# ANNUAL REPORT 1998-99

PROJECT DIRECTORATE OF BIOLOGICAL CONTROL
BANGALORE

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| Cover | *Pseudomonas fluorescens,* a bacterial antagonist effective against *Sclerotium rolfsii, Rhizoctonia solani* and *Fusarium oxysporum* f. sp. *ciceri* |
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# CONTENTS

## PREFACE

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

The Directorate has made rapid strides in basic research on different aspects of biological control forming the base for technologies in Biointensive Integrated Pest Management. The Directorate 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 biodiversity of natural enemies, introduction of potential natural enemies for managing exotic pests, standardisation and development of improved breeding and mass production techniques for natural enemies, developing low temperature storage technology for natural enemies, understanding the tritrophic relationship between host plants, pest insects and natural enemies, development of superior strains of natural enemies for different crop ecosystems and tolerance to pesticides, development of biocontrol based technologies for pest management in crops like sugarcane, cotton, maize, tobacco, vegetable, fruit crops, etc. Several of these technologies have been transferred to private enterprises for commercial exploitation, including the recently developed endosulfan tolerant strain of the egg parasitoid, *Trichogramma chilonis*.

The sixth annual report of the Project Directorate embodies the endeavours of my scientist colleagues for the period from April 1998 to March 1999. 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.A.K.Raheja, former 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. Maintenance, multiplication and supply of host insects and natural enemies

Sixty-three cultures of host insects and 108 cultures of natural enemies were sent to coordinating centers and other research organizations to facilitate their multiplication, establishment and for field trials.

#### 2.1.2. Biosystematic studies on predatory coccinellidae

An annotated checklist of the coccinellid fauna (excluding Epilachninae) of the Indian subcontinent which provides the faunal composition, recent name with all synonyms, type depository, distribution and selected bibliography for all the taxa has been prepared. Sixty-five species belonging to twenty-nine genera, nine tribes and five subfamilies were studied.

#### 2.1.3. Standardizing/rearing/culturing techniques and bioecological studies on natural enemies

The subabul psyllid predator, *Curinus coeruleus* could be multiplied using *Ferrisia virgata* as host, in addition to the psyllid, *Heteropsylla cubana*. Another effective mealy bug predator, *Brumoides suturalis* could also be multiplied on *Ferrisia virgata* in the laboratory. Cotton pad was found to be the best pupal substrate for *Ischiodon scutellaris* and *Paragus serratus*. *Ankylopteryx* sp. could be reared on *Aphis gossypii*, *A. nerii*, *Lipaphis erysimi*, *Macrosiphum rosaeformis*, *Myzus persicae* and *Corcyra cephalonica*.

Developmental time was significantly lower and longevity and fecundity higher in field collected *Scymnus coccivora* as compared to those continuously laboratory reared, stressing the importance of rejuvenating the culture with field collected predators.

The cocoons of *Eriborus argenteopilosus* could be stored up to 10 days at 11°C and up to 15 days at 15°C, without any adverse effect on the biological parameters of the parasitoid. Bio-deterioration studies on field collected and laboratory reared *Campoletis chlorideae* showed that continuous laboratory rearing affected the progeny production and sex ratio.

Life table studies on *Trichogrammatoidea bactrae* parasitising *Plutella xylostella* eggs indicated that higher rates of release are necessary at lower and higher temperatures of 18-20°C and 32-35°C. Life table studies with winter and summer generations of *I. scutellaris* showed that the population multiplied by 1.097 and 1.102 times in winter and summer, respectively.

### 2.1.4. Artificial diet for host insects and natural enemies

*Spodoptera litura* was successfully reared on a semi-synthetic diet by mixing *Cynodon dactylon* powder with the commonly used diet.

Defatted soybean based diet was very effective to rear *Chrysoperla carnea* with increased pupation, pupal weight and adult emergence. Defatted soybean based diet was also found promising for rearing the anthocorid, *Cardiastethus exiguus*. Liver powder (2.9%) with peptone based diet and ground beef liver with egg yolk based diet could be used for rearing *Cryptolaemus montrouzieri*.

### 2.1.5. Pesticide tolerant strain of *Trichogramma chilonis*

Efforts to develop multiple insecticide tolerant strain of *Trichogramma chilonis* utilizing the ENDOGRAM strain have resulted in tolerance to monocrotophos and fenvalerate after 34 and 26 generations, respectively.

### 2.1.6. Behavioural studies on natural enemies

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. Slight ovipositional induction in *Cheilomenes sexmaculata* was noticed when the aqueous extracts of aphid washings were used.

Tritrophic interaction studies with *H. armigera*, its egg parasitoid *T. chilonis* and sunflower genotypes revealed that the highest parasitisation was recorded on MSFH-17. Ten genotypes of cotton were evaluated similarly and the highest parasitisation was found on MCU-5. Among 21 genotypes of pigeonpea, highest parasitisation was recorded on ICPL-84060.

Host plant preference studies with *E. argenteopilosus* parasitising *Helicoverpa armigera* showed that on chickpea and pigeonpea 18.83 and 15.42% parasitism was obtained while it was less on dolichos and sunflower. *I. scutellaris* preferred lablab followed by cowpea and groundnut for oviposition while *Paragus serratus* preferred lablab and

cowpea followed by equal preference for groundnut and pigeonpea.

### 2.1.7. Studies on insect viruses

Nuclear polyhedrosis viruses (NPV) from *Achaea janata, Agrotis* sp., *Spodoptera exigua* and *Galleria mellonella* and granulosis viruses from *Agrotis* sp. and *Phthorimaea operculella* were isolated, identity confirmed by electron microscopic study and pathogenicity proved. Cross infectivity studies revealed the high susceptibility of *S. litura* to *S. exigua* NPV.

*Spodoptera exigua* NPV was found to be a multiple embedded virus with the polyhedral inclusion bodies measuring 1.65 + 0.1 μ in diameter.

### 2.1.8. Fungal and bacterial antagonists

A wheat bran powder based formulation of *Trichoderma harzianum* (PDBCTH 10) was found very effective in controlling chickpea root rot and wilt (*Rhizoctonia solani*) in greenhouse as well as in field trials. 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*.

Seed treatment with *Gliocladium virens* alone (@ 2g/kg) or combination of *G. virens* or *T. harzianum* with Vitavax (2g & 1g/kg) were highly effective against seed and seedling rot of soybean in Pantnagar. An isolate of *T. harzianum* has been found which is tolerant to carbendazim up to 5μg/l and this is being improved for other characteristics through protoplast fusion technique with an isolate which is fast growing, heavily sporulating and possessing excellent antagonistic potential.

### 2.1.9. Entomophilic nematodes

Different media were evaluated for mass production of *Steinernema* spp. and it was found that egg yolk medium was best and addition of milk powder to this medium enhanced the yield. Wout's medium was found best for *Heterorhabditis* sp.

Penetration rate assessed in final instar larvae of *S. litura* by soil assay method revealed that infective juveniles of *Steinernema* spp. penetrated more than *Heterorhabditis*

spp. Maximum progeny production of *Heterorhabditis* spp. and *Steinernema* spp. was observed in final instars of *S. litura* followed by *H. armigera*. Larvae reared on artificial diet yielded more infective juveniles in *S. litura* compared to larvae reared on castor and tomato.

### 2.1.10. Biological control of plant parasitic nematodes

Sorghum grain was found suitable for mass production of the fungus, *Verticillium chlamydosporium*. This fungus gave 56% reduction of *Heterodera cajani* population and 61% parasitisation of cysts when applied as a granular formulation to the soil.

### 2.1.11. Weed pathogens

Surveys undertaken for parthenium diseases in Bangalore urban and rural districts revealed the association of *Nigrospora spherica* with a leaf spot disease for the first time. *Fusarium pallidoroseum* (Cooke) Sacc. (*F. semitectum auct.*), a leaf-spotting pathogen, showed the most desirable characteristics for development as a mycoherbicide for parthenium. All the growth stages of parthenium were susceptible to *F. pallidoroseum*. Preliminary host-range testing showed that several crops amongst the Asteraceae including sunflower cultivars, were not susceptible to *F. pallidoroseum*.

Searches for pathogens of water hyacinth, *Eichhornia crassipes* yielded three new fungi, viz. *Lasiodiplodia theobromae* (=*Botryodiplodia theobromae*), *Rhizoctonia* sp., *Alternaria* sp. and *Xylaria* sp.

### 2.1.14. Software development for identifying and suggesting BIPM

Information system PDBC-INFOBASE has been developed to help the farmers, extension workers, industry, entomologists, biocontrol-experts, students, teachers, research managers and planners. This user friendly, menu driven, self-explanatory software contains information on Biocontrol Resources in the country. Ten floppies contain the visuals, text and tables, which can be retrieved at the touch of a finger. The programme can be used on any PC containing WIN-95.

## 2.2. Biological suppression of sugarcane pests

Seasonal incidence studies on natural enemies of sugarcane insect pests in Ludhiana revealed that 15.2, 51.2 and 5.9 per cent eggs of *Chilo infuscatellus, Scirpophaga excerptalis* and *Acigona steniellus*, respectively, were parasitized by *Trichogramma chilonis* and *Telenomus dignoides* (only from *S. excerptalis*), while the larval parasitoids

were *Cotesia flavipes, Stenobracon nicevillei* and *Isotima javensis.*

*Sturmiopsis inferens* was found to be active throughout the year on shoot borer in Coimbatore, its activity ranging from 2.1 to 15.2% and the maximum being in September.

*T. chilonis* dispersed to a distance of 10 m in the fields in Coimbatore as indicated by parasitisation in *Corcyra* trap cards (9.0 to 56.5%) at distances of 2-10 m. When freshly laid, 3-day-old and 4-day-old eggs of internode borer were exposed to *T. chilonis,* parasitism was very low in four-day-old eggs and 100% in freshly laid and 3-day-old eggs.

*Beauveria brongniartii* was evaluated in pot culture studies against third instar white grubs and the most effective dosages were $10^{16}$ and $10^{17}$ spores/ha. Natural incidence of *Metarhizium anisopliae* infection was also observed.

Demonstrations to test the effectiveness of *T. chilonis* for the control of *C. auricilius* at five locations in Ludhiana provided a reduction in the incidence of stalk borer by up to 54.0 per cent in plots where tricho-cards were used and 62.7 per cent where adult parasitoids were released.

### 2.3. Biological suppression of cotton pests

The Biointensive Integrated Pest Management (BIPM) modules in Hyderabad consisting of mechanical collection of infested plant parts and larvae and placing them in wire screen cage, intercropping with a row of cowpea for every two rows of cotton, random planting of maize, border sowing of castor, three releases of *C. carnea* @ 10,000 larvae/ha/week, eight releases of *T. chilonis* @ 1,50,000/ha/week and need based application of *Ha*NPV at 500 LE/ha and need based application of insecticides gave an incremental cost-benefit ratio of 1:3.0 to 3.86 while farmers' practice (1:2.52), ANGRAU practice (1:1.95) and untreated control (1:2.74) gave less.

Sucking pests as well as bollworms on cotton were effectively managed by following the BIPM package in Anand. Release of *T. chilonis* @ 1,50,000/ha/week for eight weeks by distributing 200 egg card strips @ 1 /m$^2$ resulted in least damage to squares and bolls, highest per cent parasitisation of eggs and greater yield as compared to distributing 100 egg card strips, release of adult parasitoids and untreated control.

A field trial laid out in a farmer's field in Coimbatore to manage the pests of cotton revealed that BIPM methods of protection were superior to both chemical control

and farmers' method in reducing the population of aphids, leafhoppers and bollworm incidence and recording higher yield and egg parasitism on bollworms and more number of natural enemies than in plots treated only with insecticides.

### 2.4. Biological control of tobacco pests

Alternate sprays of *Sl*NPV @ 3 x $10^{12}$ PIB/ha and *Btk* @ 1.0 kg/ha for suppression of *S. litura* in commercial tobacco nurseries at Morampudi, Andhra Pradesh, yielded two lakh more seedlings (24 lakhs) than farmers' practice (22 lakhs). BIPM practice for suppression of *H. armigera* in tobacco fields in Katheru, Andhra Pradesh, was compared with a systematic chemical spray schedule and a farmers' chemical spray schedule and found the best in recording less pest incidence and greater abundance of natural enemies. Demonstration of BIPM of *S. litura* in irrigated FCV tobacco crop in Kalavacherla, Andhra Pradesh, with 3 sprays of *Sl*NPV (3 X $10^{12}$ PIB/ha), castor trap crop and release of *Telenomus remus* (40,000/ha) resulted in a C:B ratio of 1:1.34 as against 1:1.24 in chemical control.

### 2.5. Biological suppression of pulse crop pests

BIPM of pod borer complex on pigeon pea at Coimbatore showed that *Bt* (1.0 kg/ha) - *Ha*NPV (1.5x$10^{12}$PIB/ha) - *Bt* (1.0 kg/ha) - *Ha*NPV (1.5x$10^{12}$PIB/ha) was best in reducing incidence and increasing yield. In Hyderabad sequential spray of *Bt*-*Ha*NPV-endosulfan-*Bt* at 10 days interval starting from flower initiation was found to be effective in suppressing larval population and reducing pod damage by *H. armigera* in pigeonpea. Four alternate sprays of *Ha*NPV and *Bt* were efficient in controlling pod borer complex on pigeonpea in Ludhiana.

Damage by *H. armigera* in Coimbatore on chickpea was significantly less in plots sprayed with *Ha*NPV - endosulfan.

### 2.6. Biological suppression of rice pests

Inundative release of *T. japonicum* and *T. chilonis* @ 50,000/ha/week and 1,00,000/ha/week, respectively, starting from 30 days after transplanting in farmers' field at Kakajan, Assam, for suppressing paddy stem borer and leaf folder gave good control of stem borer as compared to the unreleased plot. Similarly, leaf folder population was also lower in released plot as compared to unreleased plot. Field evaluation of integrated use of *T. japonicum, T. chilonis* and *Bacillus thuringiensis* against rice stem borer and leaf folder revealed lowest incidence of stem borer and leaf folder and highest yield in

Coimbatore. Eight simultaneous releases (@ 50,000 to 1,00,000/ha) of *T. chilonis* and *T. japonicum* at 7 days interval, starting 20 days after transplanting proved very effective for the control of stem borer in Ludhiana. White ear head incidence in Thrissur was lower in plots where *Trichogramma* was released @ 1,00,000/ha. The extent of parasitism of stem borer eggs in Ludhiana by *Telenomus* sp. varied from 61 to 100 per cent during August-September, 1998 and the population of spiders was very high during the whole season.

### 2.7. Biological suppression of plantation crop pests

A gram-negative bacterium infecting septicaemic grubs of coconut rhinoceros beetle was isolated from Kayangulam, which may be new. Coir waste could be used as feeding material to maintain baculovirus infected grubs. A large number of natural enemies were recorded in Kayangulam on coconut lacewing bug, *Stephanitis typicus* and of these *Aspergillus flavus* sprayed @ 105 - 106 spores/ml gave 100% mortality of nymphs in 5-6 days.

The scale insect, *Ischnaspis longirostris* assumed serious proportions in parts of Karnataka and *Stictobura semipolita* and *Chilocorus nigrita* were found to be important predators.

### 2.8. Biological suppression of tropical fruit crop pests

The eggs of pomegranate fruit borer, *Deudorix isocrates* were parasitised by *Ooencyrtus papilionis, Trichogramma chilotraeae* and *Telenomus* sp. and a combined parasitism of 0-80% was recorded during different months in Bangalore. Release of *Cryptolaemus montrouzieri* @ 20-25 beetles/plant brought about a reduction in population of the mealybugs *Planococcus lilacinus* and *Maconellicoccus hirsutus* on acid lime in Bangalore. Pomegranate hairy caterpillar, *Trabala vishnou* was heavily parasitised by the tachinid parasitoid, *Blepharipa ?zebina* in Bangalore. Pomegranate fruit borer, *Deudorix epijarbas* eggs were parasitised to an extent of 69.5% by *Telenomus* spp., *Anastatus* spp., and *T. chilonis* in Solan.

### 2.9. Biological suppression of temperate fruit crop pests

Parasitization of San Jose scale, *Quadraspidiotus perniciosus* by *Aphytis* sp. and *Encarsia perniciosi* was 5.1 and 2.8% in Solan (Nauni), 0.5 and 38.0 % in Shimla (Rohru and Kotkhai), and 3.3 and 2.0 % in Kullu (Bajaura), respectively. In Kashmir the

scale was parasitised by *Encarsia* spp. and *Aphytis* sp. in different areas and predated upon by *Chilocorus infernalis*.

The major natural enemies of the apple woolly aphid, *Eriosoma lanigerum* recorded in Kakpora and Narbal, Jammu and Kashmir were *Aphelinus mali* and *Coccinella septempunctata*. Release of *C. carnea* @ 20-70 / branch reduced the woolly aphid population within a week after release in Solan.

### 2.10. Biological suppression of vegetable crop pests

Five releases of *Trichogrammatoidea bactrae* @ 50,000 adults/ha/release at weekly interval recorded significant reduction in the number of *Plutella xylostella* larvae and increase in the yield of marketable cabbage heads in Pune. Release of *T. bactrae* @ 2,50,000/ha five times at weekly interval starting from 10 days after transplanting and three sprays of endosulfan at weekly interval brought about similar reductions in larval population of *P. xylostella* in Bangalore and Hyderabad.

Five sprays with *Bacillus thuringiensis* formulation Halt reduced the larval population of *P. xylostella* on cabbage at Bangalore. Formulations of *B. thuringiensis* (Delfin WG, Dipel 8L, Halt, Biolep, Biobit and Delfin DF) @ 1 kg/ha provided good control of *P. xylostella* in Pune. Biobit @ 1 kg/ha, five sprays at 10 days interval, brought about decrease in the larval population of *P. xylostella* in Hyderabad.

Trials to manage the fruit borer, *H. armigera* in tomato over two seasons revealed that two sprays of *Ha*NPV @ 250 LE/ha and *Trichogramma pretiosum* release @ 2,50,000 adults/ha recorded less fruit damage, larval count and higher yield in Bangalore. Five sprays of *Ha*NPV @ 250 LE/ha and five weekly releases of *T. pretiosum* @ 50,000 adults/ha/release + 3 sprays of *Ha*NPV @ 250 LE/ha were the most effective treatments in controlling tomato fruit borer in Pune. Five releases of *T. pretiosum* @ 50,000/ha/week and 3 sprays of *Ha*NPV @ 250 LE/ha 5 days after release and then at weekly interval was found to be best in Hyderabad. Five rounds of *Nomuraea rileyi* @ 3.2x108 spores/ml reduced the number of bored fruits by *H. armigera* and increased the yield in Bangalore.

*Brevicoryne brassicae* and *Myzus persicae* on cauliflower crop in Solan were equally preferred for parasitisation by *Diaeretiella rapae*. The hyperparasitoid *Pachyneuron aphidis* was also recorded in Solan on cabbage.

Delfin @ 1.0kg/ha was found better than Dipel in checking the shoot and fruit borer of brinjal, *Leucinodes orbonalis*.

A new aphelinid parasitoid *Encarsia* sp. nr. *meritoria* Gahan and a predatory coccinellid beetle *Axinoscymnus puttarudriahi* were collected from spiralling whitefly, *Aleurodicus dispersus* on brinjal, tomato, chillies and guava in Kerala.

### 2.11. Biological suppression of potato pests

Inundative releases of *Chelonus blackburni* @ 1 adult/kg tubers and *Copidosoma koehleri* @ 1 pair of adults per kg tubers at fortnightly intervals, initial release of *C. koehleri* @ 5 pairs of adults/kg tubers and *B. thuringiensis* @ 1g/kg tubers resulted in only 18 to 22 per cent tuber infestation after 2.5 months of storage in country stores (Arnies) in Pune. Field demonstration conducted in farmers' field near Pune showed that four weekly releases of *C. koehleri* @ 50,000 adults/ha/release was the most effective.

### 2.12. Biological suppression of weeds

Control of water hyacinth by *Neochetina eichhorniae* and *N. bruchi* is most prominently visible in the Disangmukh area of Sibsagar district, Assam where more than 7000 bighas of water hyacinth has been cleared and these areas are presently being utilized by the farmers for paddy cultivation. *N. eichhorniae*, *N. bruchi*, and mite *Orthogalumna terebrantis* were observed to have established in the waterways of Gujarat. The population of *Neochetina* spp. and mites increased during June-December in Pune.

# 3. INTRODUCTION

## 3.1. Brief History

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

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

## 3.2. Past achievements

Eighty two natural enemies (NEs) have been studied for utilisation against crop pests and weeds, out of which sixty one NEs could be successfully multiplied in the laboratory, thirty seven species have been recovered from the field, two are providing partial control, three substantial control and four are providing economic benefits worth million of rupees and twelve are augmented the same way as indigenous natural enemies. Encyrtid nymphal parasitoid *Leptomastix dactylopii* introduced from West Indies in 1983 has successfully established on common mealybug infesting citrus and many other crops in South India. Coccinellid predator *Curinus coeruleus* (Origin : South America) introduced from Thailand in 1988 has colonised on subabul psyllid. Weevil *Cyrtobagous salviniae* (Origin : Argentina) introduced in 1982 colonised on exotic water fern *Salvinia molesta* in 1983. The release of weevils has resulted in annual saving of Rs. 68 lakhs on labour alone in Kuttanad district of Kerala. Weevils *Neochetina bruchi* and *N. eichhorniae* and hydrophilic mite *Orthogalumna terebrantis* (Origin: Argentina) were introduced in 1982

and colonised in 1983 on stands of water hyacinth. Weevils have now established in 15 states. Saving on labour alone is Rs. 1120 per ha of weed mat.

A sort of classical biological control has been achieved by redistribution of *Epiricania melanoleuca,* a parasitoid of *Pyrilla perpusilla.* Breeding techniques for 46 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 three predators and seven species of weed insects. Surveys for natural enemies of key crop pests have been conducted and the list of predators, parasitoids and pathogens compiled. Tritrophic relationship between natural enemies, their hosts and host plants has been determined. *Hyposoter didymator* and *Telenomus remus* preferred to parasitise *Spodoptera litura* larvae and eggs respectively, on castor and beet root. *Cotesia kazak* preferred host plants - tomato, cotton and okra, while *Cotesia marginiventris* preferred knol-khol, castor and cowpea and *Eucelatoria bryani* preferred cotton. Suitable low temperatures for short term storage of trichogrammatids, *Sticholotis madagassa, Eucelatoria bryani, Senometopia (=Carcelia) illota, Allorhogas pyralophagus, Copidosoma koehleri, Hyposoter didymator, Cotesia marginiventris, Leptomastix dactylopii, Sturmiopsis inferens, Pareuchaetes pseudoinsulata,* etc. have been determined. Superior strains of *Trichogramma chilonis* have been determined for cotton, sugarcane and tomato crops. Different pesticides have been screened against 37 natural enemies for identifying relatively safer ones to be used in BIPM. Primary cell culture from the embryos of *Spodoptera litura* has been established which will facilitate the multiplication of obligate microorganisms. The inundative release of *T. chilonis* and *T. japonicum* has proved to be effective in suppressing the population of sugarcane tissue borers. *T. chilonis* has proved to be effective against maize stem borer, *Chilo partellus.* BIPM modules for cotton crop have been formulated comprising the use of oxydemeton methyl (0.03%), releases of *Chrysoperla carnea, T. chilonis* and spray of *Ha* NPV . The module could increase yield, conserve naturally occurring biotic agents and increase the benefit as compared to insecticidal sprays. *Ha* NPV has given encouraging results in the suppression of *H. armigera* on pulses. Integration of *Telenomus remus, Chrysoperla carnea,* insect pathogens and neem seed kernal suspension was successful in the management of *S. litura* on tobacco. The cost-benefit ratio for BIPM was 1 : 2.74 whereas for chemical control it was 1 : 1.52. *Apanteles taragamae, Bracon hebetor, Goniozus nephantidis,* and *Brachymeria nosatoi* are the key biocontrol agents on *Opisina arenosella.* Their inundative release coinciding the first release with the first appearance of the pest has proved effective. Oryctes baculovirus has been highly successful in reducing the *Oryctes*

*rhinoceros* population in Kerala, at Minicoy and Androth-Lakshadweep and Andaman Islands. Training programmes on mass production and demonstration of the impact of *Trichogramma, Cryptolaemus, Chrysoperla, Ha* NPV and *Sl* NPV have been conducted in many states.

### 3.3. Mandate

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

### 3.4. Organisational set-up

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

### 3.5. Financial statement

| Head | Plan* | Non-plan | Total |
|---|---|---|---|
| Establishment | 25.21 | 85.12 | 110.33 |
| TA | 3.06 | 2.00 | 5.06 |
| Works | 37.07 | - | 37.07 |
| Other charges including equipment | 66.52 | 14.99 | 81.51 |
| Total | 131.86 | 102.11 | 233.97 |

* Including co-ordinating centres

**Centre-wise budget**

| 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 | 2.19 | 2.19 |
| ANGRAU, Hyderabad | 2.98 | 2.98 |
| GAU, Anand | 4.13 | 4.13 |
| KAU, Thrissur | 4.24 | 4.24 |
| MPKV, Pune | 2.15 | 2.15 |
| PAU, Ludhiana | 4.66 | 4.66 |
| SKUAS&T, Srinagar | 1.66 | 1.66 |
| TNAU, Coimbatore | 2.59 | 2.59 |
| YSPUH&F, Nauni, Solan | 2.29 | 2.29 |
| GBPUA&T, Pantnagar | 1.11 | 1.11 |

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

### 3.6 Staff position

| Category | Posts sanctioned up to 31-03-1999 | Posts filled up to 31-03-1999 | Vacant positions |
|---|---|---|---|
| **PDBC, Bangalore** | | | |
| Scientific | 25 | 18 | 7 |
| Technical | 21 | 19 | 2 |
| Administrative | 8 | 7 | 1 |
| Supporting | 6 | 6 | – |
| **SAU-based Centres** | | | |
| Scientific | 15 | 15 | – |
| Technical | 41 | 39 | 2 |
| Administrative | 1 | 1 | – |
| Supporting | – | – | – |
| **ICAR Institute-based Centres** | | | |
| Scientific | 12 | 12 | – |
| Technical | 38 | 38 | – |
| Administrative | – | – | – |
| Supporting | – | – | – |

# 4. RESEARCH ACHIEVEMENTS

## 4.1. Introduction of natural enemies

### 4.1.1. Importation and maintenance of exotic natural enemies

Though no importation of natural enemy could be made this year attempts were made to correspond and import *Diglyphus begini* from Hawaii for *Liriomyza trifolii* and also *Encarsia haitiensis* and *E. guaduloupe* from International Institute of Tropical Agriculture, Benin (West Africa). Applications for revalidation of import permits were also made to the Plant Protection Advisor, Government of India, New Delhi.

## 4.2. Biosystematic studies on Indian predatory Coccinellidae

### 4.2.1. Taxonomic studies on coccinellids

Taxonomic studies on coccinellids were continued. Sixty five species belonging to twenty nine genera under nine tribes and five subfamilies were studied.

In the subfamily Chilocorinae, two species, *viz.*, *Chilocorus melas* Weise and *C. subindicus* Booth were studied.

In the subfamily Sticholotidinae, five species, *viz.*, *Pharoscymnus horni* (Weise), *P. flexibilis* (Mulsant), *Stictobura pallideguttata* (Crotch) and *S. semipolita* Sicard (tribe Sticholotidini) and *Serangium montazerii* Fürsch (tribe Serangiini) were studied.

Under the subfamily Scymninae, three genera, *viz.*, *Scymnus* Kugelann [*S. (Pullus) latemaculatus* Motschulsky and *S. (Neopullus) brunnescens* (Motschulsky)], *Nephus Mulsant* (an indeterminate species) (tribe Scymnini) and *Cryptogonus quadriguttatus* (Weise) (tribe Aspidimerini) were studied. An indeterminate genus and species of Scymnini from South India remains to be identified.

Most of the common species in the subfamily Coccinellinae studied were in the tribe Coccinellini. The genera and species studied therein include *Oenopia* Mulsant [*billieti* (Mulsant), *conglobata* (L.), *signatella* (Mulsant), *kirbyi* Mulsant, *sauzeti* Mulsant, *smetanai* Canepari, *sexareata* (Mulsant), and a new species], *Calvia* Mulsant [*shiva* Kapur, *sykesii* (Crotch), *punctata* (Mulsant), *breiti* Mader, *quattuordecimguttata* (L.)], *Bothrocalvia* Crotch [*albolineata* (Gyllenhal)], *Coccinella* Linnaeus [*septempunctata* L., *undecimpuntata* L., *transversalis* F., *luteopicta* (Mulsant)], *Harmonia* Mulsant [*octomaculata* (F.), *eucharis* (Mulsant), *dimidiata* (Fabricius), *expallida* (Weise)],

*Cheilomenes* Chevrolat [*sexmaculata* (Fabricius)], *Micraspis* Dejean [*discolor* (F.), *?vincta* (Gorham), *allardi* (Mulsant)], *Anegleis* Iablokoff-Khnzorian [*cardoni* (Weise), *perrotetti* (Mulsant)], *Hippodamia* Dejean [*variegata* (Goeze)], *Phrynocaria* Timberlake [*unicolor* (Fabricius), *circumusta* (Mulsant)], *Coelophora* Mulsant [*bissellata* Mulsant, *biplagiata* (Swartz)], *Adalia* Mulsant [*simmondsi* Kapur and Sudha Rao, *tetraspilota* (Hope)], *Alloneda* Bielawski [*dodecaspilota* (Hope)], *Synonycha* Dejean [*grandis* (Thunberg)], *Anisolemnia* Crotch [*dilatata* (Fabricius)] and *Propylea* Mulsant [*japonica* (Thunberg), *luteopustulata* (Mulsant)]. Under the tribe Psylloborini, three genera, namely, *Halyzia* Mulsant, *Macroilleis* Miyatake and *Illeis* Mulsant were studied.

In the subfamily Coccidulinae, *Rodolia* Mulsant (tribe Noviini) and *Sumnius* Weise (tribe Exoplectrini) were studied. As a result of the studies, some new combinations were proposed.

### 4.2.2. Preparation of an annotated checklist of the coccinellid fauna (excluding Epilachninae) of the Indian subcontinent

*Oridia pubescens* Gorham (from Assam), *Macroilleis hauseri* (Mader) (from Sikkim), *Bothrocalvia albolineata* (Gyllenhal) (from Sikkim and Meghalaya), *Harmonia sedecimnotata* (Fabricius) (from West Bengal and Sikkim), *Oenopia smetanai* Canepari (Sikkim) and *Shirozuella* Sasaji (from Karnataka) were recorded for the first time from India based on studies carried out at ZSI, Calcutta, and on PDBC collections.

An annotated checklist of the coccinellid fauna of the Indian subregion has been prepared. The geographical scope of the checklist covers India, Pakistan, Sri Lanka, Bangladesh, Nepal, and Myanmar (Burma). For all the genera and species, the most recent name/combination, the original citation, and all the synonyms in chronological order has been given. In addition to these, the nature of type material, method of type fixation, and type depository have also been indicated. Subsequent references of importance and selected bibliography pertaining to revisions, lectotype designations, redescriptions, distributional records, etc. have also been provided. For all the taxa, the geographical distribution (for Indian species), by states has been indicated.

## 4.3. Survey for natural enemies

### 4.3.1. Survey for natural enemies and host plants of *Aleurodicus dispersus* in different areas

Lakshadweep islands were surveyed for the natural enemies of spiralling whitefly,

*Aleurodicus dispersus*. Five islands, namely, Kalpeni, Kavaratti, Minicoy, Viringili and Andrott, were visited. The farthest island in the south is Minicoy, which is closest to Maldives where an effort to establish *Encarsia* spp. was made a few years ago.

Spiralling whitefly was recorded on 11 host plants (banana, papaya, crotons, *Thevetia neriifolia*, chillies, capsicum, *Erythrina indica*, coconut, bread fruit, *Gliricidia* and *Hibiscus tiliaceus*) from Kavaratti and on 32 hosts (guava, *Antigonon*, *Ficus benghalensis*, *Ficus* sp., *Plumeria alba*, *Hibiscus* sp., *Polyalthia longifolia*, brinjal, *Terminalia catappa*, *Calotropis gigantea*, castor, *Abutilon indicum*, *Acalypha indica*, mulberry, *Bidens pilosa*, *Cleome pentandra*, *Syzygium* sp., *Ochrosia* sp., neem and two undetermined hosts, besides those recorded in Kavaratti) from Minicoy. Whitefly incidence was not recorded in Andrott and Kalpeni. Parasitised whitefly samples and the parasitoid, *Encarsia* spp. were collected. At least two species are present and at least one of them seems different from the species found in the mainland in Kerala and in Bangalore. Attempts to identify them are on. Only two predators, namely, *Axinoscymnus puttarudriahi* Kapur and Munshi (Coleoptera : Coccinellidae) and *Cybocephalus* sp. (Coleoptera: Nitidulidae) were recorded on *A. dispersus*.

### 4.3.2. Records of predators of *Aphis craccivora*, *Ferrisia virgata*, *Ischnaspis longirostris* and *Heteropsylla cubana*

*Ankylopteryx* sp. was recorded feeding on *Aphis craccivora* on *Gliricidia sepium*. An unidentified anthocorid was recorded during winter feeding on *Ferrisia virgata* on *Bauhinia purpurea*. *Stictobura semipolita* and a new species of *Shirozuella* were recorded on arecanut scale, *Ischnaspis longirostris* during summer in Karnataka. *Serangium serratum* Poorani was recorded on *Heteropsylla cubana* from November to January.

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

### 4.4.1. Development of mass multiplication technique for *Curinus coeruleus*

Two rearing methods utilizing two hosts were evaluated by comparing biological parameters for seven generations.

Rearing on *Heteropsylla cubana*

Small strips (3x1 cm) of card board cartons were cut and placed over psyllid infested subabul bouquets for inducing egg laying and 20 pairs of adults released in each cage. After hatching grubs were reared for first two instars @ 10 grubs per vial with small

psyllid infested twigs. After about 8 days, grubs wei transferred over the bouquet in 30 $cm^3$ insect rearing cage @ 50 grubs per bouquet.

Rearing on *Ferrisia virgata*

Twenty pairs of adults were released on fully infested pumpkin. Notched subabul sticks were placed around pumpkin for inducing egg laying. After hatching 50 grubs were released on each mealybug infested pumpkin.

Biological parameters were studied by selecting 20 pairs from both the sets of experiments and exposing to the same host. Adults from each batch were reared on the same host till death and observations on fecundity, larval survivorship and larval developmental time worked out.

Table 1. Biological parameters of *Curinus coeruleus* reared on *Heteropsylla cubana* and *Ferrisia virgata*

| Generation | Host | Develop-mental time (days) | Pupal weight (mg) | Adult longevity (days) | Fecundity (Eggs/ female) | Larval survival (%) |
|---|---|---|---|---|---|---|
| First | *H. cubana* | 36.09 | 9.60 | 97.10 | 175.10 | 88.00 |
| | *F. virgata* | 42.51 | 7.85 | 72.80 | 182.20 | 86.00 |
| Second | *H. cubana* | 38.61 | 9.85 | 81.30 | 170.30 | 82.00 |
| | *F. virgata* | 39.50 | 8.93 | 79.50 | 165.50 | 84.00 |
| Third | *H. cubana* | 32.29 | 9.10 | 93.50 | 160.40 | 94.00 |
| | *F. virgata* | 29.51 | 7.60 | 69.00 | 97.50 | 86.00 |
| Fourth | *H. cubana* | 36.50 | 10.50 | 89.00 | 210.30 | 96.00 |
| | *F. virgata* | 31.79 | 10.60 | 89.50 | 220.10 | 96.00 |
| Fifth | *H. cubana* | 37.80 | 10.90 | 86.80 | 230.40 | 82.00 |
| | *F. virgata* | 38.19 | 10.63 | 88.90 | 198.90 | 86.00 |
| Sixth | *H. cubana* | 35.88 | 12.60 | 90.00 | 190.60 | 84.00 |
| | *F. virgata* | 36.50 | 11.10 | 92.50 | 200.20 | 92.00 |
| Seventh | *H. cubana* | 36.60 | 12.75 | 97.50 | 200.50 | 90.00 |
| | *F. virgata* | 37.08 | 12.55 | 95.00 | 228.60 | 92.00 |

After the seventh generation, eggs of adults reared on *F. virgata* were released on bouquet of subabul infested with *H. cubana* to evaluate its performance. Observations on larval survivorship, pupal weight and development time were recorded.

Results showed that in all but the third generation, developmental times were short for insects reared on *H. cubana* and the time ranged from 32.29 to 38.61 for insects reared on *H. cubana,* and 29.51 to 42.51 days for insects reared on *F. virgata* (Table 1).

Except fourth generation pupal weight was higher in case of larvae reared on *H. cubana*. Pupal weights ranged from 7.60 to 12.55 for larvae reared on *F. virgata,* and 9.10 to 12.75 mg for larvae reared on *H. cubana*. Except 3rd generation, larval survivorship was higher when reared on *F. virgata*. Mortality ranged from 4 to 18% when reared on *H. cubana* and 4 to 14% when reared on *F. virgata*. Out of seven, four generations exhibited higher fecundity when reared on *F. virgata*. Peak oviposition on *F. virgata* always occurred on the first few days of oviposition period, except in third generation, where the peak occurred at the end of oviposition period. However, adults reared on *H. cubana* exhibited uniform egg distribution throughout the oviposition period. After rearing on alternate host for seven generations the beetles exhibited similar developmental period, pupal weight, adult longevity and fecundity as compared to those reared on *H. cubana* continuously. The results reveal *F. virgata* is suitable for rearing *C. coeruleus* especially during summer months when psyllid population declines and mealybug multiplication is easier in the laboratory.

### 4.4.2. Host plant preference of *Eriborus argenteopilosus*

The host plant preference of *E. argenteopilosus* was evaluated utilizing pigeonpea, chickpea, dolichos and sunflower artificially infested with *H. armigera*. *E. argenteopilosus* females were released at the rate of one for every 20 *H. armigera* larvae. After 24 hours, these larvae were collected back and individually reared on artificial diet in vials. The vials were checked for cocoon formation and per cent parasitism calculated. The experiment was repeated 10 times for each host plant.

The maximum parasitism was obtained on chickpea (18.83%) and pigeonpea (15.42%) followed by dolichos (9.17%) (Fig.2) and minimum parasitism on sunflower (2.34%) indicating the higher preference of the parasitoid for pulse crops.

## 4.5. Bioecological studies on natural enemies

### 4.5.1. Population dynamics, host range and biological parameters of *Ankylopteryx* sp.

Ten *A. craccivora* colonies, each comprising of around 500 aphids, were collected every week from *Gliricidia sepium*. From the last week of May till end of October the number of *Ankylopteryx* sp. larvae associated with them were recorded.

Population of *Ankylopteryx* sp. ranged from 8 to 10 per colony up to the first week of June and it increased to an average of 24.20 during third week of June. A decline in its population (3.40 / colony) was recorded by the end of July, but the population increased again to around 31.60 per colony by the fourth week of August. However, its population showed a decline by the first week of October, which coincided with a decline in aphid population. Apart from *A. craccivora*, this predator could also be reared on *A. gossypii, A. nerii, Lipaphis erysimi, Macrosiphum rosaeformis, Myzus persicae* and *Corcyra cephalonica* indicating its wide host range and amenability for laboratory rearing.

Egg, larval, pupal and adult periods were 4-5, 12-14, 9-10 and 41-89 days, respectively. Eggs were abundantly laid only on walls of the cage and each female laid about 57.75 eggs. Each larva needed 866.48 aphids during its larval period.

### 4.5.2. Bio-deterioration studies on *Campoletis chlorideae*

The parasitising efficiency, cocoon production, per cent adult emergence and per cent females among progeny produced were recorded for the field collected adults and also for the adults continuously reared (up to 10 generations) in the laboratory.

The mean per cent parasitism was 31.28% in the case of field collected parasitoids, whereas the parasitism ranged between 16.7 to 26.14% in the case of the laboratory reared parasitoids (Fig.3). The field collected adults could produce more number of cocoons (61.7 females) in comparison to the laboratory reared ones (14 to 32 females). The parameter, which was drastically affected by continuous lab rearing, was the per cent females among the progeny. Among the progeny produced by the field collected adults, 77.2% were females, whereas in the case of laboratory reared parasitoids it ranged between 12.5 to 21.4.

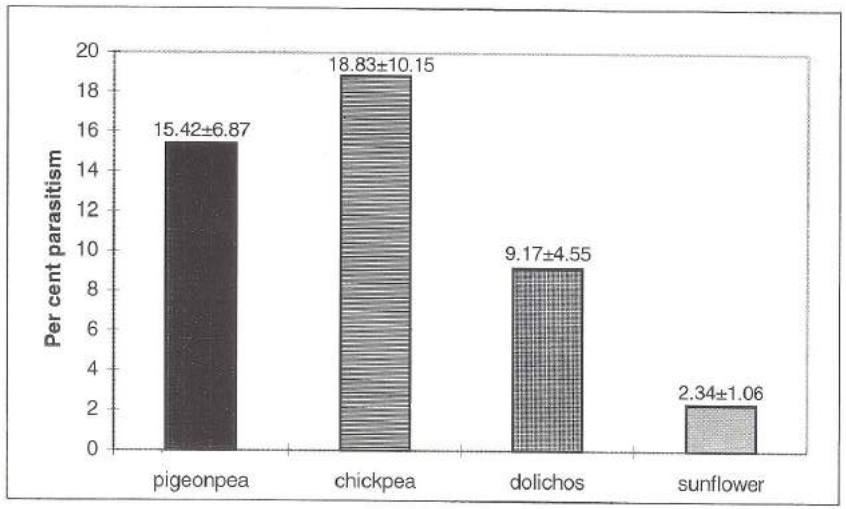


**Fig. 2. Host plant preference of *Eriborus argentiopilosus***

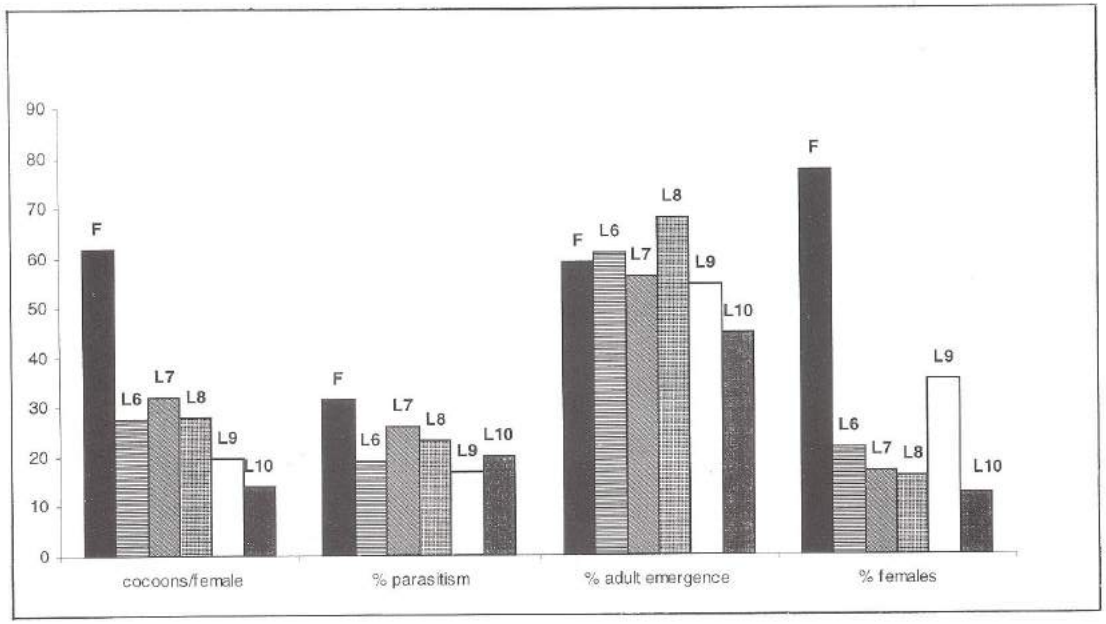


**Fig. 3. Biodeterioration studies on *Campoletis chlorideae***
**F: Field collected parasitoids; L6 – L10: Laboratory reared parasitoids from sixth to tenth generation**

### 4.5.3. Storage studies on cocoons of *Eriborus argenteopilosus*

Storage temperatures of 5, 8, 11 and 15° C were chosen for the study and at each storage temperature, the cocoons were stored for 5, 10, 15 and 20 days. The results are presented in Table 2. The parameters recorded were poor at 5°C and 8°C for different stages. At 11°C, emergence was 60, 60 and 80% after 5, 10 and 15 days of storage, respectively. The adults emerging from the cocoons stored for 5, 10 and 15 days at this temperature could produce 26, 30 and 22 cocoons females, respectively. At 15°C, by storing for 5, 10 and 15 days, 75, 60 and 63.3% emergence and 40, 38 and 31.5 cocoons females, respectively, was observed. Storage for 20 days at this temperature resulted in the adults emerging in storage. The results indicate that at 11°C, the cocoons could be stored up to 10 days, while at 15°C, they could be stored up to 15 days without any detrimental effect on the biological parameters of the parasitoid. However, it is not advisable to store *E. argenteopilosus* cocoons at 5 and 8°C (Table 2).

Table 2. Storage studies on cocoons of *Eriborus argenteopilosus*

| Storage temperature | Storage period (days) | Per cent emergence | Cocoon production females | % females among progeny |
|---|---|---|---|---|
| **5°C** | 5 | 20 | 7 | 1.5 |
| | 10 | 40 | 15 | 16.5 |
| | 15 | 0 | - | - |
| | 20 | - | - | - |
| **8°C** | 5 | 80 | 24 | 35.3 |
| | 10 | 60 | 18 | 2.2 |
| | 15 | 20 | 12.3 | 7.7 |
| | 20 | 0 | - | - |
| **11°C** | 5 | 60 | 26 | 23.5 |
| | 10 | 60 | 30 | 47.4 |
| | 15 | 80 | 22 | 5.3 |
| | 20 | 80 | * | - |
| **15°C** | 5 | 75 | 40 | 16.92 |
| | 10 | 60 | 38 | 16.52 |
| | 15 | 63 | 31.5 | 51.5 |
| | 20 | # | - | - |

* - Cocoon production could not be checked as very few females emerged from this treatment.; # - Adults emerged in storage

### 4.5.4. Evaluation of different materials to be used as substrate for pupation of *Ischiodon scutellaris* and *Paragus serratus*

Preference studies for pupation substrate *viz.*, corrugated sheet, tissue paper, dried cowpea leaf, absorbent cotton pad and muslin cloth was studied. Larvae of *I. scutellaris* and *P. serratus* were released in separate plastic jars (20x15 cm) and *A. craccivora* was provided as prey on cowpea twigs and when the larvae entered third instar, different substrates were arranged on the periphery of the feeding material. The experiment had five replications with 30 larvae for each replication. The data on per cent pupation on different substrates were subjected to analysis of variance after suitable transformation.

Results of the experiment indicated that there was a significant difference in the pupation preference of *I. scutellaris* on different substrates. Maximum pupation was observed in cotton pad (51.33%) followed by dried cowpea leaf (22.66%), which was on par with corrugated sheet (14.66%). Muslin cloth (1.99%) and jar surface (0.66%) were the least preferred substrates and they did not differ significantly (Fig. 4). In case of *P. serratus*, there was no significant difference in pupation preference on substrates *viz.*, cotton pad, dried cowpea leaf and tissue paper. The pupation ranged between 33.99 to 27.33 per cent in these substrates as against 1.99 and 0.66 per cent in muslin cloth and jar surface, respectively. It can be concluded that absorbent cotton pads were best suited substrates for pupation of syrphids.

### 4.5.5. Oviposition preference of *Ischiodon scutellaris* and *Paragus serratus* to different host plants of *Aphis craccivora*

Oviposition preference of syrphids was studied on cowpea (*Vigna unguiculata* var. C 152, lablab (*Lablab niger* var. Hebbal Avare), pigeonpea (*Cajanus cajan* var. ES 90) and groundnut (*Arachis hypogaea* var. MTV 8). Five gravid females of aphids were released on each seedling on these host plants grown in cups.

Newly emerged syrphids were separately released on different host plants for acclimatisation to a particular host plant. When they were 15 days old (after mating and pre-oviposition period), they were released on the seedling of the host plants on which they were to be tested. The host plant preference was studied by utilising single choice and multiple choice tests.

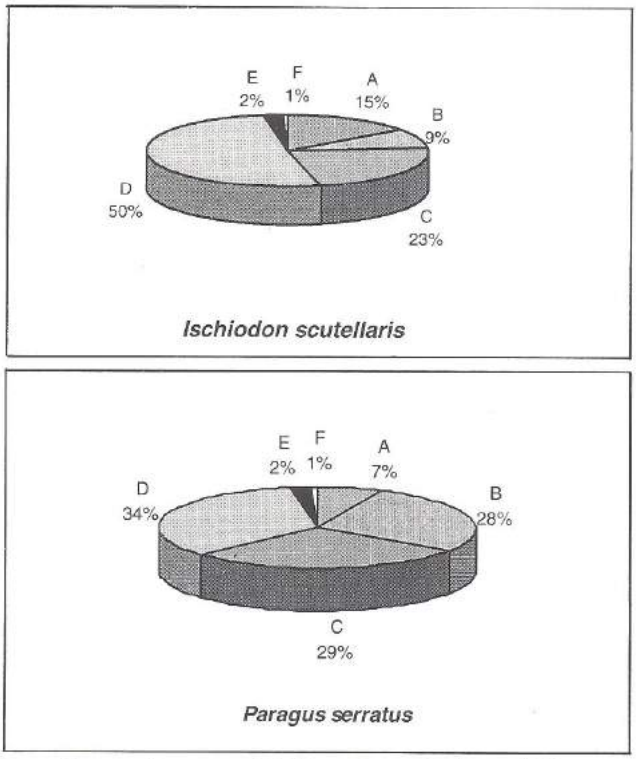


**Fig. 4. Pupation preference of different syrphids on different substrates**
**A: Corrugated sheet, B: Tissue paper, C: Cowpea leaf,**
**D: Cotton pad, E: Muslin cloth, F: Jar surface**

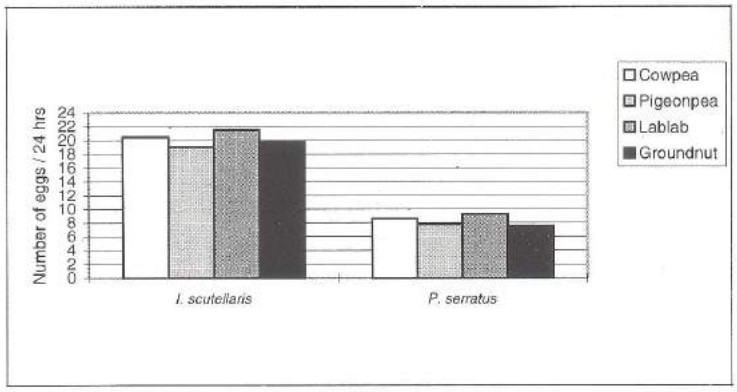


**Fig. 5. Influence of hosts of *Aphis craccivora* on oviposition of syrphids in single choice test**

i. Single choice test

In this method, aphid colony that was raised on a single host plant was exposed to a mated female of syrphid in a plastic container (15x20 cm). After exposure for 24 hrs., the eggs were counted and resulting larvae reared on aphids infesting the same host plant. Developmental time and per cent pupation were recorded. This test was replicated 12 times for all the four host plants.

ii. Multiple-choice test

In this method, all the four host plants with similar number of aphids on each were placed together in a cage measuring 30x30x30 cm, and four mated females were released into the cage. All the other steps involved were similar to those in single choice test. In both the tests, adults of syrphids were provided with 50% honey, water and castor pollen.

On the basis of the results obtained, the most preferred host plant was studied for distribution pattern of eggs of syrphids. The plants were divided into two zones *viz.*, leaf and stem. These zones were again subdivided into different parts *viz.*, upper surface of leaf, lower surface of leaf, upper half of stem, cotyledon and lower half of stem. Total number of eggs laid on each part were counted and per cent distribution worked out.

In single choice test, number of eggs laid did not differ significantly with the host plant. It ranged from 19.08 to 21.50 on pigeonpea and lablab, respectively, in *I. scutellaris* and from 7.6 to 9.30 on groundnut and lablab, respectively, in *P. serratus* (Fig. 5).

Per cent oviposition obtained on different host plants in the multi-choice test indicated that lablab was the most preferred host by both the syrphid species. Maximum percent oviposition by *I. scutellaris* was obtained on lablab (43.59) followed by cowpea (29.03). Per cent oviposition by *P. serratus* did not differ significantly in lablab (31.33) and cowpea (26.00).

Observations on the distribution pattern of eggs on the different parts of *Lablab niger* showed that the leaf zone was the most preferred by both the syrphids (Table 3). The maximum per cent eggs (69.30 and 57.80 in *I. scutellaris* and *P. serratus*, respectively) were laid on the lower surface of the leaf.

Table 3. Distribution of eggs of *Ischiodon scutellaris* and *Paragus serratus* on different parts of lablab plant

| Zone | Part | Number of eggs/part (%) | | Eggs in the zone (%) | |
|---|---|---|---|---|---|
| | | *I.scutellaris* | *P. serratus* | *I.scutellaris* | *P.serratus* |
| Leaf | Upper surface | 69.30 (56.37)[a] | 57.80 (49.52)[a] | 70.20 | 58.70 |
| | Lower surface | 0.90 (3.25)[c] | 0.90 (3.25)[c] | | |
| Stem | Upper half | 21.60 (27.66)[b] | 26.60 (30.98)[b] | 29.80 | 41.30 |
| | Cotyledon | 1.90 (7.22)[d] | 3.90 (10.94)[d] | | |
| | Lower half | 6.30 (14.35)[c] | 10.80 (18.69)[c] | | |

Figures within parentheses are arcsine-transformed values

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

### 4.5.6. Effect of pollen from different plants on fecundity and longevity of *Ischiodon scutellaris* and *Paragus serratus*

Five pairs of syrphids were released in each plastic container (15x20 cm) with 50% honey and water for feeding and cowpea seedling infested with *A. craccivora* as oviposition stimulant. A scoop of pollen from castor, sunflower and maize were provided. Each treatment was replicated 10 times. Plants for oviposition were changed daily and eggs laid per female counted daily till the death of all females. Adults of F1 generation were also exposed to pollen from the same plant species.

Results of the fecundity test showed that *I. scutellaris* preferred castor pollen with higher fecundity (554.00 eggs per female) followed by maize pollen (550.10 eggs per female) which were significantly superior to sunflower pollen (524.20 eggs per female). In case of *P. serratus*, adults fed with maize pollen showed significantly higher fecundity (38.10 eggs per female) followed by equal preference for castor (33.00 eggs per female) and sunflower (32.60 eggs per female) (Table 4).

Table 4. Effect of pollen from different plants on fecundity and longevity of *Ischiodon scutellaris* and *Paragus serratus*

| Source | Fecundity | | | | Longevity | | | |
|---|---|---|---|---|---|---|---|---|
| | *I.scutellaris* | | *P.serratus* | | *I.scutellaris* | | *P.serratus* | |
| | Parent gene- | Fl gene ration | Parent gene- | Fl gene- ration | Male | Female | Male | Female |
| Castor | 554.00 | 548.02 | 33.00 | 36.28 | 23.59 | 29.20 | 9.57 | 15.10 |
| Maize | 550.10 | 559.18 | 38.1 | 40.40 | 23.24 | 29.00 | 9.24 | 15.20 |
| Sunflower | 524.20 | 515.32 | 32.6 | 30.64 | 23.01 | 24.00 | 9.49 | 14.30 |
| Without pollen* | - | - | - | - | 22.39 | 11.60 | 9.12 | 6.70 |
| CD (P=0.05) | 8.270 | 14.801 | 2.036 | 2.044 | NS | 1.994 | NS | 1.514 |

* Not subjected to statistical analysis for fecundity

Longevity of males obtained did not differ significantly, but female longevity varied significantly with pollen. It was higher when fed with castor and maize pollen and least without pollen. Exposure of F1 generation of syrphids to the same pollen did not enhance the rate of oviposition. In general, the predators were found to be more active when fed with castor pollen resulting in higher fecundity and longevity.

### 4.5.7. Life fecundity table for *Ischiodon scutellaris*

Adults reared in December were used in the experiments as winter generation and those emerged in March as summer generation. The adults of the same age were held in pairs in plastic containers (15x20 cm) and allowed to oviposit on a cowpea seedling bearing colonies of *A. craccivora*. Honey (50%), water and castor pollen was provided as food for adults. In all 20 such sets were maintained but the data was collected on 10 randomly selected pairs which formed a cohort. All the experiments were conducted under laboratory conditions where the average temperature and R.H. was 25±2°C and 50-60% during winter (December to February) and 28±2°C and 50-60% during summer (March to April).

The eggs were gently removed after each counting in order to avoid cannibalism and overcrowding among larvae. Separate experiments were carried out simultaneously to determine sex ratio and egg viability by rearing larvae from the same stock culture. The

fertility table was worked out and other parameter *viz.*, net reproductive rate (Ro), generation time (Tc), innate capacity for increase (Rc and finite rate of increase (l) were calculated, which are presented in Table 5.

Table 5. Life table parameters for the winter and summer generations of *Ischiodon scutellaris*

| Parameter | Winter generation | Summer generation |
|---|---|---|
| Net reproductive rate (Ro) | 117.045 | 51.054 |
| Approximate generation time (Tc) | 51.453 | 40.611 |
| Innate capacity for increase (Rc) | 0.093 | 0.097 |
| Intrinsic rate of increase (Rm) | 0.095 | 0.094 |
| True generation time (T) | 50.027 | 42.01 |
| Finite rate of increase (l) | 1.098 | 1.102 |
| Sex ratio (Male : Female) | 1 : 0.964 | 1 : 1.33 |

In winter generation the species had maximum life span of 77 days out of which immature stages occupied 29 days. Oviposition began on the 36th day and maximum mean progeny per day was attained on the 15th day of oviposition. There was 61.00 per cent mortality within the cohort in the immature stages. The average number of eggs laid per female was 614.60 and the sex ratio was 1:0.96 (male : female) (Fig. 6).

In summer generation, the development was faster with a maximum life span of 57 days out of which immature stages occupied 22 days. There was 63.00 per cent mortality within the cohort in the immature stages. Oviposition began on the 30th day and maximum mean progeny per day was attained on the 13th day of oviposition. The average number of eggs laid per female was 245.60 and the sex ratio was 1:1.33 (male:female) (Fig. 7).

