 1. Effect of different parasitoid: host ratios on *Campoletis chlorideae*

Parasitoid host ratio	Per cent parasitisation	Per cent females among progeny
1:25	7.4	27.3
1:20	16.0	53.6
1:15	8.5	50.0
1:10	27.9	37.9

4.4.3. Studies on development of a mass production technique for *Pseudohypatopa pulverea*

Pseudohypatopa pulverea, a predator recorded on *M. glomerata* in Mandya and *H. lataniae* on agave in Thondebhavi was reared on *Coccus* sp. The scale insects were reared on pumpkin kept in cloth walled wooden cage (30x30x30cm). Ten pairs of freshly emerged adults of *P. pulverea* were released into a cage for oviposition. Different substrates, *viz.*, emery paper, butter paper and a piece of industrial felt were arranged in the periphery of feeding material, so that the adults had uniform access to all the substrates for oviposition. Eggs laid on different substartes were counted separately. The experiment had five replications and each replication had 20 adults. The experiments were conducted at 27±1.8 ° C and 65±2.5% R.H.

Amongst the three substrates provided, butter paper was totally rejected for egg laying, whereas eggs were laid on both emery paper (10.2%) and industrial felt strip (5.02%). Maximum oviposition (84.78%) was observed on scale colony developed on pumpkin. The newly hatched larvae readily fed on scales by making webbed galaries. The per cent egg hatch and larval survival was 92.6 and 78.9 per cent, respectively. Egg, larval and pupal periods occupied 5.2, 10.6 and 7.2 days, respectively. Fecundity ranged from 13.25 to 28.56 eggs per female. Adult longevity was 5-7 days in male and 6-9 days in female. A cage containing 15 adults with fully infested pumpkin along with 50% honey as feeding for adults could yield 95 to 200 adults in a month.

4.4.4. Studies on the influence of age and host insect on oviposition pattern of *Harmonia octomaculata*

The culture of striped mealy bug *Ferrisia virgata* was maintained on pumpkin. *Aphis craccivora* was multiplied on sprouts of cowpea. *Harmonia octomaculata* adults collected from the field were used for experiments. Oviposition preference of *H. octomaculata* was studied by providing the mealybugs as well as aphids in separate sets of experiments. Different substrates viz., dry *Bauhinia purpurea* leaves, industrial felt and absorbent cotton pad were arranged in the periphery of the feeding material, so that the adults had uniform access to all the substrates for oviposition. Eggs laid on different substrates were counted. The experiment had five replications and each replication had 30 adults. To study the effect of age of *H. octomaculata* on oviposition, five newly emerged pairs were released in an acrylic cage (30x30x30 cm) and both hosts were provided separately. This experiment had ten replications. Egg laying (%) and egg hatching were recorded daily till the females survived. All the experiments were conducted at 27±1.8 ° C and 65±2.5% R.H.

Adults of *H. octomaculata* reared on *Ferrisia virgata* showed prefence for dry *Bauhinia purpurea* leaves (43.15%) for oviposition followed by feeding substrate (*F. virgata* colony on pumpkin) (32.02%). Similarly, adults reared on *A. craccivora* preferred to oviposit on *B. purpurea* leaves (57.96%) followed by feeding substrate (aphid colony on cowpea twig) (32.15%). Fecundity of *H. maculata* was marginally higher on *A. craccivora* (289.2 eggs per female) as compared to that on *F. virgata* (275.8 eggs per female). However, average egg hatching was higher on *F. virgata* (91.05%) as against 84.72% on *A. craccivora*. Peak oviposition period was attained in the 5th week (as adult age) on *F. virgata*, and in the 3rd week when reared on *A. craccivora*. Total oviposition period was eight weeks and nine weeks on *A. craccivora* and *F. virgata*, respectively. Adults could be reared for up to eight weeks on both the hosts (Figs. 2 and 3)

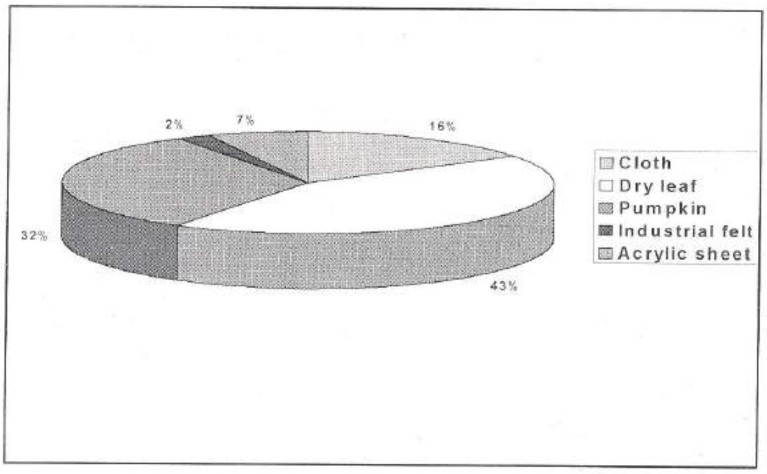


Fig.2 Oviposition substrate preference of *H. octomaculata* reared on *F. virgata*

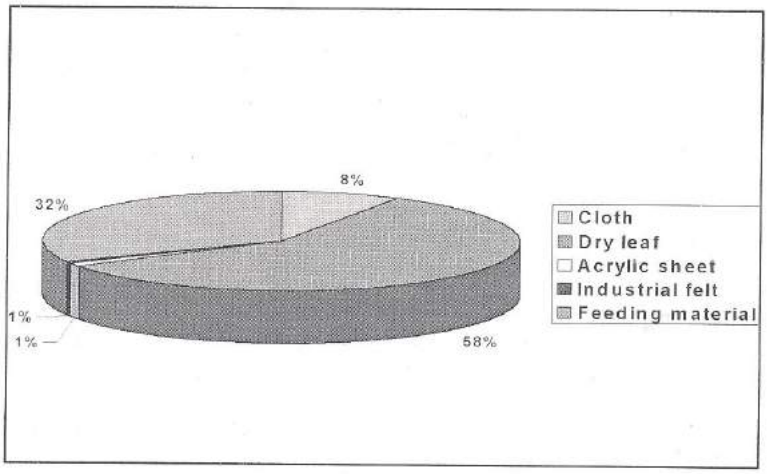


Fig. 3 Oviposition substrate preference of *H. octomaculata* reared on *A. craccivora*

4.4.5. Studies on comparative biotic potential of three coccinellids on various scale species

Biotic potential of three coccinellids *viz.*, *Sticholotis cribellata*, *S.* nr. *quadrisignata rugicollos* and *Pharoscymnus horni* was studied on different scale species *viz.*, *M. glomerata*, *H. lataniae*, *Pinnaspis strachani* and *Coccus* sp. All the host insects were reared on pumpkins, except *M. glomerata* which was reared on sugarcane setts in the laboratory. All the predators were field collected and were initially reared in the laboratory on their natural hosts. Developmental period of the predator was recorded by releasing one pair of freshly emerged beetles on each host. Each treatment was replicated four times. Pumpkins and sugarcane setts were observed daily for egg laying. Pre-oviposition, egg, larval and pupal periods were recorded on each host. Experiments were conducted to determine the rate of host consumption by grubs and adults of the predators by releasing them on known scale insect population of the same age (20 to 25 days old). Observations were recorded daily on host insects consumed by grubs. Since adults lived for more than one month, host consumption was recorded every five days and mean host consumption was derived. This experiment was replicated ten times. Observations on progeny production and longevity on various hosts were also recorded. The experiments were conducted at 27±1.8 ° C and 65±2.5% R.H.

Total developmental period on different hosts for *S. cribellata* and *S.* nr. *quadrisignata rugicollos* ranged from 34 - 39.3 and 33.1 - 39.9 days, respectively. In *P. horni* it was 24.6 - 31.5 days. *S. cribellata* and *P. horni* developed faster on *Coccus* sp. while *S.* nr. *rugicollos quadrisignata* took least time to develop on *P. strachani*. With respect to fecundity also same trend of preference was exhibited by *S. cribellata* and *P. horni*, however, *S.* nr. *rugicollos quadrisignata* fed with *Coccus* sp. and *P. strachani* laid similar number of eggs. *P. strachani* was found to be the least preferred host by *S. cribellata* and *P. horni* but *S.* nr. *rugicollos quadrisignata* preferred it with respect to fecundity, longevity and voracity. Studies thus indicated that *P. strachani* or *Coccus* sp. should be used for multiplication of *S.* nr. *rugicollos quadrisignata* whereas *M. glomerata* and *Coccus* sp. could be used for multiplication of *S. cribellata* and *P. horni*.

4.4.6. Effect of low holding temperature during pupal stage on adult emergence, longevity and fecundity of *Ischiodon scutellaris*

The culture of *Ischiodon scutellaris* was maintained on *Aphis craccivora* reared on cowpea seedlings. Immediately after pupation the pupae were harvested from cotton plug substrate. Ten replicates each containing ten pupae aged one, two and three days were incubated at 5, 10 and 15°C for one, two and three weeks each. The pupae were held subsequently at ambient temperature of 27°C until adult emergence. The day of adult emergence, longevity and fecundity were recorded from these treatments. 5° C was found to be lethal after only one week of storage. The emergence was delayed when 2 and 3 days old pupae were subjected to 10° C for 3 weeks. The initiation of oviposition was delayed with the prolongation of holding time. The fecundity of females emerging from 3-day-old pupae subjected to 10° C for two weeks was found to be higher than any other treatment. Three-day-old pupae exposed to 15° C for more than one week started emerging in storage itself. Based on this study, it can be concluded that three-day-old pupae could be stored at 15° C for three weeks with affordable reduction in the longevity and fecundity of resulting adults.

4.5. Bioecological studies on laboratory hosts and natural enemies

4.5.1. Bio-deterioration studies on *Eriborus argenteopilosus*

Adults of *Eriborus argenteopilosus* emerging from field collected cocoons were considered as field collected batch. *E. argenteopilosus* which were reared for at least three generations in the laboratory were utilised for the experiment as the LR3 (lab reared for 3 generations) batch and their progeny as the LR4 (lab reared for 4 generations) batch and so on. Parasitising efficiency, cocoon production, per cent adult emergence and per cent females among progeny produced were recorded. The mated parasitoids were exposed to larvae of *S. litura* on alternate days after a pre-oviposition period of 24 h and the number of exposures was restricted to five (based on preliminary observations). Each replication comprised of one pair and ten replications each were maintained for field collected and lab reared batches.

Field collected adults parasitised 27% of the exposed larvae, while lab reared adults parasitised 17.5 and 23.8% larvae after three and four generations in the laboratory, respectively. However, these differences were not statistically significant. From the cocoons formed from the field-collected batch, 66.4% emergence was recorded. There were 79.7 and 55.8% adult emergence from the cocoons obtained from the lab reared (3rd and 4th generations, respectively) batches. The cocoons obtained per female and the per cent adult emergence of the field collected batch and lab reared batches were all statistically on par. Amongst the progeny produced by the field collected batch, 68.77% were females and even after three generations in the laboratory, 54.08% female progeny was recorded. However, after 4 generations, a significant reduction in female progeny production occurred (only 1.3%). Sex ratio was drastically affected due to continuous laboratory rearing (Table 2).

Table 2. Bio-deterioration of laboratory reared *E. argenteopilosus*

Treatments	Parasitism %	Cocoons / female	Adult emergence (%)	Per cent females
Field Collected	27.0(31.4)	33.3	66.37(55.2)	68.77(56.4)[a]
Lab Reared-3	17.5(23.9)	16.0	79.7(54.68)	54.68(48.1)[a]
Lab Reared-4	23.8(29.5)	21.3	55.83(48.7)	1.3(7.3)[b]
CD (P=0.05)	NS	NS	NS	16.89

Figures in parentheses are angular transformed values
Figures in a column followed by the same letter are not statistically different

4.5.2. Morphometric studies on sexing of *Eriborus argenteopilosus*

A study was undertaken to find out a method to segregate the males and females of *E. argenteopilosus* at cocoon stage. *E. argenteopilosus* were reared on early second instar larvae of

S. litura or *H. armigera*. The cocoons were collected and each cocoon was weighed and its length and greatest width measured. The cocoons were maintained individually in dry glass vials measuring 4.5x1.5 cm. When adults emerged, they were sexed and related to the cocoon weight, length and greatest width. Correlation analyses were done to find out if significant correlations existed between weight, length and greatest width. Analysis of variance was done to find out if significant differences existed between the male and female cocoons with respect to the morphometric parameters. Attempts were made to arrive at the most satisfactory criterion for separating the sexes with minimum overlap.

The cocoon length, weight and width were significantly more in the case of females than males (Table 3). There was a significant positive correlation between cocoon weight and width, weight and length and between length and width of male and female *E. argenteopilosus* (Table 4). The regression lines and equations showing the relationships between the different morphometric parameters are given in Figs. 4, 5 and 6.

Table 3. Morphometrics of male and female cocoons of *Eriborus argenteopilosus*

Cocoon	Cocoon weight (mg)	Cocoon length (mm)	Cocoon width (mm)
Male	38.56 (26.98-53.23)	8.56 (7.85-9.71)	3.49 (2.94-3.93)
Female	45.92 (36.30-57.78	8.80 (8.14-9.81)	3.65 (3.43-4.12)
CD (P=0.05)	1.73	0.06	0.011

Figures in parentheses are ranges

Table 4. Correlation matrix of cocoon weight and length; weight and width and length and width in male and female *E. argenteopilosus*

Cocoon of	Weight vs Length	Weight vs Width	Length vs Width
Male	0.7457**	0.5886**	0.5632**
Female	0.7213**	0.6645**	0.6296**

The morphometrics of male and female cocoons were examined and the weight, length and the width of the cocoons were divided into 4 categories each: > 35mg, >40mg, > 43mg and >45mg in the case of weight; >8.3mm, >8.5mm, >8.6 mm and >9.0mm in the case of length and >3.4mm, >3.5mm, >3.6mm and >3.7mm in the case of width. The male and female cocoons belonging to each of these categories were recorded (Table 5). The size indices were worked out for segregating the sexes in cocoon stage.

Table 5. Per cent female cocoons and male cocoons belonging to different size indices

Cocoons with	Per cent female cocoon that get included	Per cent males cocoons that get included
Weight >		
35 mg	100	71.43
40 mg	81.43	32.86
43 mg	72.90	18.60
45 mg	55.71	11.40
Length >		
8.3 mm	88.60	68.60
8.5 mm	78.60	51.40
8.6 mm	75.70	41.40
9.0 mm	25.70	15.70
Greatest width >		
3.4 mm	98.60	72.90
3.5 mm	80.00	44.30
3.6 mm	58.60	27.10
3.7 mm	41.40	20.00

The reliability of the chosen size indices was verified by collecting 200 cocoons and measuring the parameters and categorising them. After adults emerged from these cocoons, the percentage females which were obtained from cocoons belonging to the selected size indices was worked out (Table 6). The percentage females emerging from cocoons which did not belong to the selected size indices was also noted. It is clear from Table 6 that by following any of the size indices, it was possible to segregate maximum number of females (ranging from 69.43 to 80.76%). Only a small percentage of females (23.05 to 34.18%) emerged from other cocoons, which did not belong to the selected size indices.

Table 6. Segregation of female cocoons of *E. argenteopilosus* based on selected size index

Cocoons of	Per cent probability of females emerging
Wt > 40 mg	72.21
Wt > 43 mg	80.76
L > 8.5 mm	69.95
L > 8.6 mm	74.40
W > 3.5 mm	69.43
W > 3.6 mm	71.12

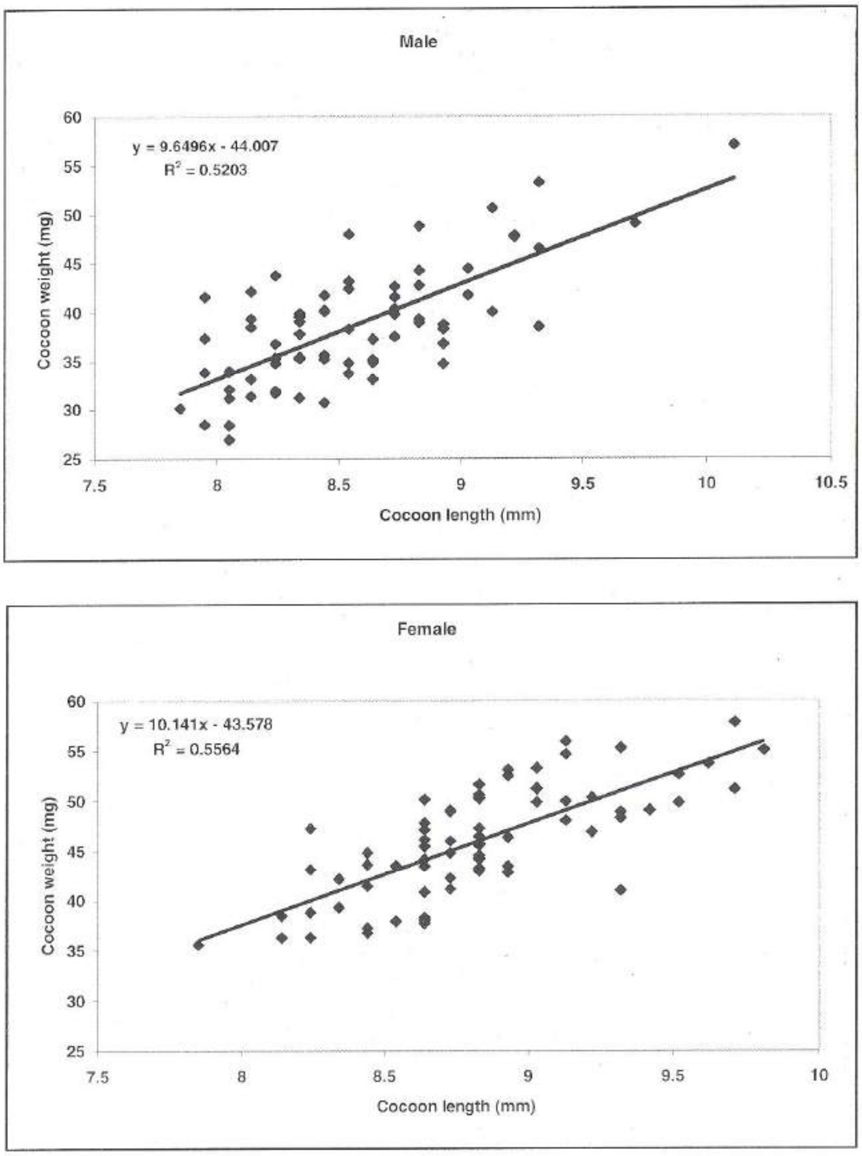
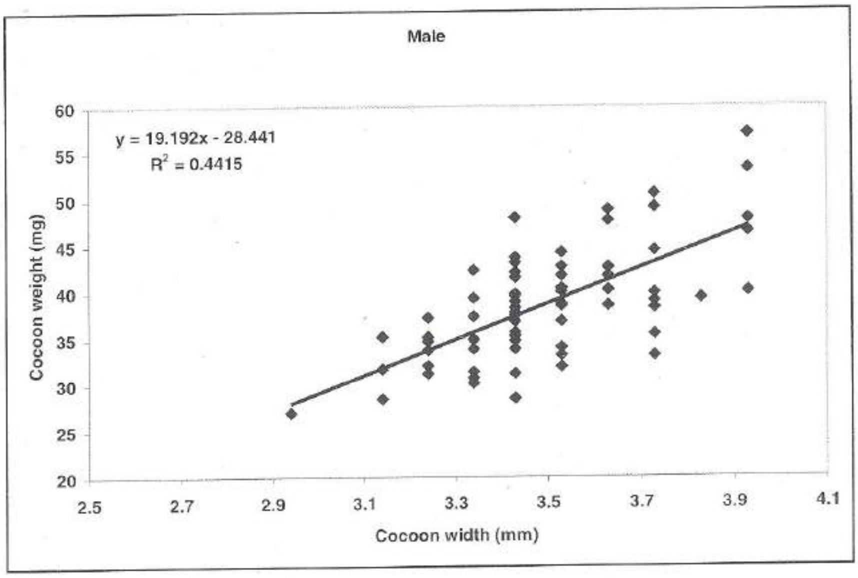


Fig. 4. Relationship between cocoon weight and length of *Eriborus argenteopilosus*



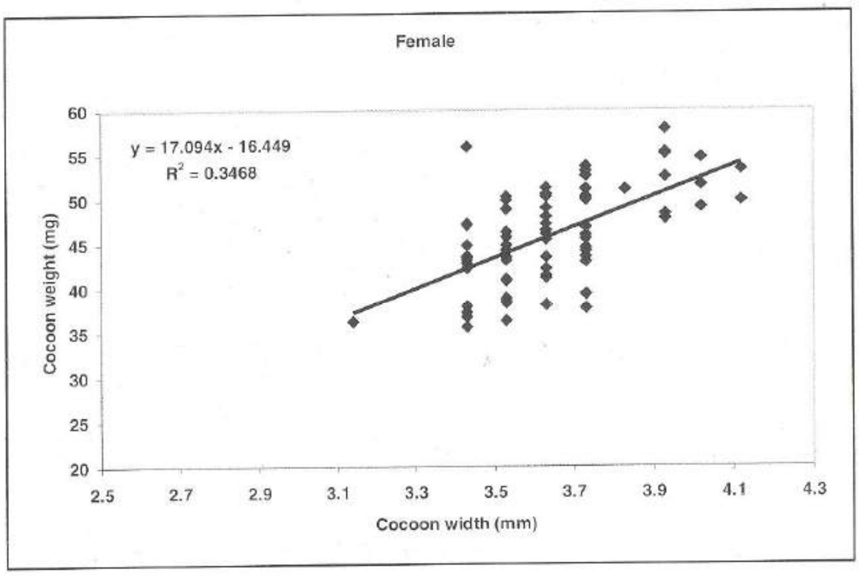


Fig. 5. Relationship between cocoon weight and width of *Eriborus argenteopilosus*

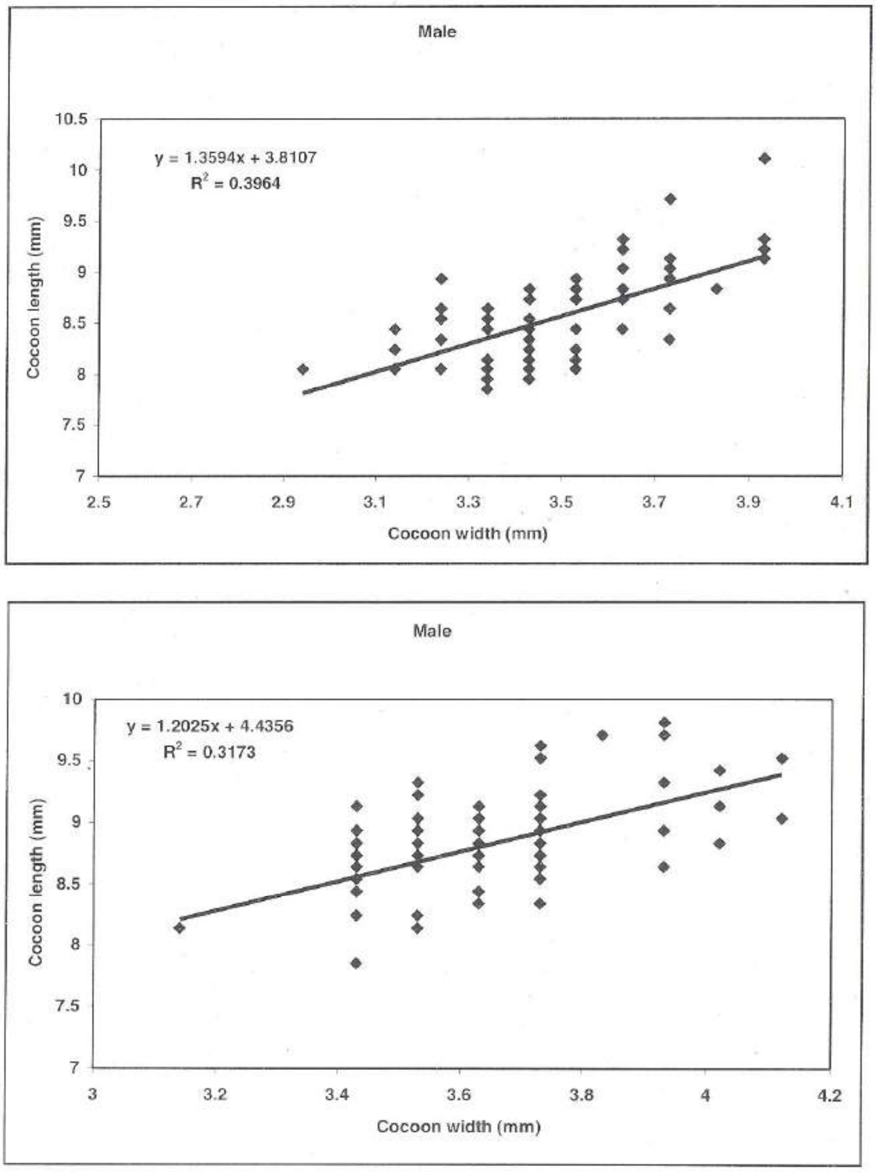


Fig. 6. Relationship between cocoon length and width of *Eriborus argenteopilosus*

4.5.3. Feeding potential of *Cardiastethus exiguus*

Cardiastethus exiguus, a potential predator of eggs and young larvae of *Opisina arenosella* can be multiplied continuously in the laboratory utilising alternate laboratory host, *Corcyra cephalonica*. The feeding potential was studied.

The experiment was conducted utilising round plastic ventilated containers (diameter 7cm; height 2.7cm). Five freshly hatched nymphs were kept in such containers (@ 1per container) with cotton to prevent cannibalism and a swab soaked in water for moisture. Daily 15 eggs of *C. cephalonica* were provided/per nymph. Observations were recorded on how many eggs were fed per day till adults were formed (damaged and shrunken eggs were considered as fed). This was replicated ten times. The same experiment was repeated for adult male, adult female and one pair. For adult male and female 15 eggs were provided per day and for a pair, 25 eggs were provided per day till mortality.

During the nymphal period, the total feeding was about 31 - 47 *C. cephalonica* eggs; (mean 39.5 eggs) and mean feeding per day was 2.69 eggs (feeding per day ranged from 1.62-3.69 eggs). One male adult of *C. exiguus* could feed on a total of about 128 eggs, and about 3.71 eggs were fed per day. Female adults fed on more eggs. Throughout its longevity one adult could feed on about 441 eggs at 8.81 eggs per day. The total feeding potential was about 383.5 eggs, while 7.45 eggs were fed on per day (Table 7).

Table 7. Feeding potential of *Cardiastethus exiguus* on *Corcyra cephalonica* eggs

Stage	Total feeding	Mean feeding/day
Nymph	39.5 eggs / nymph	2.69 eggs / day / nymph
Adult Male	128 eggs / male	3.71 eggs / day / male
Adult Female	441 eggs / female	8.18 eggs / day / female
Pair	384 eggs / pair	7.45 eggs / day / pair

The nymphal period varied between 12 and 20 days. During the first 16 days, feeding generally ranged between 2 - 3.7 eggs/day; if the nymphal period continued beyond 16 days, there was a reduction in feeding, which was less than 2.0 eggs (Fig. 7).

Adult males lived for about 42 days. The adult males could feed on 3 - 6.5 eggs per day. Some peaks showing more feeding were evident on days 8, 17, 22, 31 and 38; during which period, per day feeding was more than 5 eggs; but less than 8 eggs. Adult females could live even for 91 days. During the first 40 days of its life feeding ranged between 4 and 11.5 eggs per day, which was generally more than the male feeding potential. In the latter half of its life, the female *C. exiguus* could feed on 1-7 eggs per day. The feeding potential during this period was almost as in the case of male adults (Fig 7).

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

Pupal orientation of *Encarsia* spp. was studied and it was found that the almost all the pupae of *E. guadeloupae* were facing the dorsum of the host and were oriented with the 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 in a slower manner. This could help in identifying the pupae of the two parasitoids. Pupae of *E. guadeloupae* took 19-24 seconds for 20 movements.

The average longevity of adult *E. guadeloupae* at room temperature, 15 and 20 °C was 19.12, 36 and 25.06 days, respectively, when provided honey.

4.5.5. Studies on the biology and feeding potential of spiralling whitefly predators *Axinoscymnus puttarudriahi* and *Cybocephalus* sp.

The biology of *A. puttarudriahi* and *Cybocepahlus* sp. on the whitefly revealed that the egg period was 4 days (both), larval period 7-8 (both) and pupal period 5-6 days and 16-17 days, respectively (Table 8). The total cycle from egg to adult was 16-18 days for the coccinellid and 27-29 days for the nitidulid. The females of *A. puttarudriahi* lived for 31-47 days and laid 51-134 eggs while those of *Cybocepahlus* sp. lived for 90 days and laid 112 eggs.

Table 8. Biology of *Axinoscymnus puttarudriahi* and *Cybocephalus* sp. (n=15)

Stage	*Axinoscymnus puttarudriahi*	*Cybocephalus* sp.
Egg period (indays)	4	4
Larval Period (in days)	7-8	7-8
Pupal period (in days)	5-6	16-17
Egg to adult (in days)	16-18	27-29
Fecundity (number of eggs)	51-134	112

The feeding potential of *A. puttarudriahi* was worked out by providing 8 whitefly nymphs per day. They fed on 124-133 nymphs during their adult life of 48-64 days. The feeding potential of *A. puttarudriahi* was found to be 137.5 (124-151) nymphs of the whitefly during an average adult span of 55.25 days (n=5). A larval parasitoid, *Cerchysiella* sp. of *Cybocephalus* sp. was recorded.

4.5.6. Parasitoid-host ratio studies with *Trichogramma chilonis* and *Helicoverpa armigera* in soybean

A local soybean variety was used for this experiment and was raised in earthen pots

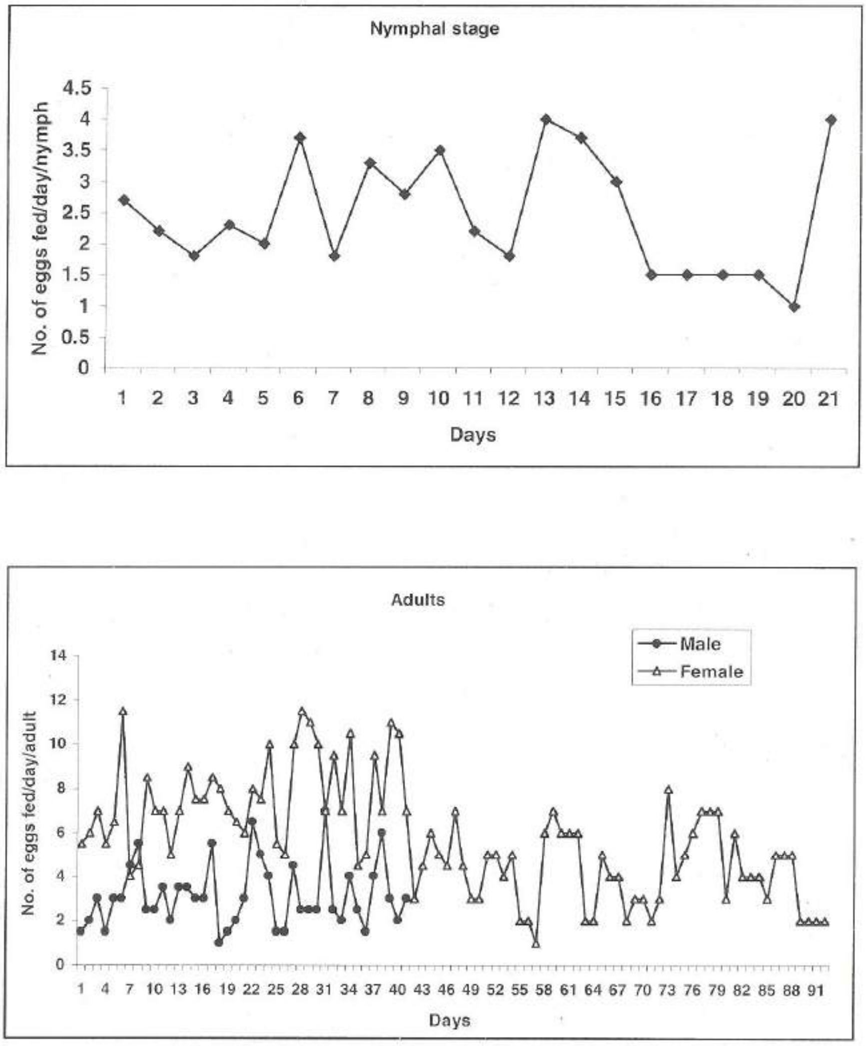


Fig. 7. Daywise feeding potential of *Cardiastethus exiguus*

measuring 30 cm. in height. Host and parasitoid cultures were maintained in the laboratory at 26±2°C and 50-60% RH. One-day-old mated female parasitoid was used for the experiment. Leaf bouquets (5-6 weeks old plants) were prepared by inserting them in glass vials containing water. These bouquets were kept inside a cage measuring 30 x 30 x 30 cm. The eggs of *H. armigera* were released on the leaves as per the treatments and one female *T. chilonis* released for parasitisation in each cage. The different ratios (parasitoid:host) tried were 1:10, 1:20, 1:30 and 1:40. Each treatment was replicated 5 times. After 24 h of exposure, the eggs were collected and kept in glass tubes for observing the per cent parasitism and adult emergence. The percentage values were subjected to angular transformations and ANOVA done.

There was an increase in per cent parasitism with increase in dosage. Maximum parasitism (70%) was recorded at 1:10 (female parasitoid : host eggs) (Table 9). When the parasitoid:host ratio was reduced to 1:20, parasitism was 64%, and on par with that at 1:10 ratio. Parasitism significantly decreased to 31.6% when the ratio was 1:30 and least parasitism (14.8%) was recorded at 1:40 ratio. The differences in the per cent parasitism among the ratios 1:20, 1:30 and 1:40 were highly significant. Per cent adult emergence varied from 86.2 to 88.2 at different dosages, all were statistically on par. At 1:10 and 1:20, highest per cent parasitism of *H. armigera* eggs by *T. chilonis* eggs could be obtained.

Table 9. Parasitising efficiency of *Trichogramma chilonis* at different dosages of *H.armigera* eggs on Soybean

Dosages (female parasitoid : host eggs)	Mean per cent parasitism	Mean per cent adult emergence
1:40	14.80 (22.75) [a]	86.20 (69.73)
1:30	31.60 (34.41) [b]	87.60 (70.45)
1:20	64.00 (53.94) [c]	86.80 (69.60)
1:10	70.00 (57.23) [c]	88.20 (70.76)
CD (P=0.05)	8.65	NS

Figures in parentheses are angular transformed values. Values followed by the same letter are not statistically different.

4.5.7. Testing of *Campoletis chlorideae* in the net house

The performance of C. *chlorideae* was evaluated on potted chickpea plants in net house, arranged 30 cm row to row and 10 cm plant to plant. These plants were artificially infested with ten 4-day-old larvae of *H. armigera* per plant. The plants were in flowering and early podding stage. The larvae were randomly distributed over leaves, flowers and pods. After 24 h of larval release, the adult pre-mated females of *C. chlorideae* were released as per the treatments below

i. Release of one adult female parasitoid / 10 larvae (1: 10 ratio) immediately after the release of host larvae

ii. Release of one adult female parasitoid / 10 larvae (1: 10 ratio) 24 h after the release of host larvae

iii. Release of two adult female parasitoids / 10 larvae (1: 5 ratio) immediately after the release of host larvae

iv. Release of two adult female parasitoids / 10 larvae (1: 5 ratio) 24 h after the release of host larvae

v. Release of 10 larvae / plant (Control)

Care was taken to prevent predation of larvae by spiders, ants, etc. by providing water barriers. The larvae were collected back after 24 h of release of parasitoids and reared individually on semi-synthetic diet. Observations were recorded on number of larvae parasitized (parasitism was measured in terms of cocoon formation). Each treatment consisted of 10 pots. The percentage values were subjected to angular transformation and ANOVA done.

Release of *C. chlorideae* female parasitoids in the ratio of 1:10 immediately after the release of *H. armigera* larvae resulted in very low parasitism (1.5%), which was on par with control. When the parasitoid was released in the same ratio 24 hrs after host release, there was a significant increase in parasitism (7.2%). When the parasitoid-host ratio was 1:5, 13% parasitism was obtained even if the parasitoids were released immediately after host release. However, when the same ratio was tried after 24 h of host feeding, a significantly higher per cent parasitism was obtained (33). *C. chlorideae* did not perform well when released immediately after infesting the plants with *H. armigera*. A ratio of 1 female parasitoid for 5 host larvae was found better.

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

4.6.1. L-tryptophan as an ovipositional attractant for *Chrysoperla carnea*

Experiments were conducted at Satya Sai Cotton Mill, White Field, Bangalore, to find out the efficiency of L-tryptophan as an ovipostional attractant. Thirty plants in a patch were selected, L-tryptophan (0.66%) was sprayed on the plants in the evening hours and 30 adults of *Chrysoperla carnea* were released in the area. Control was maintained in the adjacent field without any treatment but adults were released.

More number of eggs were laid on L-tryptophan (0.66%) treated plants compared to untreated plants (Table 10).

Table 10. Ovipostion by *C. carnea* on L-tryptophan treated cotton plants under field conditions

Trail No.	Number of eggs laid per 30 trytophan treated area	Number of eggs laid per 30 plants in untreated area
1	49	8
2	64	16
3	13	3
Mean	42	9

4.6.2. Kairomonal formulations to increase the parasitising efficiency of *Trichogramma chilonis* under field conditions

Kairomonal formulations were earlier found to increase the parasitising efficiency of *Trichogramma chilonis*. *Corcyra* egg cards treated with kairomonal formulations were tagged on to cotton plants in a small area of 5 x 3.5m and untreated cards were tagged in another patch of 5 x 3.5m area. The adults of *T.chilonis* were released in the experimental area. The eggs were collected from the field after 24 h and observed for parasitisation. Each treatment was replicated 5 times in the field. In the first trial tricosane and pentacosane were tried at 0.01% and in the second trial the compounds were tested at 0.02%. The concentration of *Corcyra* scales was kept constant (1%).

In the first trial there was significant difference between the treated and the untreated egg cards. The egg cards treated with both tricosane (3.35%) and pentacosane (5.46%) recorded more parasitisation compared to untreated control (1.09). The parasitisation increased to 6.1% in pentacosane (0.02%) and to 7.7% in tricosane (0.02%). However, statistically no difference between treatments was seen.

4.6.3. Kairomonal formulations to increase the predatory efficiency of larval chrysopids under field conditions

Earlier studies indicated that the predatory efficiency of the larvae of *Chrysoperla carnea* increased when kairomone formulations were used. In the present studies, Tricosane and pentacosane at 0.01 and 0.02% concentration were sprayed on *Corcyra* egg cards and the cards were tagged on to the cotton plants. The larvae of *C. carnea* @ 2/plant were released. The eggs were collected the next day and the predatory efficiency computed.

There was not much difference in predation by larvae of *C. carnea*, with about 3-6 % predation in all treatments including untreated control. However, the overall activity of *C. carnea* increased over the period of study. The egg counts in 30 plants was nil during the start of the experiment, but was more than 8 per 30 plants at the end.

4.6.4. Laboratory studies to find out the effect of kairomonal formulations on the parasitising efficiency of *T. chilonis*

Laboratory studies were conducted to find out the effect of kairomonal formulations on the parasitising ability of *T. chilonis* in '8' armed olfactometer. Kairomonal formulations were prepared using the scales of *Corcyra cephalonica* along with Tricosane, Pentacosane and Nonocosane. The formulations were sprayed on a *Corcyra* egg card, left for half an hour to ward off the smell of cyclohexane and the egg cards were placed inside the '8'arm olfactometer. Uniform light was maintained. Fixed number of adults of *Trichogramma chilonis* were released in the centre of '8' arm olfactometer. The eggs were collected on the next day to record per cent parasitisation.

Three sets of experiments were conducted. In the first there was variation between the treatments and untreated control. Tricosane at 0.01% recorded highest parasitisation (Table 11). In the next trial with the same concentrations not much variation between treatments was seen (Table 12). Tricosane, pentacosane and nonocosane at 0.02%, 0.03% and 0.04% were not effective (Table13).

Table 11. Parasitisation of *T. chilonis* on *C. cephalonica* eggs treated with kairomone in 8-arm olfactometer (Trial II)

Trail No.	Treatment	Percent Parasitisation
1.	Tricosane (0.01%) *Corcyra* scales (1%)	39.90
2.	Pentacosane (0.01%) *Corcyra* scales (1%)	34.17
3.	Control	28.24
4.	Tricosane (0.01%) *Corcyra* scales (1%)	35.80
5.	Pentacosane (0.01%) *Corcya* scales (1%)	33.16
6.	Control	27.53

Table 12. Parasitisation of *T. chilonis* on *C. cephalonica* eggs treated with kairomone in 8-arm olfactometer (Trail II)

Trail No.	Treatment	Percent Parasitisation
1	Tricosane (0.01%) and *Corcyra* scales (1%)	24.75
2	Pentacosane (0.01%) and *Corcyra* scales (1%)	26.50
3	Nonocosane (0.01%) and *Corcyra* scales (1%)	21.00
4	Control	22.25
5	Tricosane (0.02%) and *Corcyra* scales (1%)	19.25
6	Pentacosane (0.02%) and *Corcyra* scales (1%)	26.00
7	Nonocosane (0.02% and *Corcyra* scales (1%)	21.50
8	Control	25.50

Table 13. Parasitisation of *T. chilonis* on *C. cephalonica* eggs treated with kairomone in 8-arm olfactometer (Trail III)

Trail No.	Treatment	Percent Parasitisation
1	Tricosane (0.03%) and *Corcyra* scales (1%)	25.2
2	Pentacosane (0.03%) and *Corcyra* scales (1%)	26.8
3	Hexane	36.4
4.	Control	26.8
5	Tricosane (0.04%) and *Corcyra* scales (1%)	28.4
6	Pentacosane (0.04%) and *Corcyra* scales (1%)	29.6
7.	Hexane	32.0
8	Control	29.2

4.6.5. Laboratory studies to induce oviposition in aphidophagous coccinellids

Saturated hydrocarbons were tested for inducing oviposition in *Cheilomenes sexmaculata*. Droplets were produced on a brown paper using agar agar based synthetic diet for coccinellids and several saturated hydrocarbons in different combinations were sprayed over the droplets using an atomiser. The brown paper with droplets were pasted on the roof of an acrylic sheet measuring 60 x 30 x 30 cm and the gravid females along with males were released in the cage. The number of adults visiting the filter paper for a period of 30 minutes was recorded at 5 minutes interval. The adults were left overnight and the number of eggs laid was counted the next day.

Two sets of experiments were conducted, each with 8 replications. There was no significant difference in the number of adults visiting the filter paper (Table 14). There was no egg laying in all the treatments.

Table 14. Orientational response of *C. sexmaculata* to different kairomonal compounds

Treatment	Number responsive	Treatment	Number responsive
Honey	2.00	Honey	1.00
L-Tryptophan	1.56	L-trytophan	0.83
Hexacosane	1.44	Hexacosane	1.00
Pentacosane	1.66	Hexacosane	1.00
Nonocosane	1.56	Control	0.83
CD	NS	CD	NS

4.6.6. Parasitisation of *Spodoptera litura* by *Telenomus remus* on different soybean varieties

A preliminary test was conducted to check if *T. remus* could perform in soybean ecosystem on a local soybean variety. Leaf bouquets of local soybean were inserted in glass vials containing water. These bouquets were kept inside a cage measuring 30 x 30 x 30 cms. Egg batches of *S. litura* (a total of 200 eggs per plant) were kept on the leaves of soybean leaves. Female *T. remus* parasitoids were released at different dosages *viz*., 5, 10, 20, 40 per 200 eggs for parasitisation in each cage for 24 hours. Each treatment was replicated 5 times. After 24 h, the eggs were collected and kept in glass tubes for observing the per cent parasitism and adult emergence. The percentage values were subjected to angular transformation and ANOVA done.

The results of the preliminary test showed that when *S. litura* eggs were exposed to different dosages of *T. remus* females, parasitism ranged from 6.2 to 70.6%. Maximum parasitism (70.6%) was obtained when the parasitoid/host ratio was 1female: 5 eggs. The ratios of 1:20 and 1:10 resulted in significantly lower parasitism of 23 and 29.2% parasitism, respectively, both being on par. The lowest per cent parasitism (6.2%) was recorded when the ratio was one female per 40 eggs, which was significantly lesser than all the other treatments. The per cent adult emergence from the parasitised eggs ranged from 81.4 to 88.4 % and no significant differences were observed between the treatments (Table 15).

Table 15. Parasitising efficiency of *Telenomus remus* on *S. litura* eggs at different parasitoid: host ratios

Dosages (female parasitoid : host eggs)	Mean % parasitism	Mean % adult emergence
1:40	6.2 (14.37)a	88.4 (70.62)
1:20	23.0 (28.76)b	85.0 (67.94)
1:10	29.2 (32.85)b	81.4 (65.04)
1:05	70.6 (57.79)c	83.0 (68.25)
CD (P=0.05)	6.95	NS

Figures in parentheses are angular transformed values.
Values followed by the same letter are not statistically different.

Five soybean varieties, *viz.*, PK-472, PUSA-16, JS-335, MACS-450, NRC-12 and one local soybean variety were raised in earthen pots measuring 30 cm. in height. Host and parasitoid cultures were maintained in laboratory at 26±2°C and 50-60 % RH. Two-day-old mated female parasitoids were used for the experiment. The varietal preference was studied by employing the multiple-choice method. The releases were made based on the best ratio (1:5) from the preliminary test. Leaf bouquets of all six soybean varieties with 200 eggs each were kept inside one cage measuring 30 x 30 x 30 cm and exposed to 40 female parasitoids per 200 eggs for 24 h. The other steps followed were as in the preliminary test. The highest parasitism (72.5%) was obtained on NRC-12 followed by JS-335 (71.3%), PK-472 (70.3%), MACS-450 (69.7%) and PUSA-16 (66.4%). However, they were all statistically on par. A significant difference was observed in the parasitism, recorded on local variety (54.7%). Per cent adult emergence from the parasitised eggs from different treatments ranged from 82.2 to 88%, which were all statistically on par (Table 16).

Table 16. Influence of soybean varieties on parasitising efficiency of *Telenomus remus*

Soybean variety	Mean per cent parasitism	Mean per cent adult emergence
PK-472	70.3 (57.16)b	84.6 (67.58)
NRC-12	72.5 (58.52)b	82.8 (66.78)
JS-335	71.3 (58.16)b	87.8 (70.12)
PUSA-16	66.4 (54.71)b	88.0 (70.67)
MACS-450	69.7 (57.17)b	83.5 (66.55)
LOCAL	54.7 (47.81)b	82.2 (65.67)
CD (P=0.05)	6.34	NS

Figures in parentheses are angular transformed values.
Values followed by the same letter are not statistically different.

4.6.7. Tritrophic interactions between *Trichogramma chilonis*, *Helicoverpa armigera* and cotton genotypes

The genotypes utilized for testing were: Hybrid-6, Gujarat Hybrid 8, Gujarat Cotton 10, Abadhita, Sahana, CPD-423, CPD-428, CPD-431, CPD447, DHH-11, DHB-105, DHB-290, DHB-410, DHB-435, DHB-542 and DHH-543. The genotype DHH-543 could not be evaluated because it failed to germinate after repeated sowing. The fifteen genotypes were evaluated under multiple-choice condition in a polyhouse. Each genotype was replicated thrice, with two plants per replication. Ten eggs (one-day-old) of *H. armigera* were placed on each plant individually at flowering stage. Next day, one-day-old *Trichogramma chilonis* females were released from a central point to give equal access to the eggs placed on different genotypes for parasitisation. After 72 h, cotton leaves with eggs were removed to the laboratory for recording per cent parasitisation. The pooled data of three experiments on mean per cent parasitisation of *H. armigera* eggs by *T. chilonis* are presented in Table 17. Mean per cent parasitisation of *H. armigera* eggs on different genotypes varied from 13.33 to 42.22. Highest parasitisation was recorded on genotype CPD-447 (42.22%) and DHB-435 (42.22%), closely followed by CPD-431 (39.99%) and DHH-11 (39.99). In the second category, fall genotypes DHB-290, DHB-105, CPD-423 and CPD-428 on which 35.54, 33.33, 31.11 and 31.10 per cent egg parasitization was recorded. Lowest parasitization was observed on Hybrid-6 (13.33%) followed by Gujarat Hybrid-8 (19.99%).

4.6.8. Olfactometer response of *Trichogramma chilonis* to synomones released by leaves of different cotton genotypes cotton

Fifteen cotton genotypes, *viz.*, Hybrid-6, Gujarat Hybrid-8, Gujarat cotton-10, Abadhita, Sahana, CPD-423, CPD-428, CPD-431, CPD-447, DHH-11, DHB-105, DHB-290, DHB-410, DHB-435 and DHH542 were evaluated for their attraction to *Trichogramma chilonis* in Y- tube olfactometer. Cotton leaf discs on wet cotton were placed in one arm as cue while in second arm only wet cotton was placed as control. Ten *T. chilonis* adults were released at the base of the olfactometer and observations were recorded on their orientation towards cotton leaf.

The response varied from 6.66 to 63.33 per cent. Highest population was attracted to the leaves of genotype DHB-105 (63.33) followed by DHB-290 (60.00), CPD-447 (53.33), CPD-423 (53.33) and CPD-428 (50.00). Lowest response was observed to Hybrid-6 (Table 17).

Table 17. Mean parasitization of *H. armigera* eggs by *T. chilonis* and olfactometer response to synomones in different genotypes

Genotype	Mean per cent egg parasitization	Mean per cent response to volatiles of leaves
Hybird 6	13.33	6.66
G. Hybird 8	19.99	23.33
G. Cotton 10	28.87	23.33
Abadhita	22.22	20.00
CPD 423	31.11	53.33
CPD 431	39.99	23.33
CPD 447	42.22	53.33
DHH 11	39.99	40.00
DHB 105	33.33	63.33
DHB 290	35.54	60.00
DHB 410	-	26.66
DHB 435	42.22	26.66
DHB 452	19.99	43.33

4.6.9. Mean EAG response of *H. armigera* to the synomones released by leaves of *Solanum-viarum* and *Tagetes* sp.

Electrophysiological response of adult females of *H. armigera* to green volatiles (synomones) released by leaves and flowers of *Solanum viarum* and *Tagetes* sp. was studied through EAG. The mean response of *H. armigera* to leaves of *Tageies* sp. (-0.393 mv) was higher than that to leaves of *S. viarum* (-0.302). Similarly in case of flowers, greater response was noticed to cues of *Tagetes* sp. (-0.267mv) than cues of *S. viarum* (-0.141mv). However, the responses of both the cues are much higher to air (-0.009mv). This clearly indicated the preference of *Tagetes* sp. to *S. viarum* by *H. armigera*.

4.6.10. Olfactometer (Y-tube) response of *T. chilonis* to leaves and flowers of *Tagetes* sp. and *Solanum viarum*

Solanum viarum and *Tagetes* sp. plants were grown in pots in polyhouse. The plants were maintained free from insect pests and diseases. Leaves of *S. viarum* and *Tagetes* sp. were taken in glass beakers covered with petri-dishes to laboratory and small discs were cut to use in Y-tube olfactometer for response studies. Leaf discs were placed on wet cotton in one arm while in the other wet cotton alone was used as control. Ten adults of *T. chilonis* were released at the base arm of olfactometer and observations were recorded on per cent population attracted to different cues. *T. chilonis* responded to both *S. viarum* and *Tagetes* sp. (Table 18). Overall response to *Tagetes* sp. was slightly higher than to *S. viarum*. *S. viarum* leaves were more attractive than flower. However, in *Tagetes* sp. equal response was noticed to leaves and flowers.

Table 18. Mean response of *T. chilonis* to *S. viarum* and *Tagetus* sp. leaves and flowers

Source of cues	Mean per cent response
Solanum viarum leaves	36.66
S. viarum flowers	30.00
Tagetes sp. leaves	40.00
Tagetes sp. flowers	40.00

4.6.11. Relative olfactometer response of *T. chilonis* to different plant volatiles under multiple choice situation

Seven chemical volatiles (saturated hydrocarbons) of plant origin, *viz*., dodecane, tricosane, pentacosane, hexacosane, heneicosane, docosane and cyclohexane, were evaluated in 8-arm glass olfactometer under multiple choice condition to find out the best synomone and its perception threshold for *T. chilonis*. All these compounds at 0.05% concentration were placed at the end of each arm and 80 *T. chilonis* adults were released at the central chamber. Observations were recorded at 5 minutes interval on the number of *T. chilonis* adults reaching the cues placed in different arms for 30 minutes. Highest number of *T. chilonis* was attracted to pentacosane (8.00) followed by hexacosane (7.2) and tricosane (7.0). Least response was to cyclohexane (4.6), which was less than even control (5.8) (Table 19).

Table 19. Response of *T. chilonis* to different synomones under multiple choice condition

Synomone	Mean response
Dodecane	6.4
Tricosane	7.0
Pentacosane	8.0
Hexacosane	6.2
Docosane	6.6
Cyclohexane	4.6
Control	5.8

4.6.12 Trapping and identification of green volatiles (synomones) released by leaves of *Tagetes* sp. and *Solanum viarum*

Green volatiles released by leaves of *Solanum viarum* and *Tagetus* sp. were trapped in a specially designed trap by passing pure air over the leaves. The volatiles absorbed in activated charcoal were extracted by using hexane as solvent and then concentrated in a refrigerated vacuum concentrator. The pure concentrated fractions were injected into a GCMS system to identify the same.

The volatiles trapped from *S. viarum* represented eighteen compounds. These are: Alpha-pinene, 4-Allyl amisole, 1,2-benzenedicarboxylic acid, Camphene, Cis-alpha-bisabolene, Decane, Diethyl phtalate, Dodecane. Eicosane, Heptadecane, Hexadecane, Limonene, Nonadecane, Nonane, Octodecane, Pentadecane, Tetradecane and Tridecane.

In case of *Tagetes* sp., sixteen compounds were identified, most of them common to *S. viarum* also. Alpha-pinene, 4-Allyl- amisole, Camphene and Limonene, which were identified from *S. viarum* were not present in *Tagetes* sp. Similarly, Methyle chavicol and Phenol 1,2-bis were found only in the volatiles of *Tagetes* sp.

4.6.13. Trapping and identification of green volatiles (synomones) released by different cotton genotypes

Synomones released by leaves of fifteen cotton genotypes, *viz.*, Hybrid-6, G-Hybrid-8, G-Cotton- 10, Abadhita, Sahana, CPD-423, CPD-428, CPD-447, DHH-11, DHB-105, DHB-290, DHB-410, DHB-435 and DHH-542 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 30 compounds identified from leaves, heptadecane (15), tetradecane (15), pentadecane (14), phenol (13), hexadecane (12), nonadecane (12), eicosane (11) and tridecane were present in most of the genotypes. Two compounds, *viz.*, Germacrene and Trans-caryophyllene were present only in the genotype-DHH-11. Similarly, Alpha-Bergamotene, Ethnone, Heneicosane and Hexadecanoic acid were identified from CPD-431, G-Hybrid-8, CPD-428 and DHB-435, respectively. Alpha-Pinene and Camphene were isolated from G-Cotton-10 and and DHH-11 while Docosane was trapped from DHH-11 and CPD-423.

4.7. Artificial diets for host insects

4.7.1. Development of artificial diet for *Spodoptera litura* using cost effective materials

S. litura was reared on three experimental diets based on leaf powders of cabbage, castor and cauliflower and compared with control diet (without any leaf powder) and also with the modified diets i.e. all the above diets are enriched with casein, cystine, cholesterol and Wesson's salt mixture. Major growth attributing parameters were recorded (Table 20).

Table 20. Evaluation of modified leaf powder based semi-synthetic diet for *S. litura*

Parameter	Control	Control + X	A	A+X	B	B+X	C	C+X	D	D+X
Survival	100.0	87.0	91.0	93.0	100.0	96.0	92.0	100.0	96.0	84.0
Adult emergence(%)	80.0	46.0	64.0	68.0	64.0	63.0	53.0	75.0	69.0	65.0
Female emergence(%)	60.0	59.0	44.0	68.0	64.0	43.0	52.0	59.0	72.0	43.0
Fertile eggs (number)	116.7	290	926	1699	1045	1075	1013	2033	509	481
Longevity	13.0	11.0	13.0	13.0	11.0	12.0	13.0	12.0	13.0	13.0

A : Kabuligram + Groundnut oil cake based diet; B : Cabbage leaf powder based diet; C : Cauliflower leaf powder based diet; D : Castor leaf powder based diet;

X : Mixture of casein, cysteine, cholesterol, Wesson's salt mixture

Among the diets tested, kabuligram + groundnut oil cake + mixture of casein, cysteine, cholestrol and Wesson's salt mixture (X) and modified cabbage based diet were found to be comparable with the control with reference to increased adult emergence, per cent female emergence, and number of fertile eggs.

4.7.2. Development of artificial diet for *Plutella xylostella*

Semisynthetic diets based on blackchanna, kabuligram, defatted soybean and wheat germ were tried for *P. xylostella*. The per cent survival and adult emergence were 25 % and 10 % and attempts are on to improve the diet.

4.8. Studies on artificial diets for natural enemies

4.8.1. Artificial diet for rearing chrysopids

4.8.1.1. *Chrysoperla carnea*

A new beef liver-based artificial diet was developed for the rearing of *Chrysoperla carnea*. Two days-old larvae were taken for the experiment. The larvae were kept in plastic containers (6x5 cm) having copper mesh in three sides and the containers were changed once in 4 days. *C. carnea* adults reared on artificial diet (AD) and natural diet (ND) were provided with 30 per cent honey solution (in water), 50 per cent protinex (in water) and castor pollen grains. All the growth attributing characters were recorded for both AD and ND reared *C. carnea*.

The per cent survival, adult emergence and fecundity of the artificial diet reared *C. carnea* were 89%, 88% and 650 eggs, comparable to those of host insect reared (*Corcyra* reared) i.e. 90%, 89% and 670 eggs, respectively (Table 21). *Chrysoperla carnea* was further reared on the above diet for two generations with mean survival and adult emergence of 89.5% and 88.5%, respectively. The above diet was also tested for newly hatched *C. carnea* larvae and the survival and emergence was found to be 85%.

Table 21. Comparative biology of artificial diet and host insect (*Corcyra*) reared *C. carnea*

Growth parameter	F0 generation		F1 generation		F2 generation	
Survival (%)	AD	HI	AD	HI	AD	HI
Adult emergence (%)	89.0	90.0	89.0	90.0	90.0	90.0
Fecundity (numbers/Female)	650.0	670.0	*	*	*	*
Longevity (Days)	52.0	58.0	*	*	*	*

AD-Artificial Diet; HI- Host Insect; *Experiment continuing

4.8.1.2. *Mallada boninensis*

Beef liver based diet was also tested for rearing *M. boninensis* and the survival, adult emergence, fecundity and adult longevity were 70.0 %, 47.0 %, 48.0 eggs and 48.0 days, respectively. The same parameters when reared on host insect were 81.0 %, 70.0 %, 119.0 eggs and 62.0 days, respectively.