Population indices for two generations revealed that the predators had higher net reproductive rate in the winter generation than in summer generation. The syrphids had capacity to multiply 117.045 times during winter generation occupying 51.453 days and 51.054 times during summer occupying 40.611 days. The value for intrinsic growth rate (Rc) in the winter was slightly lower (0.0926) than that of summer population (0.0968). Almost similar mortality percentage in immature stages of winter (61.00%) and summer generation (63.00%) coupled with female biased sex ratio during summer seem to have

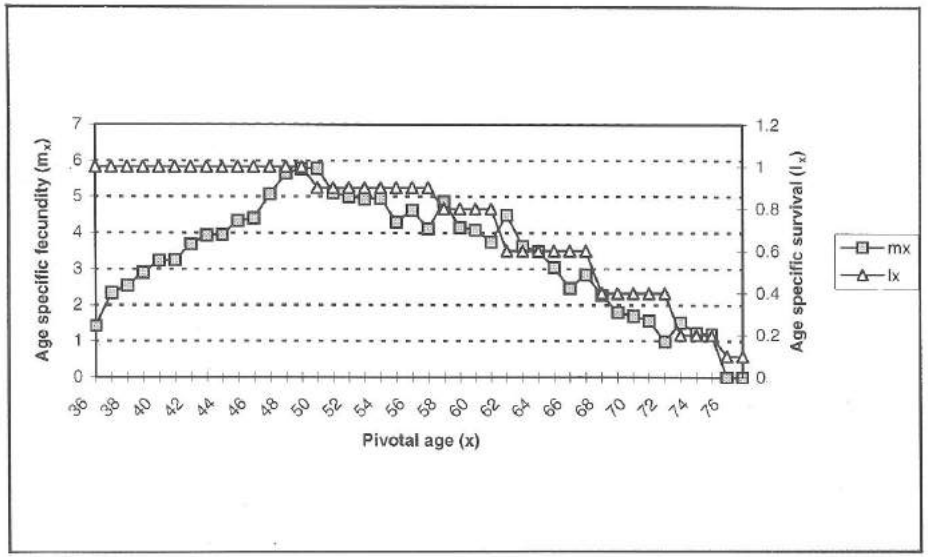


**Fig. 6. Age specific survival and fecundity of *Ischiodon scutellaris* (winter population)**

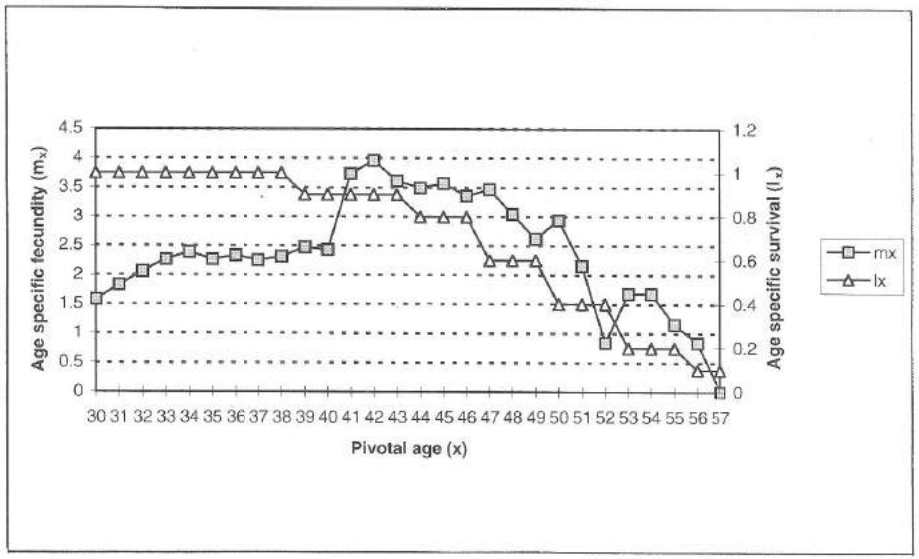


**Fig. 7. Age specific survival and fecundity of *Ischiodon scutellaris* (summer population)**

resulted in an increase in the value of Rc in summer generation. The species had a finite rate of increase (l) of 1.097 and 1.102 in winter and summer, respectively.

### 4.5.8. Effect of continuous laboratory rearing and low holding temperature on fecundity and longevity of *Scymnus coccivora*

The temperature tolerance in field collected and laboratory reared and biodeterioration in lab reared predators was studied. After rearing for one generation in the laboratory, predators were stored at 15°C. and after 15, 30, 45 and 60 days, mortality, developmental time and fecundity was recorded by using *Ferrisia virgata* as host. The laboratory-reared predators, which had passed 10 generations, were also subjected to similar storage. In both cases 20 pairs were stored.

Mortality of field collected adults after storage for 15, 30, 45 and 60 days was 20.80, 52.30, 68.60 and 77.20 in comparison to 24.60, 58.40, 81.10 and 88.20 in laboratory reared predators, respectively (Table 6).

Developmental period was greatly affected by storage and it also differed in field collected and laboratory reared predators. Field collected *S. coccivora* took 22.60, 27.40 and 31.40 days after storage for 15, 30 and 45 days whereas laboratory reared beetles took 31.60, 34.20 and 39.20. Fecundity in field collected adults was 87.60, 68.20 and 37.60 as against 69.20, 34.60 and 16.20 in laboratory reared after storage for 15, 30 and 45 days, respectively. Results thus proved that the laboratory-reared adults can be stored for 15 days in instances of shortage of hosts and field collected ones can be stored even for one month with honey as food.

Table 6. Effect of storage at 15°C on longevity, development and fecundity in field collected vs. laboratory reared *Scymnus coccivora*

| Days storage | Mortality (%) | | | Developmental time (Days) | | | Fecundity (Eggs / Female) | | |
|---|---|---|---|---|---|---|---|---|---|
| | WT | CLR | Mean | WT | CLR | Mean | WT | CLR | Mean |
| 15 | 20.80 | 24.60 | 22.70 | 22.60 | 31.60 | 27.10 | 87.60 | 69.20 | 78.40 |
| 30 | 52.30 | 58.40 | 55.40 | 27.40 | 34.20 | 30.80 | 68.20 | 34.60 | 51.40 |
| 45 | 68.80 | 81.10 | 74.90 | 31.40 | 39.20 | 35.30 | 37.60 | 16.20 | 26.90 |
| 60 | 77.20 | 88.20 | 82.70 | - | - | - | - | - | - |
| Mean | 54.72 | 63.10 | | 27.13 | 35.00 | | 64.47 | 40.00 | |

WT - Wild Type; CLR - Continuously Laboratory Reared

CD (P=0.05)

| Factor | Mortality | Developmental time | Fecundity |
|---|---|---|---|
| Culture | 0.669 | 0.496 | 0.533 |
| Storage period | 0.947 | 0.608 | 0.653 |
| Culture x storage period | 1.339 | 0.859 | 0.923 |

In another experiment both the field collected and lab reared predators, without storage, were released separately on pumpkin infested with *E. virgata* inside rearing cage (30x30x30 cm). Observations on developmental time, fecundity and longevity were recorded to know deterioration of culture in the laboratory.

Developmental stages of field collected *S. coccivora*, i.e. egg, larval, pre-pupal and pupal stages lasted for 4.50, 11.70, 1.30 and 5.70 days, respectively. (Fig. 8). Developmental stages of laboratory reared predators lasted for 6.10, 15.30, 1.50 and 6.70 days, respectively. Field collected adults lived much longer (69.30 days in females and 62.70 in males) than lab reared (62.20 in females and 59.50 in males). Fecundity of field collected female was 85.70 in comparison with 59.30 in laboratory reared. Results thus indicate that to maintain biotic potential of predators, a regular collection should be made from field to rejuvenate the culture.

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

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

Two field experiments were conducted with L-tryptophan as an ovipositional attractant for chrysopids and coccinellids. First experiment was conducted when the crop was about 60 days old with low pest infestation and natural enemy population. Three days old L-tryptophan (0.66%) was prepared by acid hydrolysis and oxidation methods and sprayed at one litre solution for 40 to 50 plants and the number of eggs, larvae, pupae and adult chrysopids counted prior to the treatment and post treatment and in control. Second experiment was conducted when the plants were around 120 days old. The treatments were similar and two patches of plants were treated with the kairomones.

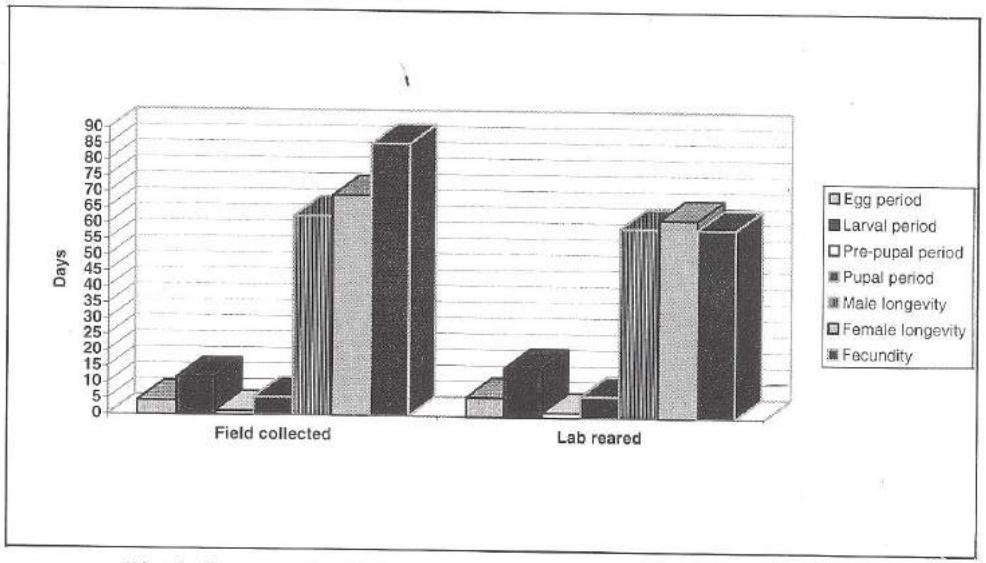


**Fig. 8. Comparative biological parameters of field collected and laboratory reared *Scymnus coccivora***

The dissolution in the hydrolysis method was complete with no salt sedimentation. However, in the oxidation method, dissolution was incomplete. As a result, patches were formed on the sprayed plants with oxidised L-tryptophan. Slight phytotoxicity was noticed in oxidised L-tryptophan. This suggests that acid hydrolysed L-tryptophan is better than oxidised L-tryptophan.

Activity of chrysopids and coccinellids was almost negligible. No egg laying was noticed before or after treatment in both treated and untreated areas during the first experiment. During the second experiment there was no activity of chrysopids in the pre-treatment and the post-treatment. However, increased oviposition was noticed by the coccinellids between the pre treatment and post treatment as well in the treated areas in comparison to untreated areas.

### 4.6.2. Kairomones for preconditioning larvae of *Chrysoperla carnea*

A mass priming experiment was conducted to estimate the efficiency of *Chrysoperla carnea* larvae against *Helicoverpa armigera*. The kairomonal solutions (tricosane 0.2 & 0.1%; abdominal extracts of *Helicoverpa armigera* (10 females/5 ml)) were prepared and sprayed in the petri dish using an atomiser. On the cotton plants, eggs of *H. armigera* were glued on the leaves from 3 to 8 nodal leaves @ 5 eggs per leaf. After drying the petri dish under the shade, the early third instar larvae of *Chrysoperla carnea* were retained in the petri dish for half an hour and then released on the cotton plants. The number of eggs consumed was counted after 24 hours. Twenty plants were used for each replication and each treatment was replicated 10 times. The average eggs consumed in 20 plants was computed and considered as one replication.

The larvae exposed to the n-tricosane (0.2%) recorded more predation (13.87 eggs) compared to other treatments.

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

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

The predation increased on the plants treated with n-tricosane and was comparatively better than control. The predatory potential was low on the third day compared to the first day. However, predation of eggs on third day indicated that the larvae were retained in the treated plants even on third day (Table 7).

Table 7. Reinforcing of *C. carnea* using kairomones

| Treatment | Number of eggs consumed on | |
|---|---|---|
| | 1st day | 3rd day |
| Scale ext.of *H. armigera* | 19.38 | 10.76 |
| Scale ext. of *C.cephalonica*(120 mg) | 18.41 | 11.39 |
| Scale ext.of *C.cephalonica*(160 mg) | 17.15 | 9.19 |
| Tricosane (1mg in 100 ml) | 20.28 | 8.8 |
| Control | 3.94 | 0.34 |
| CD (P=0.05) | 5.99 | 5.83 |

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

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

Results indicated that significant number of adults did not reach the kairomone arm in the case of *C. sexmaculata*. However, in the case of *C. septempunctata*, the number of adults reaching the kairomone arm is significantly higher, indicating that tryptophan showed some attraction in the case of *C. septempunctata* (Table 8).

The orientation and oviposition behaviour of *C. sexmaculata* was studied under the multiple-choice test. Brown papers of 10 cm radius were treated with the kairomones and glued to the inner side of the lid of an acrylic box (30 X 30 X 30 cm) and 15 adult *C. sexmaculata* released inside the chamber. The number of adults visiting the papers was observed for 30 minutes. Later the adults were left overnight and the number of eggs laid on the paper counted the next day.

There was no significant difference in the number of adults visiting the kairomone treated papers indicating that L-tryptophan did not elicit any behavioural response in the case of *C. sexmaculata*. No egg laying was noticed on the kairomone treated papers.

Table 8. Orientation behaviour of adult coccinellids to kairomones in 'Y' tube olfactometer

| Treatment | *Cheilomenes sexmaculata* | | *Coccinella septempunctata* | |
|---|---|---|---|---|
| | Kairomone | Hexane | Kairomone | Hexane |
| 0.33 Lt (acid hydrolysed) | 4.4 | 5.6 | 7.1 | 2.9 |
| 0.66 Lt (acid hydrolysed) | 5.2 | 4.8 | 8.2 | 1.8 |
| 0.33 Lt + 0.66 valine | 4.8 | 5.2 | 5.4 | 4.6 |
| 0.66 Lt + 0.66 valine | 5.6 | 4.4 | 8.3 | 1.2 |
| 0.66 valine | 4.3 | 5.7 | 4.8 | 5.2 |
| Control | 5.1 | 4.9 | 5.1 | 4.9 |
| Wilcoxons signed rank test | | NS | | |

NS : Nonsignicant; S : Significant

### 4.6.5. Ovipositional stimulation of *Cheilomenes sexmaculata* on the substrate without prey using the kairomones

Attempts were made to induce oviposition by *C. sexmaculata* using kairomones. The adult artificial diet (based on agar agar and honey) was prepared and droplets made on the polythene paper or cotton plants or freshly reared cowpea seedlings. Kairomones prepared from L-tryptophan or body washings of aphids (*Aphis craccivora*) in water and hexane were sprayed on the agar agar diet. The kairomone treated agar agar diet was kept in acrylic sheet of 30 x 30 x 30 cm and 15 gravid females of *C. sexmaculata* released on these plants. The number of eggs laid was counted. Each treatment was replicated 10 times. Only aqueous extracts of aphids recorded some oviposition compared to other treatments.

### 4.6.6. Tritrophic interaction studies

#### 4.6.6.1. *Trichogramma chilonis, Helicoverpa armigera* and sunflower genotypes

The tritrophic interaction between *Trichogramma chilonis, Helicoverpa armigera*

and sunflower genotypes was studied. Twenty two genotypes of sunflower (accession no. 109, acc. no. 194, acc. no. 244, acc. no. 344, acc. no. 367, acc. no. 450, acc. no. 1039, acc. no. 1143-1, acc. no.1172, acc. no. 1175, EC-68414, EC-68415, CMS-234A, BSH-1, GAU-SUF-15, 6D-1, KBSH-1, MSFH-17, Morden, RHA-274 and TNAU-SUF-7) were tested in a polyhouse under multiple choice conditions. 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 central point to give equal access to the eggs placed on different genotypes for parasitisation. The data on per cent parasitisation of *H. armigera* eggs were recorded. Pooled values indicated that variation in per cent parasitisation of *H. armigera* eggs on genotypes of sunflower ranged between 8.0 to 47.5. This revealed that variations in the Green volatiles released by the different genotypes of sunflower play an important role in the success or failure of parasitoids. Sunflower varieties/ hybrids like MSFH-1, Morden, RHA-274 and KBSH-1 registered 47.5, 42.5, 41.0 and 38.1 per cent parasitisation, respectively and can be categorised as biocontrol friendly.

#### 4.6.6.2. *Trichogramma chilonis, Helicoverpa armigera* and chickpea genotypes

The tritrophic interaction studies between the egg parasitoid *Trichogramma chilonis*, pod borer *Helicoverpa armigera* and six genotypes of chickpea were conducted in polyhouse condition. The genotypes tested were: Annegiri, ICCV 95992, ICCV 93122, ICC 506, ICCV 7 and ICCX 73026-3-4. Each genotype was replicated five times, having two plants per replication. Ten-day-old eggs of *H. armigera* were released individually on each plant (top leaves). After 24 hours, *Trichogramma chilonis* adult females were released and per cent parasitisation recorded. The mean per cent parasitisation ranged from 3.92 to 5.94. Highest egg parasitisation was recorded on Annegiri (5.94%) closely followed by ICCV 93122 (5.92%). However, even the highest parasitisation on Annegiri is not significant to check the pest population.

#### 4.6.6.3. *Trichogramma chilonis, Helicoverpa armigera* and cotton genotypes

The genotypes tested for synomone interactions were: C 256-4, G-27, HLS-72, MCU-5, MCU-7, SRT-1, Anjali, Kanchana, Suman and Savita. Each genotype was replicated thrice, having two plants per replication. Ten eggs of *H. armigera* were released per plant near flower buds, individually. After two days, *T. chilonis* mated females were released. Observations on per cent egg parasitisation on different genotypes were recorded. Per cent parasitisation of *H. armigera* eggs ranged from 6.66 to 26.66. Highest parasitisation was recorded on genotype MCU-5 and lowest on G-27. Similar trend was

observed in the second experiment except that Suman was on par with MCU-5. Pooled values also indicated highest parasitisation in MCU-5 (24.99%) followed by Suman (21.66%) MCU-7(18.33%) and Anjali (18.33%).

#### 4.6.6.4. *Trichogramma chilonis, Helicoverpa armigera* and pigeonpea genotypes

The genotypes tested for synomone interaction were: Bahar, Manak, ICPL27, ICPL-87 (ICRISAT), ICPL-87 (GOA), ICPL-151, ICPL-84060, ICPL-84089, ICPL-87119, ICPH-8, PPE-45-2, TPL (PV6)PB/98-di, ACT-2(M) AVT2 MTH 9611, AVT-2 (EACT) AF-239, PB/98-11, PB/98-16, PB/98-19, PB/98-V2, PB/98-V4, PB/98-V6 and PB/98-V8. Ten eggs of *H. armigera* (one-day-old) were placed on leaves near to flower buds or tender pods. Two-days-old mated adult female *T. chilonis* were released in the ratio of 1:3 (parasitoid: host). The data on parasitisation of *H. armigera* eggs on different genotypes were recorded on the basis of adult parasitoid emergence. It was observed that there is a lot of variability among genotypes in terms of their influence on the parasitoid *T. chilonis* which is reflected by the per cent parasitisation recorded on them. The extent of parasitisation ranged between 5.0% and 29.0%. Highest parasitisation was recorded on genotype ICPL-84060 followed by Manak (23.5), PPE-45-2 (22%) and Bahar (19.5). Lowest parasitisation was recorded on ICPL-87119 (5%), ICPH-8(5%) and ICPL-151(5%). Mean per cent parasitisation varied from 8.88 to 14.44. Highest parasitisation was recorded on genotype ACT-2(M)AVT2 MTH 9611 (14.44%) and lowest on PB/98-19 and PB/98-V6 (8.88% in both). Comparing overall results, highest parasitisation was observed on ICPL-84060, followed by Manak, PPE-45-2 and Bahar.

### 4.6.7. Trapping and identification of green volatiles released by different genotypes of chickpea

Chickpea green volatiles were trapped in specially designed trap for two hours by passing pure air on the top of leaves. The volatiles were extracted using hexane and then concentrated in a refrigerated vacuum concentrator. The concentrated volatiles were injected into GCMS and the peaks were identified using Wiley 275 library. About 150 peaks were recorded. The peaks having more than 92% matching quality are Tridecane, Dodecane, N- Tetradecane, 4-methyle, Pentadecane, Dodecanoic acid -Lauric acid, Hexadecane, Heptadecane, Eicosane, Octadecane, Nonadecane, 14-Beta-H-Pregna, n-Tricosane, Heneicosane, 2-Propenoic acid, Docosane, Octacosane and Moretenol. Other peaks are being identified.

### 4.6.8. Trapping and identification of green volatiles released by cotton plants

Cotton leaf volatiles were trapped in specially designed trap for two hours by passing pure air on the top of leaves. The volatiles were extracted using hexane and then concentrated in a refrigerated vacuum concentrator. The concentrated volatiles were identified using GCMS. Out of 72 peaks observed, 21 peaks having more than 92% matching quality have been identified and they are Linalool L, Moretenol, Dodecane, Eicosene, Tridecane,3-methyl, Octadecane, 3-methyl, Tetradecane, Heptadecane, 1,7-Dimethyl naphthlene, 7,9,di-tert-butyl-1 oxaspiro, 1-Pentadecane, 1 H- Indole-3-butanoic acid, Cyclododecane, Heneicosane, 9 H-Flurene, 2 - Octadecyloxy-1,1,2,2 Tetradeuter, Hexadecane,2,6,10,14- tetramethyl, N-Docosane, Tricosane, Tetracosane and Anthracene. Other peaks are being identified.

## 4.7. Artificial diets for host insects

### 4.7.1. Synthesis of diet for *Opisina arenosella*

Two diets were tested for rearing *Opisina arenosella*. The survival percentage of the neonate larvae, when transferred to the diet directly was very low. So the neonates were first reared on fresh coconut leaves and after reaching 2nd instar stage transferred to the diets and pupation and adult emergence recorded (Table 9).

Table 9. Performance of artificial diets for rearing *Opisina arenosella*

| Base of the diet | Pupation (%) | Adult emergence (%) |
|---|---|---|
| Soybean flour and coconut leaf powder based diet | 50 | 44 |
| Wheat germ flour and coconut lea. powder diet | 33 | 10 |

### 4.7.2. Evaluation of diet for *Spodoptera litura*

*S. litura* was reared on three experimental diets based on the leaf powders of castor, cauliflower and cabbage and compared with the control diet. Immediately after hatching the larvae were transferred to the respective leaf powder based diets.

Twenty-five newly hatched larvae each were transferred to the respective diets. The growth parameters such as egg, larval and pupal period, adult emergence (%), sex ratio and fecundity (%) were recorded. It was found that there was significant difference

in the pupation (%), adult emergence (%) and the number of fertile eggs obtained between the castor leaf powder based diet and the other diets (Table 10).

Table 10. Evaluation of different leaf powder based diets for *Spodoptera litura*

| Parameters | Castor | Cauliflower | Cabbage | Control |
|---|---|---|---|---|
| Egg period (days) | 4.0 | 4.0 | 4.0 | 4.0 |
| Larval Period(days) | 33.0 | 26.0 | 26.0 | 28.6 |
| Pupal Period (days) | 18.5 | 13.0 | 10.6 | 13.3 |
| Pupal weight (g) Male | 0.38601 | 0.36525 | 0.37309 | 0.39484 |
| Female | 0.34288 | 0.35208 | 0.36195 | 0.40700 |
| Pupation (%) | 78.0 | 74.6 | 82.6 | 73.3 |
| Adult Emergence (%) | 58.0 | 48.0 | 57.3 | 52.0 |
| Fertile eggs (nos. / female) | 1361.24 | 709.75 | 400.84 | 536.18 |

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

An experiment was conducted to explore the possibility of rearing *S. litura* completely on semi-synthetic diet. *Cynodon dactylon* (5 g) powder was added to the semi-synthetic diet to provide token stimulus.

Newly hatched larvae were transferred to rectangular ventilated plastic boxes, which contained a layer of the semi-synthetic diet with *C. dactylon* powder. After 7 days, these larvae were transferred to the multi-cellular tray consisting of the same diet. Another batch of larvae was transferred to a bouquet of castor leaves and after 7 days these larvae were transferred to semi-synthetic diet. This experiment was replicated 5 times with 100 larvae in each replication. Results indicated that per cent pupation was on par in both the experiments, 85% in the one-step rearing and 88% in the two-step rearing indicating that even without providing natural diet in the initial stages of its development, the larvae could survive well in the semi-synthetic diet. There was significant increase in the male and female pupal weights in the one-step rearing method in comparison to the two-step rearing method. In the former method, the male and female pupae weighed 0.459 and 0.476 g, respectively and in the latter method of rearing, it was 0.356 g and 0.362 g, respectively. When completely reared on semi-synthetic diet, the female could produce a mean of 1012 eggs and the egg production in the two-step rearing was on par, being 988 eggs/females. *S. litura* could be reared successfully by this method.

### 4.7.3. Replacement of costly ingredients in *Spodoptera litura* artificial diet with cheaper alternatives

With a view to reduce the cost of production of *Spodoptera* diet, some cheaply available cattle feed ingredients were substituted and evaluated. Five different combinations were tried. It was found that diet II and III did not support the growth of the larvae. In diet IV, the larvae grew well in the first generation but in the second generation the growth was poor, as they did not feed properly. Diet V fed larvae developed into adults but the eggs laid were sterile. The diet containing groundnut cake showed promise (Table 11).

Table 11. Evaluation of diets using cheaply available ingredients for *S. litura*

| Sl. No. | Diets | Pupation % | Adult emergence % |
|---|---|---|---|
| I | Control (Kabuligram flour) | 100 | 88 |
| II | Horsegram + Black channa husk | - | - |
| III | Horsegram + Kabuligram | - | - |
| IV | Greengram + Kabuligram | 60 | 40 |
| V | Sunflower cake + Kabuligram | 76 | 40 |
| VI | Groundnut cake + Kabuligram | 64 | 32 |

## 4.8. Studies on artificial diets for natural enemies

### 4.8.1. Synthesis of new artificial diet for rearing of *Chrysoperla carnea*

Studies were conducted to develop artificial diet using the most commonly available ingredients defatted soya four, liver powder, etc. for the *in vitro* rearing of *C. carnea*. *C. carnea* culture was maintained on *C. cephalonica* eggs (irradiated with UV rays at 30 watts for 45 minutes and kept 2 feet away from the UV tube) by using multi-cellular tray and insects from this culture provided the initial stock for the *in vitro* and *in vivo* culture.

The diet ingredients were mixed in a beaker and placed in a water bath at 50°C and a pinch of vaseline and wax (melting point 52°C) added to the diets to place them as capsules on polythene sheets. Fresh capsules were provided every day to the larvae. Two-day-old larvae were taken for the experiment. The natural and artificial diet reared adults of *C. carnea* were provided with 40 per cent honey solution (in water), 50 per cent Protinex (in water) and castor pollen grains. Observations on larval duration (days), pupal period

(days), pupal weight (mg), pupation (%), adult emergence and other parameters were recorded. The experiment was replicated 5 times with 50 larvae per replication. The study was conducted at 26.5° C and 65% RH.

Among the artificial diets, defatted soybean based diet was found to be promising with reference to increased pupation and adult emergence (Diet no. 10, 11 and 12) (Table 12). Liver and soybean flour was found to be the best diet (Diet No.12) and there was no significant difference between this diet and natural diet while rearing.

Table 12. Evaluation of different artificial diets for rearing of *Chrysoperla carnea*

| Diet No. | Larval period (days) | Pupal period (days) | Pupation (%) | Pupal weight (mg) | Adult (%) |
|---|---|---|---|---|---|
| 1 | 20 | 9.0 | 81.0 (63.92) | 4.1 | 71.0 (57.6) |
| 2 | 15.5 | 8.5 | 80.0 (63.26) | 4.8 | 71.0 (57.1) |
| 3 | 21.0 | 9.0 | 19.0 (25.64) | 3.1 | 07.0 (15.0) |
| 4 | 19.5 | 8.0 | 72.0 (58.27) | 3.8 | 58.0 (49.7) |
| 5 | 23.7 | 8.5 | 80.0 (63.31) | 3.3 | 46.0 (42.7) |
| 6 | 20.3 | 9.0 | 90.0 (71.56) | 4.4 | 80.0 (63.5) |
| 7 | 17.2 | 7.0 | 90.0 (71.61) | 4.9 | 87.0 (68.9) |
| 8 | 19.0 | 7.5 | 87.0 (68.90) | 4.6 | 72.0 (58.2) |
| 9 | 20.0 | 7.6 | 84.0 (66.50) | 4.7 | 81.0 (63.9) |
| 10 | 14.0 | 7.5 | 90.0 (71.57) | 4.3 | 88.0 (69.8) |
| 11 | 13.4 | 7.2 | 90.9 (71.61) | 4.7 | 88.0 (69.8) |
| 12 | 13.0 | 7.7 | 90.0 (71.58) | 5.7 | 89.0 (70.6) |
| Control | 8.58 | 8.5 | 90.0 (72.37) | 8.8 | 89.0 (70.7) |
| CD (P=0.05%) | 1.74 | 0.94 | (3.43) | 0.36 | (3.76) |

Figures in parentheses are angular transformed values

### 4.8.2. Rearing of *Mallada astur* using artificial diet

The efficacy of the hydrolysed soybean diet was tested for the *in vitro* rearing of *Mallada astur* for 4 successive generations.

The data was analysed in two way factorial RBD and it was found that there was significant difference in egg hatch (%), larval period (days), pupal period (days) and longevity (days) within generations of artificial diet and natural diet reared predators and also between the artificial diet and natural diet reared predators (Table 13 a). Egg hatch, larval period, pupal period and longevity in the artificial diet and natural diet reared *M. astur* were 70.4, 71.4, 21.2, 13.5 and 33.3, 59.8, respectively (mean of four generations).

Pupal weight in natural diet reared *M. astur* was significantly higher (8.2 mg) than that of artificial diet reared (4.1 mg) (Table 13b). Per cent pupation and adult emergence in natural diet reared (60.6 & 64.8) was significantly higher than that of artificial diet reared predators (55.2 & 48.5). Fecundity in artificial diet reared predators was significantly lower (145.5/female) than that of natural diet reared (169.7/female).

### 4.8.3. Biochemical analysis of prey insects and artificial diet

Protein present in the eggs of *Helicoverpa armigera, Corcyra cephalonica* and the hydrolysed soybean based diet was estimated by Folin Ciocalteau method (Lowrey *et al.*, 1957) using spectrophotometer to study the biochemical profile of prey insects of predators. Maximum protein was present in *H. armigera* (175.7 mg/g of eggs) followed by *C. cephalonica* (128.5 mg/g) and hydrolysed soybean diet (47.0 mg/g) (Table 14) indicating a need to increase the protein content in the artificial diet for better results.

Table 14. Biochemical analysis of preys and artificial diet of predators

| Prey/Diet | Protein content (mg/g) |
|---|---|
| Artificial Diet | 47.0 |
| *Corcyra cephalonica* (eggs) | 128.5 |
| *Helicoverpa armigera* (eggs) | 175.7 |

### 4.8.4. Rearing of *Cryptolaemus montrouzieri* using artificial diet

An attempt was made to rear *C. montrouzieri* on two different artificial diets. Liver powder (2.9%) with peptone (5.8%) based diet (Diet A) resulted in 59 per cent pupation and 55 per cent adult emergence and the adults survived for 48 days. Ground beef liver (8.1%) with egg yolk (20.3%) based diet (Diet B) resulted in 69 per cent pupation and 35 per cent adult emergence. The beetles could survive for 50 days (Table 15). Mating was noticed among the adults reared on both diets but such mated females did not lay any eggs though the ovaries of the beetles were well developed. However, egg laying was noticed in the presence of ovisacs of *Maconellicoccus hirsutus*.

Table 13a. Comparative study of biology of artificial and natural diet reared *Mallada astur*

| Generation | Egg hatch (%) | | Larval period (days) | | | | Pupal period (days) | | | Pupation(%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Artificial diet | Natural diet | Mean | Artificial diet | Natural diet | Mean | Artificial diet | Natural diet | Mean | Artificial diet | Natural diet | Mean |
| F1 | 71.6 (90.0) | 71.6 (90.0) | 71.6 | 21.0 | 11.6 | 16.3 | 12.0 | 12.0 | 12.0 | 55.6 | 69.0 | 62.3 |
| F2 | 70.7 (89.0) | 71.6 (90.0) | 71.1 | 18.6 | 13.0 | 15.8 | 12.0 | 12.0 | 12.0 | 58.1 | 60.7 | 59.4 |
| F3 | 70.7 (89.0) | 71.6 (90.0) | 71.1 | 22.0 | 14.0 | 18.0 | 13.0 | 15.0 | 14.0 | 53.2 | 63.8 | 58.5 |
| F4 | 69.7 (88.0) | 70.7 (89.0) | 70.2 | 23.0 | 14.0 | 18.5 | 14.0 | 15.0 | 14.5 | 53.8 | 65.7 | 59.8 |
| Mean | 70.7 | 71.4 | | 21.15 | 13.15 | | 12.75 | 13.50 | | 55.2 | 64.8 | |

Figures within parentheses are angular transformed values

| Factor | CD (P=0.05) | | | |
|---|---|---|---|---|
| | Egg hatch | Larval period | Pupal period | Pupation |
| Diet | 0.83 | 0.90 | 0.51 | 2.12 |
| Generation | 0.59 | 0.64 | 0.36 | 1.51 |
| Diet x Generation | NS | 1.28 | 0.72 | 3.02 |

Table 13b. Comparative study of biology of artificial and natural diet reared *Mallada astur*

| Generation | Pupal weight (mg) | | | Adult emergence (days) | | | | Fecundity (no. of females) | | | Longevity (days) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Artificial diet | | Natural diet | Mean | Artificial diet | Natural diet | Mean | Artificial diet | Natural diet | Mean | Artificial diet | Natural diet | Mean |
| F1 | 4.2 | 8.2 | 6.2 | 51.4 (61.0) | 69.0 (87.0) | | 60.2 | 150.0 | 170.0 | 160.0 | 29.0 | 63.0 | 46.0 |
| F2 | 4.2 | 8.3 | 6.2 | 51.4 (61.0) | 54.4 (66.0) | | 52.9 | 141.0 | 162.0 | 151.5 | 21.0 | 47.0 | 34.0 |
| F3 | 4.0 | 8.1 | 6.0 | 46.7 (53.0) | 62.9 (79.0) | | 54.8 | 160.0 | 180.0 | 170.0 | 42.0 | 73.0 | 57.5 |
| F4 | 3.9 | 8.2 | 6.0 | 44.4 (49.0) | 56.2 (69.0) | | 50.3 | 132.0 | 167.0 | 149.0 | 41.0 | 56.0 | 48.5 |
| Mean | 4.1 | 8.2 | | 48.5 | 60.6 | | | 145.5 | 169.7 | | 33.3 | 59.8 | |

Figures within parentheses are angular transformed values

| Factor | CD (P=0.05) | | | |
|---|---|---|---|---|
| | Egg hatch | Larval period | Pupal period | Pupation |
| Diet | NS | 1.92 | NS | 7.08 |
| Generation | 0.25 | 1.36 | 16.02 | 5.01 |
| Diet x Generation | 0.18 | 2.72 | NS | 10.02 |

Table 15. Development of *Cryptolaemus montrouzieri* on artificial diets

| Growth parameters | Diet A* | Diet B* |
|---|---|---|
| Larval period (days) | 21.0 | 20.0 |
| Pupal period (days) | 7.0 | 8.0 |
| Pupation (%) | 59.0 | 55. |
| Adult emergence (%) | 69.0 | 35.0 |
| Fecundity | ** | ** |
| Longevity (days) | 48.0 | 50.0 |

* Diet A - Liver powder plus peptone based diet;

* Diet B - Ground beef liver plus egg yolk based diet;

** Fecundity observed in the presence of *M. hirsutus* ovisacs

### 4.8.5. Rearing of anthocorid bug, *Cardiastethus exiguus* using artificial diets

An attempt was made to rear of *C. exiguus* on artificial diets in the laboratory. Two-day-old nymphs were kept in glass vials (4.5x2cm) individually as they are cannibalistic.

Defatted soybean plus 0.1% and beef liver 4.3% were tried for rearing *C. exiguus*. Diets were encapsulated and placed in the vials along with cotton soaked with water. About 66 per cent nymphs were able to form adults. After four days females were allowed to mate for a day and kept individually for egg laying and fecundity of the artificial diet reared *C. exiguus* was also observed. Longevity of the artificial diet reared predator was 35 days (Table 16).

Table 16. Development of *Cardiastethus exiguus* on artificial diet

| Diet | Nymphal duration (days) | Adult formation (%) | Longevity (days) |
|---|---|---|---|
| Defatted soybean | 16.0 | 66.0 | 38.0 |
| Control (*Corcyra*) | 14.0 | 90.0 | 61.0 |

### 4.8.6. *In vitro* rearing of trichogrammatids

The experiment was carried out by preparin two sets of artificial diet. Diet I contained *H. armigera* larval haemolymph (50%), e g yolk (25%) and milk suspension (25%) and streptomycin sulphate (0.15%) was added to the diet. Diet II contained *H. armigera* larval haemolymph (50%), egg yolk (20%) and new born calf serum (10%) and streptomycin sulphate (0.12%) was added to the diet. *H. armigera* haemolymph was obtained by immersing late 4th instar larvae in hot water (60°C) for 10 minutes. After the treatment, larvae were removed and prolegs were cut and larvae gently pressed. All the diet preparation was done under aseptic condition in laminar flow.

Egg laying was obtained on ovipositional stimulant egg capsules. Partial development up to pupal stage was observed on Diet no.I. However, further development was not observed due to drying up of the diet.

## 4.9. Development of resistant / tolerant species / strains of egg parasitoids

### 4.9.1. Selection of egg parasitoids for tolerance to insecticides by adult exposure method

The experiment was conducted with endosulfan tolerant strain of *Trichogramma chilonis* to develop multiple tolerant strain. Two insecticides were chosen, monocrotophos and fenvalerate. In monocrotophos treatment initial dosages taken was 0.5 ml/l and was gradually increased to 1.5 ml/l Fenvalerate exposure was done initially with 0.025 ml/l solution and then increased to 0.05 ml/l. Test units (20 x 4 cm open ended glass tube) were sprayed with required quantity of insecticide with the help of hand sprayer and dried under shade. After drying, adults (about 1500) were released in the testing unit. A *Corcyra* egg card containing about 12,000 eggs was kept inside the testing unit to obtain next generation. Parasitoids thus obtained were treated with same concentration till fixed parameters were achieved. The parameters fixed were <20 per cent mortality and >90 per cent parasitism after 6 hours of constant exposure to insecticides. For each exposure, parasitoids obtained from all three insecticidal treatments were mixed and released in three different insecticides treated glass vials. Results thus obtained is presented in Table 17.

The results suggested that after 34 generation of exposure parasitoids have become tolerant to 1.5 ml/l of monocrotophos also besides endosulfan (2.5 ml/l). The parasitism obtained was more than 90 per cent and per cent mortality less than 20 per cent after six

hours of constant exposure to both insecticides. Similarly exposure to fenvalerate after 26 generations has resulted in parasitism and mortality of more than 90 and less than 20 per cent, respectively, after six hours of constant exposure at 0.05 ml/l solution.

Table 17. Development of multiple insecticide tolerant strain of *Trichogramma chilonis*

| Insecticide | Concentration (ml/l) | Number of exposures | Number of generations reared | Per cent parasitisation (after six exposures) Generation | | Per cent mortality (after six exposures Generation | |
|---|---|---|---|---|---|---|---|
| | | | | First | Last | First | Last |
| Endosulfan | 2.5 | 17 | 23 | 60 | 95 | 80 | 20 |
| | 2.5 | 10 | 13 | 50 | 90 | 70 | 40 |
| Monocrotophos | 0.5 | 3 | 3 | 50 | 95 | 50 | 10 |
| | 0.75 | 5 | 3 | 40 | 90 | 60 | 20 |
| | 1.0 | 5 | 5 | 50 | 98 | 70 | 15 |
| | 1.25 | 10 | 12 | 45 | 95 | 60 | 20 |
| | 1.5 | 9 | 11 | 30 | 100 | 50 | 10 |
| Fenvalerate | 0.1 | 1 | 1 | 2 | - | 98 | - |
| | 0.025 | 13 | 15 | 5 | 95 | 90 | 20 |
| | 0.05 | 8 | 10 | 20 | 100 | 80 | 2 |

### 4.9.2. Development of high temperature tolerant strain of *T. chilonis*

The experiment was conducted in BOD incubator with constant temperature and varying humidity. Initial temperature set was 30°C and RH 70 and 40 per cent. Experiment was conducted in glass vials measuring 20 x 3.5 cm kept in clear plastic container with moist foam piece to maintain required humidity Parasitoids were reared at this temperature till >90 per cent parasitism and longevity of >3 days were obtained. Parasitoids were shifted to next higher temperatures, i.e. 33 and 36°C. However, at 36°C survival and parasitism was very low in lower humidity, hence experiment was conducted at 70 per cent humidity only. Observation on per cent parasitism and longevity was recorded in each generation.

Studies were continued at 33°C and 70 - 80% humidity. Results showed that after 38 generations parasitism increased from 10 to 98 per cent and longevity from 1 to 7 days (Table 18). Parasitoids were shifted from 33 to 36°C and six generations have been passed at this temperature with 80 per cent parasitism and longevity of five days. The humidity level was brought down to 55 - 60%.

Table 18. Development of high temperature tolerant strain of *Trichogramma chilonis*

| Temperature (°C) | Relative humidity (%) | Number of generations reared | Parasitisation (%) in - generation | | Longevity of adults (days) in - generation | |
|---|---|---|---|---|---|---|
| | | | First | Last | First | Last |
| 30 | 40 | 6 | 5 | 30 | 1 | 1 |
| 30 | 70 | 6 | 20 | 100 | 1 | 3 |
| 33 | 70 | 38 | 10 | 98 | 1 | 7 |
| 36 | 60 | 6 | 25 | 80 | 2 | 5 |

### 4.9.3. Life table and parasitising efficiency of *Trichogrammatoidea bactrae* at various temperatures

The experiment was carried out between 15 and 35°C utilising *Plutella xylostella* eggs and known number of *Trichogrammatoidea bactrae* females. About 500 *P. xylostella* eggs (@ 50 eggs / female) were provided daily till death of all the females in each temperature. Fine streak of honey was provided daily as adult food. Experiment was conducted in BOD incubator set at different temperatures (15, 20, 25, 30 and 35°C ) using glass vials measuring 20 x 3.5 cm. In another experiment varying females were released against known number of *P. xylostella* eggs in order to obtain >90 per cent parasitism in different temperatures.

The net reproductive rate (Ro) of 23.2 was highest at 25°C and lowest (3.59) at 35°C. The finite rate of increase (l) varied from 1.17 to 1.36/female/female/day at various temperatures (Table 19). At 15°C, though low parasitism was observed but parasitoids failed to emerge from the eggs. When parasitising efficiency was studied between 20 - 35°C, it was observed that in temperatures <20 but >18 or > 32 but <35°C would require parasitoid release at the rate of 2.50 lakhs instead of 0.50 lakhs to achieve more than 90 per cent parasitism. In temperatures between 20 and 30°C > 90 per cent parasitism was obtained when released @0.50 lakh / hectare.

Table 19. Life table statistics of *Trichogrammatoidea bactrae* at different temperatures

| Temperature (°C) | Ro | Tc | Rc | Rm | T | A |
|---|---|---|---|---|---|---|
| 15 | - | - | - | - | - | - |
| 20 | 22.3 | 17.40 | 0.1783 | 0.1826 | 17.0 | 1.20 |
| 25 | 23.2 | 12.05 | 0.2026 | 0.2619 | 12.0 | 1.29 |
| 30 | 16.4 | 9.03 | 0.3101 | 0.3110 | 9.0 | 1.36 |
| 33 | 4.7 | 9.02 | 0.1724 | 0.1728 | 9.0 | 1.18 |
| 35 | 3.6 | 8.00 | 0.1598 | 0.1597 | 8.0 | 1.17 |

### 4.9.4. Functional response of *Telenomus ?remus* in relation to temperature and host density

Studies were carried out with varying host (*Spodoptera litura eggs*) density from 20 to 200 eggs per female parasitoid (*Telenomus ?remus*) in temperature from 15 to 36°C.

Each mated female was transferred in glass vial measuring 15 x 2.5 cm and was fed with fine honey and water streaks. *Spodoptera litura* eggs varying in density, i.e. 20, 40, 60, 80, 100, 120, 140, 160, 180 and 200 were provided to each female parasitoid for 48 hours at temperatures 15, 20, 25, 30, 32, 34 and 36°C. After exposure surviving female parasitoids were removed and egg card was kept at same temperature for further observation. Observations recorded were per cent parasitism, number of adults emerged, fecundity, sex ratio and longevity in different temperatures. Each treatment, i.e. density was replicated five times at each temperature.

Results showed that developmental period was 52.0 days at 15°C and it came down to 8.0 days at 36°C. Longevity was more 15.3 days at 20°C compared to 10.7 days at 15°C. Parasitoid fecundity was highest in temperature >20 or <32°C. Parasitoid: host egg ratio of 1:100 eggs was found optimum. Parasitoid exhibited Hollings Type II functional response at various temperature and host densities.

## 4.10. Studies on Insect pathogens

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

Nuclear polyhedrosis viruses (NPVs) from castor semilooper, *Achaea janata*, greasy cut worm, *Agrotis sp.*, armyworm, *Spodoptera exigua* and greater wax moth, *Galleria mellonella* have been isolated during surveys and their identity has been confirmed through electron microscopic study and pathogenicity proved by Koch's postulates. Granulosis virus (GV) from greasy cut worm, *Agrotis sp.* and from potato tuber moth *Phthorimaea operculella* were isolated. Their identity and pathogenicity were confirmed by electron microscopic study and by Koch's postulates.

A GV from *Spodoptera litura* was recently re-isolated. Suspecting midgut infection based on the extroversion of gut, virus isolated from *S. litura* was inoculated to test verify the site of infection. It has been found infection was confined mostly to the fat bodies as evident from hypertrophy of fat bodies by visceral study. However, infection of gut was due to microsporidian infection.

### 4.10.2. Host-Pathogen relationship

#### 4.10.2.1. Pathogenicity of *Galleria mellonella* NPV

Tissue smear of NPV infected *G. mellonella* larvae from a honey bee colony showed presence of cuboidal inclusion bodies ranging from 2-5 µ in diameter. A large number of spindle shaped inclusions associated with cuboidal inclusions were also observed. Studies on the pathogenicity of NPV of *G. mellonella* revealed more than 80 per cent mortality of *G. mellonella* when young larvae were administered heavy virus suspension through diet contamination technique. The incubation period ranged from 6-10 days depending upon the size of the larvae. The infected caterpillar came out of gallery made up of silken webs and was found lying in ventral position. The diseased larvae were more opaque on the ventral side than the healthy caterpillar. Examination of the infected larvae invariably showed the occurrence of both cuboidal and spindle inclusion in all the diseased larvae. Viral genome control of these inclusions is evident from the presence of spindles invariably associated with cuboidal inclusions in almost all the larvae infected with this virus.

#### 4.10.2.2. Symptoms of *S. exigua* NPV infection

The symptoms of the NPV infected *S. exigua* were generally comparable with those of most of the nuclear polyhedrosis virus reported in other insects. Living diseased larvae of *S. exigua* showed typical sluggishness in their movement and lagged behind in their development and were also less responsive to external tactile stimuli. Further, in contrast to pale yellow to green coloured healthy larvae, NPV infected *S. exigua* became puffy and pale white in colour, mostly due to the accumulation of large number of inclusion bodies. At the time of death and immediately after death, they turned black. Unlike that of NPV of *S. litura*, the skin of NPV infected *S. exigua* is not liquified.

### 4.10.3. Characterisation of NPV

#### 4.10.3.1. *G. mellonella*

When spindle inclusions were exposed to varying strength of NaOH *viz.*, 1N, 0.1N, 0.05N, 0.025N and 0.01N spontaneous dissolution of crystals were observed in all the concentrations.

The spindle inclusions showed positive reaction to protein stains like Giemsa and iron-Haematoxylin. To study the size of the protein a Discontinuous Sodium Dodecyl Sulphate-Polyacrylamide Gel Electrophoresis (SDS-PAGE) was carried out with purified virus sample containing cuboidal viral inclusion and spindles through 15% polyacrylamide gel containing 0.1% SDS at 30 mA for 4 hours as described by Lamelli (1970) and the protein bands were detected by Coomassie brilliant blue R250 staining as per standard procedure. Both the polyhedral protein and spindle protein with molecular weight of 30 kDa and 47.5 KDa, respectively, were seen on the gel. From the results it is evident that the infection of *G. mellonella* with nuclear polyhedrosis virus not only results in prolonged polyhedral (cuboidal) protein production in the infected cells but also stimulation of (spindle) protein synthesis in the infected cells.

#### 4.10.3.2. *S. exigua*

*S. exigua* PIBs were measured at random under a phase-contrast microscope at 400x magnification and it was found that size of the PIBs averaged 1.65 + 0.1µ in diameter. Most of the PIBs are square and some of them are round in shape. Electron micrograph of sections of polyhedra revealed virus rods occluded in bundles.

### 4.10.4. Cross infectivity tests

#### 4.10.4.1. Cross infectivity of *G. mellonella* NPV

Apparently virus free 1-5 days old larvae were fed with NPV of *G. mellonella* containing both cuboidal and spindle inclusion by way of contaminating the respective food material of the following insects *Helicoverpa armigera, Spodoptera litura, Chilo partellus, Opisina arenosella, Trichoplusia ni, Agrotis* sp. and *Achaea janata.* It was found that NPV of *G. mellonella* was not cross infective to all the lepidopteran species tested. Some of the larvae of *S. litura* and *H. armigera* were found dead with their own NPVs.

#### 4.10.4.2. Cross infectivity of *S. exigua* NPV

Since *S. exigua* is found to occur and cause damage both in the nursery and transplanted tomato crop along with tomato fruit borer, *H. armigera* for which NPV is usually recommended, a preliminary cross infectivity study was conducted with NPV of *H. armigera* against second instar larvae of *S. exigua* by inoculating 2 x 106 PIBs/ larva through diet contamination technique. The above study had revealed that NPV of *H. armigera* was not able to infect the larva of *S. exigua.* However, inducement of NPV of *S. exigua* due to the application of NPV of *H. armigera* has been noticed. This has widened the scope of controlling both the species *viz., H. armigera* and *S. exigua*, occurring on the same cropping system, by the application of *H. armigera* NPV alone.

Further, studies on the cross infectivity of *S. exigua* to *S. litura* revealed the highly susceptible nature of *S. litura* to heterologous NPV of *S. exigua* recording cent per cent mortality of second instar larvae when it was administered at 2 x 106 PIBs/larva through diet surface contamination technique. However, the incubation period was found to be longer in the case of *S. litura* (4-10 days) when compared to *S. exigua* (3-8 days). The re-isolated NPV from *S. exigua* on inoculation to the original host was found to be infective thereby confirming the cross infectivity of the virus.

#### 4.10.4.3. Cross infectivity of *P. xylostella* NPV

*Plutella xylostella* GV was not cross infective to snakegoard semilooper, *Plusia peponis,* Amaranthus leaf miner, *Hymenia recurvalis*, beet armyworm, *Spodoptera exigua,* Castor semilooper, *Achaea janata* and mustard sawfly, *Athalia lugens proxima.*

### 4.10.5. Enhancement study

A preliminary study was conducted to find out whether there is enhanced infection of an NPV with the larvae of *S. litura* by the spindle associated with NPV of *G. mellonella*. When the fourth instar larvae of *S. litura* was inoculated with its polyhedra along with spindles of *G. mellonella* NPV, a weak enhancing effect was noticed by way of reduction in the incubation period (5-7 days) when compared to 7 to 9 days in case of virus treated ones. On the other hand when the fourth instar larvae of *S. litura* larvae were inoculated with spindles of *G. mellonella* only, cent per cent mortality of *S. litura* by way of inducement by the *G. mellonella* spindles was noticed.

## 4.11. Studies on fungal and bacterial antagonists

### 4.11.1. Biological control of root rot of chickpea

Fifty isolates of *Trichoderma* and *Gliocladium* isolated from chickpea rhizosphere were tested *in vitro* and under greenhouse conditions against *Rhizoctonia solani*, the incitant of seed rot, damping-off and root rot in chickpea. Four potential isolates viz., *T. harzianum* (PDBCTH 2 and PDBCTH 8), *T. viride* (PDBCTV12) and *G. deliquescens* (ITCC 3450) were selected for further studies. Conidial and mycelial suspensions of the above bioagents gave very less plant stand when applied as seed treatment to control damping-off of chickpea caused by *R. solani* (Table 20). Seed treatment with mycelial suspensions was found to be more effective than conidial treatment. *T. harzianum* (PDBCTH 8) gave maximum plant stand among all bioagents. The plant stand in fungicide treatment was only 16% after three weeks whereas in PDBCTH 8 treatment it was 20%. Mycelial preparations of all bioagents when applied in infested soil 15 days before sowing, gave more plant stand than treatments without incubation and was comparable to or even better than the plant stand in treatment with fungicide mancozeb at three weeks (Table 21). *T. harzianum* (PDBCTH 8) was found to be superior to the other bioagents tested.

Table 20. Effect of seed treatment with conidial and mycelial suspensions of *Trichoderma* spp. and *G. deliquescens* on chickpea plant stand in soil infested with *R. solani*.

| Antagonists | | Plant stand (%) during | |
|---|---|---|---|
| | | First week | Third week |
| *T. harzianum* (PDBCTH 2) | Conidia | 2 (5.8) | 0 (o.0) |
| | Mycelia | 13 (21.1) | 8 (16.2) |
| *T.harzianum* (PDBCTH 8) | Conidia | 9 (17.4) | 8 (16.4) |
| | Mycelia | 23 (28.6) | 20 (26.6) |
| *T.viride* (PDBCTV 12) | Conidia | 5 (12.8) | 2 (5.8) |
| | Mycelia | 9 (17.4) | 3 (7.0) |
| *G.deliquescens* (ITCC 3450) | Conidia | 4 (11.5) | 0 (0.0) |
| | Mycelia | 9 (17.4) | 3 (8.7) |
| Control (Mancozeb) | | 50 (45.0) | 16 (23.5) |
| Control (*R.solani*) | | 2 (5.8) | 0 (0.0) |
| Control (uninfested) | | 98 (84.2) | 98 (84.2) |
| CD (P=0.05) | | (5.8) | (6.4) |

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

Table 21.Effect of soil application of mycelial preparations (on wheat bran) of *Trichoderma* spp. and *G. deliquescens* on chickpea plant stand in soil infested with *R. solani*.

| Antagonists | | Plant stand (%) during First week | Third week |
|---|---|---|---|
| *T.harzianum* (PDBCTH 2) | without incubation | 6 (14.0) | 5 (12.8) |
| | with incubation | 25 (30.0) | 22 (28.0) |
| *T.harzianum* (PDBCTH 8) | without incubation | 30 (33.2) | 26 (30.6) |
| | with incubation | 52 (46.2) | 49 (44.4) |
| *T.viride* (PDBCTV 12) | without incubation | 10 (18.4) | 8 (16.2) |
| | with incubation | 6 (23.4) | 12 (20.1) |
| *G.deliquescens* (ITCC 3450) | without incubation | 11 (19.3) | 9 (17.4) |
| | with incubation | 34 (35.6) | 30 (33.2) |
| Control (Mancozeb) | | 43 (41.0) | 16 (23.5) |
| Control (*R.solani*) | | 3 (8.7) | 0(0.0) |
| Control (uninfested) | | 99 (87.1) | 98 (84.2) |
| CD (P=0.05) | | (4.9) | (4.2) |

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

### 4.11.2. Granular formulation of *Trichoderma* and *Gliocladium* spp. in biocontrol of *Rhizoctonia solani* of chickpea

A modified granular formulation containing powdered wheat bran, kaolin, acacia powder and biomass of isolates of *Trichoderma harzianum* (PDBCTH 10 and PDBCTH 8), *T. virens* (PDBCTVs 3 and ITCC 4177) and *Gliocladium deliquescens* (ITCC 3450) was evaluated for its effect on the reduction of chickpea damping-off caused by *Rhizoctonia solani*, reduction of pathogen inoculum and proliferation of the bioagents in the soil in a greenhouse experiment. Granules with isolates of bioagents significantly reduced damping-off. After four weeks, PDBCTH 10 and PDBCTH 8 treatments recorded better plant stand (63 and 53%) than fungicide (Captan) treatment (43%) (Table 22). None of the isolates recorded plant stand comparable to non-infested control (83%). The two

*T. harzianum* isolates were more effective in reducing saprophytic growth of the pathogen compared to other bioagents. A substantial increase in the population of all bioagents was observed after 6 weeks, but better plant stand was obtained only with isolates of *T. harzianum*.

Table 22. Effect of granular formulation of *Trichoderma* and *Gliocladium* spp. on damping-off of chickpea and on the saprophytic growth of the pathogen

| Antagonists | Plant stand (%) at* | | Saprophytic growth of the pathogen (%)* | Antagonists population (CFU g-1 of soil) | |
|---|---|---|---|---|---|
| | II week | IV week | | Initial ($10^4$) | After six weeks ($10^7$) |
| *T.harzianum* | | | | | |
| PDBCTH 10 | 68(55.3) | 63(52.3) | 25.5(30.3) | 5.5 | 7.3 |
| PDBCTH 8 | 60(50.8) | 53 (46.4) | 32.8(34.9) | 4.0 | 6.0 |
| *T.virens* | | | | | |
| PDBCTVs 3 | 33(34.7) | 23(28.2) | 66.3(54.5) | 4.0 | 4.5 |
| ITCC 4177 | 48(43.6) | 30(33.1) | 57.8(49.5) | 3.5 | 4.5 |
| *G.deliquescens* | | | | | |
| ITCC 3450 | 33(34.7) | 20(26.2) | 76.0(60.7) | 7.0 | 7.3 |
| Captan 50 WDP | 78(61.7) | 43(40.6) | - | - | - |
| Control I (Pathogen alone) | 8(13.8) | 0(0.0) | 98.3(83.6) | - | - |
| Control II (Uninfested) | 85 (67.5) | 83(65.4) | 0.8(3.5) | - | - |
| CD (P=0.05) | 6.2 | 6.4 | 4.5 | 1.7 | 2.3 |

* Figures in parentheses are angular transformations

### 4.11.3. Evaluation of a modified granular formulation of *T. harzianum* in microplots against *R. solani* on chickpea

A field experiment was conducted during rabi 1998 to evaluate the efficacy of granular formulation of *T. harzianum* (PDBCTH 10) against damping-off and root rot of chickpea incited by *R0 solani*. Two doses of bioagent granules (100 and 200 GMS/m2) were tried and granules were amended to pathogen infested soil 15 days before sowing. Bioagent treatments recorded very less seed rot and damping-off incidence (14.8 and 10.9%) after one week in 100 and 200 g of bioagent treatments, respectively (Table 23). The plant stand recorded after 45 days was significantly high in bioagent treatments (70.3 and 75.9%) compared to pathogen and bioagent seed treatments which gave only 22.2 and 38.8 % plant stand, respectively (Table 24). Maximum inhibition of saprophytic growth of *R. solani* was also observed in bioagent treatments which was significantly high compared to fungicide and bioagent seed treatments. There was a considerable increase in bioagent population up to 3 weeks in bioagent treatments (Table 25).

Table 23. Efficacy of granular formulation of *T. harzianum* against seed rot and damping-off of chickpea in microplot

| Treatment | Seed rot and damping-off after one week (%)* | Plant stand after 45 days (%)* |
|---|---|---|
| Control I (uninfested soil) | 1.9(4.6) | 98.1(85.4) |
| Control II (Pathogen alone) | 57.3(49.2) | 22.2(28.0) |
| Bioagent granules @ 100 g/m2 | 14.8(21.9) | 70.3(57.0) |
| Bioagent granules @ 100 g/m2 | 10.9(18.9) | 75.9(60.7) |
| Bioagent seed treatment @ 4.0 g/kg seed | 51.8(46.0) | 38.8(38.5) |
| Captan 50 WP | 27.7(31.7) | 55.7(55.3) |
| CD (P=0.05) | (13.0) | (18.0) |

* Figures in parentheses are angular transformations

Table 24. Saprophytic growth of *Rhizoctonia solani* in microplots

| Treatment | Saprophyticgrowth (%)* | | |
|---|---|---|---|
| | Initial | After incubation | After 3 weeks |
| Control I (uninfested soil) | 2.3(7.0) | 2.3(8.7) | 2.7(9.3) |
| Control II Pathogen alone) | 54.3(47.5) | 83.3(66.1) | 85.3(67.7) |
| Bioagent granules @ 100 g/m$^2$ | 47.7 (43.7) | 24.7 (31.2) | 22.0 (27.8) |
| Bioagent granules @ 100 g/m$^2$ | 56.3 (55.7) | 25.3 (30.2) | 26.0 (30.6) |
| Bioagent seed treatment @ 4.0 g/kg seed | 55.7 (48.3) | 72.0 (58.1) | 78.7 (62.5) |
| Captan 50 WP | 53.6 (47.1) | 71.3 (57.7) | 66.3 (54.7) |
| CD (P=0.05) | (21.0) | (10.3) | (10.6) |

* Figures in parentheses are angular transformations

Table 25. Growth and proliferation of *T. harzianum* in microplots

| Treatment | Initial | Log cfu/g of soil | |
|---|---|---|---|
| | | After 15 days of incubation | After 3 weeks |
| Control I (uninfested soil) | 0 | 0.33 | 0.77 |
| Control II (Pathogen alone) | 0.33 | 0.67 | 1.10 |
| Bioagent granules @ 100 g/m$^2$ | 4.48 | 7.46 | 7.92 |
| Bioagent granules @ 200 g/m$^2$ | 4.81 | 7.83 | 7.98 |
| Bioagent seed treatment @ 4.0 g/kg seed | 0 | 0.33 | 0.77 |
| Captan 50 WP | 0.43 | 0.82 | 1.10 |
| CD (P=0.05) | 0.66 | 0.82 | 0.69 |

### 4.11.4. Standardisation of media for mass production of *Trichoderma* species

An attempt was made to modify the molasses-yeast medium for mass production of fungal antagonists by replacing expensive yeast with various other nitrogen sources and sucrose as carbon source for production of *T. harzianum*. Molasses medium with soy flour gave maximum amount of fungal biomass and viable propagules when compared to yeast, $NaNO_3$ and $KNO_3$ treatments (Table 26). Soy flour @ 10g/l of molasses medium was found to be optimum (Table 27).

Table 26. Effect of different nitrogen sources to replace molasses-yeast medium

| Medium | Dry weight (mg) | Viable propagules ($x10^7$) | Spore count ($x10^7$) |
|---|---|---|---|
| Molasses-yeast | 444.0 | 0.8 | 1.6 |
| Molasses-soy | 760.0 | 1.6 | 3.7 |
| Molasses-$NaNO_3$ | 411.3 | 0.8 | 1.5 |
| Molasses-$KNO_3$ | 345.3 | 0.4 | 1.0 |
| CD (P=0.05) | 49.7 | 0.36 | 0.77 |

Table 27. Growth of *T. harzianum* in molasses-soy medium with different levels of soy flour as nitrogen source

| Medium | Dry weight (mg) | Viable propagules ($x10^7$) | Spore count ($x10^7$) |
|---|---|---|---|
| MSM1 | 716.7 | 2.1 | 3.7 |
| MSM2 | 892.7 | 7.2 | 11.7 |
| MSM3 | 991.7 | 38.0 | 68.8 |
| MSM4 | 1183.0 | 28.3 | 55.3 |
| CD (P=0.05) | 55.4 | 4.7 | 23.7 |

* Quantity of soy flour : MSM1 = 5.0g; MSM2 = 7.5g; MSM3 = 10.0g; MSM4 =15.0g

### 4.11.5. *In vitro* studies on bacterial antagonists

Several isolates were screened for *in vitro* antagonism in dual culture on TSA (Tryptic Soya Agar) against five fungal pathogens *viz., Botrytis cinerea, Macrophomina phaseolina, Sclerotium rolfsii, Rhizoctonia solani* and *Fusarium oxysporum* f. sp. *ciceri*. Four of the isolates were selected as potential antagonists of the five pathogens and they were *Pseudomonas putida* (PDBCAB19) and *P. fluorescens* (PDBCAB2, PDBCAB29 and PDBCAB 30). All four antagonists showed good inhibition zones against the five pathogens but *P. putida* and *P. fluorescens* (PDBCAB2) were most effective against *S. rolfsii* and *F. oxysporum* f. sp. *ciceri*, PDBCAB29 very effective against *B. cinerea* and *P. fluorescens* (PDBCAB30) against all the five pathogens (Table 28).

Table 28. Inhibition of fungal pathogens under dual culture by antagonistic bacteria

| Pathogen | Inhibition zone (mm) | | | |
|---|---|---|---|---|
| | *P.putida* (PDBCAB 19) | *P.fluoroscens* (PDBCAB 2) | *P.fluoroscens* (PDBCAB 29) | *P.fluoroscens* (PDBCAB 30) |
| *Botrytis cinera* | 32 | 28 | 48 | 60 |
| *Macrophomina phaseolina* | 38 | 32 | 35 | 54 |
| *Sclerotium rolfsii* | 70 | 42 | 23 | 38 |
| *Rhizoctonia solani* | 35 | 28 | 33 | 67 |
| *Fusarium oxysporum* f. sp. *ciceri* | 45 | 42 | 45 | 52 |

### 4.11.6. Testing for root colonizing ability of bacterial antagonists

The root colonizing ability of the above four potential antagonists was tested by estimating the total rhizosphere population over a period of time. The total rhizosphere population was highest (log number 6.4) for *P. fluorescens* (PDBCAB 29) after four days of germination (Fig. 9) indicating it's potential as a good root colonizer. The rhizosphere population stabilized (log numbers 4.0 to 5.0) after eight days of germination for all the four antagonists.

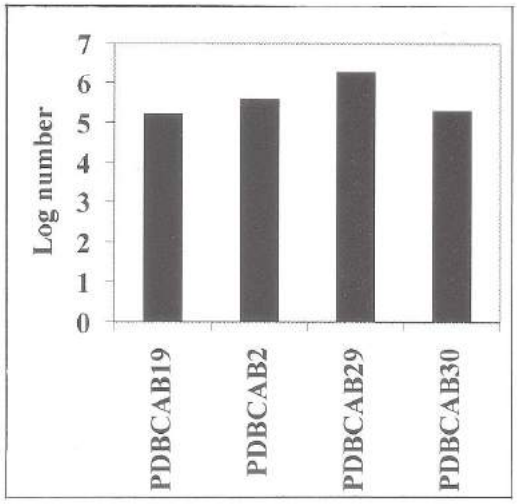


Fig. 9. Root colonising ability of bacterial antagonists (rhizosphere population after 8 days)

### 4.11.7. Inhibition of Root Pathogens of Chickpea under *in vivo* conditions

Three pathogens namely *F. oxysporum* f. sp. *ciceri, R. solani* (wilt pathogens) and *M. phaseolina* (root rot pathogen) were targeted by the four selected antagonists in greenhouse conditions in unsterile soil:vermiculite (1:1) mixture. The antagonists were first allowed to colonize the roots of chickpea plants (Annegiri cultivar) by first germinating the seeds in sterile soil mixture containing the bacterial antagonist (about $10^6$ to $10^8$ cfu per gram of soil mixture). The plants were replanted in pathogen infected unsterile soil:vermiculite mixture. Control pots having fungicide, without fungicide (infected) and plain pots with replanted plants from untreated soil were maintained. Plants surviving after 60 days of incubation were counted and per cent survival calculated. Maximum plant stand (100%) was observed with *P. fluorescens* (PDBCAB29 and 30) treated pots for *R. solani* and *M. phaseolina* (Table 29). PDBCAB30 was also able to fully control *F. oxysporum* f. sp. *ciceri.* P. *putida* was able to inhibit only *F. oxysporum* f. sp. *ciceri. P. fluorescens* (PDBCAB2) was marginally effective against *R. solani.*

Table 29. Inhibition of chickpea pathogens in soil by bacterial antagonist isolates

| Treatment | Plants survival (%) after 60 days | | |
|---|---|---|---|
| | *Fusarium oxysporum* f. sp. *ciceri* | *R.solani* | *M.phaseolina* |
| *P.putida* (PDBCAB 19) | 100 (90) | 33 (35) | 22 (23) |
| *P.fluorescens* (PDBCAB 2) | 44 (42) | 67 (55) | 22 (23) |
| *P. fluoroscens* (PDBCAB 29) | 56 (48) | 100 (90) | 100 (90) |
| *P.fluoroscens* (PDBCAB 30) | 100 (90) | 100 (90) | 100 (90) |
| Control (Fungicide) | 89 (78) | 100 (90) | 100 (90) |
| Control (infected) | 0 (0) | 0 (0) | 11 (12) |

Figures in parenthesis are angular transformations

### 4.11.8 Growth promoting characters of bacterial antagonists

The plant growth promoting ability of the four potential bacterial antagonists were determined by observing the fresh root and shoot weights of inoculated chickpea

plants after 60 days of growth. The weights were compared with uninoculated control. It was observed that all the four antagonists were able to support better growth of chickpea (Table 30). Isolates of *P. fluorescens* (PDBCAB29 and 30) were able to support maximum growth.

Table 30. Differences in growth characters of chickpea after inoculation with bacterial antagonists

| Treatment | *Fusarium oxysporum* f. sp. *ciceri* | | *R.solani* infestd soil | | *M.phaseolina* infested soil | |
|---|---|---|---|---|---|---|
| | Shoot weight (g) | Root weight (g) | Shoot weight (g) | Root weight (g) | Shoot weight (g) | Root weight (g) |
| *P.putida* (PDBCAB 19) | 7.2 | 6.3 | 9.4 | 8.9 | 9.2 | 8.0 |
| *P.fluorescens*(PDBCAB 2) | 6.5 | 6.3 | 10.2 | 9.5 | 6.0 | 5.2 |
| *P.fluorescens* (PDBCAB 29) | 8.5 | 7.3 | 10.5 | 9.4 | 7.7 | 7.0 |
| *P.fluorescens* PDBCAB 30) | 9.6 | 8.0 | 10.5 | 9.9 | 6.7 | 6.2 |
| Control (Fungicide) | 8.0 | 5.1 | 8.6 | 8.0 | 9.3 | 7.8 |
| Control (not inoculated) | 6.8 | 4.4 | 7.9 | 7.6 | 7.9 | 7.3 |
| CD (P=0.05) | 1.28 | 1.30 | 1.31 | 0.95 | 0.97 | 0.87 |

### 4.11.9. Formulation and survival studies on bacterial antagonists

Talc based formulations of potential antagonists were prepared by adding 10 g of carboxymethyl cellulose (CMC) to 1.0 kg of talc powder. The carrier was sterilized and 400 mL of the bacterial suspension containing $9x10^8$ cfu/ml was added to 1.0 kg of the carrier.

Survival of *P. fluorescens* (PDBCAB29) was monitored over a period of 60 days at room temperature in the talc-based formulation. Viable population was present only up to 30 days (Fig. 10). The population drastically reduced after 60 days of storage.

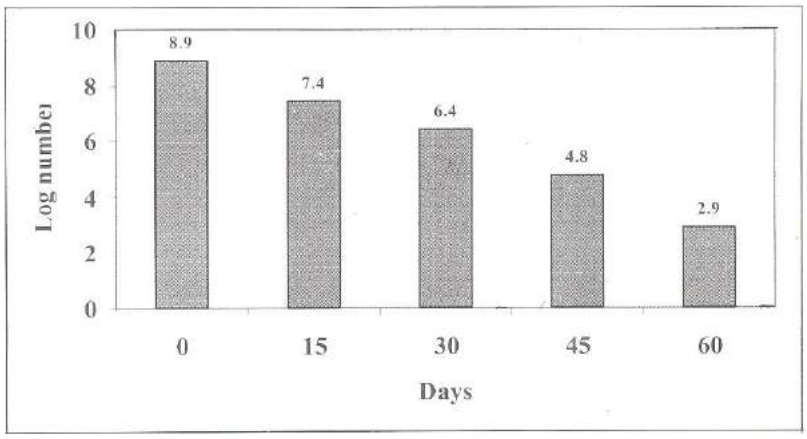


Fig.10. Survival of *Pseudomonas fluorescens* (PDBCAB 29) in talc formulation

## 4.12. Studies on entomophilic nematodes

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

A total of 96 soil samples were collected from different crop habitats and agroclimatic zones covering ten states and 17 positive samples were obtained from fruits (4), millets (3), pulses (3), vegetables (3), oilseeds (2) and others (2).

Seventeen samples baited with *Galleria mellonella* larvae yielded entomophilic nematodes viz., *Heterorhabditis* spp. from 6 (Coimbatore, Aligarh, Chidambaram, Bangalore, Kalavacherla, Minicoy and *Steinernema spp.* from 11 (Jorhat, Devanahalli, Bangalore, Madurai, Coimbatore, Aligarh, Kovvur, Minicoy and Kalavacherla).

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

Bioefficacy of different EPN isolates against insect pests were tested. The per cent mortality, 72 h after exposure was recorded (Table 31).

Per cent mortality of *Spodoptera litura* with *Steinernema* sp. PDBC EN 3.2 and 6.61 was 88.89% and among *Heterorhabditis* spp., PDBC EN 13.3 and 6.71 caused 100% mortality. In *H. armigera* maximum mortality was caused by *Steinernema* sp. PDBC EN 2.1 & *Heterorhabditis* spp. PDBC EN 6.71 & 13.3 (100%). *Steinernema* sp. PDBC EN 2.1 & 3.1 and *Heterorhabditis* sp. PDBC EN 13.3 were found best for *Phthorimaea operculella* causing 100% mortality

In case of *Plutella xylostella* maximum mortality of 100% was caused by *Steinernema* sp. PDBC EN 1.3 and *Heterorhabditis* spp. PDBC EN 7.1.

Against *Opisina arenosella*, *Heterorhabditis* sp. PDBC EN 13.3 & 14.1 were the best causing 100% mortality. There was differential reaction of these isolates for different pests and some of them did not cause any mortality.

Table 31. Bioefficacy evaluation of *Steinernema* sp. and *Heterorhabditis* sp. for different insect pests

| Isolate | Per cent mortality of larvae after 72h of exposure | | | | |
|---|---|---|---|---|---|
| | *S.litura* | *H.armigera* | *P.operculella* | *P.xylostella* | *O.arenosella* |
| PDBC EN 2.1 | 66.67 | 100.00 | 100.00 | 88.89 | 33.33 |
| PDBC EN 3.1 | 77.78 | 77.78 | 0.00 | 0.00 | 0.00 |
| PDBC EN 3.2 | 88.89 | 66.67 | 100.00 | 88.89 | 66.67 |
| PDBC EN 6.11 | 44.44 | 55.56 | 0.00 | 0.00 | 0.00 |
| PDBC EN 6.61 | 88.89 | 55.56 | 0.00 | 0.00 | 0.00 |
| PDBC EN 13.1 | 55.56 | 33.33 | 0.00 | 0.00 | 0.00 |
| PDBC EN 13.21 | 66.67 | 0.00 | 33.33 | 33.33 | 0.00 |
| PDBC EN 14.1 | 66.67 | 0.00 | 66.67 | 33.33 | 0.00 |
| PDBC EN 1.3 | 66.67 | 88.89 | 0.00 | 100.00 | 66.67 |
| *S.carpocapsae* | 55.56 | 33.33 | 0.00 | 72.78 | 66.67 |
| *H.indicus* | 77.78 | 77.78 | 33.33 | 33.33 | 66.67 |
| PDBC EN 14.3 | 0.00 | 33.33 | 88.89 | 66.67 | 0.00 |
| PDBC EN 6.71 | 100.00 | 100.00 | 88.89 | 66.67 | 0.00 |
| PDBC EN 13.3 | 100.00 | 100.00 | 100.00 | 88.89 | 100.00 |
| PDBC EN 1.41 | 77.78 | 88.89 | 0.00 | 33.33 | 100.00 |
| PDBC EN 7.1 | 88.89 | 66.67 | 0.00 | 100.00 | 88.89 |

The bioefficacy of 4 *Steinernema* and 3 *Heterorhabditis* spp. was tested against *Leucopholis coneophora*. The per cent mortality of grubs after 120 hours of exposure to IJs was recorded (Table 32). *Heterorhabditis* sp. PDBC EN 13.3 was the best with maximum mortality of 100% followed by *Heterorhabditis indicus* and *Steinernema* sp. PDBC EN 6.61 with 88.89% mortality. The progeny production of entomophilic nematodes was lower in whitegrubs compared to other insects.

Table 32. Bioefficacy and yield of EPN against *Leucopholis coneophora*

| Nematode isolates | Per cent mortality of grubs after 120h of exposure | Yield of Ijs/larva (No.) |
|---|---|---|
| PDBC EN 2.1 (S) | 44.44 | 12,341 |
| PDBC EN 3.1 (S) | 55.56 | 30,458 |
| PDBC EN 3.2 (S) | 77.78 | 21,920 |
| PDBC EN 6.61 (S) | 88.89 | 28,615 |
| PDBC EN 6.71 (H) | 66.67 | 17,280 |
| *H.indicus* | 88.89 | 32,000 |
| PDBC EN 13.3 (H) | 100.00 | 65,950 |

### 4.12.3. Penetration rate of EPN in *Spodoptera litura*

Penetration rate of 6 *Steinernema* spp. and 2 *Heterorhabditis* spp. was assessed in final instar larvae of *S. litura* by soil assay method. After 72 h exposure, IJ of *Steinernema* sp. were found to penetrate more than *Heterorhabditis* sp. Among *Steinernema* sp. the penetration rate was maximum with PDBC EN 3.1 (55.35 %) and among *Heterorhabditis* sp. PDBC EN 6.71 penetrated more (13.47%).

### 4.12.4. Production of entomophilic nematode isolates in lepidopterous pests

The progeny production of different *Steinernema* and *Heterorhabditis* spp. was quantified in different lepidopterous insect pests (Table 33). In *S. litura* the maximum yield was from PDBC EN 6.71 (2.84 lakh IJ/larva). In *H. armigera* maximum yield was obtained from PDBC EN 2.1 from PDBC EN 6.71 (1.68 lakh IJ/larva). In *Phthorimaea operculella* maximum yield was obtained from PDBC EN 6.61 (0.94 IJ/larvae). All the isolates were on par in terms of yield from *Plutella xylostella* larvae. In *Opisina arenosella*, among *Heterorhabditis* spp. PDBC EN 13.22 yielded maximum (0.39 lakh IJ/larva) & among *Steinernema* sp. PDBC EN 3.2 yielded maximum (0.68 lakh IJ / larva).

Table 33. Yield of Ijs of entomophilic nematodes from last instar larvae of different insects

| Isolate | Per cent mortality of larvae after 72h of exposure | | | | |
|---|---|---|---|---|---|
| | *S.litura* | *H.armigera* | *P.operculella* | *P.xylostella* | *O.arenosella* |
| PDBC EN 2.1(S) | 1.36 | 1.68 | 0.13 | 0.08 | 0.33 |
| PDBC EN 3.1(s) | 1.10 | 0.68 | 0.14 | 0.07 | 0.56 |
| PDBC EN 3.2 (S) | 0.96 | 0.76 | 0.17 | 0.06 | 0.68 |
| PDBC EN 6.11 (S) | 0.74 | 0.69 | 0.083 | 0.04 | - |
| PDBC EN 6.61 (S) | 0.90 | 0.54 | 0.94 | 0.05 | - |
| PDBC EN 13.1 (S) | 0.82 | 0.42 | 0.065 | 0.03 | - |
| PDBC EN 13.21 (S) | 0.57 | 0.68 | 0.061 | 0.02 | - |
| PDBC EN 14.1 (S) | 0.66 | 0.11 | 0.056 | 0.04 | - |
| PDBC EN 6.71 (H) | 2.84 | 1.68 | 0.15 | 0.01 | - |
| PDBC EN 13.3 (H) | 1.88 | 0.83 | 0.54 | 0.011 | 0.24 |
| *H.indicus* | 0.58 | 0.46 | 0.20 | 0.014 | 0.39 |
| PDBC EN 14.3 | 0.065 | 0.043 | 0.12 | 0.010 | - |

### 4.12.5. Mass production of EPN isolates in artificial diets

The mass production of *Steinernema* spp. and *Heterorhabditis* sp. were attempted with different artificial media. Wout's medium was found to be highly suitable for all the *Steinernema* spp. and *Heterorhabditis* sp. tested with an average production of 25-40 lakh IJ/250-ml flask (Table 34). However, egg yolk medium without milk powder (egg yolk I) yielded maximum IJs of *Steinernema* sp. PDBC EN 2.1 (58.29 lakh/flask).

Table 34. Mass production of entomophilic nematodes in different artificial media (lakh Ijs / 250ml flask)

| Nematode isolates | Wouts | Wheat | Egg yolk (1) | Egg yolk (2) | Dog biscuit |
|---|---|---|---|---|---|
| PDBC EN 2.1 (S) | 38.76 | x | 58.29 | 29.87 | x |
| PBDC EN 6.61 (S) | 32.82 | x | 22.41 | 17.98 | x |
| PDBC EN 13.1 (S) | 31.49 | x | 20.67 | x | x |
| PDBC EN 6.11 (S) | 26.98 | x | x | 7.88 | x |
| PDBC EN 3.1 (S) | x | x | x | x | x |
| PDBC EN 3.2 (S) | x | x | x | x | x |

x = did not multiply

### 4.12.6. Testing formulations for efficacy against insects

Alginate formulation with entomophilic nematodes embedded was prepared and the efficiency of the formulation evaluated for *S. litura* and *H. armigera* by exposing the final instar larvae to the formulation for 72 h. The mortality of the larvae of both species increased with increase in exposure time. However, different isolates performed differently (Table 35).

Table 35. Mortality of *S. litura* and *H. armigera* larvae fed on alginate formulation of different nematode isolates

| Nematode isolates | Per cent mortality of insect larvae after (h) | | | | | |
|---|---|---|---|---|---|---|
| | *Spodopetra litura* | | | *Helicoverpa armigera* | | |
| | 24 | 48 | 72 | 24 | 48 | 72 |
| PDBC EN 2.1 (S) | 66.67 | 100.00 | 100.00 | 0.00 | 44.44 | 77.78 |
| PDBC en 1.3 (S) | 0.00 | 66.67 | 88.89 | 0.00 | 0.00 | 66.67 |
| PDBC EN 1.41 (H) | 0.00 | 77.78 | 88.89 | 0.00 | 33.33 | 77.78 |
| PDBC EN 7.2 (S) | 0.00 | 0.00 | 33.33 | 0.00 | 0.00 | 55.56 |
| PDBC EN 7.1 (H) | 0.00 | 44.44 | 66.67 | 0.00 | 66.67 | 88.89 |
| PDBC EN 13.3 (H) | 0.00 | 88.89 | 100.00 | 0.00 | 88.89 | 88.89 |

*Steinernema* spp. and *Heterorhabditis* spp. were equally effective against *S. litura*. In the case of *H. armigera*, the formulations of *Heterorhabditis* spp. were more effective than *Steinernema* spp. with a mortality range of 88-100 %.

## 4.13. Studies on nematophagous fungi and bacteria with special reference to *Paecilomyces lilacinus* and *Pasteuria penetrans*

### 4.13.1. *In vitro* testing of isolated nematophagous fungi against plant parasitic nematodes

*Paecilomyces lilacinus* (2 isolates), *Fusarium oxysporum, F. sporotrichoides, Phoma glomerata* and *Trichoderma viride* were isolated from eggs of *Meloidogyne incognita.*

The fungi were grown in PDA medium in petridishes for one week to get full establishment in the petridishes. Ten egg masses of *Meloidogyne incognita* and *Rotylenchulus reniformis* and ten cysts of *Heterodera cajani* were placed in the petridishes and kept at 24$^0$C for two weeks to evaluate their efficacy against nematodes.

Hundred per cent parasitisation of all the nematodes were recorded with *P. lilacinus* and *F. oxysporum. F. sporotrichoides* recorded 30, 25 and 28 per cent parasitisation, respectively. *P. glomerata* recorded 24, 17 and 16 per cent, respectively. There was no parasitisation of egg masses and cysts with *T. viride*.

### 4.13.2. Evaluation of substrates for mass production of *Verticillium chlamydosporium* against *Heterodera cajani* in pigeonpea

*Verticillium chlamydosporium* was mass cultured in different substrates such as sorghum grains, broken wheat grains, wheat bran, broken maize grains and rice grains. Sorghum grains was found suitable for mass production of fungus. The colony forming unit (CFU) of the fungus in sorghum grains was 65 x $10^4$. Total number of spores in sorghum grains was 78x$10^4$. The next suitable substrate was wheat grain. (Table 36).

Table 36. Growth of *Verticillium chlamydosporium* on different substrates

| Substrate | CFU | Spores |
|---|---|---|
| Sorghum grains | 65 x $10^4$ | 78 x $10^4$ |
| Maize | 39 x $10^4$ | 40 x $10^4$ |
| Wheat grains (broken) | 57 x $10^4$ | 61 x $10^4$ |
| Wheat bran | 33 x $10^4$ | 38 x $10^4$ |
| Rice grains | 12 x $10^4$ | 15 x $10^4$ |

A pot culture experiment was conducted to find out the efficacy of *V. chlamydosporium* cultured on different substrates against the cyst nematode *H. cajani* in pigeonpea. Among the substrates sorghum grain recorded highest plant height (18.2 cm) which was on par with uninoculated treatment (Table 37).

Table 37. Evaluation of *V. chlamydosporium* grown on different substrates against *H.cajani*

| Substrate | Plant height(cm) | Root weight (g) | No.of cysts / root @ | Per cent reduction | Parasitisation (%) * |
|---|---|---|---|---|---|
| Sorghum | 18.2 | 1.2 | 8.0 (2.9) | 56 | 61.0 (51.4) |
| Wheat grains | 17.2 | 1.0 | 9.0 (3.1) | 52 | 54.3 (47.4) |
| Wheat bran | 15.7 | 0.8 | 11.3 (3.4) | 39 | 55.0 (47.8) |
| Maize | 16.7 | 0.9 | 9.6 (3.2) | 48 | 52.6 (46.5) |
| Rice | 15.7 | 0.7 | 11.0 (3.4) | 40 | 45.6 (42.5) |
| Nematode alone | 14.6 | 0.6 | 18.6 (4.3) | - | 0.0 (1.28) |
| Control (without inoculation) | 19.2 | 1.5 | 0.0 (0.7) | - | 0.0 (1.28) |
| CD (P=0.05) | 1.1 | 0.2 | (0.3) | - | (2.9) |

* Figures in parentheses are arc sin transformed values

@ Figures in parentheses are square root transformed values

There was a reduction of cysts population observed in all the substrates treated plants and it ranges between 39 to 56 per cent over nematode alone treated plants. Among the substrates sorghum recorded maximum reduction (56.0 %) followed by wheat grain (52.0%).

Successful parasitism of cysts by *V. chlamydosporium* was recorded with all the substrates applied to the pigeonpea plants. The parasitism ranged from 45.6 to 61 per cent. Maximum parasitism of cysts was recorded in sorghum followed by wheat bran.

### 4.13.3. Efficacy of granular formulation of nematophagous fungi for the biological control of *Meloidogyne incognita*

The efficiency of granular formulation of nematophagous fungi viz. *Arthrobotrys oligospora, Paecilomyces lilacinus, Verticillium chlamydosporium, Gliocladium virens* and *Trichoderma harzianum* for the biological control of *Meloidogyne incognita,* was evaluated in a pot culture experiment with tomato.

Among the fungi tested, *V. chlamydosporium* recorded maximum shoot length (29.9 cm) and shoot weight (29.9 g). The application of nematophagous fungi in the granular form resulted in good growth of root in all fungi (Table 38).

Table 38. Granular formulation of nematophagous fungi on the growth of tomato

| Treatment | Shoot length (cm) | Root length (cm) | Shoot weight (g) | Root weight (g) |
|---|---|---|---|---|
| *Arthrobotrys oligospora* + Mi | 23.9 | 24.1 | 24.8 | 16.3 |
| *Paecilomyces lilacinus* + Mi | 26.0 | 24.3 | 28.2 | 15.8 |
| *Verticillium chlamydosporium*+Mi | 29.9 | 25.7 | 29.9 | 18.3 |
| *Gliocladium virens* + Mi | 23.9 | 24.4 | 25.5 | 16.3 |
| *Trichoderma harzianum* + Mi | 22.4 | 23.1 | 24.8 | 15.6 |
| Nematode alone | 22.9 | 15.4 | 14.6 | 10.8 |
| Control (Not inoculated) | 29.9 | 25.2 | 31.6 | 18.5 |
| CD (P=0.05) | 3.8 | 4.4 | 3.2 | 2.5 |

Mi : *Meloidogyne incognita*

The nematode alone treated plants counted 148.7 galls/g root, whereas the plants which received granular form of fungi recorded reduced number of galls with *V. chlamydosporium* recording the least. The same trend of result was observed in soil nematode population also, where 56 per cent reduction of nematode population was observed in *V. chlamydosporium* followed by *P. lilacinus* (54 %) (Table 39).

Table 39. Effect of granular formulation of nematophagous fungi on reproduction of *M. incognita* in tomato

| Treatment | No. of galls / g of root | No. of egg masses/g of root * | Nematode population / 200 g soil | Parasitised egg masses (%) ** |
|---|---|---|---|---|
| *Arthrobotrys oligospora* + Mi | 57.0(7.4) | 40.7(6.3) | 207.5(14.4) | 6.0(13.8) |
| *Paecilomyces lilacinus* + Mi | 49.2(6.9) | 29.5(5.3) | 192.5(13.6) | 34.5(35.9) |
| *Verticillium chlamydosporium* + Mi | 43.7(6.5) | 27.2(5.17) | 185.0(13.6) | 53.7(47.1) |
| *Gliocladium virens* + Mi | 82.5(9.0) | 45.7(6.7) | 202.5(14.2) | 6.7(14.9) |
| *Trichoderma harzianum* + Mi | 82.5(9.0) | 48.7(6.9) | 245.0(15.6) | 6.5(14.7) |
| Nematode alone | 148.7(12.1) | 93.7(9.6) | 417.5(20.4) | 0.0(0.0) |
| Control (Not inoculated) | 0(0.2) | 0(0.2) | 0(0.2) | 0(0.0) |
| CD (P=0.05) | (1.3) | (0.8) | (1.0) | (3.8) |

*Mi : Meloidogyne incognita;* * Figures in parentheses are $\sqrt{x+0.05}$ transformed values; ** Figures in parentheses are arc sin transformed values

*V. chlamydosporium* and *P. lilacinus* were found very effective to reduce the egg masses in the root system and per cent reduction of eggmasses were 70 and 68, respectively, over the nematode alone treatment. Parasitism of egg masses was also obtained with *V. chlamydosporium* (53.75 %) followed by *P. lilacinus* (34.5%).

### 4.13.4. Efficacy of talc-based formulation of nematophagous fungi against *M. incognita*

A pot culture experiment was conducted to test the efficacy of talc based formulations of five nematophagous fungi against *M. incognita* on sunflower cv. Morden.

All the nematophagous fungi formulated in talc were found to be effective against *M. incognita*. They were also able to improve the growth parameters of sunflower. Among the fungi tested *T. virens* recorded maximum plant height (67.73 cm) followed by *P. lilacinus* (66.98 cm). *T. virens* recorded maximum root weight followed by *V. chlamydosporium* and *P. lilacinus* (Table 40). When compared with the nematode alone treatment, all the nematophagous fungi were able to reduce the number of galls. The maximum reduction ( 56 %) was recorded in *A. oligospora* followed by *P. lilacinus* (53 %). *V. chlamydosporium* and *P. lilacinus* were effective in reducing the eggmasses in roots and the per cent reduction was 74 and 70 per cent, respectively, compared to nematode alone. This indicates that the two fungi are efficient parasitisers. Successful parasitism of egg masses (48.25 %) was obtained with the nematophagous fungi, *P. lilacinus* and was found to be superior to *V. chlamydosporium* which was next best parasitising 33.5 per cent of the egg masses (Table 41).

Table 40. Efficacy of talc formulated nematophagous fungi on the growth of sunflower and growth of the fungi

| Treatment | Plant height (cm) | Root weight (g) | CFU of fungi | |
|---|---|---|---|---|
| | | | per g talc | per g soil at harvest |
| *Arthrobotrys oligospora* | 56.65 | 3.23 | 4.2 X 107 | 3.8 X 107 |
| *Paecilomyces lilacinus* | 66.98 | 5.00 | 5.2 X 107 | 4.8 X 107 |
| *Verticillium chlamydosporium* | 61.08 | 5.10 | 6.0 X 107 | 3.5 X 107 |
| *Gliocladium virens* | 67.73 | 5.13 | 7.3 X 107 | 5.4 X 107 |
| *Trichoderma harzianum* | 66.68 | 4.43 | 7.4 X 107 | 5.8 X 107 |
| Nematode alone | 53.65 | 2.77 | - | - |
| Control (Not inoculated) | 73.30 | 6.40 | - | - |
| CD (P=0.05) | 4.49 | 0.51 | - | - |

Table 41. Efficacy of talc formulated nematophagous fungi on reproduction of *M. incognita* on sunflower

| Treatment | No. of galls / g of root* | No. of egg masses/g of root * | Nematode population / 200 g soil* | Parasitised egg masses (%) ** |
|---|---|---|---|---|
| *Arthrobotrys oligospora* | 67.2(8.2) | 54.0(7.3) | 155.0(12.4) | 2.7(9.5) |
| *Paecilomyces lilacinus* | 71.2(8.4) | 29.5(5.4) | 105.0(10.7) | 48.2(44.0) |
| *Verticillium chlamydosporium* | 75.2(8.7) | 26.2(5.1) | 115.0(5.7) | 33.5(35.3) |
| *Gliocladium virens* | 80.5(9.0) | 46.2(6.7) | 162.5(12.7) | 8.2(16.6) |
| *Trichoderma harzianum* | 85.0(9.2) | 50.2(7.1) | 167.5(12.9) | 7.7(16.0) |
| Nematode alone | 152.7(12.3) | 101.2(10.1) | 302.5(17.4) | 0.0(1.2) |
| Control (Not inoculated) | 0(0.7) | 0(0.7) | 0(0.7) | 0(1.28) |
| CD (P=0.05) | (0.6) | (0.7) | (3.5) | (3.1) |

* Figures in parentheses are $\sqrt{x+0.5}$ transformed values; ** Figures in parentheses are arc sin transformed values.

A considerable reduction in soil nematode population was noticed in all the fungal treatments with *P. lilacinus* recording least soil nematode population (65% reduction).

## 4.14. Studies on weed pathogens with particular reference to parthenium and water hyacinth

### 4.14.1. Survey for parthenium pathogens

Surveys were undertaken for parthenium diseases in urban and rural districts of Bangalore. Disease symptoms that were targeted include various stem and leaf spots, blights, lesions, mildews, etc. The procedure suggested by Hanlin (1982), with suitable modifications, was used for isolation and purification of fungi from diseased samples. All the fungal species that satisfied Koch's postulates were preserved for future studies. *Phoma* was the dominant genus found frequently associated with lesions on parthenium plants in various areas. *P. chrysanthemicola* and *P. eupyrina* were regularly collected at a number of places. *Alternaria spp.* was equally dominant on the weed during the monsoons. A

blight disease, incited by *Rhizoctonia solani*, was also consistently isolated from diseased parthenium plants. For the first time the association of *Nigrospora spherica* with a leaf spot disease of parthenium was unravelled.

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

*Fusarium pallidoroseum* (Cooke) Sacc. (*F. semitectum* Auct.), a leaf-spotting pathogen showed desirable characteristics for development as a mycoherbicide for parthenium. The most pathogenic isolate (WF(Ph)30) of the fungus was taken up for further investigations. A single-spore isolate of *F. pallidoroseum* was propagated on potato dextrose agar (PDA) so as to get a constant supply of the same for different experiments. Stock cultures were stored at 4 to 5 °C either on PDA (freshly prepared or proprietary) slants, 1/2 PDA, 1/5 PDA or on potato carrot agar (PCA) and in some cases in potato dextrose broth (PDB).

#### 4.14.2.1. Effect of nutrient media including addition of parthenium leaf decoction and yeast extract on mycelial growth

Growth of *F. pallidoroseum* was observed on different common agar media. The media tested were potato dextrose agar (PDA), both freshly prepared PDA (FPDA) and Hi-Media brand of dehydrated PDA (HMPDA), nutrient agar (NA), commeal agar (CMA), Richard's synthetic agar (RSA), Kenknight Munaier medium (KMM), malt extract agar (MEA), potato carrot agar (PCA), oatmeal agar (OMA) and Czapek-Dox agar (CDA). All the media were dispensed into petridishes and inoculated with 8-mm agar plugs from 7-day-old cultures of *F. pallidoroseum*. Three replicates of each medium were incubated for 7 days under normal room conditions. The radial growth was recorded daily and the growth rate calculated in mm/day. Variations in radial growth were evident on the different nutrient media (Fig. 11). Whereas the maximum growth (12.0 mm/day) occurred on RSA and MEA, the minimum growth (7.4 mm/day) of the fungus was recorded on CDA.

The effect of addition of parthenium decoction and yeast to media on mycelial growth was evaluated. Leaf decoction (P) was prepared by boiling 200 g of parthenium leaves in 1 L of water and straining the mixture through cheese cloth. The resulting broth was used as the liquid component in preparation of FPDA, HMPDA and CDA. Corresponding media were prepared with distilled water to serve as checks. Yeast extract (Y) at 5 g/L was added to different media to study if there was any enhancement in growth. Both parthenium leaf decoction and yeast extract showed positive effect on the growth of the fungus as additives to the three media tested (Fig. 12). Almost the same

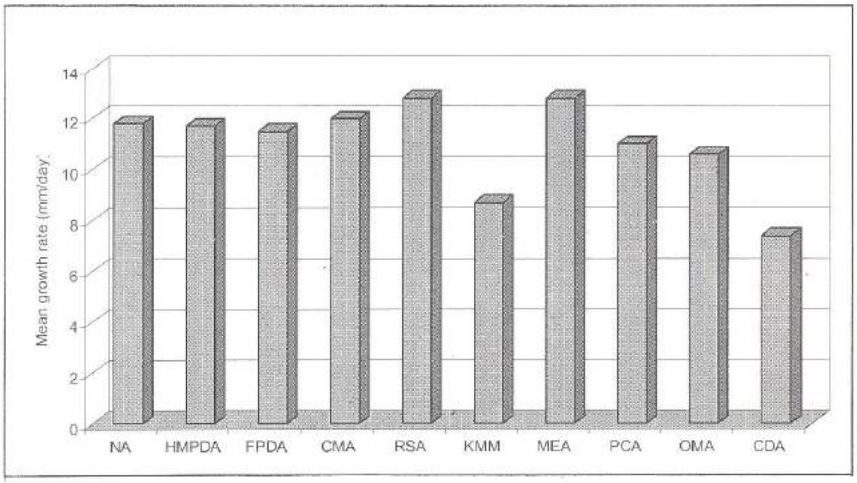


**Fig. 11. Effect of nutrient medium on *Fusarium pallidoroseum* mycelial growth**

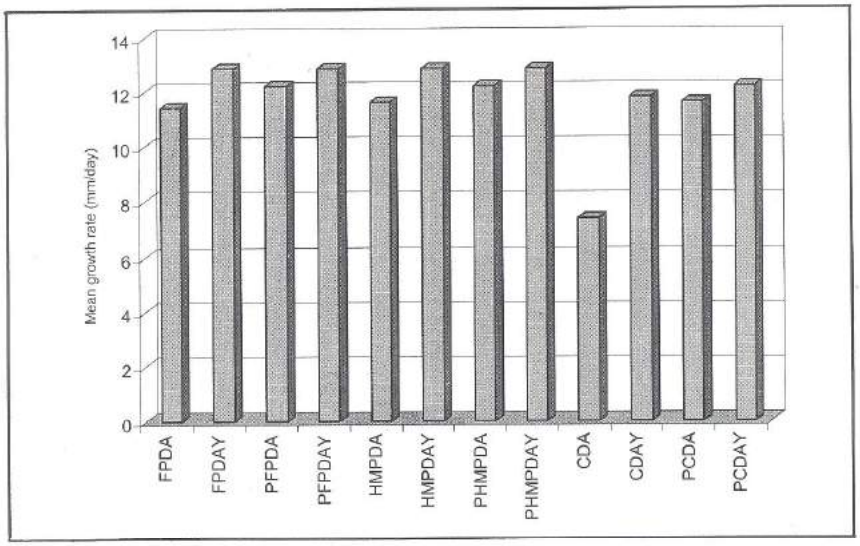


**Fig. 12. Effect of addition of parthenium leaf decoction and yeast extract on *Fusarium pallidoroseum* mycelial growth**

pattern of growth rates was observed on all the supplemented media. Yeast was the better additive. The maximum growth (12.9 mm/day) of the fungus was obtained on FPDAY, PFPDAY, HMPDAY and PHMPDAY. Growth was also enhanced on CDA due to the addition of either leaf extract (11.6 mm/day), or yeast (11.8 mm/day) or both (12.2 mm/day), clearly indicating the growth promoting effects of the supplements.

#### 4.14.2.2. Effect conidial density on disease development

The effect of various spore densities of *F. pallidoroseum* in an oil emulsion on disease development was determined in a pot culture experiment. Parthenium plants of leaf stage 5-7 were sprayed with $10^6$, $10^7$, $10^8$, $10^9$ and $10^{10}$ conidia/ml applied in oil emulsion and were exposed to 100% RH for 24 h.

After 2 weeks of inoculation, the leaves of each plant were counted and visually rated for disease symptoms using a 0-6 depending on surface area effected. The total necrotic leaf area was obtained as a percentage using the formula (2.5 x n1 + 15 x n2 + 50 x n3 + 85 x n4 + 97.5 x n5 + 100 x n6)/N, where nx is the number of leaves with a rating x and N is the total number of leaves treated. Whereas the highest necrotic leaf area (98.22%) was obtained on plants sprayed with $10^{10}$ conidia/mL, the lowest (33.67%) was noticed on plants treated with $10^6$ conidia/mL. The increments in disease severity were almost constant above the level $10^8$.

#### 4.14.2.3. Effect of plant growth stage on disease development

Parthenium plants at leaf stages 3-5, 6-9 or 10-13 were sprayed with a suspension of $10^8$ conidia/mL in oil emulsion and exposed to 100% RH for 24 h. After 2 weeks of inoculation, the leaves of each plant sprayed with the fungus were counted and visually rated. All the growth stages of parthenium were susceptible to the pathogen, younger plants being more susceptible than older ones. Plants at growth stages 3-5 and 6-9 were significantly more susceptible than those at growth stage 10-13. The first two stages had 94.56% and 91.78% necrotic area, respectively.

#### 4.14.2.4 Host-range screening

Two methods of screening viz., the detached leaf technique *(in vitro)* and the *in vivo* method consisting of intact plants were employed. 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. Conidial suspension of *F. pallidoroseum* at $10^8$ conidia/mL was evenly brushed on both surfaces of the leaves. All the plant species tested had 10 replicates of inoculated leaves. Observations were taken every day for any visible signs of infection up to a week. In the second method, intact healthy plants were sprayed with the conidial suspension and covered with polythene bags to maintain a high humidity for 48 h. Observations were taken daily to record symptom development for a week. Treated plants and control plants were replicated 10 times. This preliminary host-range testing determined that all the crops, including those species of the Asteraceae, including the eight sunflower cultivars, were not susceptible to *F. pallidoroseum* (Table 42).

Table 42. Reaction of non-target plants tested for susceptibility to *Fusarium pallidoroseum**

| Family | Test plant species / Cultivars | Reaction |
|---|---|---|
| Asteraceae | Sunflower *(Helianthus annuus)* KBSH1, Morden, MSF17, EC68414, PAC1091, GAUSUF15, Arun, SH3322 | - |
| | Zinnia *(Zinnia elegans)*, Cany cane mix, Pulcino mix | - |
| | Calendula *(Calendula officinalis)*, Touch red-orange, Touch red-yellow | - |
| | Aster *(Aster amellus)*, Pot 'n' patio, Powder puffs mix | - |
| | Cosmos *(Cosmos bipinnatus)*, Sensation mix, Sunny red | - |
| Papilionaceae | Groundnut *(Arachis hypogaea)*, JL24 | - |
| | Cowpea *(Vigna unguiculata)*, C152, Arka Garima | - |
| | Blackgram *(Phaseolus mungo var. radiatus)*, T9, LBG402 | - |
| | French bean *(Phaseolus vulgaris)*, Arka Komal | - |
| | Cluster bean *(Cyamopsis tetragonoloba)*, | - |
| Solanaceae | Brinjal *(Solanum melongena)*, Arka Nidhi, Arka Sheel, Bhagyamathi, Shyamala, Pusa Purple Long, Pusa Purple Round, Sourabha, PPL, CVK | - |
| | Tomato *(Lycopersicon esculentum)*, Arka Saurabh, Pusa Ruby, Marutham, Dwarf Hybrid, S22 | - |
| | Chillies *(Capsicum annuum)*, LCG4, LCG5, LCA206, LCA235, LCA960, GA, X235 | - |
| Cucurbitaceae | Pumpkin *(Cucurbita moschata)*, Arka Chandan, Arka Surya | - |

| Family | Test plant species / Cultivars | Reaction |
|---|---|---|
| | Bottle gourd *(Lagenaria siceraria)*, Arka Bahar, PSPL | - |
| | Musk melon *(Cucumis melo)*, Arka Jeet | - |
| | Water melon *(Citrullus lanatus)*, Madhu | - |
| | Cucumber *(Cucumis sativus)*, Green Long, Priya | - |
| Cruciferae | Radish *(Raphanus sativus)*, Arka Nishant, Pusa Chetaki, No.7, Pusa Cheti | - |
| | Cabbage *(Brassica oleraceae)*, Unnati | - |
| | Knol Khol *(Brassica caulorapa)*, EW | - |
| Malvaceae | Okra *(Abelmoschus esculentus)*, Arka Abhay, Varsha | - |
| Amaranthaceae | Amaranthus *(Amaranthus bicola)*, Arka Suguna | - |
| Chenopodiaceae | Beet *(Beta vulgaris)*, Ruby Queen | - |
| Umbelliferae | Carrot *(Daucus carota)*, Early Nantes | - |
| Gramineae | Finger millet *(Eleusine coracana)*, HR911, Indaf9, GPU28 | - |
| | Corn *(Zea mays)*, Ganga11, C6, Himalaya23, Kanchan | - |

* Results from tests with detached leaves and intact plants.

### 4.14.3. Pathogens of water hyacinth and their preliminary evaluation

Surveys were conducted to record pathogens of water hyacinth, *Eichhornia crassipes*. Studies on the pathogenicity of the isolated fungi were done on intact plants. 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. The plants were covered with clear polythene bags for 48 h to maintain a high relative humidity. *Botryodiplodia theobromae, Xylaria sp., Rhizoctonia sp.* and *Alternaria sp.* were some of the fungi associated with either leaf spots or blights of water hyacinth. All the fungi could reproduce the symptoms on detached as well as intact leaves of the host.

### 4.14.4. Studies on the mycoherbicidal properties of *Gliocladium virens* and related species towards parthenium

*Glicladium virens, G. catenulatum, G. deliquescens and G. roseum* were grown either in a special nutrient broth or in potato dextrose broth. The final pH of the medium was adjusted to be below 7.0 as the fungus does not produce the phytotoxic metabolites

under alkaline conditions. Spore-less culture filtrate was obtained after incubation for 15 days. The culture filtrate (100%) was diluted with sterile distilled water to get desired concentrations. Sterile distilled water alone served as control.

#### 4.14.4.1. Pre-emergence effect

Parthenium seeds obtained from natural populations were soaked in 70 and 100% concentration of culture filtrates of all the four *Gliocladium* species for 6 h. Treated seeds were either placed on moist blotters in petri dishes. Each treatment was replicated thrice and every replication consisted of 100 seeds. After incubation for 3 weeks, the percentage of germination was recorded. *G. virens* could suppress seed germination totally at a minimum concentration of 70% but no other species was able to do the same at this concentration (Table 43). *G. deliquescens* and *G. roseum* were effective in completely inhibiting seed germination in undiluted form.

Table 43. Effect of culture filtrates of different *Gliocladium* species on parthenium seed germination

| Species | Concentration of culture filtrate (%) | Germination (%) | Per cent decrease over control |
|---|---|---|---|
| *Gliocladium catenulatum* | 70 | 25.33 (30.22) | 70.77 |
| | 100 | 4.33 (11.90) | 95.00 |
| *Gliocladium deliquescens* | 70 | 16.67 (24.09) | 80.77 |
| | 100 | 0.00 (0.00) | 100.00 |
| *Gliocladium roseum* | 70 | 21.33 (27.49) | 75.39 |
| | 100 | 0.00 (0.00) | 100.00 |
| *Gliocladium virens* | 70 | 0.00 (0.00) | 100.00 |
| | 100 | 0.00 (0.00) | 100.00 |
| Control | - | 86.67 (68.60) | - |
| CD (P=0.05) | - | (1.83) | - |

Figures in parentheses are angular-transformed values.

To determine the effect of incorporation of *G. virens* in soil on germination of parthenium an experiment was conducted using the fungus grown on rice. The fungus-rice mixture was added to sterile garden soil taken in small plastic cups at 15, 12.5, 10, 7.5 and 5% (v/v). An equivalent amount of rice alone was added to the controls. After three weeks of incubation, the highest treatment level, with 15% of the total volume consisting of the antagonist mixture, recorded 100% reduction in seed germination (Table

44). Germination was dramatically depressed (62.44%) even at the 5% level.

Table 44. Effect of addition of *Gliocladium* virens on germination of parthenium in soil

| Application rate (% of total soil weight) | Germination (%) | Per cent decrease over control |
|---|---|---|
| 15.0 | 0.00 (0.00) | 100.00 |
| 12.5 | 7.00(15.80) | 91.14 |
| 10.0 | 12.33(20.90) | 84.39 |
| 7.5 | 20.00(26.90) | 74.68 |
| 5.0 | 29.67(33.30) | 62.44 |
| Control | 79.00(63.10) | - |
| CD (P=0.05) | (2.47) | - |

Figures in parentheses are angular transformed values.

**4.14.4.2. Post-emergence effect**

Undiluted culture filtrates of all the four species of *Gliocladium* were applied to pots consisting 10-15 day old seedlings in such a manner that the root region of the plants was sufficiently moistened. All the treatments were replicated thrice with each pot consisting of 100 seedlings. Per cent death of seedlings was recorded and root necrosis was observed on the third day when all the plants were dead in pots applied with *G. virens filtrate*. The undiluted culture filtrates of all the four *Gliocladium spp.* showed post-emergence mycoherbicidal effect on parthenium and *G. virens* could bring about 100% seedling mortality on the third day (Table 45).

Table 45. Post-emergence effects of culture filtrates of different *Gliocladium* species against parthenium

| Species | Death of seedlings on the third day (%) |
|---|---|
| *Gliocladium catenulatum* | 81.00 (64.17) |
| *Gliocladium deliquescens* | 93.00 (74.82) |
| *Gliocladium roseum* | 90.00 (71.56) |
| *Gliocladium virens* | 100.00 (90.00) |
| Control | 0.00 (0.00) |
| CD (P=0.05) | (2.89) |

Figures in parentheses are angular transformed values.

## 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, Aphis craccivora, Ferrisia virgata, Maconelicoccus hirsutus, Planococcus citri, P. lilacinus, Hemiberlesia lataniae, Helicoverpa armigera, and Plutella xylostella* are being maintained using natural food and 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.nosatai, Adelencyrtus mayurai, Coccidoxenoides peregrinus* and eleven species of *Trichogramma* and its different strains were maintained.

### 4.15.3. Predators

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

### 4.15.4. Insects pathogens

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

Antagonistic fungi maintained (with number of isolates in parantheses) are *Trichoderma harzianum*(35), *T. viride* (25), *T. hamatum* (3), *T. virens* (11), *T. koningi* (8), *T. pseudokoningi* (2), *T. piluliferum* (8), *T. citrinoviride* (3), *T. longibrachiatum* (2), *T. polysporum* (2), *Gliocladium deliquescens* (4), *G. roseum* (2), *G. catenulatum* (01) and *Chaetomium globosum* (1).

Bacterial antagonists (number of isolates in parentheses) maintained are Fluorescent pseudomonads (70), *Pseudomonas fluorescens* (24), *Pseudomonas putida*

(1), *Pseudomonas* spp. (4), *Alcaligenes odorans* (1), *Bacillus pantothenticus* (1) and *Bacillus subtilis* (1).

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

### 4.16. Shipments of host insects and natural enemies

During the reporting period, 63 cultures of various host insects and 108 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 BIPM

Information system PDBC-INFOBASE has been developed to help the farmers, extension workers, industry, entomologists, biocontrol-experts, students, teachers, research managers and planners. This user friendly, menu driven, self-explanatory software contains information on Biocontrol Resources in the country. Ten floppies contain the visuals, text and tables, which can be retrieved at the touch of a finger. The programme can be used on any PC containing WIN-95.

### 4.18. Biological suppression of sugarcane pests

#### 4.18.1. Survey and seasonal fluctuation of natural enemies of sugarcane borers (PAU, Ludhiana)

The survey and seasonal fluctuation of natural enemies of sugarcane borers were studied at farmer's field at Behram, Nawanshahr district, Punjab at fortnightly interval from April 1998 to March 1999. Egg clusters, larvae and pupae of borers were collected and reared in the laboratory for emergence of natural enemies and/or the next stage of the pest.

Forty-six egg masses, 147 larvae and 98 pupae of *Chilo infuscatellus* were collected during the period under study. In case of eggs, 15.2 per cent parasitisation was observed and two parasitoids namely *Trichogramma chilonis* (8.7%) and *T. chilotraeae*

(6.5%) were recorded during July. Out of the total larval parasitization of 17.6 per cent, 8.2 per cent was by *Cotesia flavipes* and 6.8 per cent by *Glyptomorpha nicevillei*. The parasitisation by *Isotima javensis* (2.0%) and *Bracon* sp. (0.6%) was low. The larval parasitoids were observed during May-June except *Bracon* sp. which was recorded during April. No pupal parasitoid was recorded.

In the case of stalk borer (*Chilo auricilius*) only 4 egg masses could be collected during the season and no egg parasitoid was recovered. However, out of the 215 larvae collected 45.5 per cent were parasitised. Four larval parasitoids *viz., C. flavipes* (16.2%), *G. nicevillei* (8.46%), *I. javensis* (3.7%) and *Sturmiopsis inferens* (17.2%) were recorded. *S. inferens* was recorded during December 1998 to March 1999, while the remaining three larval parasitoids were observed during September-October 1998. Although 117 pupae were collected no pupal parasitoid emerged.

Out of the 17 egg masses of Gurdaspur borer (*Acigona steniellus*) collected during the season, 5.9 per cent eggs were parasitised by *T. chilonis*. Among the 196 larvae collected, the extent of parasitism was 21.6 per cent. Parasitoids comprised *C. flavipes* (6.6%), *G. nicevillei* (8.6%), *I. javensis* (4.1%) and *Rhaconotus signipennis* (2.3%). The larval parasitoids were recovered during September-October. A pupal parasitoid, *Tetrastichus israeli* was recorded during September causing 2.3 per cent parasitisation.

*Telenomus dignoides* (48.5%) was the most abundantly available egg parasitoid of top borer, *Scirpophaga excerptalis* during the period. Two other egg parasitoids *i.e. T. chilonis* (5.8%) and *T. japonicum* (2.9%) were also recorded during June-July. The larval parasitism was also quite high as out of 315 larvae collected, 52 per cent were parasitised. Three larval parasitoids namely, *G. nicevillei* (26.6%), *Rhaconotus scirpophage* (15.2%) and *I. javensis* (10.2%) were recovered during May-October. One hundred and eighty three pupae were collected, but no parasitoid was observed.

### 4.18.2. Control of early shoot borer, *Chilo infuscatellus* through release of *Trichogramma chilonis* (PAU, Ludhiana)

The experiment for the control of early shoot borer, *C. infuscatellus* was carried out at three locations i.e. Chak Hakim (Dist. Kapurthala), Khudi Kalan (Dist. Sangrur) and Regional Research Station, Kheri (Dist. Sangrur). *T. chilonis* was released 9 times at 10 days interval during April to June @ 50,000 per ha. At Chak Hakim the plot size was 2 ha for release plots and 1 ha for control. The plot size at Khudi Kalan was 8 ha for release plot and 0.4 ha for control. At Kheri the plot size was 18x 9 m with three replications. The incidence of the borer was recorded in July.