4.8.1.3. Characterization of artificial diet and host insect reared *Chrysoperla carnea* through electrophoresis techniques

Variation in protein bands between artificial diet and host insect (*Corcyra cephalonica*) reared *Chrysoperla carnea* was studied through SDS-PAGE. There were clear protein banding patterns and changes in proteins of *C. carnea* reared on artificial diet and host insect. New protein bands that were appearing in artificial diet reared predator were compared to host insect reared predator. The molecular weight of the proteins present in both artificial diet and host insect reared predator ranged between 3000 and 43,000 KDa.

4.8.2. Artificial diet for rearing coccinellids

4.8.2.1. *Cheilomenes sexmaculata*

Larvae of *Cheilomenes sexmaculata* were reared on artificial diet and the survival and adult emergence were 64% and 63%, respectively, and the same on *Aphis craccivora* were 68% and 64%, respectively. The newly emerged adults were divided into three batches for fecundity studies. Artificial diet reared adults did not lay eggs, but survived for 54 days. However the adults laid eggs when the predators were provided aphids weekly in addition to the artificial diet. The diet was also tested for the newly hatched larva and the survival and adult emergence were 49% and 23%, respectively.

4.8.2.2. *Coccinella septempunctata*

Coccinella septempunctata was reared on artificial diet and compared with the aphid reared predators. Survival and adult emergence of the diet-reared predator were 59% and 53%, respectively. The aphid reared predator had 71% survival and 67% adult emergence. Diet reared adults did not lay eggs, but laid eggs as and when aphids were provided (11 eggs/female). Longevity of the diet-reared predator was 48.0 days. Fecundity and longevity of the aphid reared *C. septempunctata* were 236 eggs and 65 days, respectively.

4.8.2.3. *Cryptolaemus montrouzieri*

Two-three days old *C. montrouzieri* larvae were reared on artificial diet and compared with host insect reared predators. The larvae were reared individually in round plastic box fitted with copper wire mesh in three sides. Survival and adult emergence of the diet reared and host insect reared *C. montrouzieri* were 62 % and 58% (diet reared); 82 and 80 (host insect reared), respectively. Mating adults were removed and kept in plastic container for fecundity and longevity studies which are under progress.

4.8.2.4. *Chilocorus nigrita*

Larvae of *Chilocorus nigrita* were reared on the artificial diet and the survival and adult emergence were 55% and 50%, respectively.

4.8.3. Artificial diet for rearing anthocorid bugs

Two-days-old nymphs *Cardiastethus exiguus*, an important predator of *Opisina arenosella* were reared on artificial diet and the adult formation and longevity were 52% and 45 days, respectively. The same on host insect was 77% and 52 days, respectively.

4.8.4. Studies on the biochemical profile of prey insects and artificial diets

Biochemical analysis of protein, carbohydrate and lipids present in artificial diets of chrysopids and coccinellids were estimated and compared with that of its prey insects *viz., Corcyra cephalonica* eggs and *Aphis craccivora*.

Maximum protein was present in artificial diets of coccinellids (15.3%) and *C. carnea* (15.2%) followed by *Corcyra* (7.7%) and aphid (6.7%). Artificial diet of coccinellid has maximum carbohydrate (30.3%) followed by *C. carnea* diet, aphid (8.9%) and *Corcyra* (3.0%). Maximum lipid was present in diet of *C. carnea* (65.7%), followed by coccinellid diet (60.8%), aphid (26.8%) and *Corcyra* (17.2%). The study revealed that lipid was the major biochemical present in artificial diet and prey insects followed by carbohydrate and protein.

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 during the year by exposing host eggs to *T. chilonis* at a temperature of 36°C in BOD incubator with humidity ranging from 55 - 65%. During this year parasitoids were reared at 36 and 36±1.5°C and RH 55 - 65%. In each generation about 2000 eggs were exposed to female parasitoids. The exposure was done for 24 h and observation was recorded on per cent parasitism and longevity of parasitoids. The humidity was maintained by keeping exposure vial inside plastic container with moist sponge. Water was provided everyday and humidity was measured at regular interval.

Results showed that after 48 generations of constant rearing, parasitoids now show adaptability to 36°C with about 92% parasitism and survival of about 4 days in comparison to less than 8% parasitism and 1 day survival by other susceptible strains (Table 22). The parasitoids when shifted to 36 ± 1.5°C, recorded a parasitism of 59% and survival of 2 days after rearing for 15 generations at this temperature.

Table 22. Development of high temperature tolerant strain of *T. chilonis*

Temperature (°C)	Generation	Per cent parasitism	Adult longevity (days)
36	01	78	5
	10	73	5
	20	70	3
	30	70	4
	40	87	5
	48	92	4
36 ± 1.5	01	44	1
	10	44	1
	15	59	2

4.9.2. Selection of *Trichogramma chilonis* for tolerance to multiple insecticides

This study was started in 1997-98. During the year the work was continued with endosulfan, monocrotophos and fenvalerate in the laboratory. The modified glass tubes with both ends open (measuring 20x 5 cm) were sprayed with insecticide solution. After drying, about 1000 adults were released in each tube obtained from all three insecticides. An egg card each containing about 8000 *Corcyra* eggs (0.5 cc) were introduced in each tube to obtain further generations. Endosulfan exposure was done @ 2.50 ml /l for 26 generations, monocrotophos @ 1.50 ml. / l for 24 generations and fenvalerate @ 0.075 for 22 generations.

Experiment was started with 'Endogram' strain to develop multiple insecticide tolerant strain of *Trichogramma chilonis*. This strain has now become tolerant to 2.50 ml / lit of endosulfan, 1.5 ml / lit of monocrotophos and 0.075 ml / lit of fenvalerate. The parasitism on fenvalerate was about 60 per cent and survival less than 10 per cent after 2 h of constant exposure (Table 23). The experiment is to be continued till parasitism of > 90 per cent is obtained in fenvalerate treatment also.

Table 23. Exposure of *Trichogramma chilonis* adults to insecticides

Insecticide	Dose (ml/1)	Number of	Per cent	Adult survival
Endosulfan	2.50	26	90	30
Monocrotophos	1.50	24	90	15
Fenvalerate	0.075	22	60	10

4.9.3. Net house studies with insecticide tolerant strains of *Trichogramma chilonis* in comparison with susceptible strain to commonly used insecticides against *Helicoverpa armigera*

The experiment was initiated by raising cotton plants in 12" earthen pots. When plants were in flowering stage, plants were sprayed with following insecticides - endosulfan, monocrotophos, fenvalerate, cypermethrin, dimethoate and acephate at field recommended dosages. The parasitoids used were endosulfan, monocrotophos and fenvalerate tolerant strains in comparison to susceptible strain. Parasitoids were released on treated surface immediately after spray and thereafter 1, 3, 5 and 7 days after spray. The clear plastic container measuring 6 x 5 cm was used to encircle the leaf. In each container 5 pairs of parasitoids were released. The mortality was recorded 2 and 6 h after release on treated surface. Egg cards containing about 100 eggs were also placed in the container to record parasitism. After 24 h egg cards were collected back and were observed for parasitism. Each treatment (day-wise) was replicated three times.

The result presented in Table 24 on mortality pattern after 2 h of constant exposure indicated that even on 0-day old residue mortality in endosulfan tolerant strain ranged from 45.6 to 90.6 per cent, in monocrotophos tolerant strain from 60% to 93.6 per cent and in fenvalerate tolerant strain from 76.6 to 100% in six different insecticides used for the study. In susceptible strain 100% mortality was observed within 10 minutes of exposure compared to mortality recorded about one hour after exposure to tolerant strains. The mortality recorded 6 h after exposure was also significantly less in tolerant strains compared to susceptible strain. In all tolerant strains, mortality recorded in various insecticides ranged from 28.7 to 81.5 per cent compared to 73% to 100% in susceptible strain. Results indicated that tolerant strain showed ability to survive even on freshly sprayed cotton plants.

Table 24. Net house evaluation of tolerant and susceptible strains of *T. chilonis*

Strain	Insecticide	Percent mortality (after hours and days)									
		2 h					6 h				
		0 d	1 d	3 d	5 d	7 d	0 d	1 d	3 d	5 d	7 d
Endosulfan resistant	Endosulfan	60.0	62.0	78.3	59.3	48.3	93.0	86.0	65.0	41.0	23.6
	Monocrotophos	86.6	90.3	83.3	69.3	43.6	96.6	100.0	96.6	69.3	45.3
	Fenvalerate	90.6	92.3	95.6	81.6	52.3	90.0	60.0	63.3	58.6	29.6
	Cypermethrin	73.3	38.6	43.3	51.7	48.5	56.6	86.6	93.3	68.4	49.5
	Dimethoate	45.6	74.6	79.3	67.2	39.5	100.0	100.0	100.0	79.6	53.4
	Acephate	80.3	81.6	75.6	53.4	31.5	91.6	93.0	90.0	68.4	34.5
Monocrotophos resistant	Endosulfan	92.6	89.3	85.6	77.6	35.4	100.0	100.0	100.0	81.5	39.7
	Monocrotophos	82.6	68.0	59.0	41.7	28.7	92.6	78.0	65.0	48.5	31.6
	Fenvalerate	86.0	75.6	79.0	61.6	39.7	96.6	86.6	90.0	55.9	23.4
	Dimethoate	60.0	83.6	79.6	48.5	18.4	70.0	96.6	83.3	56.8	27.6
	Acephate	93.6	89.3	88.6	52.7	21.5	93.6	100.0	100.0	61.8	31.7
Fenvalerate resistant	Endosulfan	100.0	100.0	33.3	21.6	9.3	100.0	100.0	33.3	28.7	18.3
	Monocrotophos	96.6	100.0	90.0	51.4	19.7	96.6	100.0	90.0	69.6	39.4
	Fenvalerate	89.3	78.6	65.3	35.3	16.6	89.3	78.6	65.3	46.7	26.8
	Cypermethrin	76.6	100.0	56.6	23.4	8.9	76.6	100.0	56.6	38.9	18.4
	Dimethoate	100.0	100.0	93.3	63.4	39.8	100.0	100.0	93.3	75.1	51.2
	Acephate	96.6	93.0	90.0	51.5	29.3	96.6	93.0	90.0	66.7	39.4
Susceptible	Endosulfan	100.0	100.0	79.0	65.5	39.8	100.0	100.0	100.0	90.0	80.3
	Monocrotophos	100.0	100.0	100.0	70.6	63.6	100.0	100.0	100.0	89.3	73.3
	Fenvalerate	100.0	100.0	100.0	78.3	100.0	100.0	100.0	100.0	100.0	85.4
	Cypermethrin	100.0	90.0	83.3	69.3	100.0	100.0	100.0	100.0	90.0	76.6
	Dimethoate	100.0	100.0	100.0	93.3	51.3	100.0	100.0	100.0	100.0	63.3
	Acephate	98.0	91.0	53.4	23.6	100.0	100.0	100.0	100.0	73.4	49.6

The data on parasitising ability of tolerant strains in comparison to susceptible strain is presented in Table 25. The results indicated that all tolerant strains could parasitise eggs on just sprayed cotton plants to the tune of 11.6 to 56.6, 7.3 to 75.0 and 18.0 to 56.6 per cent by endosulfan, monocrotophos and fenvalerate tolerant strains, respectively, whereas susceptible could not parasitise any egg on freshly sprayed plants. Susceptible strain could parasitise to the tune of 0.0-5.0, 0.0-15.0 per cent eggs after 1 and 3 days of spraying compared to 5.0 - 79.0 by tolerant strains. After 5 and 7 days of spraying, tolerant strain parasitised significantly more eggs than susceptible strains. It was also observed that fenvalerate tolerant strain could parasitise significantly more eggs when another pyrethroid was sprayed compared to other insecticides used in the experiment.

Table 25. Net house evaluation of tolerant and susceptible strains of *T. chilonis*

Strain	Insecticide	Per cent parasitism (after days)				
		0	1	3	5	7
Endosulfan resistant	Endosulfan	43.0	58.0	79.0	51.6	91.0
	Monocrotophos	16.6	33.3	41.6	51.6	71.6
	Fenvalerate	40.0	26.6	56.6	60.0	78.3
	Cypermethrin	13.3	21.6	30.0	55.0	68.3
	Dimethoate	11.6	15.0	16.9	51.6	60.0
	Acephate	56.6	18.3	16.6	68.3	60.0
Monocrotophos resistant	Endosulfan	7.3	5.0	35.0	50.0	56.0
	Monocrotophos	75.0	79.0	83.0	90.0	96.0
	Fenvalerate	63.3	15.0	33.3	40.0	54.6
	Cypermethrin	48.3	43.3	32.0	63.3	66.6
	Dimethoate	56.6	36.6	53.3	53.3	73.3
	Acephate	35.0	10.0	11.6	30.6	50.0
Fenvalerate resistant	Endosulfan	18.0	50.0	30.0	41.6	45.3
	Monocrotophos	25.0	11.6	50.0	53.3	52.6
	Fenvalerate	28.3	21.6	43.3	58.3	66.7
	Cypermethrin	53.3	36.6	31.6	40.0	48.3
	Dimethoate	30.0	13.3	40.0	50.0	43.3
	Acephate	56.6	15.0	13.3	51.6	50.0
Susceptible	Endosulfan	0.0	0.0	10.0	6.0	23.0
	Monocrotophos	0.0	0.0	0.0	20.0	43.0
	Fenvalerate	0.0	5.0	0.0	26.6	30.0
	Cypermethrin	0.0	0.0	10.0	13.3	20.0
	Dimethoate	0.0	2.0	15.0	13.3	30.0
	Acephate	0.0	2.0	5.0	18.3	36.0

4.9.4. Identification of insecticide tolerant strains of *Trichogramma chilonis* through electrophoresis techniques

Difference in protein bands between pesticide tolerant strains of *Trichogramma chilonis* and susceptible parasitoid was studied through SDS-PAGE.

There were clear protein banding patterns in the pesticide tolerant strains and susceptible *T. chilonis* revealing that there were changes in proteins of pesticide tolerant strains and susceptible *T. chilonis*. Three new protein bands appeared in pesticide tolerant *T. chilonis* compared to susceptible strain. The molecular weight of the proteins present in pesticide tolerant strains of *T. chilonis* and susceptible species ranged between 3000 to 43,000 KDa.

4.9.5. Studies on the development of some species of trichogrammatids in the field and laboratory

The experiment was carried out with five different trichogrammatids, *viz. Trichogrammatoidea armigera*, *Trichogramma brasiliense*, *T. chilonis*, *T. evanescens* and *T. pretiosum*. Small bit of parasitised card was cut and kept in glass vial (measuring 15 x 2.5 cm). On emergence, 50 pairs were taken for the experiment for each species. Each species was provided with about 1000 eggs in each generation.

The mortality data and parasitism were recorded in each generation and mean for the month was worked out. For field developmental studies, glass tubes were kept in plastic tray in net house

Table 26. Developmental period of various trichogrammatids in net house and laboratory

Month	Development period (in days) in net house					Development period (in days) in laboratory				
	1	2	3	4	5	1	2	3	4	5
January	15.1	13.2	13.5	13.8	14.1	10.3	9.2	9.3	9.4	9.5
February	9.8	7.9	7.9	7.9	8.0	9.2	8.6	8.8	8.7	8.4
March	8.7	7.8	7.8	8.0	8.0	9.4	8.6	8.8	8.7	8.4
April	8.9	7.9	7.9	8.1	8.1	9.5	8.6	8.8	8.7	8.4
May	9.3	8.0	8.0	8.1	8.0	9.5	8.6	8.8	8.7	8.4
June	9.7	8.6	8.4	8.3	8.4	9.6	8.6	8.8	8.7	8.4
July	10.1	8.9	8.8	8.5	8.8	9.8	8.6	8.8	8.7	8.4
August	10.8	9.7	9.3	8.7	9.1	9.8	8.6	8.8	8.7	8.4
September	11.2	9.8	9.6	9.1	9.4	9.8	8.6	8.8	8.7	8.4
October	12.0	10.3	10.4	10.1	10.3	10.1	9.3	9.1	9.2	9.4
November	13.4	12.8	12.9	12.6	12.8	10.9	9.3	9.1	9.2	9.4
December	15.6	13.7	13.8	13.9	14.0	11.6	9.3	9.1	9.2	9.4

1 = *Trichogrammatoidea armigera*, 2 = *Trichogramma brasiliense*, 3 = *T. chilonis*, 4 = *T. evanescens*, 5 = *T. pretiosum*

under semi-field conditions (temperature varied as per seasonal variation) and for laboratory studies at 27 ± 1.5°C. The data on mortality and parasitism is presented in Table 26 and 27, respectively.

Table 27. Per cent prasitism by various trichogrammatids in net house and laboratory

Month	Per cent parasitism in net house					Per cent parasitism in the laboratory				
	1	2	3	4	5	1	2	3	4	5
January	65.0	88.0	85.0	91.0	93.0	79.0	88.0	85.0	91.0	93.0
February	61.0	86.0	79.0	74.0	71.0	74.0	86.0	75.0	72.0	81.0
March	53.0	66.0	62.0	65.0	57.0	66.0	86.0	72.0	66.0	65.0
April	46.0	59.0	51.0	52.0	54.0	68.0	79.0	71.0	78.0	72.0
May	58.0	61.0	53.0	54:0	50.0	71.0	81.0	74.0	76.0	79.0
June	80.0	76.0	93.0	79.0	85.0	79.0	86.0	89.0	89.0	86.0
July	82.0	79.0	92.0	84.0	88.0	85.0	89.0	87.0	88.0	88.0
August	81.0	81.0	94.0	89.0	89.0	88.0	91.0	90.0	91.0	89.0
September	84.0	85.0	89.0	86.0	83.0	89.0	95.0	91.0	89.0	87.0
October	78.0	82.0	88.0	82.0	84.0	91.0	92.0	94.0	85.0	89.0
November	71.0	81.0	90.0	85.0	87.0	89.0	91.0	92.0	87.0	92.0
December	67.0	89.0	88.0	87.0	91.0	88.0	97.0	89.0	87.0	91.0

1 = *Trichogrammatoidea armigera*, 2 = *Trichogramma brasiliense*, 3 = *T. chilonis*, 4 = *T. evanescens*, 5 = *T. pretiosum*

The five different species, *viz.*, *Trichogrammatoidea armigera*, *Trichogramma brasiliense*, *T. chilonis*, *T. evanescens* and *T. pretiosum* were reared on eggs of *Helicoverpa armigera* under glasshouse and laboratory conditions. The developmental period was 7-9 days from February to May, 11-12 days from June to October ahd 13-15 days from November to January. *Trichogrammatoidea armigera* always took 2-4 days more to complete its development in corresponding periods in glasshouse. In the laboratory, however, all *Trichogramma* species completed its development in 8-10 days in different months.

In the net house, per cent parasitism was significantly lower during February -May (summer season) in all the species in comparison to June-January. *Trichogrammatoidea armigera* was most affected by change in temperature. In the laboratory, however, not much reduction was observed due to constant rearing temperature. The results showed that development and per cent parasitism was dependent directly on temperature. All the species were found more effective from June to January than in summer months.

4.10. Studies on insect pathogens

4.10.1. Isolation of viruses

Baculoviruses comprising nuclear polyhedrosis virus (NPV) and granulosis virus (GV) has been isolated from *Agrotis segetum* and pathogenicity proved. A cytoplasmic virus (CPV) has been isolated from *Earias vittella* for the first time.

Poxviruses from *Holotrichia consanguinea* and *Agrotis segetum* have been isolated and their pathogenicity proved. A suspected poxvirus from *Helicoverpa armigera* has been isolated and pathogenicity proved. A microsporidian has been isolated both from *Sesamia inferens* as well as from *H. consanguinea*.

4.10.1.1. Host-pathogen relationship

Polyhedral occlusion bodies (POBs) were extracted from dead larvae of *Agrotis segetum* and purified through differential centrifugation. The final concentration was determined as number of POBs per ml by using a Haemocytometer (Neubaur improved double ruling). From the stock suspension serial dilutions were made for the purpose of bioassay studies. Bioassay studies were conducted through artificial diet surface contamination technique. A single dose of NPV concentration (3.4×10^{7}/ml) was tested against first, second, third, fourth, fifth and sixth instar larvae of *A. segetum*. The diet surface was treated with 0.1 ml of the viral concentrations for only one time and larvae were allowed to feed continuously. Daily observation was made on the mortality of the insect.

The larvae infected with *As*NPV became light coloured with slightly pinkish dorsal surface with fragile cuticle, often discharging drop of grey fluid containing numerous POBs. Bio-assay study conducted with *A. segetum* NPV (*As*NPV), through artificial diet surface contamination technique, with a single dose of NPV @ 3.4×10^{7}/ml tested against I – VI instar larvae of *A. segetum* had revealed cent percent mortality in the case of first and second instar larvae within six days after treatment. More than 80 per cent mortality was achieved during the same period in the case of third and fourth instar larvae. Mortality ranged from 10 -20 percent in the case of fifth instar and there was no mortality in sixth instar larvae.

In order to find out the LD_{50}, four doses of *As*NPV concentrations viz. 3.4×10^{8}, 3.4×10^{7}, 3.4×10^{6}, 3.4×10^{5}/ml, along with control were tested against third instar. LD_{50} calculated by probit analysis with the dose-mortality data recorded on 7th and 10th day after treatment against third instar larvae were 1.06×10^{6} POBs/ml and 4.45×10^{5} POBs/ml, respectively. The respective slopes of dose mortality curve are +0.797 and -1.36 for 7th day and 10th day, with respective regression equations $y=0.62 + 0.797\ x$ and $y=11.98-1.36\ x$. The fiducial limit ranged from 3.83 to 5.6 and 4.71 to 5.38 for 7th day and 10th day, respectively.

The effect of *As*NPV on leaf area consumption (both virus treated and untreated larvae) was measured by using Skye (Registered trade mark of Skye Instruments U.K.) leaf area analyser. Both leaf area consumed and body weight gained were higher in untreated larvae. The leaf area consumed in the case of treated larvae was 52.63 percent lower than that of untreated larva. Similarly body weight of *As*NPV exposed larva was 46.56 per cent lower than that of untreated larva.

Dead larvae of *Helicoverpa armigera* were found to harbour entomopoxvirus during a survey. The virus from the cadavers was extracted, purified and examined under light, phase and electron microscope. This entomopoxvirus was characterised by the presence of numerous, refractile, oval shaped bodies called "spheroids" mostly containing virus. In addition to the ovoid shaped inclusions, fusiform cytoplasmic inclusion bodies ("Spindles") devoid of viruses were also present. The pathogenicity of the virus was tested in laboratory by artificial diet surface contamination technique using 10^6 EPV occlusion/ml on third, fourth and fifth instar larvae. The larvae infected with EPV generally become soft, whitish after infection and become lethargic and exhibit partial paralysis of the abdomen, and difficulty in moulting during the later stages of infection. Dead larvae usually remain soft but intact. Towards the end, the larvae are motionless except for slight movement of feet and mouthparts. In some larvae hindgut is extroverted showing prolapse of rectum. Mortality occurs 12 - 16 days after inoculation depending upon the stage of insect. Death is frequently preceded by regurgitation or defaecation of fluid containing inclusion bodies. Several pupae that originated from *Ha*EPV infected larvae were found to be incompletely pigmented in the first abdominal segment. No adult emerged from such pupae.

To study the site of infection the diseased larvae were processed and fixed and sections were made using standard microtome procedure. The sections were stained with Harris haematoxylin and counter stained with eosin. The virus showed a range of cell and tissue specificity. The fat bodies appeared to be the most severely affected. In addition to the fat bodies, light virus infection was also noticed in epidermis, haemocytes and gut epithelium. In the case of *Galleria mellonella* NPV the sites of infection were found to be fat bodies, haemocytes, epithelial tissus, trachea, malphigian tubules, etc.

4.10.1.2. Cross infectivity

Helicoverpa armigera entomopoxvirus (*Ha*EPV) was tested against second and third instar larvae of S. *litura* @ 2 x 10^6 *Ha*EPV occlusions/ml through diet surface contamination technique and was not found cross infective.

4.10.1.3. Safety tests

Baculovirus isolated from *A. segetum* and pox virus isolated from *H. armigera* when tested against mulberry silkworm, *Bombyx mori* (PM x NB_4 D_2) as well as *Chrysoperla carnea*, were found to be safe.

4.10.2. Biocontrol of insect pests by entomopathogenic fungi and development of mycoinsecticides

Moribund specimens of *Helicoverpa armigera* from tomato and bell pepper, *Plutella xylostella* from cabbage, *Chilo partellus* from maize and aphids from bhendi, mustard and pigeon pea were collected from farmers' fields in Chandapur village for isolation of fungi. Nine fungal species were isolated from these specimens. The fungi isolated from aphid, *Aphis gossypii* were identified tentatively as *Verticillium lecanii* and *Fusarium* sp. The fungus isolated from the maize stem borer was identified as *Fusarium sp.* (Table 28).

Table 28. Fungi isolated from different species of dead / moribund insects

Insect from which isolated	Crop	Location	Tentative Identification
Chilo partellus	Maize	NDRI, Adugodi	*Fusarium*
Chilo partellus	Maize	NDRI, Adugodi	*Fusarium*
Aphis craccivora	Bhendi	Chandapur	*V. lecanii*
Aphis craccivora	Bhendi	Chandapur	*Fusarium*
Plutella xylostella	Cabbage	Chandapur	Unidentified
Plutella xylostella	Cabbage	Chandapur	Unidentified
Aphis gossypii	Pigeon pea	Chanapur	Unidentified
Aphis gossypii	Pigeon pea	Chandapur	Unidentified
Lipaphis erysimi	Mustard	Chandapur	Unidentified

4.10.3. Preparation of a new water dispersible powder based formulation of *Bacillus thuringiensis* (IARI, New Delhi)

A water dispersible powder (WDP) formulation containing *Bacillus thuringiensis* var. *kurstaki* and adjuvants was prepared. This formulation contains 20 mg of *Btk* (active ingredient), 730 mg of Bentonite (Filler), 50 mg of gum acacia, 100 mg of charcoal (UV protectant) and 100 mg of Tween 80 (spreader). This product has been named as "Pusa *Bt*". It was prepared by mixing all dry ingredients thoroughly and Tween-80 added at the time of application.

4.10.4. Bioassay of "Pusa *Bt*" against *Spodoptera litura* and comparison with a commercial formulation (HIL *Btk*) (IARI, New Delhi)

In bioassay studies, one per cent concentration of "Pusa *Bt*" as well as HIL *Btk* in aqueous solution was administered to the test insects by spot feeding method. Culture of test insect, *Spodoptera litura* was iniatially obtained from IARI fields and then sufficient number insects were reared on castor leaves at 70% R.H. and 25±2°C temperature. Last instar larvae were used in the experiment. Tender castor leaves were dipped in aqueous suspension of "Pusa *Bt*" and "HIL *Btk*" preparations. Leaves were air dried for 15 minutes and then fed to 4 h pre-starved last instar larvae of *S.litura*. Each treatment was replicated thrice with 10 insects per replications. Leaves dipped in distilled water served as control. Data on mortality were colleted and analysed statistically. This product was bioassayed under laboratory conditions. Result revealed that there was 83 per cent mortality in "Pusa *Bt*" treatment and 73 per cent mortality in HIL *Btk* treatment. Statistically there was significant difference between both the treatments indicating that "Pusa *Bt*" was superior to HIL *Btk* treatment (Table 29).

Table 29. Comparison of 'Pusa Bt' and HIL Btk against *Spodoptera litura*

Treatment	Per cent mortality
Pusa *'Bt'*	83
HIL *Btk*	73
Control	16
CD (P=0.05)	0.287

4.11. Studies on fungal and bacterial antagonists

4.11.1. Biological control of root rot and wilt of chickpea under field conditions

A field trial was conducted during *Rabi* (post-rainy) season of 1999 and 2000 in University of Agricultural Sciences experimental fields to evaluate *Trichoderma harzianum* (PDBCTH 10) and *T. viride* (PDBCTV 23) against *Rhizoctonia solani* and *Fusarium oxysporum* f. sp. *ciceri*, the incitants of root rot and wilt, respectively, in chickpea. The bioagents were added to soil @ 5 g of powder formulation of bioagents mixed in one kilogram of farmyard manure per plot (2 x 1.5 m) one week prior to sowing. Bioagent seed treatment was carried out @ 10g/kg seed (cv Annegiri). Observations on wilt and root rot incidence were recorded at 30, 60 and 90 days after sowing. In another treatment seeds treated with fungicide carbendazim at 2g/kg were sown. Seeds sown in FYM applied plots without bioagent served as control. The experiment was laid in a randomized block design with three replications. The effect seen on different parameters are summarised.

Rhizoctonia root rot and Fusarium wilt incidence

Soil application of *T. harzianum* one week before sowing resulted in significantly less root rot incidence (4.9 and 1.2%) compared to *T. harzinaum* and *T. viride* seed treatments and pathogen check at 30 and 60 days, respectively (Table 30). *T. viride* soil application also gave significantly less root rot incidence (6.7%) compared to pathogen check (16.4%) at 30 days. At 90 days the disease incidence was very low and there was no significant difference in disease incidence between treatments.

Least incidence of wilt was recorded at 60 and 90 days in plots where *T. harzianum* was used as soil and seed treatment followed by seed treatment with *T. viride* (Table 30). *T. harzianum* soil application has resulted in low wilt incidence at 60 and 90 days (4 and 5.1%) compared to pathogen check (11.8 and 16%). All bioagent treatments and carbendazim treatments recorded significantly less disease incidence compared to pathogen check.

Table 30. Effect of antagonists on Rhizoctonia root rot incidence in chickpea

Treatment	Root rot incidence (%) at days *			Wilt incidence (%) at days *	
	30	60	90	60	90
T. harzianum (PDBCTH 10) seed treatment	8.9 (17.3)	6.3 (14.4)	1.3 (6.5)	6.6 (14.8)	8.1 (16.5)
T. viride (PDBCTV 23) seed treatment	9.2 (17.6)	6.5 (14.7)	1.4 (6.7)	7.1 (15.4)	8.3 (16.7)
T. harzianum (PDBCTH 10) soil application	4.9 (12.7)	1.2 (5.0)	0.0 (0.0)	4.0 (11.5)	5.1 (12.9)
T. viride (PDBCTV 23) soil application	6.7 (14.9)	2.5 (9.2)	0.7 (3.8)	7.3 (15.6)	8.4 (16.7)
Carbendazim seed treatment	7.6 (15.9)	11.8 (19.9)	2.0 (8.2)	7.9 (16.4)	12.9 (21.0)
Pathogen check	16.4 (23.8)	17.0 (24.3)	2.6 (9.3)	11.8 (20.1)	16.0 (23.5)
CD (P=0.05)	(2.8)	(4.5)	(3.2)	(2.3)	(2.1)

* Figures in parentheses are angular transformed values

Soil application of *T. harzianum* (PDBCTH 10) resulted in better seedling emergence (91.1%) and high vigor index (3395.9), followed by soil application of *T. viride* (PDBCTV 23) and fungicide treatment (Table 31). The seedling emergence and vigor index were significantly high in all treatments compared to pathogen check.

Yield

Soil application of *T. harzianum* and *T. viride* resulted in higher yields (965.4 and 913.1 kg/ha) over the pathogen check (430.3 kg/ha) (Table 31). The increased yield in bioagent treatments may be due to high vigour index and less disease incidence.

Table 31. Effect of antagonists on seedling emergence, vigour and yield of chickpea

Treatment	Seedling emergence (%)*	Shoot length (cm)	Root length (cm)	Vigour Index	Yield (kg/ha)
T. harzianum (PDBCTH 10) seed treatment	83.6 (66.1)	19.4	11.5	2558.5	837.9
T. viride (PDBCTV 23) seed treatment	80.8 (64.0)	20.2	11.2	2540.8	733.9
T. harzianum (PDBCTH 10) soil application	91.9 (72.8)	24.1	13.2	3395.9	965.4
T. viride (PDBCTV 23) soil application	87.2 (69.3)	22.1	13.5	3125.6	913.1
Carbendazim seed treatment	88.1 (69.9)	17.4	11.4	2541.5	605.5
Pathogen check	70.5 (57.3)	16.6	7.6	1706.9	430.3
CD (P=0.05)	(4.8)	3.6	2.5	399.3	76.6

* Figures in parentheses are angular transformed values

The results indicate the positive effect of the two bioagents on plant health. Soil application of *T. harzianum* and *T. viride* prior to sowing was more effective in controlling wilt and root rot of chickpea under field conditions.

4.11.2. Biological control of fusarial wilt of redgram under field conditions

A field experiment was conducted during 2000 in *F. udum* sick plots located at University of Agricultural Sciences, Bangalore. The powder formulation of two *T. harzianum* isolates was applied as seed coat (10g/kg seed) or soil amendment by mixing the bioagent powder with farmyard manure (FYM) at 10g in a kg of farm yard manure (FYM) and one kg of that mixture was applied along seed rows in each plot. Each treatment was replicated four times in a randomized block design (RBD) with a plot size of 5.4 x 4 m and 90 x 30 cm spacing. In one treatment fungicide (carbendazim) was applied at 2.0g/kg. Plots applied with FYM alone served as control. A local susceptible pigeonpea cultivar was selected for the trial. The effect evaluated through different parameters are summarised here.

Fusarial wilt incidence

Seed treatment with *T. harzianum* isolates PDBCTH 10 and 15 resulted in a disease incidence of 35.3 and 40.3%, respectively (Table 32). Soil application of these two isolates a disease incidence of 22.5 and 28.8%, respectively, was recorded and was found to be superior to all other treatments. Disease incidence in *T. harzianum* (PDBCTH 10) soil treatment was significantly low compared to all other treatments. In fungicide treatment and pathogen check, 57.3 and 83% disease incidence was recorded.

Table 32. Effect of *T. harzianum* isolates on fusarial wilt incidence in the field

Treatments	Disease incidence (%)*
T. harzianum (PDBCTH 15) seed treatment	40.3 (39.4)
T. harzianum (PDBCTH 15) soil application	28.8 (32.4)
T. harzianum (PDBCTH 10) soil application	22.5 (28.3)
Fungicide seed treatment	57.3 (49.2)
Check (Pathogen + FYM)	57.3 (49.2)
CD (P=0.05)	(3.3)

* Figures in the parentheses are angular transformed values

Plant growth

Soil application of two *T. harzianum* (PDBCTH 10 and 15) isolates resulted in better seedling emergence (90.3 and 88%) and high vigor index (1191.5 and 1122.8) (Table 33). Seedling emergence was not significantly different in soil application treatments with two bioagents. Seed application of these two bioagents resulted in 83.8 and 80.8% seedling emergence, which was not significantly different. Fungicide treatment resulted in a seedling emergence of 83.5% and a vigor index of 936.9. In pathogen check 76% seedling emergence and vigor index of 825.8 was recorded. The seedling emergence and vigor index were significantly high in all treatments compared to pathogen check.

Table 33. Effect of *T. harzianum* isolates on pigeonpea plant growth

Treatment	Seedling emergence (%)*	Shoot length (cm)	Root length (cm)	Vigour Index	Yield (kg/ha)
T. harzianum (PDBCTH 15) seed treatment	80.8 (64.0)	7.1	4.2	910.3	712.5
T. viride (PDBCTV 10) seed treatment	83.8 (66.3)	7.0	4.6	968.9	752.0
T. harzianum (PDBCTH 15) soil application	88.3 (70.0)	7.8	4.9	1122.8	1120.5
T. harzianum (PDBCTV 10) soil application	90.3 (71.8)	8.1	5.1	1191.5	1219.5
Fungicide seed treatment	83.5 (66.1)	6.8	4.5	936.9	683.8
Check (Pathogen + FYM)	76.0 (60.8)	6.7	4.2	825.8	267.3
CD (P=0.05)	(3.85)	0.35	0.91	51.24	23.64

* Figures in parentheses are angular transformed values

Yield

A significant increase in yield was observed in all treatments compared to pathogen check. Soil application of two *T. harzianum* isolates (PDBCTH 15 and 10) resulted in higher yield (1120.5 and 1219.5 kg/ha) over the pathogen check (267.3kg/ha). The increased yield in bioagent treatments may be due to high vigour index and less disease incidence. This study indicates the positive effect of the two bioagents on plant health. Soil application of *T. harzianum* prior to sowing was found to be more effective than seed treatment.

Proliferation of bioagents in treated soil

Analysis of soil samples from field plots before initiation of experiment showed no detectable levels of native *Trichoderma*. The average bioagent population immediately after soil amendment with *T. harzianum* (PDBCTH 10) and *T. harzianum* (PDBCTH 15) varied between log 4.35 and 4.62. At 10 days, in treatments with soil amendment with *T. harzianum* (PDBCTH 10) and *T. harzianum* (PDBCTH 15) population level of log 5.16 and 5.03 was seen (Table 34). The bioagent population recorded on seeds immediately after seed treatment at 10g/kg seed varied between log 2.2 and 2.5 cfu/seed and rhizosphere population increased to log 2.85 and 3.0 cfu/gm of soil by 10 days. The bioagent population in rhizosphere reached maximum by 30 days in seed and soil treatments and thereafter the population started declining. The bioagent population was significantly different in both soil and seed treatments. The population levels recorded at 30 days with *T. harzianum* (PDBCTH 10) and *T. harzianum* (PDBCTH 15) soil and seed treatments were log 7.60, 7.18 and log 4.37 and 4.05, respectively. The population increase during 10 - 30 days was high in bioagent seed treatments and thereafter population started declining. In general, the bioagent population increased to its maximum by 30 days and declined thereafter.

Table 34. Proliferation of bioagents in treated soil

Treatment	Bioagents population (log cfu/g) at days			
	10	20	30	40
T. harzianum (PDBCTH 15) seed treatment	2.85	3.13	4.05	3.92
T. harzianum (PDBCTH 10) seed treatment	3.00	3.44	4.37	4.15
T. harzianum (PDBCTH 15) soil application	5.03	6.48	7.18	6.97
T. harzianum (PDBCTH 10) soil application	5.16	6.67	7.60	7.18
CD (P=0.05)	0.25	0.30	0.28	0.27

4.11.3. Studies on compatibility of *Trichoderma harzianum* with fungicides

Carbendazim, metalaxyl, chlorothalonil, iprodione, captan, mancozeb and blitox were tested for their compatibility to *Trichodema harzianum*. *T. harzianum* was not able to tolerate even 25ppm concentration of carbendazim. The bioagent was able to grow in media amended with metalaxyl, chlorothalonil and iprodione up to 1000ppm concentration and captan, mancozeb and blitox up to 2000ppm.

4.11.4. Bioefficacy of *T. harzianum* propagules

A pot culture experiment was conducted in a completely randomized block design under greenhouse conditions to test the bioefficacy of *Trichoderma harzianum* propagules. *Rhizoctonia solani* (not identified to anastomosis group) which incites root rot in chickpea was selected as test pathogen. The pathogen was grown on wheat bran for 15-days and used @ 3g/kg soil. The conidial and chlamydospore formulations were applied @ 10g/kg chickpea seed (cv. Annegiri). The treatment with fungicide (captan) was @ 2.5g/kg seed. Pathogen treatment served as check. Four replications were maintained for each treatment. Seedling emergence was recorded after 10 days of sowing. Incidence of root rot was recorded at 30 days after sowing. The per cent plants having root rot incidence was recorded.

Seedling emergence was 92.5% in conidial and chlamydospore treatments (Table 35). In pathogen control the seedling emergence was only 75%. The root rot incidence in conidial and chlamydospore treatments was 17.5 and 20%, respectively. Though chlamydospore treatment resulted in less root rot incidence, it was not significantly different from conidial treatment.

Table 35. Effect of *T. harzianum* propagules on root rot of chickpea incited by *Rhizoctonia solani*

Bioagent propagules	Seedling emergence (%)	Root rot incidence 9%)*
Conidia	92.5	17.5 (26.6)
Chlamydospores	92.5	20.0 (26.1)
Pathogen control	75.0	67.5 (59.0)
CD (P=0.05)	(N.S)	(12.7)

4.11.5. Shelf life of *T. harzianum* propagules

Formulations of bioagents were stored at room temperature (25°C ± 2°C) in polythene bags. One-gram samples were drawn at 30 days interval for 180 days and colony forming units (cfu) were estimated by dilution plate method using *Trichoderma* selective media. Three replications were maintained for each treatment (formulation).

The viable propagule counts of conidial and chlamydospore formulations taken at 0 day and at 30 days of storage at room temperature were not significantly different. The population levels in both formulations were above 10^8 cfu/g (Fig. 8). However, significant differences in the number of viable propagules between conidial and chlamydopsore formulations (log 7.65 for conidia and log 7.47 for chlamydospore) were observed at 60 days. The population levels in both formulations are significantly different during the storage period of 60 to 180 days. The number of viable propagules in chlamydospore formulation declined to less than 10^6 by 150 days (minimum recommended population for seed treatment is more than 10^6 cfu/g). The conidial formulation retained more than the recommended levels even 180 days after storage.

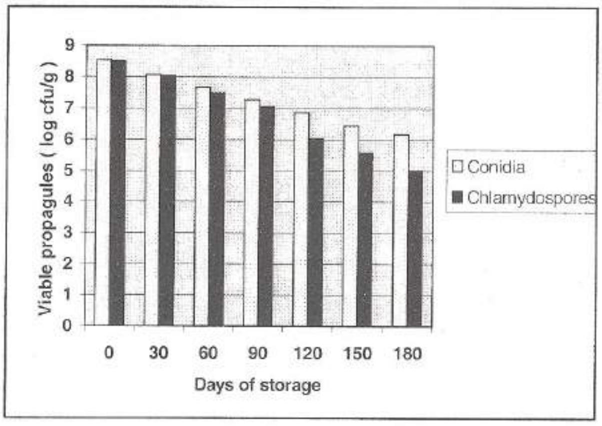


Fig. 8. Shelf life of conidia and chlamydospores of *T. harzianum* (Values for each storage period differ significantly from each other except at 0 and 30 days at P=0.05).

4.11.6. Evaluation of potential bacterial antagonists against *Rhizoctonia solani, Fusarium oxysporum* f. sp. *ciceri* and *Fusarium udum* under *in vitro* and greenhouse conditions

Twenty-five endophytic bacterial isolates and fifty rhizospheric isolates were screened for dual culture inhibition of three pathogens, *viz.*, *Rhizoctonia solani*, *Fusarium oxysporum* f. sp. *ciceri* and *Fusarium udum* on Tryptic Soya Agar (TSA). Ten endophytic isolates, two *Pseudomonas fluorescens* and two *Bacillus subtilis* isolates were selected as potential isolates as the inhibition zones were high (18 -77 mm).

In another study twenty rhizosphere bacteria were isolated from healthy sunflower roots in plots exhibiting *Sclerotium rolfsii* root rot in UAS Hebbal campus. Nine isolates were selected as potential antagonists against *S. rolfsii* and they exhibited an inhibition zone ranging from 32 to 67 mm.

4.11.7. Development of media for mass production of bacterial antagonists and standardization of fermentation conditions

Three media, *viz.*, Tryptic Soya Broth (TSB), Nutrient Broth (NB) and King's B Broth (KB medium), were tested for mass culturing of *Pseudomonas fluorescens* (PDBCAB 2). The culture flasks were kept on a rotary shaker (150 RPM) for 48 h. All the three media supported proper growth of the bacterium and a maximum population of 9 X 10^8 cfu/ml was reached.

4.11.8. Studies on control of root rot and wilt of chickpea with different formulations of bacterial antagonists

Talc based formulations of two antagonistic bacteria, *viz*., *Pseudomonas putida* (PDBCAB 19) and *P. fluorescens* (PDBCAB 2) were evaluated as seed treatment against natural incidence of wilt and wet root rot of chickpea. *In vitro* studies indicated that they were inhibitory against *Fusarium oxysporum* f. sp. *ciceri* and *Rhizoctonia solani*.

Talc based formulations of the two antagonists were prepared and the treatments included *P. fluorescens* (PDBCAB 2) seed treated @ 5 g/kg, *P. putida* (PDBCAB 19) seed treated @ 5 g/kg, combination of 10 g/kg, fungicide captan @ 2 g/kg and pathogen control. The treatments were taken up in a plot where chickpea was grown regularly. Observations on seedling emergence, root rot, wilt and seed yield were undertaken. Seedling emergence was highest (84.7%) for *P. fluorescens* (PDBCAB 2) seed treated and lowest (70.8 %) in pathogen control (Fig. 9).

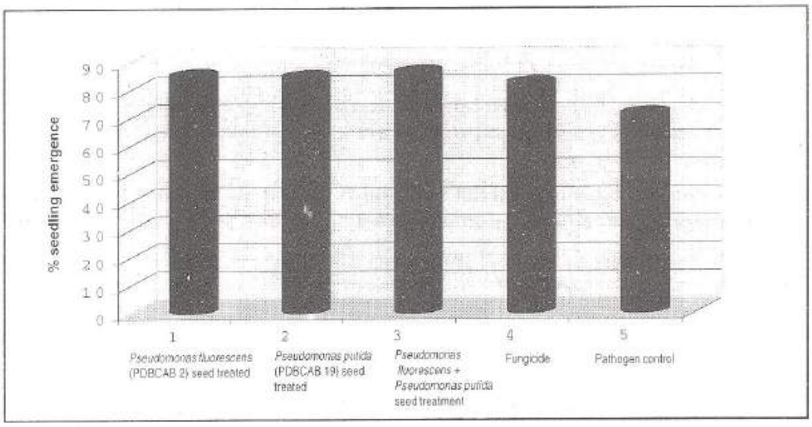


Fig. 9. Effect of *Pseudomonas putida* (PDBCAB 19) and *P. fluorescens* (PDBCAB 2) on seedling emergence of chickpea

Observations on *Rhizoctonia* root rot incidence indicated that the disease was prevalent up to 60 days of plant growth whereas fusarial wilt was observed from 60 days. At day 30 highest root rot diseased plants (10.8%) were observed in pathogen control plots and minimum was in fungicide treated plots (3.1%) but *P. fluorescens* (PDBCAB 2) @ 5 g/Kg seed treated plots also exhibited low root rot (4.4%). However, at 60 days lowest (5%) root rot was present in *P. fluorescens* (PDBCAB 2) seed treated plots and highest incidence was present in pathogen control. Low root rot (5.8%) was also noticed in *P. putida* (PDBCAB 19) @ 5 g/Kg seed treated plots (Fig. 10).

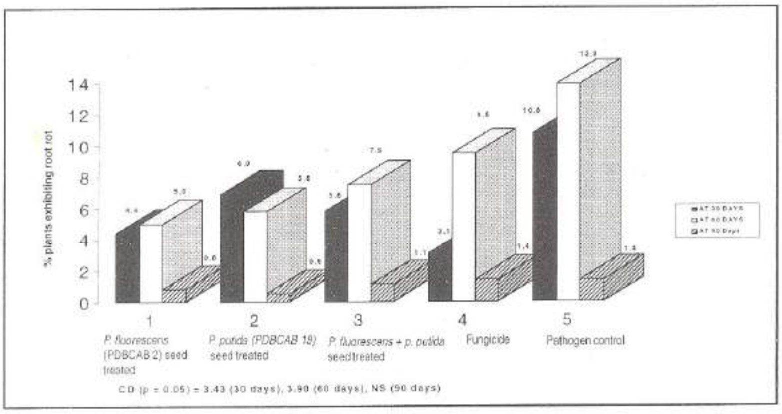


Fig. 10. Effect of *P. fluorescens* (PDBCAB 2) and *P. putida* (PDBCAB 19) seed treatment on *Rhizoctonia* root rot of chickpea

Fusarium wilt was lowest (3.3%) in *P. putida* (PDBCAB 19) seed treated and highest (14.2%) in control plots. Combination of both *P. fluorescens* (PDBCAB 2) and *P. putida* (PDBCAB 19) gave moderate control of wilt (7.5%) and root rot (5.8%) when compared to control (13.9 and 14.2%) (Table 36).

Table 36. Effect of bacterial antagonists on *Fusarium* wilt incidence in chickpea

Treatment	Per cent plants exhibiting wilt (days)		
	30	60	90
Pseudomonas fluorescens (PDBCAB 2) seed treated @ 5 g/kg	0.0	1.7 *(7.2)	5.0 (12.8)
Pseudomonas putida (PDBCAB 19) seed treated @ 5 g/kg	0.0	2.2 (8.5)	3.3 (10.5)
Pseudomonas fluorescens + *Pseudomonas putida* seed Treatment @ 10 g/kg	0.0	3.0 (10.0)	5.8 (13.9)
Fungicide	0.0	2.5 (9.0)	14.2 (12.4)
Pathogen control	0.0	8.3 (9.5)	13.3 (21.4)

* Figures in parentheses are angular transformed values. NS = not significant

Highest plant stand and seed yield were observed in *P. fluorescens* (PDBCAB 2) treated plots. There were no significant differences in the shoot and root lengths among bioagent treatments, however vigour index was highest in plots treated with a combination of *P. fluorescens* (PDBCAB 2) and *P. putida* (PDBCAB 19) (Table 37).

Table 37. Effect of bacterial antagonists on growth and yield of chickpea after 90 days

Treatment	Per cent plant stand	Yield (kg/ha)	Shoot length (cm)	Root length (cm)	Vigour index
Pseudomonas fluorescens (PDBCAB 2) seed treated @ 5 g/kg	83.1 *(65.8)	911.7	30.2	13.2	3666.2
Pseudomonas putida (PDBCAB 19) Seed treated @ 5 g/kg	81.1 (64.3)	888.3	30.4	13.7	3700.1
Pseudomonas fluorescens + *Pseudomonas putida* seed treatment @10 g/kg	+76.7 (61.1)	837.9	31.1	12.9	3784.6
Fungicide	78.8 (62.6)	801.8	32.1	12.9	3686.0
Pathogen control	54.1 (47.3)	539.0	27.3	11.1	2706.2
CD (P=0.05)	2.74	116.16	NS	NS	643.18

* Figures in parentheses are angular transformed values. NS = not significant

4.11.9. Studies on control of red gram wilt with bacterial antagonist

P. fluorescens (PDBCAB 2) and *P. putida* (PDBCAB 19) were tested against *Fusarium udum* in a wilt sick plot at UAS, GKVK Farm, Bangalore. The treatments were the same as that of chickpea field experiment. At 90 days lowest wilt incidence was recorded in fungicide (48.2%) and *P. fluorescens* (PDBCAB 2) (48.5%) seed treated (Table 38). In pathogen control plots the wilt incidence was very high (78.7%).

Table 38. Effect of bacterial antagonists on *Fusarium udum* wilt incidence in redgram

Treatment	Per cent plants exhibiting wilt (after days)		
	30	60	90
Pseudomonas fluorescens (PDBCAB 2) seed treated @ 5 g/kg	3.7 (11.1)	18.0 (25.0)	48.5 (44.1)
Pseudomonas putida (PDBCAB 19) seed treated @ 5 g/kg	3.0 (9.9)	18.7 (25.6)	58.5 (49.9)
Pseudomonas fluorescens + *Pseudomonas putida* seed Treatment @ 10 g/kg	4.5 (12.2)	17.2 (24.5)	55.0 (47.9)
Fungicide	2.0 (8.0)	14.7 (22.5)	48.2 (44.0)
Pathogen control	7.7 (16.0)	(28.2)	78.7 (62.6)
CD (P = 0.05)	2.00	1.92	4.29

* Figures in parentheses are angular transformed values NS = not significant

The effect of the antagonists on growth and vigour of redgram was also tested and vigour index was highest (1134.1) in *P. putida* (PDBCAB 19) seed treatment and lowest (877.3) in control plots (Table 39).

Table 39. Effect of bacterial antagonists on growth and vigour of redgram

Treatment	Per cent seedling emergence	Shoot length (cm)	Root length (cm)	Vigour index
Pseudomonas fluorescens (PDBCAB 2) seed treated @ 5 g/kg	86.7 (68.7)	7.0	4.4	991.1
Pseudomonas putida (PDBCAB 19) Seed treated @ 5 g/kg	89.5 (71.3)	7.8	4.9	1134.1
Pseudomonasfluorescens + *Pseudomonas putida* seed treatment @10 g/kg	83.2 (66.1)	8.0	5.1	1092.1
Fungicide	85.2 (67.5)	6.8	4.2	941.7
Pathogen control	78.2 (62.2)	6.7	4.5	877.3
CD (P = 0.05)	4.44	0.53	0.45	88.71

* Figures in parentheses are angular transformed values. NS = not significant

4.11.10. Biofungicidal characterization of potential bacterial antagonists

Methanol and chloroform extracts of three potential isolates, *viz., Pseudomonas fluorescens* (PDBCAB 2), *P. fluorescens* (sunflower isolate) and *Bacillus subtilis* were tested against *Rhizoctonia solani* and *Fusarium oxysporum* f. sp. *ciceri*. Discs with 1, 2, 5 and 10 µg/ml were prepared and used for screening against *Rhizoctonia solani* and *Fusarium oxysporum* f. sp. *ciceri*. It was observed that 10 µg/ml discs of all isolates could inhibit the pathogens. With higher concentrations of 20 and 30 µg/ml, 40-50% inhibition of *Rhizoctonia solani* and *Fusarium oxysporum* f. sp. *ciceri* was obtained. Discs with 35, 40 and 45 µg/ml exhibited 60 % inhibition of *Rhizoctonia solani* and *Fusarium oxysporum* f. sp. *ciceri*.

4.11.11. Testing of potential strains of antagonistic bacteria for root colonizing and growth promoting ability

Pseudomonas fluorescens isolated from healthy sunflower roots exhibited 1.5% enhanced shoot and root weight. Among 15 fluorescent pseudomonad rhizosphere isolates tested, six showed 1 to 2.5 per cent enhanced plant growth with chickpea as host.

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Isolation and characterization of antagonists

Two hundred and three additional isolates of *Pseudomonas* were isolated from the rhizosphere of different plant species grown in normal, acidic and alkaline soils. Population of *Pseudomonas* was high in soils of pH 8-8.5 and 9-9.5.

Antifungal activity of isolates

In dual culture, isolate PBAT2 was highly effective against *R..solani* but exhibited moderate efficacy against *F. oxysporum* but only moderate efficacy against *S. rolfsii.*

Efficacy of formulations with chlamydospore and conidia

Formulations of *Trichoderma/Gliocladium* based on chlamydospores and conidia spore types were tested for their storability and efficacy. *Chlamydospores* had longer shelf life (80% viability after 7 months at room temperature) as compared to conidia (80% viability after 4 months at room temperature). However, conidia were more effective than chlamydospores in controlling seed and root rot of tomato than chlamydospores, if seeds were sown just after treatment.

Seed priming and bioefficacy

Storing wet slurry treated seeds for 48 h before sowing enhanced bioefficacy of formulations containing 10^6 conidia/chlamydospores per g formulation. It was as effective as the formulation containing 10^9 conidia per g if seeds were sown just after treatment. Formulation containing 10^9 proved to be toxic to seed germination if treated wet seeds were stored for 48 h before sowing. Overnight dipping of soybean seeds in 3% gur suspension containing *T. harzianum* or *P. fluorescens* (@ 4 g/l; 1kg seed/ 2 l suspension) drastically improved performance of both antagonists.

Efficacy of mixed formulation

Mixed formulation were developed using one efficient strain of *Pseudomonas* (SPP-1) and *Trichoderma harzianum* (PBAT-7) with cfu of both = 10^9/g formulation. Although pure carboxy methyl cellulose (CMC) based formulation was more effective, considering the cost factor talc + CMC (99:1, w/w) based formulation were tried and it was found that mixed formulation was equally or sometimes more effective than individual formulations against chickpea wilt complex, seed and root rots of soybean, pre-and post emergence damping off of capsicum, pea, brinjal and tomato (Table 39(a) and 39(b)). Under green house conditions population dynamics of *T. harzianum* was more or less same when applied as pure or mixed formulation both in spermosphere and rhizosphere soils of chickpea.

Effect of pH on the efficiency of the antagonists

When tested against seed and root rot of pea and soybean and damping off of tomato *T. harzianum* was more effective in acidic (pH 5.5 to 6) and *P. fluorescens* more effective in soils above pH 7.0 with respect to both disease control and plant growth promotion.

Table 39(a). Efficacy of different formulation of *Trichoderma harzianum* (Th)+ *Pseudomonas fluorescens* (Psf) on chickpea wilt complex in glasshouse*

Treatment (Th+Psf)	Germination (%)	Mortality (%)
(Th+Psf) + Clay soil	95.0^{a}	14.2^{ab}
(Th+Psf) + multani soil	95.0^{a}	11.4^{ab}
(Th+Psf) + $CaCO_3$	92.0^{a}	15.3^{ab}
(Th+Psf) + (Talc powder + CMC)**	95.1^{a}	7.0^{b}
(Th+Psf) + CMC	97.7^{a}	3.8^{b}
Control (Th+Psf)	95.1^{a}	19.4^{a}

Th=*Trichoderma harzianum*; Psf = *Pseudomonas fluorescens;* Mean of 5 replicates
** 990 g Talc + 10 g CMC; Th+ Psf-@ 3g/kg seed

Means in a column followed by same letter (s) do not differ significantly from each other at CD (P=0.05)

Table 39(b). Integrated control of chickpea wilt complex in glass house when Th or Th+ Psf were applied as seed treatment @ 3g/kg seed*

Treatment	Germination (%)	Increase in germination	Post emergence mortality (%)	Disease control (%)
Th	86.3^{b}	23.8	28.2^{b}	53.3
Th + Psf	96.3^{c}	38.2	21.1^{c}	65.1
Check	69.7^{a}	-	60.4^{a}	-

Th =*Trichoderma harzianum;* Psf=*Pseudomonas fluorescens;* Th+ Psf-@ 3g/kg seed
Mean of 5 replicates; Means in column followed by same letter (s) do not differ significantly from each other at CD (P=0.05)

Efficacy of the antagonists against nematodes

Trichoderma harzianum, *Gliocladium virens* and *Pseudomonas fluorescens* were found to inhibit the hatching of *Meloidogyne sp.* When applied through soil or root they inhibited the root knot development in tomato and promoted the plant growth (Table 39(c)).

Table 39 (c). Effect of *Trichoderma harzianum, G. virens* and *Pseudomonas fluorrescens* on root knot of tomato under green house conditions

Treatment	Shoot length (cm)	Shoot fresh weight (g)	Shoot dry weight (g)	Root fresh weight (g)	Root dry galls/plant	Number of galls/ plant	Number of larvae/ 100 ml soil
Th (Soil treat. @ 1 g/kg)	80.3	47.5	5.52	7.37	1.01	216.7	30
Th (Soil treat. @ 3 g/kg)	88.7	49.5	5.60	7.87	1.00	166.7	60
Th (Root dip @ 1g/l)	92.3	27.6	3.91	6.13	0.94	275.0	45
Th (Root dip @ 3g/l)	101.7	31.2	4.06	5.97	0.76	180.0	60
Tv (Soil Treat. @ 1 g/kg)	71.0	39.9	3.98	4.00	1.19	98.3	15
Tv (Soil Treat. @ 3 g/kg)	76.7	40.3	4.31	5.03	0.79	69.3	00
Tv (Root dip @ 1g/l)	83.3	42.3,	5.07	5.17	0.79	163.3	30
Tv (Root dip @ 3g/l)	85.0	42.5	4.92	8.43	2.03	88.3	15
Psf (Soil treat. @ 2 g/kg)	74.7	40.1	4.47	6.33	0.80	175.0	30
Psf (Soil treat. @ 6 g/kg)	92.7	42.7	5.48	3.47	0.61	86.7	15
Psf (Root dip @ 2g/l)	89.0	32.0	4.36	3.70	0.53	126.0	15
Psf (Root dip @ 6g/l)	94.3	36.2	4.70	2.40	0.28	42.7	15
Psf (1 ml suspension in 20 ml water)	80.7	46.3	5.58	10.27	1.40	90.0	30
Uninoculated control (sterilized soil)	85.3	45.7	5.01	5.83	0.49	-	00
Inoculation control	74.7	30.4	3.24	2.93	0.26	400.0	60
Lsd (P=0.05)	9.7	6.04	1.09	1.60	0.48	75.6	

Th= *Trichoderma harzianum*; Tv= *G. virens*; Psf= *Pseudomonas fluorescens*

4.12. Studies on entomopathogenic nematodes

4.12.1. Bioefficacy of EPN isolates against different insect pests

Among the isolates tested *Heterorhabditis bacteriophora, H. indica, Steinernema carpocapsae* and *S. bicornutum* were found effective against all the insects tested. *H. bacteriophora, S. carpocapsae* and *S. bicornutum* were found promising against *S. litura* with 100% mortality 72 h after exposure. Against *H. armigera, H. indica,* and *S. bicornutum* proved efficient by recording

60-100% mortality. *S. bicornutum* was found very effective against *P. operculella* with 80-100% mortality 24h after inoculation. *O. arenosella* and *P. xylostella* were susceptible to all the isolates tested (Table 40).