At Chak-Hakim, the incidence of early shoot borer was 10.2 per cent where *T. chilonis* was released as tricho-cards compared to 8.4 per cent where *T. chilonis* adults were released in the form of tricho-capsules as against 22.6 per cent in the control. The pest incidence at Kheri and Khudi Kalan was quite low and the incidence in release fields (2.3-2.8%) was lower than control (6.4-9.6%). The egg clusters of *C. infuscatellus* collected from all the treatments of Chak-Hakim showed relatively higher parasitisation (12.5-17.6%) compared to control (5.0%).

### 4.18.3. Control of stalk borer, *Chilo auricilius* through release of egg parasitoids, insecticides and their combination (PAU, Ludhiana)

An experiment was laid out to evaluate *T. chilonis,* insecticides and their combination against the stalk borer, *Chilo auricilius* at the Regional Research Station, Kheri (Dist. Sangrur) on a planted crop (CoJ 82) and a ratoon crop (CoJ 83). The releases of *T. chilonis* alone and in combination with insecticidal sprays were given as indicated in Table 46 and 47. The incidence of stalk borer was recorded in December on 50 canes in each plot.

The lowest incidence of stalk borer (2.5%) in planted crop was recorded in plots where *T. chilonis* was released (May to October) at 10 days interval @ 50,000/ha and it was on par with spray of monocrotophos + releases of *T. chilonis* (July to October), releases of *T. chilonis* alone (July to October) and two sprays of monocrotophos (Table 46).

In ratoon crop, the lowest incidence of stalk borer (1.6%) was recorded in plots where one spray of chlorpyriphos + one spray of endosulfan was given and it was on par with chlorpyriphos + releases of *T. chilonis* (July to October). The release of *T. chilonis* alone was significantly better than control (Table 47).

Table 46. Efficacy of egg parasitoids, insecticides and their combination against *Chilo auricilius* (planted crop)

| Treatment | Pest incidence (%)* |
|---|---|
| Spray of monocrotophos @ 1.750 l/ha and endosulfan @ 1.500 l/ha | 9.5 (17.97) |
| Spray of cypermethrin @ 500 ml/ha | 5.0 (12.91) |
| Spray of monocrotophos @ 1.750 l/ha (end May) | 17.8 (24.91) |
| Spray of cypermethrin @ 500 ml/ha (end May) | 19.2 (25.97) |
| Spray of endosulfan @ 1500 ml/ha (1st week September) | 7.0 (15.38) |
| Spray of cypermethrin @ 500 ml/ha (1st week September) | 5.5 (13.55) |
| Spray of monocrotophos @ 1.750 l/ha (end May) and release of *T. chilonis* @ 50,000/ha (July-October) | 5.4 (13.49) |
| Release of *T. chilonis* @ 50,000/ha (July-October) | 3.2 (10.25) |
| Release of *T. chilonis* @ 50,000/ha (May-October) | 2.5 (9.05) |
| Control | 19.8 (26.42) |
| CD (p=0.05) | (6.45) |

* Figures in parentheses are arc sin transformations

Table 47. Efficacy of egg parasitoid, insecticides and their combination against *Chilo auricilius* (Ratoon crop)

| Treatment | Pest incidence (%)* |
|---|---|
| Release of *T. chilonis* (July-October) | 2.2 (8.47) |
| Spray of chlorpyriphos @ 375 ml/ha (end May) and release of *T. chilonis* (July-October) | 1.9 (7.95) |
| Spray of chlorpyriphos 875 ml/ha (end May) | 4.1 (11.67) |
| Spray of chlorpyriphos @ 875 ml/ha (end May) and endosulfan @ 1.5 l/ha (1st week September) | 1.6 (7.33) |
| Spray of cypermethrin @ 500 ml/ha (end May) and endosulfan @ 1.5 l/ha (1st week September) | 4.3 (11.90) |
| Spray of endosulfan @ 1.5 l/ha (1st Week September) | 4.6 (12.36) |
| Control | 7.0 (15.34) |
| CD (P=0.05) | (4.24) |

* Figures in parentheses are arc sin transformations

It may be concluded that the release of *T. chilonis* at 10 days interval during July to October @ 50,000/ha is very effective for the control of stalk borer. Combination of insecticides with releases of *T. chilonis* did not give additional gains in the control of the pests.

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

The efficacy of *T. chilonis* for the control of stalk borer, *C. auricilius* was demonstrated at five locations i.e. Chak-Hakim (Dist. Kapurthala), Bahar Muzara (Dist. Nawanshahr), Burj Bhugat (Dist. Jalandhar), Khudi Kalan (Dist. Sangrur) and Shekhupura (Dist. Ludhiana). A plot size of 2 ha each at Chak-Hakim, Bahar Muzara and Burj Bhugat; 8 ha at Shekhupura and 16 ha at Khudi Kalan were selected. *T. chilonis* was released in the form of tricho-cards at 10 days interval during July to October @ 50,000/ ha. At three locations, *viz.*, Chak Hakim, Bahar Muzara and Burj Bhugat, the adults were also released in the form of tricho-capsules. The incidence of the stalk borer was recorded from 100 canes each from 5 spots in each plot during November. Recovery tests for parasitoids were done at Chak Hakim, Bahar Muzara and Burj Bhugat by exposing 5 egg clusters of *Chilo* sp. for 48 h.The exposed eggs were brought to the laboratory for observations.

The mean incidence (all locations) in tricho cards, adult release and control treatments was 17.6, 14.3 and 38.3 per cent, respectively. The reduction in the incidence of stalk borer over control was 54.0 per cent in plots where *T. chilonis* was released as tricho-cards as compared to 62.7 per cent where adults were released (Table 48). The recovery tests carried out at three locations namely Chak Hakim, Bahar Muzara and Burj Bhugat showed that 40.0 per cent egg clusters were parasitised where adults in the form of tricho-capsules were released as compared to 26.7 per cent where tricho cards were used. Parasitization of just 6.7 per cent was noticed in control (Table 49).

Table 48. Demonstration of effectiveness of *Trichogramma chilonis* against *Chilo auricilius* at different locations

| Treatment | Per cent incidence of *C. auricilius* at | | | | | | Per cent reduction in incidence over control |
|---|---|---|---|---|---|---|---|
| | Chak Hakim (Kapur-thrall) | Bahar Muzara (Nawanshahr) | Burg Bhugat (Jalan-dhar) | Khudi Kalan (Sangrur) | Shekhupura (Ludhi-ana) | Mean | |
| Release of *T. chilonis* (Tricho cards) | 12.6 | 15.6 | 22.2 | 12.2 | 26.4 | 17.6 | 54.0 |
| Release of *T. chilonis* (Tricho capsules) | 10.6 | 13.8 | 18.4 | - | - | 14.3 | 62.7 |
| Control | 19.8 | 28.8 | 53.6 | 37.6 | 51.8 | 38.3 | - |

Talbe 49. Recovery of *Trichogramma chilonis* from demonstration trials at different locations

| Treatment | Number * of egg clusters of *Chilo* sp. parasitised | | | |
|---|---|---|---|---|
| | Chak Hakim | Bahar Muzara | Burj Bhugat | Total** |
| Release of *T. chilonis* (Tricho-cards) | 2 | 1 | 1 | 4 (26.7) |
| Release of *T. chilonis* (Tricho capsules) | 3 | 2 | 1 | 6 (40.0) |
| Control | 1 | 0 | 0 | 1 (6.7) |

* Five egg clusters were exposed for 48 hrs

** Per cent egg clusters parasitised given in parentheses

The release of *T. chilonis* at 10 days interval during July-October @ 50,000/ha was quite effective in reducing the incidence of stalk borer and increasing the egg parasitism. The releases of adults from tricho capsules proved better than releases in the form of tricho-cards.

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

The experiment for evaluation of *C. flavipes* alone and in combination with the egg parasitoid, *T. chilonis* was carried out at Gohawar (Dist. Kapurthala) and Bassi (Dist. Jalandhar). There were six treatments *viz.*, *T. chilonis* (12 releases as tricho cards), *T. chilonis* (12 releases as tricho capsules), *C. flavipes* (single release and 6 releases), *T. chilonis* (12 releases) + *C. flavipes* (6 releases) and control. The releases of *T. chilonis* were made at 10 days interval and of *C. flavipes* at 20 days interval during July to October. The single release of *C. flavipes* was given during September. The dosage of *T. chilonis* was 50,000/ha and *C. flavipes* was 10,000/ha. The incidence of the stalk borer was recorded during November from 100 canes each from 5 spots. The plot size was 0.2 ha for each treatment.

The lowest incidence (10.6%) was recorded in plots where and *C. flavipes* were released followed by releases of *T. chilonis* as adults (11.2%) and as tricho cards (13.4%). Six releases of *C. flavipes* were found better than single release. At Bassi (Dist. Jalandhar) similar trend was observed where releases of both the parasitoids showed lower incidence (9.6%) of stalk borer followed by releases of *T. chilonis* (11.0 & 11.8%) as compared to 25.0 per cent in control. The sequential release of *T. chilonis* and *C. flavipes* reduced the incidence of stalk borer by 61.6 per cent. The releases of *T. chilonis* as adults and as tricho cards reduced the incidence by 57.8 and 50.9 per cent, respectively. Six releases of *C. flavipes* reduced the incidence by 38.4 per cent and single release was not effective (Table 50).

The results indicated that 12 releases of *T. chilonis* + 6 releases of *C. flavipes* proved very effective for the control of stalk borer.

Table 50. Sequential releases of *Trichogramma chilonis* and *Cotesia flavipes* for the control of *Chilo auricilius* in sugarcane at different locations in Punjab

| Treatment | No. of releases period | Per cent incidence of *C. auricilius* | | | Per cent reduction in incidence |
|---|---|---|---|---|---|
| | | Gohawar (Kapurthala) | Bassi (Jalandhar) | Mean | |
| *T. chilonis* (tricho-cards) | 12 (July-October) | 13.4 | 11.8 | 12.9 | 50.9 |
| *T. chilonis* (Adults) | 12 (July-October) | 11.2 | 11.0 | 11.1 | 57.8 |
| *C. flavipes* | 1 (September) | 26.6 | 19.2 | 22.9 | 12.9 |
| *C. flavipes* | 6 (July-October) | 17.8 | 14.6 | 16.2 | 38.4 |
| *T. chilonis* + *C. flavipes* | 12+6 (July-October) | 10.6 | 9.6 | 10.1 | 61.6 |
| Control | - | 27.6 | 25.0 | 26.3 | 0 |

### 4.18.6. Dispersal studies with *Trichogramma* chilonis (SBI, Coimbatore)

Two trials were conducted to study the dispersal pattern of *T. chilonis* in the field on 1 to 1 1/2 months old crop. UV-sterilized *Corcyra* egg cards (0.1 cc/card) were placed at distances of 1 to 10 m in eight directions from the point of release of the parasitoid. The cards were distributed in all directions and 2cc of parasitised egg cards were placed in the center. The trap card-bits were collected after 24 h of placement and observed for parasitisation in the laboratory. Parasitization and adult emergence rates were recorded from 100 eggs in each of the five randomly selected card bits.

Results indicated that there was parasitisation in almost all cards representing all distances and directions and per cent parasitisation did not vary with different directions. In test 1, at 2 m distance the average parasitism was 19.2% and emergence of adults was 31.5%; at 3 m the figures were 9.0% and 23.5%; at 10 m they were 56.6% (Table 51). In test 2, the parasitism was 34.6% and emergence was 8.4 % only at 2-m distance. The per cent parasitism ranged from 20.0 to 30.8% and the adult emergence was from 22.0 to 51.3% in cards placed at 3, 5, 7 and 10 m distance (Table 52).

Table 51. Dispersal studies on *Trichogramma chilonis* in the field - Trial-1

| Sample No. | 2m* | | 3m* | | 10m* | |
|---|---|---|---|---|---|---|
| | % parasitisation | % emergenc | % parasitisation | % emergence | % parasitisation | % emergence |
| 1 | 42.0 | 28.6 | 9.0 | 55.6 | 3.0 | 33.3 |
| 2 | 0.0 | 0.0 | 0.0 | 0.0 | 67.0 | 43.3 |
| 3 | 15.0 | 46.7 | 8.0 | 37.5 | 65.0 | 29.2 |
| 4 | 27.0 | 40.7 | 2.0 | 0.0 | 32.0 | 21.9 |
| 5 | 12.0 | 41.7 | 2.6 | 26.5 | 48.0 | 22.9 |
| Mean | 19.2 | 31.5 | 9.0 | 23.5 | 56.6 | 30.1 |

*n=100 eggs per sample card-bit

Table 52. Dispersal studies on *Trichogramma chilonis* in the field - Trial-2

| Sample No. | 2m* | | 3m* | | 5m* | | 7m* | | 10m* | |
|---|---|---|---|---|---|---|---|---|---|---|
| | % parasi-tisation | % emer-gence | % parasi-tisation | % emer-gence | % parasi-tisation | % emer-gence | % parasi-tisation | % emer-gence | % parasi-tisation | % emer-gence |
| 1 | 51.0 | 33.3 | 45.0 | 42.2 | 15.0 | 66.7 | 3.0 | 33.3 | 30.0 | 53.3 |
| 2 | 37.0 | 54.1 | 21.0 | 71.4 | 34.0 | 14.7 | 31.0 | 16.1 | 24.0 | 62.5 |
| 3 | 11.0 | 36.4 | 29.0 | 37.9 | 27.0 | 59.3 | 29.0 | 20.7 | 6.0 | 33.3 |
| 4 | 38.0 | 39.5 | 40.0 | 50.0 | 63.0 | 65.1 | 12.0 | 16.7 | 18.0 | 66.7 |
| 5 | 36.0 | 47.2 | 19.0 | 31.6 | 8.0 | 25.0 | 47.0 | 23.4 | 22.0 | 40.9 |
| Mean | 34.6 | 42.1 | 30.8 | 46.6 | 29.4 | 46.1 | 24.4 | 22.0 | 20.0 | 51.3 |

*n=100 eggs per sample card-bit

### 4.18.7. Studies on parasitisation of the internode borer *Chilo saccariphagus indicus* by *Trichogramma chilonis* (SBI, Coimbatore)

In preliminary trials conducted in the laboratory to ascertain the parasitisation ability of *T. chilonis* reared continuously for many generations on *Corcyra* eggs, it was found that *T. chilonis* parasitised 100% of three day old eggs when released at 2:1

(parasitoid: host) ratio. Superparasitism was observed as indicated by adult emergence (131.4%) (Table 53). On four days old eggs per cent parasitism by parasitoids derived from INB eggs dropped to 11.7 while super parasitism still prevailed with emergence of 125.0 parasitoids. Parasitoids obtained from *Corcyra* eggs showed only 8.8% parasitism and no super parasitism was seen (Table 54).

Table 53. Parasitisation rates of 3 day old internode borer eggs by *Trichogramma chilonis*

| No. of eggs/sample | No. of fertilized eggs | % parasitisation of fertilized eggs | @ adult emergence |
|---|---|---|---|
| 21 | 16 | 100.0 | 87.5 |
| 35 | 31 | 100.0 | 158.1 |
| 15 | 15 | 100.0 | 133.3 |
| 26 | 24 | 100.0 | 137.5 |
| 17 | 17 | 100.0 | 147.1 |
| 43 | 32 | 100.0 | 125 |
| Mean | | 100.0 | 131.4 |

Table 54. Parasitisation rates of 4 day old internode borer eggs by *Trichogramma chilonis*

| No. of eggs/sample | No. of fertilized eggs | % parasitisation of fertilized eggs | % adult emergence |
|---|---|---|---|
| (a) Parasitoid derived from internode borer | | | |
| 18 | 18 | 5.5 | 100.0 |
| 25 | 25 | 24.0 | 166.7 |
| 34 | 34 | 8.8 | 133.3 |
| 24 | 24 | 8.3 | 100.0 |
| Mean | | 11.7 | 125.0 |
| (b) Parasitoid derived from *Corcyra eggs* | | | |
| 14 | 13 | 0.0 | 0.0 |
| 23 | 21 | 9.5 | 100.0 |
| 31 | 25 | 8.0 | 100.0 |
| Mean | | | 66.7 |

When the parasitoids were released at 1:3 (parasitoid: host) ratio on fresh eggs of INB, the parasitism was found to be 100% in both cases of parasitoids derived from either *Corcyra* or INB eggs. Superparasitism was found in both cases with 135.0 and 135.7% adult emergence, respectively (Table 55).

Table 55. Parasitisation rates of fresh internode borer eggs by *Trichogramma chilonis*

| No. of eggs/sample | No. of fertilized eggs | % parasitisation of fertilized eggs | % adult emergence |
|---|---|---|---|
| (a) Parasitoid derived from internode borer | | | |
| 42 | 31 | 100.0 | 125.8 |
| 12 | 12 | 100.0 | 133.3 |
| 6 | 5 | 100.0 | 140.0 |
| 23 | 23 | 100.0 | 156.5 |
| 28 | 25 | 100.0 | 136.4 |
| 30 | 27 | 100.0 | 129.6 |
| 18 | 14 | 100.0 | 128.6 |
| Mean | | 100.0 | 135.7 |
| (b) Parasitoid derived from *Corcyra* eggs | | | |
| 16 | 15 | 100.0 | 126.7 |
| 24 | 24 | 100.0 | 129.2 |
| 15 | 9 | 100.0 | 122.2 |
| 29 | 25 | 100.0 | 152.0 |
| 20 | 20 | 100.0 | 145.0 |
| Mean | | 100.0 | 135.0 |

### 4.18.8. Field efficacy of *Trichogramma chilonis* against shoot borer, *Chilo infuscatellus* (SBI, Coimbatore)

Five field trials were conducted to assess the efficacy of *T. chilonis* in containing shoot borer population build up. The parasitoid was released by stapling parasitised *Corcyra* egg card bits in different spots in the field. The parasitoid was released at 2.5 cc/ha and 5.0 cc/ha at different time intervals and release beginning times. The observations taken at 10-15 day intervals did not indicate any definite trend with erratic population fluctuations.

The results indicated a reduction in population in treated plots as compared to control plots in some trials whereas in some trials there was an increase / reduction not consistent with the treatments.

### 4.18.9. Field efficacy of *Trichogramma chilonis* against internode borer (SBI, Coimbatore)

Two trials were conducted in farmers' field with *T. chilonis* against internode borer. Releases @ 2.5 cc/ha and 5.0 cc/ha were made either as single release or two releases and the per cent incidence of internode borer observed after the releases. The results were not consistent in the two trials with some reduction in treated plots in one trial and an increase in another.

### 4.18.10. Natural occurrence of *Sturmiopsis inferens* parasitism in shoot borer (SBI, Coimbatore)

The seasonal fluctuation of natural parasitism by *S. inferens* in shoot borer was studied from February, 1998 to March, 1999 and it was found that the parasitoid was active throughout the year except for the months of May, June and November. Maximum parasitism of 15.2% was recorded in September. Though the incidence of shoot borer was ranging from 1.0 to 20.1% throughout the year, the parasitism by *Cotesia flavipes* was nil. Virus infection (GV) in shoot borer population varied from 1.3% to 30.1%. Incidence was lowest in February and highest in December.

### 4.18.11. Evaluation of *Beauveria brongniartii* against white grub (SBI,Coimbatore)

In pot culture experiment with a concentration range of $10^{14}$ - $10^{18}$ spores/ha on third instar grubs, infection rates were lower at lower dosages of $10^{14}$-$10^{15}$ (2 - 10%) as well as at the highest dosage of $10^{18}$ spores/ha (above 10%). The most effective dosages were $10^{16}$ and $10^{17}$ spores/ha with an infection rate of 34 and 26%, respectively, after six months. There was no mortality in control.

The fungus was evaluated at $10^{14}$ and $10^{15}$ spores/ha and the infection in grubs and adults due to the fungus was found to be low. The infection level in adults was in general higher than in grubs (Table 56).

Table 56. Field evaluation of *Beauveria brongniartii* against white grub

| Dosage (spores/ha) | % infection due to fungus | | | |
|---|---|---|---|---|
| | *Beauveria brongniartii* | | *Metarhizium anisopliae** | |
| | Grub | Adult | Grub | Adult |
| $10^{14}$ | 0.0 | 1.2 | 1.3 | 0.0 |
| $10^{15}$ | 3.3 | 3.8 | 5.9 | 0.0 |
| Control | 0.0 | 1.0 | 4.0 | 0.0 |

* Natural incidence

Natural occurrence of *Metarhizium anisopliae* was observed in the experimental plots and the infection was found at higher levels in grubs than in adults.

### 4.19. Biological suppression of cotton pests

A trial to standardise the release technology for *Trichogramma chilonis* in cotton was done at ANGRAU, Hyderabad; GAU, Anand; PAU, Ludhiana and TNAU, Coimbatore. The objective of the trial was to standardise the distribution rate in case of release of the egg parasitoids by the stapling of parasitoid card bits and also to compare this method with release of adults in a well distributed manner and to see the effect of these methods on the incidence of boll worms and per cent parasitisation of boll worms collected from the field.

#### 4.19.1. Standardisation of release technology for *Trichogramma chilonis*

**ANGRAU, Hyderabad**

The trial on standardisation of release methodology for the egg parasitoid, *Trichogramma chilonis* was conducted in an area of 1500 $m^2$ at Agricultural Research Station, Warangal (ANGRAU, Hyderabad) during Kharif 1998-99. Three methods of release of *T. chilonis* were tested by releasing @ 1,50,000/ha/week for 8 times. The three methods tested were: one hundred strips of parasitised egg card of *T. chilonis* (one bit/ 100$m^2$), two hundred strips of parasitised egg card of *T. chilonis* (one bit for 50 $m^2$) and release of adults of *T. chilonis* in a well distributed manner. All the treatmental plots were protected from sucking pests initially with oxydemeton methyl and triazophos and after completion of release of parasitoids for 8 times, the crop was protected from the subsequent build up of pest population with monocrotophos and acephate. The observations on the incidence of bollworms were recorded at 15 days interval. The eggs of *H. armigera* were

collected and observed for their parasitisation in the laboratory.

The results showed that the per cent damage either to squares or bolls were higher in control than in parasitoid released plots. The lowest square damage as well as boll damage was recorded in the plot where parasitoids were released in 200 strips/ha. The parasitisation of eggs of *H. armigera* by the released *T. chilonis* was highest (32.0%) in the plot where parasitised egg card bits were distributed in 200 strips/ha. The yield obtained from the above plot was also higher (9.30 Q/ha) than the other treatments tested (Table 57).

Table 57. Efficacy of *T. chilonis* released in different methods

| Method of release of T. chilonis | % damage | | Per cent parasitisation of *H. armigera* eggs | Yield (Q/ha) |
|---|---|---|---|---|
| | Squares | Bolls | | |
| 100 strips of parasitised egg card (@ 1,50,000/ha) | 10.06 | 4.01 | 24.00 | 8.60 |
| 200 strips of parasitised egg card (@ 1,50,000/ha) | 5.11 | 3.26 | 32.00 | 9.30 |
| Release of adult parasitoids (@ 1,50,000/ha) | 6.97 | 6.57 | 28.57 | 8.90 |
| Control | 11.89 | 8.51 | 11.54 | 5.70 |

**GAU, Anand**

An experiment was laid out at GAU, Anand with the same set of treatments as followed at ANGRAU, Hyderabad and the results showed that ants eat away the *Trichogramma* pupae when trichocards were installed in the cotton field. Thus, adult *Trichogramma* release seems appropriate. Damage by *E. vittella* was least and yield high in plots where adults were released as compared to other treatments (Table 58).

Table 58. Effectiveness of *T. chilonis* release with different methods

| Treatment | Per cent boll damage by *E. vittella* | Per cent square damage by *E. vittella* | Yield (kg/ha) |
|---|---|---|---|
| Adult release | 17.14 (8.69) | 18.13 (9.68) | 2000 |
| 200 bits of trichocards | 20.99 (12.83) | 21.74 (13.72) | 1925 |
| 100 bits of trichocards | 23.61 (16.04) | 24.30 (16.73) | 1753 |
| CD (P=0.05) | (1.994) | (1.981) | NS |

**TNAU, Coimbatore**

A field trial was laid out in a farmers' field at S.S.Kulam (Tamil Nadu) with the following treatments.

1. 1,50,000 parasitoids per ha week (eight releases) - one hundred strips of parasitised eggs of *T. chilonis* (one bit per 100m²)
2. 1,50,000 parasitoids per ha week (eight releases) - two hundred strips of parasitised eggs of *T. chilonis* (one bit per 50m²)
3. Eight releases of *T. chilonis* adults @ 1,50,000 parasitoids per ha per week.

Note

i. Blanket application of recommended insecticide methyl demeton for elimination of sucking pests

ii. Need based insecticidal application after eight releases of *T. chilonis*.

Two rounds of spraying with endosulfan and chlorpyriphos were given. The mean boll damage was found to be significantly less in plots released with adults followed by 200 bits/ha. The percentage parasitism was also found to be significantly high in plots where adults of *Trichogramma* were released. Significantly higher yield was also obtained in the same two treatments (Table 59).

Table 59. Evaluation of release methods of *T. chilonis* against bollworm complex of cotton

| Method of release | Mean per cent bolls damage (15 days interval after 1st release | | | | | Per cent parasitisation by *H. armigera* eggs | Yield q/ha |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | | |
| 100 strips | 2.50 | 4.58 | 5.53 | 8.60 | 11.80 | 4.90 | 10.6 |
| 200 strips | 2.35 | 3.78 | 5.38 | 8.33 | 10.73 | 6.40 | 12.2 |
| Adults | 1.80 | 3.30 | 3.85 | 6.48 | 9.12 | 20.80 | 13.4 |
| Control | 3.68 | 6.50 | 9.68 | 15.53 | 19.15 | 4.20 | 6.8 |
| CD (P=0.05) | 0.39 | 0.39 | 1.84 | 1.54 | 1.07 | 1.44 | 1.4 |

**PAU, Ludhiana**

The same experiment on the standardisation of release technology for *T. chilonis* was conducted at the Regional Research Station, Bathinda (Punjab). The three methods

of release of *T. chilonis* @ 1,50,000 per week as described under ANGRAU, Hyderabad was done during July to October. The plot size was 0.4 ha with a single replication. Each plot was divided into three parts for recording the data. The incidence of boll worms was recorded from 10 plants in each part of the plot. Total number of healthy and damaged fruiting bodies and green bolls were recorded twice during the season. Twenty-five eggs of *H. armigera* were collected from each plot to observe parasitisation. The seed cotton yield was also recorded.

The data presented in Table 60 revealed that the damage to fruiting bodies on 3-09-98 in the release plots was significantly lower (40.0 to 49.6%) than control. There was no significant difference in damage to fruiting bodies in different methods of release. However, on 30-09-98, the damage varied from 42.8 per cent to 50.2 per cent and there were no significant differences among them. The damage to the green bolls on 3-09-98 was lowest (28.5 and 29.2%) in release through tricho-cards at 200 spots and adult release and it was significantly lower (54.9%) than release at 100 spots and all of them were significantly lower than control (63.6%). The population of *H. armigera* larvae on 3-09-98 was significantly lower in the released plots (0.7 to 1.2/plant) than control plot (2.9/plant).

The yield in the release plots was significantly higher (61.0 to 73.7 kg/ha) than control (10.0 kg/ha). Since the crop was damaged by adverse climatic conditions and the yield was low no valid conclusions could be drawn. However, adult release was found slightly better than release as tricho-cards.

Table 60. Evaluation of the efficacy of releasing by different methods of *Trichogramma chilonis* against bollworm complex of cotton

| Method of release | Mean number of larvae / plant | | Per cent parasitization by *H. armigera* eggs | Yield kg/ha |
|---|---|---|---|---|
| | 03-09-1998 | 30-09-1998 | | |
| 100 strips | 1.1 (1.3) | 0.2 | 4.0 | 61.0 |
| 200 strips | 1.2 (1.4) | 0.1 | 8.0 | 66.7 |
| Adults | 0.7 (1.2) | 0.1 | 12.0 | 73.7 |
| Control | 2.9 (1.9) | 0.4 | 0.00 | 10.0 |
| CD (P=0.05) | (0.3) | NS | - | 18.7 |

From the results of the trials on methods of release at the four centres it can be concluded that release of *T. chilonis* as adults was generally better than distributing egg cards through 100 or 200 strips / ha.

### 4.19.2 Evaluation of BIPM module for cotton pests

**ANGRAU, Hyderabad**

The experiment on the evaluation of biocontrol based IPM module against pest complex of cotton was laid out at Agricultural Research Station, Warangal with the following four treatments. The variety used was RCH-2 with a spacing of 120x60 cm and in an area of 0.4 ha.

BIPM Module - I

Mechanical collection of bollworm infested plant parts and putting them in wire screen cage; sowing of cowpea as an intercrop in between two rows of cotton; random planting of maize @ 10% cotton plants; sowing of castor as trap crop at the border @ 50 plants/ha; cotton seed treatment with imidacloprid @ 5g/kg seed before sowing; three releases of *Chrysoperla carnea* @ 10,000 larvae (2-3 days old)/ha/week synchronising with the appearance of sucking pests; installation of pheromone traps @ 10/ha for *H. armigera*; eight releases of *T.chilonis* each @ 1,50,000/ha/week synchronising with the appearance of the eggs of the bollworms and need based application of *Ha*NPV $3x10^{12}$ POB/ha (500 LE/ha).

BIPM Module - II

Mechanical collection of bollworm infested plant parts and putting them in wire screen cage; sowing of cowpea as an intercrop in between two rows of cotton; random planting of maize @ 10% cotton plants; sowing of castor as trap crop at the border @ 50 plants/ha; cotton seed treatment with imidacloprid @ 5 g/kg seed before sowing; three releases of *Chrysoperla carnea* @ 10,000, 2-3 days old larvae / ha / week synchronising with the appearance of sucking pests; installation of pheromone traps @ 10/ha for *H. armigera*; eight releases of *Trichogramma chilonis* each @ 1,50,000/ha/week synchronising with the appearance of the eggs of the bollworms; need based application of monocrotophos, acephate and triazophos after 8 releases of *T. chilonis*.

ANGRAU Practice

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

Farmer's practice

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

Control

No insecticide spray was given.

The observations on the population of sucking pests, *viz.*, jassids, white flies and aphids were recorded on 15 plants selected at random from lower, middle and upper regions of the plant. The data on the incidence of *Earias* and *Helicoverpa* on squares and bolls were recorded from 15 plants from each treatment. The population of natural enemies was also recorded.

The observations presented in Table 61 showed that the mean population of jassids and white flies were lower in both IPM modules than control and other treatments. The population level of aphids was high in ANGRAU and Farmers' practice but was absent in both the IPM modules up to 50 days due to cotton seed treatment with imidacloprid @ 5 g/kg seed.

Table 61. Evaluation of BIPM module

| Particulars | IPM Module I | IPM Module II | ANGRAU method | Farmers Practice | Control |
|---|---|---|---|---|---|
| I. Sucking pests (15 samples leaves) | | | | | |
| Jassids | 23.0 | 22.1 | 27.2 | 26.1 | 19.0 |
| White flies | 21.4 | 22.1 | 23.1 | 29.7 | 21.6 |
| Aphids | 0.0 | 0.0 | 31.0 | 20.5 | 27.0 |
| II. Boll worms (per 5 plants) | | | | | |
| *H. armigera* | 5.0 | 7.0 | 7.0 | 4.0 | 9.0 |
| *S. litura* | 1.0 | 3.0 | 1.0 | 1.0 | 4.0 |
| III. Damage (%) | | | | | |
| Squares (%) | 8.9 | 6.4 | 13.7 | 10.0 | 11.9 |
| Bolls (%) | 8.3 | 10.4 | 6.8 | 4.6 | 8.5 |
| Pink bollworm (%) | 6.0 | 15.0 | 11.0 | 18.0 | 13.1 |
| IV. Natural enemies (10 plants) | | | | | |
| Coccinellids | 10.0 | 8.0 | 2.0 | 0.0 | 6.0 |
| Spiders | 4.0 | 5.0 | 3.0 | 2.0 | 5.0 |
| *Trichogramma sp. (%)* | 38.0 | 32.0 | 18.0 | 22.8 | 20.5 |
| V. Yield (Q/ha) | | | | | |
| Kapas | 12.39 | 11.30 | 8.75 | 13.40 | 5.55 |
| Cowpea | 0.75 | 0.70 | - | - | - |
| VI. Cost benefit ratio | 1:3.86 | 1:3.20 | 1:1.95 | 1:2.52 | 1:2.74 |

The damage to squares was low in IPM module-I and II, while it was high in ANGRAU, Farmers' practice and control. The damage to bolls was comparatively high in both the IPM modules than in other practices.

The presence of predatory fauna was higher in IPM modules than in other practices tested. The activity of predatory ladybird beetles was found to be high in IPM practices because the aphid population had sufficiently build up on cowpea (an intercrop) but not on cotton as its seed was treated with imidacloprid. During November-December the activity of *Trichogramma* sp. enormously increased in all the treatments but was more in IPM module-I and II.

The kapas obtained from farmer's practice was high (13.40 Q/ha) compared to IPM module I (12.39 Q/ha) and IPM module II (11.30 Q/ha). However, the incremental cost benefit ratio was high in IPM module I and II (1 : 3.86 and 1 : 3.20) as compared to farmers' practice (1:2.52), ANGRAU practice (1 : 1.95) and control (1 : 2.74). Thus, the IPM modules proved to be highly profitable practices than conventional practices.

**GAU, Anand**

An experiment was laid to evaluate the efficacy of IPM modules against pest complex in Cotton Hybrid-8 with the following four treatments.

IPM Module-1

i. Mechanical collection of bollworm infested parts and putting them in wire screen cage
ii. Random planting of maize @ 10% of plants
iii. Three releases of *Chrysoperla carnea* @ 10,000 2-3 days old larvae/ha/week synchronizing with the appearance of the pests
iv. Eight release of *Trichogramma chilonis* each @ 1,50,000/ha/week synchronizing with the appearance of the pest

IPM module- 2

i. Mechanical collection of bollworm infested parts and putting them in wire screen cage
ii. Random planting of maize @ 10% of plants
iii Three releases of *Chrysoperla carnea* @ 10,000 2-3 days old larvae/ha/week synchronizing with the appearance of the pests
iv. Eight release of *Trichogramma chilonis* each @ 1,50,000/ha/week synchronizing with the appearance of the pest

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

Insecticidal Module

As per GAU recommendation

Untreated control

Observations were recorded by dividing the entire plot (0.2 h) into 10 divisions. From each division 5 plants were selected at random and tagged. The observations on the population of aphid, jassid, whitefly and thrips were recorded from three randomly selected leaves of each tagged plant from lower, middle and upper 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 from the whole plot and kept individually in glass vials to record extent of parasitism. The mummified larvae (due to parasitism by *Rogas* sp.) 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, etc. were also recorded on each tagged plant at fortnightly interval. Yield was recorded and economics of treatments worked out.

Results presented in Table 62 revealed that the bud and boll damage was significantly low in IPM module I and II over control as well as insecticidal treatments. Both IPM modules gave significantly better protection to buds and bolls. The bud damage in IPM module I and II were found to be 14.09 and 15.91% whereas boll damage was 15.91 and 14.95%, respectively. The bud and boll damage in untreated plot was 23.88 and 26.84 %, respectively. The bollworm damage to locules was also significantly low in IPM blocks. The damage due to *E. vittella* in the IPM-I, IPM-II, insecticides and control plot was found to be 6.47, 5.53, 8.94 and 23.78, respectively. Similarly damage due to *P. gossypiella* in above treatments was 21.56, 19.71, 29.17 and 38.94 %, respectively.

The population of sucking pests was also significantly low in IPM modules as compared to control. The releases of *Chrysoperla* gave significantly better protection against aphid, jassid and whitefly. The population of aphid, jassid and whitefly in IPM module I was 5.85,50.62 and 3.38 per 15 leaves, respectively, and in IPM module II it was 5.90, 46.56 and 3.58 per 15 leaves, respectively. The population of aphids, jassids and white flies in insecticide treated plot was 9.61, 145.43 and 7.01 per 15 leaves, respectively.

Table 62. Population of sucking insect pests and bollworm infestation in different treatments (Cotton Hybrid -8).

| Treatment | Sucking pest /15 leaves | | | % Damage by Boll worms | | | | Yield kg/ha | ICBR |
|---|---|---|---|---|---|---|---|---|---|
| | Aphids | Jassids | White-flies | Buds | Bolls | Locules | | | |
| | | | | | | EV | PG | | |
| IPM-I | 7.15 (50.62) | 2.52 (5.85) | 1.97 (3.38) | 14.09 (5.93) | 15.91 (7.51) | 14.73 (6.47) | 27.66 (21.56) | 27.19 | 1:13.3 |
| IPM-II | 6.86 (46.56) | 2.53 (5.90) | 2.02 (3.58) | 13.97 (5.83) | 14.95 (6.66) | 13.60 (5.53) | 26.35 (19.71) | 2789 | 1:9.56 |
| Insecticides | 12.08 (145.43) | 3.18 (9.61) | 2.74 (7.01) | 22.15 (14.22) | 23.57 (15.99) | 17.39 (8.94) | 32.68 (29.17) | 2097 | 1:0.09 |
| Control | 15.21 (230.84) | 3.71 (13.26) | 3.20 (9.74) | 23.88 (16.39) | 26.84 (20.39) | 29.18 (23.78) | 38.61 (38.94) | 1725 | - |
| CD (P=0.05) | 0.625 | 0.179 | 0.152 | 1.281 | 0.962 | 2.613 | 3.223 | 327.83 | |

PG : *P. gossypiella* and EV : *Earias vittella*

Since IPM plots received less spray of chemical insecticides many of the bio-agents were conserved. The noteworthy amongst them were bollworm parasitoids *Rogas aligarhensis, T. chilonis* and *Agathis sp.* which caused 11.69, 26.60 and 32.24 per cent parasitism, respectively, in IPM module I and they caused 11.40, 25.83 and 33.77 per cent parasitism, respectively, in IPM module II. Further it was noted that parasitism due to *Agathis* sp. was extremely high as compared to previous years. Amongst the predators *Chrysoperla, Cheilomenes, Geocoris* and staphylinids numbered 78.92, 33.67, 15.83 and 3.00 per 25 plants in IPM module I and 77.0, 34.75, 16.0 and 2.92 per 25 plants in IPM module II, respectively. On the other hand population of these natural enemies was greatly hampered due to application of insecticide. The per cent parasitism by *R. aligarhensis* and *T. chilonis* and *Agathis* sp. was found to be 7.39, 8.65 and 29.10 per cent only. The count of *Chrysoperla, Cheilomenes, Geocoris* and staphylinids was 25.0, 16.08, 9.33 and 1.58 per 25 plants, respectively.

The effects of IPM also reflected in the yield. The yield in IPM-I and IPM-II was 2719 kg/ha and 2789 kg/ha which was significantly superior control (1725 kg/ha).

It was observed that intercropping of maize with cotton enhanced the activity of *C. sexmaculata* in cotton crop in IPM blocks. The hand picking of infested materials showed mechanical removal of *E. vittella* from the cotton crop, which were parasitised. Thus, both the IPM modules proved effective against cotton pests giving higher ICBR.

**TNAU, Coimbatore**

In the field trial laid out in a farmer's field at S.S.Kulam (Tamil Nadu), five management practices, *viz.*, IPM module 1, IPM module 2, TNAU spray schedule, farmers' practice and untreated control were compared using the variety LRA 5166.

IPM module I consisted of blanket application of dimethoate (0.05%) at 30DAS, three releases of *Chrysoperla carnea* @ 10,000 larvae (2-3 days old) per week/ha *viz.*, 40, 47, 54 days, five releases of *Trichogramma* @ 1,50,000/ha/week starting from 70 DAS and one application of *Ha*NPV @ 500 LE/ha on 110 DAS.

IPM module-2 was similar to IPM module-1 where instead of NPV spray monocrotophos @ 0.03% was sprayed at 110 DAS.

The third treatment consisted of application of dimethoate (50 DAS), endosulfan (65 DAS), monocrotophos (80 DAS), quinalphos (95 DAS) and chlorpyriphos (110 DAS) as recommended by TNAU.

Two sprays of oxydemeton methyl @ 750 ml/ha were given for the control of sucking pests. One round each of endosulfan (0.07%) and chlorpyriphos (0.05%) at 15 days interval was given 10 days after 8th release to control bollworms. The above insecticides were sprayed as and when the pest crossed ETL.

In farmers' practice of insecticidal application, eight rounds of spray were given without following ETL.

The results revealed that IPM methods of protection were superior to both chemical control and farmers' method in reducing the population of aphids and leafhoppers (Table 63). Similarly the bollworm incidence was ranging from 7 to 17 per cent in farmers' practice whereas in IPM plots involving the use of *Ha*NPV, it was only 2 to 12 per cent. In IPM plots significantly lower bollworm incidence and higher yield was recorded than in plots treated only with insecticides (Table 64). Larval and egg parasitism on bollworms and number of natural enemies were more in IPM plots (Table 65).

Table 63. Population of sucking pests in different treatments

| Treatment | Leafhoppers/plant (DAS) | | Aphids/plant (DAS) | |
|---|---|---|---|---|
| | 40 | 50 | 40 | 50 |
| IPM - Module I | 0.49[a] | 0.31[c] | 0.51[a] | 0.30[b] |
| IPM - Module II | 0.51[a] | 0.34[c] | 0.55[a] | 0.28[b] |
| TNAU spray schedule | 0.63[a] | 0.83[b] | 0.63[a] | 0.88[a] |
| Farmers' practice | 0.64[a] | 1.06[a] | 0.63[a] | 0.91[a] |
| Control | 0.48[a] | 0.98[ab] | 0.65[a] | 0.93[a] |

Table 64. Boll damage and yield under different treatments

| Treatment | Mean per cent damage of bolls | | | | | Yield q/ha |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| BIPM Module I | 2.95 | 2.13 | 4.15 | 8.00 | 10.50 | 14.2 |
| BIPM Module II | 3.53 | 1.90 | 5.23 | 9.18 | 12.25 | 13.8 |
| TNAU spray schedule | 5.48 | 3.98 | 6.08 | 8.55 | 15.78 | 11.6 |
| Farmer's practice | 7.38 | 4.85 | 7.20 | 11.18 | 17.95 | 9.6 |
| Control | 8.75 | 6.90 | 8.23 | 13.93 | 20.25 | 7.2 |
| CD | 0.98 | 0.94 | 0.84 | 1.53 | 2.54 | 1.82 |

* The observations were recorded at 15 days interval

Table 65. Natural enemies and extent of parasitism in different treatments

| Treatment | Egg parasitism | | | Larval parasitism | | | Predators | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ha | Ev | Pg | Ha | Ev | Pg | Pm | Co | Sp |
| BIPM module I | 16.25 | 12.50 | 13.50 | 11.25 | 9.50 | 10.75 | 4 | 4 | 3 |
| BIPM module II | 17.50 | 14.25 | 15.25 | 12.50 | 10.25 | 9.75 | 2 | 6 | 5 |
| TNAU spray schedule | 7.25 | 6.75 | 8.00 | 5.75 | 6.00 | 6.00 | 0 | 2 | - |
| Farmer's practice | 6.50 | 5.50 | 6.25 | 4.25 | 5.50 | 5.25 | 0 | 1 | 1 |
| Control | 12.50 | 10.25 | 11.25 | 9.25 | 8.75 | 10.50 | 1 | 5 | 2 |

Ha : *Helicoverpa armigera*; Ev : *Earias vittella*; Pg : *Pectinophora gossypiella*; Pm : Preying mantis, Co : Coccinellid*s* and Sp : Spiders

**PAU, Ludhiana**

Biocontrol based IPM module was evaluated at the Regional Research Station, Bathinda, Punjab in a plot size of 0.4 ha for each of the following treatments.

IPM Module-I

i. Need based application of insecticides (oxydemeton methyl and monocrotophos) for the control of sucking pests
ii. Sixteen releases of *Trichogramma chilonis* @ 1,50,000 per ha per week during July to October
iii. Release of *Chrysoperla carnea* @ 10,000 per ha on the appearance of sucking pests
iv. *Ha*NPV spray @ 500 LE per ha on the appearance of *Helicoverpa armigera*

IPM Module II

i. Need based application of insecticides (oxydemeton methyl and monocrotophos) for the control of sucking insects
ii. Release of *C. carnea* @ 10,000 per ha on the appearance of sucking pests
iii. Eight releases of *T. chilonis* @ 1,50,000 per ha week during July-August
iv. Need based application of insecticides (chlorpyriphos, quinalphos, and acephate) for the control of bollworms during September-October

**PAU insecticidal schedule**

PAU spray schedule consists of oxydemeton methyl (750 ml/ha), monocrotophos (1250/ha), fenvalerate (250 ml/ha), chlorpyriphos (5000 ml/ha), quinalphos (2000 ml/ha), acephate (2000 kg/ha) and chlorpyriphos (5000 ml/ha).

Control (insecticides used only to control sucking pests)

Need based application of insecticides (oxydemeton methyl and monocrotophos) for the control of sucking pests

To record the population of sucking pests (jassid, whitefly and thrips), each plot was divided into 3 parts. In each part, 10 plants were selected at random and the population was recorded from three leaves (one each from the lower, middle and upper canopy) at weekly interval. For recording, the bollworm damage, 10 plants were selected at random

from the 3 parts and the healthy and infested fruiting bodies and bolls were counted at fortnightly interval near maturity, the incidence of the bollworms was recorded on loculi basis. On the appearance of *H. armigera*, the population of larvae was counted from 10 plants in each from 3 parts of the plots. For egg parasitism, 25 eggs of *H. armigera* were collected from each plot on 3-11-1998 and were observed in the laboratory. The population of the predators was recorded from 30 plants in each plot. The yield of seed cotton was also recorded.

The mean population of cotton jassids in PAU spray schedule and IPM module-II was slightly lower than control and IPM module-I. The population of the whitefly was low throughout the crop season and not much difference was noticed in its population in different treatments (1.4 to 1.9 per 3 leaves). The population of thrips was quite high throughout the crop season and the mean population in IPM module I (Table 66) (7.4/3 leaves) was slightly lower than other treatments (9.7 - 11.6 per 3 leaves).

The damage to the fruiting bodies on 03-09-1998 in PAU spray schedule and IPM modules (39.9 to 41.4%) was at par and was significantly lower than control (73.1%). However, on 30-09-1998, the damage to green bolls varied from 31.8 to 54.2 per cent in different treatments, but there was no significant difference among them. The incidence of bollworms on loculi basis at maturity was lowest (34.0%) in PAU spray schedule and it was significantly lower than control (71.3%) and IPM module-I (64.6%) but was at par with IPM module-II (36.9%) (Table 67).

The lowest population of *H. armigera* on September 3, 1998 was recorded in IPM module-II (0.8/plant) and it was significantly lower than control (2.9/plant) and PAU spray schedule (2.0/plant). However on September 30, 1998, the population varied from 0.1 to 0.4 per plant and there was no significant differences between them. Only 4.0 per cent parasitisation of *H. armigera* eggs was observed in IPM module-I and no parasitization was recorded in other treatments. The four predators namely *Zelus* sp., *Nabius* sp., *Chrysoperla* sp., and spiders were observed in extremely low population with no great differences in population in different treatments.

The crop was damaged by adverse climatic conditions and no valid conclusions could be made with regard to yield, between the various treatments.

Table 66. Effect of biocontrol based IPM and other treatments on cotton jassids, whiteflies and thrips

| Observations | Number (mean of 9 observations) of | | |
|---|---|---|---|
| | Jassids | Whiteflies | Thrips |
| PAU spray schedule | 4.8 | 1.9 | 10.0 |
| IPM module - I | 5.9 | 1.5 | 7.4 |
| IPM module - II | 4.5 | 1.4 | 9.7 |
| Control | 6.0 | 1.7 | 11.6 |

Table 67. Evaluation of biocontrol based IPM modules on cotton (Bollworm complex)

| Treatment | Percent damage to | | *H. armigera* larvae per plant | | Per cent loculi infested (10th Octo.) | | Per cent parasitisation of *H. armigera* eggs (3rd Nov.) | |
|---|---|---|---|---|---|---|---|---|
| | Fruiting bodies | | Green bolls | | | | | |
| | 3rd Sept.* | 30th Sept. | 3rd Sept.* | 30th Sept. | 3rd Sept.* | 30th Sept. | | |
| PAU Spray Schedule | 41.4 (39.5) | 49.0 | 37.3 (36.3) | 36.8 | 2.0 (1.7) | 0.2 | 34.0 (33.8) | 0 |
| IPM Module I | 40.7 (38.7) | 40.2 | 33.8 (32.7) | 44.2 | 1.3 (1.5) | 0.1 | 64.6 (55.1) | 4 |
| IPM Module II | 39.9 (39.5) | 38.4 | 24.2 (24.8) | 31.8 | 0.8 (1.3) | 0.1 | 36.9 (37.4) | 0 |
| Control | 73.1 (62.7) | 51.1 | 63.6 (56.1) | 54.2 | 2.9 (1.9) | 0.4 | 71.3 (59.6) | 0 |
| CD (P=0.05) | (10.0) | NS | (18.9) | | (0.3) | NS | (7.6) | - |

* Figures in parentheses are arc sin transformations

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

#### 4.20.1. Evaluation of *Bacillus thuringiensis kurstaki (Btk)* and *Spodoptera litura* nuclear polyhedrosis virus (*S*lNPV) against *Spodoptera litura* in tobacco nursery

The experiment to compare BIPM with the farmer's method was laid out in

Morampudi commercial tobacco nursery. The biopesticides were applied at weekly intervals commencing from five weeks after germination on fourteen tobacco nursery beds of 15 $m^2$ each.

The following spray schedule was adopted

1st spray : *Sl*NPV 250 LE ($3X10^{12}$ PIB/ha)
2nd spray : *Btk* 1.0 kg/ha
3rd spray : *Sl*NPV 250 LE ($3x10^{12}$ PIB/ha)
4th spray : *Btk* 1.0 kg/ha

Similarly for farmer's method of control, fourteen tobacco beds of 15 $m^2$ each were selected and the spray schedule followed. These were

1st spray : Endosulfan 2.0 l/ha
2nd spray : Methomyl 3.0 l/ha
3rd spray : Chlorpyriphos @ 2.5l/ha
4th spray : Acephate 1 kg/ha

Except in nursery no.5 and 7 the BIPM method proved significantly superior over farmer's method.

The sequential sprays of biopesticides, *viz., Sl*NPV and *Btk* were statistically significant over chemical pesticides in case of percentage seedling damage per 1 $m^2$ (Table 68). The seedling yield obtained in BIPM plot was better than farmer's method. The net returns and CB ratio for biopesticides worked out to Rs.38950/- and Rs.1:1.23 whereas the farmer's method realised net returns of Rs.19,200 with a CB ratio 1:1.12 (Table 69).

Table 68. Evaluation of *B.t. kurstaki* and *Sl*NPV alternate sprays as compared to farmer's spray schedule against *Spodoptera litura* in tobacco nurseries

| Nursery no. | Percentage seedlings damaged | | |
|---|---|---|---|
| | Biopesticide | Farmer's method | Z-value |
| 1 | 5.60 | 6.81 | 9.03 |
| 2 | 2.39 | 8.89 | 5.01 |
| 3 | 6.58 | 9.76 | 1.97 |
| 4 | 3.84 | 9.85 | 4.09 |
| 5 | 5.50 | 7.51 | 0.01* |

| | | | |
|---|---|---|---|
| 6 | 7.49 | 12.50 | 8.59 |
| 7 | 6.45 | 11.33 | 1.05* |
| 8 | 6.43 | 10.03 | 2.87 |
| 9 | 5.16 | 10.46 | 3.19 |
| 10 | 3.35 | 11.14 | 2.88 |
| 11 | 6.22 | 8.94 | 5.54 |
| 12 | 5.24 | 8.82 | 4.42 |
| 13 | 4.14 | 9.70 | 5.74 |
| 14 | 2.34 | 9.21 | 5.35 |

Table 69. Cost benefit ratio for management of *S. litura* in tobacco nursery

| Particulars | Biopesticidal control (Rs./ha) | Chemical control (Farmer's Method) (Rs/ha) |
|---|---|---|
| Cost of plant protection for *S. litura* | 2,050 | 2,860 |
| Cost of fungicides | 14,000 | 14,000 |
| Land Rent | 50,000 | 50,000 |
| Labour charges | 85,000 | 85,000 |
| Fertilisers | 12,000 | 12,000 |
| Seedlings obtained | 24,00,000 | 22,00,000 |
| Gross returns (Average rate of seedlings Rs.500 / 600 seedlings) | 2,00,000 | 1,83,060 |
| Gross expenditure | 1,63,050 | 1,63,860 |
| Net returns | 37,950 | 19,200 |
| C:B ratio | 1:1.23 | 1:1.12 |

### 4.20.2. Evaluation of BARC *Bacillus thuringiensis* strains (dust formulation) against *Helicoverpa armigera* on transplanted tobacco crop

Three dosages of the *Bt* formulations ($4.5 \times 10^{12}$ spores/ha, $6.0 \times 10^{12}$ spores/ha, $7.5 \times 10^{12}$ spores/ha) were tried and compared with fenvalerate dust (1.0 kg a.i./ha) and an untreated control.

At capsule formation stage three early third instar larvae of *H. armigera* per panicle were released on five labelled plants in each treatment in a randomised block design and treatments applied immediately. Observations were recorded on number of capsules damaged per plant on the labelled plants three days and one week after application.

BARC *Bt* dust formulation @ 7.5 x $10^{12}$ spores/ha significantly reduced the damage caused by *H. armigera* (third instar larvae) with mean percentage capsules damaged at 6.54 and remained on par with fenvalerate 0.4% dust at 5.80. All the treatments were superior to control (Table 70).

Table 70. Effect of BARC *Bt* (dust formulation) on capsule damage (7 days after treatment)

| Treatment | % capsules damaged per plant |
|---|---|
| *Bt* 4.5x$10^{12}$ spores/ha | 14.94 |
| *Bt* 6.0x$10^{12}$ spores/ha | 12.14 |
| *Bt* 7.5x$10^{12}$ spores/ha | 6.54 |
| Fenvalerate dust (1.0 kg a.i./ha) | 5.80 |
| Control (no application) | 23.36 |
| CD (P=0.05) | 6.56 |

**4.20.3. Biointensive IPM of *Helicoverpa armigera* in planted tobacco crop**

The experiment was conducted in an area of 0.5 ha each for BIPM, chemical control and farmer's method of control for the second year in succession. The practices compared were

BIPM practices

i. Two rows of *Tagetes erecta* all around the plot before tobacco planting
ii. Ten bird perches erected at 30 DAP - 1 ft above the crop
iii. One spray of *Ha*NPV 450 LE (6 x $10^{12}$ PIB/ha) at 40 DAP
iv. Hand picking of larvae at 50 DAP

Chemical control practices

i. One spray of endosulfan 35% EC @ 3.0 ml/l at 30 DAP
ii. One spray of monocrotophos 36 WSC @ 3.0 ml/l at 40 DAP
iii. One spray of fenvalerate 20% EC @ 1.0 ml/l at 50 DAP

Farmer's method of plant protection practices adopted

i. Spray of acephate @ 2g/l at 15 DAP
ii. Spray of monocrotophos @ 2ml/l at 30 DAP
iii. Spray of chlorpyriphos @ 2ml/l at 55 DAP

Observations were recorded on number of larvae and plants damaged/plot at 30, 40 and 50 days after planting. Observations on natural enemies and number of *Helicoverpa* larvae on 100 tagetes plants were also recorded in BIPM block at 30, 40 and 50 days after planting.

The data presented in Table 71 indicates that the percentage plants infested by *H. armigera* was 0.15, 0.19, 0.25 in BIPM: 0.15, 0.20, 0.22 in chemical control; 1.15, 4.63, 12.00 in farmers method of control plot. The number of larvae recorded were 15, 12, 10 in BIPM; 15, 18, 20 in chemical control; 115, 310, 1140 in farmer's method of control (half an hectare) at 30, 40 and 50 days after planting, respectively. Marked differences were not observed on number of plants damaged and *H. armigera* between BIPM plot and chemical control plot while in farmers method of control the build up of *Helicoverpa* was observed between 30 and 50 days after planting.

*Helicoverpa* population on 100 tagetes plants at 30, 40 and 50 days were more than on tobacco indicating that tagetes served as a trap crop. It also served as a reservoir of natural enemies such as preying mantis, wasps, spiders, coccinellids, *Apanteles, Peribeae*, dragonflies (Table 72). Among birds, crow, mynah, black drongo were found preying on *Helicoverpa* larvae in the morning (8 to 10 am) and evening (3 to 5 pm). Constant build up of spiders was noticed on the tagetes plants.

Table 71. Plants damaged and *Helicoverpa armigera* larval population 50 days after planting

| Total No. of plants | Days after Planting | BIPM | | Chemical method | | Farmer's method | |
|---|---|---|---|---|---|---|---|
| | | Plants damaged | No. of larvae | Plants damaged | No. of larvae | Plants damaged | No. of larvae |
| 10,040 | 30 | 15 (0.15) | 15 | 15 (0.15) | 15 | 115 (1.15) | 115 |
| | 40 | 19 (0.19) | 12 | 20 (0.20) | 18 | 465 (4.63) | 310 |
| | 50 | 25 (0.25) | 10 | 22 (0.22) | 20 | 1200 (12.00) | 1140 |

Figures in parentheses are per cent plants damaged

Table 72. Population of *Helicoverpa armigera* on tobacco, tagetes and natural enemies on 100 marigold plants

| Days after planting | Number of *Helicoverpa armigera* | | Natural enemies | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | To-bacco | Tage-tes | Preying mantis | Wasps | Spiders | Cocci-nellids | *Apan-teles* | *Peri-bea* | Dragon flies |
| 30 | 0.15 | 19 | 2 | - | 6 | - | - | 2 | 5 |
| 40 | 0.12 | 39 | 7 | 9 | 39 | 9 | 10 | 7 | 7 |
| 50 | 0.10 | 75 | 10 | 7 | 136 | 15 | 20 | 21 | 12 |

### 4.20.4. Demonstration of biointensive IPM of *S. litura* in irrigated FCV tobacco crop

In an area of 1 ha in Kalavacherla (East Godavari district) irrigated FCV tobacco crop planted in the 1st week of December was taken up for demonstration of biointensive IPM of *S. litura*. Castor seed was sown around tobacco crop one fortnight before tobacco transplanting. The variety of tobacco grown was NLS-5 (K-394) and the variety of castor was Aruna. The IPM methods adopted were :

1. Castor trap crop around tobacco crop, collection and destruction of egg masses and tiny larvae from castor leaves.
2. One release of *Telenomus remus* @ 40,000/ha two weeks after transplanting
3. First spray of *Sl*NPV 3 x $10^{12}$ PIB/ha 20 days after planting
4. Second spray of *Sl*NPV 3x $10^{12}$ PIB/ha 30 days after planting
5. Third spray of *Sl*NPV 3 x $10^{12}$ PIB/ha 40 days after planting
6. One spray of *Ha*NPV 3 x $10^{12}$ PIB/ha 50 days after planting

Farmer's chemical control practices adopted were:

1. One spray of quinalphos 250 ml/ha at 10 DAP
2. One spray of chlorpyrifos 1.5 l/ha at 30 DAP
3. One spray of acephate 1 kg/ha at 60 DAP

Percentage of plants infested were recorded in one ha area at 70 DAP in 100 randomly selected plants. A total of 400 plants each were sampled for both IPM and chemical control.