Table 40. Bioefficacy of EPN against different lepidopteran insect pests

Nematode isolates	Percent mortality of (after------ hours)														
	S. litura			*H. armigera*			*O. arenosella*			*P. xylostella*			*P. operculella*		
	24	48	72	24	48	72	24	48	72	24	48	72	24	48	72
H. bacteriophora	-	40	100	-	20	20	-	60	100	40	100	100	20	60	100
H. indica	20	80	100	-	40	60	-	40	100	20	100	100	60	100	100
S. carpocapsae	-	40	80	-	-	20	-	20	60	-	60	100	-	40	80
S. carpocapsae	-	60	100	-	60	100	-	20	80	-	80	100	-	60	100
S. glaseri	-	20	60	-	-	80	-	20	80	-	40	100	-	20	80
S. bicornutum	-	60	100	-	40	100	-	80	100	-	100	100	80	100	100

4.12.2. Progeny production of *Steinernema* spp. and *Heterorhabditis* spp. on different pest species

Progeny production of different *Steinernema* spp. and *Heterorhabditis* spp. was evaluated in different lepidopteran insect pests. Maximum yield of all the isolates was observed in final instar larvae of *G. mellonella*. Of all the species and isolates tested *H. bacteriophora* recorded highest yield of 5.4 lakhs in *G. mellonella* followed by *S. litura* (3.56 lakhs/larva) and *H. armigera* (3.16 lakhs/larva). Among *Heterorhabditis* spp., progeny production of *H. indica* 13.3 was higher in *H. armigera*, *O. arenosella*, *P. xylostella* and *P. operculella* when compared to *H. bacteriophora*. Of *Steinernema* isolates *S. bicornutum* PDBC 3.2 yielded maximum in all the insects tested followed by *S. carpocapsae*, *S. carpocapsae* PDBC 6.11, and *S. glaseri* (Table 41).

Table 41. Progeny production on EPN isolates in different insect larvae

Nemotode isolates	*S. litura*	*H. armigera*	*O. arenosella*	*P. xylostella*	*P. operculella*	*G. mellonella*
H. bacetriophora	3,55,600	3,16,500	1,05,000	55,000	58,000	5,40,800
H. indica (PDBC 13.3)	3,35,500	3,21,500	1,16,000	67,000	69,000	4,81,000
S. carpocapsae (PDBC 6.11)	2,01,000	1,91,300	80,000	28,500	32,000	1,14,000
S. carpocapsae	2,15,000	1,95,000	93,750	32,600	34,500	2,18,000
S. *glaseri*	83,950	78,400	56,000	18,000	20,500	91,500
S. *bicornutum*	3,11,500	3,09,000	1,12,500	61,500	72,000	3,54,000

4.12.3. Mass production of EPN on artificial media

Different semi-solid artificial media *viz.*, Wouts, soy flour+egg yolk, soy flour+cholestrol and dog biscuit+beef extract were tested with associated bacteria for the mass production of *Steinernema* sp. and *H. indica*. Prior inoculation of symbiotic bacteria was found to enhance the yield and rate of multiplication in artificial media. Among the media tested, the standard Wouts medium was suitable for all nematodes with an average yield of 44 lakhs/250 ml flask. *S. carpocapsae* isolates multiplied in all the media which shows their higher mass production potential compared to *H. indica* PDBC 6.71. *S. carpocapsae* PDBC EN 1.4 and PDBC EN 7.2 recorded the highest yield (78.9 lakhs/250 ml flask and 74.45 lakh/250ml flask) in dog biscuit + beef exract medium followed by soy flour + cholesterol medium(71.48 lakh and 69.85 / 250 ml flask). *H. indica* multiplied only in Wout's and soy flour + cholesterol (64.78 lakhs) (Table 42).

Table 42. *In vitro* mass production of EPNs

Nemotode isolates	Wout's	Soy flour + Egg yolk	Soyflour+Chole sterol	Dog biscuit + beef extract
S. carpocapsae PDBC 1.4	55.65	69.54	71.48	78.90
S. carpocapsae PDBC 7.2	41.00	62.80	69.85	74.45
H. indica (PDBC 13.3)	38.90	Not multiplied	64.78	Not multiplied

4.12.4. Bioefficacy tests against brinjal shoot and fruit borer, *Leucinodes orbonalis* in the laboratory

In vitro studies indicated that the isolates, PDBC EN 3.1 of *S. bicornutum*, PDBC EN 13.3 of *H. indica* and PDBC EN 6.11 of *S. carpocapsae* recorded maximum mortality of *L. orbonalis* at 50 IJ/larvae in 48 to 72 h of exposure (Table 43).

Table 43. Time taken for 100% mortality of *L. orbonalis* larvae (hours of exposure) eposed to indigenous isolates of *Steinernema* spp. and *Heterorhabditis indica* (*in vitro* bioassay)

Nemotode species	Isolate	Mortality time at the dose of IJS/ *L. orbonalis* larvae		
		25	50	100
S. carpocapsae	PDBC EN 6.11	96 h*	72 h	48 h
S. bicornutum	PDBC EN 3.1	72 h	48 h	48 h
H. indica	PDBC EN 6.71	120 h	96 h	72 h
H. indica	PDBC EN 13.3	72 h	48 h	48 h

* Each value is mean of five replications

4.12.5. Field evaluation of indigenous isolates of EPN against *L. orbonalis*

Preliminary field trial with the isolates, PDBC EN 6.11 of *S. carpocapsae* and PDBC EN 6.71 of *H. indica* @ 0.5, 1.0, 2.0 billion/ac on brinjal indicated that higher concentration of infective juveniles per dose resulted in less bore holes on brinjal fruits and the results were comparable with sprays of neem seed kernel extract. PDBC EN 6.11 of *S. carpocapsae* was more effective in reducing the fruit damage in terms of number of fruits with bore holes and increase in yield (Table 44).

Table 44. Effect of field sprays of *S. carpocapsae* and *H. indica* on number of infected larvae, fruit yield and fruits with bore holes due to *L. orbonalis*

Treatment	Dose	Number of infected larvae		Per cent fruits with bore holes		Fruit yield (kg/plot)	
		First Harvest	Second Harvest	First Harvest	Second Harvest	First Harvest	Second Harvest
Neem seed kernel extract	4%	-	-	17.92	23.55	6.24	5.66
Cypermethrin	0.0005%	-	-	26.79	28.98	5.88	5.32
S. carpocapsae	0.5 billion	12.33	8.45	47.33	48.29	4.81	4.55
S. carpocapsae	1.0 billion / acre	17.23	10.66	32.76	33.56	5.65	5.25
S. carpocapsae	2.0 billion	20.22	12.50	22.39	27.33	5.96	5.30
H. indica	0.5 billion	8.50	4.65	50.75	51.65	4.65	4.22
H. indica	1.0 billion	10.00	6.90	45.23	49.50	4.95	4.86
H. indica	2.0 billion	12.25	7.45	33.25	34.12	5.66	5.14
Untreated check	-	-	-	53.88	51.45	3.65	4.25
CD (P = 0.05)	-	-	-	8.45	6.52	0.88	0.36

4.12.6. Viability and pathogenicity of formulated EPN

Shelf life of different formulations, talc, talc+china clay and alginate was tested in laboratory condition at 15°C for three months. Per cent survival of nematodes was recorded at 15 days interval for up to 90 days (Table 45). Talc + china clay and alginate was found better in retaining the viability of IJs for a longer period than talc formulation. Per cent survival of IJs was maximum in talc + china clay followed by alginate encapsulation.

Table 45. Viability of S. *carpocapsae* PDBC 1.3 and *H.indica* 6.7 in different formulations

Formulation of EPNs	Per cent viability after days of storage of					
	15	30	45	60	75	90
S. carpocapsae PDBC EN 1.3 Talc	63.2	33.2	0.4	0.0	0.0	0.0
Talc+ china clay	100	98.4	98.0	94.8	92.0	88.0
Alginate	100	99.2	97.2	92.8	89.6	88.0
H. indica PDBC EN 6.71 Talc	57.2	31.2	0.0	0.0	0.0	0.0
Talc + china clay	100	99.2	95.2	94.8	92.4	87.6
Alginate	100	98.0	94.0	91.6	88.8	84.4

Table 46. Pathogenicity of *S. carpocapsae* PDBC 1.3 and *H. indica* 6.71 in different formulations

Formulation of EPN	Per cent mortality (storage period and exposure period in days)																	
	15d			30d			45d			60d			75d			90d		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
S. carpocapsae PDBC EN 1.3 Talc	0	66.67	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Talc + china clay	0	66.67	100	0	0	100	0	66.67	100	0	100	100	0	66.67	100	0	100	100
Alginate	0	33.33	100	0	33.33	100	0	33.33	100	0	0	66.67	0	33.33	66.67	0	0	66.67
H. indica PDBC EN 6.71 Talc	0	66.67	100	0	0	33.33	0	0	0	0	0	0	0	0	0	0	0	0
Talc + china clay	0	66.67	100	0	100	100	0	66.67	100	0	66.67	100	0	100	100	0	66.67	100
Alginate	0	0	100	0	100	100	0	66.67	100	0	66.67	100	0	33.33	66.67	0	0	66.67

4.13. Nematophagous fungi against plant parasitic nematodes

4.13.1. Testing of fungal bioagents against *Meloidogyne incognita* on tomato

Suitability of different substrates such as sorghum grain, rice grain, broken wheat, maize grain and wheat bran for multiplication of *Verticillium chlamydosporium* was tested. All the substrates favored the multiplication of *V. chlamydosporium*. The fungus was able to suppress the galls, egg masses and nematode population. Per cent parasitization of egg and egg masses varied from 39 to 70 and 51 to 89, respectively. *V. chlamydosporium* cultured on sorghum grains applied @ 10g/plant and 5g/plant was superior to other substrates in terms of parasitization of egg masses (97.0 and 89.3%).

Considerable suppression of galls and egg masses was seen in plots treated with *V. chlamydosporium* grown on different substrates. The degree of suppression of nematode by *V. chlamydosporium* varied with the substrates used. The nematode alone treatment recorded maximum galls (151galls/ root), whereas in *V. chlamydosporium* treated plants the number of galls ranged from 41-78/root and this was 48-72 per cent less over nematode alone treatment. Fungus cultured on sorghum grain and applied at the rate of 10g/plant obtained 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. These two treatments were significantly different from other treatments. About 41-70 per cent reduction of egg masses was observed using *V. chlamydosporium* cultured on different substrates. Nematode population in soil also showed the same trend with lowest record due to *V. chlamydosporium* cultured on sorghum applied @10g/plant (54% reduction over nematode alone) followed by fungus cultured on broken wheat grain and applied @ 10g/plant (50 % reduction over nematode alone). The per cent reduction of nematode population for all other treatments was 38-49 (Table 47).

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

47. Effect of *V. chlamydosporium* cultured on different substrates against *M. incognita* on tomato

Fungal species	Number of galls / g root*	Number of egg masses /g root*	Nematode population / 200g soil*	Parasitisation of egg masses**	Parasitisation of 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	89.3
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	33.3	260.0	41.0	53.6
Mi alone	151.0	95.0	420.0	-	-
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 parentheses are n transformed values; ** Figures in parentheses are Arc sin transformed values.

A significant increase in growth of tomato plants 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 (34.1cm), root length (31.6 cm) and root weight (18.8g). The treatments *viz.*, broken wheat, sorghum, wheat, broken maize and wheat bran were in decreasing order of suitability as indicated by their influence on root length and root weight (Table 48).

48. Evaluation of substrates for growth of *V. chlamydosporium* and its effect on growth of tomato and CFU of the fungus

Treatment	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 94.3)
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 (P + 0.05)	0.3	0.2	0.8	2.3	2.6

Mi = Meloidogyne incov\gnita; * Figures in parentheses are n transformed values

Generally *V. chlamydosporium* applied @ 10g/plant was found to be 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 (Table 48). The superiority of sorghum and wheat grain for *V. chlamydosporium* was confirmed.

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

4.14.1. Studies on pathogens of parthenium

4.14.1.1. *Lasiodiplodia theobromae*

Lasiodiplodia theobromae (Pat.) Griffon. & Maubl. (=*Botryodiplodia theobromae* Pat.) [IMI 378919a; WF (Ph) 8] (ex Siddeswaranadurga, Chitradurga district, December 1997), was studied for its mycoherbicidal potential towards *Parthenium hysterophorus*.

The typical foliar disease caused by the pathogen was repeatedly observed in several districts of Karnataka State, especially in winter. The primary symptoms were circular to irregular, light brown to grey leaf spots, ranging between 2 and 8 mm in diameter. Careful observation of infected plants revealed that the development of several lesions in close proximity resulted in rapid necrosis and withering of the entire leaf.

The dark chocolate brown fungus grew well on potato dextrose agar (PDA) and produced slowly maturing conidia, which were dark brown, ellipsoid, thick-walled and single-septate, with longitudinal striations. As a first step to satisfy Koch's postulates, a dense conidial suspension (10^{8} per ml) of the fungus (50 ml per leaf) was evenly applied on detached, surface-sterilized, healthy leaves (N =10), and infection was ascertained after four days of incubation in petri dishes lined with moist cotton. Later, when 30-day-old pot-grown parthenium plants (N = 50) were similarly inoculated and maintained in a moisture-saturated condition (> 95% RH) for at least 48 h, typical symptoms matching those in the field were visible on 88% of the plants within 3 weeks. The experiment was performed thrice and the results were similar. The fungus was isolated consistently from diseased leaves of inoculated plants with 80% frequency of reisolation, but uninoculated controls neither showed symptoms nor yielded the pathogen.

4.14.1.2. *Nigrospora oryzae*

The isolate, WF(Ph)11 (ex Harihara, Harihara taluk, Davangere district, Karnataka, 29 April 1998) of *Nigrospora oryzae* (Berk. & Broome) Petch (teleomorph: *Khuskia oryzae* H. J. Huds.) that was identified at CABI Bioscience, UK Centre (Egham) (IMI 379979) was studied further to know its suitability as a mycoherbicide for parthenium.

Natural symptoms were circular or irregular, pale to dark brown foliar lesions (2-4 mm) with diffuse margins encircled by light yellow halos. Infection was not restricted to leaves of any particular age. Lesions in close proximity often coalesced, resulting in severe blighting of the leaves.

Pathogenicity and virulence tests were carried out in the laboratory (26 ± 2 °C) on detached leaves (*N* = 10) maintained in moist chambers built with petridishes (15-cm diameter) and in the greenhouse (28 ± 2 °C) on 2-month-old plants (*N* = 50) of parthenium, which were maintained at high humidity (> 95%) for the first 2 days of inoculation. These were sprayed with a conidial suspension (2×10^{6} conidia per ml) of the fungus at the rate of 300 ml per leaf. Detached leaves (*N* = 10) and whole plants (*N* = 10) sprayed with only sterile water served as controls. Whereas the symptoms on all the inoculated detached leaves appeared within 5 days, it took 10 days for the appearance of disease symptoms on 80% of the whole plants within 14 days after inoculation. The fungus was consistently retrieved both from the detached leaves and plants with a frequency of 96% and 75% reisolation, respectively. Control plants did not express any symptoms.

4.14.1.3. *Phoma* spp.

Phoma chrysanthemicola Hollós [isolate WF(Ph)20; ex Alur, Hassan district, Karnataka, 24 September 1998] and *P. eupyrena* Sacc. [isolates WF(Ph)23 & 24 (ex Allampura and Aralaguppe, respectively, Chikmagalur district, Karnataka, 25 September 1998) were studied in detail.

Single-conidial cultures of *P. chrysanthemicola* produced colonies that were olivaceous grey with dark and light patches. The aerial mycelium was felty and reverse dark brown. In culture, numerous chlamydospores in various shades of brown that were smooth, terminal or intercalary and catenate could be observed. Inoculation assays on detached leaves and on 45-day-old pot-grown healthy parthenium plants with a conidial suspension of the pathogens produced symptoms typical of those found in field plants. On an average 80.0% and 76.3% of the reisolates of *P. chrysanthemicola* and *P. eupyrena*, respectively, were able to cause disease on parthenium upon reinoculation under similar conditions.

4.14.2. Natural control of water hyacinth by *Alternaria* spp. and *Cercospora* spp.

Water bodies in and around Bangalore were surveyed for the occurrence of pathogens on water hyacinth (*Eichhornia crassipes*). *Alternaria* spp. (both *A. eicchorniae* and *A. alternata*) were found to be dominant on the weed covering 60% area of the lamina on an average. In the Hebbal lake the incidence of the species was up to 35%. *Cercospora* spp. were found to be the other dominant fungi causing extensive damage to the water hyacinth stands in lakes in and around Bangalore. *Lasiodiplodia theobromae* and several *Fusarium* species were also frequently noticed infecting the weed (Table 49).

Table 49. Natural incidence of some important pathogens of water hyacinth in water bodies in and around Bangalore

Fungal species	Water body	Incidence (%)
Alternaria eichhorniae	Hebbal Yelahanka Jakkar	35 12 18
A. alternata	Hebbal Yelahanka	23 5
Cercospora spp.	Hebbal Jakkur	25 10
Lasiodiplodia theobromae	Hebbal	2
Fusarium spp.	Hebbal	3

4.14.3. Host range testing of *Alternaria* spp. and *Cercospora* sp.

The pathogenicity of *Alternaria eichhorniae, A. alternata* and *Cercospora* spp. and phytotoxicity of their metabolites were tested for ensuring the safety of the organisms to non-targets.

All the test plants were pot-grown in a mixture of soil and farmyard manure. Two methods of screening viz., the detached leaf technique (*in vitro*) and the *in vivo* method consisting of intact plants were employed for studying pathogenicity as well as phytotoxicity.

Pathogenicity: In the first method, 15-cm petri plates, containing a layer of moist absorbent cotton covered with a disc of aluminium foil in the lower dish, were used as moist chambers to maintain 100% RH. Each detached leaf of the test plants was placed, one per plate, by inserting the petiole through a hole made in the foil, so as to allow it to be in contact with the moist cotton. A concentration of 1×10^8 conidia/ml of the pathogens was used. The suspension was evenly brushed on both surfaces of the leaves. All the plant species tested had 10 replicates of inoculated leaves. Control leaves, also with 10 replicates, were applied only with sterile water containing the surfactant (Tween 20). Observations were taken every day for any visible signs of infection 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 high humidity for 48 h. Treated plants and control plants were replicated 10 times.

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

All the seven different plant species tested, *viz.*, sunflower (*Helianthus annuus*), groundnut (*Arachis hypogaea*), chillies (*Capsicum annuum*), cowpea (*Vigna unguiculata*), tomato (*Lycopersicon esculentum*), brinjal (*Solanum melongena*) and blackgram (*Phaseolus mungo* var. *radiatus*) were immune to *A. eichhorniae*, *A. alternata* and *Cercospora* sp. However, phytotoxicity of the culture filtrates of *Alternaria* spp. was observed in the case of brinjal and cowpea. Similarly, the metabolites from *Cercospora* sp. were observed to be phytotoxic to brinjal.

4.14.3. Susceptibility of arthropod damaged water hyacinth plants to fungal pathogens

Alternaria eichhorniae, *A. alternata* and *Cercospora* sp. were investigated for their effect on water hyacinth damaged by weevils (*Neochetina* spp.) and the mite (*Orthogalumna terebrantis*). The combinations tried were weevil damage+*A. eichhorniae* (W+Ae), weevil damage+*A. alternata* (W+Aa), weevil damage+*Cercospora* sp. (W+C), mite damage+*A. eichhorniae* (M+Ae), mite damage+*A. alternata* (M+Aa) and mite damage+*Cercospora* sp. (M+C). All the three pathogens as individual treatments were also studied with a suitable control.

Individual water hyacinth plants were placed in plastic pots (5" diameter) containing sufficient tap water. Mycelial inoculum was prepared by blending 5 g (wet weight) of the mycelium in sterile water with the help of a mixer so as to get a concentration of 20% (w/v). The inoculum was applied to the laminae until runoff occurred. Control plants were sprayed only with sterile water. There were three replicates and all the plants were put in a plant growth chamber (12 h photoperiod-10,000 lux; 28 °C-20 °C day-night cycle). The efficacy of different treatments was determined from the level of disease severity (area of foliage damaged by the disease) with the pictorial scale developed by Freeman and Charudattan (1984) at the end of 4 weeks of incubation.

The highest disease severity (6.67) was achieved through the inoculation of mite damaged water hyacinth leaves with *A. eichhorniae* (Fig. 11). Even alone *A. eichhorniae* performed very well with a disease severity of 3.33. The next best (6.00) treatment was mite damage plus *A. alternata*, which indicates that application of an effective pathogen on mite injured water hyacinth plants could have the desired effect.

4.14.4. Interactive effect of three different pathogens on water hyacinth

The same procedure as mentioned above was followed for the experiment. However, five replicates were maintained. The different combinations tested were *A. eichhorniae*+*A. alternata* (Ae+Aa), *A. eichhorniae*+*Cercospora* sp. (Ae+C), *A. alternata*+*Cercospora* sp. (Aa+C) and *A. eichhorniae*+*A. alternata*+*Cercospora* sp. (Ae+Aa+C).

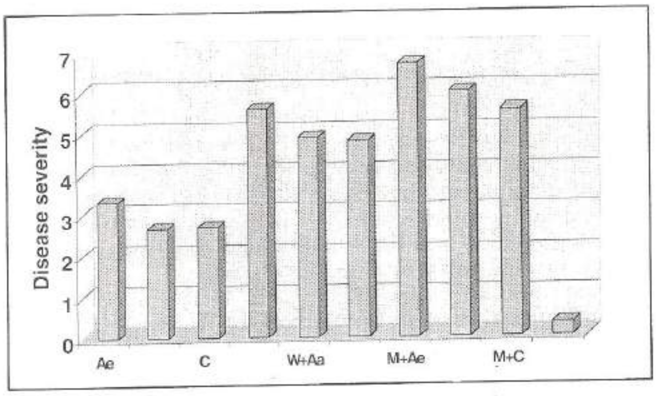

Fig. 11. Susceptibility of arthropod-damaged water hyacinth to three pathogens

Significant differences were observed between different treatments. The most potent (disease severity 8.0) treatment was the combination of all the three pathogens (Fig. 12). Among the pairs, *A. eichhorniae* and *A. alternata* were found to be the best with a score of 7.0. The results confirm that better control of water hyacinth could be obtained by combining two or more pathogens. Since the pathogens have been found to be compatible with each other, cocktails of different combinations could be tried.

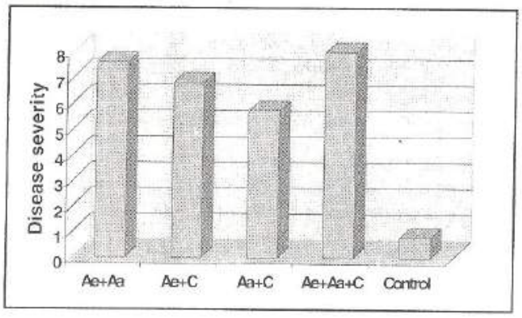

Fig. 12. Interactive effect of three pathogens on water hyacinth

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, Earias vittella, Mythimna separata, Achaea janata, Liriomyza trifolii, Plutella xylostella, Aphis craccivora, Aleurodicus dispersus, Ferrisia virgata, Maconellicoccus hirsutus, Planococcus citri, P. lilacinus, P. minor, Dysmicoccus* sp., *Hemiberlesia lataniae, Pinnaspis strachani, Coccus* sp. 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 eleven of its strains were maintained.

4.15.3. Predators

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

4.15.4. Insect pathogens

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

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

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

Entomopathogenic nematodes maintained are *Steinernema glaseri, S. carpocapsae* (2 strains), *S. bicornutum* (1 strain), *Heterorhabditis indica* (1 strain). *Nosema* sp. has been added to repository in Division of Entomology at IARI, New Delhi.

The nematophagous fungi / bacteria maintained are *Arthobotrys oligospora, Fusarium oxysporum* (4 isolates), *F. sporotrichoides, Paecilomyces lilacinus* (5 isolates), *Phoma glomerata, Trichoderma harzianum* (7), *T. viride, Verticillium chlamydosporium*, 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.

4.16. Shipments of host insects and natural enemies

During the reporting period, 68 cultures of various host insects and 135 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 crops-pests using a PC

Basic structure of the software has been prepared. Key preparation for identification of the major pests of oilseeds and their damage symptoms in the field is under progress. Pictures of the pests and the damage done are to be incorporated in the software.

CD version of the expert system, 'BIORICE' for suggesting biological control measures for rice pests using a PC has been prepared.

4.17.1. Development of National Information system on Biological Suppression of crops-pests

CD version of the software "PDBC INFOBASE" has been developed which can install the software within 3 minutes in the computer. Several pictures have been collected to include in the new version of the software.

4.17.2. Knowledge Base System of *Helicoverpa armigera* and its Natural Enemies

A database has been created in MS-Access for biology of *H.armigera*, its host plants, distribution and natural enemies. Software developed for this purpose is in its final stage and ready for scrutiny. Records are being up-dated day to day by referring scientific journals and CABPEST CD. The database helps the user to retrieve information based on user queries

4.18. Biological suppression of sugarcane pests

4.18.1. Survey and seasonal fluctuation studies on natural enemies of borers (PAU, Ludhiana)

Survey of and seasonal fluctuation studies on natural enemies of sugarcane borers were carried out at farmer's field at village Behram in Nawanshahar district. The survey was carried out at weekly interval during April 2000 - March 2001. Egg clusters, larvae and pupae of sugarcane borers were collected and reared in the laboratory until emergence of natural enemies or next stage of the pest. The mean parasitisation in different months was recorded.

In case of *Chilo infuscatellus*, 52 egg masses were collected from the selected fields. Two parasitoids, *viz*., *Trichogramma chilonis* and *T. chilotraeae* were recorded causing 7.6 and 5.8 per cent parasitism, respectively, during May - July. The four larval parasitoids, *viz*., *Cotesia flavipes* (10.4%) *Stenobracon nicevillei* (6.3%), *Sturmiopsis inferens* (7.6%) and *Bracon* sp. (8.3%) caused 32.6 per cent parasitism of the larvae. *Bracon* sp. and *C. flavipes* were most common during May and July, while *S. nicevillei* was observed during July to September. *S. inferens* was recorded during September and January-February. Only one pupal parasitoid, *Tetrastichus* sp. was observed causing 2.2 per cent parasitism.

Egg masses of *Chilo auricilius* yielded only one parasitoid *T. chilonis* causing 7.1 per cent parasitism. *C. flavipes*, *S. inferens* and *S. nicevillei* were the most common larval parasitoids and caused 10.0, 12.4 and 8.5 per cent parasitism, respectively. Two unidentified parasitoids, a braconid and an ichneumonid caused 2.4 per cent parasitism. The parasitoids were most active during September - October.

Egg masses of *Scirpophaga excerptalis* yielded *Telenomus dignoides* and it parasitised 43.0 per cent egg masses. *Telenomus* sp., *T. chilonis* and *T. japonicum* also parasitised 3.2, 2.4 and 1.6 per cent eggs masses of the top borer. Four species of larval parasitoids were recorded causing 47.6 per cent parasitism. *Rhaconotus scirpophagae*, *S. nicevillei* and *Isotima javensis* caused 17.5, 14.3 and 15.0 per cent parasitism, respectively, while *Topobracon* sp. could parasitize only 0.8 per cent larvae. The larval parasitoids were most active during August - October.

Trichogramma chilonis was recorded from the egg masses of *Acigona steniellus* and caused 6.7 per cent parasitism during August. Three larval parasitoids *S. nicevillei* (4.7%), *C. flavipes* (7.06%) and a braconid (1.2%) were recorded. The larval parasitoids were most active during September-October. Three pupal parasitoids were recovered form 46 pupae with a total parasitism of 13.0 per cent during September. *Tetrastichus* sp. was most common (6.5%) followed by *Xanthopimpla stemmator* (4.3%) and *Xanthopimpla* sp. (2.2%).

4.18.2. Studies on shoot borer and natural enemies (SBI, Coimbatore)

Shoot borer was active throughout the observation period (March 2000-February 2001), with peak incidence during August 2000. Amongst the natural enemies the tachinid, *Sturmiopsis inferens* was active almost throughout the year, except in May, September and November 2000 and January 2001. The maximum incidence of the parasitoid was noticed during July 2000 (23.3%); peak activity was also observed during March 2000 (16.7%, 18.4%). Granulosis virus was similarly active throughout the year with peaks in March (16.7%) and April (17.1%).

4.18.3. Ecological factors vs. shoot borer and natural enemies (SBI, Coimbatore)

The activity of *S. inferens* or GV was not dependent on shoot borer activity as was evident from the non-significant correlations between them (Table 50). Amongst the weather factors, afternoon RH had a significant positive correlation with shoot borer and negative correlation with *S. inferens* activity (Table 51).

Table 50. Correlation matrix for shoot borer and natural enemy incidence

	% shoot borer	% S. inferens	% GV
% shoot borer		-0.050	-0.106
% *S. inferens*			0.274
% GV			-

Table 51. Correlation matrix for shoot borer natural enemies and weather parameters

	Maximum	Minimum	Morning	Afternoon	Rainfall
% Shoot borer	-0.325	-0.011	-0.067	0.563*	0.078
% *S. inferens*	0.0392	0.096	-0.074	-0.488*	-0.294
% GV	0.236	-0.161	0.130	-0.435	-0.195

4.18.4. Field studies utilizing *Trichogramma chilonis* against borers of sugarcane (PAU, Ludhiana)

The experiments for the control of early shoot borer, *Chilo infuscatellus*, stalk borer, *Chilo auricilius* and Gurdaspur borer, *Acigona steniellus* were conducted at farmer's fields at Behram village (Nawanshahar district) and Chak-Hakim (Kapurthala district). The plot size was 2.0 ha for release and 0.4 ha for control. *T. chilonis* was released @ 50,000 per ha during April - October at 10 days interval. The incidence of early shoot borer was recorded in July, Gurdaspur borer during October and stalk borer during November on the basis of 5 units of 100 canes each from each plot. Recovery of the parasitoid was also made at regular interval by collecting the egg masses of the borers. The results are presented in Table 52 and 53 and discussed borer-wise.

Table 52. Evaluation of *T. chilonis* against different sugarcane borers at village Behram (Nawanshahar district)

Treatment	Incidence of different tissue borers			Per cent recovery *T. chilonis*
	C. auricilius	*C. infuscatellus*	*A. steniellus*	
T. chilonis release	4.8	6.4	2.2	58.0
Control (Untreated)	12.9	12.2	3.7	7.1
Reduction in damage over control (%)	62.8	47.5	40.5	

Table 53. Evaluation of *Trichgramma chilonis* against sugarcane borers at village Chak-Hakim (Kapurthala district)

Treatment	Incidence of different tissue borers			Per cent recovery *T. chilonis*
	C. auricilius	*C. infuscatellus*	*A. steniellus*	
T. chilonis release	5.2	4.4	2.1	64.0
Control (Untreated)	12.4	9.2	3.8	5.8
Reduction in damage over control (%)	58.1	52.2	44.7	-

Chilo infuscatellus: The incidence of *C. infuscatellus* in the release field at Behram village was 6.4 per cent as compared to 12.2 per cent in the control, which showed a 47.5 per cent reduction in damage. At Chak-Hakim village the incidence in release field was 4.4 per cent as compared to 9.2 per cent in the control, showing a 52.2 per cent reduction in damage.

Chilo auricilius: Releases of *T. chilonis* also proved very effective for the control of *C. auricilius*. The incidence of stalk borer at Behram in the release field was 4.8 per cent as compared to 12.9 per cent in control. At Chak-Hakim, the incidence in release field was 4.4 per cent as compared to 9.2 per cent in control, resulting in reducing the damage by 52.2 per cent.

Acigona steniellus: The incidence of *A. steniellus* was very low at both the locations. The reduction in damage over control in release fields was 40.5 and 44.7 per cent at Behram and Chak-Hakim, respectively.

4.18.5. Field efficacy of *T. chilonis* against shoot borer and internode borer (SBI, Coimbatore)

In four trials against shoot borer carried out in a farmer's field, the parasitoid was released @ 2cc/ac at weekly intervals for six weeks and observations on the proportion of dead hearts were recorded at weekly intervals. However, the general population of shoot borer was too low to assess the efficacy of the parasitoid.

Thirteen field trials were conducted against internode borer. The parasitoid was released @ 2cc/ac at fortnightly intervals and observations on the per cent incidence and per cent intensity were recorded from 400-600 canes/treatment at 30-45 days intervals as follows:

$$\text{Per cent incidence} = \frac{\text{Total number of affected canes in the sample}}{\text{Total number of canes in the sample}}$$

$$\text{Per cent intensity} = \frac{\text{Total number of affected internodes in all canes in the sample}}{\text{Total number of nodes in all canes in the sample}}$$

The data for one such trial is presented in Table 54. Harvest data indicated reduction of incidence in release plots (47.0%) compared to control (59.4%). The per cent intensity was also less (2.6%) in release plots compared to control (3.0%). Other trials also showed similar reduced incidence and intensity in released plots as compared to control plots.

Table 54. Internode borer incidence in *Trichogramma chilonis* evaluation trial

Observation	Per cent incidence		Per cent intensity	
	Treatment	Control	Treatment	Control
Pre-release count	36.8	14.8	8.3	3.4
I observation	19.5	24.5	3.9	5.7
II observation	35.4	31.2	4.9	4.6
III observation	40.0	47.6	2.8	3.8
IV observation	27.4	41.2	1.52	2.16
At Harvest	47.0	59.4	2.6	3.0

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

The experiment for the control of top borer, *Scirpophaga excerptalis* was conducted at Regional Research Station, Jalandhar and at farmer's field at Mehli village (Distt. Nawanshahar). Four releases of *T. japonicum* were made during May - July @ 50,000 per ha. It was compared with control and insecticide application (Carbofuran 3G @ 30 kg/ha). The plot size for all the treatments was 0.4 ha. The incidence of top borer (II and III brood) was recorded from five units of 100 canes each in each plot.

The incidence of the II brood of top borer was in general low at both the locations. The incidence of the pest in 2nd brood in different treatments at all the locations varied from 0.7 to 1.7 per cent (Table 55). In the third brood the incidence in release field at Jalandhar was 4.2 per cent as compared to control (7.9%) and insecticide treated (3.5%). At Mehli, the incidence in release fields was 5.4 per cent as compared to 4.2 per cent in the insecticidal treatment and 8.8 per cent in control. The reduction in damage in release fields over control was 46.8 and 38.6 per cent as compared to 55.7 and 52.3 per cent in insecticide treated plots at Jalandhar and Mehli, respectively.

Table 55. Evaluation of *Trichogramma japonicum* against *Scirpophaga excerptalis* at RRS Jalandhar and Mehli village (Distt. Nawanshahar)

Treatment	Release/ application date		Incidence of different broods of pest (%)			
	RRS, Jalandhar	Mehli	RRS, Jalandhar (brood number)		Mehli (brood number)	
			II	III	II	III
T. japonicum releases	02-05-2000	24-05-2000	0.7	4.2 (46.8)	0.8	5.4 (38.6)
	26-06-2000	29-06-2000				
	01-07-2000	03-07-2000				
	06-07-2000	06-07-2000				
Carbofuran @30kg/ha	01-07-2000	03-07-2000	1.6	3.5	1.2 (55.7)	4.2 (52.3)
Control		-	1.7	7.9	1.6	8.8

4.18.7. Field evaluation of *Beauveria brongniartii* against white grubs (SBI, Coimbatore)

A formulation of *Beauveria brongniartii*, mass cultured on molasses media and formulated with press-mud at the laboratory of M/s Bannari Sugar Ltd, was evaluated in the factory area in two field trials. The fungus was applied at 10^{12} - 10^{14} spores/acre as a single treatment as well as in combination with insecticides at full and half doses. Post-treatment white grub numbers in treated

Table 56. Field evaluation of *Beauveria brongiartii* and insecticides against white grubs

Treatment	Mean number of grubs per plot
Fungus 10^{12} spores/ac	40.33
Fungus 10^{13} spores/ac	51.00
Fungus 10^{14} spores/ac	55.33
Fungus 10^{12} spores/ac +full dose of chlorpyriphos	46.67
Fungus 10^{12} spores/ac + ½ dose of chlorpyriphos	34.67
$0.5x10^{12}$ spores/ac + full dose of chlorpyriphos	28.67
$0.5x10^{12}$ spores/ac + 1/2 dose of chlorpyriphos	44.33
Chlorpyriphos alone	43.00
Regent	53.00
Control	75.33
CD (P=0.05)	20.26

plots were significantly lower than in control (Table 56). A combination of fungus and chlorpyriphos gave lower grub numbers than other treatments.

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

4.18.8.1. Host-parasitoid relationship studies (Laboratory studies)

Host preference studies indicated that when shoot borer and internode borer eggs were simultaneously offered, parasitisation and adult emergence rates were higher on shoot borer eggs than on internode borer eggs. When *C. cephalonica,* shoot borer and internode borer eggs were offered, per cent parasitisation was the highest on shoot borer followed by internode borer and *C. cephalonica* (Table 57).

Table 57. Host preference of *Trichogramma chilonis*

Host	% fertilized eggs	% parasitisation	% adult emergence
C. cephalonica	93.8	80.7	87.9
Internode borer	92.1	94.0	89.9
Shoot borer	92.5	97.3	90.8

4.18.8.2. Orientation

When *C. cephalonica* and internode borer eggs were exposed to *T. chilonis* reared on *C. cephalonica*, the percentage parasitoids moving towards internode borer was slightly higher than that moving towards *C. cephalonica*. When shoot borer and *C. cephalonica* eggs were exposed, more parasitoids moved towards shoot borer. When internode borer and shoot borer eggs were exposed, more parasitoids moved towards shoot borer (Table 58).

Table 58. Orientation of *T. chilonis* adults as influenced by previous host

Choice	Per cent response of parasitoids to		Percent unresponsive
	C. cephalonica	Internode borer	
Corcyra-reared *T. chilonis*	37.1	38.8	24.2
Internode borer – passed *T. chilonis*	36.4	45.3	20.1
	C. cephalonica	Shoot borer	
Corcyra-reared *T. chilonis*	26.9	33.7	39.5
Shootborer passed *T. chilonis*	33.9	47.7	18.4
	Internode borer	Shoot borer	
Corcyra-reared *T. chilonis*	41.9 *T. chilonis*	47.6	10.5
Internode borer-passed *T. chilonis*	47.4	44.3	8.4
Shoot borer-passed *T. chilonis*	37.4	44.9	17.7

When the parasitoids reared on internode borer was exposed to *C. cephalonica* and internode borer eggs, more parasitoids moved towards internode borer. When the parasitoid was exposed to internode borer and shoot borer, more parasitoids moved towards internode borer eggs than towards shoot borer. A greater number of the parasitoids reared on shoot borer responded to shoot borer eggs than *C. cephalonica* eggs. When exposed to shoot borer and internode borer eggs, more parasitoids moved to shoot borer eggs than internode borer eggs.

4.18.8.3. Parasitization

Trichogramma chilonis cultured on *C. cephalonica* parasitised 92.9% of *Chilo partellus* eggs while that passed through *C. partellus* parasitised 93.8%. The parasitoid when passed through *C. partellus* parasitised 90.4% of *Corcyra*. *Trichogramma chilonis* passed through internode borer eggs parasitised 95.9% of the same borer while that reared on *C. cephalonica* parasitised 94.9% of internode borer. The parasitoid passed through internode borer parasitised 92.7% of *C. cephalonica* (Table 59).

Table 59. Per cent parasitism by *T. chilonis* as influenced by previous host

a. On *C. partellus*	Per cent fertilized	Per cent parasiti-sation	Per cent adult emergence
T. chilonis (passed through *C. partellus*) on *C.partellus*	81.8	93.8	90.3
T. chilonis (passed through *C. partellus*) on *C. cephalonica*	84.3	90.4	87.7
b. On internode borer			
T. chilonis (cultured on *C. cephalonica*) on internode borer	83.9	94.9	90.0
T. chilonis (passed through internode borer) on internode borer	84.9	95.9	92.9
T. chilonis (passed through internode borer) on *C. cephalonica*	85.0	92.7	89.2

4.18.8.4. Dispersal studies

The ability of the parasitoid to disperse in the field was studied in a 45-day old crop. The data indicated 67.7 and 89.7% parasitism and adult emergence, respectively, on *Corcyra* trap cards placed at 1m distance and 1.3 and 81.1%, respectively on cards placed at 12m distance.

4.18.9. Laboratory parasitisation studies with *Sturmiopsis inferens* (SBI, Coimbatore)

The sex ratio of field populations in different months generally remained male biased with mating rates of 20.0-55.6 (Table 60). In laboratory populations, however, the sex ratio tended to be female biased with higher mating rates (Table 61).

Table 60. Sex ratio and mating rates of field populations of *Sturmiopsis inferens*

Month	Male : Female	Per cent mating
July 2000	1.2 : 1	20.0
August	0.9 : 1	55.6
September	1.7 : 1	33.3

Table 61. Sex ratio and mating rates of laboratory populations of *Sturmiopsis inferens*

Month	Male : Female	% mating
January 2001	1.3 : 1	100.0
February	0.8 : 1	62.9
March	0.9 : 1	92.3

Parasitisation rates by Scaramuzza technique varied from 2.6 to 18.6 on shoot borer whereas on *Galleria* larvae, it was nil (Table 62). When reared by the King's method, parasitisation rates varied from zero to 11.8 on shoot borer whereas it was 10.5 on *Galleria* (Table 63).

Table 62. Parasitisation rates in laboratory rearing of *Sturmiopsis inferens* by Scaramuzza method

Month	Batch Number	Host	Number of larvae inoculated	Per cent parasitisation
July 2000	1	Shoot borer	104	5.8
August	1	Shoot borer	40	5.8
	2	Shoot borer	91	13.2
September	1	Shoot borer	25	4.0
	2	Shoot borer	39	2.6
January 2001	1	Shoot borer	43	18.6
	2	Shoot borer	69	6.3
	3	*Galleria*	23	0

Table 63. Parasitisation rates in laboratory rearing of *Sturmiopsis inferens* by King's method

Month	Batch Number	Host	Number of larvae inoculated	Per cent parasitisation
January 2001	1	Shoot borer	102	11.8
	2	Shoot borer	104	3.5
	3	Shoot borer	108	5.6
February	1	Shoot borer	75	5.3
	2	Shoot borer	78	1.2
	3	Shoot borer	25	0
	4	Shoot borer	90	3.3
	5	Shoot borer	51	7.8
	6	Shoot borer	45	2.2
	7	Shoot borer	84	0
	8	Galleria	200	10.5

4.18.10. Effect of sulphur and $CaSo_4$ on entomopathogenic fungi (SBI, Coimbatore)

Laboratory studies were conducted on the effect of sulphur or $CaSo_4$ added to molasses-based media at a concentration range of 0.05 - 0.5% on the growth of *Beauveria brongniartii* and two other species of fungi, *viz*., *Beauveria bassiana* and *Metarhizium anisopliae*. Radial growth, biomass production and spore production of *B. brongniartii* were not influenced by sulphur added to the media (Table 64). Similarly, $CaSo_4$ did not affect radial growth and spore production, but biomass was significantly higher at higher concentrations.

Table 64. Effect of sulphur and $CaSo_4$ added to molasses media on growth parameters of *Beauveria brongiartii*

Conc. (%)	Sulphur			$CaSO_4$		
	Radial growth (cm)	Biomass (g)	Spore no. ($x\ 10^{10}$)	Radial growth (cm)	Biomass (g)	Spore no. ($x\ 10^{10}$)
0.05	4.95	1.08	2.93	4.43	1.13	2.81
0.10	4.53	1.12	2.80	4.40	1.23	3.00
0.20	5.05	1.14	2.38	4.23	1.32	2.98
0.30	4.20	1.12	2.27	4.35	1.49	2.21
0.40	4.40	1.16	2.11	4.40	1.38	2.87
0.50	4.00	1.29	3.32	4.33	1.44	3.15
Control	4.90	1.10	2.29	4.48	1.10	2.29
F-test	NS	NS	NS	NS	**	NS
CD	-	-	-	-	0.196	-

Sulphur at all concentrations significantly reduced radial growth of *B. bassiana* compared to control but did not affect spore production (Table 65). Similarly, $CaSo_4$ reduced radial growth of the fungus significantly but not spore production. Biomass and spore production of *M. anisopliae* were not affected by sulphur content in the media (Table 66). However, $CaSo_4$ reduced radial growth of the fungus significantly but not spore production and slightly enhanced biomass at higher concentrations.

Table 65. Effect of sulphur and $CaSo_4$ added to molasses media on growth parameters of *Beauveria bassiana*

Conc. (%)	Sulphur			$CaSO_4$		
	Radial growth (cm)	Biomass (g)	Spore no. (x 10^{10})	Radial growth (cm)	Biomass (g)	Spore no. (x 10^{10})
0.05	3.68	1.04	2.36	4.05	1.04	3.56
0.10	3.53	1.08	2.53	4.08	1.12	3.13
0.20	3.18	1.05	2.01	3.90	1.08	3.37
0.30	3.35	1.07	2.33	3.95	1.08	3.28
0.40	3.63	1.07	2.65	3.58	1.14	3.32
0.50	3.10	1.10	2.87	3.98	1.15	3.33
Control	4.03	1.10	3.47	4.03	1.18	3.59
F-test	**	NS	NS	NS	**	NS
CD	0.31	-	-	-		-

Table 66. Effect of sulphur and $CaSo_4$ added to molasses media on growth parameters of *Metarhizium anisopliae*

Conc. (%)	Sulphur			$CaSO_4$		
	Radial growth (cm)	Biomass (g)	Spore no. (x 10^{10})	Radial growth (cm)	Biomass (g)	Spore no. (x 10^{10})
0.05	3.90	1.08	2.05	4.30	1.08	1.84
0.10	3.90	1.04	2.00	4.60	1.17	1.72
0.20	4.00	1.11	2.08	4.70	1.11	1.94
0.30	3.90	1.06	1.84	4.80	1.35	1.68
0.40	3.90	1.07	1.73	4.50	1.31	1.60
0.50	4.10	1.08	1.44	4.50	1.42	2.13
Control	4.30	1.00	2.20	4.50	1.00	2.20
F-test	**	NS	NS	**	*	NS
CD		-	-		0.26	-

4.18.11. Effect of herbicides on entomopathogenic fungi (SBI, Coimbatore)

Amongst the four herbicides evaluated for their effect on *Metarhizium anisopliae*, 2, 4-D reduced the radial growth of the fungus at normal as well as one-and-half times the normal dosage (Table 67). Amongst the other herbicides, paraquat showed some inhibitory effect at all the dosages tested. When two herbicides, *viz.*, paraquat and glyphosate were tested for their effect on three species of fungi (Table 68), the former generally showed higher inhibitory effect on spore production than the latter. Paraquat was uniformly toxic to the three species of fungi whereas glyphosate was more toxic to *Beauveria bassiana* than the other two fungi, particularly at higher dosages.

Table 67. Effect of herbicides on radial growth (cm) of *Metarhizium anisopliae*

Herbicide	Half dosage	Normal dosage	One-and-half dosage
Paraquat	2.6	2.2	1.6
Glyphosate	3.6	3.8	3.7
2,4-D	3.3	0	0
Atrataf	3.1	3.1	3.1
Control	3.9	3.9	3.9

Table 68. Effect of herbicides on spore production ($x10^{10}$) of different fungi

Herbicide	Dosage	*Beauveria brongniartii*	*Beauveria bassiana*	*Metarhizium anisopliae*
Paraquat	Half dosage	0.7	0.8	0.02
	Normal dosage	0.4	1.0	0.1
	One-and-half dosage	0.6	0.4	0.4
Glyphosate	Half dosage	2.4	2.4	2.1
	Normal dosage	2.5	0.7	2.3
	One-and-half dosage	2.3	0.3	1.7
Control		3.4	3.8	2.9

4.18.12. Demonstration of efficacy of *Trichogramma chilonis* releases against *Chiloauricilius* (PAU, Ludhiana)

To demonstrate the efficacy of *T. chilonis* for the control of stalk borer, *C. auricilius*, six locations, *viz.*, Khuban (Distt. Ferozepur), Karni Khera (Distt. Ferozepur), Khudi Kalan (Distt. Sangrur), Behram and Mehli (Distt. Nawanshahar) and Chak-Hakim (Distt. Kapurthala) were selected. In all the six locations 94 hectares were covered. The plot size for control was one ha at each location. *T. chilonis* was released @ 50,000 per ha during July - October at 7 days interval at

Khuban and Karni Khera and at 10 days interval at all other locations. The incidence of the stalk borer was recorded from 100 canes at five spots from all the locations.

The incidence of stalk borer in the release fields varied from 4.7 to 9.5 per cent in different locations as compared to 8.3 to 19.3 per cent in the control (Table 69). The mean incidence in release fields was 7.1 per cent as compared to 16.4 per cent in the control. The per cent reduction in damage in parasitoid released plots ranged 43.4 – 68.7 over control.

Table 69. Incidence of stalk borer in large-scale demonstration on sugarcane in different parts of Punjab

Location	Plot size (ha)	Percent incidence of stalk borer		Per cent reduction in incidence
		Release field	Control	
Khuban (Ferozepur)	44	4.7	8.3	43.4
Karni Khera (Ferozepur)	9	6.7	18.1	63.4
Khudi Kalan (Sangrur)	16	7.0	16.0	68.7
Behram (Nawanshahar)	10	8.2	18.7	56.1
Mehli (Nawanshahar)	10	9.5	19.3	50.8
Chak-Hakim (Kapurthala)	5	6.8	17.9	62.0
Total/Mean	94	7.1	16.4	58.1

Recoveries from the demonstration plots were made at all the locations except at Khudi Kalan. *T. chilonis* parasitised the eggs of *C. auricilius* throughout the season at all the five locations. At Behram, parasitism varied from 28.6 to 60.0 per cent (mean is 41.9%). The parasitism at Mehli was slightly higher as it varied from 40 to 66.7 per cent (mean=55.3%) during different months. At Chak-Hakim the mean parasitism was 53.3 per cent. The mean parasitism of *C. auricilius* eggs was 67.6 per cent at Khubaan and 73.3 per cent at Karni Khera.

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 also undertaken at regular interval from April - July. Using insecticidal sprays controlled sucking pests, wherever they reached the economic threshold levels. However, no insecticide was applied between July, and October. The incidence of different sugarcane borers was recorded at fortnightly interval from different villages in all the three sugar mills. The mean incidence of the stalk borer in IPM fields and non – IPM fields were recorded (Table 70).

Table 70. Biocontrol based IPM in different sugar mills in Punjab during 2000

Name of the sugar mill	Area (ha)	Per cent incidence of stalk borer		Per cent reduction in damage over control
		IPM	Non – IPM	
Morinda Coop. Sugar Mills Ltd., Morinda	800	1.36	6.3	77.44
Dooba Coop. Sugar Mills Ltd., Nawanshahar	600	4.10	11.20	63.39
Nahar Sugar & Allied Industries, Amloh	600	12.50	20.20	38.11
Total/Mean	2000	5.98	12.47	52.04

The incidence of stalk borer was comparatively higher in Amloh Mill area as compared to other two mills. The incidence of stalk borer in IPM fields was 1.36, 4.10 and 12.50 per cent as compared to 6.03, 11.20 and 20.20 per cent in Non – IPM fields in Morinda Co –op. Sugar Mills Ltd., Doaba Co-operative Sugar Mills Ltd., and Nahar Sugar and Allied Industries, respectively. The mean incidence of stalk borer in IPM fields was 5.98 per cent as compared to 12.47 per cent in non-IPM fields, resulting in 52.04 per cent reduction in damage over non-IPM fields. The incidence of early shoot borer, top borer and Gurdaspur borer was less than 5 per cent in the IPM fields.

4.19. Biological suppression of cotton pests

4.19.1. Biointensive integrated management of cotton pests

4.19.1.1. GAU, Anand

An experiment was laid out on var. H 10 at Agronomy Farm, B. A. College of Agriculture, Gujarat Agricultural University, Anand, with the following three treatments replicated 10 times.

T1: (IPM Module)

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

ii. Interplanting with maize

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

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

v Application of 1.0 kg/ha *P.* when any one of the bollworms are seen. If *Helicoverpa* is seen apply *Ha*NPV @ 3 X 10^{12} POB/ha. Apply systemic insecticide spray if necessary for sucking pests

T2 : Insecticidal control (Recommended insecticide)

T3 : Untreated control

The entire plot (0.2 h) was divided into 10 equal divisions. From each division 5 plants were selected at random and tagged. The observations on the population of aphid, leafhoppers, and whitefly were recorded from three randomly selected leaves of each tagged plant from lower, middle and upper region at fortnightly interval. 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 extent of parasitism. The mummified larvae (due to parasitism by *Aleiodes*) observed in field were also collected and added to the number of larvae collected while working out per cent parasitism. Number of other predators, *viz.*, *Chrysoperla carnea* (eggs + larvae), *Cheilomenes sexmaculata* (eggs + larvae + pupae + adults), *Geocoris* sp. (adults), spiders and staphylinids, were also recorded on each tagged plant at fortnightly interval. Yield was recorded and economics of treatments worked out.

The bud and boll damage was significantly lower in IPM module than control as well as insecticidal treatments. The IPM module gave significantly better protection to buds and bolls. The bud damage in IPM module was 5.01% whereas boll damage was 9.88%. The bud and boll damage in untreated plot was 13.80 and 28.98%, respectively. The bollworm damage to the locules was also significantly low in IPM block. The damage due to *E. vittella* in the IPM, insecticides and control plot was 6.80, 11.13, and 24.56%, respectively. Similarly the damage due to *P. gossypiella* in above treatments was 20.10, 29.97 and 40.08%, respectively. The population of sucking pests was also significantly lower in IPM module as compared to control. The release of *Chrysoperla* gave significantly better protection against aphid, leafhopper and whitefly. The population of aphid, leafhopper and whitefly in IPM module was 42.96, 2.65 and 2.76 per 15 leaves, respectively. The population of aphid, leafhopper and whitefly was 49.84, 4.02 and 4.02 per 15 leaves, respectively, in insecticide treated plot and 191.65, 11.82 and 7.76 per 15 leaves, respectively, in untreated control. Since IPM plots received less spray of chemical insecticides many of the bio-agents were conserved as revealed by the parasitism levels recorded. The yield in IPM module was 2444 kg/h, which was significantly superior to control (1278 kg/ha). (Table 71).

Table 71. Incidence of pests in biointensive IPM and other treatments

Treat ments	Sucking pests/15 leaves			% Damage by boll worms				Yield (kg/ha)
	Aphids	Leaf	White	Bud	Boll	Locules		
						E.V.	P.G.	
IPM	6.63 (42.96)	1.91 (2.65)	1.94 (2.76)	12.94 (5.01)	18.32 (9.88)	15.11 (6.80)	26.64 (20.10)	2444
Insecti cides	7.13 (49.84)	2.24 (4.02)	2.24 (4.02)	15.72 (7.34)	24.23 (16.84)	19.49 (11.13)	33.19 (29.97)	1667
Control	13.88 (191.65)	3.58 (11.82)	2.96 (7.76)	21.81 (13.80)	32.57 (28.98)	29.71 (24.56)	39.28 (40.08)	1278
CD	1.13	0.31	0.21	2.09	2.11	1.99	1.78	142

* $\sqrt{x+1}$ transformation

** Arc sin transformation

Figures in parentheses are retransformed values

Bollworm parasitoids, *Aleiodes aligharensi*, *T. chilonis* and *Agathis* caused 18.83, 25.07 and 31.15% parasitism, respectively, in IPM module (Table 72). Amongst the predators *Chrysoperla*, *Cheilomenes*, *Geocoris* and staphylinids were 65.83, 50.00, 15.33 and 5.17 per 25 plants in IPM module. On the other hand, population of these natural enemies was greatly hampered due to application of chemical insecticide. The per cent parasitism by *A. aligharensi* and *T. chilonis* and *Agathis* was found to be 5.82, 6.14 and 21.08% only. The count of *Chrysoperla*, *Cheilomenes*, *Geocoris* and staphylinids was 15.83, 16.67, 6.50 and 2.31 per 25 plants, respectively.

Table 72. Effect of biointensive IPM on parasitism

Parasitoid	IPM	Insecticide	Control
Egg parasitism by *T. chilonis*	25.07	6.14	13.63
Larval parasitism by *R. aligharensi*	18.83	5.82	11.85
Larval-pupal parasitism by *Agathis*	31.15	21.08	27.22

Further it was observed that intercropping of maize with cotton enhanced the activity of *C. sexmaculata* (3.60/ plant) in cotton crop in IPM block, whereas, it was 1.50/plant in control. Hand picking of infested materials enabled mechanical removal of *E. vittella* from the cotton crop and natural enemies like *Aleiodes*, *Agathis*, *Apanteles*, etc., emerged from them.

4.19.1.2. TNAU, COIMBATORE

A field trial was laid out on cotton variety LRA 5166 at Sarkar Samakulam, Coimbatore district, to evaluate the efficacy of different Integrated Pest Management (IPM) modules. The treatments included were IPM module, farmers' module, bio-control module and untreated check. Plot size was 9.3 x 3.3 m/ with four replications.

IPM module

i. Hand picking of pest stages twice during peak incidence

ii. One release of *Chrysoperla carnea* @ 14000 larvae/ha with the appearance of bollworm

iii. Four releases of *Trichogramma chilonis* @ 1,50,000/ha/week (as per pest incidence)

iv. Application of *Bt* @ 1.0 kg/ha when one of the bollworms is seen

*Ha*NPV @ $3x10^{12}$ POB/ha was applied when *H. armigera* was seen. Application of systemic insecticide spray for sucking pests was carried out when necessary.

Farmers' module

Eight rounds of insecticides were given without following ETL with recommended insecticides.

Biocontrol module

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 were given.

Biocontrol module

The bollworm larval population and per cent square and boll damage were observed once in 15 days starting form the 60^{th} day of sowing. The cotton boll damage by *H. armigera* was the lowest in the IPM module plots in the field experiment (Table 73). The overall mean damage in the IPM module was 24.89 per cent compared to 49.94 per cent in untreated check. Maximum kapas yield of 1632.2 kg/ha was obtained from these plots as against 832.4 kg/ha from untreated plots (Table 74).

Earias vittella incidence was noticed between 105-150 DAS and the pink bollworm *Pectinophora gossypiella* incidence started around the 135 DAS (Table 75). Both the pests occurred in significantly lesser numbers in the three pest management modules than in control. The occurrence of natural enemies is given in Table 76.

Regarding sucking pests, the lowest number of aphids and whiteflies were found in IPM module. Farmers' module and untreated check did not differ significantly in the number of aphids on 90 DAS and the number of whiteflies on 75 DAS. The application of insecticides without following ETL basis was ineffective in controlling sucking pests (Table 77).

Table 73. *Helicoverpa armigera* larval population in the experimental plots

Treatments	Mean of larvae on 15 plants					
	75 DAS	90 DAS	105 DAS	120 DAS	135 DAS	Mean
IPM module	26.2^{a}	21.8^{a}	15.3^{a}	9.4^{b}	13.1^{a}	17.1^{a}
Farmers' module	25.1^{a}	33.2^{d}	30.2^{b}	8.1^{a}	28.2^{c}	24.96^{c}
Biocontrol module	29.3^{b}	27.1^{b}	13.7^{a}	16.3^{c}	19.2^{b}	21.12^{b}
Untreated control	26.1^{a}	26.8^{c}	31.8^{b}	42.3^{d}	31.2^{d}	31.64^{d}

Data are means of four values; Means followed by similar letters are not statistically different by DMRT (P=0.05).

Table 74. Per cent boll damage and yield of cotton under different treatments

Treatments	Mean per cent damage of bolls						Yield (kg/ha)
	75 DAS	90 DAS	105 DAS	120 DAS	135 DAS	Mean	
IPM module	44.22^{a}	38.46^{a}	22.13^{a}	8.06^{a}	24.10^{a}	24.89^{a}	1632.2^{a}
Farmers' module	42.68^{a}	60.52^{d}	58.37^{b}	16.16^{b}	52.17^{b}	43.03^{c}	1116.8^{c}
Biocontrol module	48.11^{b}	44.31b	22.33^{a}	28.09^{a}	36.34^{b}	35.33^{b}	1432.3^{b}
Untreated control	42.12^{a}	48.06^{c}	55.18^{b}	70.12^{d}	54.08^{c}	49.94^{d}	832.4^{d}

Data are means of four values; Means followed by similar letters are not significantly different (P=0.05) taken on 15-plants/replicate plot.

Table 75. Incidence of bollworm species

Treatment	Bollworm	Mean number / 15 plants (days after sowing)				
		90	105	120	135	150
IPM module	*Earias vittella*	2.3	11.1[b]	21.3[b]	4.7[a]	1.2
	Pectinophora gossypiella	-	-	-	2.8[x]	2.8[x]
Farmers' module	*Earias vittella*	-	10.4[b]	19.2[b]	5.2[a]	3.3[b]
	Pectinophora gossypiella	-	-	-	3.2[x]	2.6[x]
Biocontrol module	*Earias vittella*	-	8.7[a]	16.6[a]	6.4[b]	5.2[c]
	Pectinophora gossypiella	-	-	-	8.2[y]	3.1[y]
Untreated control	*Earias vittella*	3.9	18.3[c]	13.2[c]	22.2[c]	19.9[d]
	Pectinophora gossypiella	-	-	-	18.2[z]	16.2[z]

a-d: omparisons for *E. Vittella*
x-z: Comparisons for *P. gossypiella*
Data are means of 4 values. Means followed by similar letters are not statistically different by DMRT (P=0.05).

Table 76. Occurrence of natural enemies and extent of parasitism of bollworms in different treatments

Treatments	Per cent egg parasitism on			Larval parasitism (%) on			Predator number /15 plants		
	Ha	Ev	Pg	Ha	Ev	Pg	Ha	Ev	Pg
IPM module	13.8	6.3	5.2	8.6	5.8	5.2	2.0	4.0	3.0
Farmers module	6.5	5.3	2.1	6.2	2.1	-	-	1.2	2.1
Biocontrol module	10.6	6.1	5.2	7.3	4.1	5.0	2.0	4.0	2.0
Control	11.5	7.8	4.8	7.5	3.1	2.6	1.0	3.0	1.0
CD (P=0.05)	1.2	0.8	1.1	0.6	1.1	1.8	-	0.4	0.2

Data are means of four values
Ha – *Helicoverpa armigera*; Ev – *Earias vittella*, Pg – *Pectinophora gossypiella*

Table 77. Incidence of sucking pests of cotton in different treatments

Treatments	Mean number/5 plants								
	Aphids			Whiteflies			Leafhoppers		
	60 DAS	75 DAS	90 DAS	75 DAS	90 DAS	105 DAS	30 DAS	45 DAS	60 DAS
IPM module	216.2	60.1^{a}	20.2^{a}	16.3^{b}	13.7^{a}	8.4^{a}	5.4^{a}	4.1^{a}	3.2^{a}
Farmers module	220.3	180.2^{b}	140.3^{b}	58.2^{c}	50.3^{c}	40.3^{b}	16.3^{b}	18.7^{c}	26.2^{c}
Biocontrol module	196.1	56.5^{a}	20.2^{a}	12.4^{a}	16.1^{b}	3.2^{a}	4.2^{a}	3.1^{a}	2.8^{a}
Control	210.2	180.3^{b}	142.8^{b}	60.6^{c}	56.5^{d}	52.3^{c}	16.3^{b}	13.4^{b}	18.2^{b}

Data are means of 4 values

Observations taken on 5 tagged plants per replicate plot, 20 plants/treatment

Means followed by similar letters are not statistically different ($P = 0.05$)

4.19.1.3. MPKV, Pune

The experiment on field evaluation of BIPM module in comparison with insecticidal control and untreated control was laid out at Cotton Improvement Project, MPKV, Rahuri, in RBD with 10 replications. The treatments consisted of

T1. IPM Module

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

ii. Interplanting of maize

iii. One release of *Chrysoperla carnea* @ 14,000 larvae/ha

iv. Four releases of *Trichogramma chilonis* @ 1.5 lakh adults/ha/week as per pest incidence

v. Application of *Bt* @ 1.0 kg/ha at the appearance of *Earias* spp.

vi. Spraying of *Ha*NPV @ $3x10^{12}$ POBs/ha against *H. armigera;*

T2. Insecticidal control (as per state recommendation)

T3. Untreated control.

Cotton (var. NHH 44) was grown in plots of 0.20 ha size at 90x90 cm, which was further divided into 10 equal blocks. From each block, 5 plants were selected at random and tagged. Observations on population of aphids, leafhoppers and thrips were recorded form 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 bolls were counted from each tagged plant fortnightly and the extent of damage (%) was worked out.

The number of eggs, larvae, pupae and adults of coccinellids and *Chrysoperla carnea* were recorded on each tagged plant at fortnightly interval. Yield data were also recorded.

Results indicated that the population of sucking pests, *viz*., aphids, leafhoppers, and thrips was significantly low in the treatment plots of IPM module and insecticidal application. Bolls and locules damaged by bollworms were significantly low in the insecticidal treatment, followed by IPM module. The population of *Chrysoperla carnea* and coccinellids per 25 plants were maximum (56.87 and 43.50) in the plots of IPM module and minimum (11.62 and 10.87) in insecticide treated plots. *Chrysoperla* and coccinellids were observed to be more on cotton crop (26.90 and 22.74) than on interplanted maize (21.00 and 12.23). The yield data from IPM module and insecticidal treatments were on par but significantly higher than that in untreated control (Table 78).

Table 78. Efficacy of BIPM module against sucking pests and bollworms in cotton

Treatment	Sucking pests/15 leaves*			Per cent damage by boll worms**		Yield in kg/ha
	Aphid	Leaf-hoppers	Thrips	Boll	Locule	
IPM Module	8.50 (72.27)	3.04 (9.04)	2.18 (4.57)	33.54 (35.36)	33.06 (35.06)	1096.67
Insecticide	10.08 (105.97)	3.11 (9.68)	2.25 (4.72)	25.73 (30.13)	25.55 (30.35)	1154.67
Control	11.34 (136.29)	3.89 (14.89)	3.23 (10.07)	39.95 (39.28)	41.74 (40.22)	769.11
CD (P=0.05)	(1.53)	(0.55)	(0.49)	(3.13)	(2..90)	84.70

Figures in parentheses are $*\sqrt{n+0.5}$ and ** angular transformed values.

4.19.1.4. ANGRAU, Hyderabad

An experiment on biointensive-integrated management of cotton pests was laid out at Agricultural Research Station, Warangal, with the following treatments.

T1 IPM module

Hand picking of pest stages and putting them in wire screen cage

Sowing of maize as an intercrop

One release of *Chrysoperla carnea* @ 14,000 larvae/ha synchronizing with the occurrence of bollworms

Eight releases of *T. chilonis* each @ 1,50,000/ha/week synchronizing with the appearance of eggs of bollworms

Need based application of *Ha*NPV @ 3 x 10^{12} POB/ha (500 LE/ha) and systemic insecticides against sucking pests

T2 Judicious use of insecticides (JUI)

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

T3 Untreated control

Observations were recorded in all the treatments on sucking pests by observing the number of leafhoppers and white flies on lower, middle and upper regions on 5 randomly selected plants at 10 spots and also per cent aphid infested plants. Presence of bollworms in different treatments 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. and bolls damaged by *H. armigera*. Data on natural enemies were collected by counting the number of coccinellids, spiders and *Chrysoperla* per plant basis. Yield in different treatments for kapas on q/ha basis was recorded. Finally the inputs and outputs were pooled to calculate and compare cost-benefit ratio.

The results revealed that leafhopper and aphid incidence was low in all the treatments as compared to control (Table 79). The damage by *H. armigera* was lowest in JUI and closely followed by IPM module, whereas in control higher damage levels were recorded. Coccinellids, spiders and lacewings were more abundant in IPM module and control, but in less numbers in JUI. The kapas yield was highest in JUI method followed by IPM module and lowest in control. Cost-benefit ratio was highest in IPM module followed by JUI.

Table 79. Biointensive integrated management of cotton pests

Particulars	IPM	Insecticides	Control
Sucking pests			
Leafhoppers (No./leaf)	3.75	4.50	9.80
Whiteflies (No./leaf)	54.40	55.20	63.80
Aphids (% infested plants)	4.00	6.00	7.00
Bollworms			
Eggs of *H. armigera*/plant	1.44	2.46	0.84
Larvae of *H. armigera*/plant	2.24	1.20	0.68
Damage (%)			
Squares	46.15	36.22	43.88
Bolls	30.26	19.50	32.35
Number of natural enemies			
Coccinellids/plant	1.89	0.63	1.32
Spiders (per plant)	1.98	0.85	4.70
Lace wings eggs/plant	2.60	0.55	3.30
Lace wings adults/plant	1.65	0.23	2.12
Yield			
Kapas (Q/ha)	15.25	18.02	10.86
Returns from cotton (Rs.)	33550.00	39644.00	23760.00
Returns from intercrop (Rs.)	8500.00	-	-
Total returns (Rs.)	42050.00	39644.00	23760.00
Net returns (Rs.)	38350.00	34644.00	23760.00
Cost-benefit ratio	1:3.94	1:2.10	-

4.19.1.5. PAU, Ludhiana

The experiments for the management of cotton pests were carried out at Dangar Khera (Distt. Ferozepur) and Khuban (Distt.Ferozepur). At Dangar Khera in the IPM module, 12 releases of *T. chilonis* were made at weekly interval @ 50,000 per ha during July-September. Two sprays of imidacloprid were given for the control of sucking pests. It was compared with the farmers' practice. The plot size was 6 ha (2 ha each for three varieties) each for both the treatments. At village Khuban, releases of *T. chilonis* were integrated with insecticides and compared with PAU spray schedule and control. The plot size for integrated use of parasitoid and insecticide was 10 ha, for PAU spray schedule 2 ha and for control 0.2 ha. One spray of imidacloprid was given for the control of sucking pests.

The incidence of bollworms in shed fruiting bodies (58.0%) and mature bolls (42.2%) was very high in biocontrol as compared to farmer's practice (9.7 and 8.7 per cent). The parasitisation of eggs of *H. armigera* in biocontrol varied from 2.4 to 9.4 per cent, while no parasitisation was observed in farmer's practice. The yield was very high (18.50 q/ha) in farmer's practice as compared to biocontrol (18.50 q/ha) (Table 80).

The integration of *T. chilonis* with insecticides proved more effective than insecticides alone and untreated control. The incidence of bollworm in shed fruiting bodies was 16.7 per cent in PAU spray schedule and 13.3 per cent in *T. chilonis* + insecticides as compared to 36.1 per cent in control. The bollworm damage in insecticides (4.8%) and insecticides + *T. chilonis* (3.3%) was lower than control (17.6%). The per cent parasitisation of *H. armigera* in release fields varied from 2 to 5 per cent. No parasitisation was observed in control and PAU spray schedule. The yield in PAU spray schedule (18.90 q/ha) and *T. chilonis* + insecticides (20.50 q/ha) was higher than that in control (Table 81).

Table 80. Biocontrol based management of cotton bollworms at Dangar Khera (Distt. Ferozepur)

Treatment	Incidence in shed fruiting bodies (%)		Per cent boll damage	Per cent parasitisation of *H. armigera* eggs				Yield (q/ha)
	Earias sp.	*H. armigera*		14.9.2000	21.9.2000	28.9.2000	6.10.2000	
Biocontrol*	9.7	48.3	42.9	2.9	3.8	9.4	2.4	3.80
Farmer's Practice**	3.0	6.7	8.7	0	0	0	0	18.50

Table 81. Integration of *Trichogramma chilonis* releases with insecticides for the control of bollworm complex at Khuban (Distt. Ferozepur)

Treatment	Incidence in shed fruiting		Per cent boll damage	Per cent parasitism			Yield (q/ha)
	Earias sp.	*H. armigera*		14.9.2000	29.9.2000	6.10.2000	
T_1 *Trichogramma chilonis* + Insecticides	3.7	9.6	3.3	2.0	4.0	5.0	22.50
T_2 PAU spray schedule	5.0	11.7	4.8	0	0	0	18.90
T_3 Control	8.3	27.8	17.6	0	0	0	12.63

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

The efficacy of inundative release of *T. chilonis* in combination with *Chrysoperla carnea* against cotton pest complex was evaluated at Agronomy Farm, B. A. College of Agriculture, Gujarat Agricultural University, Anand. The following three treatments were replicated 10 times.

T1 *T. chilonis* @ 1,50,000/ ha/week, releases synchronized with the appearance of bollworms and *C. carnea* @ 14,000/ha twice a week

T2 Insecticidal control (Recommended insecticide)

T3 Untreated control

The bud and boll damage was significantly lower in release plot than control and insecticidal treatments (Table 82). The bud damage in release plot was 5.39 per cent whereas boll damage was 10.65 per cent. The bud and boll damage in untreated plot was 13.80 and 28.98 per cent, respectively. The bollworm damage to the locules was also significantly low in release plot. The damage due to *E. vittella* in the release plot, insecticides and control plot was found to be 8.19, 11.13, and 24.56 per cent, respectively. Similarly the damage due to *P. gossypiella* in the above treatments was 22.80, 29.97 and 40.08 per cent, respectively. The population of sucking pests was also significantly lower in release plot as compared to control. The release of *Chrysoperla* gave protection against aphid, leafhopper and whitefly. The population of aphids, leafhoppers and whiteflies was 45.79, 3.04 and 3.00 per 15 leaves, respectively, in release plot, 49.84, 4.02 and 4.02 per 15 leaves, respectively, in insecticide treated plot and 191.65, 11.82 and 7.76 per 15 leaves, respectively, in untreated control (Table 83).

Table 82. Effect of inundative release of *T. chilonis* in combination with *C. carnea*

Treatment	Sucking pests/15 leaves			Damage by boll worms (%)				Yield (kg/ha)
	Aphids	Leaf hoppers	White flies	Bud	Boll	Locules E.V.	P.G	
T c + C. c	6.84 (45.79)	2.01 (3.04)	2.00 (3.00)	13.42 (5.39)	19.05 (10.65)	16.63 (8.19)	28.53 (22.80)	2278
Insect icides	7.13 (49.84)	2.24 (4.02)	2.24 (4.02)	15.72 (7.34)	24.23 (16.84)	19.49 (11.13)	33.19 (29.27)	1667
Control	13.88 (191.65)	3.58 (11.82)	2.96 (7.76)	21.81 (13.80)	32.57 (28.98)	29.71 (24.56)	39.28 (40.08)	1278
CD (P=0.05)	1.16	0.29	0.18	1.88	1.07	1.63	1.50	112

* $\sqrt{x+0.5}$ transformation ** Arc sin transformation

Figures in parentheses are retransformed value

Table 83. Effect of biointensive IPM on population of biocontrol agents

Months	*Chrysopa*			*C. sexmaculata*			*Geocoris* sp.			Staphylinid		
Control	IPM	Insecticides	Control	IPM	Insecticides	Control	IPM	Insecticides	Control	IPM	Insect	Control
August I	30	15	20	55	21	50	12	6	10	0	0	0
August II	40	17	25	70	19	60	19	8	18	0	0	0
September I	83	25	39	99	30	78	25	9	15	0	0	0
September II	125	20	52	42	15	32	15	7	12	10	3	5
October I	86	8	30	19	8	18	10	5	9	12	4	8
October II	31	10	18	15	7	17	11	4	8	9	3	7
Mean	65.83	15.83	30.69	50	16.67	42.50	15.33	6.50	12.00	5.17	2.31	3.33

Since release plot received no spray of chemical insecticides many of the bio-agents were conserved. Bollworm parasites *Aleiodes aligharensi*, *T. chilonis* and *Agathis* caused 17.60, 25.50 and 30.32 per cent parasitism, respectively, in release plot. Amongst the predators *Chrysoperla*, *Cheilomenes*, *Geocoris* and staphylinids were 70.67, 45.17, 13.50 and 4.11 per 25 plants in the release plot. On the other hand population of these natural enemies was greatly hampered in chemical insecticide plot. The per cent parasitism by *A. aligharensi*, *T. chilonis* and *Agathis* was found to be 5.82, 6.14, and 21.08 per cent only. The count of *Chrysoperla*, *Cheilomenes*, *Geocoris* and staphylinids was 15.83, 16.67, 6.50 and 2.31 per 25 plants, respectively.

The yield in release plot was 2278 kg/h was significantly superior to control (1278 kg/ha).

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

The efficacy of inundative release of *T. chilonis* in combination with *Chrysoperla carnea* against cotton pest complex was evaluated with three treatments replicated 10 times.

T1 Single release of *C. carnea* @ 14,000/ha

T2 Two releases of *C. carnea* @ 14,000/ha

T3 Untreated control

The bud and boll damage was significantly lower in release plots than control. Both the release plots gave significantly better protection to buds and bolls (Table 84). The bud damage in T1 and T2 was 10.84 and 7.11%, respectively and boll damage was 21.95 and 17.16, respectively. The bollworm damage to the locules was also significantly low in both the release plots. The damage due to *E. vittella* in the release plots T1, T2 and control was 14.95, 11.83, and 24.56%, respectively. Similarly the damage due to *P. gossypiella* in the above treatments was 35.13, 30.56, and 40.08%, respectively. The population of sucking pests was also significantly lower in release plots as compared to control. The release of *Chrysoperla* gave significantly better protection against aphids, leafhoppers and whiteflies. The population of aphid, leafhopper and whitefly was 56.30, 4.57, and 4.66 per 15 leaves, respectively, in T1, 48.28, 3.49, and 3.37 per 15 leaves, respectively in T2 and 191.65, 11.82 and 7.76 per 15 leaves, respectively in untreated control. Since release plots did not receive any chemical insecticide spray many bioagents were conserved. Bollworm parasites *Aleiodes aligharensi, T. chilonis* and *Agathis* caused 12.66, 8.04 and 27.50% parasitism, respectively in T1, whereas the same in T2 was 14.78, 13.69, and 28.10, respectively. *Chrysoperla, Cheilomenes, Geocoris* and staphylinids were 60.00, 43.00, 11.00 and 3.83 per 25 plants, respectively, in T1, whereas the corresponding values in T2 were 69.83, 45.33, 13.17 and 4.00, respectively. The per cent parasitism by *A. aligharensi, T. chilonis* and *Agathis* was 5.82, 6.14 and 21.08% only in control. The count of *Chrysoperla, Cheilomenes, Geocoris* and staphylinids was 15.83, 16.67, 6.50 and 2.31 per 25 plants, respectively.

Table 84. Impact of inundative release of *C. carnea*

Treatment	Sucking pests / 15 leaves			Per cent damage by boll worms				Yield (kg/ha)
	Aphids	leaf hoppers	White flies	Bud	Boll	Locules E.V.	Locules P.G.	
C. carnea 2 releases	7.02* (48.28)	2.12 (3.49)	2.09 (3.37)	15.46 (7.11)	24.47 (17.16)	20.12 (11.83)	33.56 (30.56)	1833
C. carnea 1 Release	7.57 (56.30)	2.36 (4.57)	2.38 (4.66)	19.22 (10.84)	27.94 (21.95)	22.75 (14.95)	36.35 (35.13)	1556
Control	13.88 (191.65)	3.58 (11.82)	2.96 (7.76)	21.81 (13.80)	32.57 (28.98)	29.71 (24.56)	39.28 (40.08)	1278
CD (P=0.05)	1.13	0.34	0.21	0.84	2.35	2.77	1.46	119

* $\sqrt{x+1}$ transformation ** Arc sin transformation

Figures in parentheses are retransformed values

The yield in release plot was 1556 and 1833 kg/ha in T1 and T2, respectively, and significantly superior to control (1278 kg/ha).

4.19.4. Evaluation of *Bt* products on *Helicoverpa armigera* in cotton (TNAU, Coimbatore)

A field trial was conducted at Puthur village near Coimbatore on variety LRA 5166. Totally four sprays were given and observations were recorded at weekly intervals on per cent boll damage, larval population of bollworm complex, number of natural enemies and yield. Four *Bt* products (Delfin, Biolep, Spicturin and Spic-Bio) were evaluated @ 1 kg/ha with endosulfan 0.07% as standard. The observations were made on 5 randomly selected plants.

All the treatments gave effective control of bollworms throughout the treatment period, when compared to control. In the pre-treatment count per cent boll damage ranged between 3.21 and 6.91. On 7 DAT of first spray, all the *Bt* products were significantly superior to control and on par. A similar trend was observed on 7 DAT of third and fourth sprays. On 7 DAT of second spray, Delfin and Spic-Bio recorded less boll damage (7.03 to 5.98), and were significantly superior to other *Bt* products but on par with endosulfan (0.07%). All the *Bt* products reduced boll damage and were on par with endosulfan (0.07%). The yield data recorded also showed an increase in all the treated plots when compared to control (Table 85).

Among the natural enemies, the coccinellids, *C. sexmaculata* was observed because of which the sucking pest population was kept under check. The range of mean population observed was 0.4 - 2.2. Other natural enemies like *Chrysoperla carnea* and spiders were also observed. The application of *Bt* formulations did not have a deleterious effect on coccinellids.

Table 85. Effect of *Bt* and insecticide on cotton bollworm complex and yield

Treatments	Per cent boll damage						Yield (kg/ha)
	Pre-treatment	7 DAT					
		I Spray	II Spray	III Spray	IV Spray	Mean	
Delfin 1000 g/ha	4.51	3.18 (9.91)^{a}	7.03 (15.26)^{ab}	8.52 (16.94)^{a}	4.53 (12.11)^{a}	5.82 (13.55)	1656^{a}
Biolep 1000 g/ha	6.80	3.09 (10.03)^{a}	8.84 (17.28)^{bc}	7.54 (15.78)^{a}	6.18 (14.25)^{a}	6.41 (14.33)	1544^{a}
Spicturin 1000 g/ha	5.25	3.51 (10.61)^{ab}	9.10 (17.73)^{bc}	8.80 (17.14)^{a}	4.98 (12.67)^{a}	6.60 (14.44)	1600^{a}
Spicbio 500 ml/ha	6.91	2.22 (8.40)^{a}	5.98 (14.09)^{a}	10.23 (18.33)^{a}	6.29 (14.29)^{a}	6.18 (13.78)	1632^{a}
Endosulfan 0.07%	3.21	2.00 (8.10)^{a}	8.11 (16.42)^{ab}	7.97 (16.26)^{a}	4.51 (12.10)^{a}	5.65 (13.22)	1736^{a}
Untreated control	3.72	4.98 (12.80)^{b}	11.35 (19.67)^{c}	13.11 (21.22)^{b}	11.37 (19.69)^{b}	10.20 (18.37)	1088^{b}

Means followed by a common letter are not significantly different by DMRT P = 0.05.

4.19.5. Identification of alternate hosts for natural enemies

4.19.5.1. TNAU, Coimbatore

Coccinella transversalis grub was collected and reared from the grass on the bunds. *Chrysoperla carnea* was observed in nearby red gram and sorghum fields feeding on aphids and *H. armigera* eggs.

4.19.5.2. ANGRAU, Hyderabad

Survey of cotton fields around cotton growing areas of Mahaboobnagar, Warangal and Ranga Reddy districts was carried out to record the host plants that harbour arthropod natural enemies. Eggs and caterpillars of different pests of cotton were collected from alternate hosts such as *Earias* sp. on bhendi, *H. armigera* on tomato, chickpea, pigeon pea and sorghum, *S. litura* on cabbage and castor, but none was found parasitised.

4.19.6. Studies on the natural enemy complex of *Helicoverpa armigera* (PAU, Ludhiana)

The eggs and larvae of *H. armigera* were collected at regular intervals from different parts of the state and reared in the laboratory until the emergence of parasitoids or the next stage of the pest.

No larval parasitoid of *H. armigera* was collected. However, *Trichogramma chilonis* emerged from 990 eggs collected from the second fortnight of September to first week of October. The egg parasitism in different fields varied from 2.4 to 13.6 per cent and only in 9 samples parasitism was seen out of 20 samples collected and these were from release plots.

4.20. Biological suppression of tobacco pests

4.20.1. Testing of talc based formulation of *Steinernema carpocapsae* against *Spodoptera litura* in tobacco nursery (CTRI, Rajahmundry)

Talc based formulation of entomopathogenic nematode (EPN) *Steinernema carpocapsae* at three doses, *viz.*, @ 1 lakh IJ (Infective juvenile), 2 lakh IJ, 4 lakh IJ/m^2 and *Sl*NPV alone @ 1.5 x 10^{12} PIB/ha were evaluated in comparison with chlorpyriphos (0.05%) for their efficacy against late second instar larvae of *Spodoptera litura* in tobacco nursery.

Nursery beds of 1 m^2 were prepared and six-week-old seedlings of variety VT 1158 were transplanted @ 400 on each bed. The experiment was laid out in a randomized block design and the treatments were replicated thrice. At 10 days after transplanting, the EPN, @ 1 lakh IJ, 2 lakh IJ and 4 lakh IJ were broadcast with 250 g of sand and watered. In case of combination treatment, the EPN @ 1 lakh IJ was applied and thereafter *Sl*NPV @ 1.5 x 10^{12} PIB/ha was sprayed on the same beds. Chlorpyriphos alone at 0.05% was also sprayed as separate treatment. After application of nematodes and before spraying of *Sl*NPV and chlorpyriphos, laboratory reared late second instar larvae @ 30 per 1 m^2 bed were released. All the treated beds were caged with nylon nets to avoid predation.

Observations were recorded on number of seedlings damaged/m^2 bed at 2 and 9 days after treatment. The number of surviving larvae was also recorded in each treated bed and untreated control at 2 days after treatment.

The results indicated that all the doses of EPN, EPN + *Sl*NPV, *Sl*NPV alone and chlorpyriphos gave superior protection to tobacco seedlings from damage caused by *S. litura* over untreated control at 2 and 9 days after treatment. Significant reduction of *S. litura* larvae was also recorded in all the treatments as compared to control (untreated).

At 2 days after treatment, chlorpyriphos (0.05%), while remaining on par with combination treatments of EPN @ 1 x 10^5 IJ/ 1 m^2 + *Sl*NPV @ 1.5 x 10^{12} PIB/ha, was significantly superior to the rest of the treatments. However, combination of EPN, *Sl*NPV alone and EPN @ 4 x 10^5 IJ were equally effective and significantly superior to EPN @ 1 x 10^5 IJ and 2 x 10^5 IJ/1 m^2.

Even though EPN at higher dose, combination of EPN with *Sl*NPV and *Sl*NPV alone significantly reduced the number of seedlings damaged, they could not protect the tobacco seedlings below the threshold level of 6 seedlings/m^2. Chlorpyriphos could keep the damage below the threshold level.

At 9 days after spraying chlorpyriphos recorded less seedling damage and was significantly superior to the rest of the treatments. The combination treatment of EPN with *Sl*NPV while not differing from *Sl*NPV alone was significantly superior to the rest of the EPN treatments.

With increase of EPN doses there was a significant reduction in population of *S. litura*. However, EPN @ 1 x 10^5 IJ/ 1 m^2 in combination with *Sl* NPV @ 1.5 x 10^{12} PIB/ha was significantly superior

Table 86. Effect of EPN on seedling damage and survival of *S. litura* larvae

Treatment	Mean number of seedlings damaged		Mean number of larvae survived
	2 days	9 days	
S. carpocapsae @ 1 x 105 IJ	26.33	35.67	20.67
S. carpocapsae @ 2 x 105 IJ	17.3	30.33	15.33
S. carpocapsae @ 4 x 105 IJ	11.6	20.67	11.33
S. carpocapsae @ 1 x 105 IJ + SlNPV 1.5 x 1012 PIB/ha	8.67	14.67	8.00
SlNPV 1.5 x 1012 PIB/ha	10.00	15.67	10.00
Chlorpyriphos @ 0.05%	4.00	5.33	0.0
Control	91.67	121.33	27.67
CD (P=0.05)	5.94	5.80	0.37

to all the doses of EPN and *Sl* NPV alone in reducing the larval population. None of the larvae survived in chlorpyriphos treated plot (Table 86).

4.20.2. Evaluation of FCV germplasm for pest incidence and natural enemies (CTRI, Rajahmundry)

FCV germplasm accessions raised in CTRI nursery and Katheru farm were screened for incidence of *S. litura* and *H. armigera* and their natural enemies. The nursery beds of 0.5 m^2 size were given non-chemical plant protection measures. In tobacco field, microplots of 20 plants each were maintained likewise.

Observations were recorded on the incidence of *S. litura* in the nursery and *H. armigera* in the field. The incidence was scored as low, moderate and severe based on number of second instar larvae present in 0.5 m^2 bed or per plant. In case of *S. litura* below 5 larvae as low, 5-10 moderate and above 10 severe and in case of *H. armigera* 2 as low, 2-5 as medium and above 5 as high. The presence or absence of natural enemies was based on collections per 0.5 m^2 or per microplot of 20 plants.

Out of 400 accessions screened, the incidence of *S. litura* and *H. armigera* was high in several accessions of Bell and Cocker series. It was also observed that presence of natural enemies like *Campoletis chlorideae*, *Peribaea* sp., *Chelonus* sp., reduviids, syrphids, etc., were high in the nursery while *Campoletis chlorideae*, *Carcelia* sp. and *Apanteles* sp. were high in the field.

4.21. Biological suppression of pulse crop pests

4.21.1. Biological control based management of pod borer complex in pigeon pea (GAU, Anand)

An experiment was laid out to study the biocontrol based management modules for the control of pod borer complex in pigeon pea using variety BDN 2. There were six treatments with six replications.

T1 *Bt* - *Ha*NPV - *Bt*- *Ha*NPV
T2 *Bt* - *Ha*NPV - Endosulfan - *Bt*
T3 Endosulfan - *Bt* - *Ha*NPV - *Bt*
T4 NSKE - *Bt* - *Ha*NPV - *Bt*
T5 Endosulfan 3 sprays at 15 days interval
T6 Control

Initial population of pod borer complex was recorded on 10 randomly selected plants/plot and on three branches per plant. Subsequent observations were recorded after 7 days of each spray. One more observation was taken to adjust even number of observation in case of T5. Seed damage at harvest on 10 randomly selected plants per plot and 3 branches per plant was recorded. Blister beetle was also monitored. Yield record was taken at the time of harvest.

The population of *H. armigera* was low. However, all the treatments were significantly superior to control. Amongst the treatments, *Bt* - *Ha*NPV - *Bt*- *Ha*NPV and endosulfan three sprays at 15 days interval (1.96 & 1.89 larvae/10 plants, respectively) were found superior to control (6.13 larvae/ 10 plants) which also reflected in per cent pod damage (6.36 & 6.61 per cent, respectively) and yield (1376 & 1339 kg/h, respectively) (Table 87).

Table 87. Efficacy of different modules for control of pod borer complex in pigeon pea

Treatments	Periods (mean larval population per 3 branches/ 10 plants					Per cent pod damage	Per cent grain damage	Yield kg/h
	P1	P2	P3	P4	Mean			
Bt - *Ha*NPV - *Bt*- *Ha*NPV	1.49	2.06	1.93	1.39	1.72 (1.96)	14.61 (6.36)	10.40 (3.26)	1376
Bt - *Ha*NPV - Endosulfan – *Bt*	1.57	2.12	2.22	1.93 (2.84)	1.96 (7.87)	6.29 (4.74)	12.57	1071
Endosulfan - *Bt* - *Ha*NPV – *Bt*	1.57	2.12	2.10	2.05	1.96 (2.84)	6.68 (8.24)	12.68 (4.82)	1010
NSKE - *Bt* - *Ha*NPV – *Bt*	1.65	2.17	1.90	1.70	1.86 (2.46)	16.28 (7.86)	12.78 (4.89)	1051
Endosulfan 3 sprays at 15 days interval	1.49	2.05	1.87	1.39	1.70 (1.89)	14.90 (6.61)	10.99 (3.63)	1339
Control	2.23	2.55	3.03	2.87	2.67 (6.13)	7.45 (8.99)	15.21 (6.88)	780
CD (P=0.05) T P TxP					0.17 0.16 NS	0.72 - -	- 2.51 -	- 2.93 -

Figures in parenthesis are $\sqrt{x+1}$ transformed values

A survey in and around the fields of pigeon pea was done to see the association of natural enemies on weed and other hosts. Table 88 gives the host plants and the natural enemies harboured by them.

BIPM of pigeon pea with special reference to pigeon pea pod borer complex (TNAU, Coimbatore)

A field trial was conducted at Puthur, Coimbatore district, to evaluate IPM strategies for pod borer complex. The treatments were *Ha*NPV – NSKE – *Ha*NPV – NSKE alternate sprays; *Bt* – NSKE – *Bt* – NSKE; NSKE 5% (4 rounds); Endosulfan and control

Table 88. Host plants harboring natural enemies

Host plant	Natural enemies
Rustica tobacco	Mirid bug, *Rhinocoris*, *Bracon* sp., *Geocoris* sp.
Bidi tobacco	Mirid bug, *Rhinocoris*, *Bracon* sp., *Geocoris* sp.
Sunnhemp	*Geocoris* sp.
Marigold	*Trichogramma*, *Geocoris*, *Nabis*, *Rhinocoris*, Spider-crab
Maize	*C. sexmaculata*, *Xanthogramma*, *Geocoris* sp., Anthocorid, *C. carnea*, *C. tubiana*.
Weed hosts - Matsagandha, Cassia, star burr, Parthenium, Duranta	*Trichogramma*, *C. carnea*, etc.

Spraying was initiated when the pest appeared on the 70th day and subsequently at 15 days interval. Larval counts of *Helicoverpa armigera* and plume moth were taken from 3 branches of 10 randomly selected plants per plot, 7 days after each spray. Pod fly and pod wasp infestation was recorded twice from 100 pods of 10 randomly selected plants once at maturation and later at harvest. The larval populations of *H. armigera* crossed ETL on the 70th day of sowing, the highest being on 85 DAS in all the plots. The pod borer damage at full maturation was the lowest in endosulfan treated plots (4.1%), followed by *Ha*NPV – NSKE – NSKE treatment (5.1%) (Table 89). Besides *H. armigera*,

Table 89. Occurrence of various pod borers at pigeon pea experimental plots.

Treatments	7 DAT (85 DAS)				Numbers/10 plants at maturation (135 DAS)				At harvest time			
	Ha	Pf	Pw	Pm	Ha	Pf	Pw	Pm	Ha	Pf	Pw	Pm
*Ha*NPV-NSKE-*Ha*NPV-NSKE	27.2	8.25^{a}	1.2^{a}	6.0^{a}	17.68^{d}	0.66^{a}	0.09^{a}	0.48^{a}	14.14^{d}	0.49^{a}	0.07^{a}	0.36
Bt-NSKE-*Bt*-NSKE	21.6	18.0^{b}	19.5^{b}	7.5^{b}	11.88^{b}	1.44^{b}	1.56^{b}	0.60^{a}	7.12^{b}	1.08^{b}	1.17^{b}	0.45
NSKE	18.0	15.7^{b}	0.5^{a}	5.5^{a}	14.4^{c}	1.25^{ba}	0.04^{a}	0.44^{a}	7.92^{b}	0.94^{b}	0.03^{a}	0.33
Endosulfan 350 g/ha	19.5	7.2^{a}	0.7^{a}	7.7^{b}	7.7^{a}	0.58^{a}	0.05^{a}	0.61^{a}	6.16^{a}	0.43^{a}	0.43^{a}	0.46
Control	21.3	16.8^{b}	22.3^{b}	13.2^{c}	18.3^{c}	1.34^{b}	1.78^{c}	1.05^{b}	11.3^{c}	1.00^{b}	1.33^{b}	0.79
	NS											NS

Ha – *Helicoverpa armigera;* Pf – Pod fly *Melanagromyza* spp., Pw – Pod wasp, Pm – Plume moth pod fly, pod wasp and plume moth were the pod pests recorded at maturation and at harvest time. All the pests were in significantly lower numbers in the treatments than in control plots Pigeon pea yield was highest in NSKE treated plots (997 kg/ha) followed by endosulfan (1164 kg/ha), compared to 939 kg/ha from untreated check (Table 90).

Table 90. Effect of IPM treatments on *Helicoverpa armigera*, total pod borer damage and yield of pigeon pea (CO 5)

Treatments	Pre-treatment *H. armigera*		*H. armigera* larval population				Peak pod borer damage (%)	% pod borer damage at maturation *	Grain yield (kg/ha)
	Eggs	Larvae	85	100	115	130			
*Ha*NPV-NSKE-*Ha*NPV-NSKE	19	7.7^{a}	27.2	8.2^{b}	17.68^{d}	4.3^{b}	6.9^{b}	5.14^{b}	1077^{c}
Bt-NSKE-*Bt*-NSKE	19	11.1^{b}	21.6	9.9^{b}	11.88^{b}	5.1^{c}	9.2^{c}	5.50^{b}	1055^{d}
NSKE	22	7.5^{a}	18.0	6.2^{a}	14.40^{c}	2.1^{a}	4.2^{a}	7.58^{c}	997^{a}
Endosulfan 350 g/ha	27	9.3^{b}	19.5	7.8^{a}	7.70^{a}	2.8^{a}	6.1^{b}	4.20^{a}	1164^{b}
Control	26	11.6^{b}	21.3	23.1^{c}	18.3^{e}	16.2^{d}	17.1^{d}	12.47^{d}	939^{e}
	NS		NS						

Means followed by similar letters are not statistically different by DMRT (P = 0.05)

4.21.2. Effect of entomopathogenic nematode *Heterorhabditis* sp. on *Helicoverpa armigera* in pigeon pea (ANGRAU, Hyderabad)

An experiment was carried out to test the efficacy of different doses of entomopathogenic nematode, *Heterorhabditis* sp. against *Helicoverpa armigera* in randomized block design (RBD) with 6 treatments including control and replicated 4 times. Pigeon pea variety "Asha" was used and plot size was 25 m^2. Spray application of three different doses of nematode, *viz*., 0.5, 1.0, and 2 billion/ha was implemented with two more treatments with endosulfan (0.07%) and *Ha*NPV (250 LE/ha) and control for comparisons. The sprays were given during evening hours at 50% flower initiation stage of the crop. Pre-count of the larval population was recorded prior to administering the treatments. A post-treatment irrigation was given to maintain humidity levels in the field. Larval populations were counted on 10 randomly selected plants per plot before and 7, 10 and 15 days after the sprays. For computation of per cent pod damage, total number of pods and damaged pods were counted on 10 randomly selected plants per plot.

All the nematode treatments were superior to control as well as endosulfan and NPV treatments. The lowest larval populations (9.75, 6.75 and 2.0 on 7th, 10th and 15th day, respectively) were recorded in the treatment where 2.0 billion nematodes/ha were used followed by the treatment where 1.0 billion nematodes/ha were used (11.25, 7.50, and 3.5 on 7th, 10th and 15th day, respectively). Similar trend was reflected in case of pod damage also. Least damage (12%) was recorded in the treatments where nematodes were sprayed at the dosages of 1.0 and 2.0 billion/ha whereas it was 40.58% in control. In the treatments where endosulfan and NPV were applied, the damage was between 30 and 40%.

The overall results suggest that treatments where nematodes were sprayed at 1.0 billion/ha and 2.0 billion/ha were on par in minimizing the larval populations of *H. armigera* and pod damage and increasing the yield in pigeon pea and significantly superior to other treatments (Table 91).

Table 91. Effect of entomopathogenic nematode *Heterorhabditis* sp. against *H. armigera* in pigeon pea

Treatment	Pre-count larval population	Larval population (10 plants) after			Per cent pod damage	Yield (kg/ha)
		7 days	10 days	15 days		
0.5 billion nematodes / ha	26.00 (5.14)	22.25 (4.76)	31.25 (5.63)	16.75 (4.15)	23.33 (28.84)	565.00
1.0 billion nematodes / ha	21.50 (4.68)	11.25 (3.42)	07.50 (2.81)	03.50 (2.00)	11.24 (19.55)	782.50
2.0 billion nematodes / ha	23.50 (4.89)	09.75 (3.20)	06.75 (2.69)	02.00 (1.56)	11.71 (19.99)	775.00
*Ha*NPV @ 250 LE/ha	26.50 (5.17)	35.00 (5.95)	30.50 (5.57)	22.25 (4.76)	36.78 (37.29)	400.00
Endosulfan (0.07%)	27.00 (5.22)	31.25 (5.63)	31.50 (5.65)	27.25 (5.26)	31.09 (33.87)	412.50
Control	25.75 (5.11)	34.50 (5.91)	33.75 (5.84)	33.75 (5.85)	40.58 (39.57)	372.50
CD (P=0.05)	NS	(0.43)	(0.40)	(0.19)	(3.08)	58.12

4.21.3 Large-scale demonstration of *Bt*-*Ha*NPV-endosulfan-*Bt* in pigeon pea for the management of pod borer complex in farmer's field (ANGRAU, Hyderabad)

A demonstration trial was conducted in a farmer's field to see the efficacy of sequential spray application of *Bt*-*Ha*NPV-endosulfan-*Bt* with an interval of 10 days between each spray by administering the first spray at 50% flowering of the crop. An area of two acres (one for adopting the treatment and the other for farmer's practice) with pigeon pea (variety"Asha") was selected from the farmer's field at Sangamkurdu village near Tandur. The total number of larvae on 10 randomly selected plants at five locations before and 7 days after each spray was counted. Similarly counts were taken in the plot where farmer's practices like hand shaking, application of insecticidal dust and spray application of endosulfan were followed.

The pre-treatment larval population ranged from 25-27/10 plants. The larval population in the treated area started diminishing with the administration of each spray of spray schedule. However, in the field where farmer's practice was followed, the larval population remained higher. The sequential spray application was equally promising in terms of per cent pod damage with least damage of 22%, whereas in farmers' practice it was as high as 44%. Similarly the yield was 735 kg/ha in treated area and as low as 310 kg/ha in farmer's practice (Table 92). The cost benefit ratio based on plant protection inputs also was higher in treatment plot (1:3.29) as compared to farmer's practice (1:2.51).

Table 92. Effect of *Bt* – *Ha*NPV – Endosulfan – *Bt* spray schedule against *H. armigera* in pigeon pea

Treatment	Pre-count larval population	Average larval population seven days after spray				Mean larval population	Per cent pod damage	Yield (kg/ha)
		I	II	III	IV			
Bt – *Ha*NPV-Endosulfan-*Bt*	27.00	18.00	12.00	7.00	5.00	10.50	22.03	735
Farmers' practice	25.00	34.00	45.00	38.00	22.00	37.25	43.80	310

4.21.4. NPV based management of *Helicoverpa armigera* in chickpea (TNAU, Coimbatore)

A field trial was carried out at Sarkar Samakulam, Coimbatore district to evaluate the NPV based management of *Helicoverpa armigera* on chickpea. The following treatments were given.

a. *Ha*NPV (1.5 x 10^{12} POB/ha (250 LE)) + 10% crude sugar + 10% cotton seed kernel extract + 0.1% egg yolk + 0.1% ranipol

b. *Ha*NPV (1.5 x 10^{12} POB/ha (250 LE)) alone + 0.5% teepol adjuvant

c. *Ha*NPV (1.5 x 10^{12} POB/ha (250 LE)) – NSKE (5%) alternation

d. *Ha*NPV (1.5 x 10^{12} POB/ha (250 LE)) – endosulfan alternation

e. Endosulfan 350 g/ha

f. Control

The plot size was 100 m^2 with four replications under RBD. While sowing, *Trichoderma* @ 4 g/kg of seed was used as seed treatment. Starting with initial outbreak, three treatments were given at 15 days interval. First treatment started when the mean larval population exceeded 2/plant. A cloth screen was placed all around the plot to prevent spray drift to adjacent plots. The damage caused by *Helicoverpa armigera* in untreated and treated plots was recorded. Three sprays were given and all the treatments were effective in reducing pod borer damage compared to untreated plots.

Pod damage was significantly less and yield higher in plots sprayed with *Ha*NPV – endosulfan alternation (5.60%) and *Ha*NPV – NSKE (5.11%) alternation. These two treatments yielded 1182 and 1201 kg/ha, respectively (Table 93).

Table 93. Effect of biocontrol treatments and insecticide alternations on *Helicoverpa armigera* and chickpea yield

Treatments	Per cent pod borer damage pre treatment	Mean per cent pod borer damage after 7 days post treatment			Seed damage (%)*	Yield (kg/ha)
		I Spray	II Spray	III Spray		
*Ha*NPV + CS + CSE 0.1% egg + ranipol	26.28^{a}	11.38^{b}	11.81^{c}	8.31^{c}	7.28^{b}	1012^{b}
*Ha*NPV alone + 0.5% teepol spray	24.31^{a}	10.32^{b}	10.38^{b}	7.82^{b}	8.31^{c}	1032^{b}
*Ha*NPV/NSKE 5% alternation	23.28^{a}	7.03^{a}	9.12^{a}	6.82^{a}	5.60^{a}	1182^{a}
*Ha*NPV/endosulfan alternation	26.31^{a}	7.58^{a}	9.38^{a}	7.02^{a}	5.11^{a}	1201^{a}
Endosulfan 350 g/ha	24.22^{a}	10.82^{b}	13.42^{d}	10.82^{d}	7.80^{b}	990^{c}
Control	25.33^{a}	30.36^{c}	28.31^{c}	16.31^{e}	14.31^{d}	688^{d}

Means followed by similar letters are not statistically different (P = 0.05)

4.21.5. *Helicoverpa armigera* and its natural enemies (Dr.YSPUH & F, Solan)

Campoletis chlorideae (18%) and an unidentified encyrtid parasitoid were recorded on *H. armigera* during the studies.

4.22. Biological suppression of rice pests

4.22.1. Field evaluation of integrated use of *Trichogramma japonicum*, *T. chilonis* and *Bacillusthuringiensis* against rice stem borer and leaf folder

The following treatments to evaluate the use of *Trichogramma* and *Bt* against rice stem borer and leaf folder were tested in TNAU, Coimbatore, MPKV, Pune, PAU, Ludhiana and AAU, Jorhat centers. The differences amongst different centers in method of observation, plot size and other parameters are given against each centre.

T_1 – *T. japonicum* @ 50,000 parasitoids/ha and *T. chilonis* @ 50,000 parasitoids/ha, simultaneously at weekly interval. Three releases were made with the first release commencing on 20 DAT.

T_2 - *T. japonicum* @ 100,000 parasitoids per hectare and *T. chilonis* @ 100,000 parasitoids per hectare simultaneously at weekly interval. Three releases were made with the first release commencing on 20 DAT.

T_3 – *Bt* application (Delfin) at 1 kg/ha based on ETL was made two times on 40 DAT and 55 DAT.

T_4 - Need based insecticide protection. Monocrotophos @ 1 lit/ha – Two rounds were given on 40 DAT and 55 DAT for leaf folder and one spray of phosphamidon 300 ml/ha on 70 DAT was given.

T_5 - Untreated check

4.22.1.1.TNAU, Coimbatore

The plot size was 2 cents/replication in RBD design with five replications. All other recommended cultivation procedures for ADT 36 were followed and the field trial was laid out at Puthur village, Coimbatore district. Pretreatment observations for stem borer were recorded on 5 hills in each subplot. Second and subsequent observations were made at weekly intervals, on 30, 37 and 44 DAT and on 80, 87, 94 DAT. Dead heart and white ears were counted in all subplots on five hills. Egg masses were collected on observation dates and per cent parasitism was observed by maintaining them in the laboratory. On five plants/plot the number of healthy and damaged leaves by leaf folder were counted on 30, 37, 44 DAT. Yield data was recorded.

The stem borer incidence was lowest (10.9 per cent at 44 DAS and 5.8 per cent dead heart on 94 DAS) in plots where *T. chilonis* and *T. japonicum* were released @ 100,000/ha. More damage due to stem borer (14.8 per cent 94 DAS) was observed in insecticide treated plots whereas it was 36.4 per cent in untreated check. Thus parasite releases were superior to *Bt* applications or insecticide in controlling the stem borer. Rice yield was highest in parasitoid released plot (5692 kg/ha) compared to 3529 kg/ha in untreated plots. All the treatments led to significant control of stem borer and leaf roller, compared to untreated plots (Table 94). Similar effects were observed on per cent parasitism of stem borer eggs by *Trichogramma chilonis* and *T. japonicum*. The per cent parasitisation was 73.7 in *Trichogramma* plots compared to 2.8 per cent in control and 1.9 per cent in insecticide plots (Table 95).

4.22.1.2. MPKV, Pune

The experiment was conducted at the Agricultural Research Station Farm, Vadgaon Maval, Pune District. Releases of parasitoids and sprays of *Bt* and insecticides were commenced 25 days after transplanting (DAT) of the crop. Observations on white earheads per m^2 and yield per plot at harvest were recorded. For leaf folder, healthy and folded/damaged leaves per m row at 5 places in each treatment plot were recorded at weekly interval during 30 to 50 DAT and again from 80 to 110 DAT.

Table 94. Effect of biocontrol methods and insecticide applications on stem borer damage

Treatments	% Damage by stem borer						Yield (kg/ha)
	Dead hearts			White ears			
	30 DAS	37 DAS	44 DAS	80 DAS	87 DAS	94 DAS	
T. chilonis 50,000/ha + *T. japonicum* 50,000/ha	16.3[b]	23.8[a]	12.9[a]	7.0[b]	6.9[b]	9.0[c]	5407[b]
T. chilonis 100,000/ha + *T. japonicum* 100,000/ha	11.4[a]	23.1[a]	10.9[a]	6.1[a]	6.2[a]	5.8[a]	5692[a]
Bt – Two rounds 1 kg/ha	21.3[c]	22.1[a]	11.2[a]	7.2[b]	6.8[b]	7.0[b]	5247[c]
Monocrotophos 1 lit/ha – 2 rounds + phosphamidon 300 ml/ha	26.2[d]	28.1[b]	13.1[b]	11.2[c]	14.2[c]	14.8[d]	5132[d]
Untreated check	25.2[c]	26.8[b]	27.2[c]	27.9[d]	34.3[d]	36.4[e]	3529[e]

Table 95. Per cent damage by leaf folder and per cent parasitism of stem borer eggs by *Trichogramma* spp.

Treatments	Per cent leaf folder damage			Per cent parasitism on stem borer eggs by *Trichogramma* spp.		
	30 DAS	37 DAS	44 DAS	37 DAS	44 DAS	80 DAS
T. chilonis 50,000/ha + *T. japonicum* 50,000/ha	17.1[b]	15.6[b]	9.2[b]	34.2[b]	39.8[b]	42.1[b]
T. chilonis 100,000/ha + *T. japonicum* 100,000/hs	16.8[b]	14.2[b]	8.1[b]	55.7[a]	68.1[a]	73.7[a]
Bt –Two rounds 1 kg/ha	13.8[a]	6.1[a]	4.2[a]	9.0[c]	6.1[c]	4.2[c]
Monocrotophos 1 lit/ha – 2 rounds+phosphamidon 300 ml/ha	11.4[a]	8.2[a]	6.1[c]	4.7[d]	1.3[d]	1.9[c]
Untreated check	52.8[c]	59.4[c]	62.1[d]	3.9[d]	4.1[d]	2.8[c]

The treatment with three simultaneous releases of *T. japonicum* @ 1,00,000 adults/ha/release + *T. chilonis* @ 1,00,000 adults/ha/release at weekly interval recorded minimum white earheads (4.78%) due to stem borer and it was on par with chemical control schedule and *Bt* @ 1.0 kg/ha.

The treatment with chemical control schedule was found effective showing minimum leaf folder infestation (3.92%) as against 10.68% in the untreated plots. Maximum yield (32.0 q/ha) was recorded in the treatment plots with three simultaneous releases of *T. japonicum* + *T. chilonis* @ 1,00,000 adults/ha/release, followed by chemical control schedule (29.8 q/ha) (Table 96).

Table 96. Evaluation of efficacy of *Trichogramma* spp. for the control of stem borer and leaf folder on rice

Treatment	White earheads due to stem borer	Leaf folder infestation (%)	Yield q/ha
T. japonicum @ 50,000 adults/ha/rel. + *T. chilonis* @ 50,000 adults/ha/rel. - simultaneous releases at weekly interval	6.10 (14.30)	6.77 (15.04)	22.2
T. japonicum @ 1,00,000 adults/ha/rel. + *T. chilonis* @ 1,00,000 adults/ha/rel. - 3 simultaneous releases at weekly interval	4.78 (12.63)	4.38 (12.08)	32.0
Bt @ 1 kg/ha (Delfin WG)	5.00 (12.92)	4.60 (12.36)	24.0
Chemical control: Two sprays of monocrotophos @ 1 lit./ha and one spray of phosphamidon @ 300 ml/ha	4.90 (12.78)	3.92 (11.42)	29.8
Untreated check	10.37 (18.79)	10.68 (19.09)	14.0
CD (P=0.05)	(1.05)	(0.12)	2.31

Figures in parentheses are angular transformations

4.22.1.3. PAU, Ludhiana

The experiment was carried out at village Khudi Kalan (Distt. Sangrur). The plot size was 0.4 ha for each treatment. Per cent leaves folded and per cent dead hearts were recorded on the basis of 10 hills each from 3 spots from 75 DAT. Per cent white ears were recorded near maturity on the basis of 10 hills each from 3 spots in a plot. The yield was recorded on whole plot basis.

The per cent leaves folded were significantly lower (1.64 to 4.14%) in treated / release plots than control (6.48%). The leaves folded in insecticidal spray were lowest (1.64%) and were at par with higher dose of parasitoid (2.08%) but were significantly lower than lower dose of the parasitoid (4.14%). The per cent dead hearts and white ears were significantly lower in all the treatments than control. Insecticidal spray and the higher dose of the parasitoid were on par, but were significantly better than lower dose of the parasitoids. Similarly, the yield in all the treatments (52.40 to 62-24 q/

ha) was significantly higher than that in control, with insecticidal spray and higher dose of parasitoid on par with each other Table (97).

Table 97. Effectiveness of *Trichogramma chilonis* and *T. japonicum* for the control of stem borer and leaf folder in rice

T. chilonis + T. japonicum (Dosage/ha)	Percent leaves folded	Percent dead hearts	Per cent white ears	Yield (q/ha)
50,000*	4.14 (11.69)	4.34 (11.95)	4.74 (12.54)	52.40
1,00,000	2.08 (8.13)	1.98 (8.00)	2.00 (8.02)	61.78
Insecticidal spray**	1.64 (7.20)	1.62 (7.17)	1.86 (7.70)	62.24
Untreated check	6.48 14.67)	5.40 (13.35)	6.28 (14.44)	48.71
CD (P=0.05)	(1.96)	(2.24)	(2.18)	3.06

* Six releases were made at weekly interval, starting 30 days after transplanting

** One spray of monocrotophos @ 1.4 l/ha (August 16,2000)

Figures in parentheses are arc sin transformed values

4.22.1.4. AAU, Jorhat

The experiment was conducted in a farmer's field at Alengmora, Jorhat (Assam) during kharif 2000.

The incidence of stem borer was significantly less in biocontrol treatment as compared to untreated control. The incidence of dead heart was 3.52% in *Trichogramma* released plot of 1,00,000/ha followed by 4.00% dead heart in the released plot of 50,000/ha against 10.31% dead heart in the unreleased plot. 5[th] week after the field release of the parasitoid. Per cent white ear head was recorded near maturity. Per cent white ear head was 4.69% in the released plot of *T. japonicum+ T. chilonis* @ 1,00,000/ha against 11.58% in the unreleased plot and the incidence of white ear head was at par with the release rate of *T. japonicum + T. chilonis* @ 50,000/ha. The highest grain yield (4200 kg/ha) was obtained in the plot where *Trichogramma* @ 1,00,000/ha was released and was on par with the release of *Trichogramma* @ 50,000/ha (Table 98). Field recovery of *T. japonicum* as estimated by placing *Corcyra* egg cards during kharif 2000 was 25.0%. The per cent infestation of leaf folder was lowest 1.42% in the 5[th] week after field release of the egg parasitoid against 5.74% in the unreleased plot (Table 99).

Table 98. Evaluation of *Trichogramma japonicum* and *T. chilonis* against rice stem borer (kharif)

Treatment	Pre release	Per cent dead hearts at weekly intervals					Per cent white ear heads	Yield kg/ha
		I	II	III	IV	V		
T. japonicum + *T. chilonis* @ 50,000 / ha	8.91	10.46	7.74	6.76	5.65	4.00	4.89	4104
T. japonicum + *T. chilonis* @ 1,00,000 /ha	8.32	10.32	6.68	6.41	5.95	3.52	4.69	4200
Bt (Delfin)	8.83	9.91	6.24	6.58	7.32	4.38	5.88	3415
Insecticide	9.19	9.68	8.27	6.18	5.55	5.06	5.19	3911
Untreated check	8.45	10.14	7.65	6.18	10.65	10.31	11.58	3391
CD (P=0.05)	NS	NS	0.54	NS	0.42	0.49	0.43	473.76

Table.99 Evaluation of *Trichogramma japonicum* and *T. chilonis* against rice leaf folder (kharif)

Treatment	Pre release	Per cent leaves damaged by leaf folder					
		I	II	III	IV	V	VI
T. japonicum + *T. chilonis* @50,000/ha	3.77	3.39	3.12	2.76	2.14	1.42	1.67
T .japonicum + *T. chilonis* @ 1,00,000/ha	3.40	2.74	2.53	2.46	2.63	1.41	1.58
Bt (Delfin)	3.56	3.88	2.72	2.95	2.42	2.21	1.64
Insecticide	3.57	3.99	3.52	2.74	2.38	2.41	1.69
Untreated check	3.64	3.41	3.22	2.84	5.83	5.74	5.61
CD at P=0.05	NS	0.53	0.57	NS	0.59	0.64	0.57

4.22.2. Evaluation of Biocontrol based IPM in rice

4.22.2.1. PAU, Ludhiana

The experiment on evaluation of biocontrol based IPM in rice was conducted at farmer's field at village Karni Khera (Distt. Ferozepur). The plot size for IPM was 20 ha and for control 1.0 ha. The observations were recorded as in the previous experiment.