The results indicated that the mean percentage plants infested were significantly less in all IPM adopted blocks compared to chemical control (Table 73).

The cost of cultivation, yield and economics of IPM practice and farmer's chemical control method presented in Table 74 showed that the IPM farmer could get a net profit of Rs.24,225 with a CB ratio of 1:1.37 whereas in the chemical control practice the farmer obtained Rs.15,576 only as net profit with a CB ratio of 1:1.24.

Table 73. Results of the demonstration trial on BIPM practices

| Observation block | Mean % plants damaged | | |
|---|---|---|---|
| | Chemical control | IPM | Z-value |
| I | 29 | 10 | |
| II | 30 | 7 | |
| III | 35 | 10 | 1.9209* |
| IV | 18 | 17 | |

Table 74. Cost of cultivation and economics of farmer' method s IPM of *S. litura* in irrigated FCV tobacco, Kalavacherla

| Particulars | IPM | Farmer's method |
|---|---|---|
| Cost of cultivation | 62,075 | 62,075 |
| Cost of Plant Protection for *S. litura* (one spray of H*a*NPV 250 LE) | 1,700 | 2,349 |
| Gross expenditure | 63,775 | 64,424 |
| Yield (q/ha.) | 22Q | 20Q |
| Gross income (Rs.4000/q.) | 88,000 | 80,000 |
| Net profit | 24,225 | 15,576 |
| CB ratio | 1:1.37 | 1:1.24 |

## 4.21. Biological suppression of pulse crop pests

### 4.21.1. Biological control based management of pod borer complex in pigeonpea

**ANGRAU, Hyderabad**

The trial on the management of pod borer complex on pigeonpea was conducted with ICPL 85063 in randomised block design with five treatments replicated four times and a plot size of 50m$^2$. Different spray applications of *Bt*.(1.0 kg/ha), *Ha*NPV ((1.5 x $10^{12}$ POB/ha), NSKE (5%) and endosulfan (350 g a.i./ha) in the following sequence were tested by spraying them at 10 days interval. First treatment was given at flower initiation and the subsequent three sprays were given at 10 days interval, except for endosulfan, where 3 sprays were given at 15 days interval. The treatments included were:

i. *Bt* - *Ha*NPV - *Bt* - *Ha*NPV
ii. *Bt* - *Ha*NPV - Endosulfan - *Bt*
iii. Endosulfan - *Bt* - *Ha*NPV - *Bt*
iv. NSKE - *Bt* - *Ha*NPV - *Bt*
v. Endosulfan - Endosulfan - Endosulfan
vi. Control

All the treatments were given during evening hours. The data on larval population was recorded on 10 randomly selected plants per plot on three branches in each plant before and seven days after each treatment application. Seed, pod damage and yield were recorded at the time of harvest.

The results indicated that all the treatments in different sequences of spray application were significantly effective over control in reducing the larval population of *Helicoverpa armigera* as well as pod damage and increasing the yield (Table 75). The lowest larval population and pod damage was recorded with 3 spray applications of endosulfan. Among the different biocontrol based spray applications, sequential spray application of *Bt* - *Ha*NPV - endosulfan - *Bt* significantly suppressed the *H. armigera* larval population to just 12.93 as compared to 41.44 in control. Similarly, the lowest pod damage (20.15%) was recorded with the sequential spray application of *Bt* - *Ha*NPV - endosulfan - *Bt* as against 37.77% in control. The yield was significantly higher than control in all sequential spray applications except NSKE - *Bt*-*Ha*NPV-*Bt*. Significantly higher yield (755 kg/ha) was obtained with the spray application of endosulfan - endosulfan - endosulfan followed by *Bt* - *Ha*NPV - endosulfan - *Bt* (710 kg/ha) and was on par with other sequential sprays except NSKE - *Bt* - *Ha*NPV - *Bt*.

Table 75. Effect of sequential application of different bioagents and endosulfan against *H. armigera* in pigeonpea

| Treatment | Pre count larval population (10 plants) | Mean larval population (10 plants) 7 days after | | | | Mean larval population | Pod damage (%) | Seed damage (%) | Yield (kg/ha) |
|---|---|---|---|---|---|---|---|---|---|
| | | I spray | II spray | III spray | IV spray | | | | |
| *Bt-Ha*NPV-*Bt-Ha*NPV | 43.00 (6.56) | 28.89 (5.37) | 12.75 (3.57) | 10.00 (3.16) | 10.75 (3.28) | 15.56 (3.94) | 23.35 (28.88) | 4.82 (12.68) | 675 |
| *Bt-Ha*NPV-Endosulfan-*Bt* | 39.25 (6.25) | 24.50 (4.95) | 13.00 (3.60) | 8.75 (2.96) | 8.50 (2.91) | 12.93 (3.60) | 20.15 (26.67) | 4.20 (11.81) | 710 |
| Endosulfan-*Bt-Ha*NPV-*Bt* | 45.00 (6.71) | 25.25 (5.02) | 15.25 (3.90) | 10.50 (3.24) | 9.75 (3.12) | 15.19 (3.89) | 22.87 (28.55) | 4.87 (12.73) | 585 |
| NSKE-*Bt-Ha*NPV-*Bt* | 45.00 (6.71) | 26.75 (5.17) | 18.25 (4.27) | 10.50 (3.24) | 12.00 (3.46) | 16.88 (4.10) | 23.37 (28.87) | 4.12 (11.67) | 520 |
| Endosulfan-Endosulfan-Endosulfan | 46.75 (6.84) | 24.00 (4.90) | 15.27 (3.91) | 9.00 (3.00) | 10.75 (3.28) | 12.80 (3.57) | 11.50 (19.74) | 4.17 (11.79) | 755 |
| Control | 38.75 (6.22) | 41.50 (6.35) | 45.75 (6.76) | 42.50 (6.51) | 36.00 (5.98) | 41.44 (6.43) | 37.77 (37.92) | 7.50 (15.89) | 330 |
| CD (P=0.05) | NS | 0.97 | 0.34 | 0.48 | 0.43 | 0.31 | 2.11 | 1.01 | 171 |

Figures in parentheses are the transformed values

Considering the over all performance of the biocontrol treatments, sequential spray application of *Bt* - *Ha*NPV - endosulfan - *Bt* at 10 days interval starting from flower initiation was highly effective in suppression of larval population as well as pod damage and increasing the yields and comparable with three sprays of endosulfan.

**GAU, Anand**

An experiment was laid out to study the biocontrol based management modules for the control of pod borer complex in pigeon pea (var. BDN 2). The treatments and observations were as described in the trial under ANGRAU, Hyderabad.

Plots treated with *Bt* - *Ha*NPV - *Bt*- *Ha*NPV and three sprays of endosulfan spray at 15 days interval gave maximum decrease in *H. armigera* larval population (47.99% and 49.75% decrease, respectively). All other treatments were also found superior to control. Minimum seed damage was also observed in the same treatments as also high yields.

**TNAU, Coimbatore**

A field trial was laid out during August 1998 with the same treatments and observations.

The results indicated that the data on the pod damage in different treatments was significant. The pod borer damaged was significantly less in plots treated with endosulfan in first and second observation. In the third and fourth observation the pod borer incidence was significantly less in plots treated with endosulfan spray - *Bt* - *Ha*NPV - *Bt* followed by endosulfan spray. The pod damage was significantly less in plots treated with neem seed kernel extract - *Bt* - *Ha*NPV - *Bt* sprays followed by endosulfan sprays in the final observation. With regard to yield significantly more yields were obtained in plots sprayed with *Bt* - *Ha*NPV - *Bt* - *Ha*NPV followed by endosulfan sprays (Table 76).

Table 76. Incidence of pod borer complex in pigeonpea and yield in different biocontrol based treatments

| Treatments | Per cent pod borer damage | | | | | Yield (kg/ha) |
|---|---|---|---|---|---|---|
| | 1* | 2* | 3* | 4* | 5* | |
| *Bt-Ha*NPV-*Bt-Ha*NPV | 4.98$^{c}$ | 4.18$^{bc}$ | 3.4$^{bc}$ | 11.53$^{b}$ | 9.6$^{a}$ | 799.4$^{a}$ |
| *Bt-Ha*NPV- Endosulfan - *Bt* | 2.98$^{b}$ | 5.55$^{c}$ | 3.48$^{bc}$ | 15.4$^{c}$ | 16.33$^{c}$ | 33.1$^{ab}$ |
| Endosulfan - *Bt-Ha*NPV-*Bt* | 3.65$^{bc}$ | 3.48$^{b}$ | 1.18$^{a}$ | 0.03$^{a}$ | 13.5$^{b}$ | 96.9$^{bc}$ |
| NSKE-*Bt-Ha*NPV-*Bt* | 4.15$^{bc}$ | 4.30$^{bc}$ | 3.25$^{bc}$ | 9.55$^{a}$ | 9.6$^{a}$ | 625.0$^{c}$ |
| Endosulfan 3 sprays at 15 days interval | 1.53$^{a}$ | 1.38$^{a}$ | 2.45$^{b}$ | 9.43$^{a}$ | 11.58$^{a}$ | 753.1$^{ab}$ |
| Control | 6.50$^{d}$ | 10.15$^{d}$ | 4.58$^{c}$ | 19.73$^{d}$ | 25.18$^{d}$ | 521.9$^{d}$ |

* First four observations recorded 7 days after each treatment

**PAU, Ludhiana**

The experiment on the management of pod borer complex in pigeon pea was conducted at farmer's field at Raquba (Ludhiana) in a randomised block design with four replications and a plot size of 100 m$^2$. The treatments and observations were as given under ANGRAU, Hyderabad.

The pod damage, seed damage and yield in all the treatment combinations was significantly lower/ higher than control (Table 77). The damage in endosulfan treated plots (11.4%) was significantly lower than all other treatments. The damage in the alternate sprays of *Ha*NPV and *Bt* was 15.1 per cent and it was at par with all other combinations. The highest yield (9.07 q/ha) was obtained from the plots treated with endosulfan and it was significantly higher than all other combinations except alternate spray of *Ha*NPV and *Bt*.

Table 77. Efficacy of different combinations of biopesticides for the control of pod borer complex of pigeonpea

| Treatment* | Mean per cent pod Infestation | Mean seed Damage** | Grain yield (Q/ha) |
|---|---|---|---|
| *Bt-Ha*NPV-*Bt-Ha*NPV | 15.10 (24.87) | 17.00 | 8.73 |
| *Bt-Ha*NPV-Endosulfan-*Bt* | 17.60 (24.82) | 18.50 | 6.80 |
| Endosulfan-*Bt-Ha*NPV-*Bt* | 19.50 (26.18) | 24.00 | 6.46 |
| NSKE-*Bt-Ha*NPV-*Bt* | 22.10 (28.00) | 26.25 | 5.38 |
| Endosulfan | 11.40 (19.72) | 15.50 | 9.07 |
| Control | 31.20 (33.98) | 31.00 | 4.08 |
| CD (P = 0.05) | (4.12) | NS | 1.21 |

Figures in parentheses are angular transformation values

It can be concluded that three sprays of endosulfan and four sprays alternately with *Ha*NPV and *Bt* proved effective in reducing the pod damage and increasing the yield.

From the results of the trials in the four centres it can be concluded that three sprays of endosulfan was best and amongst the biocontrol based treatments *Bt* - *Ha*NPV alternate use was better than others.

### 4.21.2. NPV based management of *Helicoverpa armigera* on chickpea

**TNAU, Coimbatore**

A field trial was laid out in a farmers' field at S.S.Kulam in Coimbatore with following treatments in a randomised block design replicated four times.

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

Totally there were only two sprays during the season. The results indicated that

the pod damage was significantly less (10.73 per cent) in plots sprayed with *Ha*NPV - endosulfan in alternation followed by endosulfan in all the three observations recorded at 7 days interval after spraying (Table 78).

Table 78. Pod damage in chickpea by *Helicoverpa armigera* in different treatments

| Treatments | Per cent pods damaged | | |
|---|---|---|---|
| | 1* | 2* | 3** |
| *Ha*NPV + 10% crude sugar + 10% CSKE + 0.1% ranipal | 12.48a | 15.53$^{b}$ | 16.95$^{b}$ |
| *Ha*NPV above + 0.5% teepol adjuvant | 16.55b | 19.23$^{c}$ | 20.35$^{b}$ |
| *Ha*NPV-NSKE alternation | 16.70b | 21.68$^{cd}$ | 24.10$^{c}$ |
| *Ha*NPV-Endosulfan alternation | 10.73a | 12.43$^{a}$ | 15.5$^{a}$ |
| Endosulfan | 12.65a | 11.40$^{a}$ | 16.25$^{a}$ |
| Control | 19.15b | 23.10$^{d}$ | 28.0$^{d}$ |

## 4.22. Biological suppression of oilseed crop pests

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

An experiment was laid out in a farmer's field at Kapadvanj to evaluate the efficacy of *Metarhizium anisopliae* and *Bacillus popilliae* against white grubs in groundnut (Var. Gujarat 2). The following four treatments were replicated four times.

T1. *Metarhizium anisopliae* @ 0.5 Kg/h
T2. *Bacillus popilliae* @ 0.5 Kg/h
T3. Control
T4. Chlorpyriphos @5.0g a.i./kg seed.

Furrow application once at the time of sowing with *B. popilliae* and *M. anisopliae* @ 0.5 kg/ha and seed treatment with chlorpyriphos @ 5.0g.a.i./kg was done. The initial grub population at the time of ploughing was recorded. Crop damage assessment was done by recording the plant mortality and yield. Initial germination count was considered as 100 per cent for calculating the plant mortality percentage.

Initial grub population recorded at the time of ploughing was 9.5 grubs per $m^2$ The results indicated that minimum plant mortality (8.06 %) was observed in the plots treated with *M. anisopliae* closely followed by the plots treated with chlorpyriphos (8.33%).

The plots treated with *B. popilliae* and control showed plant mortality of 28.3% and 31.64%, respectively. Similar results were exhibited in the yield with *M. anisopliae* recording maximum yield (1269.53 kg/ha) and control the minimum yield (383.47 kg/ha).

## 4.23. Biological suppression of rice pests

### 4.23.1. Survey and quantification of natural enemy complex in rice

**KAU, Thrissur**

Three panchayats were chosen for the study during Rabi, 1998 and from each panchayat in Thrissur two 20 cent plots were identified for taking observations. Sweep net collections were done at weekly intervals and the number of natural enemies recorded. The arthropods obtained from the samples were counted, sorted and identified up to species level, wherever possible. They were then grouped as predators and parasitoids. The pattern of abundance of different groups from locations were represented as mean percentage values and given in Table 79.

Predators constituted between 18.23 and 43.12 of all arthropods in all sites except in Avinissery II where they were substantially low (4.8%). Parasitoids were primarily represented by Hymenoptera and they constituted between 6.68 per cent to 21.14 of all arthropods in all sites except in Avinissery II where it was very high (40.85 %). Diptera were also present in all locations, which ranged from 5.43 to 24.28 per cent.

The results of the studies conducted during Rabi 1997 revealed significant variation in natural enemy population in different locations.

Table 79. Mean percentage of natural enemies in six locations during Rabi, 1998

| Guilds | Sampling sites | | | | | |
|---|---|---|---|---|---|---|
| | Avini-ssery I | Avini-ssery II | Koorkken-cherry I | Koorkkh-encherry II | Man-nuthy I | Man-nuthy II |
| PREDATORS | 18.23 | 4.8 | 18.47 | 27.05 | 43.12 | 36.15 |
| Spiders | 5.03 | 1.63 | 8.69 | 9.61 | 14.29 | 13.41 |
| Coccinellids | 5.15 | 1.22 | 3.26 | 2.31 | 6.82 | 9.33 |
| *Cyrtorhinus lividipenis* | 3.49 | 0.81 | 1.81 | 11.03 | 10.88 | 5.54 |
| Others | 2.90 | 0.60 | 2.54 | 1.42 | 6.16 | 1.46 |
| PARASITOIDS | | | | | | |
| Hymenoptera | 21.14 | 40.85 | 11.23 | 15.84 | 6.68 | 7.87 |
| Diptera | 18.00 | 24.28 | 5.43 | 15.30 | 8.65 | 10.20 |

Two panchayats were selected during Kharif season and the survey conducted. Five observations were recorded from four locations. A reasonably high predatory population was represented in all the sites ranging from 42.74 to 61.04 per cent. A substantially low parasitoid population was observed in all the sites during Kharif, 1998 (Table 80).

Table 80. Mean percentage of natural enemies in four locations during Kharif, 1998

| Guilds | Sampling sites | | | |
|---|---|---|---|---|
| | Kizhakkaloor | Koonammoochi | Mannuthy | Nettissery |
| PREDATORS | 47.77 | 42.74 | 61.04 | 48.45 |
| Spiders | 6.45 | 7.26 | 6.21 | 5.52 |
| Coccinellids | 16.18 | 5.56 | 8.57 | 10.07 |
| *Cyrtorhinus lividipenis* | 5.49 | 3.42 | 9.64 | 0.00 |
| Others | 13.58 | 16.24 | 23.13 | 16.79 |
| PARASITOIDS | | | | |
| Hymenoptera | 3.47 | 4.70 | 5.14 | 4.56 |
| Diptera | 11.85 | 8.55 | 3.64 | 6.24 |

Data were statistically analysed and it was found that as compared to the Rabi season natural enemy population was low during Kharif though significant differences were found between locations.

**PAU, Ludhiana**

The survey for natural enemies of rice pests were carried out at farmer's field in villages Kot Kalan, Pragpur and Sofi Pind (Dist. Jalandhar) at weekly interval from August to October, 1998. The egg masses of stem borer and larvae of leaffolder 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 population of predators was recorded in the field. The extent of parasitism by *Telenomus* sp. was very high and it varied from 61.94 to 100 percent and was available throughout the crop season. However, *Trichogramma* sp. was recorded only during the last week of September and the extent of parasitism was 15.81 per cent. The population of spiders was quite high in the field and ten genera of spiders were observed in the field. They were present throughout the crop season and among them the population of the genus *Oxypes* (3-21/10 sweeps) and *Tetragnatha* (3-23 / 10 sweeps) was higher.

**TNAU, Coimbatore**

A plot of 20 cent area, one at Agricultural Research Station, Aliyarnagar and another at Paddy Breeding Station, TNAU, Coimbatore, with variety ADT 36 were fixed for the survey and quantification and samples of insects collected at weekly intervals in four subplots with 5 double sweeps in each sub plot. Egg masses of rice yellow stemborer were also collected and parasitism recorded. Phyophagous insect (45.34% ± 7.20), predators (37.42% ± 6.88), parasitoids (8.10% ± 3.74) and scavengers and tourists (9.14%) were collected from these plots. The predators include spiders (*Lycosa, Tetragnatha, Oxyopes, Argiope*), coccinellids (*Chielomenes, Coccinellia, Harmonia, Glleis*) as major fauna; parasitoids comprised *Trichogramma, Telenomus, Xanthopimpla, Temeleucha, Cotesia, Opius, Phanerotoma, Stenobracon* and *Tetrastichus.*

**AAU, Jorhat**

The experiment was conducted at three locations of Jorhat districts, *viz.*, ICR Farm of AAU, Kakajan and Charinga village for weekly monitoring on population build up of natural enemies of rice insect pests. From each location one 20 cent plot (var. Ranjit) was identified for taking observations and the farmers were requested not to apply insecticides. The samples of insect and spiders were collected at weekly intervals with 5 double sweeps in each subplot ( 4 $m^2$ ) at the three locations.

The sampling was started from the third week of August and continued up to 1st week of November. The maximum per cent of predators (33.37) and parasitoids (9.44 ) was recorded at Charinga village, and Kakajan, respectively (Table 81).

Three species not hitherto recorded from here were also got identified from IARI, New Delhi. They are

1. *Ischnojoppa luteator* (Ichneumoinidae)
2. *Amauromorpha* sp. (Schneumonidae)
3. *Polistes habracus* (Vespidae)

Table 81. Per cent population of predators and parasitoids at three locations

| Location | Predators (%) | Parasitoids(%) |
|---|---|---|
| ICR Farm , AAU, Jorhat | 28.31 | 7.56 |
| Kakajan | 30.29 | 9.44 |
| Charinga | 33.97 | 6.90 |

### 4.23.2. Field evaluation of integrated use of *T. japonicum, T. chilonis* and *Bacillus thuringiensis* against rice stem borer and leaffolder

A field trial was laid out at TNAU, Coimbatore during Kharif'98 with variety ASD18 to find out the effectiveness of the release of egg parasitoids in combination with *Bt* against yellow stemborer and leaffolder with the following treatments.

i. *Trichogramma japonicum* was released at 1,00,000/ha thrice at weekly interval. The first release was done after observing yellow stem borer moth activity in the field and then spraying *Bt* @ 1.0 kg/ha.
ii. *T. chilonis* was released at 1,00,000/ha thrice at weekly interval, after observing adult leaffolder activity and *Bt* spray given @ 1.0 kg/ha.
iii. Both *T. japonicum* and *T. chilonis* were released along with *Bt* spray
iv. Need based application of insecticides
v. Untreated control

The incidence of stem borer was significantly less in the biocontrol treatments as compared to untreated control. The data revealed that lowest incidence of stem borer was recorded in plots where *T. chilonis* was released along with *Bt* spray, followed by *T. chilonis* and *T. japonicum* with *Bt*. The incidence of leaffolder was significantly less in all the biocontrol treatment plots compared to chemical control on 75th day (Table 82). Highest grain yield was obtained in plots where both *T. japonicum* and *T. chilonis* were released along with *Bt* spray.

Table 82. Evaluation of *Trichogramma* spp. and *Bacillus thuringiensis* against rice pests

| Treatment | Incidence of stem borer (DAT) | | | Incidence of leaffolder (DAT) | | Grain yield mt/ha |
|---|---|---|---|---|---|---|
| | 25 | 45 | 90 | 50 | 75 | |
| *Trichogramma japonicum* + *Bt* | 12.48$^{a}$ | 5.22$^{b}$ | 3.44$^{bc}$ | 3.36$^{d}$ | 3.32$^{c}$ | 3.350 |
| *T. japonicum* + *T. chilonis* + *Bt* | 11.94$^{a}$ | 5.04$^{b}$ | 3.18$^{c}$ | 6.08$^{c}$ | 3.38$^{c}$ | 3.600 |
| *T. chilonis* + *Bt* | 8.86$^{b}$ | 4.46$^{b}$ | 3.02$^{c}$ | 6.20$^{c}$ | 3.80$^{c}$ | 3.040 |
| Chemical control | 10.54$^{ab}$ | 4.88$^{b}$ | 5.28$^{b}$ | 8.08$^{b}$ | 6.36$^{b}$ | 3.320 |
| Untreated control | 12.54$^{a}$ | 9.56$^{a}$ | 7.86$^{a}$ | 23.62$^{a}$ | 14.84$^{a}$ | 2.470 |

### 4.23.3. Field evaluation of integrated use of *Trichogramma japonicum* and *Trichogramma chilonis* and *Bt* against rice stem borer and rice leaf folder

The experiment was laid out at KAU, Thrissur during October 1998 in confounded block design with five treaments and eight replications. Observations on leaf roller and stem borer infestation were recorded from five hills in each replication. The results indicated that incidence of stem borer and leaf roller were inconsistent with the applications of treatments and so no conclusions could be drawn (Table 83). Yields however was significantly different in Delfin treated plots as compared to untreated control while the rest of the treatments were on par with controls. No firm conclusions could be drawn from this trial.

Table 83. Incidence of infestation of rice leaffolder and stem borer in different treatments

| Treatment | Leaf folder incidence (DAT) | | | Stem borer incidence (DAT) | | | | Grain yield ($g/m^2$) |
|---|---|---|---|---|---|---|---|---|
| | 20 | 28 | 36 | 20 | 28 | 36 | 60 | |
| Chemical control | 2.24 | 1.61 | 0.59 | 0 | 7.72 | 2.49 | 11.1 | 331.5 |
| Control | 5.13 | 0.81 | 1.15 | 0 | 5.49 | 0.48 | 8.30 | 326.5 |
| *Trichogramma* @50,000/ha | 3.91 | 2.08 | 1.60 | 0 | 8.29 | 4.98 | 13.88 | 310.6 |
| *Trichogramma* @1,00,000/ha | 4.82 | 1.73 | 1.04 | 0.5 | 7.29 | 3.29 | 12.46 | 364.1 |
| Delfin | 0.72 | 1.80 | 1.58 | 0.43 | 3.75 | 1.01 | 12.32 | 389.9 |
| CD(P=0.05) | - | - | - | - | - | - | - | 40.5 |

### 4.23.4. Field evaluation of integrated use of *Trichogramma chilonis* and *T. japonicum* against rice stem borer and leaf folder

The experiment on the evaluation of *T. chilonis* and *T. japonicum* against rice stem borer and leaf folder was conducted at farmer's field at Khudi Kalan (Dist. Sangrur, Punjab). Simultaneous releases of *T. chilonis* + *T. japonicum* were made at 20 DAT at three dosages i.e. 50,000, 75,000 and 1,00,000 per ha at 7 days interval. The plot size was 0.4 ha for all the treatments. The data on the per cent leaves folded and per cent dead hearts were recorded on the basis of 10 hills each from 3 spots at 60 DAT. The per cent white ears were recorded near maturity on the basis of 30 hills each from 3 spots in a plot. The yield was recorded on whole plot basis.

The lowest dead hearts (1.7%) were recorded in plots where parasitoids were released @ 1,00,000 per ha and was at par with insecticidal spray but better than lower

dosages of the parasitoids and control. The per cent white ears were lowest (5.0%) in insecticidal spray and at par with higher dosages of the parasitoids (1,00,000 and 75,000 per ha) but was significantly lower than lower dosages of parasitoids (12.5%) and control (16.5%). The highest yield (63.0 q/ha) was obtained in plots where the parasitoids were released @ 1,00,000 per ha and it was at par with insecticidal spray (62.00 q/ha) but was significantly better than remaining treatments (Table 84).

Table 84. Effectiveness of *T. chilonis* and *T. japonicum* for the control of stem borer

| *T. chilonis* + *T. japonicum* (Dosage/ha)* | Per cent dead hearts | Per cent white ears | Yield (Q/ha) |
|---|---|---|---|
| 1,00,000 | 1.7 (7.53) | 5.0 (12.92) | 63.0 |
| 75,000 | 3.7 (11.12) | 5.5 (13.59) | 61.6 |
| 50,000 | 6.8 (15.80) | 125 (20.70) | 56.1 |
| Insecticidal spray** | 2.2 (8.49) | 5.0 (12.92) | 62.0 |
| Control | 7.7 (16.15) | 16.5 (23.97) | 55.3 |
| CD(0=0.05) | (2.98) | (3.31) | 1.3 |

It can be thus inferred that 8 releases of *T. chilonis* and *T. japonicum* at 7 days interval starting 20 DAT gave effective control of stem borer.

### 4.23.5. Field evaluation of *T. japonicum* and *T. chilonis* against rice stem borer and leaf folder

The experiment for the evaluation of *T. japonicum* and *T. chilonis* against rice stem borer and leaf folder was conducted in farmer's field at Kakajan (Assam). In this experiment *T. japonicum* and *T. chilonis* both @ 50,000/ha were simultaneously released at weekly intervals. The releases of two species of *Trichogramma* were also made @ 1,00,000/ha simultaneously at weekly intervals. *Bt* application and a need based spray of insecticide were also given. The dead heart per cent was lowest (3.12%) in the 5th week after the field release of *T. japonicum* + *T. chilonis* @ 1,00,000/ha followed by *T. japonicum* + *T. chilonis* @ 50,000/ha (3.71). In general there were no differences between the release rates @ 50,000/ha and 1,00,000/ha in checking the formation of the dead heart during different weeks of observation. The per cent infestation of leaf folder was lowest (3.12) in the 5th week after the release of *T. japonicum* + *T. chilonis* @ 1,00,000/ha followed by the release of *T. japonicum* + *T. chilonis* @ 50,000/ha (3.71) against 8.87% in the unreleased plot (Table 85).

Table 85. Evaluation of *T. japonicum* and *T. chilonis* against rice stem borer and leaf folder (Rabi 1998)

| Treatment | Per cent dead hearts due to stem borer (at weekly intervals) | | | | | | | Mean infestation of leaffolder (at weekly intervals) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-released | I | II | III | IV | V | VI | Pre-released | I | II | III | IV | V | VI |
| *T.japonicum*+ *T.chilonis* @ 50,000/ha | 7.25 | 9.48 | 5.71 | 6.42 | 5.19 | 3.71 | 3.99 | 4.63 | 6.41 | 9.48 | 9.50 | 6.38 | 5.19 | 3.71 |
| *T.japonicum*+ *T. chilonis* @ 1,00,000/ha | 7.71 | 9.40 | 3.71 | 7.18 | 5.44 | 3.12 | 4.77 | 5.54 | 6.97 | 9.51 | 7.35 | 7.18 | 5.41 | 3.12 |
| Need based insecticidal application | 7.70 | 9.71 | 8.35 | 6.87 | 4.04 | 3.35 | 3.36 | 4.56 | 8.36 | 9.57 | 8.32 | 6.87 | 4.06 | 3.34 |
| Control | 7.89 | 8.54 | 13.4 | 11.17 | 8.26 | 7.90 | 9.72 | 9.53 | 6.50 | 5.58 | 6.94 | 7.03 | 8.02 | 8.87 |
| CD (P=0.05)NS | NS | 2.00 | 2.09 | 1.48 | 1.22 | 1.42 | 0.89 | 1.35 | 1.53 | 1.74 | NS | 1.09 | 0.83 | |

Evaluation of *T. japonicum*, *T. chilonis* and *B. thuringiensis* against rice stem borer and leaf folder (Kharif 1998)

| Treatment | Per cent dead hearts due to stem borer (at weekly intervals) | | | | | | | Mean infestation of leaffolder (at weekly intervals) | | | | | | | Yield (kg/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-released | I | II | III | IV | V | VI | Pre-released | I | II | III | IV | V | VI | |
| *T.japonicum*+ *T.chilonis* @ 50,000/ha | 3.22 | 4.23 | 4.79 | 2.74 | 6.22 | 6.01 | 4.15 | 4.95 | 3.33 | 2.96 | 2.77 | 2.74 | 2.55 | 3.99 | 3322.6 |
| *T.japonicum*+ *T. chilonis* @ 1,00,000/ha | 3.80 | 4.77 | 4.67 | 3.95 | 6.93 | 7.15 | 4.12 | 5.80 | 3.37 | 2.86 | 2.74 | 5.01 | 2.01 | 3.16 | 3195.8 |
| Delfin | 3.82 | 5.57 | 5.03 | 3.84 | 8.31 | 7.19 | 5.68 | 5.10 | 3.82 | 3.27 | 3.16 | 3.79 | 3.33 | 4.96 | 2985.0 |
| Insecticide for protection | 3.31 | 5.32 | 4.47 | 4.24 | 9.99 | 4.05 | 4.89 | 4.32 | 3.74 | 2.94 | 2.79 | 4.24 | 3.00 | 4.02 | 3388.8 |
| Control | 3.96 | 5.28 | 4.71 | 11.21 | 11.97 | 10.09 | 9.19 | 9.14 | 3.97 | 3.68 | 5.06 | 5.00 | 5.60 | 3.83 | 2618.0 |
| CD (P=0.05) | NS | NS | NS | 1.31 | 1.27 | 1.42 | 2.20 | 1.82 | NS | 0.51 | 0.83 | 0.87 | 0.57 | 0.83 | 405.43 |

The evaluation was also done during Kharif, 1998. The results presented in Table 85 revealed that the per cent dead heart was lowest (2.74) in the third week after the field release of *Trichogramma* @ 50,000/ha against 11.21% in the unreleased plot followed by the release of the parasitoid @ 1,00,000/ha (3.95%). The leaf folder damage was lowest (2.55%) in the 4th week after the release of *Trichogramma* @ 50,000/ha against 5.60% in the unreleased plot.

The field recovery of *T. japonicum* as estimated by placing *Corcyra* egg cards during Kharif 1998, was to the extent of 24.0%.

### 4.23.6. Evaluation of biocontrol based IPM in rice

**TNAU, Coimbatore**

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

i. In the biocontrol treatment *T. japonicum* and *T. chilonis* @ 50,000/ha were released thrice at weekly interval after observing the moth activity to control yellow stem borer and leaffolder

ii. Spraying of endosulfan (0.07%) thrice on 50th, 70th and 90th day

iii. Untreated control

The results revealed that both biocontrol and chemical treatments recorded significantly lesser incidence of dead heart and leaffolder and highest grain yield compared to untreated control. The yield increase was significant in biocontrol treatment over chemical control (Table 86).

Table 86. Evaluation of biocontrol based IPM in rice (var-ASD-18)

| Treatment | Incidence of stem borer (DAT) | | Incidence of leaffolder (DAT) | | | Grain yield mt/ha |
|---|---|---|---|---|---|---|
| | 25 | 45 | 90 | 50 | 75 | |
| *Trichogramma japonicum* + *T. chilonis* @ 50,000/ha | 12.60$^{b}$ | 6.00$^{b}$ | 4.84$^{b}$ | 5.51$^{c}$ | 2.97$^{c}$ | 3.200$^{c}$ |
| Endosulfan (0.07%) | 13.33$^{ab}$ | 4.71$^{b}$ | 4.93$^{b}$ | 6.83$^{b}$ | 7.21$^{b}$ | 2.921$^{b}$ |
| Untreated control | 14.63$^{a}$ | 8.77$^{a}$ | 9.33$^{a}$ | 16.40$^{a}$ | 10.40$^{a}$ | 2.607$^{a}$ |

Figures followed by same letter are not significantly different

**AAU, Jorhat**

Biocontrol based IPM was evaluated in comparison with chemical control in the farmer's field at Kakajan (Assam) during Rabi, 1998. The release of *Trichogramma* @ 50,000/ha could check the formation of dead heart significantly. The infestation of stem borer gradually declined from the fourth week after the field release of the parasitoid and the lowest population of dead heart was recorded in the 5th week after the field release (3.62%) against the unreleased plot (8.76%) (Table 87). The white ear head population was also low (4.88%) in the *Trichogramma* released plot against 9.62% in the unreleased

plot. Significantly good control of leaffolder was also achieved from 2nd week onwards (Table 88).

The results of a similar trial during Kharif, 1998 revealed that the dead heart population was lowest 3.47% in the released plot (*T. japonicum* 50,000/ha) against 7.76% in the unreleased plot. The dead heart population in the unreleased plot ranged from 7.99% to 8.30% (Table 89). The leaf folder population was low and so the evaluation could not be done for the pest.

Table 87. Effect of biocontrol based IPM on the incidence of rice stem borer (Rabi 1998)

| Treatment | Pre-released % dead hearts | Mean % dead hearts at weekly intervals | | | | | % White ear heads |
|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | |
| Biocontrol | 7.83 | 7.36 | 8.95 | 5.37 | 4.28 | 3.62 | 4.88 |
| Chemical control | 7.43 | 9.41 | 7.09 | 6.53 | 4.20 | 3.82 | 6.56 |
| Control | 9.18 | 15.64 | 12.60 | 9.42 | 7.43 | 8.76 | 9.62 |
| CD (P=0.05) | NS | 2.51 | 1.42 | 1.31 | 1.12 | 1.00 | 1.09 |

Table 88. Effect of biocontrol based IPM on the incidence of leaf folder (Rabi 1998)

| Treatment | Pre-released % of leaffolder damaged leaves | Mean % of leaffolder damaged leaves at weekly intervals | | | | |
|---|---|---|---|---|---|---|
| | | I | II | III | IV | V |
| Biocontrol | 6.35 | 5.14 | 2.80 | 1.50 | 2.26 | 1.91 |
| Chemical control | 6.74 | 3.99 | 3.04 | 2.13 | 2.18 | 1.69 |
| Control | 6.32 | 5.49 | 6.05 | 6.66 | 8.63 | 6.60 |
| CD (P=0.05) | NS | 1.24 | 0.70 | 0.89 | 1.09 | 0.61 |

Table 89. Effect of biocontrol based IPM on the incidence of rice stem borer (Kharif 1998)

| Treatment | Pre-released % dead hearts | Mean % dead hearts at weekly intervals | | | | | | % White ear heads |
|---|---|---|---|---|---|---|---|---|
| | | I | II | III | IV | V | VI | |
| Biocontrol | 8.30 | 7.45 | 10.84 | 5.84 | 6.60 | 4.74 | 3.47 | 3.71 |
| Chemical control | 8.08 | 7.45 | 10.34 | 7.51 | 7.24 | 6.54 | 3.72 | 4.35 |
| Control | 7.99 | 7.70 | 11.77 | 6.09 | 10.21 | 7.53 | 7.76 | 6.67 |
| CD | NS | NS | 0.97 | 1.24 | 1.27 | 0.92 | 1.42 | 1.39 |

### 4.23.8. Evaluation of biocontrol based IPM in rice

The experiment was laid out in confounded block design at KAU, Thrissur during October,1998 with three treatments and eight replications. Observations were recorded on incidence of leaffolder and stem borer. Leaf folder and stem borer infestation was variable and not entirely consistent with application of treatments. The analysis of yield data showed no significant difference between the treatments for total grain weight (Table 90).

Table 90. Percentage infestation of rice leaffolder and stem borer

| Treatment | Per cent leaf folder incidence (DAT) | | | Per cent stem borer incidence (DAT) | | | | Grain yield ($g/m^2$) |
|---|---|---|---|---|---|---|---|---|
| | 20 | 28 | 36 | 20 | 28 | 36 | 60 | |
| Chemical control | 3.6 | 1.64 | 1.12 | 0.39 | 0.95 | 1.59 | 6.34 | 312.4 |
| Neem+ Biocontrol | 7.13 | 0.59 | 1.06 | 0.50 | 2.70 | 1.07 | 7.48 | 297.4 |
| Control | 4.05 | 0.53 | 0.94 | 0 | 3.87 | 1.15 | 7.298 | 307.0 |
| CD (P=0.05) | - | - | - | - | - | - | - | 49.4 |

### 4.23.9. Parasitism of rice hispa

Rice hispa infested leaves were collected from remote areas and reared in the laboratory for the emergence of natural enemies. *Bracon hispae* and *Chrysonotomyia* sp. emerged from the larvae of rice hispa and the per cent parasitism was 30.67% and 9.33%, respectively. Two numbers of *B. hispae* emerged from a single infested hispa larva.

Attempts to rear this parasitoid using other hosts have not proved successful so far.

## 4.24. Biological suppression of coconut pests (CPCRI, Kayangulam)

### 4.24.1. Mass multiplication and field evaluation of *Apanteles taragamae* against *Opisina arenosella*

Monthly samples collected to record the seasonal incidence from two locations,

Ayiramthengu and Thodiyur revealed maximum parasitism of 12.5% in October and 44.4% in December minimum parasitism of 1.5% in March and 1.8% in February.

Outbreak of *Opisina arenosella* was observed in and around CIFT, Cochin. High level of parasitism by *A. taragamae* was noticed.

### 4.24.2. Seasonal incidence of baculovirus, green muscardine fungus and bacteria on *Oryctes rhinoceros*

*Oryctes rhinoceres* was collected from Alleppey, Quilon and Kottayam districts. A total of 3119 grubs and 179 beetles were collected and observed. Of which 21.2% beetles and 6.7% of the grubs showed positive baculovirus infection, 2.05% of the grubs were mycosed by the green muscardine fugus and 24% of them were infected by opportunistic bacteria. Preliminary microbial and biochemical tests on the two bacterial isolates isolated from septicemia *Oryctes* grubs proved to be gram-negative bacteria having biochemical characters of *Pseudomonas*.

#### 4.24.2.1. Field evaluation of baculovirus

The study has been initiated in an area of 2.7 ha in Block I of CPCRI, Kayangulam. Out of 534 palms in this block, 75 have been randomly selected for pre-release data for *Oryctes* damage and it was found that 20.02% of the leaves and 2.3% of the spindles showed damage symptoms. Site occupancy by the pest in nearby breeding spots showed occupancy of 46.87%.

From September 1998 to May 1999, 41 beetles inoculated with the baculovirus have been released in Block 1. The releases were made in four batches and post-release observations are to be taken six months after the final release (November, 1999).

#### 4.24.2.2. Alternate feed material for labouratory maintenance of OBV inoculum

Sterilized or unsterilized coir waste when used as feeding material for OBV inoculated grubs, yielded 46% and 36% OBV infected samples whereas, sterilized and unsterilized cow dung yielded 32% and 12% OBV infected samples, respectively. Secondary infection due to bacteria was very low in coir waste when compared to cow dung. Coir-waste that has been found to be the best is being used as the staple feeding material for the maintenance of OBV inoculated *Oryctes*.

### 4.24.3. Pathogenicity trials with bacteria and virus against *Rhynchophorus ferrugineus*

Isolations from field collected red palm weevils/grubs have yielded eleven strains of bacteria and two yeast like organisms, which have been purified and sub-cultured.

### 4.24.4. Search for bioagents of *Stephanitis typica*

Search for natural enemies of lace bug, *Stephanitis typica* revealed the presence of 14 sp. of insects and 23 spiders as predators, in addition to the mirid predator *Stethoconus praefectus* recorded earlier. *Endochus inornatus Rhinocoris fuscipes, Ankylopteryx octopunctata, Chelisoches morio, Phidippus* sp., *Tetragnatha andamanensis* are new records of natural enemies of *S. typica*..

*Aspergillus flavus* gave 100 mortality against nymphs within 5-6 days with spore concentration of $10^5$-$10^6$ spores/ml.

## 4.25. Biological suppression of fruit crop pests

### 4.25.1. Population of dynamics of spiralling whitefly, *Aleurodicus dispersus* and its natural enemies on guava (IIHR, Bangalore)

Population dynamics of the white fly studied for two years revealed that the population was higher (164.20 to 218.60 per leaf) from March to June and low (11.70 to 29.90) from October to January. The density of the whitefly was positively correlated with maximum and minimum temperature and negatively correlated with morning and evening humidity. A total of 12 predators were encountered on *A. dispersus* during the study period. Among them *Axinoscymnus puttarudriahi*, *Cryptolaemus montrouzieri* and *Mallada astur* were found to occur more frequently than the other predators. Correlation between the predators and the whitefly or the partial regression co-efficient of the predators was not significant. The multiple regression equation fitted was $Y = -641.875 + 1.879\ X_1 + 22.807\ X_2 + 2.175\ X_3 - 0.836\ X_4 + 1.513\ X_5 - 0.415$ with $R^2 = 0.782$ where Y denotes the whitefly population, $X_1$, $X_2$, $X_3$, $X_4$, $X_5$ and $X_6$ indicates the total predators, maximum temperature, minimum temperature, morning and evening relative humidity and the rainfall, respectively (Table 91).

Table 91. Correlations of the spiralling whitefly population with the predators and weather factors on guava at Bangalore

| | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | Y (Whitefly) |
|---|---|---|---|---|---|---|
| $X_1$ (Predators) | -0.156 | 0.139 | 0.314 | 0.387 | 0.337 | - 0.099 |
| $X_2$ (Maximum temperature) | | 0.389 | -0.771** | -0.780** | - 0.255 | 0.860** |
| $X_3$ (Minimum temperature) | | | 0.059 | 0.070 | 0.414* | 0.433* |
| $X_4$ (Morning humidity) | | | | 0.981 | 0.569** | - 0.630** |
| $X_5$ (Evening humidity) | | | | | 0.577* | - 0.646** |
| $X_6$ (Rainfall) | | | | | | - 0.354 |

### 4.25.2. Evaluation of *Cryptolaemus montrouzieri* in suppressing the spiralling whitefly on guava (IIHR, Bangalore)

Three to four day larvae of *C. montrouzieri* were released in the morning hours on the guava plants infested with the spiralling whitefly in two locations, *i.e.* Hebbal and Ivarakandapura. Six releases of *C. montrouzieri* were made @ 50 larvae/plant and a total of 300 predators were released per plant during January-June 1998 coinciding with higher incidence of whiteflies. Releases of the predator were discontinued between July to March to see the impact of *C. montrouzieri*. Observations were recorded on five plants. Sampling was done at monthly interval on four side shoots per guava plant. From each shoot, five leaves (6th to 10th leaf) were collected and brought to the laboratory. The number of nymphs and adults of *A. dispersus* present on each leaf were counted. The results indicated that there was not much variation in the population of whitefly on the released plant and check. As long as the predator was released there was some temporary reduction in the whitefly population. After the releases were discontinued, the population remained more or less similar on both the released (181.4/leaf) and check (172.38).

Similar results were obtained at Ivarakandapura during March 1998-March 1999. Five releases at monthly intervals @ 60/plant were carried out. In both the predator released plant and check, the whitefly population was comparable in March 1999.

### 4.25.3. Survey for the natural enemies of spiralling whitefly

**KAU, Thrissur**

A survey for the natural enemies of the whitefly was commenced during summer 1998-99 in Thrissur district. Whitefly infested leaves of brinjal, chillies, guava, tomato, ceara rubber etc., were collected from the field and observed in the laboratory for the occurrence of parasitoids and predators. Parasitisation by an aphelinid parasitoid was noticed on the last stage whitefly nymphs. The parasitoid is probably an undescribed species of *Encarsia* close to *meritoria*. This is the first report of a parasitoid of *A. dispersus* from India. A coccinellid predator *Axinoscymnus puttarudriahi* was also found on *A. dispersus* at Vellanikkara. Parasitism ranging from 6.72 to 49.06 per cent could be noticed on the host plants like chillies, guava, brinjal and tomato. In the case of ceara rubber, tapioca and *Poinsettia* the parasitism was extremely low.

**TNAU, Coimbatore**

Periodical samples of guava and citrus damaged by spiralling whitefly were collected during April, 1998 - March 1999 in Coimbatore and Erode districts and the natural enemies found feeding on spiralling whitefly, *Aleurodicus dispersus* were identified and recorded. The natural enemies were predominantly coccinellid predators *viz., Cryptolaemus, Chilocorus, Scymnus, Cheilomones,* an unidentified *Chrysopa* and a hymenopterous parasitoid.

### 4.25.4. Relative abundance of the egg parasitoids of pomegranate fruit borer, *Deudorix isocrates* (IIHR, Bangalore)

The eggs of *D. isocrates* were collected at 15 days interval from four-year-old pomegranate plants cv.Ganesh. Five plants were chosen randomly and eggs collected at monthly interval. Eggs were kept individually in glass vials (3"x1") and emergence of the parasitoids recorded daily.

The parasitoids of *D. isocrates* were active almost throughout the year except December. Parasitoid activity was higher in July-August during which period egg laying by the host *D. isocrates* was also more. As many as 38 eggs of *D. isocrates* were collected in the first week of July but the activity of *D. isocrates* was less in December-January (0-3 eggs/plant). Among the parasitoids, *Telenomus* sp was a major one while

*Ooencyrtus papilionis* was found in lesser number. *Trichogramma chilotraeae* was collected during the first week of June. The total parasitism went up to 80% in May.

### 4.25.5. Activity of pomegranate fruit borer and its parasitoids (Dr.YSPUH & F, Solan)

The incidence of pomegranate fruit borer, *Deudorix epijarbas* was noticed during first week of June (2.0%). The pest activity increased by last week of July (21.6%). Maximum number of borer infested fruits was sampled in second week of August (63.8%) and the severity persisted up to first week of October. While recording the borer incidence eggs present were also examined for parasitisation. Per cent parasitisation varied from 0 to 100 with a mean of 42.7±10.6%.

The eggs encountered during field observation were collected and brought to the laboratory for emergence of adult parasitoids. During the season, 161 eggs were collected of which, 69.5% were parasitised, 21.7% hatched, and 8.7% did not hatch. Three parasitoids, *Telenomus* (Scelionidae), *Anastatus* (Eupelmidae) and *Trichogramma* (Trichogrammatidae) with a frequency of occurrence of 11 (100%), 2 (18%) and 3 (27%) emerged. Amongst the parasitised eggs, 93.7, 2.7 and 3.6% were parasitised by these three respective species.

### 4.25.6. Safety of some commonly used pesticides to the pomegranate fruit borer parasitoid, *Telenomus* sp. (IIHR, Bangalore)

Six pesticides, *viz.* dichlorvos (0.10%), endosulfan (0.07%), neem seed kernel extract (4%), carbaryl (0.10%) and neem oil (2%) were tested for their safety against *Telenomus* sp. Ten adults were exposed to each treatment and the mortality was recorded at 1, 3, 6 and 24 hrs of exposure. Endosulfan and dichlorvos had quick knock down effect causing 100% adult mortality within an hour of exposure. Carbaryl caused cent per cent mortality after six hours of exposure. Botanical pesticides did not cause mortality of the parasitoids up to 6 hours of exposure. However, Azadirachtin and neem oil proved highly toxic inflicting 80-100% mortality after 24 hours of exposure. Only NSKE was found to be less toxic causing 25% mortality of adults after 24 h of exposure.

### 4.25.7. Collection of natural enemies of fruit crop pests (IIHR, Bangalore)

A total of 24 natural enemies were collected from 11 insect pests attacking mango, guava, grapes, pomegranate, custard apple and acid lime. *Trichogramma chilotraeae* was reported for the first time from *Deudorix isocrates*. The coccinellid predator,

*Cheilomenes sexmaculata* was found dominant on *Aphis punicae* infesting pomegranate in December-January. *Spalgis epius* and *Aneglcis cardoni* were recorded for the first time on the spiralling whitefly, *Aleurodicus dispersus*.

### 4.25.8. Predatory potential and development of *Chrysoperla carnea* on pomegranate aphid (IIHR, Bangalore)

Larvae hatching from freshly laid eggs of *C. carnea* were transferred individually to glass vials. Ten larvae of *C. carnea* were offered known number of freshly collected pomegranate aphids (*Aphis punicae*) daily until the predator pupated. Prey consumption by *C. carnea* was computed instar-wise. The number of aphids consumed during first, second and third instars averaged 63.60, 108.20 and 674.50, respectively. A single larva of *C. carnea* during its development consumed a total of 846.30 aphids. A total of 12.5 days were required for the larvae to complete development on *A. punicae*.

### 4.25.9. Natural parasitism on pomegranate hairy caterpillar, *Trabala vishnou* (IIHR, Bangalore)

Larvae of *T. vishnou* were collected from pomegranate plants from Hessarghatta, Yelahanka and M.S.Palya and reared in the laboratory. The pupae yielded the tachinid parasitoid, *Blepheripa zebina* (2-3 pupa) and the per cent parasitism ranged from 66.67 to 100% during October-November.

### 4.25.10. Seasonality of *Encarsia azimi* on the pomegranate whitefly (IIHR, Bangalore)

Seasonal incidence studies on the ash whitefly, *Siphoninus phylireae* and its parasitoid *Encarsia azimi* was initiated in January 1998 and continued up to March 1999. The leaf infestation by whitefly went up to 90.25% in May and was found to be low during July to November. The activity of both *S. phyllireae* and *E. azimi* were higher in February-May. A maximum of 94.70% parasitism by *E. azimi* was observed on the ash whitefly in June 1998.

### 4.25.11. Suppression of *Pseudococcus lilacinus* and *Maconellicoccus hirsutus* on acid lime (IIHR, Bangalore)

The oriental mealybug *P. lilacinus* appeared on three-year-old acid lime plants at IIHR Farm, Bangalore in September 1998. The initial sampling did not yield any natural

enemy. Releases of *C. montrouzieri* were made @ 20/plant. A mean of 160.50 mealybugs/shoot was observed when the study was initiated. The mealybug population started declining and was found in negligible numbers by mid November, 1998 and ceased to be a problem from January, 1999 to March, 1999. The cecidomyiid *Triommata coccidivora* had emerged in negligible numbers during September.

During January-March, 1999, the sampling of acid lime shoots infested with *M. hirsutus* yielded the encyrtid parasitoid, *Anagyrus dactylopii* and the cecidomyiid predator, *Triommata coccidivora* in negligible numbers. *Cryptolaemus montrouzieri* was released twice @ 25/plant. The results indicated that there was reduction in the mealybug population from 39.40/shoot in January, 1999 to 1.30 in mid March, 1999.

**4.25.12. Seasonal abundance of the woolly aphid and its natural enemies (Dr.YSPUH & F, Solan)**

Monitoring of the woolly aphid and its natural enemies at weekly interval at Solan revealed that from April to first week of June, 1998, colony count was low and the mean varied from 0.8 to 2.4 with coverage of the aphid from 0.12-0.86. The activity of predators mainly chrysopids and *Coccinella septempunctata* (0.1-0.6/replicate) was low during April-May and thereafter nil. *Aphelinus mali* also remained active but in small numbers (0.1-0.6/replicate) during April-May. Increase in aphid population was recorded after the first week of June. From September second week to October end, low aphid population was recorded. Heavy parasitisation of the woolly aphid by *A. mali* was observed in November at Sharbo (Rekong Peo), Kinnaur district.

**4.25.13. Incidence of wooly aphid and its natural enemies (SKUAS & T, Srinagar)**

Two orchard areas (Kakpora and Narbal) were selected to record the incidence of the pest and its natural enemies from March to November at 15 days interval. Infected twigs were randomly collected and live and parasitised aphids counted and kept in small cages for emergence of parasitoids. Visual observations were made for the presence of predators.

The incidence of the aphid commenced in second fortnight of April and continued till last week of November at both areas. The population/cm$^2$ at Kakpora was minimum (2) during second fortnight of April and highest (20) during first fortnight of August whereas at Narbal the maximum of (21) was during second fortnight of August.

The parasitoid, *Aphelinus mali* and predators, *Chilocorus bijugus* and *Coccinella*

*septempunctata* were recorded. The parasitisation was in the range of 3.15 to 7.47% at Kakpora and 4.58 to 10% at Narbal. The emergence of parasitoids started from last week of June (Kakpora) and I week of July (Narbal) and continued till November in both areas.

### 4.25.14. Impact of release of the predator, *Chrysoperla carnea*, on woolly aphid population in the apple orchard (Dr.YSPUH & F, Solan)

Six trees in the apple orchard with woolly aphid were selected and pretreatment count (number of aphid colonies, their mean-size and total spread on branches) was recorded before the release of young larvae of *Chrysoperla carnea* (2-3 day old). Post-treatment counts were recorded after one and three weeks of release and expressed as per cent increase or decrease over the pretreatment counts. Similar observations were made on the trees where no release of the predator was made.

Within a week of release of larvae of *C. carnea*, reduction in number of colonies, mean colony size and spread of aphids was evident and the reduction was between 36 and 65 %. Reduction in colony count was observed on trees representing control where no release of predators was made due to the population of local predators (coccinellids and syrphids) and the parasitoid, *Aphelinus mali*. Overall reduction was between 3.1 and 13.9 % over the pretreatment counts. However, after 3 weeks of release, reduction in aphid population was more on the trees receiving *Chrysoperla* larvae (72.4 - 96.2 %) than on control trees (51.8 - 83.5 %).

### 4.25.15. Seasonal abundance of San Jose scale and its natural enemies (Dr.YSPUH & F, Solan)

The twigs regularly collected from apple orchards at Nauni, Solan had parasitisation by *Aphytis* sp. (the *proclia* group) up to 18.8 % (mean 5.1%). Parasitization by *Encarsia perniciosi* was up to 12.5 % (mean 2.8 %). Predatory coccinellids, primarily *Chilocorus bijugus*, were quite active and removed 0-100 % (mean 56.0 %) of the scale in the orchard where *C. bijugus* was released two years ago. The samples of scale infested twigs collected from apple orchards in Shimla (Rohru and Kotkhai) district had parasitisation by *Aphytis* and *E. perniciosi* up to 1.8 (mean 0.5) and 70.3 per cent (mean 38.0). However, in Kullu (Bajaura) district it was up to 6.3 (mean 3.3) and 3.1 per cent (mean 2.0), respectively, by these two parasitoids. Feeding by coccinellids was up to 14.1 (mean 7.8) and 3.7 per cent (mean 1.9) in these two districts, respectively.

### 4.25.16. Incidence of San Jose scale and its natural enemies (SKUAS & T, Srinagar)

Three orchards each at different altitudes of the valley were selected. Observations were recorded on 25 plants at each locality at fortnightly interval. The randomly selected twigs reveal that infestation by the scale ranged between 13.3 per cent in Kanipora (Budgam) to 46.6 per cent in Veerchurus (Pulwama). The population count/cm$^2$ during first flush was 9 -70, whereas during second flush it was 12 -95. *Encarsia* sp. was recorded at Zawoora (Srinagar). Khanda, Budgam, Karimbabad and Veerchurus during second fortnight of May until end of September. *Aphytis* sp. was recorded at Zakura, Srinagar during the end of May.

## 4.26. Biological suppression of vegetable crop pests

### 4.26.1. Evaluation of *Trichogrammatoidea bactrae* against *Plutella xylostella* on cabbage

**MPKV, Pune**

Trials were conducted with cabbage var. Golden Acre over two years. *T. bactrae* was released five times at weekly interval @ 50,000 / ha / release from three weeks after transplanting. Observations on number of larvae per 10 plants from each treatment plot were recorded a day before release and then at weekly interval starting from initiation of parasitoid release. Yield data was also recorded.

The surviving populations of the larvae in the parasitoid released plots were 1.6 to 3.6 larvae/10 plants during 1997-98 and 7.6 to 9.4 larvae/10 plants during 1998-99 as against 7.6 to 9.2 larvae/10 plants and 10.9 to 12.8 larvae/10 plants in the control plots, respectively. Significant differences among both these treatments showed influence of *T. bactrae* in suppression of DBM population. Yield of marketable cabbage heads also increased significantly due to releases of *T. bactrae* during both the years (Table 92).