The incidence of leaf folder and stem borer was low. The per cent leaves folded was 2.0 in biocontrol as compared to 3.8 in control resulting in 47.6 per cent reduction in damage over control.

The dead hearts in biocontrol were 2.7 per cent as compared to 4.9 per cent in control, which resulted in 45 per cent reduction in damage. Similarly in biocontrol, the reduction in white ears was 40 per cent. The yield in biocontrol was 58 q/ha as compared to 52 q/ha in the control and the increase in yield over control was 12 per cent (Table 100).

Table 100. Evaluation of biocontrol based IPM on rice

Treatment	Per cent incidence of stem borer		Per cent leaves folded	Yield (q/ha)
	Dead hearts	White ears		
Biocontrol*	2.7	5.1	2.0	58.0
Control	4.9	8.5	3.8	52.0
Reduction in damage over control (%)	45.0	40.0	47.6	12.3

* Six releases of *T. chilonis* and *T. japonicum* each @ 1,00,000 per ha at weekly interval, starting 30 DAT.

4.22.2.2. AAU, Jorhat

Biocontrol based IPM was evaluated in comparison with chemical control in the farmer's field at Kakadonga during rabi 2000. The release of each of *Trichogramma japonicum* and *T. chilonis* @ 1,00,000/ha at weekly intervals could check the formation of dead heart significantly. The occurrence of dead heart due to stem borer in the released plot ranged from 2.82% to 3.84%, whereas the per cent dead heart in the unreleased plot ranged from 3.80% to 8.15%. The white ear head population was also low (2.25%) in *Trichogramma* released plot as compared to unreleased plot (6.53%) (Table 101). The leaf folder population was lowest (1.64%) in the released plot against 6.90% in the unreleased plot 4th week after the release of the parasitoid (Table 102).

Table 101. Effect of biocontrol based IPM on the incidence of rice stem borer (Rabi)

Treatment	Pre release	Per cent dead heart at weekly intervals				White ear head %
		I	II	III	IV	
Biocontrol	2.62	3.84	3.70	2.84	2.82	2.25
Chemical control	2.77	3.78	3.72	3.03	2.88	2.24
Control	2.70	3.80	3.83	8.15	7.60	6.53
CD at P=0.05	NS	NS	NS	0.78	0.71	0.83

Table 102. Effect of biocontrol based IPM on the incidence of rice leaf folder (Rabi)

Treatment	Pre release	Per cent leaves damaged by leaf folder at weekly intervals			
		I	II	III	IV
Biocontrol	2.30	2.45	2.16	1.92	1.64
Chemical control	2.36	2.35	2.27	1.89	1.70
Control	2.40	2.50	3.71	5.02	6.90
CD (P=0.05)	NS	NS	0.58	0.38	0.40

The same experiment was also conducted in two villages during kharif 2000 in the farmer's field located at Alengmara, Jorhat as well as at Kakadonga. The results of the IPM trial conducted at Alengmara (Table 103) revealed that the release of both the species of *Trichogramma* @ 1,00,000/ha could check the formation of dead heart from 4[th] week onwards. The lowest incidence of dead heart was recorded (3.56%) in the released plot against 11.92% in the unreleased plot 7[th] week after the release of the parasitoid. The white ear head population was also low (3.46%) in the released plot against 12.02% in the unreleased plot. The release of the parasitoid could check the leaf folder population from the 4[th] week onwards. The lowest incidence of leaf folder damaged leaves (1.23%) was recorded in the released plot of *T. japonicum* +*T. chilonis* @1,00,000/ha against 6.52% in the unreleased plot (Table 104). The yield was highest (4354 kg/ha) in the *Trichogramma* released plot as compared to that in the unreleased plot (3101 kg/ha).

Table 103. Effect of biocontrol based IPM on the incidence of rice stem borer (kharif)

Treatment	Pre release	Per cent dead heart at weekly intervals							Per cent white ear heads	Yield kg/ha
		I	II	III	IV	V	VI	VII		
Bio-control	7.25	5.79	6.85	9.85	4.68	3.63	3.70	3.56	3.46	4354
Chemical control	9.64	8.42	6.14	10.16	6.64	5.55	3.68	5.08	7.32	3926
Control	5.53	7.76	8.45	10.36	9.67	10.09	12.01	11.92	12.02	3101
CD (P=0.05)	0.78	1.14	0.48	NS	1.19	0.91	1.13	0.93	1.07	437.73

Table 104. Effect of biocontrol based IPM on the incidence of leaf folder (kharif)

Treatment	Pre release	Per cent leaves damaged by leaf folder at weekly intervals						
		I	II	III	IV	V	VI	VII
Biocontrol	2.34	2.42	2.29	2.41	1.62	1.77	2.03	1.23
Chemical control	2.72	2.69	2.81	2.34	2.30	2.34	2.04	1.80
Control	2.59	2.20	2.70	4.69	5.60	5.90	6.18	6.52
CD (P=0.05)	NS	NS	NS	0.99	0.57	0.50	0.67	0.71

The results of the similar experiment conducted at Kakodonga during kharif 2000 revealed that the per cent dead heart in the released plot was 3.03% as against 6.10% in the unreleased plot, 3rd week after the field release of *Trichogramma* and 3.59% dead heart in the released plot as against 8.63% in the unreleased plot, 4th week after the field release of the parasitoid (Table 105). The incidence of leaf folder was very low (1.11%) in the released plot against 5.29% in the unreleased plot 4th week after the release of the parasitoid (Table 106).

Table 105. Effect of biocontrol based IPM on the incidence of rice stem borer (kharif)

Treatment	Pre release	Per cent dead heart at weekly intervals				Per cent white ear heads	Yield kg/ha
		I	II	III	IV		
Biocontrol	2.47	2.64	2.68	3.03	3.59	2.79	4050
Chemical control	2.37	2.84	3.08	3.26	3.53	3.02	3780
Control	2.31	3.17	3.23	6.10	8.63	9.26	3204
CD (P=0.05)	NS	NS	0.39	0.59	0.82	1.13	415.38

Table 106. Effect of biocontrol based IPM on the incidence of leaf folder (kharif)

Treatment	Pre release	Per cent leaves damaged by leaf folder at weekly intervals			
		I	II	III	IV
Biocontrol	2.09	2.39	3.04	1.22	1.11
Chemical control	2.15	2.16	3.07	1.41	1.46
Control	2.09	3.12	3.15	5.12	5.29
CD (P=0.05)	NS	NS	NS	0.53	0.74

4.22.2.3. KAU, Thrissur

The experiment was laid out in confounded block design during December 2000 with three treatments and eight replications in the farmer's field at Koorkkenchery panchayath. In the biocontrol plot six releases of *T. chilonis* and *T. japonicum* were done at weekly intervals starting from 15 DAT on observing stem borer adults and egg mass. Need based chemical application was given in the chemical control plot with monocrotophos at tillering stage and methyl parathion at ear head formation stage. Observations were recorded on leaf folder and stem borer infestation and yield.

Leaf folder infestation was significantly high in untreated control on 20 DAT (8.975) and on 35 DAT (2.325) when compared to biocontrol and chemical control (Table 107). However, biocontrol and chemical control were on par on these days. On 50 DAT, leaf folder infestation was low and all the treatments were on par.

In the case of stem borer significantly higher incidence of dead hearts was observed in untreated control (0.700 and 0.625) as compared to chemical control (0.050 and 0.350) and biocontrol (0.325 and 0.350) on 20 DAT and 50 DAT, respectively (Table 108). Biocontrol and chemical control were on par on these days. On 35 DAT, number of dead hearts per hill was comparatively high and all the treatments were on par. The occurrence of white ear heads was low and all the treatments were on par at 65 DAT.

The yield parameters like grain weight and the number of white earheads were recorded from the harvested samples taken from one m^2 (Table 109). No significant differences in the case of grain weight as well as white ear head incidence were noticed.

Table 107. Leaf folder infestation in evaluation of biocontrol based IPM

Treatments	No. of infested leaves/hill		
	20 DAT	35DAT	50DAT
Biocontrol	1.025	0.600	0.425
Chemical control	1.875	1.050	0.225
Control	8.975	2.325	0.100
CD 0.05	3.534	0.861	0.337

Table 108. Stem borer infestation in evaluation of biocontrol based IPM (Mean number / hill)

Treatments	20 DAT (DH)	35 DAT(DH)	50 DAT(DH)	65 DAT(WEH)
Biocontrol	0.325	1.400	0.350	0.300
Chemical control	0.050	1.575	0.350	0.425
Control	0.700	1.450	0.625	0.325
CD (0.05)	0.289	0.564	0.256	0.262

Table 109. Yield parameters recorded in evaluating biocontrol based IPM

Treatments	Grain weight (kg/ha)	Total ear heads (Number /m^2)	White ear heads (Number / m^2)
Biocontrol	5170.00	420.750	9.750
Chemical control	5235.00	466.00	7.875
Control	5151.25	414.63	7.250
CD (P = 0.05)	530.59	77.65	4.385

4.22.3. Survey and quantification of natural enemies

4.22.3.1.KAU, Thrissur

Two plots each in two locations of Avinissery, Koorkkenchery and Mannuthy panchayats of Thrissur district were selected for the study. Sweep net samples were taken from the selected plots at weekly intervals (five samples) from six locations during October 1999 to January 2000.

The population of leafhoppers was found to be high in all the locations. The mean number of lepidopteran pests was significantly high at Mannuthy I location (8.2) and Koorkkenchery II (7.8) as compared to a population of 1.4 recorded at Avinissery I. The population of total pests was highest (148.8) at Mannuthy II and lowest (64) in Koorkkenchery I.

Hymenopteran parasitoids were the most abundant, the mean number of which ranged from 21.8 to 57.4 (Table 110). Among the predators, spiders were found to be high in number in all the locations. There was no significant difference in the population of spiders and mirid bugs (*Cyrtorhinus lividipennis*) in the six locations. Coccinellid predators were found to be significantly high at Avinissery panchayath as compared to the low densities recorded at Koorkkenchery panchayath. In the case of Odonata a significantly high population (10.8) was recorded at Mannuthy II location as compared to the other locations except in Koorkkenchery II (4.8).

Table 110. Mean number of natural enemies at six locations (Mean of five samples)

Locations	Spiders	Coccine llids	Odonata	*Cyrtor hinus*	Other predators	Total predators	Hymene optera	Diptera
Avinissery I	12.2	6.6	1.8	3.0	7.4	31	23.6	21.8
Avinissery II	12	6.8	4.4	5.8	6.2	35.2	57.4	35.6
Koorkken chery I	16.4	1.6	4.8	9.2	3.4	35.4	21.8	16.6
Koorkken chery II	25.8	0.2	1	10	7.4	44.4	51.6	20.2
Mannuthy I	38.8	3	3.2	1.6	8.2	54.8	31.8	25.8
Mannuthy II	25	2.2	10.8	4.6	8.8	51.4	51.4	45.6
CD (P= 0.05)	29.437	4.607	6.188	9.052	9.425	35.208	34.211	33.988

4.22.3.2. TNAU, Coimbatore

The survey was done in three locations in Coimbatore district. A 20 cent unsprayed area was selected and the samples of natural enemies were collected at weekly intervals with five double sweeps using sweep net in a 4 m^2 area. The predators included coleopterans, spiders, dragonflies, damselfly, crickets, grasshoppers and preying mantids; parasitoids comprised *Tetrastichus*, *Telenomus*, *Cotesia* and *Trichogramma* at Agricultural College and Research Institute, Coimbatore and Puthur. Predators constituted between 16.72 – 21.0 per cent of all arthropods and parasitoids 11.38 – 13.1 per cent and phytophagous insects the rest. The phytophagous insects, in the order of occurrence were leaf folders, stem borers and to a lesser extent, leaf hoppers.

4.22.3.3. PAU, Ludhiana

The survey of natural enemies of rice pests was carried out at farmer's field at village Behram (Distt. Nawanshahar) at weekly interval during July to October 2000. 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 parasitoids or next stage of the pest.

Seventeen species of spiders belonging to seven families were recorded [Araneidae (*Araneus inustus, Neoscona theisi, Argiope catenulata*), Clubionidae (*Clubiona* sp.), Metidae (*Leucauge decorata, L. celebesiana*), Oxypidae (*Oxyopes javanus*), Salticidae (*Plexippus* sp., *P. paykulli*), Thomisidae (*Runcinia albostriata, R. sangasanga, Runcinia* sp., *Thomisus* sp.) Tetragnathidae (*Tetragnatha javana, T. virescens, Tetragnatha* sp.)]. The spiders were available throughout the crop season. *Tetragnatha javana* was most common followed by *A. inustus, T. virescens* and *O. javanus*. Maximum population was recorded during second fortnight of July followed by first fortnight of September.

4.22.3.4. AAU, Jorhat

The survey for natural enemies of rice pests was carried out at farmer's field in villages of Kakadonga, Alengmara and ICR farm (District-Jorhat) at weekly intervals from September to November 2000. From each location one 20 cent plot was identified for taking observations and the farmers were requested not to apply insecticides. The egg masses of stem borer and larvae of leaf folder and rice stem borer were collected and reared in the laboratory until the emergence of natural enemies and /or the next stage of the pest. The samples were collected at weekly intervals with 5 double sweeps in each subplot ($4m^2$) at three locations.

The extent of parasitism of leaf folder by larval parasitoid *Bracon* sp. during kharif season varied from 15% to 20% and the extent of parasitism of *Aulosaphes* sp. varied from 10% to 16.6%. *Trichogramma* was recorded during the last week of September and the extent of parasitism was 23.3%. Among the spiders, *Lycosa pseudoannulata, Oxyopes javanus* and *Tetragnatha* sp. were dominant during kharif.

4.23. Biological suppression of oilseed crop pests

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

The experiment was conducted in a randomized block design with five replications in a plot of $100m^2$. The population of the mustard aphid was recorded from 10 plants (10 cm central shoot) selected at random from each plot. Two releases of *Ischiodon scutellaris* and two sprays of *Verticillium lecanii* were given at 20 days interval in biocontrol plots. In insecticide treated plots two sprays of oxydemeton methyl were given at 15 days interval.

The population of the mustard aphid in insecticide sprayed plots (48.44) was significantly lower than that in control and biocontrol plots (14.67 - 16.64) on 22-02-2001 (Table 111). Similar trend was observed on 02-03-2001 and 12-03-20001. The yield in insecticide sprayed plots (496.5 kg) was significantly higher than that in all other treatments. Both the bioagents did not prove effective for the control of mustard aphid and were on par with untreated control.

Table 111. Biological control of mustard aphid

Treatment	Population of mustard aphid / 10 cm shoot				Yield (kg/ha)
	Pre-treatment		Post treatment		
	16-02-2001	22-02-2001	02-03-2001	12-03-2001	
Ischiodon scutellaris adults @ 100/ha	120.00	218.68 (14.67)	296.46 (17.00)	31.16 (5.31)	22.1
Verticillium lecanii @ 10^8 conidia/ml	127.88	211.92 (14.38)	293.88 (17.12)	21.16 (4.17)	26.8
Oxydemeton methyl @ 625cc /ha	156.32	48.44 (5.97)	109.52 (10.21)	2.96 (1.89)	496.5
Control	139.68	284.04 (16.64)	67.60 (17.28)	298.68 (7.34)	18.9
CD (P=0.05)	NS	(4.55)	(3.25)	(3.43)	52.3

4.24. Biological suppression of coconut pests

4.24.1. Evaluation of 'Mycohit' for the management of coconut eriophyid mite

4.24.1.1. PDBC, Bangalore

'Mycohit', the mycoacaricide formulation of *Hirsutella thompsonii* developed at PDBC was evaluated against the coconut eriophyid mite (*Aceria guerreronis*) under field conditions. The treatments consisted of 'Mycohit', two and three sprays at 14-day intervals, a chemical (Dicofol) control and an untreated control. The percentage of dead colonies was recorded at weekly intervals for up to 70 days after treatment (DAT).

Although, Dicofol could bring about 12.94 per cent death of mite colonies by the 7th day of spraying, comparable results with 'Mycohit' were obtained only after a fortnight. Maximum (60.47%) dead colonies were noticed at 49 DAT in trees sprayed with 'Mycohit' twice and thereafter, there was a decline in mortality. In contrast, there was a steady increase in the percentage of dead colonies in trees treated thrice with 'Mycohit', indicating the usefulness of an additional spray to sustain the mortality for more than 2 months. The highest mortality (75.00%) was realized at 63 DAT (Table 112).

Table 112. Effect of 'Mycohit' on coconut mite

Treatment	Per cent death of mite colonies (days after treatment)										
	BS	7	14	21	28	35	42	49	56	63	70
'Mycohit' two sprays*	2.00	5.19	18.62[#]	29.90	30.58	42.01	50.47	60.47	60.00	60.00	60.00
'Mycohit' three sprays*	0.00	5.50	15.13[#]	25.04	31.62[#]	50.38	64.70	72.40	74.31	75.00	75.00
Chemical control (Dicofol)	2.00	12.94	44.21	57.91	54.16	56.42	60.27	58.50	48.60	40.30	40.00
Untreated control	0.00	2.00	5.00	5.00	5.00	3.00	4.60	7.00	5.00	6.50	7.00

Note: DAT- Days after treatment; BS- Before spray

* 14 days interval between sprays

\# Sampling done just before spraying

Unlike in 'Mycohit' sprayed trees, in the case of Dicofol, maximum kill (60.47%) of the colonies was recorded at 42 DAT and from then on the dead colonies started reducing dramatically suggesting the need for more sprays to keep the mite in check. In unsprayed trees, maximum natural mortality was 7.00 per cent and no clear trend was noticed because of the fluctuations in the number of dead colonies. It is concluded from the experiment that though two sprays of 'Mycohit' are sufficient to check the mite numbers, an additional spray can give more stable control for a longer period.

4.24.1.2. Regional Station, CPCRI, Kayangulam

Mycohit (a formulation of *Hirsutella thompsonii*) was applied in a farmers' garden 7 km east of Kayangulam. Two treatments of Mycohit two sprays at 14 days interval and three sprays at 14 days interval were taken up and compared with untreated control. A maximum of 65% dead colonies were observed after seven days of the first spray and they came down to 25% after 28 days of the first spray or 14 days of the second spray. Interestingly, after seven days of the third spray only about 14.8% dead colonies were noticed. The experiment was incomplete and therefore another trial with all the treatments (including the wettable sulphur treatment, which was not taken up in the present trial as chemical control) needs to be laid out.

4.24.1.3. KAU, Thrissur

A field experiment was laid out for the management of the coconut mite with the following four treatments, with ten trees in each replication.

T1 Dicofol – single spray

T2 Mycohit – two sprays at 14 days interval

T3 Mycohit – three sprays at 14 days interval

T4 Untreated control

Spraying of Dicofol and first round of Mycohit was done in the second fortnight of February 2001 followed by second and third sprays. Nut samples collected one week after 'Mycohit' application for isolation of the fungus revealed no establishment of *H. thompsonii* in the sites.

4.24.2. Seasonal fluctuations of natural enemies of *Opisina arenosella* (CPCRI, Kayangulam)

The seasonal fluctuation of *Opisina arenosella* and its natural enemies was studied in a coconut garden comprising one hundred 8 - 10 year old palms at Ayiramthengu (Kerala). Twenty palms were marked as sample palms and 20 leaflets of 20 leaves observed at monthly intervals. Maximum pest population was observed during April-June (Table 113). The major parasitoids observed were *Brachymeria* spp, *Goniozus nephantidis*, *Elasmus nephantidis* and *Apanteles taragamae*.

Table 113. Seasonal fluctuations of natural enemies of *Opisina arenosella*

Month	*Opisina* population	Parasites recorded
April, 2000	54.50	*Brachymeria, Goniozus & Elasmus*
May	67.15	*Brachymeria*
June	44	-
July	22.11	*Elasmus*
August	37.40	*Elamus, Apanteles*
September	26.20	-
October	21.28	-
November	7.55	-
December	6.36	-
January, 2001	16	*Apanteles*
February	24.12	*Elasmus*
March	24.1	*Goniozus & Brachymeria*

4.25. Biological suppression of fruit crop pests

4.25.1. Development of *Trichogramma chilotraeae* at different temperatures (IIHR, Bangalore)

Paper card bits (1.0 cm^2) containing about 400 UV exposed *Corcyra cephalonica* eggs were exposed to 10 females of *T. chilotraeae* for 24 h in a glass vial (3 x 1 cm) and kept at 10, 15, 20, 25, 30, and 35°C separately. Number of adults emerged and duration of development from egg to adult were recorded. Fifty newly emerged *T. chilotraeae* were selected and released into a glass vial (15 x 2.5 cm) with honey and maintained at the above temperatures to record adult longevity.

The rate of development of *T. chilotraeae* at different constant temperature regimes accelerated with increasing temperature. The overall development period decreased from 36 days at 10°C to 7.2 days at 35°C. Emergence of progeny occurred in all the temperature regimes. Higher progeny production occurred at 15 and 20°C and very low production of 51.76 progeny was observed at 10°C. Temperature regimes 25 – 35°C affected the progeny production. Adults survived for 3.11 days at 11°C, 8.05 days at 15°C and decreased to 1.74 days at 35°C (Table 114).

Table 114. Effect of temperature on the development, progeny production and longevity of *T. chilotraeae*

Temperature (°C)	Developmental period (days)	Number of progeny produced	Adult longevity (days)
10	36.40	51.76	3.11
15	29.80	534.40	8.05
20	10.75	559.25	3.16
25	8.24	247.75	2.85
30	7.32	154.42	2.75
35	7.20	165.80	1.74

4.25.2. Residual toxicity of botanicals and conventional pesticides to *Trichogramma chilotraeae* (IIHR, Bangalore)

T. chilotraeae was obtained from the eggs of *Deudorix isocrates* and maintained on rice moth in the laboratory. Thirteen chemicals were tested for their residual toxic effects on *T. chilotraeae* (Table 115). Potted pomegranate plants were sprayed to run-off level 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 on the inner walls of the tube served as food for the parasitoids. Mortality was recorded after 24 hours of exposure. The toxic effect of chemicals was studied by exposing the adults at 0, 1, 14, 21, 28, 35 and 42 days after application.

All the botanicals and conventional pesticides caused mortality but the extent of mortality varied considerably with different treatments. There was a dramatic drop in the mortality of parasitoids when exposed to botanicals one day after application. They proved nontoxic to the parasitoids within a day after application. Both carbaryl and monocrotophos proved highly toxic, causing 100% mortality even after 42 days.

4.25.3. Evaluation of *Trichogramma chilotraeae* to control the pomegranate fruit borer (IIHR, Bangalore)

Releases of *T. chilotraeae* were initiated in February and continued up to April. A total of 35,000 parasitoids were released during the study period. The data on the number of healthy and damaged fruits were recorded at regular intervals. The results indicated that the fruit damage due to *D. isocrates* was less on parasitoid released plants than control. A pooled mean of 14.15 % fruit damage was recorded in the parasite released orchards as compared to 24.24% damage in the check.

Table 115. Toxicity of botanicals and conventional pesticides to *T. chilotraeae*

Treatment (concentration)	Per cent mortality of adults (days after application)							
	0	1	7	14	21	28	35	42
Nimbicidin 0.3%	30.00	0	0	0	0	0	0	0
Neem gold 0.3%	25.00	0	0	0	0	0	0	0
Neem azal 0.3%	16.00	0	0	0	0	0	0	0
Neemark 0.3%	22.00	0	0	0	0	0	0	0
Rakshak 0.3%	36.00	0	0	0	0	0	0	0
Neem guard 0.3%	41.50	0	0	0	0	0	0	0
Econeem 0.3%	41.50	0	0	0	0	0	0	0
Nivaar 0.3%	63.15	0	0	0	0	0	0	0
Neem Rich 0.3%	24.00	0	0	0	0	0	0	0
Neem oil 2%	100.0	3.00	0	0	0	0	0	0
NSKE 4%	30.50	0	0	0	0	0	0	0
Carbaryl 0.10%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Monocrotophos 0.05%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Check (Water)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

4.25.4. Pomegranate fruit borer and its natural enemies (Dr.YSPUH & F, Solan)

Cumulative incidence of pomegranate fruit borer, *Deudorix epijarbas* increased from 5.5% of bored fruits in second half of June to 31.6% in first half of August 2000. Only egg parasitoids were observed and parasitisation varied from 47.1 to 75% with a mean of 59.2%. Amongst the emerged parasitoids, 93.1% were the scelionid *Telenomus* (*T. ?cyrus*) and 6.9% were the eupelmid *Anastatus* sp. nr. *kashmirensis*.

4.25.5. Efficacy of *Trichogramma chilonis* against the ber fruit borer, *Meridarchis scyrodes* (IIHR, Bangalore)

The tricho cards were tied to ber shoots from the time of fruit set and releases were initiated from mid July and continued up to first week of August 2000. The data on the number of healthy and bored fruits were recorded at regular intervals. About 100 fruits were sampled in the release and check plots at a given time. Mean fruit damage was 22.33% on the released plants as compared to 34.95% in check.

4.25.6. Field evaluation of *Cryptolaemus montrouzieri* in the suppression of striped mealy bug, *Ferrisia virgata* on custard apple (IIHR, Bangalore)

C. montrouzieri was evaluated for its efficacy against *F. virgata* infesting custard apple in two locations around Bangalore. The predator was released @ 30/plant. The population of the mealy bug was recorded on 10 randomly selected plants at regular intervals.

In the orchard I, the mealy bug population appeared in June (2450/plant) and the predator was released on 10-06-2000. There was a continuous reduction in the population of the mealy bugs following the release of *C. montrouzieri* and a mean of 5.20 /plant was recorded on 14th August 2000.

In the second orchard, the pest appeared in the last week of October (1400/plant) and releases of the predator were made on 2nd November. By 30th December, a very low population of 4.00/plant was recorded.

4.25.7. Survey for the natural enemies of spiralling whitefly

4.25.7.1. IIHR, Bangalore

Surveys for the natural enemies were carried out in Karnataka, Kerala, Tamil Nadu, Andhra Pradesh and Maharashtra. A total of 25 natural enemies were collected on different host plants in different areas (Table 116).

Table 116. Natural enemies of the spiralling whitefly in peninsular India

Family & Order	Natural enemy recorded
PARASITOIDS	
Aphelinidae, Hymenoptera	*Encarsia guadeloupae* Viggiani
	Encarsia sp. nr. *haitiensis* Dozier
PREDATORS	
Coccinellidae, Coleoptera	*Axinoscymnus puttarudriahi* Kapur&Munshi
	Cryptolaemus montrouzieri Mulsant
	Cheilomenes sexmaculata (Fabricius)
	Chilocorus nigrita (Fabricius)
	Anegleis cardoni (Weise)
	Scymnus nubilus Mulsant
	Serangium parcesetosum Sicard
	Curinus coeruleus (Mulsant)
	Jauravia sp.
Nitidulidae, Coleoptera	*Cybocephalus* sp.
Drosophilidae, Diptera	*Acletoxenus indica* Malloch
Cecidomyiidae, Diptera	*Triommata coccidivora* (Felt)
Chamaemyiidae, Diptera	*Leucopis* sp
Chrysopidae, Neuroptera	*Mallada astur* (Banks)
	Chrysoperla carnea (Stephens)
	Mallada boninensis (Okamoto)
	Nobilinus sp.
	Apertochrysa sp.
Hemerobiidae, Neuroptera	*Notiobiella* sp. & *Hemerobius* sp.
Lycaenidae, Lepidoptera	*Spalgis epeus* (Westwood)
PATHOGEN	
Deuteromycetes, Moniliales	*Paecilomyces farinosus* (Holms.)

E. ?haitiensis was recorded at Sirsi, Hessaraghatta, Puttur, Hebbal, Hosallipalaya, Yelahanka and Kadur (Karnataka); Thiruvananthapuram and Thrissur (Kerala) and Krishnagiri (Tamil Nadu), while *E. guadeloupae* was collected from Hessaraghatta, Hebbal, Linganalli, Hosallipalaya and Yelahanka (Karnataka).

4.25.7.2. KAU, Thrissur

A survey for the natural enemies of spiralling whitefly was carried out during October 2000 - February 2001 in Thrissur district. Whitefly infested leaves of guava, chillies, ceara rubber, tapioca, brinjal, poinsettia, rose, balsam and *Hibiscus* were collected from the fields and observed for parasitism. Parasitisation by the aphelinid parasitoid, *Encarsia* sp. was noticed on the last stage of the whitefly nymphs on all host plants. The extent of natural parasitism on different host plants ranged from 0–66.6 per cent. Maximum parasitism was observed on chillies (66%) during October. Though pest population was maximum in Ceara rubber, parasitism was less.

4.25.8. Colonisation of *Encarsia* spp. on spiralling whitefly (IIHR, Bangalore)

Encarsia spp. were not present in several areas. The adult parasitoids that emerged from the field samples collected in the colonized areas were released in the areas where *Encarsia* spp. were not known to occur.

E. guadeloupae was released at Ivarakandapura from 14.2.2000 to 28.3.2000. A total of 221 adults were released during this period on guava. A mean of 14.47 % nymphs were found parasitised by *E. guadeloupae* on 23-03-2000. The parasitism by *E. guadeloupae* gradually increased to 62.74% in June 2000.

A total of 77 *E. haitiensis* adults were released on guava at Hessaraghatta from 16-02-2000 to 31-03-2000. Samples were collected from at monthly interval. Parasitoid activity was first noticed in the samples collected on 18–02-2000. A maximum of 47.83 nymphs were found parasitised by *E. ?haitiensis* on guava at Hessaraghatta in the second week of June 2000.

In addition, *E. guadeloupae* was also released in Mysore, Sirsi, Shimoga, Kolar, Chickaballapur, Madikeri, Kadur, Bellary, Puttur, Mudigere, Mandya, Davangere, Belgaum and Dharwad (Karnataka), Trivandrum and Thrissur (Kerala), Coimbatore (Tamil Nadu), Pune (Maharashtra), Hyderabad and Madanapalli (Andhra Pradesh).

4.25.9. *Encarsia guadeloupae* on spiralling whitefly infesting banana and guava (IIHR, Bangalore)

Banana plants (var. Mondan) were found infested with the spiralling whitefly in December 1999. Samples were collected at fortnightly intervals and the number of healthy and parasitised nymphs recorded in a marked area of 4 cm^2 from April 2000 to March 2001. The parasitism ranged from 8.60 to 66.04% and only *E. guadeloupae* was found. Similarly the incidence of spiraling whitefly in relation to *E. guadeloupae* was studied on guava and parasitism by *E. guadeloupae* ranged from 22.62 to 92.60% from June 2000 to March 2001.

4.25.10. Safety of botanicals to *Encarsia guadeloupae* (IIHR, Bangalore)

Potted guava plants were sprayed to run-off level with nine botanicals. The treated leaves after drying were kept individually in glass vials. In each vial, 10 adults of *E. guadeloupae* were released. A streak of honey on the inner walls of the tube served as food for the parasitoids. Mortality was recorded 24 hours after exposure. The toxic effect of chemicals was studied by exposing the adults at 0, 1and 7 days after application.

Neem gold, Econeem, Nimbicidin all at 0.03 % and NSKE 4% were not toxic to the adult parasitoids soon after application. The other botanicals, *viz.*, neem oil, Neem azal, Neem mark were found to be toxic, causing 20-40% mortality of the parasitoids, but a drop in the mortality of parasitoids was seen one day after application. Neem guard proved to be highly toxic causing 100% mortality on the day of application and 20% one-day after application and none on the 7th day after application.

4.25.11. Field evaluation of *Bt* commercial formulations against *Papilio demoleus* on citrus (IIHR, Bangalore)

Commercial formulations of *Bacillus thuringiensis* var. *kurstaki* (*Bt*), *viz.* Delfin, Dipel, Biobit and Halt @ 1.0 kg/ha were evaluated along with cypermethrin. Five sprays were given at weekly interval. Results showed that all the *Bt* formulations tested were highly effective in controlling the larval population of *P. demoleus* on citrus and comparable to cypermethrin. The mean larval count was the lowest in *Bt* sprayed plants (0.13 – 0.20 larvae/plant), a reduction of 93.4 to 95.7% over control (Table 117).

Table 117. Effect of *Bt* formulations against *Papilio demoleus* on citrus

Treatment	Mean larval count	Per cent reduction over control
Halt @ 1.0 g/l	0.13	95.7
Delfin @ 1.0 g/l	0.20	93.4
Biobit @ 1.0 g/l	0.15	95.0
Dipel @ 1.0 g/l	0.20	93.4
Cypermethrin @ 0.5ml/l	0.20	93.4
Control	3.03	-

4.25.12. Field evaluation of commercial formulations of *Bacillus thuringiensis* var. *kurstaki* against pomegranate fruit borer, *Deudorix isocrates* (IIHR, Bangalore)

Commercial formulations of *Bacillus thuringiensis* var. *kurstaki* (*Bt*), *viz.*, Delfin, Dipel, Biobit and Halt were evaluated for their field efficacy in controlling *Deudorix isocrates* and compared with deltamethrin and unsprayed control. *Bt* commercial formulations were sprayed @ 1.0 g/l, five times at weekly interval. Deltamethrin @ 0.5 ml/l was sprayed thrice at ten-day interval. Observations were recorded on the per cent bored fruits at the time of harvest. Results showed that there was significant reduction in mean fruit damage in all the *Bt* formulation treated plants, (0.5-1.1% damage/tree) as compared to untreated control (2.95% damage/tree). *Bt* was as good as deltamethrin which recorded a mean percentage fruit damage of 0.90/tree.

4.25.13. Seasonal abundance of woolly apple aphid in relation to natural enemies (Dr.YSPUH & F, Solan)

Monitoring of the woolly apple aphid (*Eriosoma lanigerum*) population throughout the year at weekly intervals along with their natural enemies revealed that mean colony number/replicate increased from 1.6 to 31.7 during April - May. The mean colony size and aphid coverage on the marked infested twigs increased from 0.19 to 0.3 cm and 0.343 to 9.843 cm, respectively. The count of mummified aphids by *Aphelinus mali* also increased from 0.6 to 18.6/replicate and continued to be higher till July I-week, though by then aphid activity was declining. The aphid population (colony number 0.3, size 0.04 and coverage 0.09 cm) and parasitization (0.1 mummy/replicate) declined to minimum in the second week of August. During mid-August to September-end, aphid population was low (1.6-7.4 colonies of 0.16-0.34 cm size with coverage of 0.6-2 cm) and mummified aphid count was 0.1 to 2.3. In October-November, the aphid activity increased to attain second peak (in the third week of November: colony count 24, with mean size of 0.395 cm and coverage of 13.15 cm) when 24.1 mummified aphids were counted/replicate. Although high aphid activity continued till December end (21.1 colonies, 0.348 cm size and 10.81 cm coverage), mummified aphid count was below 4/replicate. During January - March 2001, population count of the aphid declined (15.1 to 1.1 colonies, size 0.29 to 0.101 cm and coverage 4.52 to 0.28 cm).

Among natural enemies, the activity of *Aphelinus mali* persisted almost throughout the year. Chrysopids and coccinellids were frequently encountered during April - June, and syrphids during June, November and February.

4.25.14. Effect of insecticides on natural enemies of woolly apple aphid (Dr.YSPUH & F, Solan)

Chrysoperla carnea

Chlorpyriphos (0.04%), endosulfan (0.05%) and methyl parathion (0.05%) are often used for suppression of apple pests. To find out, the waiting period for commencing releases of *C. carnea*. an experiment was planned in October-November. From sprayed apple trees, leaves were periodically brought to the laboratory. Eggs of *Corcyra cephalonica* were sprinkled on leaves, transferred to petriplates and on these, 2-3 day old *C. carnea* larvae were released. Mortality was recorded at 24 hr intervals.

Chlorpyriphos continued to result in 100% mortality on three-day-old deposits within a day of release and 24 h mortality dropped to 20% on 6-day old deposits. On 8-day old deposits, mortality was 20% 2-days after release. From surviving larvae, adult formation, survival and egg laying were normal. However, on 10-day old deposits there was no mortality. Methyl parathion gave complete mortality in 24 h up to 3-day old deposits and was reduced to 75-78% in 4 and 5-day old deposits. Mortality ceased on 7-day old deposits. Endosulfan on the other hand provided 100% mortality only on fresh and 1-day old deposits. On 2-day old deposits, mortality was 72% one day after the release of larvae, which did not increase, in subsequent observations. On 3-day-old deposits, larval mortality was reduced to 6% 1-day after the release, 17% 2-day after release and increased to a maximum of 22% 6 day-after release. Surviving larvae developed to normal adults.

It can be concluded that in chlorpyrifos, methyl parathion and endosulfan treated orchards, *C. carnea* can be safely released 10, 7 and 5 days after the spray.

Aphelinus mali

Insecticides chlorpyrifos (0.04%), endosulfan (0.05%), methyl parathion (0.05%), imidacloprid (0.01% and 0.02%) and thiamethoxam (0.013 and 0.0063%) were sprayed in the first half of November 2000 and 10 days after the spray mummified aphids were collected from the sprayed trees to observe for emergence of *Aphelinus mali*. Adult emergence commenced in mid-February 2001 and continued till March 10. None of the insecticide treatments affected the over wintering population of the parasitoid.

4.25.15. Impact of parasitoids of San Jose scale at already released sites (SKUAS & T, Srinagar)

The impact of parasitoids released during previous years at different locations in the valley was studied in five districts. Four twigs from each tree measuring 12 - 15 cm were taken randomly and brought to the laboratory and maintained at 22 ± 2°C for emergence of parasitoids and parasitisation/cm^2 was counted and recorded. The results showed parasitisation from 20 to 54% in Anantnag, Pulwama, Budgam, Baramulla and Srinagar districts. Both *Aphytis* sp. and *Encarsia* spp. have established well at the released sites.

4.25.16. Incidence of San Jose scale, woolly aphid and their natural enemies at different altitudes (SKUAS & T, Srinagar)

San Jose scale

Extensive survey was conducted in the valley and scale infested twigs collected from different locations at different altitudes were brought to the laboratory to estimate the population of the pest and their natural enemies (Table 118).

Table 118. Quantitative estimation of San Jose scale at different altitudes

District	Location	Altitude	Scale density	Live	Parasitised
Srinagar	Gulabagh	4512	168	48	120
Budgam	Wagoora	4460	132	39	93
Pulwama	Ladoo	4225	87	36	51
Budgam	Wadwan	4200	190	82	108
Baramulla	Pattan	4120	173	89	84
Anantnag	Awantipora	4300	95	46	49
Anantnag	Bejbehara	4210	118	45	73
Baramulla	Putkhak Muqam	4000	96	38	68
Srinagar	Ganderbal	4450	177	57	60
Baramulla	Singoo	4430	89	25	64

Woolly aphid

Srinagar, Baramulla, Pulwama, Budgam and Anantnag districts were surveyed to ascertain the woolly aphid infestation in fruit orchards. Woolly aphid samples from each experimental site were collected and brought to the laboratory for further observation.

Parasitism by *A. mali* to the extent of 20-34% was recorded from May-September. The predators recorded were *Chilocorus infernalis, Coccinella septempunctata, Pharoscymnus batteatue, Chrysoperla confrator*.

4.26. Biological suppression of vegetable crop pests

4.26.1. Management of tomato fruit borer *Helicoverpa armigera* with *Trichogramma pretiosum* and *Ha*NPV

4.26.1.1. IIHR, Bangalore

Tomato var. Pusa Ruby was planted in 500 m² during October-March 2001 for trials against biocontrol of *H. armigera* using egg parasitoid *Trichogramma pretiosum*, *Ha*NPV and *Bt* (Halt). The following six treatments were used.

i. *Trichogramma 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. *Trichogramma 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. *Trichogramma pretiosum* was released as above and *Ha*NPV was sprayed twice at the above concentration, first spray 5 days after release and second one 10 days later

v. Halt (*Bt*) @ 1.0g/l was sprayed at weekly interval from the day of observation of larvae and a total of 3 sprays were given

vi. Control

Observations were made on 5 plants in each plot at weekly interval on the level of parasitism. Per cent fruit damage was recorded at the time of harvest. The data revealed no natural parasitism in the field. Wherever parasitoid was released, per cent parasitism was more, ranging from 55.65 - 59.50 (Table 119).

Table 119. Effect of *Ha*NPV and *Trichogramma pretiosum* against tomato fruit borer

Treatment	Mean parasitism (%)	Larval count		Fruits bored (%)		Total yield (Kg/plot)	Per cent increase Over control
		Mean	Reduction overcontrol	Mean	Reduction Over control		
*Ha*NPV @ 250 LE/ha (5 sprays)	3.20	0.48	85.14	10.08	63.53	24.80	40.59
*Ha*NPV @ 250 LE/ha (3 sprays) + *T. prestiosum* @ 2,50,000 adults/ha	55.65	0.52	83.52	8.12	70.62	25.40	44.00
*Ha*NPV @ 250 LE/ha (2 sprays) + *T. pretiosum* @ 2,50,000 adults/ha	57.50	0.50	84.52	8.21	70.30	25.80	46.25
Halt (*Bt*) 1.0g/l	2.20	0.51	84.21	8.75	68.34	24.75	40.31
T. pretiosum @ 2,50,000 adults/ha	59.50	0.56	82.66	9.95	64.00	24.60	39.45
Control	5.00	2.23	-	27.64	-	17.64	-

The larval population was ranged from 0.28 - 0.90 per plant. The increase in larval population was steadily observed in control compared to treatments throughout the cropping season. The mean larval population was 0.48 per plant in *Ha*NPV sprayed plots and 0.56 in parasitoid released plot. Among treatments with parasitoid & *Ha*NPV 2 and 3 sprays and Halt (*Bt*), there was not much difference (0.50, 52, and 0.51). Hence, integrating sprays with the parasitoid appears to be better than parasitoid alone and control, but per cent reduction was almost uniform in all the treatments except control.

Per cent borer damage was more during early harvests than the rest of the harvests. The mean fruit borer damage was between 8.12 and 10.08% in various treatments compared to control (27.64%). Therefore, damage reduction over control was 64.00%, 68.34% and 70.30% in parasitoid release, in parasitoid + two sprays of NPV and parasitoid + three sprays of NPV treatments, respectively.

The data showed that parasitoid released plot recorded 39.45% yield increase over control. Other treatments recorded 40.31 % - 46.25% increase in yield over control. Yield-wise the treatment with parasitoid and 2 sprays of NPV was found better (Table 119).

4.26.1.2. ANGRAU, Hyderabad

A trial was laid out with var. Pusa Ruby with 5 treatments including control and each treatment was replicated four times.

i. Release of *Trichogramma pretiosum* alone @ 50,000 adults/ha release 5 times with observation of eggs in the field (Release of Tricho bits 5 mt apart).
ii. Sprays of *Ha*NPV alone @ 250 LE/ha (1.5 x 10^{12} LE) 5 sprays at weekly interval.
iii. *Trichogramma pretiosum* @ 50,000 adults/ha/release 5 times at weekly interval + *Ha*NPV @ 250 LE/ha (1.5 x 10^{12} LE) 3 sprays – First spray 5 days after release of parasitoids and subsequent sprays at weekly interval.
iv. *Trichogramma pretiosum* 50,000 adults/ha/release five times with weekly intervals + *Ha*NPV @ 250LE/ha 2 sprays - First spray 5 days after release of parasitoids and subsequent sprays at 10 days interval.
v. Control

Observations on larval population were recorded on 5 randomly selected plants in each treatment at weekly intervals. At each picking percent bored fruits were also recorded along with yield data in each treatment. The data revealed that all the treatment combinations were significantly superior to the control. The lowest mean larval population (1.75) and the lowest fruit damage (3.87%) were recorded in the treatment where *T. pretiosum* was released @ 50,000/ha/release for 5 times with 3 sprays of NPV @ 250 LE/ha and proved to be significantly superior to others. The highest yield of 130.50 Q/ha was also recorded in the same treatment (Table 120).

Table 120. Biocontrol based management of tomato fruit borer, *H. armigera*.

Treatment	Pre count of larval population	Mean larval population	Per cent bored fruits	Yield (q/h)
T. prestiosum @ 50,000/ha/week for 5 times	11.00 (3.38)	4.70 (2.28)	6.80 (15.06)	100.25
*Ha*NPV @ 250 LE/ha 5 sprays at weekly interval	12.50 (3.59)	4.75 (2.29)	5.24 (13.15)	103.75
T. prestiosum @ 50,000/haa/week for 5 times + *Ha*NPV @ 250 times + NPV	12.50 (3.60)	4.75 (1.48)	5.24 (11.21)	103.75
T. prestiosum @ 50,000/ha/week 5 times + *Ha*NPV @ 250 LE/ha 2 sprays	9.75 (3.20)	5.95 (2.54)	6.56 (14.81)	78.50
Control	12.00	11.15	21.02	53.25
CD (P=0.05%)	NS	0.27	2.84	19.83

Figures in parentheses are transformed values

4.26.1.3. MPKV, Pune

A field trial was conducted on the Research Farm of Entomology Section, College of Agriculture, Pune, on tomato (var. Pusa Ruby) in 20m^2 plot at 60 x 30 cm plant spacing. The trial was laid out in RBD with four replications and five treatments similar to that given under ANGRAU, Hyderabad.

Application of treatments i.e. release of parasitoids and sprays of *Ha*NPV were carried out at flowering stage of the crop. Observations on larval population from five plants/plot were recorded as pre-count, one day before initiation of treatments and thereafter at weekly interval. At each fruit picking, number and weight of healthy and infested fruits/plot were recorded for computing per cent fruit infestation and yield of marketable fruits.

The results of the trial indicated that 5 releases of *T. pretiosum* @ 50,000 adults/ha/release+3 sprays of *Ha*NPV @ 250 LE/ha was the most effective treatment against *H. armigera* on tomato in respect of fruit infestation (12.73%). However, minimum surviving larval population (2.77 larvae/5 plants) and maximum tomato yield (338.6 q/ha) were observed in the treatment with 5 sprays of *Ha*NPV @ 250 LE/ha (Table 121).

Table 121. Efficacy of *Trichogramma* against *Helicovera armigera* on tomato

Trea tment	Larval population / 5 plant *		Per cent fruit infestation**	Yield (q/ha)	Yield of marketable fruits (q/ha)
	Pre-count	Average surviving population			
T. pretiosum @ 50,000 adults / ha / release as 5 releases	11.80 (12.42)	4.12 (2.15)	20.23 (26.70)	281.6	279.0
*Ha*NPV @ 250 LE/ha as 5 sprays	12.42 (3.60)	2.77 (1.81)	16.42 (23.90)	338.6	340.6
T. prestiosum @ 50,000 adults / ha / release as 5 releases + *Ha*NPV @ 250 LE/ha as 3 sprays	13.40 (3.73)	3.22 (3.73)	12.73 (20.88)	297.8	293.3
T. prestiosum @ 50,000 adults / ha / release as 5 release + *Ha*NPV @ 250 LE/ha as 2 sprays	13.27 (3.70)	3.57 (2.02)	16.92 (24.29)	293.8	288.9
Untreated control	12.59 (3.62)	7.50 (3.62)	33.38 (35.28)	138.2	136.7
CD (P=0.05)	(N.S.)	(0.19)	(1.54)	66.50	17.43

* Figures in parentheses are * $\sqrt{n+0.5}$ and ** angular transformations; Surviving population of larvaeare averages of five observations N.S. = Non-significant

Additional receipts due to treatments were maximum (Rs.1,22,340) in the treatment with 5 sprays of *Ha*NPV and Rs.93,960/- in the treatment with *T. pretiosum* + *Ha*NPV 3 sprays (Table 122).

Five releases of *Trichogramma pretiosum* @ 50,000 adults/ha/release + 3 sprays of *Ha*NPV @ 250 LE/ha or 5 sprays of *Ha*NPV @ 250 LE/ha were found to be the most effective and may be recommended against *H. armigera* on tomato.

4.26.1.4. GAU, Anand

The experiment was laid out with a plot size of 25 m^2 and five treatments with four replications similar to that given under ANGRAU, Hyderabad.

Larval counts were made in five plants per plot per treatment at weekly interval. Per cent bored fruits during each harvest and yield were recorded. The population of *H. armigera* was low. However, it can be seen from the data that *T. pretiosum* + *Ha* NPV 3 sprays, was superior to control. Per cent parasitism ranged from 20.16 to 22.65 per cent in the release plots whereas the control exhibited 7.93 % parasitism (Table 123).

Table 122. Economics of *Trichogramma pretiosum* and *Ha*NPV against *Helicoverpa armigera* on tomato

Treatment	Cost of Treatment			Increase in yield over control (q/ha)	Additional receipt due to treatment (Rs.)	ICBR
	Cost of bioagent/ insecticide per ha (Rs.)	Labour charges (Rs.)	Total Cost (Rs.)			
T. pretiosum @ 2.5 lakhs/ha (50,000 adults/ha as 5 releases)	585	125	710	142.3	853.80	1:120.25
*Ha*NPV @ 250 LE/ha as 5 sprays	2100	500	2600	203.9	122340	1:47.05
T. pretiosum @ 2.5 lakh/ha (50,000 adults/ha as 5 release) + *Ha*NPV @ 250 LE/ha - 3 sprays	1845	425	2270	156.6	93960	1:41.39
T. pretiosum 2.5 lakhs/ha + *Ha*NPV @ 250 LE/ha as 2 sprays	1425	325	1750	152.2	91320	1:52.18
Untreated control	---	---	---	----	---	---

Cost: 1. Marketable tomato yield = Rs.60/-per qt.

2. *T. pretiosum* Trichocard = Rs.39/- per card (3 Trcihocards/release x 5releases = 15 Trichocards)

3. *Ha*NPV = Rs.840/-per 500 LE

4. Treatment = Labour charges Rs.50/- per man-day

= Labour requirement 0.5 man-day/release; 2 man-days/spray

Table123. Effectiveness of different treatments against *H. armigera* on tomato

Treatment	Eggs/ 5 plants	Larvae/ 5 plants	Per cent damage	Parasitism (%)	Yield kg/ha
TP+NPV 3 sprays	1.48* (1.19)	1.26* (0.59)	10.60** (3.38)	22.65	1588
TP+NPV 3 sprays	1.70 (1.89)	1.43 (1.04)	15.18 (6.86)	21.37	1553
TP alone	1.89 (2.57)	1.52 (1.31)	10.97 (3.62)	20.16	1498
NPV alone	2.12 (3.49)	1.58 (1.90)	10.26 (3.17)	7.76	1406
Control	2.32 (4.38)	1.72 (1.96)	8.99 (2.44)	7.93	1212
CD (P=0.05)	0.20	0.11	3.26		152.04

** Arc sin transformation, figures in parentheses are transformed values

To test IPM module against tomato fruit borer *H. armigera*, an experiment was laid out at GAU, Anand in a plot of 25m² size per each treatment with two treatments and four replications.

T1 Module

i. Interspersing marigold with tomato

ii. Inundative release of *Trichogramma chilonis* @ 50,000/week synchronizing with *H. armigera* oviposition in tomato

iii. Hand picking of *H. armigera* at weekly interval and placing them in cages installed in the field which will facilitate escape of parasites like *Campoletis chlorideae*, *Eriborus* sp., *Apanteles* sp., etc.

iv. Perching sites for insectivorous birds (50perches/ha)

v. Need based application of *Ha* NPV @ 1.5 x 10^{12}/ha

T2 Control

Observations were recorded on *H. armigera* larval population, and extent of fruit damage in 20 randomly selected plants at weekly interval. Estimation of egg parasitism was done by collection of at least 25 eggs of *H. armigera* from all over the field.

The results presented in Table 124 indicate that IPM module was superior to insecticides as well as control.

Table 124. Effictiveness of different treatments against *H. armigera* on tomato

Treatment	IPM	Control
Eggs / 20 plants	5.25	18.50
Larvel / 20 plants	2.50	8.13
Per cent damage	1.59	10.64
Per cent parasitism	24.43	7.93
Yield (q/ha)	1670	1212

4.26.2. Evaluation of *Trichogrammatoidea bactrae* against *Plutella xylostella* on cabbage

4.26.2.1. IIHR, Bangalore

Cabbage (var. Krishna) was planted in 100m² area. A total of 5 plots were made each with 20m² area. The entire area was subjected to parasitoid release. A separate 100m² area was held at an isolated distance for both chemical (endosulfan 3 sprays at weekly interval) and control treatments. Egg parasitoid, *Trichogrammatoidea bactrae* was released @ 2.5 lakh adults per hectare right before primordial formation (10 days from transplanting). A total of 5 releases were made at weekly intervals. Every week prior to the release of egg parasitoids, observation was made on larval population from 10 heads per plot.

The larval population gradually reduced to 1.0/plant by fourth week from 5.10 and almost maintained the same trend in parasitoid released plot (Table 125). In endosulfan treated plot a mean of 1.80 larvae per plant was recorded which was however lower than that in control (3.80 per plant).

Table 125. Effect of egg parasitoid, *Trichogrammatoidea bactrae* against *Plutella xylostella* on cabbage

Treatment	Larval population						Mean larval population	Reduction over control (%)	Yield (kg/plot)	Increase over control (%)
	Before release	After release								
		I	II	III	IV	V				
T1	5.10	2.10	1.90	1.40	1.00	1.00	1.48	61.05	76.20	56.15
T2	4.60	2.00	2.20	2.00	1.20	1.60	1.80	52.63	68.00	39.34
T3	3.60	4.80	3.10	4.50	3.50	3.10	3.80	-	48.80	-

T1 *Trichogrammatoidea bactrae* @ 2.5 lakhs ha
T2 Endosulfan @ 2.0 ml/l
T3 Control
* Mean of 10 plants, excluding parasitised ones

A reduction of 52.63% and 61.05% in larval population in endosulfan and parasitoid released plots, respectively, over control was observed. Yield data revealed that there was 56.15 % increase in yield in parasitoid release treatment over control.

4.26.2.2. ANGRAU, Hyderabad

The experiment was conducted with cabbage var. Golden Acre. Two 100 m^2 plots were prepared with a separation distance of 150 m to act as parasitoid release plot and control plot. The release plot was again subdivided into 5 equal parts of $20m^2$ for recording observations. *Tr. bactrae* was released ten days after transplanting @ 2.5 lakh/ha and thereafter at weekly intervals. A total of five releases were made. The efficacy of the parasitoid was determined on the basis of larval population. Establishment of the parasitoid in cabbage ecosystem was ascertained on the basis of recovery of the parasitoid from the released plot.

The number of *P. xylostella* larvae per plant in released plot started declining from 3.2 per plant to 0.58 per plant whereas in control it was 4.8 larvae per plant and remained 4-5 larvae per plant. The recovery of *Tr. bactrae* from the released plot suggested successful establishment of the parasitoid in cabbage ecosystem.

4.26.2.3. MPKV, Pune

The trial was laid out on the Research Farm of Entomology Section, College of Agriculture, Pune, on transplanted seedlings of cabbage (Golden Acre). The plot size was $100m^2$, divided into 5 subplots of 4 x 5 m^2. The treatments were:

T1 *Trichogrammatoidea bactrae* @ 50,000 adults/ha/release-five releases at weekly interval

T2 Untreated control

Release of parasitoids was commenced 25 days after transplanting of the crop. Observations on number of larvae per 10 plants from each subplot were recorded a day before initiation of release and thereafter at weekly interval. Yield of marketable cabbage heads per plot was recorded, and converted into q/ha.

The releases of *Tr. bactrae* @ 50,000 adults/ha/release 5 times at weekly interval commencing 25 days after planting was found significantly superior to control. The average surviving population was 9.1 larvae/10 plants and yield of 363.3 q/ha as against 12.86 average surviving larvae/ 10 plants and 233.5q/ha yield in control. The additional receipts due to this treatment were worth Rs.39,510/- with 1:55.64 ICBR.

4.26.3. 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 tenth harvest @ 40,000 to 70,000 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 9.00% in parasitoid release plot, whereas in control damage was between 18.1 and 28.5%. Mean borer damage in parasitoid release plot was 12.65% as against 23.10% in control. Cypermethrin treatment recorded a fruit damage of 14.70%. The yield data showed that there was 57.08% and 35.64% increase in yield in parasitoid and cypermethrin treatments over the control (Table 126).

Table 126. Effect of egg parasitoid, *Trichogramma chilonis* against *Leucinodes orbonalis* on brinjal

Treatment	Mean per cent bored fruits	Per cent reduction over control	Total marketable yield/plot	Per cent increase over control
Trichogramma chilonis	12.65	45.24	26.75	57.08
Cypermethrin @ 0.5ml/l	14.70	36.36	23.10	35.64
Control	23.10		17.03	-

4.26.4. Evaluation of different formulations of *Bacillus thuringiensis* against *Plutella xylostella* in cabbage

4.26.4.1. ANGRAU, Hyderabad

An experiment with cabbage var.Golden acre was conducted to evaluate the efficacy of different *Bt* formulations against Diamond Back Moth (DBM). A total of 7 *Bt* formulations, *viz*., Dipel, Spicturin, BTK-I, BTK-II, Biobit, Delfin and Halt were tested and the dosages for treatments were kept as 1.0 Kg/ha except for endosulfan (0.07%). Each treatment was replicated thrice and the plot size 25 m² was maintained. 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 number of *P. xylostella* larvae on 10 randomly selected plants from each plot at weekly interval.

The results presented in table 127 revealed that all the *Bt* formulations and also endosulfan were effective in reducing the larval build up on cabbage over the control. Among the various *Bt* formulations tested, biobit proved to be effective in keeping a check on DBM with least mean number of larvae (17.00) followed by Dipel (21.93). Endosulfan was also equally effective (18.67) and was on par with biobit. Overall observation of data also suggested that, there was no much difference in treatments in the initial spray applications but with the increase in the number of sprays, the differences among different treatments started looking prominent. Yield of marketable cabbage heads was determined at each harvest in each treatment. There were significant differences among the treatments. Of the *Bt* formulations, biobit yielded maximum marketable cabbage (56.00 q/ha) and performed equally with endosulfan (53.00 q/ha).

Table 127. Evaluation of different *Bt* formulations for their effectiveness against *P. xylostella* in cabbage

Treatment	Dosage (per ha)	Pre count of larval pop.	Mean larval population (10 plants) at 10 days interval					Mean larval population	Yield (q/ha)
			I	II	III	IV	V		
Dipel	1 kg	7.33 (2.78)	22.67 (4.80)	32.00 (5.69)	35.00 (5.96)	15.67 (4.02)	4.33 (2.19)	21.93 4.73	31.67
Spicturim	1 kg	10.00 (3.24)	24.67 (5.01)	44.67 (6.72)	37.33 (6.14)	17.33 (4.21)	5.67 (2.48)	25.93 (5.14)	36.00
BTK-I	1 kg	11.33 (3.43)	25.00 (5.05)	37.67 (6.17)	39.33 (6.31)	14.00 (3.81)	6.67 (2.67)	24.54 (5.00)	40.67
BTK-II	1 kg	10.33 (3.29)	22.00 (4.73)	45.00 (6.74)	45.67 (6.69)	11.33 (3.43)	5.67 (2.45)	25.93 (5.14)	36.33
Biobit	1 kg	11.67 (3.48)	14.33 (3.84)	30.00 (5.52)	28.33 (5.37)	10.00 (3.23)	2.33 (1.68)	17.00 (4.18)	56.00
Delfin	1 kg	10.00 (3.24)	19.33 (4.45)	31.00 (5.61)	30.67 (5.58)	9.00 (3.08)	3.33 (1.93)	18.67 (4.38)	32.33
Endosulfan	0.07%	10.33 (3.24)	19.33 (4.45)	31.00 (5.61)	30.67 (5.58)	9.00 (3.08)	3.33 (1.93)	18.67 (4.38)	53.00
Halt	1 kg	10.33 (3.27)	25.00 (5.05)	37.33 (6.14)	40.67 (6.41)	14.67 (3.89)	6.00 (2.54)	24.73 (5.02)	38.67
Control	-	9.67 (3.13)	40.67 (6.41)	56.67 (7.55)	58.67 (7.68)	33.33 (5.81)	19.67 (4.94)	41.80 (6.50)	23.67
CD (P=0.05)	NS	0.37	0.57	0.45	0.47	0.44	0.21	5.89	

Figures in parentheses are transformed values.