Table 92. Efficacy of *Trichogrammatoidea bactrae* on *Plutella xylostella* larval population

| Treatment | 1997-98 | | | 1998-99 | | |
|---|---|---|---|---|---|---|
| | Number of larvae / 10 plants | | | Number of larvae / 10 plants | | |
| | Precount | Surviving population | Yield (q/ha) | Precount | Surviving population | Yield (q/ha) |
| Release of *T. bactrae* | 12.0 | 2.60 | 338.35 | 14.6 | 8.50 | 369.16 |
| Control | 12.4 | 8.80 | 215.43 | 15.0 | 11.80 | 226.66 |
| t (4 d.f.) | 0.61<br>NS | 22.95<br>21.68 | 23.67<br>** | 0.67<br>49.02 | 21.68<br>** | 49.02<br>** |

Surviving population is the average of five weekly observations

**ANGRAU, Hyderabad**

A trial with cabbage var. Golden acre was transplanted during November 1998. Two plots of 100 m² area each including control were prepared. The control plot was laid 150m away from the parasitoid released plot. Each plot was sub divided into 20m² plots. *T. bactrae* was released @ 2.5 lakh/ha commencing from 10 days after transplanting and thereafter at weekly interval. Egg parasitoids were released a day before their emergence by stapling the parasitised egg card bits on the lower surface of the leaves. A total of five releases were made at weekly interval. Recovery of the parasitoid was taken as establishment in the cabbage ecosystems and the efficacy of parasitoid determined based on the number of larvae present per plant compared to control.

A decline in the number of larvae per plant in the parasitoid released plot was noticed from 0.0 to 3.74, while in control plot it was 0.4 to 5.10. However, the variation in yield between these two plots was not much.

**IIHR, Bangalore**

Cabbage (var. Maharani) was planted at 100m² area. A total of 25 plots each with 20m² area were made. The entire area was subjected for parasitoid release. A separate 100m² area was planted at an isolated distance for endosulfan (three 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 interval. Level of larval population of *P. xylostella* was used as a tool to assess the effect. Every week prior to release of egg parasitoid, observations were made on larval population from ten heads per plot (Table 93).

Table 93. Effect of *Trichogrammatoidea bactrae* on the larval population of *P. xylostella*

| Treatment | Mean larval count on fifty plants (weekly intervals) | | | | | | Mean | Per cent reduction | Yield (kg/plot) |
|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | | | |
| *T. bactrae* | 3.16 | 2.20 | 1.88 | 1.68 | 1.80 | 1.84 | 2.10 | 33.54 | 57.6 |
| Endosulfan spray | 3.24 | 1.40 | 1.80 | 2.10 | 1.40 | 1.52 | 1.91 | 39.56 | 59.8 |
| Control | 3.36 | 3.88 | 2.12 | 5.56 | 2.14 | 1.90 | 3.16 | - | 53.8 |

The larval population gradually reduced to 1.88/plant by third week from 3.16 during first and maintained the same throughout the cropping period. In endosulfan treated plot the reduction was quick and less population was observed in second and third week and again increased to 1.88 - 2.16 per plant. A reduction of 39.56 and 33.54% larval population in endosulfan and parasitoid release plot, respectively over control was observed. Release of egg parasitoid was found to be on par with endosulfan for the control of *P. xylostella* on cabbage. Yield data revealed that there was only marginal increase of yield in treatments over control. An increase of 10.03% and 6.60% was recorded in chemical and parasitoid released plot over control.

The results of this trial in three centres utilizing *T. bactrae* releases @ 2.5 lakh adults/ha at 10 days/weekly interval showed a reduction in the population of the larvae as compared to untreated control.

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

**MPKV, Pune**

The experiment was conducted over two years using variety Golden Acre with an individual plot size of 20 $m^2$ under RBD with three replications. Application of treatments was initiated 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 as precount, a day before initiation of sprays and post-counts at weekly interval.

All the treatments were significantly superior to control in respect of surviving larval population and yield of marketable cabbage heads (Table 94). Amongst the treatments, Delfin WG @ 1 kg/ha which showed least surviving population of DBM larvae and recorded highest yield of marketable cabbage heads, proved to be the best during both the years. It was however, on par with Dipel 8L, Halt, Biolep and Biobit all @ 1 kg/ha during both the years, in terms of reducing the larval population. Dipel and Halt were on par with Delfin WG in increasing yield of cabbage.

Table 94. Efficacy of *Bacillus thuringiensis* formulations (1.0 kg/ha) against *Plutella xylostella*

| Treatment | 1997-98 | | | 1998-99 | | |
|---|---|---|---|---|---|---|
| | Number of larvae / 10 plants | | | Number of larvae / 10 plants | | |
| | Precount | Mean weekly surviving population | Yield (q/ha) | Precount | Mean weekly surviving population | Yield (q/ha) |
| Delfin WG | 5.00 (2.32) | 1.00 (1.22) | 393.9 | 7.33 (2.80) | 2.60 (1.76) | 372.8 |
| Dipel 8L | 5.33 (2.40) | 1.33 (1.35) | 365.4 | 8.33 (2.96) | 3.53 (2.00) | 345.7 |
| HALT | 4.67 (2.27) | 1.33 (1.34) | 349.2 | 7.33 (2.80) | 3.07 (1.88) | 366.1 |
| Biolep | 5.00 (2.34) | 1.53 (1.42) | 287.1 | 8.67 (3.02) | 3.47 (1.97) | 289.7 |
| Biobit | 5.00 (2.33) | 1.40 (1.37) | 301.3 | 9.00 (3.06) | 3.00 (1.87) | 290.6 |
| Bioasp | 4.33 (2.18) | 1.73 (1.49) | 307.9 | - | - | - |
| Centari | 5.00 (2.34) | 1.87 (1.53) | 299.2 | 8.00 (2.89) | 4.40 (2.21) | 285.6 |
| Delfin DF | - | - | - | 7.00 (2.74) | 3.27 (1.94) | 309.7 |
| Endosulfan | (4.33 (2.18) | 1.67 (1.47) | 286.7 | 7.00 (2.74) | 3.73 (2.05) | 265.6 |
| Control | 4.67 (2.24) | 7.33 (2.79) | 201.3 | 8.67 (3.03) | 16.40 (4.11) | 194.8 |
| CD (P=0.05) | NS | (0.24) | 70.23 | NS | (0.25) | 58.92 |

Figures in parentheses are $\sqrt{n+0.05}$ transformation

## ANGRAU, Hyderabad

The efficacy of the different *Bt* formulations (Dipel, BTT, BTK I, BTK II, Biobit and Delfin) at @ 1.0 kg/ha was evaluated similarly at Hyderabad. Cabbage seedlings of the var. Golden acre were transplanted in 600 m² area with eight treatments and three replications. One plot was treated with foliar spray of endosulfan (0.07%) and one plot as control for comparison. The treatments were initiated at primordial formation stage. Five sprays were given at 10 days interval starting from 30 days after transplanting. Observations on the number of diamond back moth larvae present on ten randomly selected cabbage heads were counted at weekly interval. Yield data was recorded at the

time of harvest.

The results indicated that all the *Bt* formulations and spray of endosulfan reduced the larval population after second release of parasitoids/spray application. Among the different *Bt* formulations, Biobit (1.0 kg/ha) was found to be superior in reducing the larval population of *P. xylostella*. However, the yield differences in different treatments were not significant. Highest marketable cabbage heads were obtained from Biobit (52 q/ha) treated plots followed by endosulfan (0.07%) treated plots (51.46 q/ha).

**IIHR, Bangalore**

An experiment was laid to determine the efficacy of various *Bt* formulations (Delfin, Halt, Dipel-DF and Biobit) against *P. xylostella*. Results showed that application of five rounds of *Bt* formulation @ 1.0 kg/ha at weekly interval right from initiation of primordium, gave effective control of larval population of *P. xylostella* (0.61-0.81/plant) as compared to 3.02 / plant . Among the *Bt* formulations tested Halt was found to be very effective recording 79.9% reduction in larval population over control (Table 95). The yield was also high in Halt treated plot (70.2 kg/plot) as compared to other *Bt* formulation treated plots (58.6 - 59.8 kg/plot).

Table 95. Effect of various *Bt* formulations on *Plutella xylostella*

| Treatment | Pretreat-mental population/5 | Post treta-mental mean | Per cent reduction | Yield (kg/ | Per cent increase |
|---|---|---|---|---|---|
| Delfin (1.0 g / l) | 3.56 | 0.71 | 76.8 | 58.6 | 8.20 |
| Halt (1.0 g / l) | 3.64 | 0.71 | 79.8 | 70.2 | 23.36 |
| Dipel (1.0 g / l) | 3.28 | 0.81 | 73.2 | 68.6 | 21.57 |
| Biobit (1.0 g / l) | 3.24 | 0.80 | 73.5 | 59.8 | 10.03 |
| Endosulfan (2.0 cc/l) | 3.24 | 1.28 | 57.6 | 61.0 | 10.03 |
| Control | 3.36 | 3.02 | - | 53.8 | - |

**GAU, Anand**

An experiment was laid out to evaluate different *B. thuringiensis* formulations against cabbage (var. Sutton Express) pests. The plot size was 25m²/ treatment. The various formulations used were Dipel, BTT, BTK I, BTK II, Biobit, Agree at 1.0 kg /ha and a separate plot maintained by spraying endosulfan (0.07 %) for comparison. An untreated plot served as control. The experiment was replicated thrice. Number of pests / leaf was recorded by sampling ten heads at weekly interval starting from tenth day after transplanting. Yield data was recorded.

Population of *P. xylostella* in the experimental area was very low and so observations were not taken. However, the population of H. armigera was high in different treatments. Minimum pest incidence was observed in BTK I treated plot (1.00/plant) and correspondingly the yield was also more (407.33 q/ha) (Table 96).

Table 96. Effect of *Bacillus thuringiensis* on *Helicoverpa armigera* in cabbage

| Treatment | Mean larval population / 10 plants | Yield (kg/ha) |
|---|---|---|
| Dipel (1.0 kg/ha) | 2.12 (3.49) | 35,440 |
| BTT (1.0 kg/ha) | 2.04 (3.16) | 37,100 |
| BTK I (1.0 kg/ha) | 1.00 (3.00) | 40,733 |
| BTK II (1.0 kg/ha) | 2.18 (3.75) | 34,907 |
| Biobit (1.0 kg/ha) | 2.06 (3.24) | 40,080 |
| Agree (1.0 kg/ha) | 2.18 (3.80) | 35,813 |
| Endosulfan (0.07%) | 1.82 (3.35) | 40,213 |
| Control | 2.17 (6.40) | 14,613 |
| CD (P=0.05) | (0.15) | 2,444 |

In general the formulations Delfin, Dipel, Halt and Biobit were found promising in reducing the larval population and recording higher yields in the four centers.

### 4.26.3. Monitoring of aphid populations on cauliflower crop and their hymenopterous natural enemies (Dr.YSPUH & F, Solan)

Continuous monitoring of aphid populations on 100 randomly observed cauliflower plants right after transplantation in October 1997 up to April 1998 at weekly interval revealed that the initiation of infestation by alates occurred in late December. With increase in aphid infested plants from 23 to 48% during January 5 to March 16, the aphid population increased (795 to 13087/100 plants) and parasitisation by *Diaeretiella rapae* was 1.0 to 3.8%. However, in declining phase of aphid infestation (till April 6), the parasitisation increased to 7.4% and the coccinellids number was 75-945/100 plants. The increase in population was significantly correlated with the increase in number of parasitised aphids (r = 0.805). There was occurrence of both *Brevicoryne brassicae* and *Myzus persicae* and the former comprised more of the population (overall 65.3%). Parasitisation varied from 0.7 - 8.3 % (mean 3.6) and 1.8 - 8.2 % (mean 4.4), in both these species showing they were equally preferred for parasitisation. Aphid population was maximum on inner whorl of leaves, followed by middle and outer whorl of leaves but number of mummified aphids did not differ significantly with respect to the position of leaves.

From 255 and 967 *Diaeretiella rapae* mummies collected the per cent parasitoid emergence was 92.2 and 5.6, and sex ratio was female biased (0.42 males, or 1 : 1.38). Pteromalid hyperparasitoid, *Pachyneuron aphidis* emerged from the aphid mummies collected from cabbage field only (6.3%). Majority of mummies without exit hole collected from the cabbage field had the dead developing stage of the parasitoid (86%) or that of the hyperparasitoid (14%). Observations made on mummified aphids revealed that the exit hole of the parasitoid was bigger, oval with regular margins, often covered with a flap and located between or slightly above the cornicles, but the exit hole made by the hyperparasitoid was smaller, had irregular margins, and in majority of cases, it was away from the cornicles. Longevity of the primary parasitoid was not affected by mating but feeding of honey prolonged the survival of the male (mean 3.93 and 2 days for fed and unfed). Feeding of honey to the female prolonged longevity significantly from 3.27 to 5.18. Female longevity was 7.07 days at 8-17 °C in January-February and 2.83 days at 22.2-33.5 °C in summers. Hyperparasitoid, however, lived on an average for 50.6 days in January-February but its longevity was reduced to 10.3 days in April-June (21-32.5 °C).

### 4.26.4. Management of tomato fruit borer, *Helicoverpa armigera*

**GAU, Anand**

The trial had the following treatments with four replications and a plot size of 25m$^2$.

T1 : Five releases of *T. pretiosum* @ 50,000 adults / ha / week + *Ha*NPV @ 1.5 x $10^{12}$ /ha 3 sprays - first spray 5 days after release of parasitoids and subsequent sprays at seven days interval.

T2 : Five releases of *T. pretiosum* @ 50,000 adults / ha / week + *Ha*NPV @ 1.5 x $10^{12}$ / ha 2 sprays - first spray 5 days after release of parasitoids and subsequent spray after ten days.

T3 : Five releases of *T. pretiosum* @ 50,000 adults / ha /week first release commencing soon after observing eggs in the field (tricho bits placed 5 m apart)

T4 : Five sprays of *Ha*NPV @ 1.5 x $10^{12}$ / ha at seven days interval

T5 : Control

Observations were recorded on the number of fruits damaged in five plants per plot per treatment at weekly intervals, the number of bored fruits during harvest and yield in different treatments.

Population of *H. armigera* was very low. However, it can be seen from the data that five releases of *T. pretiosum* @ 50,000 adults / h / week + *Ha*NPV @ 1.5 x $10^{12}$ /h 3 sprays - first spray 5 days after release of parasitoids and subsequent sprays at seven days interval proved to be significantly superior to control and at par with the other treatments (Table 97).

Table 97. Effect of the release of bioagents on the incidence of tomato fruit borer

| Treatment | Per cent damage | Per cent parasitism | Yield (q/ha) |
|---|---|---|---|
| Five releases of *T. pretiosum* @ 50,000 adults / ha / week + *Ha*NPV @ 1.5 x 1012 /h 3 sprays | 8.56 (2.22) | 31.30 | 1531 |
| Five releases of *T. pretiosum* @ 50,000 adults / ha / week + *Ha*NPV @ 1.5 x 1012 / h 2 sprays | 11.00 (3.64) | 30.08 | 1528 |
| Five releases of *T. pretiosum* @ 50,000 adults / ha / week | 12.88 (4.97) | 30.08 | 1520 |
| Five sprays of *Ha*NPV @ 1.5 x $10^{12}$ / ha at seven days interval | 14.31 (6.11) | 12.22 | 1384 |
| Control | 18.46 (10.03) | 11.67 | 1208 |
| CD (P=0.05) | (5.233) | - | 181.73 |

**MPKV, Pune**

A field experiment was conducted on transplanted tomato seedlings (var. Pusa Ruby) with a plot size of 25 $m^2$ for each treatment. The trial was laid out in RBD with five treatments as detailed under GAU, Anand. Release of parasitoids and spraying of *Ha*NPV were started at flowering stage of the crop. Observation on larval counts from 5 plants/plot were recorded a day before initiation of treatments and then at weekly interval till termination of experiment. At each fruit picking, number and weight of healthy and infested fruits per plot was recorded for computing per cent fruit infestation and yield of marketable fruits.

All the treatments were significantly superior to control in reducing larval population and fruit infestation and increasing yield of marketable fruits (Table 98). The treatment with five sprays of *Ha*NPV @ 250 LE/ha ($1.5x10^{12}$ POBs/ha), which gave least surviving larvae (1.95 larvae/5 plants) was the most effective treatment and on par with five releases of *T. pretiosum* @ 50,000 adults/ha/release at weekly interval + three sprays of *Ha*NPV @ 250 LE/ha. The lowest fruit infestation (9.94%) was recorded in the treatment with five weekly releases of *T. pretiosum* @ 50,000 adults/ha/release + three sprays of *Ha*NPV @ 250 LE/ha and was statistically superior to remaining treatments. Maximum yield of marketable fruits (354.96 q/ha) was obtained with five sprays of *Ha*NPV @ 250 LE/ha and it was significantly superior to rest of the treatments.

Table 98. Effect of the releases of *T. pretiosum* on the fruit borer incidence

| Treatment | Number of larvae / 5 plants* | | Per cent infested fruits ** | Yield (q/ha) |
|---|---|---|---|---|
| | Precount | Average surviving population | | |
| Five releases of *T. pretiosum* @ 50,000 adults /ha / release | 0.25 (3.11) | 3.55 (2.01) | 16.28 (23.74) | 281.63 |
| Five sprays of *Ha*NPV @ 250 LE/ha | 8.75 (3.03) | 1.95 (1.56) | 12.88 (21.02) | 354.96 |
| Five releases of *T. pretiosum* @ 50,000 adults /ha / release + three sprays of *Ha*NPV @ 250 LE/ha | 9.50 (3.16) | 2.35 (1.60) | 9.94 (18.35) | 295.31 |
| Five releases of *T. pretiosum* @ 50,000 adults /ha / release + two sprays of *Ha*NPV @ 250 LE/ha | 9.75 (3.20) | 2.70 (1.78) | 13.76 (21.75) | 289.75 |
| Control | 9..50 (3.15) | 6.40 (2.63) | 32.02 (47.47) | 144.31 |
| CD (P=0.05) | NS | (0.17) | (2.24) | 47.44 |

*Figures in parentheses are $\sqrt{n+0.05}$ transformation; ** angular transformations; surviving population of larvae is the mean of five counts.

**ANGRAU, Hyderabad**

A trial with var. Pusa Ruby was conducted in an area of 500 $m^2$ during November. There were four replications and five treatments as listed under GAU, Anand. Observation on the number and weight of the healthy and infested fruits was recorded at each picking and per cent fruit infestation and yield were recorded.

All the treatments significantly reduced the larval population as well as fruit infestation and increased the yield of marketable fruits. Lowest mean larval population (1.62/5 plants), lowest per cent fruits bored and highest yield was recorded in the plot treated with five releases of egg parasitoids @ 50,000/ha along with three foliar sprays of *Ha*NPV @ 250 LE/ha ($1.5 \times 10^{12}$ LE) at weekly intervals (Table 99).

Table 99. Effect of biocontrol based treatments for the control of tomato fruit borer, *Helicoverpa armigera*

| Treatment | Pretreatmental population/5 plants | Post treatmental mean population/ 5plants | Per cent fruits bored at harvest | Yield (q/ha) |
|---|---|---|---|---|
| *T. pretiosum* @ 50,000/ ha/ week for 5 times | 13.75 (3.68) | 2.11 (1.45) | 5.52 (13.58) | 107.75 |
| *Ha*NPV @ 250 LE/ha 5 sprays at weekly interval | 13.75 (3.70) | 2.15 (1.46) | 5.17 (13.12) | 108.60 |
| *T. pretiosum* @ 50,000/ha/ week 5 times + *Ha*NPV @ 250 LE/ha 3 sprays 5 days after release subsequently at weekly interval | 11.50 (1.27) | 1.62 (3.38) | 4.21 (11.84) | 126.00 |
| *T. pretiosum* @ 50,000/ha/ week 5 times + *Ha*NPV @ 250 LE/ha 2 sprays 5 days after release subsequently at 10 days interval | 12.75 (3.56) | 2.35 (1.53) | 5.40 (13.43) | 75.70 |
| Control | 12.40 (3.54) | 3.19 (1.79) | 17.29 (24.46) | 51.40 |
| CD (P=0.05) | NS | 0.04 | 2.30 | 28.38 |

**IIHR, Bangalore**

Tomato (var. Pusa Ruby) was planted in 500m² during September-December, 1998 and January-April, 1999 and the treatments were as given under GAU, Anand plus an additional treatment of spraying Dipel (@ 1.0 g/l) at weekly interval. Number of eggs was observed on 5 plants in each plot at weekly interval. Fruit damage at harvest was recorded.

The borer damage in treatments was ranging from 3.56% to 6.60% as against 21.79% in control which indicated that about 69.7% to 83.7% reduction in fruit borer damage was noticed in treatments where biocontrol agents were used as compared to control (Table 100). The larval population in January planted crop increased steadily in

control compared to treatments throughout the cropping season. The mean larval population was 0.33 in plots treated with *Ha*NPV (five sprays), whereas it was 0.48 to 0.50 in Dipel and parasitoid released plots. Combination with two sprays of *Ha*NPV along with release of egg parasitoids was found to be the best over other treatments. It recorded 86.7% reduction of larval population over control. Mean fruit borer damage was between 14.3 and 16.20% in various treatments compared to control recording 40% fruit borer damage (Table 101). Therefore per cent reduction over control was in the range of 59.50% in parasitoid release plot to 64.25% in *Ha*NPV alone-sprayed plot.

Table 100. Effect of *Ha*NPV and *Trichogramma pretiosum* against tomato fruit borer (egg count) (September - December 1998).

| Treatment | Pretreatmental population/5 plants | Post treatmental mean population/ 5plants | Per cent fruits bored at harvest | Per cent reduction over control |
|---|---|---|---|---|
| *Ha*NPV @ 250 LE/ha (5 sprays) | 0.44 | 0.49 | 4.43 | 79.79 |
| *Ha*NPV @ 250 LE/ha (3 sprays) + Parasitoid @ 2,50,000 adults/ha | 0.36 | 0.44 | 6.60 | 69.7 |
| *Ha*NPV @ 250 LE/ha (2 sprays) + Parasitoid @ 2,50,000 adults/ha | 0.40 | 0.45 | 4.18 | 80.8 |
| Dipel @ 1g/lit. | 0.44 | 0.55 | 3.56 | 83.7 |
| Parasitoid @ 2,50,000 adults/ha | 0.52 | 0.43 | 5.85 | 73.2 |
| Control | 0.56 | 0.57 | 21.79 | - |

Table 101. Effect of *Ha*NPV and *Trichogramma pretiosum* against tomato fruit borer (January - planted crop)

| Treatment | Pretreat-mental popula-tion/5 plants | Post treat-mental mean popula-tion /5 plants | Per cent fruits bored at harvest | Per cent redu-ction over contr ol | Yield (kg/ plot) | Percent increase over control |
|---|---|---|---|---|---|---|
| Five sprays of *Ha*NPV @ 250 LE/ha ($1.5x10^{12}$ POB) at weekly intervals | 0.72 | 0.33 | 14.30 | 83.3 | 42.5 | 60.0 |
| Five releases of *T. pretiosum* @ 50,000 adults / ha / release at weekly interval +three sprays of *Ha*NPV @ 250 LE/ha at weekly interval | 0.56 | 0.36 | 14.70 | 85.1 | 43.2 | 60.6 |
| Five releases of *T. pretiosum* @ 50,000 adults / ha / release at weekly interval +two sprays of *Ha*NPV @ 250 LE/ha at weekly interval | 0.56 | 0.32 | 14.54 | 86.7 | 43.9 | 61.2 |
| Spraying Dipel (@ 1.0 g/l) at weekly interval | 0.72 | 0.48 | 15.50 | 80.1 | 42.5 | 60.0 |
| Five releases of *T. pretiosum* @ 50,000 adults / ha / release starting from flower initiation period | 0.58 | 0.50 | 16.20 | 79.1 | 41.4 | 58.9 |
| Control | 0.72 | 2.41 | 40.00 | - | 17.0 | - |

The trials conducted at four centers for the management of tomato fruit borer with BIPM methods revealed that five releases of *T. pretiosum* @ 50,000 adults /ha and three sprays of *Ha*NPV @ 250 LE/ha ($1.5 \times 10^{12}$ POB/ha) at weekly interval gave the best results in reducing damage and producing higher yields.

### 4.26.5. Integrated pest management of tomato fruit borer (GAU, Anand)

An observational trial was laid out to test the IPM module against tomato fruit

borer, *Helicoverpa armigera,* with four treatments in duplicate plots of 25 $m^2$ of each plot.

IPM 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 to facilitate escape of parasites like *Campoletis chlorideae, Eriborus* sp., etc.

iv Perching sites for insectivorous birds (50 perches / ha)

v Need based application of *Ha*NPV @ 1.5 x $10^{12}$ /ha.

vi Untreated control

Observations were taken on the population of *H. armigera* on twenty randomly selected plants, extent of fruit damage and recording per cent fruit damage on 20 plants at weekly intervals, egg parasitism on at least 25 eggs of *H. armigera* from all over the field and number of birds using perches between 5.30 pm and 6.30 pm during the peak period of oviposition by *H. armigera.*

The results indicate the superiority of IPM module where reduced number of larvae and higher per cent parasitism was recorded as compared to control (Table 102).

Table. 102. Effectiveness of IPM module in tomato

| Observation | IPM Module | Control | STD | Error | T |
|---|---|---|---|---|---|
| Larvae /20 plants | 3 | 10 | 3.38 | 1.20 | 5.44 |
| Parasitism (%) | 33 | 12 | 15.63 | 5.33 | 3.86 |
| Yield (q/ha) | 1590 | 1208 | - | | - |

**4.26.6. Extent of parasitisation of *Helicoverpa armigera* eggs on tomato (Dr.YSPUH & F, Solan)**

Tomato (cv.Naveen) was cultivated during April-May. The population of egg

and larvae of *H. armigera* was monitored on randomly selected 75 plants in the plot. From infested plants 120-466 eggs were collected (with egg density of 2.5-6.7 per infested plant). Amongst these, 23.6 - 91.0 % eggs were parasitised by the local strain of *Trichogramma chilonis*. During the period June 8 to July 4, the egg laying was reduced (10-106 eggs/75 plants, with egg density of 1.1 to 2.4/infested plant). The egg parasitization was 54.8 to 100 %.

### 4.26.7. Field assessment of *Trichogramma pretiosum* on tomato (ANGRAU, Hyderabad)

A demonstration trial in farmers' field was taken up in the village Pedda Shapur near Shamshabad using tomato (var. Pusa Ruby) in 0.2 ha to demonstrate the effectiveness of the egg parasitoid, *Trichogramma pretiosum* against *Helicoverpa armigera*. A total of five releases were made at weekly interval @ 50,000/ha starting from flower initiation synchronising with the egg laying of *H. armigera*. Control plot was selected 500 $m^2$ away from the released plot. The eggs of *H. armigera* from 25 plants at random were collected at weekly interval prior to release of parasitoids to record the per cent parasitism. At each picking the per cent fruit damage and yield of marketable fruits was recorded.

The pre-release count showed no natural egg parasitism. The observations recorded a week after each release of egg parasitoids revealed that the level of egg parasitism varied from 0.0 to 40.0% with a mean parasitism of 27.5%. The fruit borer damage in biocontrol plot was 5.6% as against 17.3% in control plot.

### 4.26.8. Control of tomato fruit borer, *Helicoverpa armigera* using *Nomuraea rileyi* (IIHR, Bangalore)

Application of five rounds of *N. rileyi* @ 3.2x108 spores/ml + triton X-100 (0.01%) at weekly intervals right from peak flowering significantly reduced the larval population of *H. armigera* on tomato (0.75/plant) as compared to control (1.53/plot) (Table 103). The percentage bored fruit was also low in fungus treated plot (10.40%) as compared to 18.0% in untreated control plot. An increase of 53.2% of yield of tomato over control was observed in fungus treated plot.

Table 103. Effect of *Nomuraea rileyi* against tomato fruit borer, *Helicoverpa armigera*

| Treatment | Mean larval population | Per cent reduction over control |
|---|---|---|
| Fungus @ 3.2 x $10^8$ spores/ ml | 0.75 | 50.9 |
| Control | 1.53 | - |

### 4.26.9. Control of *Leucinodes orbonalis* utilizing *Bacillus thuringiensis* on brinjal (IIHR, Bangalore)

The comparative field efficacy of Dipel and Delfin (*Bt* formulations) against brinjal shoot and fruit borer was determined and the results showed that application of five rounds of Delfin @ 1.0 kg/ha at weekly interval, right from flower initiation was more effective in checking the pest than Dipel applied at the same rate. There was not much difference in shoot damage caused by *L. orbonalis* among the treatments. The percentage borer damage to the fruits was significantly low in Delfin treated plots (13.44%) as compared to 19.25% damage in control plot (Table 104). An increase in yield of 48.3% over control was observed in Delfin treated plots.

Table. 104. Effect of various *Bt* formulations on *Leucinodes orbonalis*

| Treatment | Mean number of shout damaged | Mean percent bored | Per cent reduction over control | Yield (kg/ plot) | Per cent increase over control |
|---|---|---|---|---|---|
| Dipel (1.0 g / l) | 0.10 | 19.00 | 1.30 | 27.4 | 46.2 |
| Cypermethrin (0.5 ml / l) | 0.07 | 17.08 | 11.30 | 25.3 | 41.7 |
| Delfin (1.0 g / l) | 0.07- | 13.44 | 30.20 | 28.5 | 48.3 |
| Control | 0.15 | 19.25 | - | 14.7 | - |

### 4.26.10. Parasitisation of pea leaf-miner (Dr.YSPUH & F., Solan)

Population of the leaf miner *Chromatomyia horticola* per compound leaf (mean of 10) in March varied from 18 to 83, most of the progeny being present on lower leaf

lamina (62.9 %). Out of 1241 larvae and pupae sampled during March it was found that their percentages were almost equal (50.6 and 49.4 %. Mean larval parasitisation by the ectoparasitoid (*Diglyphus* sp.) was 9.4 % while from 2 % puparia emerged an unidentified eulophid.

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

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

Field experiments were carried out in farmers' field at village Peth (Pune) during Kharif and Rabi seasons. The plot size was 50 $m^2$ with a spacing of 45 x 30 cm. using var. Kufri Jyoti. The experiments were laid out in randomized design with eight treatments and three replications. Four weekly releases of *Copidosoma koehleri* @ 50,000, 37,500 and 25,000 and *Chelonus blackburni* @ 15,000, 10,000 and 5,000 adults/ha/release were made. A treatment with two sprays of endosulfan (0.05%) at ten days interval was kept as a check for comparison. A control plot was left without any treatment.

Observations on leaf minor/m row at five places in each treatmental plot were recorded a day before initiation of releases of parasitoids and a week after every release. Recovery / parasitism was studied by placing egg sheets, each containing 50 eggs at 5 different spots in each treatment plot after second release of the parasitoids which were retrieved after two days. These eggs were further reared in the laboratory on punctured potatoes till formation of PTM pupae or mummies/pupae of the parasitoids. At, harvest, tubers from each plot were collected separately to record PTM infestation and yield (marketable tubers).

During Kharif the treatments significantly reduced PTM infestation during 2nd, 3rd and 4th week after initiation of treatments (Table 105). Four releases of *C. koehleri* @ 50,000 adults/ ha/release showed least infestation during these weeks. It was however, on par with four weekly releases of *C. koehleri* @ 37,500 adults/ha/release, *C. blackburni* @ 15,000 and 10,000 adults/ha/release for 2nd, 3rd and 4th weeks, endosulfan 0.05% during 2nd and 3rd weeks and *C. koehleri* @ 25,000 adults/ha/release in the 4th week.

Recovery of the parasitoids was dose dependent. *C. blackburni* @ 15,000 adults/ ha recorded 62.40% parasitism followed by *C. koehleri* @ 50,000 adults/ha (60.00%).

As regards tuber infestation and yield, all the treatments were significantly

superior to control (Table 105). Amongst the treatments, four weekly releases of *C. koehleri* @ 50,000 adults/ha/release showed the least tuber infestation and it was on par with *C. blackburni* @ 15,000 adults per release and *C. koehleri* @ 37,000 adults/ha/release. Maximum tuber yield was recorded from the treatment with four weekly releases of *C. blackburni* @ 15,000 adults/ha/release and it was on par with *C. koehleri* @ 50,000 and 37,000 adults/ha/release, *C. blackburni* @ 10,000 adults/ha/release and endosulfan (0.05%).

The experiment conducted in Rabi showed that all the treatments were significantly superior to control in reducing the leaf mines/m row in 2nd, 3rd and 4th weeks, tuber infestation at harvest and increasing yield of marketable potatoes (Table 106). Amongst the treatments, the treatment with four weekly releases of *C. blackburni* @ 15,000 adults/ ha/ release showed minimum leaf mines/m row in 2nd week and it was on par with *C. koehleri* @ 50,000 and 37,500 adults/ha/release and endosulfan (0.05%). *C. koehleri* @ 50,000 adults/ha/release proved to be the most effective in 3rd and 4th weeks. It was however on par with *C. koehleri* @ 37,000 adults/ha/release and *C. blackburni* @ 15,000 and 10,000 adults/ha/release. In addition, *C. koehleri* @ 25,000 adults/ha/release and endosulfan (0.05%) were comparable with the superior treatment during 3rd week.

Maximum recovery of parasitoids was observed with *C. koehleri* @ 50,000 adults (63.60%), followed by *C. blackburni* @ 15,000 adults *C. koehleri* @ 37,000 adults/ha and *C. blackburni* @ 10,000 adults.

Four weekly releases of *C. koehleri* @ 50,000 adults/ha/release showed the least tuber infestation (5.89%) and maximum yield (226.1 q/ha). It was however on par with *C. blackburni* @ 15,000 adults/ha/release, *C. koehleri* @ 37,500 adults/ha/release, *C. blackburni* @ 10,000 adults/ha/release for both infestation and yield parameters and endosulfan (0.05%) for yield.

The results of the trials over two seasons reveal that four weekly of *C. koehleri* @ 50,000 adults/ha/release was the most effective treatment.

Table 105. Efficacy of parastoids against potato tuber moth and potato yield (Kharif)

| Treatment | Leaf mines / m row* | | | | | Per cent parasitism (recovery) | Average tubers infested (%)** | Per cent control | Yield (q/ha) |
|---|---|---|---|---|---|---|---|---|---|
| | Per cent | Post count after (week) | | | | | | | |
| | | I | II | III | IV | | | | |
| Release of adult *C. koehleri* @ 50,000 / ha | 0.93 (1.19) | 0.80 (1.14) | 0.47 (0.98) | 0.30 (0.91) | 0.13 (0.80) | 60.00 | 7.36 (15.72) | 59.16 | 201.8 |
| Release of adult *C. koehleri* @ 37,500 / ha | 0.87 (1.17) | 0.87 (1.17) | 0.60 (1.05) | 0.47 (0.98) | 0.30 (0.83) | 48.40 | 9.79 (18.20) | 45.67 | 197.3 |
| Release of adult *C. koehleri* @ 37,500 / ha | 0.93 (1.19) | 1.00 (1.22) | 0.87 (1.16) | 0.73 (1.11) | 0.33 (0.91) | 35.20 | 11.95 (20.49) | 33.68 | 168.3 |
| Release of adult *C. blackburni* @ 15,000 / ha | 0.80 (1.14) | 0.80 (1.14) | 0.53 (1.02) | 0.40 (0.95) | 0.20 (0.84) | 62.40 | 7.74 (16.11) | 57.05 | 212.5 |
| Release of adult *C. blackburni* @ 10,000 / ha | 1.07 (1.25) | 0.93 (1.19) | 0.67 (1.08) | 0.53 (1.01) | 0.27 (0.88) | 46.80 | 9.85 (18.24) | 45.34 | 194.5 |
| Release of adult *C. blackburni* @ 5,000 / ha | 1.07 (1.25) | 0.93 (1.19) | 0.93 (1.19) | 0.67 (1.08) | 0.53 (1.01) | 30.40 | 12.69 (20.83) | 29.58 | 163.0 |
| Endosulfan (0.05%) spray | 0.87 (1.17) | 1.00 (1.22) | 0.47 (0.98) | 0.60 (1.05) | 0.40 (0.95) | - | 10.38 (18.76) | 42.40 | 199.0 |
| Control | 0.93 (1.19) | 1.07 (1.25) | 1.13 (1.27) | 1.40 (1.38) | 1.07 (1.25) | - | 18.02 (25.11) | - | 141.8 |
| CD (P=0.05) | NS | NS | (0.12) | (0.15) | (0.14) | | (2.49) | - | 22.14 |

Figures in parentheses are* $\sqrt{n+0.05}$ and** angular transformations

Table 106. Efficacy of parastoids against potato tuber moth and potato yield (Rabi)

| Treatment | Leaf mines / m row* | | | | | Per cent parasitism (recovery) | Average tubers infested (%)** | Per cent control | Yield (q/ha) |
|---|---|---|---|---|---|---|---|---|---|
| | Per cent | Post count after (week) | | | | | | | |
| | | I | II | III | IV | | | | |
| Release of adult *C.koehli* @ 50,000 / ha | 1.13 (1.27) | 1.13 (1.35) | 0.47 (0.98) | 0.33 (0.91) | 0.20 (0.83) | 63.60 | 5.89 (14.00) | 71.41 | 226.1 |
| Release of adult *C.koehli* @ 37,500 / ha | 1.07 (1.25) | 1.40 (1.38) | 0.53 (1.02) | 0.47 (0.98) | 0.30 (0.91) | 54.00 | 6.98 (15.20) | 66.12 | 203.3 |
| Release of adult *C.koehli* @ 25,500 /ha | 1.13 (1.27) | 1.27 (1.33) | 1.00 (1.22) | 0.66 (1.08) | 0.60 (1.05) | 41.60 | 10.83 (19.03) | 48.88 | 180.5 |
| Release of adult *C.blackburni* @15,000 / ha | 1.20 (1.30) | 1.40 (1.38) | 0.40 (0.95) | 0.40 (0.95) | 0.27 (.0.88) | 61.20 | 6.07 (14.27) | 70.53 | 221.1 |
| Release of adult *C.blackburni* @ 10,000/ ha | 1.07 (1.25) | 1.27 (1.33) | 0.67 (1.08) | 0.47 (0.97) | 0.40 (0.95) | 52.80 | 8.46 (16.77) | 58.93 | 202.2 |
| Release of adult *C.blackburni* @ 5,000/ ha | 1.33 (1.35) | 1.33 (1.35) | 1.07 (1.25) | 0.80 (1.14) | 0.80 (1.14) | 42.40 | 11.01 (19.28) | 46.55 | 167.2 |
| Endosulfan(0.05%) spray | 1.13 (1.27) | 1.47 (1.40) | 0.47 (0.98) | 0.53 (1.02) | 0.66 (1.08) | - | 9.75 (18.16) | 52.67 | 192.2 |
| Control | 1.13 (1.35) | 1.47 (1.40) | 1.40 (1.40) | 1.40 (1.38) | 1.73 (1.49) | - | 20.60 (26.98) | - | 150.5 |
| CD (P=0.05) | NS | NS | (0.10) | (0.19) | (0.16) | | (3.39) | - | 34.97 |

Figures in parentheses are *m $\sqrt{n + 0.05}$ and ** angular transformations

### 4.27.2. Studies on the carry over of parasitism from field to storage

The experiment was carried out in farmers' field (var. Kufri Jyoti) at Peth village of Pune district during Rabi 1998-99. *C. koehleri* @ 50,000 adults/ha/release and *C. blackburni* @ 15,000 adults/ha/release were released four times at weekly interval commencing 52 days after planting. The plot size was 1000 $m^2$. After harvest, infested tubers from each of the plots were collected and kept for observations under laboratory conditions in baskets with fine sieved layer of soil at the bottom. From 10 kg infested tubers collected from each treatment plot, 12 mummies of *C. koehleri* and seven pupae of *C. blackburni* were recovered showing that the parasitoids were carried over from field to the store.

### 4.27.3. Evaluation of doses of release of *Copidosoma koehleri, Chelonus blackburni* and microbial agents against PTM in country stores (Arni)

Miniatures of 7 arnies each of 20 kg capacity were constructed under the shade in the screen house. Healthy marketable tubers were used for setting up the arnies. Twenty five newly emerged pairs of PTM were released in the vicinity of arnies for creating artificial infestation. The applications of GV and *B. thuringiensis* were given before arranging the arnies; whereas parasitoids were released after their construction. All the arnies were covered with double layer of grass and paddy straw as per the local practice. Observations on per cent tuber infestation from each treatment and in three replications were recorded after one and two and a half months.

The tuber infestation after one month in various treatments ranged from 10.67 to 32.67 per cent, which increased to 18.00 to 58.00 per cent after two and a half months (Table 107). All the treatments were significantly superior to control. Initial release of *C. koehleri* @ 5 pairs of adults/kg tubers was the most effective after one month and it was on par with rest of the bioagents. Release of *C. blackburni* @ one adult/kg tubers at fort nightly interval showed the least tuber infestation after two and a half months and it was statistically on par with *C. koehleri* @ one pair of adults/kg tubers at fortnightly interval, *C. koehleri* @ five pairs of adults/kg tubers as initial release and *B. thuringiensis* @ 1.0g/kg tubers as initial application.

Table 107. Efficacy of parasitoids and microbial agents against PTM in country Arnies

| Treatment (Dose / kg tubers) | Per cent tubers infested after | |
|---|---|---|
| | One month | Two and half months |
| *Copidosoma koehleri* @ one pair of adults at 15 days interval | 14.00 (21.94) | 18.67 (25.25) |
| *C. koehleri* @ five pairs of adults as initial release | 10.67 (18.95) | 23.33 (28.79) |
| *Chelonus blackburni* @ one pair of adults at 15 days interval | 13.33 (21.33) | 18.00 (24.84) |
| *C. blackburni* @ five pairs of adults as initial release | 12.00 (20.15) | 26.00 (30.61) |
| Granulosis virus @ 1.0 g as initial application | 14.00 (21.94) | 31.33 (33.98) |
| *Bacillus thuringiensis* @ 1.0 g as initial application | 12.67 (20.60) | 22.00 (27.95) |
| Control | 32.67 (34.83) | 58.00 (49.64) |
| CD (P=0.05) | (5.07) | (5.11) |

Figures in parentheses are angular values

### 4.27.4. Effect of different foliage powders on PTM parasitoids

Foliage powders of different plants were placed in test tubes (10 g each) and a batch of 10 adults of *C. blackburni* and *C. koehleri* were released separately in each test tube. Mortality of adult parasitoids was recorded after 24, 48 and 72 h. The results (Table 108) revealed *C. koehleri* to be more sensitive to foliage powders' exposure than *C. blackburni*. *Ocimum* powder was most hazardous and gave 100 per cent mortality of the species within 24 hrs. The adult mortality of *C. koehleri* was very high after 72 h of exposure. *C. blackburni* could survive up to 72 h exposure to nirgundi, custard, eucalyptus and karanj.

Table 108. Efficacy of different foliage powders on mortality of PTM parasitoids

| Treatment | Per cent mortality of parasitoids after | | | | | |
|---|---|---|---|---|---|---|
| | *Copidosoma koehleri* | | | *Chelonus blackburni* | | |
| | 24 h | 48 h | 72 h | 24 h | 48 h | 72 h |
| Nirgundi | 60 | 20 | 10 | - | - | 50 |
| Lantana | 60 | 40 | - | 30 | 20 | 50 |
| Ocimum | 100 | - | - | 100 | - | - |
| Custard apple | 20 | 60 | 10 | - | 10 | 40 |
| Neem | 40 | 40 | 20 | - | 80 | 20 |
| Eucalyptus | 40 | 40 | 10 | - | 50 | - |
| Karanj | 20 | 40 | 40 | - | 10 | 40 |

Another laboratory experiment was carried out by placing 1 kg potatoes, 50 g foliage powder and an egg strip of PTM containing 50 eggs in a plastic bowl covered with double layer of black muslin cloth. Five adults of *C. blackburni* and 10 pairs of *C. koehleri* were released in each bowl. Almost all the adults of *C. koehleri* died within 72 h and no parasitism was recorded. The adults of *C. blackburni* were alive till 72 h. The average parasitism recorded was 10.67 to 18.67 per cent in all the foliage powders except paddy straw (Table 109). The emergence of PTM was 27.33 to 32.67 per cent in various treatments and neem foliage powder showed the least percentage of PTM emergence.

Table 109. Effect of different foliage powders on parasitism by *C. blackburni* and PTM emergence

| Treatment | Per cent parasitism due to *Chelonus blackburni* | Per cent PTM emergence |
|---|---|---|
| Nirgundi | 13.33 | 30.67 |
| Lantana | 12.00 | 31.33 |
| Ocimum | 10.67 | 30.00 |
| Custard apple | 18.67 | 29.33 |
| Neem | 12.67 | 27.33 |
| Eucalyptus | 13.33 | 34.67 |
| Karanj | 12.67 | 32.00 |
| Paddy straw | 37.33 | 32.67 |

### 4.27.5. Field evaluation of *Spodoptera litura* nuclear polyhedrosis virus and *Bacillus thuringiensis* in comparison with endosulfan against *Spodoptera litura*

A field experiment was conducted during Kharif 1998 with six treatments and four replications (RBD). Potato (var. Kufri Jyoti) was raised in the plots of 15 $m^2$ size. Spraying was undertaken during evening hours. The average initial pest population was 2 larvae/m row. After one hour, ten larvae/treatment plot were collected along with treated foliage from the respective plots and reared under laboratory conditions for one week. The larvae were provided with fresh food daily by collecting treated foliage from the respective treatment plots. Observations on larval mortality and yield per plot were recorded.

All the treatments were significantly superior to control in respect of larval mortality and yield. Amongst the treatments, *Sl*NPV @ 750 LE/ha ($4.50x10^{12}$ POBs/ha) which gave 90.00 per cent larval mortality and 209.6 q/ha tuber yield, proved best and on par with *Sl*NPV @ 500 LE/ha ($3x10^{12}$ POBs/ha) and *B. thuringiensis* @ 0.5 kg/ha (Table 110).

Table 110. Field evaluation of *Spodoptera litura* nuclear polyhedrosis virus and *Bacillus thuringiensis* in comparison with endosulfan against *Spodoptera litura*

| Treatment | Larval mortality (%) | Yield (q/ha) |
|---|---|---|
| *Sl*NPV @ 250 LE/ha ($1.5 \times 10^{12}$ POBs/ha) | 67.50 (55.51) | 166.3 |
| *Sl*NPV @ 500 LE/ha ($3.0 \times 10^{12}$ POBs/ha) | 85.00 (67.50) | 196.4 |
| *Sl*NPV @ 750 LE/ha ($4.5 \times 10^{12}$ POBs/ha) | 90.00 (74.14) | 209.6 |
| *Bacillus thuringiensis* @ 0.5 kg/ha | 77.50 (62.15) | 192.1 |
| Endosulfan (0.05%) | 67.50 (55.44) | 169.8 |
| Control | 7.50 (13.83) | 140.1 |
| CD (P=0.05) | (12.68) | 29.52 |

Figures in parentheses are angular transformed values

### 4.27.6. Occurrence of natural enemies of PTM in different seasons

The larval stages of PTM mining potato leaves were found to be parasitised by *Apanteles* sp. and *Bracon* sp. to the extent of 4.5 to 9.6 per cent. In the stores, the predatory beetle, *Evorinia indica* was noticed on PTM eggs after commencement of rains in May and emergence continued up to September. Larvae of *S. litura* were parasitised by *Apanteles* sp. and infected with white muscardine fungus at harvest time of potato crop.

### 4.27.7. Demonstration of effectiveness of biotic agents against PTM in farmers' field

Effectiveness of *C. koehleri* and *C. blackburni* against PTM on potato were assessed in demonstration plots both during Kharif and Rabi. Five villages *viz*., Peth, Karegaon, Shriramnagar, Malegaon and Thugaon in Pune district were selected and 17, 6, 9, 12 and 7 farmers from the respective villages were chosen for the parasitoid releases. The total area covered was 22 ha during both Kharif and Rabi seasons. The parasitoids, *C. koehleri* @ 50,000 adults/ha/release and *C. blackburni* @ 15,000 adults/ha/release were liberated 4 times at weekly interval commencing from 45 to 52 days after crop planting. From each village 5-7 plots were selected and the data on tuber infestation and yield at the time of harvest were recorded (Table 111).

Table 111. Efficacy of parasitoids against PTM in farmers' field

| Season | Parasitoids released | Area covered (ha) | Infestation of tubers at harvest (%) | Yield (q/ha) (Marketable tubers) |
|---|---|---|---|---|
| Kharif 1998-99 | Four releases of adult *Copidosoma koehleri* @ 50,000 / ha / release | 6.5 | 7.84 | 207.6 |
| | Four releases of adult *Chelonus blackburni* @ 15,000 / ha / release | 4.3 | 8.03 | 207.3 |
| | Control | - | 19.12 | 150.9 |
| Rabi 1998-99 | Four releases of adult *Copidosoma koehleri* @ 50,000 / ha / release | 6.0 | 6.94 | 227.5 |
| | Four releases of adult *Chelonus blackburni* @ 15,000 / ha / release | 4.4 | 7.63 | 211.5 |
| | Control | - | 20.66 | 160.7 |

The results revealed that there was drastic reduction in tuber infestation (2.5-3.0 times) as compared to control and the yield was also higher in both parasitoid released plots during the Kharif and Rabi seasons.

## 4.28. Biological Suppression of Weeds

### 4.28.1. Monitoring, evaluation and impact assessment of *Neochetina eichhorniae, N.bruchi* and *Orthogalumna terebrantis* against *Eichhornia crassipes* (KAU, Thrissur; MPKV, Pune; AAU, Jorhat and GAU, Anand)

Sampling of water hyacinth plants from Alleppey, Kottayam, Trichur (two locations) and Ernakulam was done during the months of June, October and December, 1998 and the number of leaves per plant, leaf size, number of weevils per plant and number of scars per leaf were estimated. Ten plants were sampled for estimating number of leaves per plant, number of weevils per plant and the fourth leaf of each plant measured for length and breadth. Scoring number of scars per leaf was done for 25 leaves in each sample. Maximum number of weevils of 5.7 per plant was found in Ernakulam while the maximum of 3.8 scars per leaf was seen in Trichur. However, the weevils had established and observed in all areas surveyed.

*Orthogalumna terebrantis* released during 1990 has established in all release sites and in neighboring locations. Mite population and its damage was assessed from the samples collected from Alleppey (two locations), Kottayam and Trichur (two locations) districts in June, October and December 1998. The number of mites per leaf and mines/ leaf were estimated from 25 leaves for each sample. The number of mites varied from 16.16 to 133.16 in different samples and areas but was present in all areas. The mines per leaf were fairly uniform (2.24 - 3.52) in all areas surveyed.

Observations were continued in the pond in Pune where 2000 adults of *Neochetina* spp. and 40 leaves containing mites, *O. terebrantis* were released during July, 1997. Observations were taken on visual damage i.e. feeding score and per cent damage on 25 leaves at three months interval. Simultaneously number of weevils and mite population was also recorded by taking random samples of 25 plants and 25 leaves per pond. The score and leaf damage due to feeding by *Neochetina* spp. increased from 1.00 to 1.85 and 10.15 to 31.65 per cent, respectively from June to December; while they declined to 1.34 and 24.40 per cent by March, 1999. The weevil population increased from 1.00 to 3.04 per plant from June to December and reduced to 2.00 weevils/plant in March. Similarly, the mite number also increased from 10.00 to 21.60 mites/leaf from June to December and further reduced to 15.70 mites/leaf in March. The observations reveal that the weevils and mites could survive, breed and cause considerable damage to water hyacinth.

More than 7000 bighas of water body has been cleared in Disangmukh area of Sibsagar district of Assam mainly due to the activity of these exotic species and its effect on water hyacinth. The control achieved is 95% and the farmers for paddy cultivation are presently utilizing these areas. In Lakhaibill area of Alengmara also the weevil has established. The dispersal of the weevil has taken place into six districts of Assam. The number of weevils/leaf, intensity of leaf damage and number of scars/leaf was recorded from July to December in Sibsagar, Kakajan, Alengmara, Disangmukh, Bokakhat and Biswanath Chairali areas. The number of adults varied from 0.52 to 5.68, intensity of damage from 0.80 to 2.60 (0-4 scale depending on area of leaf damaged) and the number of scars/leaf from 38.60 to 208.16 in different areas from July to December.

The weevils have adapted well to the conditions in Gujarat as evidenced by the presence of the larvae and adults in the bulbs and fresh damage observed on the leaves. Number of scars/leaf and number of adults/plant were recorded from March 1998 to February 1999. The adult count varied from 1.50 to 3.20 per plant and scars/leaf from 50.0 to 180.25 per leaf during these months.

### 4.28.2. Monitoring and evaluation of *Cyrtobagous salviniae* (KAU, Thrissur)

Field releases of the weevils continued in Kerala from the College of Horticulture, Vellanikkara, Rice Research Station, Moncompu and the Regional Agricultural Research Station, Kumarakom. Samples of water fern were collected from isolated ponds (seven ponds in all) in Trichur and Kottayam districts during the period to assess the field population of the weevils. During each observation three samples were taken from 1 $m^2$ area/sample and healthy buds, number of weevils, total number and number of affected plants were estimated. Infestation could be noticed in all the locations and the field population of the weevil varied from 0-15.0 in different locations. The number of healthy buds varied from 3.3 to 72.0 and similar variation was observed in number of affected plants to healthy plants.

A random sampling was also carried out in different locations of Trichur district and similar observations taken. Out of the three locations, *viz.*, Chalakkady, Elanjikulam and Chirakkakode, Elanjikulam had no weevils or affected plants while Chalakkady and Chirakkakode had 2.00 and 1.67 weevils and 49.26 and 52.31 per cent of the plants were affected.

### 4.28.3. Activity of *Zygogramma bicolorata* on *Parthenium hysterophorus* (Dr.YSPUH and F, Solan)

Studies were conducted on the biology of *Zygogramma bicolorata* in Solan to find out the differences among beetles emerged during different parts of the year. Sixty per cent of the females formed in September, that had stopped laying at mean age of 43 days, entered into diapause. Some females did resume egg laying in small numbers in the third week of February, but the eggs laid up to mid March did not hatch. Adult female survival was 117 to 297 (212 + 21.8) days. These females laid up to 253 (92.2 + 42) eggs in the second phase of oviposition. Females formed in November end to early December, which had entered into diapause without beginning to lay eggs, commenced oviposition by end of March.

Beetles emerged from the eggs laid in the first week of April, during last week of April to first week of May, and started oviposition during last week of May after a pre-oviposition period of 21-29 (23 + 2) days and laid 163-632 (303.8 + 111.1) eggs in 10-103 (66.5 mean) days. Adult survival was 31-160 (mean 107.3) days. The beetles emerged in mid July commenced egg laying after a pre-oviposition period of 9-16 (10.9 + 0.9) days and laid 104-1022 (458.8 + 187.9) eggs in 15-42 (26 + 5.8) days. However, the beetles formed during third week of October to first week of November entered into diapause and

commenced egg laying only during second week of March. From the eggs laid in the last week of August, development was completed during first week of October in 36-39 days.

Periodic observations were taken in the field to record the activity of the beetles by estimating the population of eggs, larvae and adults twice in a month from June. The studies revealed that in the field, its activity persisted from June to mid December. Adult population was 0.1-0.8 beetles/plant up to November end, with a seasonal mean of 0.5 beetles/plant. The maximum count was during second half of August and second half of September. Egg count per plant varied from 0.03 to 9.87 (mean 2.33) during June to mid October and maximum eggs were counted during second half of August. However, larval count was comparatively low and varied up to 1.2/plant during June to December with a seasonal mean of 0.4 larva/plant. Higher larval count was obtained in early July and early August.

## 4.29. Research achievements made in the lateral funded projects

### 4.29.1. Use of semiochemicals to increase biocontrol potential of predators and parasitoids (DBT funded project, Principal Investigator: Dr.N.Bakthavatsalam)

Kairomones were used to induce oviposition by the common lacewing *Chrysoperla carnea* (Stephens), inducing oviposition of parasitoids of coconut caterpillar on the non host *Corcyra cephalonica* and to increase the searching ability of *Goniozus nephantidis*, the larval parasitoid of *Opisina arenosella*. The cotton plants treated with 0.33% L-tryptophan recorded more oviposition compared to others in repeated trials under caged conditions. The combination of 0.66 : 0.11 and 0.66 : 0.44 of tryptophan-valine was found to evoke better oviposition compared to L-tryptophan alone. The ultimate breakdown product of L-tryptophan was identified as the indole acetaldehyde, which was found responsible for the attraction of the chrysopids to the L-tryptophan. The predatory potential was very high in the cotton plants treated with the tricosane and the scale extracts compared to untreated control. Formulations of kairomones based on tricosane, pentacosane, heneicosane and hexatriacontane were prepared and tested for their efficiency on the egg parasitoids, *Trichogramma chilonis* in Y tube tests and cage tests. The formulations based on tricosane were found to attract more adults than control. The washings from the *O. arenosella* infested galleries were found to attract more adults of *Goniozus nephantidis* than the other kairomones like larval washings. More adult emergence of *G. nephantidis* was noticed in kairomone treated larvae than untreated control. *Brachymeria nephantidis* was able to parasitise more number of kairomone treated pupae of *C. cephalonica* compared

to untreated pupae. More number of adults was obtained from the kairomone treated pupae than untreated pupae. Chemical analysis of the pupal washings of *C. cephalonica, O. arenosella* and the gallery washings were done using GC-MS. All the kairomones were found to contain long chain hydrocarbons like hexatriacontane, tricosane, eicosane, heneicosane, pentacosane, docosane, tetracosane, ocatocosane etc. Hexacosane was detected in the gallery washings of *Opisina arenosella* in addition to the other hydrocarbons. This may be one of the factors for more attraction to gallery washings than other kairomones. Electro antennogram tests were done to screen the best kairomones for the *Chrysoperla carnea*. The adults of *C. carnea* responded to the various concentrations of tryptophan - valine combinations. The combination of tryptophan -valine 0.66:0.11 was found to evoke good response among the concentrations tested. Another EAG study revealed that indole acetaldehyde also evoked antennal response like other kairomones.