4.26.4.2. MPKV, Pune

The trial was laid out on the Research Farm of Entomology Section, College of Agriculture, Pune on cabbage (Golden Acre). The plot size was 5 x 4 m². There were seven treatments in three replications (RBD). Five *Bt* formulations, *viz.*, Delfin WG @ 1kg/ha, Dipel 8L @ 1 lit/ha, Biolep @ 1kg/ha, Biobit @ 1kg/ha, Halt @ 1kg/ha and endosulfan (0.07%) were compared with untreated control.

Application of treatments was initiated from one month after transplanting of the seedlings and five sprays were given at 10 days interval. Observations on number of larvae/plant were recorded from 10 heads in each plot, a day before initiation of sprays and thereafter at weekly interval. Yield of marketable heads/plot was recorded at harvest and then converted into q/ha.

The results showed that all the treatments were significantly superior to control in respect of larval population and yield of marketable cabbage heads. Spraying of Delfin WG @ 1kg/ha recorded minimum surviving larvae/plant (2.00) and maximum yield (314.7 q/ha) and was found to be most effective. It was however on par with Halt @ 1kg/ha for yield parameter (Table 128).

4.26.4.3. Dr.YSPUH & F, Solan

A field trial was laid out on cabbage in a farmer's field at village Bagairi, (Shimla district) in May 2000, with five formulations of *Bacillus thuringiensis* var. *kurstaki*, *viz*., Biobit DF (32000 IU/mg), Biolep (16000 IU/mg), Halt (55000 IU/mg) and Hill-BTK (32000 IU/mg) each @ 1.0 kg/ha taking 32000 IU/mg potency as base, to suppress lepidopteran larval complex. Pretreatment larval count on 15 marked plants / replicate (3 replicates/treatment) revealed that only larvae of cabbage butterfly were predominantly present on the crop and their count was 10-28 (mean 18.3) per infested plant. The count of other larvae, *viz. Helicoverpa armigera* (1-4 larvae with a mean of 2.1/15 plants), *Plutella xylostella, Plusia orichalcea* and *Spodoptera litura* (0-2 lavae, mean 0.7/15 plants) was very low. Larval counts taken 5 days after the spray revealed that these formulations brought about 85 to 97% reduction in larvae of *P.brassicae*, but the larvae that had hatched from eggs oviposited before or after the spray were feeding on the plant and no residual effect of the treatment was apparent. There was no reduction in other lepidopteran larvae.

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

4.26.5.1. IIHR, Bangalore

An experiment was conducted on the field efficacy of *Bt* commercial formulations (Dipel, Delfin, Biobit and Halt) against brinjal shoot and fruit borer, *Leucinodes orbonalis*. Results showed that there was no significant difference in percent bored fruits among the treatments including cypermethrin and untreated control. The mean per cent bored fruits in *Bt* treatments was 9.0–13.5% on par with that obtained in cypermethrin (14.2%) and control (13.5%), respectively (Table 129).

4.26.5.2. ANGRAU, Hyderabad

Two *Bt* formulations, *viz*., Dipel and Delfin, were tested with control and insecticidal (endosulfan) treatment for their effectiveness against brinjal fruit borer. Each treatment was replicated 5 times and the sprays were given during evening hours at 10 days interval starting from flower initiation stage. Per cent fruit damage was recorded. Observations were made seven days after the spray with precount of damaged fruits taken before the 1st spray application.

The effect of *Bt* formulation on *L. orbonalis* population was not very encouraging when compared with control and insecticidal treatments. Although the mean per cent damage by

Table 128. Economics of *Trichogramma pretiosum* and *Ha*NPV against *Helicoverpa armigera* on tomato

Treatment	Larval population/plant			Increase in yield over control due to treatment (q/ha)	Additional income due to treatment (Rs.300/q)	Cost of treatments including application charges (Rs.)	ICBR
	Pre count	Surviving Population	Yield (q/ha)				
Delfin WG @ 1kg/ha	6.00 (2.54)	2.00 (1.59)	314.7	167.0	50100	16400	1:3.05
Dipel 8L @ 1kg/ha	4.33 (2.19)	3.00(1.88)	279.1	157.5	47,250	7500	1:6.30
Biolep @ 1 kg/ha	5.00 (3.34)	4.00 (2.12)	215.9	70.8	21,240	7500	1:2.83
Biobit @ 1 kg/ha	5.33 (2.41)	3.33 (1.97)	237.1	82.8	24,840	10300	1:2.41
Halt @ 1kg/ha	5.66 (2.47)	2.66 (1.79)	293.1	142.6	42,780	7730	1:5.53
Endosulfan 0.07%	5.00 (2.34)	4.33 (2.21)	260.8	71.8	21,450	2020	1:10.66
Untreated control	4.00 (2.13)	10.30 (3.29)	184.5	-	-	-	-
CD (P=0.05)	(N.S.)	0.19	21.85				

Figures in parentheses are $\sqrt{n+0.5}$ transformation: Surviving population of larvae is the average of five post-counts;

N.S. = Non-significant, Cost: Marketable cabbage Rs. 300/q.

Delfin WG = Rs.3180/-per kg   Biobit @ 1kg = Rs.1960/-kg

Dipel 8 L = Rs.1400/-per lit.   Biolep @ 1kg= Rs.1400/-kg

Halt = Rs.1446/-per kg   EEndosulfan 35 EC = Rs.304/lit.

Labour requirement: Labour charges=Rs.50/-per day; 2 man-days/spray x 5 sprays = 10 man-days for spraying

Table 129. Effect of formulations against larval populations of *Plutella xylostella*

Treatment	Larval count (mean of ten plants)
Delfin @ 1.0 g/l	0.71
Halt @ 1.0 g/l	1.00
Dipel @ 1.0 g/l	0.74
Biobit @ 1.0 g/l	0.94
Endosulfan @ 2.0 ml/l	0.99
Control	0.98

L. orbonalis showed significant difference with control, much variation among the treatments was not seen.

4.26.5.3. MPKV, Pune

A field trial was conducted on the Research Farm of Entomology Section, Agricultural College, Pune, on transplanted brinjal seedlings (variety Manjari Gota). The plot size was 5 x4.5m^2 and plant spacing was 60 x 45 cm. The trial was laid out in RBD with five replications. The *Bt.* formulations, Dipel 8L @ 1 lit/ha and Delfin Wg @ 1kg/ha were compared with endosulfan 0.07% and untreated control.

Application of treatments was started 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 untreated control in reducing fruit infestation and increased yield of marketable brinjal. The treatment with five sprays of Delfin WG @ 1kg/ha recorded least fruit infestation (8.93%) and maximum yield (136.5 q/ha) and proved to be the best. It was, however, on par with the rest of the treatments except untreated control (Table 130).

Table 130. Efficacy of *T. chilonis* and different *B. thuringiensis* formulations for the control of *L. orbonalis* on brinjal

Treatment	Fruit infestation (%)	Yield of marketable fruits (q/ha)
Dipel 8L @ 1 lit./ha	9.36 (17.76)	134.4
Delfin WG @ 1 kg/ha	8.93 (17.36)	136.5
Endosulfan 0.07%	10.44 (18.77)	116.4
Untreated Control	28.90 (32.40)	86.4
CD (P=0.05)	(3.29)	25.18

* Figures in parentheses are angular transformed values

4.26.6. Control of *Helicoverpa armigera* in tomato using oil formulations of *Nomuraea rileyi* (IIHR, Bangalore)

To increase the field efficacy of *N. rileyi* against *H. armigera* on tomato, different oil formulations of the fungus were evaluated. Application of 5 sprays of gingelly oil formulation of the fungus at weekly interval right from flowering recorded least borer damage (1.68%) followed by groundnut oil and coconut oil formulations. Significant increase in yield (43.8-65.5%) was observed in oil formulation treated plots when compared to control plot (Table 131).

Table 131. Effect of various oil formulations of *Nomuraea rileyi* against tomato fruit borer

Treatment	Mean per cent bored fruits	Total yield (kg/plot)	Per cent increase over control
Fungus + Coconut oil	3.35	15.94	49.7
Fungus + Ground nut oil	2.89	16.76	52.4
Fungus + Gingelly oil	1.68	18.39	56.5
Fungus + Sunflower oil	3.56	14.23	43.8
Fungus + Water	3.78	13.05	38.7
Endosulfan 0.07%	4.68	12.31	35.1
Control	19.73	7.98	

4.26.7. Evaluation of Spic-bio (*Bacillus thuringiensis* var. *kurstaki*) against *Helicoverpa armigera, Spodoptera litura, Plutella xylostella* and *Crocidolomia binotalis* (IIHR, Bangalore)

Spic-bio, the new *Bt* commercial formulation of Tuticorin Alkali Chemicals and Fertilizers

Limited, Chennai, was evaluated for pathogenicity against second instar larvae of *Helicoverpa armigera*, *Spodoptera litura*, *Plutella xylostella* and *Crocidolomia binotalis* in the laboratory. Results showed that Spic-bio was effective against *H. armigera*, *P. xylostella* and *C. binotalis* and not effective against *S. litura*. *P. xylostella* and *C. binotalis* were highly susceptible when compared to *H. armigera*. Cent percent mortality to II instar larvae of *P. xylostella* was obtained after 48h at 1ml/l concentration of Spic-bio. In the case of *C. binotalis*, cent percent mortality was observed at 1.5ml/l concentration of Spic-bio after 48h. In the case of *H. armigera*, cent per cent mortality was observed at higher concentration of 1.75ml/l Spic-bio in an extended period of 120h.

4.26.8. Survey of natural enemies of vegetable crop pests

4.26.8.1.ANGRAU, Hyderabad

The vegetable growing areas in and around Hyderabad were surveyed for natural occurence of bioagents against major pests of cabbage and tomato. Diamondback moth, *Plutella xylostella* larvae were parasitised by *Cotesia plutellae* to an extent of 29%. *Helicoverpa armigera* in tomato recorded no natural parasitisation.

4.26.8.2. MPKV, Pune

The PTM leaf mining larvae were found to be parasitised by indigenous parasitoids, *Apanteles* sp. and *Bracon* sp. to the extent of 2.95 - 7.50 and 3.50 - 7.85 per cent in *kharif* and 8.50 - 13.45 and 6.65 - 10.75 per cent in *rabi* seasons, respectively. Maximum parasitism was recorded after 70 days. The coccinellid predators, *Cheilomenes sexmaculata* and *Coccinella septempunctata* were abundant, recording average 2.6 grubs/plant and 2.5 adults per plant after 60 days of planting. Adults of *Ischiodon scutellaris* were recorded in 50 days old crop. *S. litura* was very serious during *kharif* on potato. However, epizootics of *Nomuraea rileyi* was noticed in September and an average of 4.3 infected larvae/plant were recorded during the last fortnight of the crop.

In cabbage fields, parasitism by *Cotesia plutellae* (6.80 - 14.25%) was recorded in diamondback moth larvae. The syrphid, *I. scutellaris* was noticed during February-March in cabbage fields. The spiralling white fly was very serious on guava, papaya and other ornamental plants. *Mallada* spp. and *Encarsia* spp. were recorded in guava and papaya orchards.

4.26.8.3. Dr.YSPUH & F, Solan

All eggs collected from tomato field on May 10, were parasitised by *Trichogramma chilonis*. A week later, each of 60% infested tomato plants had density of 2/plant and from 20 collected eggs *T. chilonis* and *T. achaeae* emerged (10:1 ratio). In second half of May, 90% of tomato plants bore eggs (2.6 eggs/infested plant) and 41.3% were already blackened (parasitised). Among 44 field-collected eggs, 21 were parasitised (87.5%), Hardly 4 larvae were noticed on 30 plants. In the first fortnight of June, egg infested tomato plants fell to 40% and only 2 larvae/30 plants were found. Among 10 collected eggs, 8 were parasitised by *T. chilonis*.

At Solan, incidence of the green house whiteflies, *Trialeurodes vaporariorum* on ornamentals and vegetable crops is on increase. French bean crop in some fields was severely attacked by the whitefly during July - October. On one leaflet up to 200 nymphs and pupae were counted. Pale-yellow grubs of a coccinellid predator, *Serangium montazerii* were observed feeding on larvae and pupae of whiteflies. Average number of grubs recorded on a leaflet was 9 in late July, 16 in August and 16 in mid-September. The predator activity continued up to October. The number of larvae was more on older leaves than on the younger leaves.

The aphelinid endoparasitiod, *Encarsia transvena* parasitised 2-8% of the whitefly pupae. Both these natural enemies are being reported for the first time from Himachal Pradesh. The impact of natural enemies was not sufficient to suppress the population build up of the whiteflies.

4.26.9. Studies on the biology of *Hemiptarsenus varicornis*, an indigenous natural enemy of serpentine leafminer, *Liriomyza trifolii* (IIHR, Bangalore)

Field collections of serpentine leafminer (SLM) from fields of french bean, tomato, etc, were made. Field collected SLM infested leaves were kept in wooden cages of 24" x 15" x15" with sliding front glass door for emergence of natural enemies. During the period under report a total of 1816 adults of SLM and 112 adults *Hemiptarsenus varicornis* were collected from the field. Field parasitism thus was found to be 6.62%.

A stock culture of *L. trifolii* was maintained in the glass house, on french bean seedlings in earthen pots. A plastic jar (15 cm dia, 20 cm ht) with wire mesh ventilation on one side was used for exposing *H. varicornis* to *L. trifolii*. French bean twig with 2 leaves and 2nd instar larvae of *L. trifolii* (5-6 days after exposure to *L. trifolii* adults) were kept in a conical flask with water and the mouth plugged with cotton. This conical flask with the twig was kept in a wide Petri-plate and the plastic jar was kept inverted over the flask. Ten *H. varicornis* adults were collected in a small vial and released into the jar, by slightly lifting the jar. Honey streaks were provided inside the jar for *H. varicornis* adults. After 24 h the exposed twig was taken out and kept in a jar for further observation. This procedure was repeated 4-5 days to observe the leaves after different days of exposure to *H. varicornis*. The exposed leaves were observed every 24 h for number of living larvae, dead larvae and parasitised larva. The leaves with parasitised larvae were maintained to observe the different larval instars and pupae of *H. varicornis*.

Twenty-four hours after exposure to *H. varicornis*, parasitism of *L. trifolii* was indicated by the presence of light brown mark on the larval body. The larvae used for host feeding by *H. varicornis* adults were considered as dead. The egg stage of the parasitoid was not clearly visible. There are four larval instars with a larval period of 4-5 days. The pupa was naked and black and the pupal period lasted 5-6 days. The adult was a small, shiny, metallic green coloured insect, 1-2 mm in length. The adult longevity was 7-8 days.

4.26.10. Studies on stage preference of serpentine leaf miner by the parasitoid *H. varicornis* (IIHR, Bangalore)

All the four instars of the leaf miner were exposed separately to the adults of the parasitoid for 24h for parasitisation. The first instar of *L. trifolii* was least preferred with 3.03% parasitism, whereas the second instar was the most preferred with parasitism ranging from 25% to 61%. The third instar was parasitised to the extent of 0 % to 36%.

4.26.11. Studies on the progeny sex ratio of *Hemiptarsenus varicornis* (IIHR, Bangalore)

A preliminary study was conducted to study the sex ratio of the progeny of *Hemiptarsenus varicornis* when exposed to *Liriomyza trifolii*. One or two twigs of french bean seedlings with 2nd instar of *L. trifolii* (with 2 - 4 leaves) depending on the number of *H. varicornis* adults, was exposed to *H. varicornis* adults in a ventilated plastic jar. The twig was exposed to parasitoids for 24 h. After 24 h, the twig was removed and when the leaves started drying, they were stored in ventilated plastic jars till adult emergence. The total number of *H. varicornis* adults emerging and the number of male and female were recorded separately and the male:female ratio ranged from 1 : 0.12 to 1 : 0.44 with a mean of 1 : 0.25.

4.26.12. Potential of *Hemiptarsenus varicornis* in controlling serpentine leaf miner, *Liriomyza trifolii* (IIHR, Bangalore)

A single female of *H. varicornis* could parasitise up to 11 larvae in 24 h which means that the parasitoid could produce up to 30 per cent mortality of larvae of *L. trifolii* due to parasitisation and up to 15 larvae could be killed either for feeding or feeding and parasitisation (Table 132) Thus up to 75% mortality due to feeding and parasitisation was observed. Total death due to parasitisation and feeding and parasitisation varied from 1 to 20. Thus, the mortality due to feeding and feeding and parasitisation together ranged from 3.23 to 100 per cent of the exposed larvae. Forty five per cent of ovipositional attempts yielded parasitoids besides feeding on leaf miner indicating that the remaining 55 per cent mortality of leaf miner was exclusively contributed by feeding only. Recovery of parasitoids from fed and parasitized leaf miner larvae (presented as per cent shift in parasitism) was in the range of 30 to 100 per cent with a mean of 58.88 per cent. On an average 25 per cent increase in mortality was observed due to feeding. However, there was no significant correlation between per cent parasitism and the leaf miner population and leaf miner population and the per cent mortality due to feeding and parasitism.

4.26.13. Studies on the toxicity of pesticides to *H. varicornis* (IIHR, Bangalore)

A study was carried out to evaluate the safety of pesticides to the larval parasitoid, *H. varicornis*. French bean seedlings at two-leaf stage with *L. trifolii* mines were transplanted in small plastic cups of 8 cm dia (@ 2 seedlings/cup). The pesticide solution at the recommended dosage was prepared and sprayed on the seedlings with a glass atomizer. A control was also maintained where only water was sprayed. The seedlings were shade dried. Ten freshly emerged adults of *H. varicornis* were released into a glass vial (11 x 4.5 cm). A piece of leaf from treated seedlings after shade drying was placed inside the vial. Observations on the mortality of adults were recorded at 1 h, 3 h, 6 h, 24 h and 48 h after exposure.

Table 132. Feeding and parasitism of *L. trifolii* larvae by *H. varicornis*

Replication	Number of *L. trifolii* mines	Number of *L trifolii* larva killed due to parasitism	Number of *L trifolii* larva killed due to feeding and parasitism	Total death
1	17	4	3	7
2	39	2	4	6
3	15	0	1	1
4	20	5	15	20
5	16	0	1	1
6	40	11	12	23
7	26	1	4	5
8	12	2	2	4
9	42	1	2	3
10	18	0	10	10
11	10	3	0	3
12	40	1	5	6
13	9	1	5	6
14	10	1	4	5
15	46	1	2	3
16	31	0	1	1
17	27	3	10	13
18	20	2	2	4
19	10	0	2	2
20	12	1	2	3
'r' value	0.247	0.184	0.225	

Among the pesticides tested, insecticides imidacloprid and cypermethrin, pongamia oil and NSKE and fungicides like chlorothalonil, mancozeb and copper oxy chloride were found safe to *H. varicornis*. Monocrotophos and phosphamidon were moderately toxic after 6 h of exposure, but recorded 100% mortality after 48 h. Metalaxyl, mancozeb and carbendazim recorded 20% mortality after 48 h and dinocap recorded 40% mortality after 48 h (Table 133).

Table 133.Toxicity of different pesticides to *H. varicornis*

Treatment	Dose	Mortality after				
		1 h	3 h	6 h	24 h	48 h
I. Insecticides						
Monocrotophos	1.25 ml/l	0.0	10	60.0	80.0	100.0
Phosphamidon	0.5 ml/l	0.0	0.0	40.0	80.0	100.0
Imidacloprid	0.4 ml/l	0.0	0.0	0.0	0.0	0.0
Cypermethrin	0.5 ml/l	0.0	0.0	0.0	0.0	0.0
II. Botanicals						
NSKE	4%	0.0	0.0	0.0	0.0	0.0
Pongamia oil	20 ml/l	0.0	0.0	0.0	0.0	0.0
III. Fungicides						
Chlorothalonil	2 g/l	0.0	0.0	0.0	0.0	0.0
Manocozeb	2 g/l	0.0	0.0	0.0	0.0	0.0
Metalaxyl manocozeb	2 g/l	0.0	0.0	0.0	0.0	20.0
Copper oxy chloride	2 g/l	0.0	0.0	0.0	0.0	0.0
Carbendazim	1 g/l	0.0	0.0	10.0	20.0	20.0
Karathane	1 ml/l	0.0	0.0	10.0	20.0	40.0
IV. Water (Check)	-	0	0	0	0	0

4.26.14. Residual toxicity of monocrotophos and phosphamidon to *H. varicornis* (IIHR, Bangalore)

Residual toxicity of monocrotophos and phosphamidon to *H. varicornis* was studied. French bean seedlings at two-leaf stage were transplanted in small plastic cup (8 cm dia) (@ 2 seedlings/ cup). The pesticide solution at the recommended dosage was prepared and sprayed on the seedlings with a glass atomizer. Leaves from the treated seedlings were removed and exposed to adults of *H. varicornis* on 3rd, 7th, 14th, 21st and 28th day after spray. Mortality after 1 h, 3h, 6 h, 24 h and 48 h was recorded. A leaf sprayed with water was used as check.

Moderate toxicity of monocrotophos was observed for up to 21 days after spray and thereafter it was least harmful to the parasitoid. Phosphamidon showed least toxic effect for up to 14 days after treatment and became totally safe to the parasitoid when exposed for 24 h (Table 134).

Table 134. Residual toxicity of monocrotophos and phosphamidon to adults of *H. varicornis*

Treatment	Per cent mortality (Days after application)									
	3		7		14		21		28	
	24 h	48 h	24 h	48 h	24 h	48 h	24 h	48 h	24 h	48 h
Monocrotophos	40.0	100.0	40.0	100.0	20.0	80.0	10.0	50.0	.0.0	10.0
Phosphamidon	20.0	30.0	20.0	30.0	10.0	20.0	0.0	20.0	0.0	10.0

4.26.15. Leaf-miner on pea and tomato and their parasitisation (Dr.YSPUH & F, Solan)

Incidence of pea leafminer, *Chromatomyia horticola* was moderate. In second half of March, total miner population was 0-10 (mean 5.8) per leaflet. Larval and pupal population was 0-5 (1.7)/ leaflet, while 1-10 (mean 4.1) larvae and a few pupae were found dead due to one or other cause. Larval parasitization was 51.3% (47.9% by ectoparasitic and 3.4% by endoparasitic eulophid). In the first half of April, 41.7% larvae were parasitised.

On tomato, serpentine leaf miner, *Liriomyza trifolii* incidence prevailed from June. Among the sampled leaves, 28.9% leaflets exhibited infestation and in these infested leaflets, on an average, 1.8 larvae were present. Among these, 17.4% were alive, 39.1% had died due to unknown reasons and parasitisation was 43.5%. In July and August, infested leaflets were 56.3 and 75%, with a mean population of 0.9 and 0.5 larvae/leaflet. The live maggot population was 35.3 and 24%, while dead maggots were 52.9 and 71.7%, respectively, in these two months. Parasitisation was of lower magnitude (11.8 and 4.3%) in July and August.

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

4.27.1. Standardization of mass release techonology for parasitoids *Copidosoma koehleri* and *Chelonus blackburni* against PTM under field conditions

The experiment was conducted in farmers' field at village Peth (Dist.Pune) during *rabi* season 2000-2001. The potato variety 'Kufri Jyoti' was raised in 20 x 10 m^2 plots with spacing of 45x30 cm. The trial was laid out in RBD with three replications and seven treatments including control. The parasitoids were released 4 times in equal doses at weekly interval starting from 45 days after planting. Recovery of parasitoids through retrieval was done by displaying egg sheets each containing 50 eggs at 5 different spots for 48 h in each treatment plot after second release. Recovery of parasitoids (% parasitism) was also recorded by collecting 20 - 30 leaf- mining larvae from each treatment plot after four releases of the parasitoids. The eggs and larval stages were further reared in the laboratory on punctured tubers and potato leaves till formation of PTM pupae or mummies/ pupae of the parasitoids. At harvest, tuber samples from 2x2m^2 area from each plot at 3 places were collected to record tuber infestation. Yield data were recorded on per plot basis and further computed to q/ha.

All the treatments were significantly superior to control in reducing leaf mines during 2nd, 3rd and 4th week after initiation of parasitoid releases and tuber infestation and increasing the yield of marketable tubers (Table 135).

135. Efficacy of different methods of release of parasitoids against PTM on potato under field conditions

Treatment	Leaf mines/m row *					Per cent parasitism through		Average tuber infestation * * (%)	Yield of marketable tuber
	Per cent	Post-count, after weeks from initial release							
		I	II	III	IV	Retrieval	Recovery		
C. koehleri @ 50000 mummies/ha in plastic vials	2.73 (1.80)	2.53 (1.74)	1.33 (1.35)	0.80 (1.14)	0.33 (.091)	65.08	20.25	5.86 (13.95)	235.7
C. koehleri @ 50000 mummies/ha in gelatinous capsules	2.47 (1.72)	2.67 (1.78)	1.73 (1.50)	1.13 (1.27)	0.73 (1.11)	59.73	17.33	9.30 (17.72)	201.0
C. koehleri @ 2 lakh adults/ha	2.67 (1.78)	2.80 (1.82)	1.60 (1.45)	1.07 (1.25)	0.67 (1.08)	62.40	17.77	6.90 (15.22)	225.4
C. blackburni @ 6000 pupae/ha in plastic vials	2.60 (1.76)	2.60 (1.76)	1.27 (1.33)	0.87 (1.17)	0.40 (0.95)	61.73	18.43	6.84 (15.19)	228.5
C. blackburni @ 6000 pupae/ha in gelatinous capsules	2.73 (1.80)	2.67 (1.78)	1.73 (1.49)	1.27 (1.33)	0.87 (1.17)	53.13	9.67	9.93 (18.33)	196.3
C. blackburni @ 6000 adult/ha	2.73 (1.80)	2.80 (1.82)	1.40 (1.38)	1.13 (1.27)	0.80 (1.14)	61.10	15.33	7.80 (16.22)	223.0
Untreated control	2.70 (1.79)	2.93 (1.85)	3.73 (2.05)	3.47 (1.99)	2.40 (1.70)	-	-	29.87 (33.11)	157.8
CD (P=0.05)	(N.S)	(N.S)	(0.10)	(0.12)	(0.17)			(2.11)	19.05

Figures in parentheses are * $\sqrt{n+0.5}$ and ** angular transformation; NS- Non-significant at weekly interval

Releases of *C. koehleri* @ 50,000 mummies/ha in four equal doses at weekly interval in perforated plastic vials hung 5 m apart in the field 45 days after planting recorded minimum leaf mines (0.33-0.80 mines/m row) during 3rd and 4th weeks, tuber infestation of 5.86% and maximum tuber yield of 235.7 q/ha and proved to be the best treatment. It was however, on par with *C. koehleri* @ 2 lakh adults/ha and *C. blackburni* @ 60,000 pupae/ha released in perforated plastic vials hung in the field, and *C. blackburni* @ 60,000 adults/ha released in four equal doses. Maximum parasitism through retrieval (65.08%) and recovery from leaf mining larvae (20.25%) were recorded in the treatment plots where *C. koehleri* mummies were released in plastic perforated vials.

4.27.2. Large scale evaluation, recovery and carryover of parasitism of *Copidosoma koehler* and *Chelonus blackburni* against PTM from field to storage

The experiment was conducted in farmers' field using potato var. Kufri Jyoti at Malegaon (Dist. Pune) during *kharif* 2000. The plot size was 0.20 ha, divided into 7 subplots and the spacing was 45x30 cm. Inundative releases of *C. koehleri* @ 50,000 adults/ha/release and *C. blackburni* @ 15,000 adults /ha/release were followed four times at weekly interval commencing from 45 days after planting. Observations on leaf mines, tuber infestation, yield of marketable tubers and recovery of parasitoids through retrieval and collection of leaf mining larvae were recorded. The carryover parasitism from field to storage was recorded by collecting 20 kg infested tubers from the treatment plots at harvest, which were then brought to laboratory for observations. The potatoes were placed separately in plastic baskets on a layer of coarsely sieved soil to record number of PTM pupae and/ or mummies of *C. koehleri* and pupae of *C. blackburni*.

Releases of adult, *C. koehleri* and *C. blackburni* were found to be significantly superior to control in reducing leaf-mining after 2nd, 3rd and 4th weeks after initiation of their releases and tuber infestation and increased yield of marketable potatoes (Table 136). Four releases of *C. koehleri* @ 50,000 adults/ha/release at weekly interval recorded minimum of 0.34-0.57 leaf mines/m row, 6.82% tuber infestation and maximum of 215.7 q/ha tuber yield and proved to be the best treatment. It was, however, on par with *C. koehleri* @ 15,000 adults/ha/release 4 times at weekly interval. The parasitism through retrieval (63.64%) and recovery through leaf mining PTM larvae (13.79%) was also higher. Carry over was higher in case of *C. blackburni* (6.74%) than *C. koehleri* (5.94%).

4.27.3. Evaluation of release methods of *Copidosoma koehleri* and *Chelonus blackburni* and microbial agents against PTM in country stores (*Arnies*)

An experiment was conducted by preparing seven miniature *Arnies*, each of 20 kg capacity under shade in screen house. Potatoes harvested from *rabi* crop were obtained from farmers fields, sorted out to separate infested tubers and only healthy marketable potatoes were used for setting up *Arnies*. Two applications of GV and *B. thuringiensis* were given, first one before arranging the *Arnies* and second one month after, whereas the parasitoids were released five times at 15 days interval starting from setting up *Arnies*. All the *Arnies* were covered with double layer of grass and paddy straw as per the local practice.

136. Large-scale evaluation, recovery and carryover of parasitism of *C. koehleri and C. blackburni* against PTM from field to storage

Treatment	Leaf mines/m row *					Per cent parasitism		Average tuber infestation (%)	Yield q/ha	Per cent carry over
	Pre-count	Post-count, after weeks from initial				Through retrieval	Through recovery			
		I	II	III	IV					
C. koehleri @ 2 lakh adults/ha	2.40 (1.70)	2.57 (1.75)	1.83 (1.52)	0.57 (1.03)	0.34 (0.92)	63.64	13.79	6.82 (14.96)	215.7	5.94
C. blackburni @ 60,000 adults/ha	2.29 (1.67)	2.66 (1.78)	1.57 (1.43)	0.69 (1.08)	0.40 (0.95)	62.43	1.50	7.96 (16.35)	202.9	6.74
Untreated control	2.37	2.74	3.11	3.17	2.80	-	-	27.21	150.8	
CD (P=0.05)	(NS)	(NS)	(0.22)	(0.24)	(0.15)	-	-	(2.46)	16.88	-

Figures in parentheses are * $\sqrt{n+0.5}$ and ** angular transformation; NS = Non-significant

Twenty-five newly emerged pairs of PTM were released in the vicinity of *Arnies* for creating artificial infestation. Observations on per cent tuber infestation were recorded 1 and 2 1/2 months (at termination) after application of treatments.

All the treatments were significantly superior to control in reducing tuber infestation at 1 and 2 1/2 months from initiation of treatments (Table 137). Release of *C. koehleri* @1 mummy/4 kg tubers was most effective and recorded minimum of tuber infestation (11.36%) in storage after one month and was on par with *C. blackburni* @2 pupae/kg tubers. After 2 1/2 months at termination of *Arnies*, the treatment with releases of *C. blackburni* @ 2 adults/kg tubers recorded minimum of infestation (25%) as against untreated control (55.03%). The rest of the treatments except GV @ 1.0 g/kg tubers were on par with these treatments.

Table 137. Efficacy of release method of parasitoids and microbial agents against PTM in country stores (*Armies*)

Treatments	Tuber infestation (%) after	
	1 month	2 ½ months
C. koehleri @ 5 pairs of adults/1 kg tubers at fortnigtly interval	14.61 (22.46)	25.68 (30.41)
C. koehleri mummy /4 kg tubers at fornightly interval	11.36 (19.70)	25.74 (30.48)
C. blackburni @ 2 adults /1 kg tubers at fornightly interval	14.91 (22.70)	25.00 (29.99)
C. blackburni pupae @ 2 per kg tubers at fornightly interval	12.89 (21.04)	29.10 (32.62)
GV @ 1 g at monthly interval	15.42 (23.13)	37.14 (34.54)
B. thuringiensis @ 1 kg at monthly interval	13.50 (22.55)	25.68 (31.27)
Untreated control	34.85 (36.19)	55.03 (47.89)
CD (P=0.05)	(1.79)	(2.15)

4.27.4. Evaluation of the safety of different foliage powders to parasitoids of PTM in storage conditions

Laboratory experiments were carried out by directly exposing 10 pairs of *C. koehleri* adults and 10 adults of *C. blackburni* to finely ground foliage powders of seven plants (Nirgundi, Lantana, Ocimum, Custard apple, neem, Eucalyptus and Karanj) kept in glass vials plugged with cotton. A separate experiment was also carried out by placing two kg potatoes dusted with 100 g foliage powders (5% w/w) of eight plants in bell jars. Then, egg sheets with 100 eggs of PTM were placed in each jar and 10 pairs of *C. koehleri* and 10 adults of *C. blackburni* were released. Data on per cent mortality of the parasitoids, parasitism and emergence of PTM adults were recorded.

spray each of *Sl*NPV @ 500 LE/ha (3x10[12] PIB/ha), *Nomuraea rileyi* @ 10[9] conidia/ml (10[12] conidia/ha), endosulfan (0.07%) and untreated control. The application of treatments was given 52 DAP when an average of 2.04 larvae/plant were recorded.

The observations on per cent larval mortality were recorded by collecting 10 larvae from each treatment plot one hour after spray and reared in the laboratory on treated foliage collected from respective treatments till mortality and/or pupation. Tuber damage at harvest from unit area in each treatment plot and yield of marketable tubers/plot were recorded.

The data indicated that spraying of *Sl*NPV @ 500 LE/ha recorded maximum larval mortality (85%) and minimum tuber infestation (8.83%) with higher marketable tuber yield of 209.1 q/ha (Table 140). This treatment was most effective and was on par with *B. thuringiensis* (Delfin WG) @ 0.5 kg/ha.

Table 140. Efficacy of different entomopathogens against *S. litura* on potato

Treatmet	Larval mortality (%)	Tuber infestation (%)	Yield of marketable tubers (q/ha)
*Sl*NPV @500 LE/ha (3x1012 POBS/ha)	85.00 (67.50)	8.83 (17.18)	209.1
B. thuringiensis (Delfin WG) @ 0.5 kg/ha	75.00 (60.64)	10.81 (19.16)	194.6
B. bassiana @ 250 LE/ha (1x1012 conidia/ha)	42.50 (40.61)	16.80 (24.19)	188.1
N. rileyi @ 109 conidia/ml (1x1012 conidia/ha	52.50 (46.44)	15.45 (23.11)	171.3
Endosulfan 0.07%	72.50 (58.61)	14.58 (22.46)	180.5
Untreated control	12.50 (20.47)	29.47 (32.84)	139.9
CD (P=0.05)	(9.74)	(3.21)	17.45

Figures in parentheses are angular values

4.27.6. Studies on recovery and establishment of parasitoids of PTM

During *rabi* season (Nov.2000 to Jan.2001), the potato fields where earlier parasitoid releases trials were conducted, were sampled for leaf mining larvae of PTM. The larvae were collected at fortnightly interval starting from 40 days after planting of the crop, brought to the laboratory and reared till pupation/mortality. The infested tubers after harvest of the crop were collected from different fields and reared for recovery of the parasitoids.

Parasitoids, *C. koehleri* and *C. blackburni* were not recovered from the leaf mining larvae collected in parasitoid released fields. However, one adult of *C. blackburni* was recovered from the infested tuber samples collected at harvest. The indigenous parasitoids, *Apanteles* spp. and *Bracon* spp. were recorded from PTM leaf mines after 70 days of planting.

During the year, large scale demonstration of parasitoids against PTM in potato fields at village Peth (Tal-Amgegaon) and *Cryptolaemus* beetles against grapevine mealy bugs at Narayangaon (Tal-Junnar) in Pune district were conducted. Besides, "Trichocards" (530), *Cryptolaemus* beetles ((9,500), *Ha*NPV (117 lit), *Sl*NPV (10 lit) and *So*NPV (24 lit) were mass produced in this laboratory for distribution to farmers.

The natural enemies recorded in the potato fields included parasitoids, *viz.*, *Apanteles* spp, *Bracon* spp, *Eriborus* spp, predators *Chrysoperla carnea, Ischiodon scutellaris, Cheilomenes sexmaculata* and *Coccinella septempunctata.*

4.28. Biological suppression of weeds

4.28.1. Monitoring and evaluation of *Neochetina eichhorniae* and *Orthogalumna terebrantis*

4.28.1.1. KAU, Thrissur

Water hyacinth plants from Alappuzha, Kottayam, Thrissur and Ernakulam were sampled and observations recorded on number of *Neochetina* weevils and grubs per plant and score values for weevil and mite infestation (Tables 141 & 142). The weevils were recorded in greater numbers during July in all locations, while mites were more during November.

Table 141. Population of *Neochetina eichhorniae* and morphological parameters of water hyacinth

Locations	Sampled during	Number of weevils/plants**	Number of grubs/plant*	Scar/leaf (score)**
Alappuzha	April	3.6	1.4	2.9
	July	1.4	0.8	2.4
	November	1.0	1.6	1.6
Kottayam	April	3.1	0.3	2.4
	July	0.9	0.1	1.6
	November	0.8	1.6	1.4
Thrissur II (Karuvannur)	April	2.9	1.1	2.4
	July	1.6	0.9	2.6
	November	2.2	0.5	2.3
Ernakulam	Apri'l	3.5	2.4	3.6

* Average number from 10 plants samples

** Scoring was done from 25 leaves

Table 142. Population of *Orthogalumma terebrantis* in Kerala

Locations	Observation	Number of mites/leaf*	Mines/leaf (score)*
Alappuzha	April	70.12	2.84
	July	32.92	2.52
	November	63.69	3.16
Kottayam	April	59.70	2.68
	July	56.28	2.44
	November	78.84	3.72
Thrissur II	April	83.00	2.64
	July	72.24	3.28
	November	93.16	2.76
Ernakulam	November	163.44	3.68

* Mean of 25 leaves

4.28.1.2. AAU, Jorhat

Successful control of water hyacinth has been achieved in Assam by the exotic weevils *Neochetina eichhorniae* and *N. bruchi*. The dispersal of the weevil has taken place in eight districts of Assam, *viz.*, Sonitpur, Lakhimpur, Dibrugarh, Sibsagar, Jorhat, Golaghat, Nowgaon and Kamrup through aerial migration in Brahmaputra river and its tributaries. Stunted growth of water hyacinth accompanied by less flowering was observed in all the eight districts. The presence of the weevils was noticed in Kamrup district about 300–330 km from Jorhat (where initial releases were made). The adult count varied from 0.16 to 1.80 and damage scars from 14.40 to 207.96. The population build up and intensity of leaf damage were recorded in all the migrated areas (Table 143).

Table 143. Establishment of *Neochetina eichhorniae* and *N. bruchi* in Assam

Locations	Number of adults per plant			Intensity of leaf damage *			Number of scars/leaf		
	July	Dec	March	July	Dec	March	July	Dec	March
Alengmora	1.44	1.35	1.80	1.96	1.87	1.48	1.47	59.40	26.08
Moriani	0.16	-	0.28	1.36	-	0.96	18.72	-	14.40
Disangmukh	0.68	-	0.88	1.72	-	2.72	36.68	-	207.96
Samuguri	0.52	0.48	0.25	1.28	1.50	1.40	53.44	35.15	23.48
Selenghat	0.36	0.37	0.56	0.76	1.27	1.30	21.00	28.15	25.65

0=Nil; 1=25 leaf area damaged; 2=50% leaf area damaged; 3=75% leaf area damaged and 4= Above 75% leaf area damaged

4.28.2. Monitoring and evaluation of *Cyrtobagous salviniae* (KAU, Thrissur)

Samples of salvinia were collected from Thrissur and Kottayam districts during the period to assess the field population of the weevils. Samples were taken from 1 m^2 area and healthy buds, weight of plants, number of weevils and per cent plants affected were recorded. The weevils and their damage could be noticed in almost all the locations though the field population of the weevil varied (Table 144).

Table 144. *C. salviniae* infestation in different areas of Thrissur and Kottayam districts

Location	Sampled during	Healthy buds	Number of weevils / sample	Weight of plants (g)
Vellanikkara	April	11.00	2.0	6.33
	July	5.30	2.0	593.3
	November	56.66	-	863.3
Palkulam	April	14.67	2.67	396.67
	July	11.60	1.6	460.0
	November	23.00	2.66	720.0
Marappatti-kulam	April	17.67	4.67	410.0
	July	20.60	6.3	536.6
	November	6.66	9.33	423.33
Irinjalakuda I	April	0.67	15.0	385.0
	July	3.60	9.0	610.0
	November	3.60	9.0	610.0
Irinjalakuda II	April	10.33	7.67	653.3
Pudukkad	April	19	8	561.6
	July	9.6	5.6	510
	November	10.6	8.3	543.3
Kottayam	April	18.3	3	517
	July	14.3	7.33	608.33
	November	45.3	2.3	416.6

All figures are means of three samples

4.28.3. Parthenium control with *Zygogramma bicolorata* under mid-hill conditions (Dr.YSPUH & F)

The chrysomelid beetle is spreading very slowly from the established site. The diapausing females started laying eggs in the last week of April. In the field, larvae were noticed for the first time in the first week of July (2 larvae/50 plants). By August end, their population had increased to 0.5 adults, 0.9 eggs and 0.1 larvae per plant. Further observations could not be recorded at the site as the weed was eradicated manually. At another site, about one kilometer away, the beetle activity was found to be 0.2, 0.2 and 0.06 adult, eggs and larva per plant by August end. There was no significant increase in the population thereafter at that location.

5. TECHNOLOGY ASSESSED AND TRANSFERRED

5.1. Technology assessed

5.1.1. Mass production of *Hirsutella thompsonii* and *Steinernema carpocapsae*

Technology for mass production of *Hirsutella thompsonii* for the control of coconut mite, *Aceria guerreronis* on coconut was assessed and standardized.

A mass multiplication technique for the entomopathogenic nematode, *Steinernema carpocapsae* was developed.

5.2. Technology transferred

5.2.1. *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. *ciceri, F. oxysporum* f. sp. *udum* and *Pythium* spp.

5.2.2. Nucleopolyhedrovirus for the control of *Spodoptera exigua*

A multiple embedded nucleopolyhedrovirus (NPV) for the control of beet armyworm, *Spodoptera exigua*. (*Se*MNPV) is highly effective @ 2×10^6 PIBs/ml and safe to the mulberry silkworm, *Bombyx mori* and the predator *Chrysoperla carnea*. It is highly cross infective to *S. litura*.

5.2.3. Granulosis virus for the control of *Plutella xylostella*

A potential granulosis virus (GV) identified for the control of diamondback moth, *Plutella xylostella* is ready and is safe to *Cotesia plutellae, Chrysoperla carnea* and *Bombyx mori*. It is not cross infective to other lepidopteron pests.

6. EDUCATION AND TRAINING

6.1. Education

Mr.B.S.Bhumannavar, Senior Scientist was awarded Ph.D. for his thesis entitled, "Studies on the fruit piercing moths (Lepidoptera: Noctuidae), species composition, biology and natural enemies" from the University of Agricultural Sciences, Bangalore, on 10-11-2000.

Mr. S.K.Jalali, Scientist (SS) was awarded Ph.D. for his thesis entitled, "Studies on the management of borer pests of fodder maize with special reference to *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae)" from the University of Mysore, Mysore, on 18-12-2000.

6.2 Training

Dr.(Ms.)C.R.Ballal, Scientist (SS), attended a programme on "Management of Development Programmes for Women Scientists" from 1st May to 6th May 2000 at National Academy of Agricultural Research Management, Hyderabad.

Ms. M. Pratheepa, Scientist, attended a training programme, "Advanced Techniques in Geographic Information System" from 7th August to 11th August, 2000 at Centre for Development of Advanced Computing, Pune.

Dr.S.S.Hussaini, Senior Scientist attended a training programme on "Mass production and quality control of entomopathogenic nematodes" from 1st to 30th September 2000 at Rutgers University, New Jersey, USA.

Dr.N.S.Rao, Senior Scientist was deputed to All Russia Biological Control Institute, Krasnodar and All-Russian Research Institute of Plant protection, Moscow, Russia, from September 18-27, 2000, for study in the field of "Biological and microbiological Control of Pests and Diseases".

Dr.S.P.Singh, Project Director, attended a course on "Information Communications Technology for Agricultural Research and Extension" from 04-12-2000 to 09-12-2000 at National Institute of Agricultural Extension Management, Hyderabad.

Dr. P.L.Tandon, Principal Scientist, attended an interaction meet on "Intellectual Property Rights and Its Implications for Industry, R&D and Consultants" on 26th March, 2001 at Indian Institute of Technology, Chennai.

Mr.J.J.Jani, Assistant Research Assistant, Gujarat Agricultural University, Anand, attended a refresher course on "Plant Sciences" at Academic Staff College, University of Hyderabad, Hyderabad from, 18-08-2000 to 07-09-2000 and a refresher course on "Emerging Trends in Microbial Control of Crop Pests" at Department of Entomology, Tamil Nadu Agricultural University, Coimbatore, from 14-11-2000 to 13-12-2000.

Dr.D.S.Pokharkar, Assistant Entomologist (Selection Grade), College of Agriculture (Mahatma Phule Krishi Vidyapeeth), Pune, attended a training course in "Diploma in Computer Application" organized by MITCON, Computer Training Centre, Pune from, September 11-09-2000 to 10-11-2000.

Dr.(Ms.) Chandrika Mohan, Scientist (SS), Regional Station, Central Plantation Crops Research Institute, Kayangulam, attended a refresher course on " Emerging Trends in Microbial Control of Crop Pests" at Department of Entomology, Tamil Nadu Agricultural University, Coimbatore, from 14-11-2000 to 13-12-2000.

7. AWARDS AND RECOGNITIONS

Dr.S.P.Singh was elected Fellow, Indian Society for Advancement of Insect Science w.e.f. October 2000; Fellow of National Academy of Agricultural Sciences, w.e.f. January 2001.

Mr. J. Srikanth, Scientist (Senior Scale) was awarded the Best Oral Paper presentation for the research article presented at the National Symposium on Vistas of Entomological Research for the New Millennium, G.S. Gill Research Institute, Chennai, during December 28-30, 2000.

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
Indian Institute of Horticultural Research, Bangalore (Karnataka)	- Fruits and vegetables
Indian Institute of Sugarcane Research, Lucknow (Uttar Pradesh)	- Sugarcane
Sugarcane Breeding Institute, Coimbatore (Tamil Nadu)	- Sugarcane
State Agricultural University based centres	
Assam Agricultural University, Jorhat (Assam)	- Rice and weeds
Acharya N.G.Ranga Agricultural University, Hyderabad (Andhra Pradesh)	- Pulses, cotton, vegetables, oilseeds and coconut
Govind Ballabh Pant University of Agricultural Sciences and Technology, Pantnagar (Uttar Pradesh)	- Plant diseases (pulses & oilseeds)
Gujarat Agricultural University, Anand (Gujarat)	- Cotton, pulses, oilseeds vegetables and weeds
Kerala Agricultural University, Thrissur (Kerala)	- Weeds, rice, fruits and coconut
Mahatma Phule Krishi Vidyapeeth, Pune (Maharashtra)	- Potato, vegetables and cotton
Punjab Agricultural University, Ludhiana (Punjab)	- Sugarcane, cotton, pulses, rice and oil seeds
Sher-E-Kashmir University of Agricultural Sciences & Technology, Srinagar (Jammu & Kashmir)	- Temperate fruits and vegetables
Tamil Nadu Agricultural University, Coimbatore (Tamil Nadu)	- Rice, cotton and pulses
Dr.Y.S.Parmar University of Horticulture & Forestry, Solan	- Temperate fruits, (Himachal Pradesh) vegetables and weeds

GENERAL / MISCELLANEOUS

10. LIST OF PUBLICATIONS

10.1 Publications in scientific journals

Project Directorate of Biological Control, Bangalore

Bakthavatsalam, N., Singh, S.P., Tandon, P.L., Chaudhary, M. and Preethi, S. 2000. Electrophysiological responses of *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae) to some potential kairomonal substances. *Journal of Entomological Research* **24** (2): 109-114.

Ballal, C. R. and Ramani, S. 1999. Fertility table for an exotic parasitoid, *Telenomus remus* Nixon (Hymenoptera: Scelionidae). *Journal of Biological Control.* **13** : 25-31.

Ballal, C. R. and Ramani, S. 2000. Cocoon production by host-deprived parasitoid. *Insect Environment* **6** (1): 7-8.

Ballal, C. R., Joshi, S. and Rao, N. S. 2000. Technique for segregating male and female *Campoletis chlorideae* at cocoon stage. *Pest Management in Horticultural Ecosystems.* **6** (2): 106-109.

Hussaini, S.S., Singh, S.P., Parthasarathy, R. and Shakeela, V. 2000. Infectivity of native populations of *Steinernema* spp. and *Heterorhabditis indicus* in sand and sandy loam soil columns against *Agrotis ipsilon* (Hufnagel). *Annals of Plant Protection* **8**(2): 200-205.

Hussaini, S.S., Singh, S.P., Parthasarathy, R. and Shakeela, V. 2000. Virulence of native entomopathogenic nematodes against black cutworms, *Agrotis ipsilon* and *A. segetum*. *Indian Journal of Nematology* **30**(1): 102-104.

Hussaini, S.S., Singh, S.P. and Parthasarathy, R. 2000. Storage effects on activity of native *Steinernema* and *Heterorhabditis* spp. *Indian Journal Nematology* **30** (1): 76-81.

Jalali, S.K., Singh, S.P. and Biswas, S.R. 2000. Parasitisation behaviour of *Leptomastix dactylopii* Howard (Hymenoptera: Encyrtidae) at various densities of *Planococcus citri* Risso. *Journal of Entomological Research* **24** (2): 159-162.

Jalali, S.K., Singh, S.P. and Biswas, S.R. 2000. Population dynamics of *Aphis gossypii* Glover (Homoptera: Aphididae) and its natural enemies in the cotton ecosystem. *Journal of Aphidology* **14**: 25-32.

Joshi, S., Ballal, C.R. and Rao, N.S. 2000. The age-specific life-table of *Paragus serratus* (Fabr.) and *Paragus yerburiensis* Stuck. (Diptera: Syrphidae), predators of *Aphis craccivora* Koch (Homoptera: Aphididae). *Journal of Aphidology*, **14**: 67-72.

Joshi, S., Ballal, C.R. and Rao, N. S. 2001. Influence of temperature on biological, predatory and reproductive attributes of *Sticholotis cribellata* Sicard (Coleoptera: Coccinellidae) on *Melanaspis glomerata* Green. *Annals of Plant Protection Sciences*, **9**: 26-31.

Joshi, S., Ballal, C.R. and Rao, N.S. 2000. Effect of low holding temperature during adult stage on biological attributes of *Brumoides suturalis* (Fabricius). *Indian Journal of Ecology*, **27**: 136-141.

Joshi, S., Kumar, P. S. and Singh, S. P. 2000. Occurrence of *Fusarium coccophilum* (Desm.) Wollenw. & Reinking on sugarcane whitefly, *Aleurolobus barodensis* (Maskell) (Homoptera: Aleyrodidae). *Journal of Biological Control*, **14**(1): 49-50.

Kumar, P. S. 2000. A new disease of *Parthenium hysterophorus* incited by an undescribed species of *Cryptosporiopsis*. *Plant Disease*, **80**(10): 1151.

Kumar, P. S. and Singh, S. P. 2000. First Report of *Lasiodiplodia theobromae* as a foliar pathogen of *Parthenium hysterophorus*. *Plant Disease*, **84**(12): 1343.

Kumar, P. S. and Singh, S. P. 2000. *Hirsutella thompsonii*: the best biological control option for the management of the coconut mite in India. *Indian Coconut Journal*, **31**(5): 11-17.

Poorani, J., 2000. First record of the genus *Microserangium* Miyatake (Coleoptera: Coccinellidae) from India, with description of a new species. *Journal of Biological Control*, **14**: 45-47.

Poorani, J., 2001. A review of the genus *Pseudaspidimerus* Kapur (Coleoptera: Coccinellidae) from India, with description of a new species. *Oriental Insects* **35**: 299-310.

Prasad, R. D. and Rangeshwaran, R. 2000. A modified liquid medium for mass production of *Trichoderma* by fermentation process. *Plant Disease Research* **15**: 209-211.

Prasad, R. D. and Rangeshwaran, R. 2000. Effect of soil application of a granular formulation of *Trichoderma harzianum* on seed rot and damping-off of chickpea incited by *Rhizoctonia solani*, saprophytic growth of the pathogen and bioagent proliferation. *Journal of Mycology and Plant Pathology* **30**: 216-220.

Prasad, R. D. and Rangeshwaran, R. 2000. An improved medium for mass production of the biocontrol fungus *Trichoderma harzianum*. *Journal of Mycology and Plant Pathology* **30**: 233-235.

Prasad, R. D. and Rangeshwaran, R. 2000. Shelf life and bioefficacy of *Trichoderma harzianum* formulated in various carrier materials. *Plant Disease Research* **15**: 38-42.

Ramani, S. 2000. Fortuitous introduction of an aphelinid parasitoid of the spiralling whitefly, *Aleurodicus dispersus* Russell (Homoptera: Aleyrodidae) into the Lakshadweep islands with notes on host plants and other natural enemies. *Journal of Biological Control*, **14**: 55-60.

Rangeshwaran, R. and Prasad, R. D. 2000. Isolation and screening of rhizobacteria for control of chickpea diseases. *Journal of Biological Control* **14**: 9-15.

Rangeshwaran, R. and Prasad, R. D. 2000. Biological control of Sclerotium rot of sunflower. *Indian Phytopathology* **53**: 444-449.

Sankaranarayanan, C., Hussaini, S. S., Kumar, P. S. and Rangeshwaran, R. 2000. Biological control of *Meloidogyne incognita* (Kofoid and White 1919) Chitwood 1949 on tomato by *Verticillium chlamydosporium* Goddard cultured on different substrates. *Journal of Biological Control*, **14**(1): 39-43.

Sankaranarayanan, C., Hussaini, S. S., Kumar, P. S. and Rangeshwaran, R. 2001. Evaluation of substrates for the multiplication of *Verticillium chlamydosporium* Goddard and its biocontrol efficacy against *Heterodera cajani* Koshy on pigeonpea. *Annals of Plant Protection Sciences* **9**(1): 73-76.

Venkatesan, T. Singh, S.P. and Jalali, S. K. 2000. Rearing of *Chrysoperla carnea* (Neuroptera: Chrysopidae) on semi-synthetic diet and its predatory efficiency against cotton pests. *Entomon* **25** (2): 81-89.

Venkatesan, T., Singh, S.P. and Jalali, S.K. 2000. Effect of cold storage on cocoons of *Goniozus nephantidis* Muesebeck (Hymenoptera: Bethylidae) stored for varying periods at different temperature regimes. *Journal of Entomological Research* **24**(1): 43-47.

Central Plantation Crops Research Institute, Regional center, Kayangulam

Chandrika Mohan, Sathiamma, B. and Sabu, A.S. 2001. Observations on laboratory mass multiplication of braconid endoparasitiod, *Apanteles taragamae* Wilk. on early instar caterpillars of *Opisina arenosella* Walker on coconut. *Entomon* **25** (4): 261-268.

Gopal, Murali, Gupta, A, Nair, K.R.C., Sathiamma, B. and Radhakrishnan Nair, C.P. 2000. Studies on cross infectivity with entomofungal isolates of *Aspergillus flavus* Link. against *Stephanitis typica* D. and *Opisina arenosella* W., two pests of coconut. *Indian Coconut Journal* **31**(7): 12-15.

Gopal, Murali, Gupta, A., Sathiamma, B., Mohan, C., Nair, K.R.C. and Soniya, V.P. 2000. A fungal pathogen of lace bug and leaf eating caterpillar, two insect pests of coconut palm. CORD (APCC, Indonesia) **16** (1): 49-60.

Gopal, Murali and Gupta, A. 2001. Has *Hirsutella thompsonii* the wherewithal to counter coconut eriophyid mite scourge? *Current Science* **80** (7): 831-836.

Gopal, Murali and Gupta, A. 2001. The green muscardine fungus *Metarhizium anisopliae* as mycoinsecticide for control of rhinoceros beetle of coconut palm. *Indian Coconut Journal* **31** (11): 4-6.

Gopal, Murali, Gupta, A., and Sathiamma, B. 2000. *Baculovirus Oryctes* for controlling rhinoceros beetle of coconut palm. *Indian Farming*. **50** (4): 17-19.

Gupta, A., Gopal, Murali, and Iyer, R. 2001. Need for introducing the concept of "PGPR" in coconut crop production system for improved plant growth and establishment. *Indian Coconut Journal* **30** (11): 12-14.

Ponnamma, K.N., Gopal, Murali, and Sharmila, S. 2000. Record of *Aspergillus flavus* (Link) on the plant hopper *Proutista moesta* Westwood (Hemiptera: Derbidae). *Journal of Plantation Crops* **28** (3): 231-232.

Indian Institute of Horticultural Research, Bangalore

Mani, M., Dinesh, M.S. and Krishnamoorthy, A. 2000. Presence of *Encarsia* spp. on the spiraling whitefly, *Aleurodicus dispersus* Russell in peninsular India. *Insect Environment* **6** (3): 100.

Mani, M., Gopalakrishnan, C. and Krishnamoorthy, A. 2001. Natural incidence of *Xanthopimpla* sp.,and *Paecilomyces farinosus* (Holms.) on pomegranate hairy caterpillar, *Trabala vishnou* (Lefevere). *Insect Environment* **6** (4): 161-162.

Mani, M., Gopalakrishnan, C. and Krishnamoorthy, A. 2000. Natural parasitism on the pomegranate hairy caterpillar *Trabala vishnou* Lefebvre (Lepidoptera: Lasiocampidae) in Karnataka. *Entomon* **25**: 241-243

Mani, M. and Krishnamoorthy, A. 1999. Development and predatory potential of the green lacewing, *Mallada astur* (Banks) (Neuroptera, Chrysopidae) on the spiraling whitefly *Aleurodicus dispersus* Russell (Homoptera: Aleyrodidae). *Journal Biological Control* **13**:45-49.

Mani, M. and Krishnamoorthy, A. 2000. Population dynamics of spiraling whitefly, *Aleurodicus dispersus* Russell (Aleyrodidae, Homoptera) and its natural enemies on guava in India. *Entomon* **25** (1): 29-34.

Mani, M. and Krishnamoorthy, A 2001. Suppression of *Maconellicoccus hirsutus* (Green) on guava. *Insect Environment* **6** (4): 152.