### 4.29.2. Biological control of *Agrotis* spp. with entomophilic nematodes (DBT funded project, Principal Investigator: Dr.S.S.Hussaini)

Intensive surveys were undertaken covering 11 States and 196 soil samples were collected from potato growing areas and other host crops of *Agrotis* spp. Eight isolates were detected, six were *Steinernema* spp. and two *Heterorhabditis* spp. *Steinernema* sp. PDBC EN 3.1, 3.2 were most effective against *Agrotis ipsilon* with 83.3 % mortality and PDBC EN 2.1 with 75% mortality while *Steinernema* spp. PDBC EN 6.61,3.2 6.11 were promising against *A. segetum* with 91.7 % mortality. *Heterorhabditis* spp. PDBC EN 13.3, 6.71 were effective against both *Agrotis* spp. with 100 % mortality. Same trend was observed in soil assays. Progeny production of Ijs in *A. ipsilon* was maximum with *Steinernema* spp. PDBC EN 3.2-9 (1.1 lakh /larva). *Steinernema* sp. PDBC EN 3.2 penetrated in *A. ipsilon* larvae much better ( 63.5%) followed by *Heterorhabditis* PDBC EN 13.3(40.2%). A positive correlation was worked out between the nutritional status of insect pest and yield of Ijs. Protein : lipid ratio of insect varied with highest in *A. ipsilon* (1: 5.1 ) and lowest in *G. mellonella* (1:2.7) but the yield was in the reverse trend indicating the more influence of protein than lipid of the hosts on the *in vivo* production of entomophilic nematodes. Scatter plots and linear regression models on the yield and protein and lipid profiles depicted regression equations, protein (Y=6482.1x-110406) ; $r^2$ = 0.6695) and lipid (Y= 3.440x-417933; r2= 0.6267) which determine the nutritional requirements for the production of desirable quantities of Ijs. The production was average in Wout's medium which was most suitable for all isolates except *Steinernema* spp. Pot culture assay was conducted to assess the effectiveness of different formulation of *Steinernema* sp. PDBC EN 3.2 against *A. ipsilon*. The pellet formulation was highly effective (88.9% mortality) in terms of its effectiveness and escape of Ijs.

### 4.29.3. Biocontrol of Maize Tissue Borers using entomophilic nematodes (ICAR adhoc scheme, Principal Investigator: Dr.S.S.Hussaini)

Ten states were surveyed for the collection of soil samples from maize growing areas and other host crops of *Chilo partellus*. Out of 95 samples collected 1 *Steinernema* sp. and 2 *Heterorhabditis* spp. were detected. Four isolates were tested against *C. partellus* larvae in the laboratory and *Heterorhabditis* sp. PDBC EN 6.71 was found to be the most effective with 60% mortality at 120 h post inoculation. The progeny production of *Heterorhabtidis* spp. was higher than *Steinernema* spp. from last instar *C. partellus* larvae. The nematode yield per instar increased progressively as weight of larva increased. On maize leaves nematodes survived (20 - 24 %) for 48 h in 1& 2% liquid paraffin, 1% glycerine whereas they were spotted alive for about 3-5 h only in other antidesiccant solutions. Storage of infective juveniles of *Steinernema* and *Heterorhabditis* spp. at 8 and 24 $^{0}$ C revealed that survival was better at 24 $^{0}$ C. Eighty nine diets were tried for mass production of which 23 yielded positive results. Different combinations of alginate based capsules and wheat bran pellets were tried of which wheat bran pellets with groundnut oil were the most attractive to *C. partellus* larvae. Nematodes survived well in the above as well as in Alginate + glycerin + triton X 100 formulation for more than 30 days.

### 4.29.4. Developing Strategies for the Management of Parthenium Weed in India Using Fungal Pathogens (CABI-ICAR Collaborative Project: Principal Investigator: Dr. P. Sreerama Kumar)

A total of 14 isolates of some of the most damaging fungal pathogens of parthenium were identified and confirmed at CABI Bioscience, UK Centers (Ascot and Egham). Also, many of the commonly occurring fungal pathogens of parthenium in Karnataka collected during 1997-99 were identified at least up to the genus level and documented. *Cryptosporiopsis* sp., a leaf-spotting pathogen, showed the most desirable characteristics for development as a mycoherbicide for parthenium. The most pathogenic isolate [WF(Ph)3] (IMI 378270) of the fungus, collected in Mysore district, was taken up for further investigations. A total of 83 cultivars of economically important plants falling under 10 families, including Asteraceae, Papilionaceae, Solanaceae, Cucurbitaceae, Cruciferae, Malvaceae, Amaranthaceae, Chenopodiaceae, Umbelliferae and Poaceae were screened against *Cryptosporiopsis* sp. and found to be immune. Both mycelial and conidial inoculations did not incite disease on any of the plant species screened. The preliminary host-range testing determined that all the crops, including those species of the Asteraceae especially the 8 sunflower cultivars, were not susceptible to *Cryptosporiopsis* sp. *Cryptosporiopsis* sp. biomass and conidia production in two different media viz. PDB

and molasses yeast medium (MYM) was compared through the fermentation technique. MYM was found to be superior to PDB in terms of biomass as well as conidia production. After 7 days of fermentation in PDB and MYM, the conidial number obtained was 6.52 X $10^7$ and 8.75 X $10^7$ per every mL of the medium, respectively.

### 2.29.5. National repository of natural enemies of crop pests and weeds (DBT funded project, Principal Investigator : Dr.S.P.Singh)

Eleven species of trichogrammatids and 13 strains of *Trichogramma chilonis* were collected from different parts of the country. These strains and species were maintained on the eggs of *Corcyra cephalonica* and *Helicoverpa armigera*. Life table studies on *Trichogrammatoidea bactrae* (collected from Assam) at different temperatures indicated that net reproductive rate was high (23.2) at 25°C and lowest at 35°C. Six species of coccinellids *Cheilomenes sexmaculata, Chilocorus nigrita, Cryptolaemus montrouzieri, Coccinella septempunctata, Scymnus coccivora* and *Brumoides suturalis* were continuously maintained in the laboratory. Weed insects, namely, *Neochetina eichhorniae, N. bruchi,* and *Orthogalumna terebrantis* on water hyacinth, and *Cyrtobagous salviniae* from *Salvinia molesta* were maintained in plastic pools. *Chelonus blackburni, Cotesia flavipes* and *Cotesia plutellae* collected from different regions were maintained in the laboratory. Chrysopids such as *Mallada boninensis, M. astur, Apertochrysa* sp., *Chrysoperla carnea* were maintained in the laboratory. Two new species of *Ankylopteryx* were collected from Mandya and Lakshadweep Island respectively. A strain of *Chrysoperla carnea* resistant to monocrotophos and cypermethrin was maintained by continuous exposure to these insecticides over 17 generations. Scelionids and eulophids were collected from different localities. An eulophid identified as *Oomyzus sokolowskii* was collected from eggs of *Plutella xylostella* from cabbage. Functional response studies were conducted with *Telenomus remus* at different temperatures. The parasitoid exhibited Hollings Type II functional response at various temperature and lost densities. Anthocorids like *Cardiastethus exiguus* were maintained continuously in the laboratory. *Orius tantillus* collected from maize could be multiplied for a generation or two. Unidentified anthocorids were collected from cotton, and from *Ferrisia virgata* infesting *Bauhinia purpurea*. Parasitoids of *Opisina arenosella* such as *Goniozus nephantidis, Elasmus nephantidis, Brachymeria nosatoi,* and *B. nephantidis* collected from parts of Karnataka, Goa, Kerala and Tamil Nadu were maintained in the laboratory. Ichneumonid parasitoids, *Campoletis chlorideae,* and *Eriborus argenteopilosus* were maintained on the larvae of *Spodoptera litura* and *Helicoverpa armigera*. 3600 cocoons of *C. chlorideae* and 3760 cocoons of *E. argenteopilosus* were reared during this period. Seasonal incidence of these parasitoids

was also studied. Encyrtid parasitoids of *Planococcus citri* and *P. lilacinus* were collected from Nagpur, Pune and Bangalore. *Leptomastix dactylopii* and *Coccidoxenoides peregrina* were collected from *Planococcus* spp. and *Copidosoma koehleri* was collected from *Phthorimaea operculella*. A number of leaf spot and leaf blight inducing pathogens was found to be associated with *Parthenium hysterophorus*. Different entomopathogens such as *Fusarium roseciln, F.moniliforme, Scopulariopsis brecrocaulis* and *Botrydiplodia theobromae* were isolated from different crop pests. *Phoma glomerata* and *Fusarium sporotrichiodes* were the fungi isolated from the egg masses of plant parasitic nematodes. More than 200 isolates of *Trichoderma* spp. and *Gliocladium* spp. were added to the existing culture. Fifty isolates were proved to be effective against different pathogens.

# 5. TECHNOLOGY ASSESSED AND TRANSFERRED

## 5.1 Technology assessed

### 5.1.1. Multiplication of *Ischiodon scutellaris* (Fabricius)

Syrphids are one of the most important predators of many economically important aphid species. Mass multiplication technology has been evolved at the Project Directorate for production of a potential syrphid - *Ischiodon scutellaris*. Rearing procedure developed includes three steps *viz.*, raising of host plants for aphids, rearing of aphids as host for predators and rearing of syrphids and all of them have to be done simultaneously. Adult rearing cage and larval rearing units have been fabricated and dosage of aphid to be provided per larva and number of larvae to be released per unit have been standardized. These predators could be used in cotton, legumes and oilseeds for suppression of different aphid species.

### 5.1.2. Multiplication of *Eriborus argenteopilosus*

*E. argenteopilosus* is an important larval parasitoid of the polyphagous pest *Helicoverpa armigera* in the pulses ecosystem. The earlier method of multiplying the parasitoid is individual vials is now modified for mass producing the parasitoid. Ventilated breadboxes (24x12.5x6 cm) can be used to produce 50-60 cocoons per box. This procedure facilitates easy collection of cocoons and is cost effective.

### 5.1.3. Potential *Trichoderma* isolates

Fungi under genus *Trichoderma* were recognized as potential bioprotectants of many plant pathogens. Research efforts at PDBC has resulted in identification of two isolates *Trichoderma harzianum* (PDBCTH 10) and *Trichoderma viride* (PDBCTH 23) which have potential to control diseases caused by *Rhizoctonia solani, Sclerotium rolfsii, Fusarium oxysporum* f. sp. *ciceris, Fusarium oxysporum* f. sp. *udum, Macrophomina phaseolina, Botrytis cinerea* and *Pythium aphanidermatum*. These two bioagents were found to be superior to some of the seed treatment chemicals. The bioagents were efficient solubilizers of phosphate and promote plant growth.

### 5.1.4. Improved medium for mass production of *Trichoderma*

A cost-effective medium, which supports maximum biomass of fungal bioagents, is highly essential for mass production and commercialization. A modified medium

(Molasses based) which supports high amount of biomass and viable propagules was identified and fermentation technology was standardized for mass production of *Trichoderma* by using this medium.

*5.1.5.* A new granular formulation of *Trichoderma*

Formulation technology is very important for successful commercialization and efficient use of any bioagent. Wheat bran based granular formulation of *Trichoderma harzianum* developed was highly effective in controlling *Rhizoctonia solani* of chickpea under field conditions.

## 5.2. Technology transferred

A multicellular larval rearing unit has been devised for rearing *Helicoverpa armigera*. The tray is made of transparent acrylic and is amenable to surface sterilisation. It is reusable, durable and hence economical. Rearing in this tray provided 80 to 90% recovery of *H. armigera* pupae. Larval escape was nil and disease incidence by contamination was minimum. Cannibalism was totally avoided. Pupal formation could be recorded easily and pupal collection was also easy.

## 6. EDUCATION AND TRAINING

### 6.1. Education

Mr.B.S.Bhumannavar, Senior Scientist has been deputed to University of Agricultural Sciences, Bangalore for higher studies (Ph.D.) on study leave for three years to work on the project entitiled "Studies on fruit piercing moths with particular reference to species composition, biology and role of natural enemies"

### 6.2. Training

Dr.P.Sreerama Kumar, Scientist (Plant Pathology) attended a training programme on "Biological Control and Management of parthenium weed" from March 17th to April 5th 1998 at CABI Bioscience, UK Centre, Ascot, Berkshire (UK)

Ms.I.M.Dautie, Assistant Administrative Officer, attended a training programme on "Improving Administrative Efficiency in Agricultural Research, Teaching and Extension Organisations of ICAR" from July 29th to August 4th 1998 at National Academy of Agricultural Research Management, Rajendranagar, Hyderabad

Mr.S.R.Biswas, Senior Scientist (Agricultural Statistics) attended a training programme on "Usage and operation of FTDMA VSATs" on October 22nd and 23rd 1998 at National Informatics Centre, Lodhi Road, New Delhi 110 003

Dr.N.Bakthavatsalam, Scientist SS (Agri. Entomology) attended a training programme on "Fundamentals and Applications of Gas Chromagraph Mass Spectral Detector at Singapore" from January 25th and 28th 1999 at Hewlett Packard Sales Private Limited, Alexandra Techno Park, Singapore

Dr.S.P.Singh, Project Director attended a training programme on "Executive Development Programme in Agricultural Research Management" on January 28th and 29th 1999 at National Academy of Agricultural Research Management, Rajendranagar, Hyderabad

## 7. AWARDS AND RECOGNITIONS

Dr.S.P.Singh, Project Director was presented an award of honour at National Seminar on Biological Suppression of Plant Diseases, Phytoparasitic Nematodes and Weeds at Bangalore on 16-05-1998.

Dr.S.P.Singh, Project Director elected as President, Society of Biocontrol Advancement, Bangalore

Dr.R.D.Prasad was awarded the Best Poster presentation for his poster entitled "A modified liquid medium for mass production of *Trichoderma* by fermentation process" presented in National Symposium on *"Eco-friendly approaches in the management of plant diseases"* December 22-24, 1998, held at Shimoga, Karnataka.

Project Directorate of Biological Control, Bangalore has been awarded with "BEST INSTITUTE AWARD, 1998"

## 8. LINKAGES AND COLLABORATION IN INDIA AND ABROAD INCLUDING EXTERNAL PROJECTS

AP Cess Fund Project entitled "Implications of tritrophic interaction in the Integrated Pest Management of some important crop pests" with a total budget of Rs.39,68,430/-. The project is operative at PDBC with four co-operating centres (GAU, Anand; AAU, Jorhat; CTRI, Rajahmundry and CPCRI, Regional Centre, Kayangulam).

## 9. AICRP / COORDINATION UNIT / NATIONAL CENTRES

With a view to fulfil the mandate given, the Project Directorate has divided the workload based on the infra-structural facilities and expertise available at six ICAR Institute based and ten State Agricultural University (SAUs') based co-ordinating centres and the following are the crops allotted to work on biological control.

**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) | - Fruit & Vegetables |
| Indian Sugarcane Research Institute, Lucknow (Uttar Pradesh) | - Sugarcane |
| Sugarcane Breeding Institute, Coimbatore (Tamil Nadu) | - Sugarcane |

**State Agricultural University based centres**

| | |
|---|---|
| Assam Agricultural University, Jorhat (Assam) | - Rice & Weeds |
| Acharya N.G. Ranga Agricultural University, Hyderabad (Andhra Pradesh) | - Pulses, Oilseeds & Cotton, |

| | |
|---|---|
| Govind Ballabh Pant University of Agricultural Sciences Technology, Pantnagar (Uttar Pradesh) | - Plant Disease & control (Pulses & Oilseeds) |
| Gujarat Agricultural University, Anand (Gujarat) | - Cotton, Pulses, Weeds, Tobacco & Oilseeds |
| Kerala Agricultural University, Thrissur (Kerala) | - Weeds & Paddy |
| Mahatma Phule Krishi Vidyapeeth, Pune (Maharashtra) | - Potato, Cotton, Rice & Weeds |
| Punjab Agricultural University, Ludhiana (Punjab) | - Sugarcane, cotton Pulses Rice, Oil seeds & Weeds |
| Sher-E-Kashmir University of Agricultural Sciences & Technology, Srinagar (Jammu & Kashmir) | - Fruit & Vegetables |
| Tamil Nadu Agricultural University, Coimbatore (Tamil Nadu) | - Rice, Cotton, & Pulses |
| Dr.Y.S.Parmar University of Horticulture & Forestry, Solan (Himachal Pradesh) | - Fruit & Vegetables |

## GENERAL / MISCELLANEOUS

## 10. LIST OF PUBLICATIONS

### Project Directorate of Biological Control, Bangalore

Ballal, C.R. and Singh, S.P., 1998. Effect of pesticide applications on pheromone trap catches and distribution pattern of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) in pigeonpea ecosystem, pp. 124-128. **In:** Proceedings of the First *National Symposium on Pest Management in Horticultural Crops: Environmental Implications and Thrusts- Advances in IPM for Horticultural Crops* P.Parvatha Reddy, N.K.Krishna Kumar and Abraham Verghese (Eds.), 363 pp.

Ballal, C. R. and Singh, S. P. (1998) Host plant mediated orientational and ovipositional behaviour of three species of chrysopids (Neuroptera: Chrysopidae). *Biological Control (Theory and Application in Pest Management)* (Accepted for publication).

Ballal, C. R., Singh, S. P., Joshi, S. and Rao, N. S. (1998) Multicellular tray for rearing the larvae of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) *Entomon* **23:** 307-312.

Joshi, S., Venkatesan, T. and Rao, N. S. 1997. Host range and predatory fauna of *Aphis craccivora Koch* (Homoptera: Aphididae) in Bangalore, Karnataka. *J. Biol. Control,* **11:** 59-63.

Joshi, S., Ballal, C. R., Venkatesan, T. and N. S. Rao. 1998. Influence of host plants on the biological parameters of *Aphis craccivora Koch* (Homoptera: Aphididae). *Entomon* **23:** 127-132.

Joshi, S., Ballal, C. R. and Rao, N. S. 1998. An efficient and simple mass culturing technique for *Ischiodon scutellaris* (Fabricius), an aphidophagous syrphid. Indian *J. Plant Prot.* **26:** 56-61.

Hussaini, S.S. and Singh, S.P. 1998. Entomophilic nematodes for control of insect pests. **In** : Biological suppression of plant diseases, phytoparasitic nematodes and weeds. Project Directorate of Biological Control, Bangalore. 238-267.

Hussaini, S.S., Singh, S.P., Sankaranarayanan, C., Parthasarathy, R., Thilagavathy, G. and Shakeela,V., 1998. Influence of protein and lipid content of host insects on in vivo production of native entomopathogenic nematodes, *Steinernema* sp. Paper presented in National symposium on ' *Rational approaches in nematode management for sustainable Agriculture'* held at B.A. College of Agriculture Anand campus, Anand, Nov 23-25, 1998.

Narayanan, K. 1998. Efficient utilisation of insect microbes through Biotechnology: An overview. *'National Symposium on Development of Microbial Pesticides and Insect Pest Management'*, Pune, November 12-13. Ab.pp. 7

Narayanan, K.1998. Characterisation of spindle shaped inclusions associated with baculovirus of greater wax moth, *Galleria mellonella. 'National Symposium on Development of Microbial Pesticides and Insect Pest Management '*, Pune, November 12-13. Ab.pp. 29

Narayanan, K. and Gopalakrishnan, C. 1998. Occurrence of nuclear polyhedrosis of *Spodoptera exigua* (Hubner) (Noctuidae: Lepidoptera). *'National Symposium on Development of Microbial Pesticides and Insect Pest Management'*, Pune, November 12-13. Ab. pp. 40.

Narayanan, K. 1999. Role of genetic engineering and tissue culture for microbial control of insect pest management in India. In *Recent trends in pest management in sericulture.* (Ed. Dr. R.K. Datta, Director, Central Silk Board, *Central Sericulture Research and Training Institute, International Centre for Training and Research in Tropical Sericulture,* Mysore-570 008) (In Press).

Poorani, J. 1998. A new species of *Serangium* Blackburn (Coleoptera: Coccinellidae) from India, with a key to species. *Journal of Biological control* **12** (in press).

Prasad, R. D. and Rangeshwaran, R. 1999. Wilt and root rot of chickpea. *The Hindu* **159**: 24

Prasad, R. D. Paadap rogomka jaivik niyamthran. In: Jaivik niyamthran ki safalathaye, published by Project Directorate of Biological Control (ICAR), India, pp.28-29.

Prasad, R. D., Sreerama kumar, P. and Narayanan, K. 1998. Biological control of *Botrytis* grey mold of rose. *J. Mycol. Plant Pathol.* **28 :** 61-63.

Prasad, R. D. and Rangeshwaran, R. 1998. A modified liquid medium for mass production of *Trichoderma* by fermentation process. In: Abstracts of national symposium on *"Eco-friendly approaches in the management of plant diseases"* December 22-24, 1998 held at Shimoga, Karnataka,pp.26.

Rangeshwaran, R. and Prasad, R. D. 1998. Screening and selection of *Rhizobacteria* for biological control of *Sclerotium rolfsii* and *Rhizoctonia solani*. In: Abstracts of national symposium on *"Development of microbial pesticides and insect pest management"* November 12-13, held at Pune, pp.41.

Rangeshwaran, R. and R. D. Prasad. 1998. Antagonistic *Rhizobacteria* and Biological Control of *Sclerotium rolfsii* the causal organism of root/collar rot in Sunflower. *Indian Phytopathology* (in press).

Rangeshwaran, R. and R. D. Prasad. 1998. Screening and Selection of *Rhizobacteria* for Biological Control of *Sclerotium rolfsii* and *Rhizoctonia solani*. Presented as poster in the National Symposium on Microbial Pesticides and Insect Pest Management organized by BARC and Hindustan Antibiotics at Pune from November 12-13.

Sankaranarayanan, C., Hussaini, S.S., Sreerama Kumar, P. and Prasad. R.D. 1998. Nematicidal effect of fungal filtrates against root-knot nematodes. *J. Biol. Control* **11** : 37-41.

Sankaranarayanan, C., Hussaini, S. S., Sreerama Kumar, P. and Rangeshwaran, R. 1998.Antagonistic effect of *Trichoderma* and *Gliocladium* spp. against the root knot nematode *Meloidogyne incognita* in sunflower. Paper presented in the National symposium on "Rational Approaches in nematode management for sustainable Agriculture" held at B. A. College of Agriculture Anand Campus, Anand from November 23-25, 1998.

Singh, S.P. 1997. Biotechnological approaches for the management of insect and nematode pests, pp. 243 - 257. In: *Proc. of Regional Expert Consultation on the Application of Biotechnology in Plant Pest Management,* (February 25-28, 1997). Indian Agricultural Research Institute, New Delhi, India, FAO-UN-RAP, and Bangkok, Thailand Publication 1997/40, 364 pp.

Singh, S.P. 1997. Biological control of insect pests of pulse crops, pp. 377-391. In-*Recent Advances in Pulses Research,* A.N.Asthana and Masood Ali, (Eds.). Indian Society of Pulses Research and Development, IIPR, Kanpur, India, 825 pp.

Singh, S.P. 1998. Biological suppression of water hyacinth in India. *Biocontrol News and Information* **19** (3) :73N.

Singh, S.P. 1998. India fights bollworm upsurge. *Biocontrol News* and *Information* **19** (3): 74N-75N.

Singh, S.P. 1998. Biointensive integrated pest management, pp. 343-372. In: *Crop Productivity* and Sustainability - *Shaping the Future- Proceedings of the 2nd International Crop Science Congress*, V.L.Chopra; R.B.Singh and Anupam Varma (Eds.). Oxford & IBH Publishing Co.Pvt. Ltd., New Delhi, 1111 pp.

Singh, S.P., 1998. Increasing the effectiveness of natural enemies. Presented at *National Seminar on Entomology in 21st Century: Biodiversity, Sustainability, Environmental Safety and Human Health* organized by Entomological Society of India (April 30 to May 2, 1998), Udaipur, Rajasthan.

Singh, S.P., 1998. BIPM in Cotton. Presented at *National Seminar on Cotton.* Directorate of Cotton Development, Mumbai. (May 3-4, 1998)

Singh, S.P., 1998. Biointensive integrated management (BIPM) of cotton pests. (In Hindi). Presented at Kissan Ghosti at Sangria, Rajasthan on 26th July, 1998.

Singh, S.P., 1998. Biointensive integrated management of mustard pests. Presented at *Seminar on Rapeseed-Mustard Research in 21st Century* - Golden Jubilee Year of India's Independence (August 6, 1998) organized by AICRP on Rapeseed Mustard Annual Workshop, Birsa Agricultural University, Ranchi, Bihar.

Singh, S.P., 1998. Integrated pest management for accelerated growth of horticultural crops. Presented at National Horticultural Conference 1998 held on 29th November 1998 at Vigyan Bhavan, New Delhi.

Singh, S.P., 1999. Biological suppression - present status and future strategies. Presented at *3rd International/15th National Symposium on Recent Trends in Life Sciences* at Bangalore University on 12th February 1999.

Singh, S.P. 1999. Pest Management - The Ecofriendly Approach, pp. 175-184. *The Hindu Survey of Indian Agriculture 1999* N.Ravi (Ed). National Press, Chennai, 208 pp.

Singh,S.P.1998. Biological suppression, pp. 46-51. In: Critical issues of IPM in the Changing Agricultural Scenario in India (D.R.C.Bakhetia, V.K.Dilawari, Jaginder Singh, Balbir S.Joia (Eds.). Punjab Agricultural University, Ludhiana, India, 109 pp.

Singh, S. P., Jalali, S. K. and Prasad, R. D. 1998. Biological control-Route to pesticide free food products. Paper presented in a national conference and expo on " *The Future of Processed Fruits and Vegetable Industry-Summit 1998*" held at Bangalore on 21st and 22nd August 1998.

Singh, S.P. and Ballal, C.R. (1998) *An Annotated Bibliography on Biological Control of Sugarcane Pests in India* (1919-1998). *Tech. Bull.* No. 23, Project Directorate of Biological Control, Bangalore, 191 pp.

Singh, S. P., Ballal, C.R. and Jalali, S. K. (1998) *Production and Use of Nuclear Polyhedrosis Viruses of Spodoptera litura* and *Helicoverpa armigera*. *Tech. Bull.* No. 15, Project Directorate of Biological Control, Bangalore, 12 pp.

Singh, S. P., Ballal, C. R. and Jalali, S. K. (1998) *Spodoptera litura aur Helicoverpa armigera ke nuclear polyhedrosis vishanuvon ka uthpadan aur prayog*. *Tech. Bull.* No. 16, Project Directorate of Biological Control, Bangalore, 14 pp.

Singh, S.P. and Hussaini, S.S. 1998. Biological Suppression of Plant Diseases, Phytoparasitic Nematodes and Weeds. Project Directorate of Biological Control, Bangalore, India, 284 pp. (price $25).

Singh, S.P., Jalali, S.K., Bhumannavar, B.S., Bakthavatsalam, N. and Pushpalatha, N.A. 1998. Trichogrammatid und parajivi keet ka utpadan aur prayog. *Tech. Bull.* No.22. PDBC (ICAR), 16 pp.

Singh, S.P., Jalali, S.K., Bhumannavar, B.S., Bakthavatsalam, N. and Pushpalatha, N.A.1998. Parabakshi keet chrysopid ka utpadan aur prayog. *Tech. Bull.* 29. PDBC (ICAR), 12+1 pp.

Singh, S.P., and Venkatesan, T. 1998. *An annotated bibliography of biological control of tobacco pests in India* (1938-1998). *Tech. Bull* No.23, PDBC: ICAR, Bangalore-24, India, 56 pp.

Sreerama Kumar, P. 1998. Biological suppression of parthenium with pathogens. pp. 192-210. In: Biological Suppression of Plant Diseases, Phytoparasitic Nematodes and Weeds (S. P. Singh and S. S. Hussaini, Eds.), Project Directorate of Biological Control, Bangalore, India.

Sreerama Kumar, P. 1998. Mycoherbicidal properties of *Gliocladium virens* towards *Parthenium hysterophorus*. Poster presented at the International Symposium on The Future of Fungi in the Control of Pests, Weeds and Diseases, University of Southampton, Southampton, United Kingdom, 5-9 April 1998 (Abstract).

Sreerama Kumar, P. 1998. Initial efforts towards the development of mycoherbicides for the management of parthenium, a serious weed in India. Poster presented at the National Symposium on Development Microbial Pesticides and Insect Pest Management, Bhabha Atomic Research Center (Mumbai) and Hindustan Antibiotics Limited (Pune), Hotel Pride, Pune, 12-13 November 1998, p. 45 (Abstract).

Sreerama Kumar, P. 1999. Prospects for the development of mycoherbicides in India. Proceedings of the Second Asia-Pacific Crop Protection Conference: Recent Advances in the Control of Pests, Diseases and Weeds, Pesticides Manufacturers and Formulators association of India, The Retreat, Mumbai, India, 18-20 February 1999. Pestology (Special issue) 23(1): 194-205.

Venkatesan, T., Jalali, S. K. and Singh, S.P. 1997 A semi-synthetic diet for *Cheilomenes sexmaculata* (Fabricius) (Coleoptera: Coccinellidae), *J. Entomol. Res.*, 22(2): 169-172.

**Central Plantation Crops Research Institute, Kayangulam**

Chandramohanan Nair, K.R. and Sathiamma, B. 1999. Biocontrol of lace bug. *The Hindu.* 11th February page 28.

Chandrika Mohan and Sathiamma, B. 1999. Coconut leaf eating caterpillar and biological control (Mal.). *Indian Naleekera* J. 29 (4) : 1-3.

Gopal Murali, Sathiamma, B., K.R.Chandramohanan Nair and Soniya, V.P. 1998. A fungal pathogen of lace bug and leaf eating caterpillar, two insect pests of coconut palm. Paper presented at the 39th Annual Conference of Association of Microbiologist in India: 5-6 December 1998., Mangalore. Abstract 275.

Gopal Murali and Sathiamma, B. 1998. Coir waste: An alternative feed material for baculovirus inoculated rhinoceros beetle, *Oryctes rhinoceros* L. Paper presented at PLACROSYM XIII: 26-28 December 1998, Coimbatore Abstract No. 46.

Gupta Alka, Gopal Murali and Sathiamma, B. 1998. Biological control of rhinoceros beetle by entomopathogenic fungus *Metarhizium anisopliae* (Hindi). *Bharatiya Nariyal Patrika* **9** (3) : 66-67.

Gupta Alka and Sathiamma, B. 1999. Incidence of a nut infesting eriophyid mite in coconut plantations of Kerala (Hindi). *Bharatiya Nariyal Patrika* **49** (4) : 9-10.

Nair, C.P.R., Sathiamma, B., Chandrika Mohan and Gopal Murali, 1998. Newer approaches in Integrated Pest Management in Coconut. *Indian Cocon. J.* **29** (4) : 99-105.

Nair, C.P.R., Sathiamma, B.,Chandrika Mohan and Gopal Murali, 1998. Integrated Pest Management in Coconut - new outlook (Malayalam). *Indian Naleekera J.* **77** (10) : 34-39.

Sathiamma, B. 1998. Biological suppression of rhinoceros beetle and leaf eating caterpillar - two major pests of coconut. *Indian cocon. J.* **28** (12) : 4-8.

Sathiamma, B. 1999. Pest control through biological means (Malayalam). *Kerala Karshakan* **44** (9) : 32-34.

Sathiamma, B. 1999. Techniques for mass rearing of parasitoids of *Opisina arenosella*, the leaf-eating caterpillar of coconut palm. *Indian Cocon. J.* **29** (9) : 2-5.

Sathiamma, B. and Chandramohanan Nair, K.R. 1998. Observations on the indigenous predators of the lace bug *Stephanitis typica D.* (Heteroptera: Tingidae), the vector of root (wilt) disease of coconut palm. PLACROSYM XIII, 16-18 December 1998, Coimbatore

Sathiamma, B., Chandramohanan Nair, K.K. and Soniya, V.P. 1998. Record of the natural enemies of the lace bug *Stephanitis typica* (D), a pest of coconut palm. *Entomon.* : **23** (4) : 321-324.

Sathiamma, B., Chandramohanan Nair and Soniya, V.P. 1998. Lace bug and its natural enemies (Malayalam). *Indian Naleekera J.* **27** (10) : 40-41.

Sathiamma, B., Gopal Murali and Chandrika Mohan, 1998. Biological Control preferred against rhinoceros beetle of coconut (Malayalam). *Indian Naleekera J.* **27** (9) : 1-5.

**Central Tobacco Research Institute, Rajahmundry**

Sreedhar, U., Ramaprasad, G. and Sitaramaiah, S. 1998. IPM of Chilli caterpillar. *The Hindu* (English) 121 : 279.

Sreedhar, U., Ramaprasad, G. and Sitaramaiah, S. 1999. Trap crops to control pests. *The Hindu* (English) 14th January 1999.

Sreedhar, U., Ramaprasad, G. and Sitaramaiah, S. 1999. Pogaku thotalo Tenae manchu purugu bedada nivarana (Telugu). *Eenadu* 20th January 1999. Pages 15 & 17.

Srinivas, I., Nagarajan, K., Ramaprasad, G., Chari, M.S. and Gunneswara Rao, S. 1999. Extractor to make NPV. *The Hindu.* 21st January.

**Indian Institute of Horticultural Research, Bangalore**

Gopalakrishnan, C. and Asokan, R. 1998. On-farm trials of HaNPV against *Helicoverpa armigera Hubner* (Lepidoptera: Noctuidae) in tomato. *Advances in IPM for Horticultural Ecosystems. Proc. I Nat. Symp. Pest Mgmnt. Hort. Crops, Bangalore*, pp. 215-217.

Gopalakrishnan, C. and Mohan, K.S. 1999. Incidence of the entomopathogenic fungus *Nomuraea rileyi* on Noctuid pests of cabbage and banana. *Journal of Pest Management in Horticultural Ecosystems.* (Press)

Krishnamoorthy, A. and M. Mani. 1999. Effect of low temperature on the development and survival of *Trichogrammatoidea bactrae* Nagaraja. *Insect Environment* (in press)

Krishnamoorthy, A, Krishna Kumar, N.K. and Mani, M. 1999. Record of egg parasitoids from *Achyrontia styx* infesting brinjal. *Pest Management in Horticultural Ecosystems* **5** (1): (in press)

Krishnamoorthy, A. Rajagopal, D. 1998. Effect of insecticides on the California red Scale *Aonidiella aurantii* (Maskell) and its natural enemies, *Pest Management in Horticultural Ecosysytms* **4**(2): 83 - 88

Krishnamoorthy, A. Rajagopal, D. 1999. A record of predatory mite *Erygiopus* sp on *Aonidiella aurantii* (Maskell). *Insect Environment* (in press)

Krishnamoorthy, A. Rajagopal, D. 1999. Suitability of host for rearing California red scale *Aonidiella aurantii. Insect Environment* (in press).

Mani, M. and Krishnamoorthy, A. 1997. Suppression of spherical mealybug, *Nipaecoccus viridis* (Newstead) (Homoptera : Pseudococcidae) on jackfruit. *Entomon* **22** (2) : 161-163.

Mani, M. and Krishnamoorthy, A. 1998. Biological control studies on the mango green shield scale, *Chloropulvinaria polygonata* (Ckll.) (Homoptera: Coccidae) in India. *Entomon* **23** (2) : 105-110

Mani, M. and Krishnamoorthy, A. 1998. Regulation of *Rastrococcus iceryoides* (Green) on guava. *Insect Environment* **4** : 71.

Mani, M. and Krishnamoorthy, A. 1998. Suppression of the soft green scale *Coccus viridis* (Green) on acid lime in India. Proc. *I Natl. Symp. Pest Mgmnt. Hort. Crops*. Bangalore, 1998. p. 210-212.

Mani, M. and Krishnamoorthy, A. 1998. *Kerria communis* (Mahdn.) and its natural enemies on custard apple in Karnataka. *Insect Environment* **4** (2): 38-39.

Mani, M. and Krishnamoorthy, A. 1996. Record of two insect pests and their natural enemies on phalsa. *J. Insect Sci.* **9** (2): 182.

Mani, M. 1996. *Parthenium* - A new collateral host for pink mealybug, *Maconellicoccus hirsutus* (Green). *J. Insect Sci.* 9 (1): 78.

Mani, M. 1996. Safety of neem and other plant products to parasitoids and predators of citrus insect pests. *J. Insect Sci.* **9** (1): 89-90.

Mani and M. and Krishnamoorthy, A. 1999. Suppression of green shield scale, *Chloropulvinaria psidii* (Maskell) with Australian ladybird beetle on lemon. *Insect Environment.* **4** (4) : 116-117.

Mani.M. and Krishnamoorthy, A. 1999. Suppression of green shield scale, *Chloropulvinaria psidii* (Maskell) with Australian ladybird beetle on lemon. *Insect environment.* **4** (4) : 116-117.

Mani.M. and Krishnamoorthy, A. 1999. *Chilocorus nigrita* on spiralling whitefly. *Insect environment.* **4** (4) : 118-199.

Mani.M. and Krishnamoorthy, A. 1998. Biocontrol technology for mealybugs of fruit crops. *SAIC Newsletter.* **8** (4) : 6.

Mani.M. and Krishnamoorthy, A. 1999. Biocontrol of green shield scales. *Science Express (The New Indian Express).* 2nd March, 1999, p.4.

**Sugarcane Breeding Institute, Coimbatore**

Easwaramoorthy, S., Srikanth, J. and Santhalakshmi, G. 1999. Laboratory and field evaluation of *Bacillus thuringiensis* subsp. *kurstaki* formulations against sugarcane borers. *Abstracts of the National Symposium on Biological Control of Insects in Agriculture, Forestry, Medicine and Veterinary Science*, 21- 22 January 1999, Bharathiar University, Coimbatore.

Easwaramoorthy,S., Srikanth, J. and Kurup, N.K. 1998. Ground beetles in sugarcane ecosystem : new records and seasonal fluctuations. *Journal of Soil Biology and Ecology* (in press).

Easwaramoorthy, S., Srikanth, J., Santhalakshmi, G. and Kurup, N.K. 1996. Life history and prey acceptance in commonly occuring spiders in sugarcane ecosystem. *Journal of Biological Control,* **10** : 39 - 47.

Srikanth, J., Easwaramoorthy, S., Kumar, R. and Shanmugasundram, M. 1999. Pattern of *Cotesia flavipes* Cameron ( Hymenoptera : Braconidae ) parasitization rates in sugarcane and sorghum borers in laboratory rearings. *Abstracts of the National Symposium on Biological Control of Insects in Agriculture, Forestry, Medicine and Veterinary Science,* 21 - 22 January 1999, Bharathiar University, Coimbatore.

Srikanth, J., Easwaramoorthy, S., Shanmugasundram, M. and Kumar, R. 1998. Seasonal fluctuations of *Cotesia flavipes* Cameron (Hymenoptera : Braconidae) parasitism in borers of sorghum and sugarcane in southern India. *Insect Science and its Application* (in press).

**Assam Agricultural University, Jorhat**

Bhattacharyya B. and Basit A. 1996. Effect of age and diurnal cycle of *T. chilonis* Ishii on parasitism of *Corcyra cephalonica* eggs. *Plant Health.* **2** : 105.

Bhattacharyya B. and Basit A. 1997. Parasitism of *T. chilonis* as affected by different colours. *JASS,* **10** (1): 125-127.

Bhattacharyya B. and Dutta S.K. 1998. Black citrus aphid, *Toxoptera aurantii* Boyer in Assam. *Insect Environment.* **3** (4) : 109.

Bhuyan M. and Basit A. 1996. Studies on functional response of hunting spider *(Lycosa pseudoannulata,. Plant Health* **2** : 105-107.

Borah M. and Basit A. 1998. Comparitive toxicity of some insecticides to the adults of the egg parasitoid *T. japonicum* . *Plant Health* **2** : 120-123.

**Acharya N.G.Ranga Agricultural University, Hyderabad**

Ganeswara Rao A. and Ramesh Babu T. 1998. Biological control of Arthropod pests of Pulse crops, as a chapter in book series "Integrated Pest and Disease Management". (Ed) Rajeev K. Upadyaya *et. al.* Plant Protection, Quarantine & Storage, Faridabad, APH Publishing Corporation, New Delhi.

**Gujarat Agricultural University, Anand**

Chavada,S.K. and Yadav,D.N. 1998. Suitability of four preys for rearing homopteran predator *Geocoris ochropterus* - A paper presented in the National seminar on Entomology in 21st century.

Jadav, H.R.; Mehta, D.M.; Godhani, P.H. and Jani,J.J. 1999. Evaluation of biocontrol based IPM modules against *Helicoverpa armigera* Hubner infesting tomato (*Lycopersicon esculentum* Mill). Paper presented in national symposium on biological control of insects in agriculture, forestry, medicine and veterinary science at Coimbatore during 21-22 Jan. 1999.

Urmila Sharma and Yadav D.N. 1997. Sunnhemp *Crotolaria juncea* Linn.- A reservior for entomophages at Anand. *GAU Res. Journal* **23** (1) : 44-48.

Urmila Sharma and Yadav D.N.(1997). A new record of Arthropod predators in groundnut at Anand (India) *GAU Res. Journal* **22** (2) : 157.

Urmila Sharma and Yadav, D.N.1998. Relay cropping in the conservation of *Geocoris ochropterus* an arthropod predator in cotton. Paper presented in the National seminar on Entomology in 21st century, Biodiversity, Environmental safety on human health during April 30 to may 2 1998.

Yadav D.N. and Godhani P.H. 1999. Integrated Pest Management in Maize -Paper presented in state level training programme on production technology of Maize and coarse cereals at Vadodara during 10-12 Feb. 1999.

Yadav, D.N. and Kamala Chhaiya 1998. Biological control in vegetable crops in Gujarat. Paper presented in state level seminar on Horticulture Industry during December 1998 organised by Horticultural society of Gujarat.

Yadav, D.N.; Valand, S.M. and Patel V.B. 1997. Success story of Integrated pest management in cotton, Anand, Gujarat (India). Paper presented at Natonal seminar "Non pesticidal management of cotton and pigeon pea held at Hyderabad April, 10-11, 1998.

**College of Agriculture (MPKV), Pune**

Kurhade, V.P. and Pokharkar, D.S. 1997. Biological controlof potato tuber moth, *Phthorimaea operculella* (Zeller) on potato. *J.Maharashtra Agric. Univ.*, **22** (2) : 187-189.

**Punjab Agricultural University, Ludhiana**

Bakhetia, D.R.C. and Brar, K.S. 1998. Role of biocontrol in the integrated pest management. *Prog. Fmg.* **36** (8) : 6-8.

Bakhetia, D.R.C., Brar, K.S., Shenhmar, Maninder and Singh, Jagmohan. 1998. Ecofriendly approaches in the management of cotton and pigeon pea pests. Presented at Workshop on Non-pesticide management of cotton and pigeon pea pests, Hyderabad, April 10-11, 1998 (Abst. P.6)

Brar, K.S., Sekhon, B.S., Singh, Jagmohan, Shenhmar, Maninder and Bakhetia, D.R.C. 1998. Evaluation of biocontrol based IPM modules for the control of bollworm complex on cotton. National Seminar on Entomology in 21st Century, Rajasthan College of Agriculture, Udaipur, April 30-May 2, 1998p. 24 (Abst.)

Brar, K.S., Singh, Jagmohan, Shenhmar, Maninder and Bakhetia, D.R.C. 1998. Control of pod borer complex in pigeon pea with biopesticides. National Symposium on Biopesticides and Insect Pest Management, Lyolla College, Chennai, Feb. 26-27, 1998, p.25 (Abst.).

Joshi, N. Shenhmar, M. Brar, K.S. and Bakhetia, D.R.C. 1998. Comparative efficacy of some formulations of *Bacillus thuringiensis* Berliner against *Plutella xylostella* Linnaeus on Cabbage. *J. Insect Sci.* (In Press).

Shenhmar, Maninder and Brar, K.S. 1997. Efficacy of *Bacillus thuringiensis* Berl. Formulations against *Pieris brassicae* (L.) and *Plutella xylostella* (L.) *Insect Environment.* **3** (3) : 82.

Shenhmar, Maninder, Brar, K.S., Bakhetia, D.R.C. and Singh, Jagmohan, 1988. Tricho-capsules A new approach in Bio-control of sugarcane stalk borer, *Chilo auricilius.* National Seminar on Entomology in 21st Century, Rajasthan College of Agriculture, Udaipur, April 30-May 2, 1998 p. 18(Abst.)

Shenhmar, Maninder, Singh, Jagmohan, Brar, K.S. and Bakhetia, D.R.C. 1998. Tricho-capsules A new technique for release of egg parasitoids - Trichogrammatids. *Insect environment* **4** (3) : 95.

Shenhmar, Maninder, Singh, Jagmoha, Brar, K.S. and Bakhetia, D.R.C. 1998. First record of *Zygogramma bicolorata* Pallister (Coleoptera : Chrysomellidae) on sunflower in Punjab. *Insect Environment* **3** (4) : 111.

Shenhmar, Maninder, Singh, Jagmohan, Brar, K.S. and Bakhetia, D.R.C. 1998. Spread of phytophagous chrysomelid, *Zygogramma bicolorata* Pallister on Parthenium in Punjab and adjoining states. *Insect Environment* **4** (3) : 83.

Shenhmar, Maninder, Singh, Jagmohan, Brar, K.S. and Bakhetia, D.R.C. 1998. Record of coccinellids from Punjab. *Insect Environment* **4** (3) : 67.

Singh, Jagmohan, Brar, K.S., Shenhmar, Maninder and Bakhetia, D.R.C. 1998. Effect of storage on the emergence, sex ratio and parasitization efficiency of *Trichogramma japonicum* Ashmead, *J. Insect Sci.* (In press).

**Dr. Y.S. Parmar University of Horticulture & Forestry, Solan**

Chandel, R.S., Thakur, J.R. and Gupta, P.R. 1998. Population dynamics of different morphs of peach leaf curling aphid in relation to its natural enemies in mid hills of Himachal Pradesh. **In** : *Tree Science Conference-1998*. Organised by Indian *Society of Tree Scientists*, Dr.Y.S.Parmar Univ. of Horticulture and Forestry, at New Delhi. Abstract pp.139.

Gupta, P.R. and Babu, R.R.M. 1998. Management of *Helicoverpa armigera* on tomato with *Trichogramma pretiosum* and *Bacillus thuringiensis* var. *kurstaki*. **In** : *Advances in IPM for Horticultural Crops* (Parvatha Reddy, P., Krishna Kumar, N.K. and Verghese A. eds.), pp.*75-80*. Proceedings of the First National Symposium on Pest Management in Horticultural Crops : Environmental implications and thrusts, Oct. 15-17, 1997, by Association for Advancement of Pest Management in Horticultural Ecosystems at Bangalore.

Gupta, P.R. and Babu, R.M. 1998. Performance of *Trichogramma pretiosum* continuously multiplied on *Corcyra cephalonica* egg against *Helicoverpa armigera*. **In** : *National Seminar on Entomology in 21st Century* (April 30-May 2, 1998). Organised by the entomological Society of India, at Rajasthan College of Agriculture, Udaipur. Abstract pp.21.

Gupta, P.R. and Sood, Anil, 1998. Activity of *Zygogramma bicolorata* on parthenium in mid hills of Himachal Pradesh. **In** : International Conference on Pests and Pesticide Management for Sustainable Agriculture (ICPPPSA - 1998) (Dec. 11-13, 1998). Organised by C.S.Azad University of Agriculture and Technology, Kanpur. Abstract pp. 98-99.

## 11. LIST OF APPROVED ON-GOING PROJECTS

**Project Directorate of Biological Control, Bangalore**

i. Introduction and studies on the exotic natural enemies of some lepidopterous insect pests

ii. Introduction and studies on the exotic natural enemies of some dipterous and homopterous insect pests

iii. Biosystematic studies on predatory coccinellids

iv. Evaluation of artificial diet, release rates and genetic improvement of important predators

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

vi. Evaluation and development of artificial diet for important lepidopterous pests

vii. Development of viable mass production techniques for some important parasitoids

viii. Development of mass production techniques for some important predators

ix. Use of semiochemicals to improve the efficiency of important predators

x. Behaviour ecology of the potential parasitoids to enhance their efficiency in biological suppression of key crop pests

xi. Studies on insect viruses

xii. Biological control of soil borne and other plant pathogens by antagonistic fungi and development of biofungicides for field application

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

xiv. Biological control of plant parasitic nematodes with fungi and bacteria with special reference to *Paecilomyces lilacinus* and *Pasteuria penetrans*

xv. Survey, identification and utilization of entomopathogenic nematodes against some important lepidopterous and coleopterous insect pests

xvi. Biological control of soil borne and other pathogens by antagonistic bacteria and development of bacterial biocontrol agents

xvii. Software development for identifying and suggesting biological control measures for different crop pests using personal computer

**At Coordinating Centers**

i. Biological suppression of sugarcane pests

a. Survey and seasonal fluctuation studies of natural enemies of borers (PAU, SBI and IISR)

b. Field studies on *Trichogramma chilonis* against borers of sugarcane (PAU, SBI, IISR)

c. Field studies on *Cotesia flavipes* against early shoot and stalk borers (PAU, IISR)

d. Field evaluation of *Epiricania melanoleuca* against *Pyrilla perpusilla* (IISR)

e. Evaluation of *Beauveria brongniartii* against white grubs (SBI)

ii. Biological suppression of cotton pests

a. Evaluation of biocontrol based IPM (PAU)

b. Identification of host plants which harbor arthropod natural enemies (PAU, GAU, TNAU, ANGRAU)

c. Standardization of release technology for *Trichogramma chilonis* (PAU, GAU, TNAU, ANGRAU)

d. Evaluation of BIPM for cotton pests (GAU, TNAU and ANGRAU)

iii. Biological suppression of tobacco pests

a. Evaluation of *Bacillus thuringiensis kurstaki, B.t. aizawai* and *Spodoptera litura* nuclear polyhedrosis virus against *Spodoptera litura* in tobacco nursery (CTRI)

b. Evaluation of BARC *Bt* strain (dust formulation) against *Helicoverpa armigera* in transplanted crop (CTRI)

c. Biointensive IPM of *Helicoverpa armigera* in transplanted crop (CTRI)

iv. Biological suppression of pulse crop pests

a. Biological control based management of pod borer complex on pigeon pea (PAU, TNAU, GAU, ANGRAU)

b. NPV based management of *Helicoverpa armigera* on chickpea (PAU, TNAU)

v. Biological suppression of rice pests

a. Survey and quantification of natural enemy complex in rice (AAU, KAU, PAU, TNAU)

b. Field evaluation of integrated use of *Trichogramma japonicum, T. chilonis* and *Bacillus thuringiensis* against rice stem borer and leaf folder (AAU, KAU, PAU, TNAU)

c. Evaluation of biocontrol based IPM in Rice ( TNAU, KAU, AAU, PAU)

d. Evaluation of *Beauveria bassiana* against rice hispa (AAU)

vi. Biological suppression of oilseed crop pests

a. Testing *Metarhizium anisopliae* and *Bacillus popilliae* against white grubs in groundnut (GAU, NRC for groundnut & ANGRAU)

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

vii. Biological suppression of coconut pests

a. Field evaluation of *Apanteles taragamae* against *Opisina arenosella* (CPCRI)

b. Field evaluation of *Trichogramma embryophagum* against *Opisina arenosella* (CPCRI)

c. Seasonal incidence of baculovirus, green muscardine fungus and bacterium on *Oryctes rhinoceros* (CPCRI)

d. Pathogenicity trials with bacterium and viruses against *Rhynchophorus ferrugineus* (CPCRI)

e. Search for bioagents of *Stephanitis typica* (CPCRI)

viii. Biological suppression of tropical and subtropical fruit crop pests

a. Survey for the natural enemies of spiralling whitefly (IIHR, KAU, TNAU)

b. Predatory potential of chrysopids on spiralling whitefly under field conditions (IIHR)

c. Evaluation of *Cryptolaemus montrouzieri* against spiralling whitefly on guava (IIHR)

d. Seasonality of natural enemies of spiralling whitefly in guava (IIHR)

ix. Biological suppression of temperate fruit crop pests

a. Seasonal incidence of the San Jose scale and its natural enemies at different altitudes (SKUAST, Dr.YSPUH&F)

b. Seasonal incidence of woolly apple aphid and its natural enemies at different altitudes (SKUAST, Dr.YSPUH&F)

c. Collection of local *Trichogramma* spp. from apple orchard ecosystem (Dr.YSPUH&F)

d. Release of local *Aphytis* spp. parasitising the San Jose scale in apple orchards of Himachal Pradesh (Dr.YSPUH&F)

x. Biological suppression of vegetable crop pests

a. Survey for natural enemies of vegetable crop pests (IIHR, ANGRAU, MPKV, SKUAS & T, GAU, Dr.YSPUH & F)

b. Evaluation of *Trichogrammatoidea bactrae* against *Plutella xylostella* on cabbage (IIHR, ANGRAU, MPKV, GAU, Dr.YSPUH & F)

c. Evaluation of different formulations of *Bacillus thuringiensis* against *Plutella xylostella* on cabbage (IIHR, ANGRAU, MPKV, GAU, Dr.YSPUH & F)

d. Control of *Leucinodes orbonalis* using *Bacillus thuringiensis* on brinjal (IIHR, ANGRAU and MPKV)

e. Control of *Helicoverpa armigera* using *Nomuraea rileyi* (IIHR)

f. Management of tomato fruit borer (IIHR, MPKV, ANGRAU, GAU, Dr.YSPUH&F)

g. Integrated pest management of tomato fruit borer (GAU)

xi. Biological suppression of potato pests

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

b. Evaluation of doses of release of *Copidosoma koehleri* and *Chelonus blackburni* and microbial agents against PTM in country stores (Arni) (MPKV)

c. Field evaluation of *Spodoptera litura* nuclear polyhedrosis virus and *Bacillus thuringiensis* in comparison with endosulfan as standard check against *Spodoptera litura* on potato (MPKV)

xii. Biological suppression of weeds

a. Assessment of impact of *Cyrtobagous salviniae* in suppressing *Salvinia molesta* (KAU).

b. Assessment of impact of *Neochetina eichhorniae*, *N. bruchi* and *Orthogalumna terebrantis* in suppressing water hyacinth (AAU, KAU, PAU, MPKV, GAU)

xiii. Field evaluation of effectiveness and assessment of biotic agents

a. Biological suppression of cotton pests (GAU, TNAU)

b. Biological suppression of sugarcane pests (PAU, MPKV, VSI)

c. Biological suppression of rice pests (PAU, MPKV, TNAU)

d. Biological suppression of tobacco pests (CTRI)

e. Biological suppression of pulse crop pests (GBUAS & T)

f. Biological suppression of coconut pests (CPCRI)

g. Biological suppression of temperate fruit crop pests (Dr.YSPUH & F)

h. Biological suppression of vegetable crop pests (ANGRAU)

i. Biological suppression of potato pests (MPKV)

## 12. CONSULTANCY, PATENTS, COMMERCIALISATION OF TECHNOLOGY

Consultancy service was provided to Government of Pondicherry in the establishment of Biological control laboratory for the mass production of natural enemies for an amount of Rs.15,000/-.

Training has been given to various plant protection specialists on the mass production of biocontrol agents with a training fee of Rs.4000/- per participant from private companies and Rs.2000/- per participant from government or NGO organizations. During 1998-99, an amount of Rs.37,300/- was realized.

An amount of Rs.35,267/- was obtained from sale of technical bulletins and an amount of Rs.21,909/- obtained from sale of natural enemies.

An amount of Rs.31,000/- was obtained by sale of technology.

## 13. RAC, MANAGEMENT COMMITTEE, SRC, QRT ETC., MEETINGS WITH SIGNIFICANT DECISIONS

### 13.1 Significant decisions or recommendations made in the Third Research Advisory Committee Meeting held on 16-04-1998

i. It was suggested to include the list of technologies evolved by PDBC, Bangalore in TOT programmes

ii. The efficacy of *Diglyphus begini* may be evaluated on watermelon as the amount of insecticides used on this crop is negligible

iii. Field keys along with the host plants on which coccinellids are found may be prepared on priority basis

iv. Efficacy of the parasitoid *Campoletis chlorideae* may be determined on *Agrotis* spp.

v. For sex determination in *Campoletis chlorideae*, morphological characters can be seen critically in comparison with other parasitoids, which have already been studied

vi. Survey for natural enemies on various crops can be included in the repository project rather than mass production laboratory

vii. A programme on improvement of strains, particularly with reference to crops like cotton, sugarcane, tomato may be further strengthened in case of trichogrammatids

viii. Behavioural studies on different crop ecosystems can be concentrated on sunflower, cotton, chickpea and tomato

ix. Field testing of *Steinernema* spp. may be initiated

x. The efficacy of *Trichoderma harzianum* may be tried in aerobic and anaerobic conditions - particularly with reference to cropping systems like rice - groundnut

xi. Intensive surveys for the natural enemies of fruit sucking moths - particularly with reference to ber, pomegranate may be taken up on priority basis under Repository Project

xii. Studies on evolving artificial diets for natural enemies and strains tolerant to insecticides may be strengthened on priority basis in a similar fashion like *"Trichogramma chilonis* tolerant to endosulfan"

xiii. Identification of natural enemies for the control of *Bemisia tabaci* may be tackled on priority basis

xiv. Bioefficacy studies of *Bacillus thuringiensis* can be taken up on priority basis

xv. Efforts should be made to publicize various programmes of biocontrol of crop pests and weeds for conservation of natural enemies

xvi. It was also suggested to circulate the agenda, technical programme, brief report and proposed technical programme among the Chairman and Members in advance, so that the member come prepared for better interaction and suggestions

xvii. Efforts are to be made to develop NPV tolerant to radiation and heat

xviii. Explore and exploit possibilities of utilizing biological agents other than insects and microbes in biosuppression of weeds

### 13.2. Significant decisions made in Fourth Management Committee Meeting held on 17th April 1998

1. The committee has recommended to get the funds from the Council for the construction of first floor on the existing ground floor of the newly constructed laboratory building. As far as the second floor is concerned, it has been advised to include in the ninth plan under the head "Works".

2. The committee approved the post facto approval for the reappropriation of funds from the head "Other charges including equipments" to the head "Works" under plan for the year 1997-98 for Rs.9,90,063/-.

3. The names of the two doctors Dr.Vishwanath.N.Patil, Ganganagar, Bangalore and Dr.(Ms.)P.V.Mahalakshmi, Sanjaynagar, Bangalore has been approved for the appointment as authorized medical attendants.

4. The proposal for the replacement of unserviceable equipments has been recommended for revalidation, so as to facilitate to procure during the year 1997-98.

5. The proposal of upgrading the existing electro-phoretic unit (Model Pharmacia Multiphor II) has been approved to study the variation in different species and strains of natural enemies, especially in sequencing DNA.

6. The committee has recommended for sending the proposal for recruitment of vacant technical posts (Technical Officer (T-6), Technical Assistant (T-II-3), Computer Assistant (T-II-3), Library Assistant (T-II-3).

### 13.3. Monthly Staff Research Council Meeting

Monthly scientific, technical and administrative staff meetings were held separately on every third Friday of the month and the detailed proceedings were sent to the Council for information. During the meetings discussions were held on the work done in different projects and the duties discharged by the technicians and general difficulties faced and the solutions for the same.