Gopalakrishnan, C. 2000. Susceptibility of *Spodoptera litura* (Fab.) to different isolates of the entomopathogenic fungus *Nomuraea rileyi* (Farlow) Samson. *Insect Environment* **6** (2): 52-53.

Gopalakrishnan, C. and Mohan, K.S. (2000). A simple and cost effective *in vitro* method for the mass production of conidia of *Nomuraea rileyi* (Farlow) Samson. *Pest Management in Horticultural Ecosystems* **6** (1): 36-39.

Gopalakrishnan, C. and Mohan, K.S. (2000). Effect of certain insecticides and fungicides on the conidial germination of *Nomuraea rileyi* (Farlow) Samson. *Entomon* **25** (3): 217-223.

Gopalakrishnan, C., Anusuya, D. and Narayanan, K. 2000. Susceptibility of *Plutella xylostella* L. to the entomopathogenic fungus, *Paecilomyces farinosus* (Holmskiold) Brown and Smith. *Indian Journal of Agricultural Sciences* **70** (5): 341-343.

Sugarcane Breeding Institute, Coimbatore

Easwaramoorthy, S. and Santhalakshmi, G. 2000. The granulosis virus of the sugarcane borer, *Chilo infuscatellus* Snellen. *Sugarcane International* pp. 5-8.

Easwaramoorthy, S., Kurup, N.K., Santhalakshmi, G. and Shanmugasundaram, M. 2000. Effect of low temperature storage on the viability of puparia of *Sturmiopsis inferens* Townsend (Diptera: Tachinidae), a larval parasitoid of sugarcane moth borers. *Journal of Biological Control* **14**: 63-65.

Ehlers, R.U., Niemann., I., Hollmer, S., Strauch, O., Jende, D., Shanmugasundaram, M., Mehta, U.K., Easwaramoorthy, S. and Burnell, A.M. 2000. Mass production potential of the bacto-helminthic biocontrol complex *Heterorhabditis indica- Photorhabdus luminescens. Biocontrol Science & Technology* **10**: 607-616.

Karunakar, G., Easwaramoorthy, S. and David, H. 2000. Pathogencity of steinernematid and heterorhabditid nematodes to white grubs infesting sugarcane in India. *International Journal of Nematology* **10**:19-26.

Srikanth, J., Easwaramoorthy, S. and Kurup, N.K. 2000. Borer and predator incidence in sugarcane intercropped with pulses. *Sugarcane Technology* **2**(1&2): 36-39.

Srikanth, J., Easwaramoorthy, S. and Kurup, N.K. 2000. Behavioral response of *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) to frass extract of *Chilo partellus* Swinhoe (Lepidoptera: Crambidae). *Insect Environment* **6**(2): 75-76.

Srikanth, J., Easwaramoorthy, S., Kumar, R. and Shanmugasundaram, M. 2000. Patterns of *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) parasitisation rates in sugarcane and sorghum borers in laboratory rearing. *Insect Science and its Application* **21** (3): 195-202.

Stack, C.M., Easwaramoorthy S., Mehta, U.K., J.Downes, M., Griffin, C.T. and Burnell, A.M. 2000. Molecular characterization of *Heterorhabditis indica* isolates from India, Kenya, Indonesia and Cuba. *Nematology* **2**: 477-487.

Assam Agricultural University, Jorhat

Bhattcharya, B., Dutta, P., Basit, A. and Das, B.C. 1998. Compatibility of some common pesticides to *Bacillus thuringiensis. Journal of Agriculture Science Society, North East India* **11** (2): 127-130.

Bhattacharyya, B., Basit, A. and Saikia, K. 1998. Records of predatory spiders in sugarcane ecosystem of Assam. *Insect Environment* **4** (3): 89-90

Sarma, M., Basit, A. and Hazarika, L.K. 1999. Effect of *Polygonum hydropiper.*L. and *Lantana camara* L. on tea red spider mite, *Oligonychus coffeae. Two and a Bud* **46** (1): 2-22.

Gujarat Agricultural University, Anand

Pathak, S.K. and Yadav, D.N. 2000. Biology of *Eublemma scitula* Ramb. (Lepidoptera: Noctuidae), a predator of brown scale *Saissetia coffeae* Wlk. (Homoptera: Coccidae) infesting pointed gourd, *Trichosanthes dioica* Roxb. *Journal of Entomological Research* **24** (2): 167-175.

Yadav, D.N., Jha, A and Komla Devi, P. 2000. *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae) from the eggs of *Plutella xylostella* (Lepidoptera: Plutellidae) from Gujarat. *Indian Journal of Agricultural Sciences* **70** (1).

College of Agriculture (Mahatma Phule Krishi Vidyapeeth), Pune

Pokharkar, D.S. and Kurhade, V.P. 1999. Cross-infectivity and effect of environmental factors on the infectivity of granulosis virus of *Phthorimaea operculella* (Zeller) (Lepidoptera: Gelechiidae) *Journal of Biological Control* **13**: 79 - 84.

Kerala Agricultural University, Thrissur

Beevi, S.P., Beena, S., Lyla, K.R., Varma, A.S., Mathew, P.M. and Nadarajan, L. 1999. *Hirsutella thompsonii* var. *synnematosa* Samson, McCoy & O'Donnell on coconut mite *Aceria (Eriophyes) guerreronis* (Kiefer) – a new report from India. *Journal of Tropical Agriculture* **37**: 91-93.

Beevi, S.P., Beena, S., Lyla, K.R., Varma, A.S., Mathew, P.M. and Nadarajan, L. 2000. Report of pathogen, *Hirsutella thompsonii* var. *synnematosa* Samson, McCoy & O'Donnell on coconut mite *Aceria (Eriophyes) guerreronis* (Kiefer). *Insect Environment*, **5**(4): 190-191.

Beevi, S.P., Lyla, K.R. and Narendran, T.C. 2000. Hymenopteran diversity in single and double-cropped rice ecosystems in Kerala, India. IRRN 1/25: 20-21.

Lyla, K.R., Abraham, C.C. and Joy, P.J. 2000. Biology of *Pareuchaetes pseudoinsulata* Rego Barros (Lepidoptera: Arctiidae)-a biocontrol agent of *Chromolaena odorata*. *Insect Environment* **5**(4): 161-162.

Punjab Agricultural University, Ludhiana

Kumar, A., Shenhmar Maninder and Brar, K.S. 2000. Development of *Corcyra cephalonica* (Stainton) on different food materials. *Journal of Research, Punjab Agricultural University* (Accepted).

Singh, J., Singh, S.P., Brar, K.S. and Shenhmar, Maninder, 2000. Natural Control of sugarcane pyrilla in Morinda (Ropar) Mill area of Punjab. *Insect Environment* **6** (3): 128-129.

Snehdeep Kaur, Brar, K.S, Sekhon, B.S., Joshi, N., Shenhmar, Maninder and Singh, J. 2000. Role played by *Campoletis chlorideae* Uchida in natural mortality of *Helicoverpa armigera* (Hubner) on chickpea in Punjab. *Journal of Biological Control* **14**(1): 51-54.

Snehdeep Kaur, Shenhmar, Maninder and Brar, K.S. 2000. Parasitoids of insect pests of rice in the Punjab. *Insect Environment* **6** (2): 83-84.

Sher-e-Kashmir University of Agricultural Science & Technology, Srinagar

Zaz, G.M. 1999. Incidence and biology of black cutworm, *Agrotis ipsilon* (Hufnagel). *Applied Biological Research*, **1**: 67-70.

Dr.Y.S.Parmar University of Horticulture and Forestry, Nauni, Solan

Sood, A., Sharma, K.C. and Sharma, D. 2000. Biology and predatory potential of *Eupeodes frequens* Matsumura on *Aphis fabae* infesting *Solanum nigrum* L. *Pest Management in Horticultural Ecosystems* 6 (1): 55-56.

10.2 Papers presented in Seminars/Symposia/Workshops/Meetings/Training

Project Directorate of Biological Control, Bangalore

Ballal, C.R., Joshi, S., Jalali, S.K. and Rao, N.S. 2001. Quality control parameters in mass produced bioagents. In *Augmentative Biocontrol, Proceedings of the ICAR-CABI Workshop on Augmentative Biocontrol*. S. P. Singh, S. T. Murphy and C. R. Ballal (Eds.).

Joshi, S., Ballal, C.R. and Rao, N.S. 2000. Comparative analysis of two rearing procedures for *Curinus coeruleus* (Mulsant) (Coleoptera: Coccinellidae). *Presented at Entomocongress 2000: Perspectives for the New Millennium*, held at Trivandrum from 5-8 November, 2000.

Hussaini, S.S., Singh, S.P. and Nagesh, M. 2001. *In vitro* production of entomopathogenic nematodes in different artificial media. Presented at the *Nematology Symposium*, Orissa University of Agriculture and Technology, Bhubaneswar, Nov. 23-25, 2000 (abs.).

Hussaini, S.S., Singh, S.P. and Nagesh, M. 2001. *In vitro* and field evaluation of some indigenous isolates of *Steinernema* and *Heterorhabditis indica* against shoot and fruit borer, *Leucinodes orbonalis*. Presented at the *Nematology Symposium*, Orissa University of Agriculture and Technology, Bhubaneswar, Nov. 23-25, 2000.

Kumar, P. S. and Singh, S. P. 2001. Development of 'Mycohit', the first mycoacaricide based exclusively on *Hirsutella thompsonii*, for suppressing the coconut mite in India. Paper presented at the 23rd Annual Conference of the Indian Society of Mycology and Plant Pathology & the National Symposium on "Bioinoculants for Sustainable Agriculture & Forestry" at Kakatiya University, Warangal, from 16-18 February 2001.

Kumar, P. S., Singh, S. P., Marulasiddesha, K. N. and Anuroop, C. P. 2001. Role of the acaropathogenic fungus, *Hirsutella thompsonii* Fisher, in the natural suppression of the coconut eriophyid mite, *Aceria guerreronis* Keifer, in Andhra Pradesh, India. Paper presented at the 23rd Annual Conference of the Indian Society of Mycology and Plant Pathology & the National Symposium on "Bioinoculants for Sustainable Agriculture & Forestry" at Kakatiya University, Warangal, from 16-18 February 2001.

Narayanan, K. 2000. Genetic Engineering of insect pathogens: Novelty or necessity?. In the Conference on Biopesticides: Emerging trends, Chandigarh February 7-9, 2001.

Narayanan, K. 2000. Cross infectivity and safety of nuclear polyhedrosis virus of *Spodoptera exigua* (Hubner). Paper presented in the Conference on Biopesticides: Emerging Trends BET 2001, February 7-9, 2001, Chandigarh.

Narayanan, K. and Tandi, B. L. 2000. A new record on the occurrence of entomopoxvirus on whitegrub, *Holotrichia consanguinea* Blanchard (Coleoptera: Scarabaeidae). Paper presented in the Biopesticide Conference on Biopesticides: Emerging Trends BET 2001, February 7-9, 2001, Chandigarh.

Prasad, R. D. and Rangeshwaran, R. 2000. Dose-response studies in biological control of fusarial wilt of pigeonpea. In: Abstracts of papers presented in "3rd International Crop Science Congress" held at Hamburg, Germany, from August 17-22, 2000.

Prasad, R. D. and Rangeshwaran, R. 2000. Biocontrol potential, production, formulation of *Trichoderma* species and their genetic improvement. In proceedings of "Symposium on Biotechnology of Plant Protection" held at Banaras Hindu University, Varanasi, India from February 24-27. (Abstract)

Ramani, S. and Singh, S.P. 2000. Registration, import/export including quarantine of mulberry silkworm (*Bombyx mori* L.) germplasm. Base paper presented during the National Workshop on Management of Sericultural Germplasm for posterity held at CSGRC, Hosur, from July 26-27, 2000.

Ramani, S. and Singh, S.P. 2001. Quantification of Natural Enemy Biodiversity. Lead paper presented during the Workshop and Collaborative Project Planning Meeting on Biological Control of Pests and Weeds for sustainable development from January 17-20, 2001, Bangalore.

Rangeshwaran, R. and Prasad, R. D. 2000. Role of antagonistic rhizobacteria in inhibition of pathogens involved in chickpea wilt complex. In proceedings of "Symposium on Biotechnology of Plant Protection" held at Banaras Hindu University, Varanasi, India, from February 24-27, 2000.

Rangeshwaran, R., Prasad, R. D. and Anuroop, C. P. 2000. Field evaluation of two bacterial antagonists against wilt and wet root rot of chickpea. Presented in national symposium on "Eco-friendly Approaches in Plant Disease Management" held at Chennai, during January, 2001.

Sidde Gowda, D. K., Kumar, P. S. and Singh, S. P. 2001. Evaluation of oil-based formulation of *Nomuraea rileyi* (Farlow) on feeding potential and mortality of *Spodoptera litura* (Fabricius). Paper presented at the Conference on Biopesticides: Emerging trends (BET 2001), organized by Punjab State Council for Science and Technology (Chandigarh), Society for Biopesticide Sciences, India (Jalandhar) and Indian Ecological Society (Ludhiana) during 7-9 February, 2001, Chandigarh, India.

Sidde Gowda, D. K., Kumar, P. S. and Singh, S. P. 2001. Compatibility of entomopathogenic fungus *Nomuraea rileyi* (Farlow) with selected pesticides. Paper presented at the Conference on Biopesticides: Emerging trends (BET 2001), organized by Punjab State Council for Science and Technology (Chandigarh), Society for Biopesticide Sciences, India (Jalandhar) and Indian Ecological Society (Ludhiana) during 7-9 February, 2001, Chandigarh, India.

Singh, S.P. 2000. Biocontrol agents in pest management. Presented at *One Day Seminar on Biocontrol of Pests* at PAU, Ludhiana, on 11[th] April, 2000.

Singh, S.P. 2000. Present Status of biological control research in the country. Presented at the workshop on *Biological Control of Mites* held at KAU, Thrissur, on 17[th] April, 2000.

Singh, S.P. 2000. Role of Biocontrol in Pest Management. Presented during National Conference on Plant Protection at Vigyan Bhavan, New Delhi, on 19[th] May, 2000.

Singh, S.P. 2000. Biological suppression of coconut pests using parasitoids and predators - current status and future thrust. Delivered during the Group Meeting of Researchers and Development/ Extension Officials working on coconut pest problems at CPCRI, Kayangulam, on 25[th] May, 2000.

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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. Biosystematic studies on Indian Tachinidae
5. Development of mass production techniques for parasitoids
6. Development of viable mass production techniques for predators
7. Development of mass production techniques for cecidomyiid and acarine predators for use in biological control programmes
8. Behaviour ecology of the potential parasitoids to enhance their efficiency in biological suppression of key crop pests
9. Use of semiochemicals to improve the efficiency of important predators
10. Studies on insect pathogens
11. Bicontrol of insect pests using entomopathogenic fungi and development of mycoinsecticides
12. Studies on baculoviruses of arctiid hairy caterpillars.
13. Survey, identification and utilization of entomophathogenic nematodes against some important lepidopterous and coleopterous insect pests
14. Biological control of plant parasitic nematodes with fungi and bacteria with special reference to *Paecilomyces lilacinus* and *Pasteuria penetrans*
15. Biological suppression of plant parasitic nematodes exploiting antagonistic fungi and bacteria in specific cropping systems
16. Biological control of soil borne and other plant pathogenic fungi by antagonistic fungi and development of biofungicides
17. Biological control of soil borne plant pathogens by anatagonistic bacteria and development of bacterial biocontrol agents
18. Survey, identification and utilization of plant pathogens for the biological control of weeds with particular reference to parthenium and water hyacinth
19. Evaluation of improved and selected species / strains of egg parasitoids
20. Evaluation of artificial diet, release rates and genetic improvement of important predators
21. Evaluation and development of artificial diet for important lepidopterous pests
22. Software development for identifying and suggesting biocontrol measures for different crop pest using PC

23. Development of national information system on biological suppression of crop pests - Knowledge base system of *Helicoverpa armigera* and its natural enemies
24. Decision support system of safer pesticides and its natural enemies.

NATP Funded projects at PDBC, Bangalore

1. Team of Excellence for HRD in Biological Control
2. Control of leaf curl virus in cotton and development of protocols for mass multiplication
3. Development of biointensive IPM Modules in chickpea against *Helicoverpa armigera*, wilt, and dry root rot
4. Development of IPM modules in oilseed based criopping system
5. Development of integrated pest management for erophyiid mite of coconut in southern states

Indian Agricultural Research Institute, New Delhi

1. Basic studies and maintenance of *Bacillus thuringiensis* strains
2. Studies on formulations of microbial pesticides - based on baculoviruses and *Bacillus thuringiensis*

G.B.Pant University of Agriculture and Technology, Pantnagar

1. Testing of *Trichoderma harzianum*, *T. virens* and *Pseudomonas fluorescens* against Karnal bunt of wheat and root knot of vegetable crops
2. Demonstration of the above bioagents in various crops like chickpea (100 ha), field pea (20 ha), lentil (20 ha), tomato (10 ha), *Capsicum* (10 ha) and rice (200 ha)
3. Development of mixed formulation of fungal and bacterial antagonists
4. Relative efficacy of conidia *vs* chlamydospore based formulations of *Trichoderma*
5. Seed and root priming to improve efficiency of bioagents

At Co-ordinating centres

Biological suppression of crop pests and weeds

Sugarcane

1. Survey of and seasonal fluctuation studies on natural enemies of borers (PAU, SBI and IISR)
2. Field studies on *Trichogramma chilonis* against borers of sugarcane (PAU, SBI, IISR)
3. Field studies on *Cotesia flavipes* against early shoot and stalk borers (PAU, IISR)
4. Field evaluation of *Epiricania melanoleuca* against *Pyrilla perpusilla* (IISR)
5. Evaluation of *Beauveria brongniartii* against white grubs (SBI)

Cotton

1. Biointensive integrated pest 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 sucking pest complex (GAU)
4. Identification of host plants which harbour arthropod natural enemies (ANGRAU, TNAU)
5. Studies on the natural enemy complex of *H. armigera* (PAU)
6. Evaluation of different *Bt* products for efficacy against cotton bollworm complex (TNAU)
7. Colonization and establishment of *Chelonus blackburni* in cotton (GAU, TNAU, ANGRAU)

Tobacco

1. Testing of a sprayable formulation of EPNs in tobacco nursery against *Spodoptera litura* (CTRI, Rajahmundry)
2. Screening tobacco germplasm for incidence of pests and natural enemies

Pulses

1. Large-scale demonstration of *Bt-Ha*NPV-*Bt-Ha*NPV in pigeonpea for the management of pod borer complex in farmers' field in 1 ha area. (ANGRAU, GAU)
2. NPV based management of *H. armigera* (TNAU, PAU)
3. Effect of entomopathogenic nematode *Heterorhabditis* sp. against *Mylabris pustulata* and *Helicoverpa armigera* in pigeon pea (ANGRAU)
4. Incidence of *Maruca testulalis* and other pests and their natural enemies in pigeon pea in relation to crop phenology (ANGRAU, TNAU, GAU)
5. BIPM of pigeonpea with special reference to pea pod borer complex (ANGRAU, GAU, TNAU)
6. NPV based management of *Helicoverpa armigera* on chick pea (PAU, TNAU)

Rice

1. Survey and quantification of natural enemy complex in rice (AAU, KAU, PAU, TNAU)
2. Field evaluation of integrated use of *Trichogramma japonicum*, *T. chilonis* and *Bacillus thuringiensis* against rice stem borer and leaf folder (AAU, KAU, PAU, TNAU)
3. Evaluation of biocontrol based IPM in Rice (TNAU, KAU, AAU, PAU)
4. Evaluation of *Beauveria bassiana* against rice hispa (AAU)

Oilseeds

1. Testing of *Metarhizium anisopliae* and *Bacillus popilliae* against white grubs in groundnut (GAU, NRC for groundnut & ANGRAU)
2. Biological control of mustard aphid, *Lipaphis erysimi* (PAU)

Coconut

1. Field testing of *Hirsutella thompsonii* formulations (CPCRI, KAU, PDBC, ANGRAU, TNAU)
2. Studies on seasonal incidence of *Opisina arenosella* and its natural enemies (CPCRI)

Fruit crops

1. Survey for the natural enemies of spiralling whitefly (IIHR, KAU, TNAU)
2. Predatory potential of chrysopids on spiralling whitefly under field conditions (IIHR)
3. Evaluation of *Cryptolaemus montrouzieri* against spiralling whitefly on guava (IIHR)
4. Seasonality of natural enemies of spiralling whitefly in guava (IIHR)
5. Seasonal incidence of San Jose scale and its natural enemies at different altitudes (SKUAST, Dr.YSPUH&F)
6. Seasonal incidence of woolly apple aphid and its natural enemies at different altitudes (SKUAST, Dr.YSPUH&F)
7. Collection of local *Trichogramma* spp. from apple orchard ecosystem (Dr.YSPUH&F)
8. Release of local *Aphytis* spp. parasitizing the San Jose scale in apple orchards of Himachal Pradesh (Dr.YSPUH&F)

Vegetables

1. Survey for natural enemies of vegetable crop pests (IIHR, ANGRAU, MPKV, SKUAS & T, GAU, Dr.YSPUHF)
2. Evaluation of *Trichogrammatoidea bactrae* against *Plutella xylostella* on cabbage (IIHR, ANGRAU, MPKV, GAU, Dr.YSPUHF)
3. Evaluation of different formulations of *Bacillus thuringiensis* against *Plutella xylostella* on cabbage (IIHR, ANGRAU, MPKV, GAU, Dr.YSPUHF)
4. Control of *Leucinodes orbonalis* using *Bacillus thuringiensis* on brinjal (IIHR, ANGRAU and MPKV)
5. Control of *Helicoverpa armigera* using *Nomuraea rileyi* (IIHR)
6. Integrated Management of tomato fruit borer (IIHR, MPKV, ANGRAU, GAU, Dr.YSPUH&F)

Potato

1. Standardization of mass release technology for parasitoids *Copidosoma koehleri* and *Chelonus blackburni* against PTM under field conditions (MPKV)
2. Evaluation of release methods of parasitoids *Copidosoma koehleri* and *Chelonus blackburni* and microbial agents against PTM, *Phthorimaea operculella* on potato in country stores (MPKV)
3. Effect of plant products on parasitoids of PTM (MPKV)
4. Studies on recovery and establishment of parasitoids of PTM (MPKV)

5. 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, GAU, AAU)
2. Evaluation of fungal pathogens in combination with the weevil *Neochetina eichhorniae* and the mite *Orthogalumna terebrantis* in suppressing water hyacinth (KAU)
3. Assessment of impact of *Cyrtobagous salviniae* in suppressing *Salvinia molesta* (KAU)
4. Parthenium control with *Zygogramma bicolorata*, a case study under mid hill conditions (Dr.YSPUH&F)

12. CONSULTANCY, PATENTS, COMMERCIALISATION OF TECHNOLOGY

Consultancy service was provided to M/S DENOCIL, Mumbai, in evaluating Spinosad and Magister against natural enemies (2000-01).

Consultancy service was provided for and identifying pheromones/kairomones of insects and realized an amount of Rs.36,000/-.

Biocontrol agents were supplied to different Research and Development Departments of Centre and State Governments. Multicellular tray units were supplied to various State Agricultural Universities for rearing *Helicoverpa armigera*.

An amount of Rs.1,75,311/- was obtained from sale of technical bulletins.

Training was given to various plant protection specialists on the mass production of biocontrol agents. During 2000-01, 10 trainees were trained.

13. MEETINGS HELD AND SIGNIFICANT DECISIONS MADE

13.1 Significant decisions and recommendations made in the Fifth Research Advisory Committee Meeting held on 12-05-2000

1. It was observed that the cost of production of predatory coccinellid beetles is on a little higher side and efforts have to be made to reduce the cost of production as far as possible.
2. It was suggested that feed back should be collected from various agencies to whom biocontrol agents were supplied for further planning in biocontrol programmes in different crop ecosystems.
3. It was advised to supply L-Tryptophan to other centres including UAS, Dharwad, for evaluation on cotton crop in different agroclimatic conditions.
4. Collaboration with Indian Institute of Chemical Technology, Hyderabad, or similar organizations may be explored with regard to formulation of kairomones.

5. Production of *Helicoverpa armigera* nuclear polyhedrosis virus (*Ha*NPV) and *Spodoptera litura* nuclear polyhedrosis virus (*Sl*NPV) should be scaled up as there is a lot of demand for these.

6. Cross infestation studies on granulosis virus (GV) of *Chilo infuscatellus* may be taken up at the earliest.

7. Attempts may be made to start production of powder form of nuclear polyhedrosis virus with necessary collaboration from other organizations.

8. Observations may be taken up to verify the consistency of heat tolerance in *Trichogramma chilonis* strain by crossing the tolerant strain with susceptible ones.

9. The duration of the new project proposal "Decision support system on identification of potential natural enemies and pesticides safe to them" may be reduced to two years as most of the information is already available.

10. Collaboration between PDBC and SAUs may be further strengthened especially in the field of Post-graduate research work as PDBC has qualified persons and the best available infrastructural facilities.

11. Meeting between RAC members and scientists twice a year may be ideal rather than once in a year.

12 Duration of the nominated RAC Members may be increased from three to five years (Plan period).

13. Efforts should made to popularize the viable biocontrol technologies through Krishi Vigyan Kendras.

14. In view of more insight that the RAC Members will have had in their tenure, they may be included in the QRT to assess the progress made by PDBC.

13.2 Significant decisions made in Management Committee Meetings

Meeting held on 20-12-2000

1. The committee recommended the proposal of filling up of vacant posts for Technical Officer (Estate/Farm Officer) (T-6), Technical Assistant (T-II-3) for Pathology Laboratory and Technical Assistant (T-II-3) (Computer) by circulating among the ICAR institutes in view of the urgency.

2. The names of the two private doctors Dr.(Ms.)P.V.Mahalakshmi, Sanjaynagar, Bangalore, and Dr. Vishwanath N.Patil, Ganganagar, Bangalore, were approved for appointment as authorized medical attendants for the period of one year from 01-04-2001.

3. The proposal of furnishing Trainers Hostel at institute level after observing the codal formalities has been approved.

4. Replacement of the old BOD Incubator and Hot Air Oven was recommended.

5. The proposal of upgrading existing Image Analysis Systems could not be recommended, however the Committee requested to project it in X plan EFC.

6. Proposal of replacement of five Typewriters with with five computers has been approved subject to the availability of funds under Non-Plan.

7. The proposal of replacing the old and unserviceable Gestetner duplicating machine with a xerox machine has been approved subject to the availability of funds under Non-Plan.

8. Approved for importing Columns and detectors chromatography.

9. Approved for the proposal of procuring Donewell Floor cleaning, polishing machine and hand operated cleaning toilets etc., at a total cost of Rs.29,490/- + taxes from M/s. Donewell Rotaries, New Delhi as it is a proprietary item.

10. Post facto approval has been given for consultancy service rendered as a part of Institutional project and approval to disburse the consultancy fee to the Scientists and other staff members of the Directorate after observing the rules and guidelines prescribed by the ICAR.

11. The Committee recommended to convene a meeting between PDBC, Bangalore and UAS, Bangalore for inter-institutional collaboration for biological control methods.

13.3. Monthly Staff Research Council Meeting

Monthly scientific, technical and administrative staff meetings were held separately on every third Friday of the month and the detailed proceedings were sent to the Council for information. During the meetings discussions were held on the work done in different projects, general difficulties faced and solutions for the same.

14. PARTICIPATION OF SCIENTISTS IN CONFERENCES, MEETINGS, WORKSHOPS, SYMPOSIA, etc. IN INDIA AND ABROAD

Project Directorate of Biological Control, Bangalore

Dr.S.P.Singh, Project Director participated in

One Day Seminar on Biocontrol of Pests at PAU, Ludhiana, on 11th April, 2000.

Workshop on Biological Control of Mites held at KAU, Thrissur, on 17th April, 2000.

National Conference on Plant Protection at Vigyan Bhavan, New Delhi, on 19th May, 2000.

Group Meeting of Researchers and Development/Extension Officials working on coconut pest problems at CPCRI, Kayangulam, on 25th May, 2000.

National Conference on Plant Protection organised by Directorate of Plant Protection, Quarantine and Storage, Faridabad, on 25th and 26th May, 2000.

National Seminar on Hi-tech Horticulture, organized by National Academy of Agricultural Sciences, New Delhi and Horticultural Society of India, New Delhi, and Indian Institute of Horticultural Research, Bangalore. (June 26-28, 2000)

National Conference on Recent Trends on Biotechnology and Biocontrol Approaches of the New Millennium (July 18-20, 2000), Indian Institute of Chemical Technology, Hyderabad

Entomocongress-2000- Perspectives for the New Millennium (an International Meet) (November 5-8, 2000) Trivandrum, Kerala

Biopesticide Conference BET 2001 at Chandigarh, on February 8, 2001.

State level workshop on Resource management for sustainable Agriculture. (Feb. 8-9) University of Agricultural Sciences, Bangalore

Plant Protection - New Horizons in the Millennium (February 23, 2001), Department of Entomology, Rajasthan College of Agriculture, Udaipur

Dr.S.P.Singh, Dr.P.L.Tandon, Dr.K.Narayanan, Dr.N.S.Rao, Mr.S.R.Biswas, Dr.S.S.Hussani, Dr.B.S.Bhumannavar, Dr.N.Bakthavatsalam, Dr.S.Ramani, Dr. (Ms.) Chandish R.Ballal, Dr.S.K.Jalali, Dr. R.D. Prasad, Mr. Rangeshwaran, Mr. S. Joshi, Ms. M. Pratheepa, Dr. T. Venkatesan and Dr.(Ms.)J.Poorani attended the

Ninth Biocontrol Workers' Group Meeting held at PDBC, Bangalore, from 4th to 6th October 2000.

Dr.K.Narayanan attended a conference on Biopesticides: Emerging trends held at Chandigarh, February 7-9, 2001.

Dr.N.S.Rao Senior Scientist, attended

ICAR-CABI Workshop at PDBC, Bangalore, between 29th June to 1st July, 2000.

Workshop on Technology Mini Mission on Cotton for finalizing the technical programme at CICR, Nagpur, on 19th and 20th December 2000

Workshop and collaborative Project Planning meeting on biocontrol of pests and weeds for sustainable Agricultural Development during January 17th to 20th, 2001.

Review meeting of Mini Mission I of Technology Mission on Cotton on 23rd and 24th February 2001 at NCIPM, New Delhi organized by CICR, Nagpur.

Meeting for the formulation of technical programme under Technology Mission on Cotton (MMEI) on 7th and 8th March 2001 at NCIPM, New Delhi.

Dr.S.S.Hussani, Senior Scientist, attended

Nematology Symposium, Orissa University of Agriculture and Technology, Bhubaneswar, Nov. 23-25, 2000

Dr.S.Ramani attended the

35th Annual Rice Group Meeting at DRR, Hyderabad, from April 9 - 12, 2000.

National Workshop on Management of Sericultural Germplasm for posterity held at Central Sericultural Germplasm Research Centre, Hosur, from July 26-27, 2000 and presented a base paper.

Workshop and Collaborative Project Planning Meeting on Biological Control of Pests and Weeds for sustainable development from January 17-20, 2001

DST sponsored methodology workshop cum brainstorming on Bioresource Mapping at Jawaharlal Nehru Centre for Advanced Scientific Research, IISc campus, Bangalore, from January 23-25, 2001.

Brainstorming workshop on "Integrated sustainable farming systems approach in Kodagu district" organized by Coffee Board held on Feb. 4, 2001

Dr.(Ms.)Chandish R.Ballal attended the

"Entomocongress 2000" at Trivandrum from 5th November 2000 to 8th November, 2000 and presented a poster.

ICAR-CABI Workshop at PDBC, Bangalore between 29th June, to 1st July, 2000.

Workshop and Collaborative Project meeting on biocontrol of pests and weeds for Sustainable Agricultural Development during January 17th to 20th, 2001.

NATP Annual Workshop at PDBC, Bangalore between 7th to 8th March, 2001.

Dr.S.K.Jalali attended the

Workshop and Collaborative Project meeting on biocontrol of pests and weeds for Sustainable Agricultural Development during January 17th to 20th, 2001.

ICAR-CABI Workshop at PDBC, Bangalore between 29th June, to 1st July, 2000.

Dr.(Ms.)J.Poorani attended the

Workshop and Collaborative Project meeting on biocontrol of pests and weeds for Sustainable Agricultural Development during January 17th to 20th, 2001.

Workshop-cum-training on Mapping Biodiversity resources of India (sponsored by the Department of Science & Technology) held at Jawaharlal Nehru Centre for Advanced Scientific Research (IISc Campus), Bangalore, during January 23rd-25th 2001.

Dr.P.Sreerama Kumar attended the

Group Meeting on Recent Advances in the Management of Coconut Pests (RAMCOP 2000) at Central Plantation Crops Research Institute (CPCRI), Regional Station, Krishnapuram, Kayangulam, Kerala, from 24-25 May 2000.

ICAR-CABI Workshop on Augmentative Biocontrol organized by CABI Bioscience and PDBC from 29 June to 1 July 2000, at Bangalore.

Review meeting on coconut eriophyid mite and horticulture development in Kerala, convened by the Secretary (Agriculture and Cooperation), Government of India (GOI) and to discuss the horticulture development aspects in KeralaThiruvananthapuram, on 1 July 2000.

Akhila Bharata Kobbari Rythula Sadhasu" (All-India Coconut Farmers' Meeting) conducted by the Bharathiya Kisan Sangh (BKS) at Ambajipeta, Andhra Pradesh, on 4 October 2000

Annual Meeting of the Indian Phytopathological Society and Symposium on Emerging Trends in Plant Disease Management," 7-8 December 2000 at University of Agricultural Sciences, Hebbal, Bangalore.

23rd Annual Conference of the Indian Society of Mycology and Plant Pathology & the National Symposium on "Bioinoculants for Sustainable Agriculture & Forestry" at Kakatiya University, Warangal from 16-18 February 2001.

Dr.R.D.Prasad and Mr.R.Rangeshwaran attended the

National Symposium on "Eco-friendly Approaches in Plant Disease Management" held at Chennai during February, 2001.

Central Plantation Crops Research Institute, Regional Station, Kayangulam

Dr.(Ms.)Chandrika Mohan, Scientist SS, and Dr.Murali Gopal, Scientist, attended the Ninth Biocontrol Workers' Group Meeting held at PDBC, Bangalore from 4th to 6th October 2000.

Central Tobacco Research Station, Rajahmundry

Dr.S.Gunneswara Rao, Scientist, attended the Ninth Biocontrol Workers' Group Meeting held at PDBC, Bangalore, from 4th to 6th October 2000.

Indian Agricultural Research Institute, New Delhi

Dr.K.L.Srivastava, Senior Scientist, attended the Ninth Biocontrol Workers' Group Meeting held at PDBC, Bangalore, from 4th to 6th October 2000.

Indian Institute of Horticultural Research, Bangalore

Dr. M. Mani, Dr.A.Krishnamoorthy and Dr. C. Gopalakrishnan participated in

National Seminar on High Tech Horticulture at Bangalore, June 26-28, 2000.

Ninth Biocontrol Workers' Group Meeting held at PDBC,Bangalore, from 4th to 6th October 2000.

Dr.M.Mani and Dr. C. Gopalakrishnan participated in

Entomocongress-2000-Perspectives for the New Millennium (An International Meet) held from 5-8, November, 2000 at Techno Park, Trivandrum.

ICAR-CABI workshop on Augmentative biocontrol, Bangalore on 29th June 1st, 2000 at Bangalore.

Participated in the National symposium on Insect Pest Management strategies – Current trends and future prospects, Loyola college, Chennai, Feb. 1-2, 2000.

Dr. C. Gopalakrishnan participated in

National conference on Recent Trends in Biotechnology and Biocontrol approaches of the new millennium held from July 18-20, 2000 at Indian Institute of Chemical Technology, Hyderabad.

International conference on Microbial Biotechnology, Trade and Public policy held from July 14-17, 2000 at Osmania University, Hyderabad.

Biopesticide conference BET 2001 held during February, 7-9, 2001 at Chandigarh

Sugarcane Breeding Institute, Coimbatore

Dr.S.Easwaramoothy, Senior Scientist and Mr.J.Srikanth, Scientist participated in

ENTOMOCONGRESS 2000 Perspectives for the New Millennium, held at Trivandrum, Kerala, during 5-8 November 2000.

National Symposium on Vistas of Entomological Research for the New Millennium, held at the G.S. Gill Research Institute, Chennai, during December 28-30, 2000.

Assam Agricultural University, Jorhat

Dr.A.Basit, Senior Entomologist attended the Ninth Biocontrol Workers' Group Meeting held at PDBC,Bangalore from 4th to 6th October 2000.

Acharya N.G.Ranga Agricultural University, Hyderabad

Dr.A.Ganeswara Rao, Sr.Scientist and Dr.S.J.Rahman, Scientist participated in

IX Biocontrol Workers Group Meeting held at PDBC, Bangalore from 4th to 6th October 2000.

National Agricultural Fair organized by ANGRAU at Rajendranagar from 1st to 4th March 2001.

Gujarat Agricultural University, Anand

Dr.D.N.Yadav attended the

Entrepreneur's workshop on Ecofriendly Technologies of Biopesticides and Biofertilizers for crop management held at Delhi on 16th April 2000.

National conference held at Vigyan Bhavan Delhi and presented a paper on status of IPM in Gujarat during 25-26 May 2000.

National conference on taking Biotechnology to the Indian farmers held at Ahmedabad from 25th to 26th June 2000.

INDO-CABI workshop on Augmentative Bio-control held at Bangalore, 29-06-2000 to 01-07-2000

Workshop on collaborative project planning meeting on biocontrol of pests and weeds for sustainable agriculture development held at Bangalore during January 17-20,2001.

National conference on plant protection: New Horizons held at Udaipur, February, 23-25,2001

Dr.D.N.Yadav, Dr.D.M. Mehta and Shri. J.J.Jani attended

Ninth Biocontrol Workers' Group Meeting at PDBC, Bangalore from 4th to 6th November 2000.

G.B.Pant University of Agricultural Sciences & Technology, Pantnagar

Dr.U.S.Singh, Associate Professor, attended the Ninth Biocontrol Workers' Group Meeting held at PDBC,Bangalore from 4th to 6th October 2000.

Kerala Agricultural University, Trichur

Dr.(Ms.)S.Pathummal Beevi, Associate Professor and Ms.K.R.Lyla, Assistant Professor attended the Ninth Biocontrol Workers' Group Meeting held at PDBC,Bangalore from 4th to 6th October 2000.

Mahatma Phule Krishi Vidyapeeth, College of Agriculture, Pune

Dr.D.S.Pokharkar, Assistant Entomologist, participated in Ninth Biocontrol Workers' Group Meeting held at PDBC, Bangalore from 4th to 6th October 2000

Punjab Agricultural University, Ludhiana

Dr.K.S.Brar, Dr.Maninder, Sh. Jagmohan Singh and Dr.Snehdeep Kaur attended a seminar on Biocontrol of Crop Pests at PAU, Ludhiana on 11-04-2000.

DR.K.S.Brar and Dr.Maninder participated in ICAR-CABI Workshop on "Augmentative Biological Control at Bangalore from June 29 to July 1, 2000.

Dr.K.S.Brar, Dr.Maninder and Sh.Jagmohan Singh participated in
Ninth Biocontrol Workers' Group Meeting held at PDBC, Bangalore from 4th to 6th October 2000.
National Conference: Plant Protection – New Horizons in the Millennium" at Udaipur, from 23rd to 25th February 2001.

Sher-e-Kashmir University of Agricultural Sciences & Technology, Srinagar

Dr.G.M.Zaz, Entomologist, attended the Ninth Biocontrol Workers' Group Meeting held at PDBC, Bangalore from 4th to 6th October 2000.

Tamil Nadu Agricultural University, Coimbatore

Dr.P.Sivasubramanian, Associate Professor, attended the Ninth Biocontrol Workers' Group Meeting held at PDBC, Bangalore from 4th to 6th October 2000.

Dr.Y.S.Parmar University of Horticulture & Forestry, Nauni, Solan

Dr.P.R.Gupta, Entomologist, and Dr.Anil Sood, Assistant Entomologist, attended the Ninth Biocontrol Workers' Group Meeting held at PDBC, Bangalore from 4th to 6th October 2000.

15. WORKSHOPS, SEMINARS, SUMMER INSTITUTES, FARMERS' DAY, etc., ORGANIZED BY THE PROJECT DIRECTORATE

15.1. Organized

ICAR-CABI Workshop on augmentative biocontrol – 29th June to 1st July 2000

Ninth Biocontrol Workers' Group Meeting – October 4-6, 1999.

Annual Workshop of the NATP Project on control of cotton leaf curl viral diseases and mass production protocols – 7th and 8th March 2001

PDBC-NAM S & T Centre-Workshop and Collaborative Project Planning Meeting on Biological Control of Pests and Weeds for Sustainable Development for Non-Aligned and Other Developing Countries – January 17-20,2001.

15.2. Celebrated

"Rajbhasha Hindi ka Swarna Jayanthi Varsh" through scientific seminars in Hindi every month up to September 2000

ICAR Foundation Day on 17-07-2000 and presented awards to 4 staff members for their valuable contribution.

World Food Day on 16-10-2000

Anticorruption week from October 30th to 4th November 2000

Quami Ekta Week from 19th to 25th November 2000

16. DISTINGUISHED VISITORS

Project Directorate of Biological Control, Bangalore

Dr.R.S.Paroda, Director General, ICAR, New Delhi, on 26-06-2000

Dr.Sushil Mohan, Secretary, Finance (APC Wing) U.P. Government, Lucknow, on 08-07-2000

Dr.Prem Nath, Former Assistant Director General, FAO, Bangalore, on 10-07-2000

Prof. Amerika Singh, Director, NCIPM, New Delhi, on 06-10-2000

Dr.Darshan Singh, Professor and Head, Department of Entomology, PAU, Ludhiana, on 06-10-2000

Dr.M.Veerabhadra Rao, Deputy Director (PP), NPPTI, Hyderabad, on 14-11-2000

Dr.Samudra Lal Joshi, Senior Scientist (S4), Entomology Division, NARC, P.O. Box 976, Kathmandu, Nepal, on 26-12-2000

Dr Oscar B.J. Mfugale, Biocontrol Scientist, Plant Protection Division, Dar-es-salam Tanzania on 20-01-2001

Dr.C.Regmi, Chief, Science Faculty, RONAST, P.O. Box. 3323, Kathmandu, Nepal, on 20-01-2001

Dr.Yakub D. Deedat, Senior Lecturer, School of Agriculture, UNZA, Box 32379, Lusaka, Zambia, on 20-01-2001

Dr.Dekek, Abedallah, Plant protection Advisor, Ministry of Agriculture and water, Saudi Arabia, on 21-01-2001

Dr.A.S.Khera, Ex VC (PAU) and Chairman, QRT cotton on 02-02-2001

Dr. S.P.S.Ahlawat, Director, CARI, Port Blair, A&N Islands on 27-02-2001

Gujarat Agricultural University, Anand

Dr.A.K Sharma (IAS) Jr. Commissioner, S S P A Vadodara, Gujarat on 19-04-2000

Dr.S.Lingappa, HOD, Entomology, UAS, Dharwad , Karnataka on 21-6-2000

Dr.C.R.Hazra, Agri.commissioner, Govt.of India, New Delhi on 07-11-2000

Dr.R.K.Khetarpal, Head, Plant Quarantine Division, NBPGR, New Delhi on 29-12-2000

Dr.John Witconle, CAZS, University of Wales, U.K. on 05-03-2001

Dr.S.P.Singh, Project Director, PDBC, Bangalore on 24-03-2001

Mahatma Phule Krishi Vidyapeeth, Pune

Shri S.K.Chakraworty, M.P. State Agriculture, Mancept Board on 14-05-2000

Dr.S.P.Singh, Project Director, PDBC, Bangalore on 18-08-2000

Punjab Agricultural University, Ludhiana

Dr.S.P.Singh, Project Director, PDBC, Bangalore on April 11, 2000

Dr.S.H.Sinha, Principal Scientist and Head IARI, Regional Research Station Karnal on May 19, 2000

Dr.Seema Wahab, Director, Department of Science and Technology, Govt. of India, New Delhi, on September 12, 2000

Dr.D.R.Yadav, Head, Dept. of Entomology, HAU, Hissar on Nov. 23, 2000

Dr.O.P.Dubey, ADG (PP), ICAR, New Delhi on Feb.4, 2001

Assam Agricultural University, Jorhat

Dr.S. Jayaraj, Former Vice-Chancellor, TNAU, Coimbatore

Dr.D.Raychaudhuri, Prof. of Zoology, Calcutta University.

Kerala Agricultural University, Trichur

Dr. Mangala Rai, Deputy Director General (Crop Science), ICAR New Delhi on 20-9-2000

Dr. O.P. Dubey, Additional Director General (Plant Protection) ICAR, New Delhi on 28-9-2000.

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
Mr.S.R.Biswas	Principal Scientist
Dr.N.S.Rao	Senior Scientist
Dr.S.S.Hussaini	Senior Scientist
Dr.B.S.Bhumannavar	Senior Scientist
Dr.S.Ramanujam	Senior Scientist
Dr.N.Bakthavatsalam	Senior Scientist
Dr.S.Ramani	Senior Scientist
Dr.(Ms.)Chandish R.Ballal	Senior Scientist
Dr.S.K.Jalali	Scientist SS
Dr.M.Nagesh	Scientist SS
Mr.Sunil Joshi	Scientist SS
Dr.(Ms.)J.Poorani	Scientist SS
Dr.P.Sreerama Kumar	Scientist SS
Dr.R.D.Prasad	Scientist SS
Mr.R.Rangeshwaran	Scientist
Dr.T.Venkatesan	Scientist
Ms.M.Pratheepa	Scientist
Dr.(Ms.)P.Sadhana	Scientist

Central Plantation Crops Research Institute, Regional Station, Kayangulam

Dr.(Ms.) Chandrika Mohan	Scientist (SS)
Dr.Murali Gopal	Scientist

Central Tobacco Research Institute, Rajahmundry

Mr.S.Sitaramaiah	Senior Scientist
Mr.S.Gunneswara Rao	Scientist SS

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
Dr.C.Gopalakrishnan	Scientist (SS)

Indian Institute of Sugarcane Research, Lucknow

Dr.N.K.Tewari	Senior Scientist
Dr.R.K.Tanwar	Scientist

Sugarcane Breeding Institute, Coimbatore

Mr.J.Srikanth	Scientist SS

Assam Agricultural University, Jorhat

Dr.A.Basit	Principal Scientist
Dr.D.K.Saikia	Senior Scientist

Acharya N.G.Ranga Agricultural Univeristy, Hyderabad

Dr.A.Ganeswara Rao	Senior Scientist
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.S.A.Ghorpade	Entomologist
Dr.D.S.Pokharkar	Assistant Entomologist

Punjab Agricultural University, Ludhiana

Dr. Maninder	Entomologist
Shri. Jagmohan Singh	Assistant Entomologist
Dr Neelam Joshi	Assistant Microbiologist
Dr.(Ms.)Snehdeep Kaur	Assistant Entomologist
Mr.Navdeep Singh	Assistant Entomologist

Sher-e-Kashmir University of Agriculture and Technology, Srinagar

Dr.G.M.Zaz	Head
Mr.R.K.Tikoo	Junior Scientist
Dr.Ab.Majid Bhat	Junior Scientist

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

18. ANY OTHER RELEVENT INFORMATION SUCH AS SPECIAL INFRASTRUCTURAL DEVELOPMENT

18.1. Equipments

The laboratories were further strengthened during 2000-01 with the acquisition of incubators and hot air oven as replacement for the old ones, pelletizer, wind-tunnel olfactometer, columns and detectors, hardware and software for behavioural analysis, Insect sampler, elutriator, multitemperature thermostatic water circulation, vaccum filteration unit, balance, computers (Pentium 4), wooden cabinets for storing insect boxes, upgraded server in ARIS cell and statistical package SPSS 10.1 version.

18.2. Library

The library has a collection of 1,592 books, 940 volumes of journals, 43 bulletins and several miscellaneous publications including several reprints on various aspects of biological control. Nine foreign and fifteen Indian Journals have been subscribed. CABPEST CD upgraded up to February, 2001. New CDs on World Chalcidoidea and AGRIS were procured.

18.3. Aris Cell

After installation of VSAT, some of the computers were further upgraded with Pentium IV and old server was upgraded with the latest version.

18.4. National Insect Reference Collection

The PDBC has 3,441 authentically identified species belonging to 216 families under 16 orders. The collection includes representatives of the orders Hymenoptera, Coleoptera, Hemiptera, Orthoptera, Strepsiptera, Thysanoptera, Neuroptera, Diptera, Lepidoptera, etc. encompassing crop pests, parasitoids and predators. The information is available in the form of a catalogue.

18.5. Buildings

An amount of Rs.37.86 lakh was deposited with CPWD, Bangalore for construction of hostel facility including training hall and furniture and fixtures. Also the first installment of Rs.13.35 lakh was deposited with CPWD, Bangalore for construction of Quarantine laboratory with glass house and net house facility.

१९ निष्पादित सारांश

१९.१ मौलिक अनुसंधान

१९.१.१ प्राकृतिक शत्रुओं का उपोद्घात

कॉफी फल बेधकों के दो परजीवी कीटों, *प्रोरोपस नेसुटा* ओर *फायमेस्टिकस कॉफीए* को एक बार फिर से कोलम्बिया से लाया गया। *प्रो. नेसुटा* और *फा. कॉफीए* को खेतों में छोड़ा गया, किंतु इनकी पुनः प्राप्ति अच्छी नहीं पाई गई।

१९.१.२ परपोषी कीटों और प्राकृतिक शत्रुओं का रखरखाव, संगुणन एवं आपूर्ति

पैंतीस प्रजातियों के परपोषी कीटों, रोगाणुओं, पादप-सूत्रकृमियों और खरपतवारों सहित २५ परजीवी कीटों (११ विभेदों सहित), १९ परभक्षी कीटों, ४ खरपतवार नियंत्रण करने वाले संधिपाद प्राणी (ऑर्थ्रोपोड्स), कीट रोगाणुओं की ११ प्रजातियाँ और विभेदों, कवक रोगाणुओं और जीवाणुवीय प्राकृतिक शत्रुओं की ३२६ प्रजातियाँ और विभेदों, कीटाहारी रोगाण्विक सूत्रकृमियों की ६ प्रजातियों और विभेदों, पादप-सूत्रकृमियों के प्रति कवकों और जीवाणुओं की २९ प्रजातियाँ ओर विभेदों तथा खरपतवार नियंत्रण करने के लिए रोगाणुओं की एक प्रजाति के संवर्धनों का रखरखाव किया गया।

परपोषी कीटों के ६८ संवर्धनों और प्राकृतिक शत्रुओं के १३५ संवर्धनों को समवर्गीय केंद्रों ओर अन्य अनुसंधान संगठनों को न्युक्लियस संवर्धनों के रूप में भेजा गया, जिससे कि क्षेत्रीय परीक्षणों के लिए इनको संगुणित किया जा सके।

१९.१.३ स्वदेशी परभक्षी कीट कोक्सीनेलिड पर जैव सैद्धांतिक अध्ययन

वंश *डीओमस* मुल्सेन्ट कोक्सीनेलिड भारत में पहली बार अभिलेखित हुआ। एक नई जाति *सिनोनिकीमोर्फा* मियाटेके कर्नाटक और केरल में अभिलेखित हुई। वंश *स्युडेस्पाईडिमेरस* कपूर पुनरुज्जीवित हुआ। दो नई जातियाँ *माइक्रोसिरेन्जियम ब्रुनेओनिग्रम* और *स्युडेस्पाईडिमेरस इनफसकेटस* पूरणी अभिलेखित की गई। कोक्सीनेलिड कीट टिप्पण सूची (एपिलेक्निए सहित) को उत्कृष्ट बनाया गया। परभक्षी कीट कोक्सीनेलिड की पहचान करने के लिए एक गाइड तैयाराधीन है।

१९.१.४ प्राकृतिक शत्रुओं के लिए सर्वेक्षण

सर्वेक्षणों के दौरान, श्वेत मक्खी के स्वदेशी परभक्षी कीटों की अनेक प्रजातियों (कोक्सीनेलिडों की १५ प्रजातियों सहित) का अभिलेख पाया गया। एफेलिनिड्स, *ऐनकारसीआ ? हेटिएन्सिस* और *ए. गुआडेलोउपे* क्षेत्रों में भली प्रकार से स्थापित हो गए हैं और दूसरे क्षेत्रों में भी फैल रहे हैं। *एनकार्सिआ* की दोनों जातियों को लक्षद्वीप प्रायद्वीप के कावराट्टी ओर अगाट्टी क्षेत्रों में छोड़ा गया, जहाँ पर ये परजीवी कीट पहले उपलब्ध नहीं थे।

स्युडोहाइपोटेपा पुलवेरिआ को शल्क कीटों *हेमिबर्लेसिआ लेटेनिए* और *कोकस* स्पे. पर भक्षण करते हुए पाया गया।

१९.१.५ प्राकृतिक शत्रुओं का पालन/संवर्धन संबन्धी तकनीकों का मानकीकरण और जैविक अध्ययन

प्रयोगशाला में कोक्सीनेलिड *हारमोनिआ आक्टोमेकुलेटा* को संगुणन करने के लिए मीलीबग, *फेरीसीआ विरगेटा* और लोबिया के माँहू *एफिस क्रैक्सीवोरा* को सफलतापूर्वक प्रयोग किया गया। इसी प्रकार *स्टिकोलोटिस क्रिबेलाटा* और *फेरोस्किमनस होरनाई* कोक्सीनेलिडो को संगुणित करने के लिए *मिलेनोस्पिस ग्लोमेराटा* और *कोकस* स्पे. शल्क कीटों को अनुकूल पाया गया।

इश्चिओडोन स्कुटेलेरिस के २-३ दिन वाले प्यूपों को १०° सेग्रे. तापमान पर लगभग तीन सप्ताह तक संग्रह करना उचित पाया गया, किंतु वातावरण के तापमान (२७° सेग्रे.) की तुलना में इन प्यूपों से निकले प्रौढ़ों की जीवन क्षमता और जनन क्षमता थोड़ी कम पाई गई।

स्पोडोप्टेरा लिटच्यूरा पर पाले गए *एरीबोरस अर्जेन्टिओपिलोसस* की परजीवीकरण और उनके पैदा होने की दर में कोई अंतर नहीं पाया गया, किंतु प्रयोगशाला में निरंतर पाले जाने के कारण चार पीढ़ियों के बाद ही लिंग अनुपात बुरी तरह से (१.३% मादाएँ) प्रभावित होता है जबकि खेत से एकत्रित प्रौढ़ों में लिंग अनुपात अच्छा (६८.७७% मादाएँ) होता है। *ए. अर्जेन्टिओपिलोसस* की खेप भेजने के लिए मादाओं की प्रतिशतता अधिक सुनिश्चित करने के लिए कोकुनों के वज़न (७४३ मिग्रा.), लंबाई (७८.६ मिमी.) और चौड़ाई (७३.६ मिमी.) को प्रयोग में लाते हैं।

नेट हाउस में किए गए अध्ययनों से यह पता चलता है कि *टेलेनोमस रेमस* और *ट्राइकोग्रामा किलोनिस* परजीवी कीट सोयाबीन फ़सल पर परजीवीकरण और निकलने के लिए प्रमुखता देते हैं तथा *स्पो. लिटच्यूरा* और *हेलिकोवर्पा आर्मिजेरा* के अंडों को अधिक मात्रा में

परजीवित करते हैं।

नेट हाउस में किए गए अध्ययन से यह पता चलता है कि चने पर तुरंत छोड़े गए लार्वों की अपेक्षा २४ घंटे पहले छोड़े *हे. आर्मिजेरा* के ४ दिन आयु के लार्वों को *केम्पोलेटिस क्लोरिडिए* अत्यधिक परजीवीत करते हैं।

सर्पिलाकार श्वेत मक्खी के परभक्षी कीट *एक्सिनोस्किमनस पुट्टारूद्रैही* के प्रौढ़ ने अपने ५५.२५ दिन के औसत जीवनकाल में १३७.५ श्वेत मक्खी के निम्फों का भक्षण किया।

१९.१.६ प्राकृतिक शत्रुओं पर व्यवहारिक अध्ययन

ट्राइकोग्रामा किलोनिस द्वारा कपास की १५ वंशानुप्रकारों पर किए गए परीक्षणों में से डी एच बी-४३५ (४२.२२% परजीवीकरण) और सी पी डी-४४७ (४२.२२% परजीवीकरण) पर *हे. आर्मिजेरा* का अत्यधिक परजीवीकरण अभिलेखित किया गया। *ट्रा. किलोनिस* का डी एच बी-१०५ की पत्तियों की सुगंध का अत्यधिक (६३.३३%) और हाईब्रिड-६ का सबसे कम (६.६६%) प्रभाव दिखाई पड़ता है।

इलैक्ट्रोएन्टिनोग्राम अध्ययन में, *सोलेनम वाइएरम* ओर *टैगेटस* स्पे. द्वारा निकलने वाली सुगंध के प्रति *हे. आर्मिजेरा* पर प्रभाव के अध्ययन से पता चलता है कि कीट *टैगेटस* स्पे. की अपेक्षा *सो. वाइएरम* की तरफ अधिक आकर्षित होते हैं। "Y" ट्यूब अल्फेक्टोमीटर अध्ययन से पता चलता है कि *ट्रा. किलोनिस* के प्रौढ़ *सो. वाइएरम* की अपेक्षा *टैगेटस* की पत्तियों और फूलों की तरफ अधिक आकर्षित होते हैं।

एल-ट्राइप्टोफेन द्वारा *क्राइसोपरला कारनीआ* की अण्डनिक्षेपण प्रमुखता का क्षेत्रीय अध्ययन करने पर यह पाया कि कपास के अनुपचारित पौधों की अपेक्षा उपचारित पौधों पर *क्रा. कारनीआ* ने अधिक अंडे दिए। प्रयोगशाला और खेतों में पेन्टाकोसेन और ट्राइकोसेन दोनों ही ०.०१% की दर से प्रयोग करने पर *ट्रा. किलोनिस* की परजीवीकरण की क्षमता को बढ़ाते हैं।

१९.१.७ परपोषी कीटों ओर प्राकृतिक शत्रुओं के लिए कृत्रिम आहार

स्पोडोप्टेरा लिटच्यूरा को चना, मूँगफली की खली, केसीन, सिस्टिन, कोलेस्ट्रोल और वेसन्स साल्ट मिश्रण आधारित आहार पर सफलतापूर्वक पाला गया और इस आहार पर पालने से *स्पो. लिटच्यूरा* के अधिक प्रौढ़ मिलना और निकले प्रौढ़ों में से मादाओं की प्रतिशतता अधिक होना एवं उनसे प्राप्त अंडों में निषेचित अंडों की अधिक संख्या का मिलना, आदि यह दर्शाते हैं कि प्रयुक्त आहार उत्कृष्ट है।

गौ यकृत आधारित एक नए कृत्रिम आहार को, *क्राइसोपरला कारनीआ* पालने के लिए बनाया और परीक्षण में ८५% परभक्षी सफलतापूर्वक पाले गए। गौ यकृत आधारित कृत्रिम आहार पर *मलाडा बोनिनेन्सिस* को भी सफलतापूर्वक पाला गया।

किलोमिनस सेक्समेकुलेटा, कोक्सीनेल्ला सेप्टमपंकटेटा, काइलोकोरस नीग्रीटा ओर *क्रिप्टोलेमस मोन्ट्रयुजिएरी* को पालने के लिए कृत्रिम आहार को संश्लेषित बनाया गया। आहारों में सुधार करने के लिए परपोषी कीटों के जैव रसायनों की रूपरेखा और कृत्रिम आहारों का विस्तृत अध्ययन किया गया।

१९.१.८ ट्राइकोग्रामेटिड्स के विभेदों में सुधार

ट्रा. किलोनिस के उच्च तापक्रम विभेद तैयार करने के प्रयास में ४८ पीढ़ियों तक पालने पर एक विभेद तैयार किया गया, जो कि ३६° सेग्रे. तापमान और ६०% आपेक्षिक आर्द्रता पर अधिक परजीवीकरण (८५%) और आयु काल भी अधिक (४ दिन) होता है। इससे भी उच्च तापमान ३६ + १.५° सेग्रे., पर १५ पीढ़ियों के बाद परजीवीकरण ५९% और आयु काल २ दिन अधिक पाया गया।

एन्डोसल्फान (०.०५%) की सहिष्णुता वाले एन्डोग्राम विभेद के *ट्राइकोग्रामा किलोनिस* में अन्य कीटनाशकों के अधिक मात्रा में प्रयोग करने पर सहिष्णुता विभेद विकसित करने के लिए एन्डोसल्फान, मोनोक्रोटोफॉस और फेनवेलीरेट कीटनाशकों का उपयोग किया गया। इस परजीवी कीट में ३६ पीढ़ी कीटनाशक के प्रति सहिष्णुता प्रयोग से, एन्डोसल्फान (०.०८७५%), मोनोक्रोटोफोस (०.०६%) और फेनवेलीरेट (०.००१५%) ओर अधिक सहिष्णुता विकसित हुई। कीटनाशकों के प्रति *ट्रा. किलोनिस* के सुग्राही विभेद की तुलना में सहिष्णु विभेदों में एस डी एस-पी एजी ई रूपरेखा वाले तीन नए प्रोटीन ज्ञात हुए।

कीटनाशक सहिष्णु विभेद *हे. आर्मिजेरा* के अंडों को कीटनाशक (एन्डोसल्फान, मोनोक्रोटोफॉस, फेनवेलीरेट, सीपरमेथ्रिन, डाइमेथोएट,एसीफेट) कपास के पौधों पर छिड़काव करते ही परजीवित कर देते हैं और नेट हाउस अध्ययनों से यह पता चलता है कि छिड़काव के ५-७ दिनों के बाद परजीवीकरण अधिक पाया जाता है।

१९.१.९ कीट विषाणुओं और कवकों पर अध्ययन

सीसेमिआ इनफेरेन्स और *एग्रोटिस सेजेटम* से एन पी वी, *ए. सेजेटम* से कणिकामय विषाणु, *ए. सेजेटम, हेलिकोवर्पा आर्मिजेरा* और *होलोट्रीकिआ कोन्साग्युनिआ* से कीट

पॉक्सवायरस और *इरिआस विटेल्ला* से साइटोप्लाज्मिक विषाणु पृथक किए गए। *सी. इनफेरेन्स* और *हो. कोन्साग्युनिआ* से माइक्रोस्पोरीडिअन रोगाणुओं को पृथक किया गया।

ए. सेजेटम (एन पी वी सांद्रता ३.४ × $१०^{११}$ मिली. के जैव-विश्लेषण अध्ययनों से यह पता चलता है कि पहले और दूसरे निरूप के १००% लार्वे केवल ६ दिन में ही मर जाते हैं, जबकि तीसरे और चौथे निरूप के ८०% लार्वे और पाँचवें निरूप के १०-२०% लार्वे मर जाते हैं तथा छठवें निरूप के लार्वे इससे नहीं मरते हैं। उपचार के ७ और १० दिनों के बाद एल $डी_{५०}$ क्रमशः १.०६ × $१०^{६}$ पी ओ बी/मिली. और ४.४५ × $१०^{५}$ पी ओ बी/मिली. प्राप्त हुई। उपचारित लार्वों द्वारा पत्ती भक्षण कम किया गया और उनका भार कम पाया गया।

हे. आर्मिजेरा और *गे. मेलोनेल्ला* पर एन्टोमोपॉक्सवायरस के हिस्टोपैथोलोजिकल अध्ययन में पाया कि संक्रमण की विभिन्न जगहों पर वसा बॉडीज बुरी तरह से प्रभावित थी।

हे. आर्मिजेरा, प्लु. जाइलोस्टेल्ला और *काइलो पारटीलस* से कवकीय रोगाणुओं को पृथक किया गया। *हे. आर्मिजेरा, स्पो. लिटच्यूरा* और *प्लु. जाइलोस्टेल्ला* पर निवेशन के लिए *नोम्युरिआ रिलेई* को **एस एम ए वाई** माध्यम पर संवर्धित किया गया।

बेसीलस थ्युरिन्जिएन्सिस के पानी में घुलने वाले पाउडर जिसका नाम 'पुसा *बीटी*' है, को नियमित किया गया और इसको *स्पो. लिटच्यूरा* के प्रति जैव विश्लेषित किया गया।

१९.१.१० कवकीय और जीवाणुवीय शत्रु

एक किग्रा. गोबर की खाद में *ट्राइकोग्रामा हरजिएनम* (पी डी बी सी टी एच १०) और *ट्रा. विरिडे* (पी डी बी सी टी वी २३) का ५ ग्राम पाउडर नियमन मिलाकर मृदा उपचार करने से चने की फ़सल में फ्युजेरियम उक्ठा रोग और राइजोक्टोनिया जड़ सड़न रोग प्रभावपूर्ण ढंग से नियंत्रित होता है और उपज भी अधिक प्राप्त होती है। अरहर की फ़सल में *फ्यु. उदम* के कारण होने वाले फ्युजेरियम उक्ठा रोग को नियंत्रित करने के लिए *ट्रा. हरजिएनम* द्वारा बीज उपचार (१० ग्राम/किग्रा. बीज) की अपेक्षा मृदा उपचार (१० ग्राम/किग्रा. गोबर की खाद) अति उत्तम पाया गया और इसके प्रयोग से पौधों की वृद्धि अच्छी एवं उपज भी अधिक प्राप्त हुई। निवेशन उपरांत ३० दिन तक प्रचुर मात्रा में जैव कारक उत्पन्न हुए।

चने के फ्युजेरियम उक्ठा राइजोक्टोनिया और जड़ सड़न रोग के प्रति जीवाणुवीय प्राकृतिक शत्रु, *स्युडोमोनाज प्युटिडा* (पी डी बी सी १९) और *स्यु. फ्लुओरेसेन्स* (पी डी बी सी ए बी २) बहुत अधिक पाए गए। अरहर की फ़सल में जीवाणुवीय प्राकृतिक शत्रुओं का बीज उपचार भी फ्युजेरियम उक्ठा रोग के नियंत्रण के लिए बहुत प्रभावी पाया गया।

शैल्फ लाइफ अध्ययनों से पता चला कि *ट्रा. हरजिएनम* के जीवनक्षम प्रोपेग्युल्स कमरे

के तापमान पर १८० दिन तक योग्य बने रहते हैं। *ट्रा. हरजिएनम* ओर कार्बेन्डैजिम की संगतता के लिए २५ पी पी एम पर ७ कवकनाशक विकसित किए गए, जो कि स्वयं में विषैले पाए गए।

स्युडोमोनाज फ्लुओरेसेन्स को अधिक मात्रा में संवर्धित करने के लिए ट्राइप्टिक सोया ब्रोथ, न्युट्रीएन्ट ब्रोथ और किन्गस बी ब्रोथ अनुकूल पाए गए।

१९.१.११ कीटाहारी सूत्रकृमि

स्टेइनरनेमा कार्पोकेप्से और *हेटरोरहब्डिटिस इन्डिका* को औसतन ४४ लाख/२५० मिली. फ़्लास्क की दर से वाउट्स माध्यम उत्तम पाया गया। कुत्ते को खिलाने वाले बिस्किट+ गौ मांस अर्क माध्यम, *स्टे. कार्पोकेप्से* को अधिक मात्रा में संगुणन करने के लिए बहुत अच्छा पाया गया इससे ७५ लाख/२५० मिली. फ़्लास्क की दर से उत्पादन मिलता है।

प्रयोगशाला विश्लेषण में, *स्टेइनरनेमा कार्पोकेप्से* और *स्टे. बाइकोर्नुटम* को *स्पो. लिटच्यूरा, हे. आर्मिजेरा, ओ. एरेनोसेल्ला, थ्यो. ओपरकुलेल्ला* और *प्लु. जाइलोस्टेल्ला* के प्रति प्रभावी पाया गया। *हे. आर्मिजेरा, स्पो. लिटच्यूरा, प्लु. जाइलोस्टेल्ला* और *थ्यो. ओपरकुलेल्ला* की तुलना में *गेलेरिआ मिल्योनेला* (अंतिम निरूप) को *स्टेइनरनेमा* स्पे. और *हेटरोरहब्डिटिस* स्पे. उत्पन्न करने के लिए अति उत्तम पाया गया।

इन विट्रो और क्षेत्रीय दोनों ही दशाओं में बैंगन के फल बेधक *ल्युसीनोडस ओरबोनेलिस* के प्रति *स्टे. बाइकोर्नुटम*, *हे. इन्डिका* और *स्टे. कार्पोकेप्से* से प्राप्त पृथक्करण की उच्च दर (१ - २ बिलियन आई जे एस/एकड़) अति उत्तम पाई गई।

शैल्फ लाईफ के परीक्षण के लिए टॉल्क+चाइना क्ले और एल्जिनेट नियमनों के मूल्यांकन से यह पाया कि १५° सेग्रे. पर टॉल्क +चाईना क्ले नियमन में अन्य दोनों नियमनों की अपेक्षा अत्यधिक जीवन क्षमता और रोगजनकता ९० दिनों तक बनी रहती है।

१९.१.१२ पादप परजीवी सूत्रकृमियों का जैविक नियंत्रण

टमाटर में *मी. इन्कोग्निटा* को नियंत्रित करने के लिए *वर्टिसिलियम क्लेमायडोस्पोरियम* अत्यंत प्रभावी पाया गया, इसके द्वारा गॉल्स नियंत्रण, अंडों का अधिक परजीवीकरण और टमाटर के पौधों की अधिक वृद्वि पाई गई। ज्वार और गैंहू के दानों पर कवक संवर्धन किया गया और १० ग्राम/पौधा की दर से इनका प्रयोग सर्वोत्तम पाया गया।

१९.१.१३ खरपतवार रोगाणु

लेसीओडिप्लोडिआ थीओब्रेमे, निग्रोस्पोरा ओराइजे, फोमा क्राइसोन्थेमिकोला और *फो. युपिरिना* के इन रोगाणुओं को *पारथेनियम हीस्टेरोफोरस* से वियुक्त करके इन कवक खरपतवारनाशकों की संभाव्यता का मूल्यांकन किया गया और ये सभी निवेशन करने के बाद पौधे में रोग उत्पन्न करने में सफल पाए गए।

जलाशयों में *आईकोर्निआ क्रैसीपस* में *अल्टरनेरिआ* स्पे. और *सर्कोस्पोरा* स्पे. के ग्रसन की प्राकृतिक उपस्थिति देखी गई। विविलों, *निओकेटिना* स्पे. और माइट, *आर्थोगेलुम्ना टेरेब्रेन्टिस* से क्षतिग्रस्त पत्तियाँ पहले से ही *अल्टरनेरिआ आइकोर्निआ, अ. अल्टरनेटा* और *केर्कोस्पोरा* स्पे. से ग्रसित थी और सबसे अधिक प्रचंडता तब पाई गई जब माइट ग्रस्त पत्तियों पर *अ. आईकोर्निए* को निवेशित किया गया। इन तीनों रोगाणुओं के परस्पर प्रभाव के अध्ययन में पाया कि इन तीनों रोगाणुओं का संयुक्त प्रभाव अत्यधिक प्रभावी है।

१९.१.१४ सॉफ्टवेयर का विकास

तिलहनी और दलहनी फ़सलों के कीटों के नियंत्रण लिए एक एक्सपर्ट सिस्टम तैयाराधीन है, जिसमें प्रमुख कीटों की मुख्य पहचान और उनके द्वारा क्षति करने वाले लक्षणों को तैयार किया जा चुका है। एक्सपर्ट सिस्टम **''बायोराईस''** का सीडी रूपांतरण उपलब्ध है। फ़सल कीटों के जैविक दमन के लिए राष्ट्रीय सूचना प्रणाली के विकास में एक सॉफ्टवेयर **''पीडीबीसी इन्फोबेस''** सीडी रूपांतरण तैयार किया गया जिसमें सुस्पष्ट दिर्शना और चित्रों को शामिल किया गया है।

हेलिकोवर्पा आर्मिजेरा और इसके प्राकृतिक शत्रुओं की पूर्ण जानकारी प्राप्त करने के लिए **एम एस** -कीट की अभिगम जैविकी, परपोषी पौधे, वितरण, प्राकृतिक शत्रुओं आदि की एक आँकड़े आधारित सूचना विकसित की गई।

१९.२ गन्ने के हानिकारक कीटों का जैविक दमन

पंजाब के नवाँशहर ज़िले में *टेलेनोमस रेमस* द्वारा *स्किरपोफागा एक्सर्पटेलिस* के ४३% अंडे परजीवित पाए गए जबकि *ट्रा. किलोनिस* द्वारा *काइलो इन्फस्कटेलस* के ७.६% और *ट्रा. काइलोट्रिए* (५.८%), *ट्रा. किलोनिस* (७.१%) द्वारा *काइलो आरीसीलीअस* और *ट्रा. किलोनिस* (६.७%) द्वारा *एकिगोना स्टेनिएलस* परजीवित पाए गए। कोयंबटूर में कोंपल बेधक, *का. इन्फस्कटेलस* के प्राकृतिक शत्रुओं में से टेकेनीड़, *स्टरमियाप्सिस इनफेरेन्स* और कणिकामय

विषाणु लगभग पूरे वर्ष पाए गए। खेत में *स्ट. इनफेरेन्स* की संख्या में लिंग अनुपात विभिन्न महीनों में प्रायः नरों की अधिकता पाई गई, किंतु प्रयोगशाला में मादाओं की अधिकता और सहवास दर अधिक पाई गई।

कोयंबटूर में *ब्युवेरिआ ब्रोन्गनिआर्टी* का नियमन शीरा माध्यम पर संवर्धित किया गया और प्रैस-मड के साथ $१०^{१२}$- $१०^{१४}$ बीजाणु/एकड़ एक उपचार के साथ-साथ क्लोरपायरीफॉस के संयोजन से सफ़ेद लट (व्हाइट ग्रब्स) का सफल नियंत्रण किया गया। सल्फ़र और कैलशियम सल्फ़ेट की सभी सान्द्रताओं से *ब्यु. बेसीआना, ब्यु. ब्रोन्गनिआर्टी* और *मे. एनाइसोप्लिए* की वृद्धि को काफ़ी हद तक कम किया, किंतु बीजाणुओं के उत्पादन पर उनका कोई असर नहीं पड़ा। *ब्यु. बेसीआना, ब्यु. ब्रोन्गनिआर्टी* और *मे. एनाईसोप्लिए* के लिए पेराक्वाट विषैले पाए गए जबकि ग्लॉयफासेट अन्य दोनों कवकों की अपेक्षा *ब्यु. बेसीआना* के प्रति अत्यधिक विषैले पाए गए।

पंजाब में ३ चीनी मिलों के सहयोग से बड़े स्तर पर किए गए क्षेत्रीय प्रदर्शनों से स्पष्ट पता चलता है कि जुलाई-अक्टूबर माह के दौरान अंड परजीवी कीट, *ट्रा. किलोनिस* को ५०,०००/हे. की दर से १० दिनों के अंतराल पर छोड़ने पर *का. आरीसिलीअस* के ग्रसन को कम करता है, तीन चीनी मिलों के क्षेत्रों में किए गए प्रदर्शन में अनुपचारित खेतों में *का. आरीसिलीअस* का ग्रसन ६.०३, ११.२० और २०.२० प्रतिशत की तुलना में उपचारित खेतों में केवल १.३६, ४.१० और १२.५० प्रतिशत ही पाया गया।

१९.३ कपास के हानिकारक कीटों का जैविक दमन

आनंद, कोयंबटूर, पुणे, हैदराबाद और लुधियाना में जैव कारकों को छोड़ने सहित आईपीएम की विभिन्न विधियाँ अपनाई गई और इनकी तुलना कीटनाशक प्रयोग और अनोपचारित खेतों से तुलना की गई। आनंद में कीटनाशक उपचारित और अनुपचारित क्षेत्रों की तुलना में आईपीएम विधियों से फ़सल की कलिकाएँ और गूलर कम क्षतिग्रस्त होने के साथ-साथ चूसने वाले कीटों की संख्या प्रभावपूर्ण ढंग से कम पाई गई। यह भी देखा गया कि चूँकि आईपीएम के अंतर्गत प्लॉट में रासायनिक कीटनाशकों का कम छिड़काव किया गया इसलिए प्राकृतिक शत्रुओं को संरक्षण प्राप्त हुआ जिससे परजीवीकरण स्तर भी अधिक पाया गया। इसी प्रकार के परिणाम कोयंबटूर में देखे गए वहाँ अनुपचारित खेतों की अपेक्षा आईपीएम अपनाए गए क्षेत्रों में *इरिआस स्पे., पेक्टिनोफोरा गॉसीपिएल्ला* और चूसने वाले कीटों की संख्या कम पाई गई। पुणे में आईपीएम और कीटनाशक उपचारित प्लॉट में चूसने वाले कीटों की संख्या काफ़ी कम पाई गई जबकि आईपीएम अपनाए गए क्षेत्रों में प्रत्येक २५ पौधों पर *क्राइसोपरला कारनीआ* और कोक्सीनेलिडों की संख्या क्रमशः ५६.८७ और ४३.५० और कीटनाशक उपचारित क्षेत्रों में

केवल क्रमशः ११.६२ और १०.८७ ही पाई गई। हैदराबाद में कीटों द्वारा क्षति और प्राकृतिक शत्रुओं की संख्या के एक समान परिणाम प्राप्त हुए और आईपीएम की लागत लाभ अनुपात अधिक पाया गया। लुधियाना में अनुपचारित या केवल कीटनाशकों के प्रयोग की अपेक्षा *ट्रा. किलोनिस* और कीटनाशक की सुरक्षित मात्रा के प्रयोग से इनको और अधिक प्रभावी पाया गया, जिससे गूलर कम क्षतिग्रस्त हुए और उपज भी अधिक प्राप्त हुई।

आनंद में कीटनाशकों के छिड़काव और अनुपचारित क्षेत्रों की तुलना में *ट्रा. किलोनिस* के साथ *क्राइसोपरला कारनीआ* को मिलाकर छोड़ने से कपास के कीटों के प्रति खेतों में मूल्यांकन करने पर पाया कि जैव कारक छोड़े गए क्षेत्रों और कीटनाशक प्रयोग किए गए क्षेत्रों में अनुपचारित क्षेत्रों की अपेक्षा, *ई. विटेल्ला* और *पे. गॉसीपिएल्ला* द्वारा क्षतिग्रस्तता कम पाई गई और अन्य क्षेत्रों की अपेक्षा जैव कारक छोड़े गए क्षेत्रों में गोलक शलभ कीट के परजीवी कीट *एलीओडस एलीग्रहेन्सी, ट्रा. किलोनिस* और *एगोथिस* स्पे. द्वारा अत्यधिक परजीवीकरण पाया गया। आनंद में अनुपचारित प्लॉट की अपेक्षा *क्रा. कारनीआ* को आप्लावित रूप से छोड़ने पर कपास के चूसने वाले कीटों, फुदकों, माँहू और श्वेत मक्खियों की संख्या पर्याप्त मात्रा में कम पाई गई।

कोयंबटूर में कपास की फ़सल में *बीटी* उत्पादों के मूल्यांकन से पता चलता है कि *बीटी* उत्पादों (डेल्फिन, स्पिक-बायो) के प्रयोग करने से अनुपचारित क्षेत्र की तुलना में गोलक शलभों का प्रभावी नियंत्रण हुआ, प्राकृतिक शत्रुओं की अधिक संख्या प्राप्त हुई और अत्यधिक उपज प्राप्त हुई।

१९.४ तंबाकू की फ़सल के हानिकारक कीटों का जैविक दमन

रजाहमुन्द्री में तंबाकू नर्सरी में *स्पोडोप्टेरा लिट्यूरा* के नियंत्रण के लिए *स्टेइनरनेमा कार्पोकेप्से* के टॉल्क आधारित नियमन की तुलना *स्पो.* एन पी वी और क्लोरपायरीफॉस से करने पर यह निष्कर्ष निकला कि ईपीएन १, २ और ४ x १०^{९} आई जे, ईपीएन १ x १०^{९} आईजे+*स्पो*. एनपीवी पर १.५ x १०^{१२} पी ओ बी, केवल *स्पो*. एनपीवी पर १.५ x १०^{१२} पी ओ बी और क्लोरपायरीफॉस से ०.०५% *स्पो. लिट्यूरा* द्वारा क्षति, अनुपचारित क्षेत्रों की अपेक्षा तंबाकू नवोदभिदों को संरक्षण प्राप्त हुआ और *स्पो. लिट्यूरा* के लार्वों की संख्या पर्याप्त मात्रा में कम पाई गई। ईपीएन की मात्रा अधिक बढ़ाने से *स्पो. लिट्यूरा* की संख्या पर्याप्त मात्रा में कम पाई गई और ईपीएन को *स्पो*. एनपीवी के सम्मिश्रण ईपीएन की सभी मात्राओं से श्रेष्ठ पाई गई तथा केवल *स्पो.* एनपीवी के प्रयोग से *स्पो. लिट्यूरा* के लार्वों की संख्या में बहुत कमी आई।

१९.५ दलहनी फ़सलों के हानिकारक कीटों का जैविक दमन

दो केंद्रों पर अरहर की फ़सल में फली बेधकों के नियंत्रण के लिए जैविक नियंत्रण आधारित प्रबंधन के अंतर्गत *बीटी* (१.० किग्रा.), *हे*. एनपीवी (१.५x१०^{१२} पीओबी/हे.), नीम बीज अर्क (५%) और एन्डोसल्फान (३५० a.i./हे.) का विभिन्न क्रमों में परीक्षण किया गया और परिणामों से यह पता चला कि कोयंबटूर में एन्डोसल्फान को १५ दिन के अंतराल पर ३ बारी में छिड़काव करना श्रेष्ठ पाया फिर इसके बाद *हे*. एनपीवी और नीम बीज अर्क के एकांतर छिड़काव को जबकि आनंद के केंद्र पर *बीटी*- *हे*. एनपीवी- *हे*. एनपीवी का क्रमवार प्रयोग और एन्डोसल्फान का प्रयोग श्रेष्ठ पाया गया।

हैदराबाद के केंद्र पर खेत में अरहर की फ़सल में किए गए प्रयोग *हेटरोरहब्डिटिस* स्पे. का ०.५, १ और २ बिलियन आई जे एस/हे. का *हे. आर्मिजेरा* पर प्रभावों का परीक्षण किया गया जिसमें यह परिणाम ज्ञात हुआ कि *हे. आर्मिजेरा* के लार्वों की संख्या को कम से कम करने के लिए १.० बिलियन/हे. और २.० बिलियन/हे. सूत्रकृमियों की दोनों मात्राएँ एकसमान प्रभावी पाई गई, इनके प्रयोग से फलियों की क्षति कम पाई और अरहर की उपज अत्यधिक प्राप्त हुई।

हैदराबाद में किसान के खेत में अरहर की फ़सल में फली बेधकों के प्रबंधन के लिए *बीटी*- *हे*. एनपीवी- एन्डोसल्फान-*बीटी* का बड़े स्तर पर क्रमवार प्रयोग करने पर किसान द्वारा अपनाई जाने वाली प्रक्रिया की तुलना में लार्वों की संख्या में कमी और फलियाँ कम क्षतिग्रस्त पाई गई, किसान द्वारा अपनाई गई विधि से ३२० किग्रा./हे. की अपेक्षा ७३५ किग्रा./हे. उपज प्राप्त हुई तथा किसान द्वारा अपनाई गई विधि से लागत लाभ अनुपात १:२.५१ की अपेक्षा १:३.२९ अधिक लागत लाभ अनुपात प्राप्त हुआ।

कोयंबटूर में चने की फ़सल में *हे. आर्मिजेरा* का एनपीवी आधारित प्रबंधन के मूल्यांकन के अंतर्गत जिन खेतों में *हे*. एनपीवी (१.५x१०^{१२} पीओबी/हे.) - एन्डोसल्फान (३५० ग्राम/हे.) एकांतरण रूप से छिड़काव किया उन खेतों में केवल ५.६०% फलियाँ क्षतिग्रस्त पाई गई और जिनमें *हे*. एनपीवी (१.५x१०^{१२} पीओबी/हे.) - नीम बीज अर्क (५%) एकांतरण रूप से प्रयोग किया गया उनमें ५.११% की तुलना में जिन खेतों में *हे*. एनपीवी (१.५x१०^{१२} पीओबी/हे.) + सहायकों का प्रयोग किया गया उनमें ८% और जिनमें केवल एन्डोसल्फान (३५० ग्राम/हे.) का छिड़काव किया गया उनमें ७.८% फलियाँ क्षतिग्रस्त पाई गई। अन्य उपचारों की तुलना में इन संयोजनों से उपज भी अत्यधिक प्राप्त हुई।

१९.६ धान के हानिकारक कीटों का जैविक दमन

कोयंबटूर , पुणे, लुधियाना और जोरहाट में धान के तना बेधक और पत्ती मोड़क कीट

के प्रति *ट्राइकोग्रामा जेपोनिकम* और *ट्रा. किलोनिस* को ०.५ और १ लाख/हे. की दर से साप्ताहिक अंतराल पर रोपण के २० दिनों के बाद एक साथ छोड़ना (३ बार में), *बेसीलस थ्युरिन्जिएन्सिस* को रोपण के ४० और ५५ दिनों के बाद १ किग्रा./हे. की दर से प्रयोग और कीटनाशक की आवश्यकता के अनुसार सुरक्षित मात्रा प्रयोग करने के लिए मोनोक्रोटोफॉस १ लिटर/हे.(रोपण के ४० और ५५ दिनों के बाद दो बार में) और फॉस्फेमिडान को ३०० मिली./हे. की दर से प्रयोग किया गया।सभी चारों केंद्रों पर तना बेधकों (सफ़ेद बाली और डेड हर्ट दोनों) और पत्ती मोड़क कीटों के अंड परजीवी कीट *ट्राइकोग्रामा* स्पे. द्वारा कीटों का ग्रसन कम और अंडों का परजीवीकरण अधिक मिला तथा परजीवी कीट छोड़े गए क्षेत्रों में, कीटनाशक व्यवस्थित क्षेत्रों और *बीटी* प्रयोग किए क्षेत्रों की तुलना में उपज अधिक मिली। परजीवी कीटों की ०.५ लाख/ हे. की दर की अपेक्षा १ लाख/हे. की अधिकतम दर से छोड़ना श्रेष्ठ पाया गया।

जोरहाट (ख़रीफ़ और रबी मौसम में), लुधियाना और थ्रिसूर में जैवनियंत्रण आधारित आईपीएम का परीक्षण किसानों के खेतों में किया गया, इनमें तना बेधक और पत्ती मोड़क कीट का प्रबंधन करने के लिए *ट्रा. किलोनिस* और *ट्रा. जेपोनिकम* को फ़सल की विभिन्न अवस्थाओं में १ लाख/हे./सप्ताह की दर से छोड़ा गया और परिणाम प्राप्त हुआ कि अनुपचारित और कीटनाशक व्यवस्था की अपेक्षा जैव आधारित आईपीएम अपनाने से कीटों का ग्रसन कम और उपज अधिक मिलती है।

धान में प्राकृतिक शत्रुओं का सर्वेक्षण और अनुमान लगाने की प्रक्रिया में पाया कि सभी जगहों पर अनेक परभक्षी और परजीवी कीट उपलब्ध थे। थ्रिसूर में प्रमुख प्राकृतिक शत्रुओं में हायमेनोप्टेरस परजीवी कीट, इसके बाद परभक्षी कीट, मिरिड, मकड़ियाँ और कोक्सीनेलिड पाए गए। कोयंबटूर में परभक्षी कीट १६-२१% पाए गए, जिनमें मकड़ियाँ, कोलिओप्टेरिअन्स, ड्रैगन फ्लाई, झींगुर, टिड्डे और परभक्षी कीट, मेंटिस पाए गए, जबकि ११-१३% परजीवी कीटों में *टेट्रास्टिकस* स्पे., *टेलेनोमस* स्पे., *कोटेशिआ* स्पे. और *ट्राइकोग्रामा* स्पे. पाए गए तथा अन्य शेष कीट प्रजातियाँ पाई गई। लुधियाना में मकड़ियों की १७ प्रजातियाँ पाई गई जो कि ७ कुलों से संबंध रखती हैं, पूरे फ़सल मौसम में पाई गई और *टेट्रागनाथा जेवाना* इनमें सबसे प्रमुख, इसके बाद *अरेनिअस इन्सटस, टे. वायरसेन्स* और *आक्सीओपस जेवेनस* पाई गई। जोरहाट में ख़रीफ़ मौसम के दौरान लार्वा परजीवी कीट *ब्रेकोन* स्पे. द्वारा पत्ती मोड़क कीट का परजीवीकरण विविध रूप में १५% से २०% तक मिला और सितंबर माह के अंतिम सप्ताह में *ट्राइकोग्रामा* स्पे. पाए गए तथा तना बेधक कीट के अंडों का अधिकतम (२३.३%) परजीवीकरण पाया गया।

१९.७ नारियल के हानिकारक कीटों का जैविक दमन

बंगलौर, कायान्गुलम और थ्रिसूर में नारियल की माइट, *अकेरिआ गुएरेरोनिस* के प्रति *हिर्सुटेल्ला थोम्पसोनाई* के मायकोअरेकिडे नियमन "मायकोहिट" के साथ-साथ अकेरेकिडे डाइकोफाल (केल्थेन) और अनुपचारित क्षेत्रों का मूल्यांकन किया गया। बंगलौर में १४ दिन के अंतराल पर ३ बार में उपचारित वृक्षों पर कीटों की मृत संख्या की प्रतिशतता से इसकी उपयोगिता सिद्ध हुई। कवक नियमन की अवस्था में रोपण के ६३ दिनों के बाद ७५% घातकता देखी गई, जबकि अकेरिकिडे उपचार में दो बार छिड़काव के बाद रोपण के ४९ दिनों के बाद ६०% घातकता देखी गई। अनुपचारित वृक्षों पर प्राकृतिक रूप से अधिकतम ७% घातकता देखी गई। कायांगुलम और थ्रिसूर में इनका मूल्यांकन किया जा रहा है और परिणामों की प्रतीक्षा है।

१९.८ फल वृक्षों के हानिकारक कीटों का जैविक दमन

बंगलौर में अनार के फल बेधक *डीयुडोरिक्स आइसोक्रेटस* के परजीवी कीट *ट्रा. काइलोट्रिए* छोड़ने पर फलों की क्षतिग्रस्तता कम हुई, अनुपचारित वृक्षों पर २४.२४% फल क्षतिग्रस्त हुए, जबकि परजीवी कीट छोड़े गए वृक्षों पर केवल १४.१५% फल क्षतिग्रस्त हुए। सोलन में फल बेधक *डीयुडोरिक्स एपिजर्बस* कीट ५९.२% तक परजीवित पाए गए और उनमें से निकलने वाले परजीवी कीटों में ९३.१% सिलीओनिड, *टेलेनोमस ? साइरस* पाए और ६.९% युपेल्मिड, *एनास्टेटस* स्पे. नियर *कश्मीरेन्सिस* थे। बंगलौर में बेर के फल बेधक कीट *मेरीडार्किस स्किरोडस* को नियंत्रित करने के लिए *ट्रा. किलोनिस* को छोड़ा गया और इसकी तुलना अनुपचारित बेर वृक्षों से करने पर यह देखा गया कि अनुपचारित वृक्षों पर ३४.९५% फल क्षतिग्रस्त हुए, जबकि परजीवी कीट छोड़े गए वृक्षों पर केवल २२.३३% ही फल क्षतिग्रस्त हुए, जिससे इनके प्रभावी होने का प्रमाण मिलता है। बंगलौर में नींबू वृक्ष पर *पेपिलिओ डेमोलिअस* के लार्वों की संख्या को नियंत्रित करने के लिए *बीटी* के सभी व्यवसायिक नियमनों को अत्यधिक प्रभावी पाया गया।

कर्नाटक, केरल, महाराष्ट्र और तमिलनाडु राज्यों में सर्पिलाकार श्वेत मक्खी के *ए. ? हेटिएन्सिस* और *ए. गुआडेलोउपे* प्राकृतिक शत्रु पाए गए। बंगलौर के पास अमरूद के एक बाग़ में फ़रवरी में *ए. गुआडेलोउपे* परजीवी कीट के प्रौढ़ छोड़े गए और मार्च में श्वेत मक्खी के १४.४७% निम्फ परजीवित पाए तथा धीरे-धीरे यह मात्रा बढ़ी और जून माह में बढ़कर ६२.७४% हो गई। थ्रिसूर में विभिन्न परपोषी पौधों पर इन एफेलिनिड्स द्वारा ०-६६.६% परजीवीकरण देखा गया, जिसमें अक्टूबर माह के दौरान मिर्चों में अधिकतम ६६% परजीवीकरण पाया गया।

के प्रति *ट्राइकोग्रामा जेपोनिकम* और *ट्रा. किलोनिस* को ०.५ और १ लाख/हे. की दर से साप्ताहिक अंतराल पर रोपण के २० दिनों के बाद एक साथ छोड़ना (३ बार में), *बेसीलस थ्युरिन्जिएन्सिस* को रोपण के ४० और ५५ दिनों के बाद १ किग्रा./हे. की दर से प्रयोग और कीटनाशक की आवश्यकता के अनुसार सुरक्षित मात्रा प्रयोग करने के लिए मोनोक्रोटोफॉस १ लिटर/हे.(रोपण के ४० और ५५ दिनों के बाद दो बार में) और फॉस्फेमिडान को ३०० मिली./हे. की दर से प्रयोग किया गया।सभी चारों केंद्रों पर तना बेधकों (सफ़ेद बाली और डेड हर्ट दोनों) और पत्ती मोड़क कीटों के अंड परजीवी कीट *ट्राइकोग्रामा* स्पे. द्वारा कीटों का ग्रसन कम और अंडों का परजीवीकरण अधिक मिला तथा परजीवी कीट छोड़े गए क्षेत्रों में, कीटनाशक व्यवस्थित क्षेत्रों और *बीटी* प्रयोग किए क्षेत्रों की तुलना में उपज अधिक मिली। परजीवी कीटों की ०.५ लाख/ हे. की दर की अपेक्षा १ लाख/हे. की अधिकतम दर से छोड़ना श्रेष्ठ पाया गया।

जोरहाट (ख़रीफ़ और रबी मौसम में), लुधियाना और थ्रिसूर में जैवनियंत्रण आधारित आईपीएम का परीक्षण किसानों के खेतों में किया गया, इनमें तना बेधक और पत्ती मोड़क कीट का प्रबंधन करने के लिए *ट्रा. किलोनिस* और *ट्रा. जेपोनिकम* को फ़सल की विभिन्न अवस्थाओं में १ लाख/हे./सप्ताह की दर से छोड़ा गया और परिणाम प्राप्त हुआ कि अनुपचारित और कीटनाशक व्यवस्था की अपेक्षा जैव आधारित आईपीएम अपनाने से कीटों का ग्रसन कम और उपज अधिक मिलती है।

धान में प्राकृतिक शत्रुओं का सर्वेक्षण और अनुमान लगाने की प्रक्रिया में पाया कि सभी जगहों पर अनेक परभक्षी और परजीवी कीट उपलब्ध थे। थ्रिसूर में प्रमुख प्राकृतिक शत्रुओं में हायमेनोप्टेरस परजीवी कीट, इसके बाद परभक्षी कीट, मिरिड, मकड़ियाँ और कोक्सीनेलिड पाए गए। कोयंबटूर में परभक्षी कीट १६-२१% पाए गए, जिनमें मकड़ियाँ, कोलिओप्टेरिअन्स, ड्रैगन फ्लाई, झींगुर, टिड्डे और परभक्षी कीट, मेंटिस पाए गए, जबकि ११-१३% परजीवी कीटों में *टेट्रास्टिकस* स्पे., *टेलेनोमस* स्पे., *कोटेशिआ* स्पे. और *ट्राइकोग्रामा* स्पे. पाए गए तथा अन्य शेष कीट प्रजातियाँ पाई गई। लुधियाना में मकड़ियों की १७ प्रजातियाँ पाई गई जो कि ७ कुलों से संबंध रखती हैं, पूरे फ़सल मौसम में पाई गई और *टेट्रागनाथा जेवाना* इनमें सबसे प्रमुख, इसके बाद *अरेनिअस इन्सटस, टे. वायरसेन्स* और *आक्सीओपस जेवेनस* पाई गई। जोरहाट में ख़रीफ़ मौसम के दौरान लार्वा परजीवी कीट *ब्रेकोन* स्पे. द्वारा पत्ती मोड़क कीट का परजीवीकरण विविध रूप में १५% से २०% तक मिला और सितंबर माह के अंतिम सप्ताह में *ट्राइकोग्रामा* स्पे. पाए गए तथा तना बेधक कीट के अंडों का अधिकतम (२३.३%) परजीवीकरण पाया गया।

१९.७ नारियल के हानिकारक कीटों का जैविक दमन

बंगलौर, कायान्गुलम और थ्रिसूर में नारियल की माइट, *अकेरिआ गुएरेरोनिस* के प्रति *हिर्सुटेल्ला थोम्पसोनाई* के मायकोअरेकिडे नियमन "मायकोहिट" के साथ-साथ अकेरेकिडे डाइकोफाल (केल्थेन) और अनुपचारित क्षेत्रों का मूल्यांकन किया गया। बंगलौर में १४ दिन के अंतराल पर ३ बार में उपचारित वृक्षों पर कीटों की मृत संख्या की प्रतिशतता से इसकी उपयोगिता सिद्ध हुई। कवक नियमन की अवस्था में रोपण के ६३ दिनों के बाद ७५% घातकता देखी गई, जबकि अकेरिकिडे उपचार में दो बार छिड़काव के बाद रोपण के ४९ दिनों के बाद ६०% घातकता देखी गई। अनुपचारित वृक्षों पर प्राकृतिक रूप से अधिकतम ७% घातकता देखी गई। कायांगुलम और थ्रिसूर में इनका मूल्यांकन किया जा रहा है और परिणामों की प्रतीक्षा है।

१९.८ फल वृक्षों के हानिकारक कीटों का जैविक दमन

बंगलौर में अनार के फल बेधक *डीयुडोरिक्स आइसोक्रेटस* के परजीवी कीट *ट्रा. काइलोट्रिए* छोड़ने पर फलों की क्षतिग्रस्तता कम हुई, अनुपचारित वृक्षों पर २४.२४% फल क्षतिग्रस्त हुए, जबकि परजीवी कीट छोड़े गए वृक्षों पर केवल १४.१५% फल क्षतिग्रस्त हुए। सोलन में फल बेधक *डीयुडोरिक्स एपिजर्बस* कीट ५९.२% तक परजीवित पाए गए और उनमें से निकलने वाले परजीवी कीटों में ९३.१% सिलीओनिड, *टेलेनोमस ? साइरस* पाए और ६.९% युपेल्मिड, *एनास्टेटस* स्पे. नियर *कश्मीरेन्सिस* थे। बंगलौर में बेर के फल बेधक कीट *मेरीडार्किस स्किरोडस* को नियंत्रित करने के लिए *ट्रा. किलोनिस* को छोड़ गया और इसकी तुलना अनुपचारित बेर वृक्षों से करने पर यह देखा गया कि अनुपचारित वृक्षों पर ३४.९५% फल क्षतिग्रस्त हुए, जबकि परजीवी कीट छोड़े गए वृक्षों पर केवल २२.३३% ही फल क्षतिग्रस्त हुए, जिससे इनके प्रभावी होने का प्रमाण मिलता है। बंगलौर में नींबू वृक्ष पर *पेपिलिओ डेमोलिअस* के लार्वों की संख्या को नियंत्रित करने के लिए *बीटी* के सभी व्यवसायिक नियमनों को अत्यधिक प्रभावी पाया गया।

कर्नाटक, केरल, महाराष्ट्र और तमिलनाडु राज्यों में सर्पिलाकार श्वेत मक्खी के *ए. ? हेटिएन्सिस* और *ए. गुआडेलोउपे* प्राकृतिक शत्रु पाए गए। बंगलौर के पास अमरूद के एक बाग़ में फ़रवरी में *ए. गुआडेलोउपे* परजीवी कीट के प्रौढ़ छोड़े गए और मार्च में श्वेत मक्खी के १४.४७% निम्फ परजीवित पाए तथा धीरे-धीरे यह मात्रा बढ़ी और जून माह में बढ़कर ६२.७४% हो गई। थ्रिसूर में विभिन्न परपोषी पौधों पर इन एफेलिनिड्स द्वारा ०-६६.६% परजीवीकरण देखा गया, जिसमें अक्टूबर माह के दौरान मिर्चों में अधिकतम ६६% परजीवीकरण पाया गया।

लिए जैव नियंत्रण आधारित प्रबंधन की विभिन्न प्रक्रियाओं के अंतर्गत केवल *ट्रा. प्रेटिओजम* को ५०,००० प्रौढ़/हे./बार, केवल *हे.* एनपीवी २५० एल ई/हे. (१.५ x १०[१२] पीओबी) की दर से , विभिन्न संयोजनों से छोड़ने की दर और प्रयोग की बारी अपनाने पर पाया कि परजीवी कीट ५ बार छोड़ने और एनपीवी के २ या ३ छिड़काव करने से फल बेधको द्वारा फल कम क्षतिग्रस्त हुए और उपज अत्यधिक प्राप्त हुई। अन्य उपचारों की तुलना में परजीवी कीट छोड़ने और एनपीवी छिड़के प्लॉटों में अधिक उपज प्राप्त हुई। क्षेत्रों में *ट्रा. प्रेटिओजम* को ५ बार छोड़ना और *हे.* एनपीवी के ३ या हे. एनपीवी के ५ छिड़काव बहुत अधिक प्रभावी पाए गए।

बंगलौर में पातगोभी पर *प्लु. जाइलोस्टेल्ला* के प्रति *ट्रायकोग्रामेटॉयडिआ बेक्टरे* को २.५ लाख प्रौढ़ प्रति हैक्टेयर (साप्ताहिक अंतराल पर कुल ५ बार) छोड़ने की तुलना एन्डोसल्फान का साप्ताहिक अंतराल पर ३ छिड़काव करने पर परिणाम मिला कि जैव आधारित प्रयोग अपनाने से कीटों के लार्वो की संख्या में कमी और उपज अधिक प्राप्त हुई। इसी प्रकार के परीक्षण हैदराबाद में भी हुए, परिणाम स्वरूप परजीवी कीट छोड़े गए क्षेत्रों में लार्वो की संख्या को ३.२ लार्वे/पौधा से ०.५८ लार्वे/पौधा कमी की जा सकी और *ट्रा. बेक्टरे* की पुनः प्राप्ति हुई, जिससे परजीवी कीटों के सफल स्थापन के संकेत मिले। पुणे में रोपण के २५ दिनों के बाद ही साप्ताहिक अंतराल पर *ट्रा.. बेक्टरे* को ५०,०००/प्रौढ़/हे./बारी की दर से ५ बार छोड़ना सर्वश्रेष्ठ पाया गया, जिसमें औसतन ९.१ लार्वे/१० पौधे जीवित पाए और उपज ३६३.३ कुंतल/हे. प्राप्त हुई जबकि अनुपचारित क्षेत्र में १२.८६ लार्वे/ १० पौधे और उपज केवल २३३.५ कु./हे. ही प्राप्त हुई। इस उपचार से लागत लाभ अनुपात १: ५५.६४ पाया गया।

बंगलौर में बैंगन के कोंपल और फल बेधक *ल्युसिनोडस ओरबोनेलिस* के नियंत्रण के लिए खेत में कीटनाशक साइपरमेथ्रिन के ०.५ मिली./लिटर की तुलना परजीवी कीट *ट्रा. किलोनिस* के ५०,००० प्रौढ़/हे. छोड़ने के मूल्यांकन से की गई, इसमें पाया कि अनुपचारित क्षेत्र में फल २३.१०% और साइपरमेथ्रिन उपचारित क्षेत्र में फल १४.७०% क्षतिग्रस्त की तुलना में परजीवी कीट छोड़े गए क्षेत्र में केवल १२.६५% फल क्षतिग्रस्त पाए गए। उपज के आँकड़े देखने पर पता चलता है कि अनुपचारित क्षेत्र की अपेक्षा परजीवी छोड़े गए क्षेत्रों और साइपरमेथ्रिन उपचारित क्षेत्रों में क्रमशः ५७.०८% और ३५.६४% उपज अधिक मिलती है।

हैदराबाद में *प्लु. जाइलोस्टेल्ला* के प्रति *बीटी* के सभी अनेक व्यवसायिक नियमनों की दक्षता की तुलना में किए गए परीक्षणों से यह पाया कि अनुपचारित क्षेत्र की अपेक्षा *बीटी* के सभी नियमन और एन्डोसल्फान पातगोभी में लार्वों की संख्या को प्रभावी रूप से कम करते हैं। *बीटी* के विभिन्न नियमनों के परीक्षण में *प्लु. जाइलोस्टेल्ला* के लार्वों की संख्या कम (१७.००) करने के लिए बायोबिट सबसे अधिक प्रभावी और फिर डाईपेल (२१.९३) पाया गया। 'बायोबिट' प्रयोग करने से पातगोभी की बाज़ार योग्य उपज ५६.०० कु./हे. प्राप्त हुई और एन्डोसल्फान

सोलन में सेब के वुली माँहू की संख्या और उनके प्राकृतिक शत्रुओं के साप्ताहिक अंतराल पर पूरे वर्ष किए गए अनुवीक्षणों से यह पता चलता है कि *एफिलिनस माली* निरंतर जबकि क्राइसोपिड्स और कोक्सीनेलिड्स अप्रैल-जून माह के दौरान और सिरफिड जून, नवंबर और फ़रवरी माह के दौरान प्राप्त हुए। इसी प्रकार के सर्वेक्षण जम्मू और कश्मीर राज्य के श्रीनगर, बारमुला, पुलवामा, बडगॉम और अनंतनाग ज़िलों में भी किए गए और पाया कि *एफिलिनस माली* मई से सितंबर तक सभी क्षेत्रों में माँहू को २०-३४% परजीवीत करता है और *काइलोकोरस इन्फरनेलिस, कोक्सीनेल्ला सेप्टमपंटेटा, फेरोस्किमनस बेटीएटुए* और *क्राइसोपरला कानफ्रेटर* पाए गए। अनंतनाग, पुलवामा, बडगॉम, बारमुला और श्रीनगर ज़िलों में सेन जोश स्केल कीट के परजीवी कीटों को छोड़कर, उनके प्रभाव के मूल्यांकन में २० से ५४% परजीवीकरण पाया गया और *एफाइटिस* स्पे. और *एनकार्सिआ* स्पे. दानों ही भली-भाँति क्षेत्र में स्थापित हो गए।

बंगलौर स्थित प्रयोगशाला में किए गए वानस्पतिक परीक्षण संबन्धी प्रयोग के एक दिन बाद *ट्रा. काइलोट्रीए* के लिए विषैले साबित नहीं हुए, जबकि कार्बोरिल और मोनोक्रोटोफॉस अत्यधिक विषैले साबित हुए। नीम गोल्ड, इकोनीम, नींबीसीडिन सभी के ०.०३% और नीम बीज अर्क ४% को प्रयोग के तुरंत बाद भी *ए. गुआडेलोउपे* के प्रौढ़ के लिए विषैले नहीं पाए गए, किंतु नीम तेल, नीम अजाल और नीम मार्क इस परजीवी कीट के लिए विषैले पाए गए। सोलन में सेब के वुली माँहू के प्राकृतिक शत्रुओं पर कीटनाशकों के प्रभाव का परीक्षण किया गया और पाया कि क्लोरपायरीफॉस, मिथाइल पेराथिऑन और एन्डोसल्फान को छिड़काव करने के बाद *क्रा. कारनीआ* को क्रमशः १०, ७ और ५ दिनों के बाद छोड़ना सुरक्षित पाया गया। क्लोरपायरीफॉस (०.०४%), एन्डोसल्फान (०.०५%), मिथाइल पेराथिऑन (०.०५%), इमिडेक्लोप्रिड (०.०१% और ०.०२%) और थायमिथॉक्सम (०.०१३% और ०.००६३%) की मात्राएँ *ए. माली* की सर्दी में पैदा होने वाली संख्या और माँहू पर बनी ममीज से परजीवी प्रौढ़ निकलने पर कोई प्रभाव नहीं डालते।

१९.९ सब्ज़ी वाली फ़सलों के हानिकारक कीटों का जैविक दमन

सोलन में अलंकृण और सब्ज़ी वाली फ़सलों पर ग्रीन हाउस श्वेत मक्खी, *ट्राइएलेयुरोडस वेपोरेरीओरम* का प्रकोप देखा गया। श्वेत मक्खी के प्राकृतिक शत्रुओं में कोक्सीनेलिड, *सीरेन्जियम मोन्टेजिएरी* और एफेलिनिड, *एनकार्सिआ ट्रान्सवेना* अभिलेखित किए गए।

बंगलौर, पुणे और हैदराबाद में टमाटर फल बेधक, *हेलिकोवर्पा आर्मिजेरा* के प्रबंधन के

उपचारित क्षेत्र से ५३ कु./हे. उपज प्राप्त हुई, इससे इसकी श्रेष्ठता सिद्व होती है। पुणे में किए गए परीक्षणों से ज्ञात होता है कि डेल्फिन डब्लयू जी को १ किग्रा./हे. की दर से प्रयोग करने से लार्वों की संख्या कम , २ लार्वे/पौधा और अत्यधिक उपज ३१४.७ कु./हे. प्राप्त हुई यह उपचार सबसे अधिक प्रभावी पाया गया।

पुणे में बैंगन के *ल्यु. ओरबोनेलिस* को नियंत्रित करने के लिए *बीटी* के व्यवसायिक नियमनों का जाँच परीक्षण किया गया, इसमें पाया कि डेल्फिन डब्लयू जी को १ किग्रा./हे. की दर से ५ बार छिड़काव करने से फल ग्रसन कम (८.९३%) और अधिकतम उपज (१३६.५/कु./हे.) प्राप्त होती है, इस प्रकार डेल्फिन डब्लयू जी उत्कृष्ट नियमन पाया गया। बंगलौर में व्यवसायिक नियमन, स्पाइक-बायो (*बेसीलस थ्युरिन्जेन्सिस* जाति *कुर्सटेकी*) का *हे. आर्मिजेरा, स्पो. लिटच्यूरा, प्लु. जाइलोस्टेल्ला* और *क्रोसीडोलोमिआ बाइनोटोलिस* के प्रति मूल्यांकन किया गया और यह विभिन्न मात्राओं (१-१.७५ मिली./लिटर) और समयों पर *हे. आर्मिजेरा, प्लु. जाइलोस्टेल्ला* और *क्रो. बाइनोटेलिस* के प्रति बहुत प्रभावी पाया गया।

बंगलौर में सर्पिलाकार पत्ती सुरंगी कीट, *लिरयोमाइजा ट्राइफोली* के स्वदेशी परजीवी कीट, *हेमिप्टेर्सेनस वेरीकोर्निस* द्वारा ६.६२% तक परजीवित पाए गए। पत्ती सुरंगी कीट के दूसरे निरूप के लार्वों को परजीवीकरण के लिए प्राथमिकता देते हैं, और पररजीवीकरण विस्तार २५%-६१% तक पाया गया। *हेमि. वेरीकोर्निस* के लिए इमिडेक्लोप्रिड, साइपरमेथ्रिन, पोन्गामिआ तेल, नीम बीज अर्क, क्लोरोथेनोमिल, मेनकोजेब और कॉपर ऑक्सी क्लोराइड सुरक्षित पाए गए। *हेमि. वेरीकोर्निस* के लिए मोनोक्रोटोफॉस और फॉस्फेमिडॉन के विषैलेपन अवशेष के अध्ययन में देखा गया कि मोनोक्रोटोफॉस छिड़काव के २१ दिनों के बाद विषैलापन सामान्य होता है और फास्फेमिडॉन प्रयोग करने के १४ दिनों के बाद विषैलापन सामान्य होता है और फिर इन उपरोक्त दिनों के बाद ये सुरक्षित होते हैं।

१९.१० आलू के हानिकारक कीटों का जैविक दमन

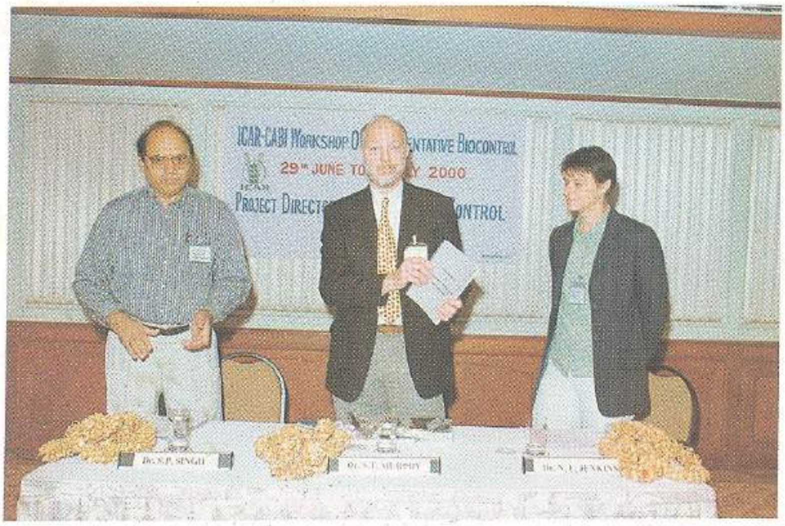
पुणे में *कोपिडोसोमा कोइहेल्री* को ५०,००० ममीज/हे. की दर से चार बराबर मात्राओं में साप्ताहिक अंतराल से खेत में रोपण के ४५ दिनों के बाद छिद्रित प्लास्टिक की शीशी में ५ मीटर की दूरी पर अलग-अलग लटका देते हैं, यह विधि सर्वोत्तम पाई गई और इस विधि के अपनाने से *थ्योरिमिआ ओपरकुलेल्ला* द्वारा कंदों की कम क्षति हुई तथा कंदों की उपज अधिक प्राप्त हुई। *को. कोईहेल्री* और *किलोनस ब्लैकबर्नी* को क्षेत्रों में छोड़ना अति उत्तम पाया गया क्योंकि इनके प्रयोग से पत्ती सुरंगें और क्रंद भी कम क्षतिग्रस्त हुए और बाज़ार योग्य कंदों की उपज अधिक प्राप्त हुई। भंडारण में *को. कोईहेल्री* (५.९४%) की तुलना में *कि. ब्लैकबर्नी*

(६.७४%) का प्रयोग उत्तम पाया गया। स्वदेशी भंडारण में *को. कोईहेल्ली* को १ ममीज/४ किग्रा. कंदों की दर से छोड़ने पर स्वदेशी भंडारण के लिए प्रभावी पाया गया और भंडारण के एक महीने के बाद कंदों का ग्रसन कम (११.३६%) पाया गया तथा इसी प्रकार *कि. ब्लैकबर्नी* को २ प्यूपे/किग्रा. कंदों की दर से छोड़ने पर ऐसे ही परिणाम प्राप्त हुए।

आलू की फ़सल में *स्पो. लिटचूरा* को नियंत्रित करने के लिए कीटाहारी रोगाणुओं, *ब्युवेरिआ बेसीआना, नोम्युरेइआ रिलेई, बेसीलस थ्युरिन्जिएन्सिस* और *स्पो.* एनपीवी का मूल्यांकन किया गया और यह पाया गया कि *स्पो.* एनपीवी को ५०० एल ई/हे. की दर से प्रयोग करने पर लार्वों के लिए अधिक घातकता (८५%) और कंद ग्रसन बहुत कम (८.८३%) तथा साथ ही साथ बाज़ार योग्य कंदों की उपज २०९.१ कु./हे. प्राप्त हुई और यह *बे. थ्युरिन्जिएन्सिस* (डेल्फिन डब्लयू जी) के ०.५ किग्रा./हे. की दर से प्रयोग करने के समान ही प्रभावी पाया गया।

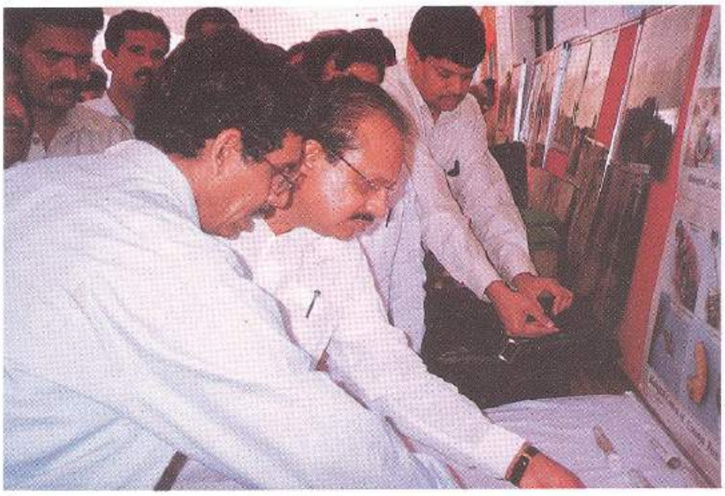
१९.११ खरपतवारों का जैविक दमन

थ्रिसूर और जोरहाट में *नीओकेटिना आईकोर्निए, नी. ब्रुकी* और *आर्थोगेलूम्ना टेरेब्रेन्टिस* के अनुवीक्षण और मूल्यांकन के प्रयोग किए जा रहे हैं। अलापुझा, कोट्टायाम, थ्रिसूर और अर्नाकुलम से जलकुम्भी के पौधे लाकर पौधों का निरीक्षण किया गया, सभी क्षेत्रों में जुलाई माह के दौरान विविलों की संख्या अधिक पाई गई, जबकि माईट्स नवंबर माह के दौरान अधिक पाई गई। असम में यह देखा गया कि विसर्जित विविल सोनितपुर, लखीमपुर, डिबरूगढ़, शिबसागर, गोलाघाट, नवोंगाँव और कामरूप ज़िलों में पाए गए और वहाँ पर इन कीटों ने खरपतवार की वृद्धि को पूर्णतः अवरुद्ध कर दिया तथा खरपतवार की वृद्धि कम होने के कारण उन पर फूल कम बन पा रहे हैं।



Dr. S.T. Murphy, CABI-BIOSCIENCE, UK releasing a book on production of bioagents during the ICAR-CABI Workshop on Augumentative Biological Control

ICAR Foundation Day



Shri. T. B. Jayachandra, Minister of Agriculture, Govt. of Karnataka at the PDBC stall during a coconut farmer's meet at Tiptur

'Rajbhasha Hindi Ka Swarnajayanthi Varsha' celebrations

Ninth Biocontrol Workers' Group Meeting

Participants in the Workshop and Collaborative Project Planning Meeting on Biological Control of Pests and Weeds for Sustainable Development

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