## 14. PARTICIPATION OF SCIENTISTS IN CONFERENCES, MEETINGS, WORKSHOPS, SYMPOSIA, ETC., IN INDIA AND ABROAD

**Project Directorate of Biological Control, Bangalore**

Dr.S.P.Singh participated in

the National Seminar on Entomology in 21st Century: Biodiveristy, Sustainability, Environmental Safety and Human Health organized by the Entomological Society of India from April 30th to May 2nd, 1998, chaired a session on Biological Control of Insects and presented a lead paper on `Increasing the effectiveness of natural enemies'.

the National Seminar on cotton as a Resource Person on 4th and 5th May, 98 at Directorate of Cotton Development, Mumbai and delivered a keynote lecture on `BIPM in cotton'.

the NATP National Workshop on IPM on 18th May, 98 at NCIPM, New Delhi for the development of IPM projects, various systems were recommended for consideration.

the Review Meeting called by ICAR on May 30-31, 98 at CICR Nagpur in which the technical programme (Entomology) under AICRP on cotton was reviewed and suitably modified.

the final meeting of the *Heliothis* Network Project (ICAR) at Punjab Agricultural University, Ludhiana on 24th and 25th June, 1998 and co-chaired the session on IPM as well as drafted future programmes for tomato and sunflower crops.

the meeting chaired by the Deputy Director General (CS), ICAR and presented a proposal on the Team of Excellence for Human Resource Development in Biological Control at Project Directorate of Biological Control, Bangalore for funding through NATP on 21st July, 1998.

the Kissan Ghoshti on 26th July, 98. Organized a stall in which *Helicoverpa armigera, Bemisia tabaci,* other important sucking as well as chewing pests of cotton and some of the important diseases were depicted through colour photographs and delivered a lecture on `Biointensive integrated management (BIPM) of cotton pests' in Hindi.

the seminar on Rapeseed-Mustard Research in 21st Century organized in connection with the celebration of Golden Jubilee Year of India's Independence during the time of Fifth Annual Rapeseed-Mustard Workshop at the Birsa Agricultural University, Ranchi held on August 6, 1998. Presented a lead-invited paper on `Biointensive Integrated Management of Mustard Pests'.

the Directors' Meeting of ICAR institutes on 7th and 8th October, 98 at NBPGR, New Delhi.

the in-house meeting of Crops Division for discussing and finalizing the IX plan proposals under the Chairmanship of DDG (CS), ICAR.

the first meeting of the RPC as Principal Investigator of TOE of NATP on 5th November, 98 at IARI, New Delhi and in divisional meeting to scrutinize the IX plan proposals of PDBC held on 6th November, 98 under the chairmanship of DDG (CS), ICAR, New Delhi.

the National Discussion on `Critical Issues of IPM in the Changing Agricultural Scenario in India' at PAU, Ludhiana on November 28th, 98 and presented a key paper on `Biological Suppression'.

the National Horticulture Conference-1998 held on November 29, 98 at Vigyan Bhawan, New Delhi and presented a paper entitled `Integrated pest management for accelerated growth of horticultural crops'.

the 3rd International /15th National Symposium on Recent Trends in Life Sciences at Bangalore University on 12th February 1999 and chaired a session and delivered a plenary lecture entitled `Biological suppression - present status and future strategies'.

the XVII meeting of ICAR Regional Committee No. VIII held at IMAGE Conference Hall-II, Chennai from January 5th and 6th 1999.

Dr.P.L.Tandon attended

National ARIS workshop on Networking during 17-18th August,1998 at New Delhi

Seventh workers' meeting held at Bangalore during August, 1998.

As Invitee to finalize the NATP Project on Development of Residue Free IPM Package for vegetable crops at IIHR, Bangalore.

Dr.K.Narayanan invited

to present a paper "Impact of Biotechnology on Biopesticide Development" at BMS Women's College, Basavangudi Bangalore - 4.

by Dr. Rananavare, Convener, National Symposium on Development of Microbial Pesticides and Insect Pest Management at Pune, Nov. 12-13, 1998.

by Dr.M.S. Jagannath, Professor and Director, Centre of Advanced Studies, Department of Parasitology, UAS, Bangalore to deliver a lecture "Microbial Control of Vectors" during the 4th National training programme on 'Vector Control' conducted by the University of Agricultural Sciences, Bangalore on 29.1.1999.

Mr.S.R.Biswas attended

a workshop on "Computerization and providing electrinic connectivity of all Institutes" on August 17th and 18th 1998 at National Buareau of Palnt Genetics and Resourses, New Delhi 110 012.

S.S.Hussaini attended

the National symposium on *' Rational approaches in namatode management for sustainable Agriculture'* held at B.A. College of Agriculture Anand campus, Anand , Nov 23-25, 1998.

Dr.N.Bakthavatsalam attended

National Symposium on "Emerging Trends in Biotechnological Application for Integrated Pest Management" held at Layola College, Chennai during 25-26th February 1999 and presented a research paper entitiled, "Kairomones for Chrysoperla carnea"

Ms.Chandish R. Ballal attended

Seventh Biocontrol Workers' Group Meeting at PDBC, Bangalore between 25th to 26th August, 1998.

Dr.S.Ramani attended

the Review meeting of *Zygogramma bicolorata* net work project held at PDBC, Bangalore on 14.5.98 and presented the progress report of the work done at PDBC, Bangalore.

the Group meeting of Biocontrol Workers' held at PDBC, Bangalore from August 25-26, 1998 and presented the consolidated report on Basic Research from PDBC, Bangalore.

R. Rangeshwaran

Attended and participated in the Workshop on Biosafety Issues Emanating from use of Genetically Modified Organisms organised by the Department of Biotechnology, Govt. of India, at Bangalore on October 21st and 22nd, 1998.

Attended and presented poster in the National Symposium on Microbial Pesticides and Insect Pest Management, organised by BARC and Hindustan Antibiotics at Pune from November 12-13, 1998.

Sunil Joshi

Attended the Seventh Biocontrol Workers' Group Meeting at PDBC, Bangalore between 25th to 26th August, 1998.

Dr.T.Venkatesan

Attended the VIIth Biocontrol workers group meeting at PDBC, Bangalore on August 25 and 26th 1997.

Attended seminar on Transgenic plants-Technology and Issues at Hebbal Campus, UAS, Bangalore on 22nd December 1998.

Dr.(Ms.)J.Poorani

Participated in the Seventh Biocontrol Workers' Group Meeting held at PDBC, Bangalore, during August 25-26, 1998.

P.Sreeramakumar

Attended the Seventh Biocontrol Group Workers' Group Meeting of the All-India Co-ordinated Research Project (AICRP) on the Biological Control of Crop Pests and Weeds held at PDBC from 25-26 August 1998 and presented the work done under my projects during 1997-98 in the Session on "Biological Suppression of Weeds".

Dr.R.D.Prasad

Attended a national symposium on "Eco-friendly approaches in the management of plant diseases" December 22-24, 1998, held at Shimoga, Karnataka

Dr.C.Sankaranarayanan

Attented National symposium on "Rational Approaches in nematode management for sutainable Agriculture" held at B. A. College of Agriculture Anand Campus, Anand from November 23-25, 1998.

Ms.P.Sadhana

Attended National symposium on the role of biochemistry and biotechnolgy in the twenty first century at UAS, Bangalore.

## 15. WORKSHOPS, SEMINARS, SUMMER INSTITUTES, FARMERS' DAY, etc., ORGANIZED BY THE PROJECT DIRECTORATE

Seventh Biocontrol Workers' Meeting was organized on 25-26, August 1998 at Project Directorate of Biological Control, Bangalore

A Group Discussion was held on 16-04-1998 with various commercial organizations producing bio-control agents. Five companies actively participated in the meeting and discussed various problems encountered in the production of bioagents. An exhibition was arranged to depict the activities of PDBC and also to inform the salient achievements made so far in biological suppression of crop pests and weeds.

A seminar on "Biological Suppression of Plant Diseases, Plant Parasitic Nematodes and Weeds with Plant Pathogens - Scenario and Future Thrusts" was conducted on 16-05-1998 and the following papers were presented in three different sessions:

A seminar on Seminar on Hundred years of Cryptolaemus in India was conducted on 14-08-1998 and Dr.S.P.Singh, Project Director in his introduction narrated how a biological suppression method using predatory beetle *Cryptolaemus montrouzieri* was evolved and demonstrated under the ICAR Lab-to-Land programmes Phase I to the small and marginal farmers. The technology has been tested for the past two decades and it has become a commercial success. Dr.M.Mani, Senior Scientist, India Institute of Horticultural Research, Bangalore gave a lecture on the "Status of Australian ladybird beetle, *Cryptolaemus montrouzieri* in Karnataka". In Maharashtra, the chemical sprays advocated from 1984-85 to 1995-96 have not given satisfactory control of mealy bugs on various fruit crops particularly grapes. Simultaneously to find out an effective biocontrol agents, studies were on at isolated pockets. Most of the studies on release aspects were on isolated pockets with encouraging results. Mass culturing and timely availability of this predator is an important tact for an effective control of the pest on various fruit crops. The status in Tamil Nadu and Andhra Pradesh indicates that *C. montrouzieri* has established on mealybugs infesting a variety of crop hosts. But artificial multiplication and release at appropriate time only solves the pest problem in pest endemic areas. There is lot of scope for utilization of this predator.

Celebrated Independence Day on 15-08-1998 and Dr.S.P.Singh, Project Director detailed the progress made in celebrations of 50 years of Independence through monthly programmes and congratulated all the staff members for making the programme a grand success. The ceremonies of 50 years of Independence ended by signing the pledge by all the participants.

## 16. DISTINGUISHED VISITORS

**Project Directorate of Biological Control, Bangalore**

Dr.Ryang Hui Yur, Deputy Director of Crop Protection Institute of AAS and Mr.Tong Bong Guk, Head of the Laboratory, Kim Chan, DPR Korea visited on 27-06-1998

Dr.B.Rajendran, Sugarcane Research Institute, Tamil Nadu Agricultural University visited on 12-08-1998

Shri Diwakar Vikram Singh, Hon'ble Minister of Agriculture, Government of Uttar Pradesh visited on 12-11-1998

Dr.K.Krishnaiah, Project Director, Directorate of Rice Research (ICAR), Hyderabad visited on 09-12-1998

Dr.Jasvir Singh, Regional Research Station, ICRI, Tadong, Sikkim on 21-12-1998

Shri Sompal, Hon'ble Union Minister of State for Agriculture, Government of India visited on 02-01-1999

Dr.(Ms.)Amita Biswas, Secretary, Department of Biotechnology, New Delhi visited on 18-01-1999

Dr.Bobby D.Moser, David O. Hansen, Dr.Bobbie Celeste and Dr.Rattan Lal, Ohio State University, USA on 22-01-1999

Dr.Anil Rao, Pest Control (India) Limited, Mumbai visited on 02-02-1999

Dr.Ashok K.Raina, USDA, ARS, Weslaco, Texas, USA visited on 12-02-1999

Shri Narinder Bragta, Hon'ble Minister of Agriculture, Government of Himachal Pradesh visited on 23-2-1999.

Dr.S.Sithanantham, ICIPE, Nairobi, Kenya visited on 01-03-1999

Dr.S.T.Murphy, CABI Bioscience, London, UK visited on 15-03-1999

**Assam Agricultural University, Jorhat**

Dr. T. Shivashankar , Associate Professor of Entomology , Agril. Research Station,

ARSIKERE, Karnataka visited biocontrol lab from 22 to 26 th June , 98.

Dr. D. Rabha , Chief officer, IPM Center for North East India visited on 23 rd August..

**Gujarat Agricultural University, Anand**

Hon.Shri Sompal Singh, Central Minister Agriculture, Ministry of Agriculture, Government of India, New Delhi visited on 4-5-1998..

Dr. R.C. Saxena, Professor and Head, RCA, Udaipur visited on 8.5.98

Dr. T. Premnathan, Professor, Kerala Agricultural College visited on 22.1.99

Sh. Ramrakhiani, Principal Secretary of Agriculture, Gandhinagar visited on 22.1.99

**Mahatma Phule Krishi Vidyapeeth, Pune**

Dr.K.Narayanan, Principal Scientist, Project Directorate of Biological Control, Bangalore visited the Biocontrol laboratory on 13th November 1998.

Monitoring team for research and other activities appointed the University under the Chairmanship of Associate Direcotr of Research, NARP (G.Z.) and NARP (Sub M.Z.) visited during November 1998 and February 1999.

**Punjab Agricultural University, Ludhiana**

Dr.S.P.Singh, Project Director, Project Directorate of Biological Control, Bangalore (March 17-18, June 6 and November 29, 1998).

Dr.A.K.Raheja, Assistant Director General (PP), ICAR, New Delhi (June 25, 1998 and February 13, 1999).

Dr.G.C.Tewari, Principal Scientist (Agric. Entomology), ICAR, New Delhi (June 25 and November 29, 1998)

Dr.V.M.Pawar, Directorate of Plant Protection, Quarantine and Storage, Faridabad (November 29, 1998)

Dr.N.Kashyap, Professor and Head, Department of Entomology, HPKVV, Palampur (November 29, 1998)

## 17. PERSONNEL

**Project Directorate of Biological Control, Bangalore**

| | |
|---|---|
| Dr.S.P.Singh | Project Director |

**Biosystematics, Introduction and Qurantine laboratory**

| | |
|---|---|
| Mr.B.S.Bhumannavar | Senior Scientist (Agri. Entomology) & Laboratory Chief (on study leave w.e.f.17-09-1997) |
| Dr.S.Ramani | Scientist (SS) (Agri. Entomology) |
| Dr.(Ms.)J.Poorani | Scientist (Agri. Entomology) |

**Mass Production Laboratory**

| | |
|---|---|
| Dr.N.S.Rao | Senior Scientist (Agri. Entomology) & Laboratory Chief |
| Ms.Chandish R.Ballal | Scientist (SS) (Agri. Entomology) |
| Mr.Sunil Joshi | Scientist (Agri. Entomology) |

**Pathology Laboratory**

| | |
|---|---|
| Dr.K.Narayanan | Principal Scientist (Agri. Entomology) & Laboratory Chief |
| Dr.S.S.Hussaini | Senior Scientist (Nematology) |
| Mr.R.Rangeshwaran | Scientist (Agri. Microbiology) |
| Mr.P.Sreerama Kumar | Scientist (Plant Pathology) |
| Dr.R.D.Prasad | Scientist (Plant Pathology) |
| Dr.C.Sankaranarayanan | Scientist (Nematology) |

**Insect Behavioural Laboratory**

| | |
|---|---|
| Dr.P.L.Tandon | Principal Scientist (Agri. Entomology) & Laboratory Chief |
| Dr.N.Bakthavatsalam | Scientist (SS) (Agri. Entomology) |

**Biotechnology Laboratory**

| | |
|---|---|
| Mr.S.K.Jalali | Scientist (SS) (Agri. Entomology) |
| Dr.T.Venkatesan | Scientist (Agri. Entomology) |
| Ms.P.Sadhana | Scientist (Biochemistry) |

**Coordination, Documentation, Training & ARIS cell Unit**

| | |
|---|---|
| Mr.S.R.Biswas | Senior Scientist (Agri. Statistics) |

**Central Plantation Crops Research Institute, Regional Station, Kayangulam**

| | |
|---|---|
| Dr.B.Sathiamma | Senior Scientist |
| Ms.Chandrika Mohan | Scientist (SS) |
| Dr.Murali Gopal | Scientist |

**Central Tobacco Research Institute, Rajahmundry**

| | |
|---|---|
| Mr.S.Gunneswara Rao | Scientist |

**Indian Agricultural Research Institute, New Delhi**

| | |
|---|---|
| Dr.K.L.Srivastava | Senior Scientist |

**Indian Institute of Horticultural Research, Bangalore**

| | |
|---|---|
| Dr.M.Mani | Senior Scientist |
| Dr.K.P.Jayanth | Senior Scientist (up to 31-05-1998) |
| Dr.A.Krishnamoorthy | Senior Scientist |
| Mr.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 |

**Assam Agricultural University, Jorhat**

| | |
|---|---|
| Dr.A.Basit | Professor |
| Mr.B.Bhattacharyya | Junior Entomologist |

**Acharya N.G.Ranga Agricultural University, Hyderabad**

| | |
|---|---|
| Dr.A.Ganeswara Rao | Entomologist (w.e.f. 23-12-1998) |
| Ms.Ramila Saxena | Assistant Entomologist (up to 18-12-1999) |
| Dr.(Ms.) P.Swarna Sree | Assistant Entomologist (up tp 28-11-1998) |
| Dr.S.J.Rahman | Assistant Entomologist (w.e.f. 19-2-1999) |

**Gujarat Agricultural University, Anand**

| | |
|---|---|
| Dr.D.N.Yadav | Principal Scientist (Entomology) |
| Dr.D.M.Mehta | Associate Research Scientist (Entomology) |
| Mr.J.J.Jani | Assistant Research Scientist (Senior Scale) (Microbiology) |

**Kerala Agricultural University, Vellanikkara, Thrissur**

| | |
|---|---|
| Dr.(Ms.)S.Pathummal Beevi | Associate Professor (Entomology) |
| Dr.K.R.Lyla | Assistant Professor (Entomology) |

**Mahatma Phule Krishi Vidhyapeeth, College of Agriculture, Pune**

| | |
|---|---|
| Dr.Dhoble Shivaji Yashavant | Associate Professor (Entomology) |
| Dr.D.S.Pokharkar | Assistant Professor (Entomology) |

**Punjab Agricultural University, Ludhiana**

| | |
|---|---|
| Dr.Maninder Shenhmar | Associate Professor (Entomology) |
| Mr.Jagmohan Singh | Assistant Professor (Entomology) |
| Dr.(Ms.)Neelam Joshi | Assistant Professor (Microbiology) |
| Dr.(Ms.)Sanehdeep Kaur | Assistant Professor (Entomology) |

**Sher-e-Kashmir University of Agricultural Science & Technology, Srinagar**

| | |
|---|---|
| Dr.G.M.Zaz | Associate Professor (Entomology) |
| Mr.R.K.Tikoo | Assistant Professor (Entomology) |

**Tamil Nadu Agricultural University, Coimbatore**

| | |
|---|---|
| Dr.P.Sivasubramanian | Associate Professor (Entomology) |

**Dr. Y. S. Parmar University of Horticulture & Forestry, Nauni, Solan**

| | |
|---|---|
| Dr.Prem Raj Gupta | Senior Entomologist |
| Dr.Anil Sood | Assistant Entomologist |

**Govind Ballabh Pant University of Agricultural Sciences & Technology, Pantnagar**

| | |
|---|---|
| Dr.U.S.Singh | Associate Professor |

## 18. ANY OTHER RELEVENT INFORMATION SUCH AS SPECIAL INFRASTRUCTURAL DEVELOPMENT

Equipments

The laboratories were further strengthened during 1998-99 with scientific instruments like Beta Counter Liquid Scintillation Analyzer, Plant Growth Chambers, Camera (replacement for the old and unserviceable), upgrading the existing electro-phoretic unit with a facility to sequence DNA/RNA, Seven Stereozoom Binocular microscopes (replacement for old ones) Compound microscope (replacement for the old one) Microwave oven. The centers have acquired need-based equipments and other necessary facilities.

Library

The library has a collection of 1,448 books, 940 volumes of journals, 40 bulletins and several miscellaneous publications including several reprints on various aspects of biological control. Eight foreign journals and ten Indian Journals had been subscribed. For quick and efficient literature search CD-ROM (Compact Disc- Read Only Memory) is provided with CABPESTCD abstracts upgraded up to February 1999 and also ANICD-1995.

Aris Cell

VSAT was installed and the ARIS cell computers were given Internet connection, with E-mail facility. Scientists are now able to browse the net to get the latest scientific information. Upgraded the computers to make them Y2K compliant.

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. A technical bulletin entitled "A catalogue of natural enemies and other insects in PDBC Reference collection" is available.

Buildings

First floor of the main laboratory building was completed at a cost of Rs.55.32.

# १९. निष्पादित सारांश

## १९.१ मौलिक अनुसंधान

### परियोजना निदेशालय जैविक नियंत्रण, बंगलोर

परपोषी कीटों के ६३ संवर्धनों और प्राकृतिक शत्रुओं के १०८ संवर्धनों को समन्वित केंद्रों और अन्य अनुसंधान संगठनों पर संख्या बढ़ाने, स्थापित करने और क्षेत्रीय परीक्षणों के लिए भेजा गया।

भारतीय उपमहाद्वीप के कोक्सीनेलीड कीट समूह (एपिलेक्निने को छोड़कर) की जानकारी देने वाली सूची तैयार की गई जिसमें इस कीट समूह की बनावट, सभी पर्यायवाची नामों के साथ नया प्रचलित नाम, प्राप्ति का स्थान, क्षेत्रीय विस्तार और सभी दर्ज कीटों की चुनिंदा ग्रंथ विवरणी के संदर्भ में विवरण दिया गया है। २९ वंशों, ९ जातियों और ५ उपकुलों के अंतर्गत आने वाली ६५ जातियों का अध्ययन किया गया।

सिलिड *हेटेरोसीला कुबाना* के साथ-साथ *फेरीसिआ विरगेटा* को भी परपोषी कीट के रूप में उपयोग करके सुबाबुल सिलिड परभक्षी कीट *क्युरीनस सिरूलियस* को गुणित किया जा सका। सफेद फूँगा के एक ओर महत्वपूर्ण परभक्षी कीट *ब्रुमॉइडेस सुचुरैलिस* को प्रयोगशाला में *फेरीसिआ विरगेटा* पर भी गुणित किया गया। *इश्चिओडोन स्कुटेलेरिस* और *पेरागस सेरेटस* को प्युपा प्रदान करने के लिए रूई के बने पैड सर्वश्रेष्ठ सतह पाई गई। *एन्काइलोप्टेरिक्स* स्पे. को *एफिस गोसीपी*, *ए. नेरी*, *लिपेफिस एरीसाइमी*, *मेक्रोसाइफम रोजीफोर्मिस*, *माइजस पर्सिके* और *कोरसेरा सीफेलोनिका* पर पाला जा सका।

प्रयोगशाला में निरंतर पाले गये *स्किम्नस कोक्सीवोरा* के अपेक्षा खेत से एकत्र किये गये *स्कि. कोक्सीवोरा* का वृद्धिकाल काफी कम और उनका जीवन काल एवं जनन क्षमता बहुत अधिक पाई गई जिससे प्रयोगशाला के संवर्धन में नवशक्ति लाने के लिए, खेत से परभक्षी कीटों को पकड़ कर प्रयोगशाला के संवर्धन में मिलाने की महत्ता को बल मिला।

*एरीबोरस अर्जेन्टिओपाइलोसस* को परजीवी कीट के जैविक मापन पर प्रतिकूल प्रभाव

पड़े बिना ११° से. ग्रे. पर १० दिनों तक और १५° से. ग्रे. पर १५ दिनों तक संग्रहित किया जा सका। खेत से पकड़े गये और प्रयोगशाला में पाले गये *केम्पोलेटिस क्लोरिडीए* के जैवह्वास अध्ययन में देखा गया कि प्रयोगशाला में निरंतर पालने से इनके संतान उत्पत्ति और लिंग अनुपात पर प्रतिकूल प्रभाव पड़ता है।

*प्लूटेल्ला जाइलोस्टेल्ला* के अंडों को परजीवित करने वाले *ट्राइकोग्रामाटॉयडिआ बेक्ट्रे* की जीवन सारणी के अध्ययन से यह पता चलता है कि १८-२०° से.ग्रे. और ३२-३५° से.ग्रे. के क्रमशः कम और अत्याधिक तापक्रमों पर इनको अत्याधिक मात्रा में प्रयोग करना आवश्यक है। *इश्चिओडोन स्कुटेलेरिस* की शरद और ग्रीष्म काल की पीढ़ीयों की समय सारणी अध्ययन से प्रदर्शित होता है कि शरद और ग्रीष्म काल में क्रमशः १.०९७ और १.१०२ गुना संख्या बढ़ी।

प्रायः उपयोग में आने वाले अर्द्ध संश्लेषित आहार में *सायनोडोन डेक्टीलोन* मिलाकर तैयार किये गये आहार पर *स्पोडोप्टेरा लिटूरा* को सफलतापूर्वक पाला गया।

वसारहित सोयाबीन आधारित आहार, *क्राइसोपरला कारनीआ* को पालने के लिए अत्यन्त प्रभावी पाया गया साथ ही साथ इनके प्युपों, प्युपों का भार और प्रौढ़ों के निकलने की संख्या बढ़ी। वसारहित सोयाबीन आधारित आहार एन्थोकोरिड बग, *कार्डिआस्टेथस एक्विग्युअस* को पालने के लिए भी अत्युत्तम पाया गया। *क्रिप्टोलीमस मोन्ट्रोयुजीएरी* को पालने के लिए यकृत पाउडर (२.९%) के साथ पेप्टोन आधारित आहार और पिसे हुए गो यकृत के साथ अंडे की जरदी आधारित आहार का उपयोग किया गया।

**एन्डोग्राम** विभेद उपयोगिता के लिए *ट्राइकोग्रामा किलोनिस* की कीटनाशक सहिष्णु विभेद विकसित करने के प्रयास किये गये, परिणाम स्वरूप मोनोक्रोटोफॉस और फेनवेलेरेट के प्रति क्रमशः ३४ और २६ पीढ़ीयों के बाद सहिष्णुता पाई गई।

उपचयित और जल अपघटित एल- ट्राइप्टोफेन के उपयोग से कपास के खेत में कोक्सीनेलिडों ने अधिक मात्रा में अंडे दिये। *क्रा. कारनीआ* के लारवों की परभक्षी संभाव्यता बढ़ाने के लिए ट्राइकोसेन महत्वपूर्ण प्रभावी कारक पाया गया। जब माँहू की धोअन का जलीय निष्कर्ष उपयोग किया गया तो *किलोमीनस सेक्समेक्युलेटा* की अण्डनिक्षेपण दर थोड़ी बढ़ी पाई गई।

*हेलिकोवर्पा आर्मीजेरा*, इसके अण्ड परजीवी कीट *ट्रा. किलोनिस* और सूर्यमुखी आनुवंशिक प्ररूप के त्रिकोणीय परस्पर प्रभाव क्रिया के अध्ययन से मालूम हुआ कि एम एस एफ एच- १७ पर अत्याधिक परजीवीकरण होता है। इसी प्रकार कपास के दस आनुवंशिक प्ररूप विकसित किये गये और एम सी यु-५ पर अत्याधिक परजीवीकरण पाया गया। अरहर के २१ आनुवंशिक प्ररूपों में से आइ सी पी एल-८४०६० पर अत्याधिक परजीवीकरण पाया गया।

*एरी. अर्जेंटिओपाइलोसस* द्वारा *हेलिकोवर्पा आर्मीजेरा* का परजीवीकरण करने के लिए परपोषी पौधे की प्राथमिकता के अध्ययन में पाया कि यह चना और अरहर पर क्रमशः १८.८३ और १५.४२% परजीवीकरण करता है जबकि, सेमवंश ओर सूर्यमुखी पर कम परजीवीकरण करता है। इ. *स्कुटेलेरिस* अंडनिक्षेपण करने के लिए परपोषी पौधे के रूप में सेम तथा इसके बाद लोबिया ओर मूँगफली को प्राथमिकता देते हैं जबकि *परागस सेरेटस* सेम और लोबिया को प्राथमिकता देते हैं तथा इसके बाद मूँगफली और अरहर को एक समान प्राथमिकता देते हैं।

*एकीया जनेता*, *एग्रोटिस* स्पे. *स्पोडोप्टेरा एक्जिगुआ* और *गेलेरीआ मेलोनेला* से न्यूक्लियर पॉलीहेड्रोसिस विषाणुओं को और *एग्रेटिस* स्पे. और *थोरीमिया ओपरक्युलेला* से ग्रेनुलोसिस विषाणुओं को पृथक किया गया, इनकी पहचान को इलेक्ट्रोन सूक्ष्मदर्शी के अध्ययन से सुनिश्चित करके रोगजनकों को प्रमाणित किया गया। प्रति संक्रामकता के अध्ययन में पाया कि *स्पो. एक्जिगुआ* एन पी वी, *स्पो. लिटयूरा* के लिए अत्याधिक सुग्राही है।

पोलीहेड्रल अंतर्वेशन बॉडीज १.६५ + ०.१ माइक्रोन की त्रिज्या के आकार के साथ *स्पोडोप्टेरा एक्जिगुआ* एन पी वी की विषाणु गुणित अंतर्निहितता पाई गई।

ग्रीन हाउस के साथ-साथ क्षेत्रीय परीक्षणों में चने के जड़ सडन और म्लानि रोग (*राइजोक्टोनिआ सोलेनाई*) को नियंत्रित करने के लिए *ट्राइकोडर्मा हारजीएनम* (पी डी बी सी टी एच १०) का गेहू के चौकर आधारित नियमन अत्याधिक प्रभावी पाया गया। एक कम लागत वाला नया माध्यम (सोया-शीरा) खोजा गया जिसके फलस्वरूप *ट्रा. हारजीएनम* के क्लेमीडोस्पोर्स का अत्याधिक उत्पादन किया गया।

*बोट्राइटिस सीनेरिआ*, *मेक्रोफोमिना फेजीओलिना*, *स्कलिरोशियम रोल्फसाई*, *राइजोक्टोनिआ सोलेनाई* और *फ्युजेरिअम ऑक्जीस्पोरम* एफ. स्पे. *सिसेरी* के संभाव्य प्राकृतिक

शत्रुओं के रूप में *स्युडोमोनॉज पुटिडा* (पी डी बी सी ए बी १९) और *स्यु. फ्लुओरेसेन्स* (पी डी बी सी ए बी २, पी डी बी सी ए बी २९ और पी डी बी सी ए बी ३०) का अभिनिर्धारण किया गया।

पन्तनगर में केवल *ग्लॉयोक्लेडियम वाइरेन्स* (२ ग्राम/किलोग्राम की दर से ) या *ग्ला. वाइरेन्स* के सम्मिश्रण या *ट्रा. हारजीएनम* के साथ वाइटावेक्स (२ ग्राम और १ ग्राम/किलोग्राम की दर से) मिलाकर बीजोपचार करने से सोयाबीन के बीज और नवोदभिद सडन रोग के प्रति अत्याधिक प्रभावी पाया गया। *ट्रा. हारजीएनम* का एक वियुक्त पाया गया जो कि कार्बेन्डेजिम के ५ माइक्रोन ग्राम/l तक सहिष्णु होता है और इसको अन्य विलक्षणों के लिए एक वियुक्त के साथ जो कि तीव्रगति से वृद्धि करता है, अत्याधिक बीजाणुक करता है और जिसकी प्राकृतिक शत्रुता संभाव्यता अत्युत्तम होती है, को प्रोटोप्लास्ट संलयन तकनीक के माध्यम से उत्कृष्ट बनाया गया।

*स्टिनरनेमा* स्पे. का अधिक संख्या में उत्पादन करने के लिए विभिन्न माध्यमों का मूल्यांकन किया गया और यह पाया गया कि अंडे की जरदी सर्वश्रेष्ठ माध्यम है और इस माध्यम में दुध पाउडर मिलाने से उत्पादन ओर अधिक बढ़ जाता है। *हेटरोरहब्डाइटिस* स्पे. के लिए वाउट का माध्यम सर्वश्रेष्ठ पाया गया।

*स्पो. लिटचूरा* के अंतिम निरूप के लारवों में प्रवेश की दर के निर्धारण को मृदा जॉच विधि द्वारा करने पर पाया कि *स्टेइनरनेमा* स्पे. के छोटे-छोटे संक्रमित लारवे *हेटरोरहब्डाइटिस* स्पे. की अपेक्षा अधिक घुसते हैं। *हेटेरोरहब्डाइटिस* स्पे. और *स्टिनरनेमा* स्पे. की अधिकतम संतान उत्पत्ति *स्पो. लिटचूरा* के अंतिम निरूपों में तथा इसके बाद है. *आर्मिजेरा* में पाई गई। अरण्डी और टमाटर पर पाले गये लारवों के अपेक्षा कृत्रिम आहार पर पाले गये *स्पो. लिटचूरा* के लारवों में अधिक संक्रमित लारवे प्राप्त हुये।

*वर्टिसिलिअम क्लेमीडोस्पोरिअम* कवक के अधिक मात्रा में उत्पादन के लिए ज्वार के दाने अनुकूल पाये गये। इस कवक ने *हेटेरोडेरा कजानी* की ५६% संख्या कम की और जब मृदा में दानेदार नियमन के रूप में प्रयोग किया गया तो कृमि कोषों का ६१% परजीवीकरण किया।

बंगलोर के शहरी और ग्रामीण इलाकों में पार्थेनियम के रोगों का सर्वेक्षण करने पर धब्बेदार पर्ण रोग के साथ *नाइग्रोस्पोरा स्पेरिका* को पहली बार पाया गया। पर्ण धब्बे रोग के एक रोगाणु *फ्युजेरिअम पेलीडोरोजियम* (कुके) सैक. (*फ्यु. सेमिटेक्टम* आक्ट.) द्वारा पार्थेनियम पर कवक खरपतवारनाशी के समान असाधारण विलक्षण विकसित होते दिखाई दिये। पार्थेनियम की सभी अवस्थायें *फ्यु. पेलिडोरोजीयम* के लिए सुग्राही थी। प्राथमिक तौर पर परपोषी विस्तार परीक्षण में देखा गया कि सूर्यमुखी सहित उगाये जाने वाली कंपोजिटी कुली फसलें, फ्यु. पोलीडोरोसीयम के लिए सुग्राही नहीं थी।

जलकुंभी *आईकोर्निआ क्रैसीपस* के रोगाणुओं की खोज करने पर तीन नये कवक *लेसिओडिप्लोडिआ थीओब्रोमे* (*बोट्रीओडिप्लोडिआ थीओब्रोमे*), *राइजोक्टोनिआ* स्पे., *अल्टरनेरिआ* स्पे. और *जाइलेरिआ* स्पे. पाये गये।

## १९.२ गन्ने के हानिकारक कीटों का जैविक दमन

पंजाब में गन्ने के प्राकृतिक शत्रुओं पर सामयिक आपतन अध्ययन में पाया कि *काइलो इनफसकेटेलस*, *सिरपोफेगा एक्सर्पटेलिस* और *एरिगोना स्टिनिएलस* के अंडे *ट्राइकोग्रामा किलोनिस* और *टेलीनोमस डिम्नॉयडस* (केवल *सि. एक्सर्पटेलिस* से) द्वारा क्रमशः १५.२, ५१.२ और ५.९ प्रतिशत परजीवित थे, जबकि लारवा परजीवी कीटों में *कोटेशिया फ्लोविपस*, *स्टेनोब्रेकोन नाइसेविली* और *आइसोटिमा जवेन्सिस* थे। पंजाब के पाँच इलाकों में *का. आरीसीलियस* को *ट्रा. किलोनिस* द्वारा नियंत्रण के प्रभाव के परीक्षण के प्रदर्शनों में इस बेधक कीट के संक्रमण को, उन खेतों में जिनमें कि **ट्राइको** कार्डों का प्रयोग किया गया था उनमें ५४.० प्रतिशत तक कम किया और जिनमें परजीवी कीट प्रौढ़ों को छोड़ा गया था उनमें ६२.२% तक कम किया।

कोयम्बटुर में कोंपल बेधक पर *स्टरमिआप्सिस इन्फेरेन्स* पूरे साल सक्रिय पाया गया, इसका प्राप्यता विस्तार २.१ से १५.२% और अधिक सक्रियता सितम्बर में देखी गई।

कोयम्बटुर में *ट्रा. किलोनिस* खेतों में १० मीटर की दूरी तक फैले पाये गये, इनके द्वारा *कोरसेरा* प्रपंच कार्डों को २-१० मीटर की दूरियों पर परजीवीकरण (९.० से ५६.५%) करने से यह पता चला। जब *ट्रा. किलोनिस* को तना बेधक के ताजे, ३ दिन और ४ दिन आयु के अंडे

उदभासित किये तो ४ दिन वाले अंडों को परजीवीकरण बहुत कम और ताजे अंडों और ३ दिन के अंडों में १००% परजीवीकरण पाया गया। *ब्युवेरिआ ब्रोंगनिएरती* का श्वेत ग्रबों के तीसरे निरूप के प्रति गमले में संवर्धन का अध्ययन किया और इसकी अत्यंत प्रभावी मात्रा $10^{11}$ और $10^{12}$ बीजाणु/है. पाई। *मेटारीजियम एनाइसोप्लिए* का प्राकृतिक संक्रमण भी देखा गया।

## १९.३ कपास के हानिकारक कीटों का जैविक दमन

आन्ध्र प्रदेश में जैव प्रबलित समन्वित कीट प्रबंधन (बी आई पी एम द्वारा) नियमन में ग्रसित पौधे के भागों और लारवों को यांत्रिक रूप में एकत्र करके जालीदार स्क्रीन वाले पिंजड़े में रखते हैं, कपास की फसल की प्रत्येक दो लाईनों के बाद एक लाईन में लोबिया को अन्तःफसल के रूप में उगाना, मक्का का यादृच्छिक रूप से रोपण, खेत के किनारों पर अरण्डी उगाना, *क्रा. कारनीआ* को १०,००० लारवे/है./सप्ताह की दर से तीन बारी में छोड़ना, *ट्रा. किलोनिस* को १,५०,०००/है./सप्ताह की दर से ८ बारी में छोड़ना और है. एन पी वी का ५०० सूंडी अर्क/है. की दर से आवश्यकतानुसार प्रयोग तथा आवश्यकता के अनुसार कीटनाशकों के प्रयोग करने से १:३.० से ३.८६ का एक उत्साहवर्द्धक लागत-लाभ अनुपात मिलता है जबकि किसानों द्वारा अपनाई जाने वाली प्रक्रिया से १:२.५२, आ.एन. जी. रंगा राव कृ.वि.वि. में अपनाई गई प्रक्रिया से १:१.९५ और अनोपचारित प्रक्रिया में १:२.७४ का लागत-लाभ अनुपात कम मिलता है।

गुजरात में बी आई पी एम प्रक्रिया अपनाकर कपास की फसल के चूसने वाले कीटों के साथ-साथ गूलर सूंडियों को प्रभावपूर्ण ढंग से व्यवस्थित रखा गया। २०० अंडों वाली कार्ड पट्टियों को १/वर्ग मीटर की दर से वितरण करके *ट्रा. किलोनिस* को १,५०,०००/है./सप्ताह के दर से ८ सप्ताहों तक छोडा गया परिणामस्वरूप गूलरों की क्षति बहुत कम हुई, अंडों का परजीवीकरण अत्यधिक पाया गया और १०० अंडें कार्ड पट्टियों के वितरण, परजीवी कीट प्रौढ़ छोड़ने और अनोपचारित खेतों की प्रक्रियाओं के अपेक्षा उपज अत्याधिक प्राप्त हुई।

तमिलनाडू में कपास के हानिकारक कीटों को नियंत्रित करने के लिए किसानों के खेत में किये गये क्षेत्रीय परीक्षणों में पाया गया कि माँहू और फूदकों की संख्या नियंत्रण करने एवं गूलरों के ग्रसन कम करने के लिए रासायनिक और किसानों द्वारा अपनाये जाने वाली प्रक्रियाओं

के अपेक्षा बी आई पी एम विधियाँ अपनाने से अधिक उपज मिली और गूलर सूँडियों के अंडे अत्याधिक परजीवी पाये और केवल कीटनाशकों से उपचारित खेत की अपेक्षा अधिक संख्या में प्राकृतिक शत्रुओं की उपलब्धता पायी गई, अतः रासायनिक और किसानों द्वारा अपनाये जाने वाली प्रक्रियाओं के अपेक्षा बी आई पी एम विधियाँ सर्वोत्तम पायी गई।

## १९.४ तम्बाकू के हानिकारक कीटों का जैविक दमन

मोरामपुडी आंध्र प्रदेश में व्यवसायिक तम्बाकू की नर्सरियों में *स्पो. लिटचूरा* नियंत्रित करने के लिए *स्पो.* एन पी वी को ३X१०$^{१२}$ पी आई बी/है. की दर से और *बी. टी.* के. को १ कि.ग्रा./है. की दर से एकान्तर छिड़काव किया गया जिससे दो लाख नवोदभिद ओर अधिक प्राप्त हुये (कुल २४ लाख) जबकि किसानों की प्रक्रिया अपनाने से केवल २२ लाख नवोदभिद प्राप्त होते हैं। कथेरू आंध्र प्रदेश में तम्बाकू के खेतों में *हे. आर्मिजेरा* के नियंत्रण के लिए बी आई पी एम विधियों के अंतर्गत व्यवस्थित रासायनिक छिड़काव अपनाकर इसकी तुलना किसानों द्वारा अपनाये जाने वाले रासायनिक छिड़काव से की गई और बी आई पी एम को हानिकारक कीटों का ग्रसन कम करने और प्राकृतिक शत्रुओं की अधिकतम संख्या प्राप्त करने एवं उनके संरक्षण के लिए अत्युत्तम पाया गया। कलावहेरला आंध्र प्रदेश में सिंचित एफ सी वी तम्बाकू की फसल में *स्पो. लिटचूरा* के नियंत्रण के लिए *स्पो.* एन पी वी (३X१०$^{१२}$ पी आई बी/है.) के तीन छिड़काव, प्रपंची फसल के रूप में अरण्डी उगाकर और *टेलेनोमस रेमस* (४०,०००/है.) छोड़कर बी आई पी एम का प्रदर्शन किया गया परिणाम स्वरूप रासायनिक नियंत्रण से मिले लागतः लाभ अनुपात १:१.२४ के तुलना में अधिक लागत लाभ अनुपात १:१.३४ मिला।

## १९.५ दलहनी फसलों के हानिकारक कीटों का जैविक दमन

कोयम्बटूर में अरहर में फली बेधक के बी आई पी एम के अंतर्गत *बी. टी.* (१ किलोग्राम/है.) और *हे.* एन पी वी (१.५X१०$^{१२}$ पी आई बी/है. ) का प्रयोग करने से ग्रसन कम करने और उपज बढ़ाने के लिए सर्वश्रेष्ठ पाये गये। आंध्र प्रदेश में *बी. टी.-हे.* एन पी वी-एन्डोसल्फान का फूल खिलने के साथ ही १० दिनों के अंतराल पर अनुक्रमिक छिड़काव करने से अरहर में लारवों की संख्या को सफलता पूर्वक नियंत्रित किया गया और *हे. आर्मिजेरा* द्वारा फली के नुकसान को कम किया गया। पंजाब में *हे.* एन पी वी और *बी. टी.* के चार

एकान्तर छिड़काव करने से अरहर के फली बेधकों को सफलतापूर्वक नियंत्रित किया गया।

तमिलनाडु में चने की फसल में *हे.* एन पी वी- एन्डोसल्फान का छिड़काव करने से फसल को *हे. आर्मिजेरा* द्वारा की जानी वाली हानि को महत्वपूर्ण मात्रा में कम किया गया।

## १९.६ धान के हानिकारक कीटों का जैविक दमन

काकाजन असम में धान के तना बेधक और पत्ती मोडक के नियंत्रण के लिए किसानों के खेत में पौध रोपण के ३० दिनों के बाद *ट्रा. जेपोनिकम* और *ट्रा. किलोनिस* को क्रमश: ५०,०००/है./सप्ताह और १,००,०००/है./सप्ताह की दर से आप्लावित रुप से छोड़ने पर तना बेधक का अनोपचारित खेतों की अपेक्षा प्रभावी नियंत्रण पाया गया। इसी प्रकार अनोपचारित खेतों के अपेक्षा परजीवी छोड़े गये खेत में पत्ती मोडकों की संख्या भी बहुत कम थी। कोयम्बटुर में *ट्रा. जेपोनिकम*, *ट्रा. किलोनिस* और *बेसीलस थूरिन्जेन्सिस* के समन्वित प्रयोग करके धान के तना बेधक और पत्ती मोडक का खेत मूल्यांकन करने में पाया कि तना बेधक और पत्ती मोडक का ग्रसन खेत में बहुत कम था और उपज अत्याधिक प्राप्त हुई। पंजाब में धान रोपाई के २० दिनों के बाद ७ दिनों के अंतराल पर *ट्रा. किलोनिस* और *ट्रा. जेपोनिकम* साथ-साथ ८ बार (५०,००० से १,००००० /है. की दर से) छोड़ने से तना बेधक के नियंत्रण के लिए प्रभावी पाया गया। केरल में जिन खेतों में *ट्राइकोग्रामा* को एक लाख प्रति हेक्टर की दर से छोड़ा गया था उनमें श्वेत बाली शीर्ष का संक्रमण कम पाया गया। पंजाब में अगस्त-सितम्बर १९९८ के दौरान *टेलेनोमस* स्पे. द्वारा तना बेधक के अंडों को परजीवीकरण ६१ से १०० प्रतिशत तक पाया गया और पूरे मौसम के दौरान मकड़ियों की अत्याधिक संख्या पाई गई।

## १९.७ रोपण फसलों के हानिकारक कीटों का जैविक दमन

केरल में रहाइनोसेरस बीटल की ग्रसित पूतिदूषित ग्रबों से एक ग्राम निगेटिव बेक्टेरियम को वियुक्त किया गया जो कि एक नया प्राकृतिक शत्रु हो सकता है। बेक्युलोवायरस से संक्रमित ग्रबों को पालने के लिए व्यर्थ नारियल की जटाओं को भोजन के रूप में देकर प्रयोग किया गया। केरल में नारियल की लेसविंग बग *स्टिफेनाइट्स टीपीकस* पर अनेक प्राकृतिक शत्रु पाये गये और इनमें से *एस्पर्जिलस फ्लेवस* को $10^{7}$ - $10^{8}$ बीजाणु/मि.ली. की दर से छिड़काव करने के पाँच-छ: दिनों के अंदर ही निम्फों के प्रति १००% घातक होने के

परिणाम मिले।

शल्क कीट *इश्नास्पिस लोन्जिरोस्ट्रिस* कर्नाटक के कई भागों में प्रमुख हानिकारक कीट के रूप में पाया गया और *स्टिक्टोबुरा सेमीपोलिटा* तथा *काइलोकोरस नाइग्रीटा* इसके प्रमुख परभक्षी कीट पाये गये।

## १९.८ उष्णकटिबंधी फल फसलों के हानिकारक कीटों का जैविक दमन

बंगलोर में अनार के फल बेधक *ड्यूडोरिक्स आइसोक्रेटस* के अंडों को, *ओएनसिरटस पेपिलीओनिस*, *ट्राइकोग्रामा काइलोट्रीए* और *टेलीनोमस* स्पे. परजीवी कीटों ने परजीवित किया और इन परजीवी कीटों ने मिलकर विभिन्न माहों में ०-८०% तक परजीविकरण किया। बंगलोर में खट्टा नींबू में *क्रिप्टोलीमस मोन्ट्रोयुजीएरी* के २०-२५ बीटल/वृक्ष की दर से छोड़ने पर सफेद फूँगा *प्लेनोकोकस लिलेसिनस* और *मेकोनेलिकोकस हिर्सुटस* की संख्या को सफलतापूर्वक नियंत्रित किया। बंगलोर में अनार की रोएँदार सूँडी *ट्राबाला विष्णु*, टेकिनिड परजीवी कीट *ब्लेफेरिपा ? जेबिना* द्वारा अत्याधिक मात्रा में परजीवित पाई गई। हिमाचल प्रदेश में अनार के फल बेधक *ड्यूडोरिक्स एपिजर्बस* के अंडे *टेलीनोमस* स्पे., *एनास्टेट्स* स्पे. और *ट्रा. किलोनिस* द्वारा ६९.५% तक परजीवित पाये गये।

## १९.९ शीतोष्ण फल फसलों के हानिकारक कीटों को जैविक दमन

काकपोडा और नार्बल जम्मु कश्मीर में सेब के वूली एफिड *एरीओसोमा लेनीजीरम* के *एफीलीनस माली* और *कोक्सीनेल्ला सेप्टमपंकटेटा* प्रमुख प्राकृतिक शत्रु पाये गये। *एफाइटिस* स्पे. और *एनकार्सिआ परनीसिओसी* द्वारा सेन जोस शल्क कीट *क्वाड्रेस्पिडिओट्स परनीसिओसस* क्रमशः सोलन में ५.१ और २.८%, शिमला में ०.५ और ३८.०% और कुल्लू में ३.३ और २.०% परजीवी पाया गया। कश्मीर के विभिन्न क्षेत्रों में यह शल्क कीट *एनकार्सिआ* स्पे. और *एफाइटिस* स्पे. द्वारा परजीवी पाया गया और *काइलोकोरस इनफर्नेलिस* को, शल्क कीटों का भक्षण करते हुए पाया।

सोलन में *क्रा. कारनिआ* को २०-७०/ शाखा की दर से छोड़ने पर छोड़ने के एक सप्ताह के अंदर ही वूली एफिड की संख्या को काफी कम किया।

## १९.१० सब्जी वाली फसलों के हानिकारक कीटों का जैविक दमन

पुणे में पातगोभी में *ट्राइकोग्रामाटॉयडिया बेक्ट्रे* को ५०,००० प्रौढ़ प्रति हेक्टेयर प्रति बारी में एक सप्ताह के अंतराल पर पाँच बारी में छोड़ने से *प्लुटेल्ला जाइलोस्टेल्ला* के लारवों की संख्या को महत्वपूर्ण रूप से कम किया और पातगोभी शीर्ष की बाजार योग्य उपज बढ़ी पाई गई। बंगलोर और हैदराबाद में *ट्रा. बेक्ट्रे* को २,५०,००० प्रति हेक्टेयर की दर से पौध रोपण के १० दिन बाद साप्ताहिक अंतराल पर पाँच बार और एन्डोसल्फान को साप्ताहिक अंतराल पर तीन बार छिड़काव करने से *प्लु. जाइलोस्टेल्ला* के लारवों की संख्या को काफी कम किया गया।

बंगलोर में पातगोभी पर *बेसीलस थुरिन्जोन्सिस* नियमन के पाँच छिड़काव करके *प्लु. जाइलोस्टेल्ला* के लारवों की संख्या को कम किया गया। पुणे में *बे. थुरिन्जोन्सिस* (डेलफिन डब्लयू जी, डाइपेल ८ एल, हाल्ट, बायोलेप, बायोबिट और डेलफिन डी एफ) को एक किलोग्राम प्रति हेक्टेयर की दर से प्रयोग करने पर *प्लु. जाइलोस्टेल्ला* के प्रति प्रभावी पाया गया। हैदराबाद में बायोबिट को एक किलोग्राम प्रति हेक्टेयर की दर से १० दिनों के अंतराल पर ५ छिड़काव करने से *प्लु. जाइलोस्टेल्ला* के लारवों की संख्या काफी कम की गई।

बंगलोर में टमाटर के फल बेधक *हेलीकोवर्पा आर्मिजेरा* को दो ऋतुओं में व्यवस्था के परीक्षण में पाया कि *हे.* एन पी वी को २५० सूँडी अर्क प्रति हेक्टयर की दर से छिड़काव करके और *ट्राइकोग्रामा प्रेटिओजम* को २,५०,००० प्रौढ़ प्रति हेक्टयर की दर से प्रयोग करने से फल कम क्षतिग्रस्त हुए, लारवों की संख्या कम पाई और उपज अत्याधिक मिली। पुणे में *हे.* एन पी वी को २५० सूँडी अर्क प्रति हेक्टयर की दर से ५ छिड़काव और *ट्रा. प्रेटिओजम* के ५०,००० प्रौढ़ प्रति हेक्टयर प्रति बारी की दर से एक सप्ताह के अंतराल पर ५ बार में छोड़ने + *हे.* एन पी वी को २५० सूँडी अर्क प्रति हेक्टयर की दर से ३ छिड़काव करने से टमाटर के फल बेधक को सफलतापूर्वक नियंत्रित किया गया। आन्ध्र प्रदेश में *ट्रा. प्रेटिओजम* को ५०,००० प्रति हेक्टयर प्रति सप्ताह की दर से पाँच बार और परजीवी कीट छोड़ने के पाँच दिन बाद *हे.* एन पी वी को २५० सूँडी अर्क प्रति हेक्टर की दर से ३ छिड़काव और आगे फिर साप्ताहिक अंतराल पर प्रयोग करना प्रभावी पाया गया। बंगलोर में *नोमोरीया रैलीई* को $३.२\times१०^{८}$ बीजाणु प्रति मि.ली. की दर से पाँच बारी में प्रयोग करने से *हे. आर्मिजेरा* द्वारा फलों में होने वाले नुकसान को कम किया गया और उपज अधिक प्राप्त हुई।

हिमाचल प्रदेश में *ब्रेविकोराइन ब्रासीके* और *माइजस पर्सिके* को परजीवी करने के लिए परजीवी कीट *डाएरेटीएला रेपे* फूलगोभी की फसल पर एक समान प्राथमिकता देते हैं और अतिपरजीवी कीट *पेचीन्युरोन एफिडिस* को भी पातगोभी पर देखा गया।

बैंगन *ल्युसिनोड्स ओर्बोनेलिस* पर कोंपल और फल बेधक नियंत्रित करने के लिए डाइपेल की तुलना मे डेलफिन का एक किलोग्राम प्रति हेक्टयर की दर से प्रयोग सर्वश्रेष्ठ पाया गया।

केरल में बैंगन, टमाटर, मिर्च और अमरूद की सर्पिलाकार श्वेत मक्खी *एलीयुरोडिकस डिस्पर्सस* पर एक नया एफीलिनिड परजीवी कीट *एनकार्सिआ* स्पे. पास *मेरीटोरिआ* और परभक्षी कीट कोक्सीनेलिड बीटल *एक्जिनोस्किमनस पुट्टरूब्रैय्याह* एकत्रित किया गया।

## १९.११ आलू के हानिकारक कीटों का जैविक दमन

पुणे में *कीलोनस ब्लैकबर्नी* को एक प्रौढ़ प्रति किलोग्राम कंद और *कोपिडोसेमा कोहलेरी* के एक जोड़ी प्रौढ़ प्रति किलोग्राम कंद की दर से १५ दिनों के अंतराल पर छोड़ने, प्रारंभिक रूप में *को. कोहलेरी* को ५ जोड़ी प्रौढ़ प्रति किलोग्राम कंद और *बे. थुरिन्जोन्सिस* को एक ग्राम प्रति किलोग्राम कंद की दर से आप्लावित रूप में छोड़ने पर देशी भंडार गृहों (अनीओं) में २.५ महीने के संग्रहण के बाद केवल १८ से २२ प्रतिशत कंद ही ग्रसित पाये गये। पुणे के पास किसानों के खेतों में किये गये प्रदर्शन में *को. कोहलेरी* को ५०,००० प्रौढ़ प्रति हेक्टेयर प्रति बारी की दर से साप्ताहिक अंतराल पर ४ बार छोड़ने पर अत्यन्त प्रभावी पाया गया।

## १९.१२ खरपतवारों का जैविक दमन

असम के शिबसागर जिले के दिशांगमुख क्षेत्र में जलकुंभी को *निओकेटिना आईकोर्निए* और *नि. बुकी* द्वारा अत्याधिक सफलतापूर्वक नियंत्रित किया गया है, जहाँ पर ७००० बीघा क्षेत्र को जलकुंभी रहित किया गया और इन क्षेत्रों को अब किसान धान की फसल लेने के लिए उपयोग कर रहे हैं। गुजरात के जलाशयों में जलकुंभी पर *नि. आईकोर्निए*, *नि. बुकी* और माइट *आर्थोगेल्यूमना टेरेब्रेन्टिस* स्थाई हो गये हैं। पुणे में जून-दिसम्बर माह के दौरान *निओकेटिना* स्पे. और माइटों की संख्या अधिक पाई गई।

## ACRONYMS

| | | |
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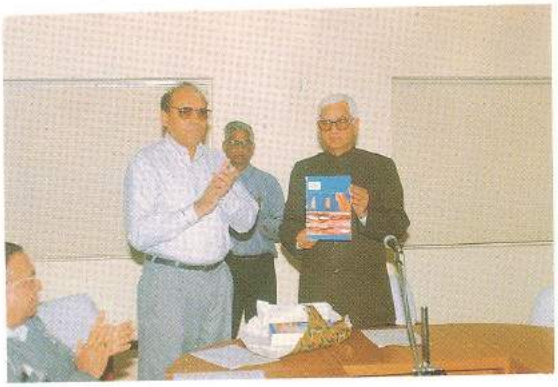
| PDBC | : | Project Directorate of Biological Control, Bangalore |
| CPCRI | : | Central Plantation Crops Research Institute, Kayangulam |
| CTRI | : | Central Tobacco Research Institute, Rajahmundry |
| IARI | : | Indian Agricultural Research Institute, New Delhi |
| IIHR | : | Indian Institute of Horticultural Research, Bangalore |
| IISR | : | Indian Institute of Sugarcane Research, Lucknow |
| SBI | : | Sugarcane Breeding Institute, Coimbatore |
| AAU | : | Assam Agricultural University, Jorhat |
| ANGRAU | : | Acharya N.G. Ranga Agricultural University, Hyderabad |
| GAU | : | Gujarat Agricultural University, Anand |
| KAU | : | Kerala Agricultural University, Thrissur |
| MPKV | : | Mahatma Phule Krishi Vidyapeeth, College of Agriculture, Pune |
| PAU | : | Punjab Agricultural University, Ludhiana |
| SKUAS&T | : | Sher-e-Kashmir University of Agricultural Sciences & Technology, Srinagar |
| TNAU | : | Tamil Nadu Agricultural University, Coimbatore |
| Dr.YSPUH&F | : | Dr. Yashwant Singh Parmar University of Horticulture & Forestry, Nauni, Solan |
| GBPUA&T | : | Gobind Ballabh Pant University of Agriculture & Technology, Pantnagar |

Dr. Amita Biswas, Scientific Advisor, Department of Biotechnology, New Delhi evincing interest in the clutures being maintained in the DBT Project on Repository of Natural Enemies

Shri Diwakar Vikram Singh, Minister for Agriculture, Uttar Pradesh, discussing a point regarding formulations of fungal antagonists during his visit

A team of Scientists from Ohio State University, USA showing keen interest in the exhibition arranged at PDBC during their visit


Participants at the National Seminar on Biological Suppression of Plant Diseases, Phytoparasitic nematodes and Weeds



Shri Sompal, Union Minister of State for Agriculture releasing the Annotated Bibliography of Biological Control of Sugarcane Pests in India


Dr. A.K. Raheja, Assistant Director General (Plant Protection), ICAR, New Delhi releasing the PDBC Infobase Software during the Seventh Biocontrol Workers' Group Meeting

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